Ensuring Tank Car Safety

A Government and Industry Partnership

Proceedings from the Planning Committee Meeting
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On January 14, 1997, the Ensuring Tank Car Safety Planning Committee met to discuss the outcome of the *Ensuring Tank Car Safety Public Information Meeting* held in Houston, Texas on February 14, 1996. The Committee also discussed the minutes of the *1996 North American Tank Car Research Coordination Meeting* (RCM) held at the Association of American Railroad's Headquarters Building in Washington, D.C., on November 19, 1996.

In recognition of the participants at both meetings who contributed their insight with respect to designing, operating, maintaining, and transporting tank cars, the Federal Railroad Administration thanks you. The final outcome of these meeting will be realized in the years ahead through both government and industry research, rulemaking, and industry standard setting activities and the mutual desire to achieve improved safety. To this end, the Planning Committee developed the following priority list of government and industry initiatives to ensure tank car safety (a summary of each initiative follows the main listing). It is important to note that the initiatives do not represent a hierarchy of safety needs, but merely a list of needs that industry and government should review when establishing long-term research, rulemaking, and industry standard setting activities:

1. Non-Accident Release Reduction (NARs)
2. Responding to Transportation Emergencies (Operation Respond)
3. Tank Car Damage Assessment (Mechanical and Thermal Damage)
4. Tank Car Fire Protection (Thermal Modeling)
5. Tank Car Structural Integrity:
    - Rail Car Operating Environment
    - Track/Train Dynamics
    - Empirical Data Collection and Quantitative Risk Analysis
    - Reliability Assessments:
        - Damage-Tolerance Analysis
        - Full Structural Analysis of Car Designs and Modifications
        - Design Criteria to Reduce Structural Fatigue
        - Weld Quality, Technology, Techniques and Stress Relieving
    - Inspection of Tank Cars Involved in Derailments and Over-Speed Impacts
    - Life-Cycle Maintenance Plans for Tank Cars
    - Nondestructive Evaluation
    - Pressure Relief Devices (Liquid, Vapor, and Two-Phase Flow)
6. Performance-Oriented Standards
7. Negotiated Rulemaking
8. Railroad Operating Practices (Human Factors)
9. Public Workshops, Information Meetings, and Lessons Learned
10. 286,000 Gross Weight on Rail
11. Safety of Intermodal Portable Tanks Transported by Rail

Government and Industry Initiatives
Summary and Status

1. **Non-Accident Release Reduction (NARs)**
   The on-going North American Non-Accident Release Program provides a cost-effective, industry sponsored, opportunity to reduce the number of hazardous material releases through the collection of data, data analysis, communication of the data results, and follow-up with the initial shipper.

   Recently, the Association of American Railroads amended the industry standard for the construction of hinged manway covers on tank cars to require improved closure design and the identification of manway style. Current research is focused on the cause of pre-mature rupture disc failure and the ergonomic design of loading and unloading valves and fittings.

2. **Emergency Preparedness and Operation Respond©**
   Operation Respond© is a program designed to improve information available to First Responders at hazardous materials and passenger train incidents. Operation Respond© began as a funded government and industry project to provide critical information to First Responders. In April 1995, Operation Respond© became a not-for-profit organization. Funding for the organization is provided by participating rail and motor carriers, as well as users of the system.

   The Operation Respond Emergency Information System (OREIS ™) connects police and fire departments directly with participating rail and motor carrier databases for verification of hazardous material cargo. The system also provides schematics of Amtrak cars and locomotives, including seat configuration, emergency exit doors and windows, and the location of electric and fuel sources.

   For more information contact Operation Respond© at 202-906-2770, or OREIS@erols.com, or visit Operation Respond's home page at www.oreis.org (May 1997).

3. **Tank Car Damage Assessment (Mechanical and Thermal Damage)**
   FRA is reviewing and evaluating the present tank car damage assessment procedures currently used by the railroad industry and emergency responders. In addition to the review of the current procedures, this research activity will validate additional (presently used) parameters, such a fire damage to the tank shell.

4. **Tank Car Fire Protection (Thermal Modeling)**
As early as 1984, government and industry have been developing an analytical procedure for calculating the effects of fire on a railroad tank car. The procedure was developed so that the consequences of using different conductances for thermal insulation on a tank car and different flow capacities of the pressure relief device could be determined. The analysis is used to predict the time to failure and the amount of product remaining in the tank at the time of failure for both upright and overturned car cases.

The model was developed based on full-scale research on loaded tank cars containing propane in 1975. Research is needed to validate the model for other commodities, such as chlorine, anhydrous ammonia, and other gases. In addition, there is a need to improve on the "friendliness" of the program for all users.

5. **Tank Car Structural Integrity:**

- **Rail Car Operating Environment**
  Rail cars are designed, built, and maintained for an expected operating environment. A significant factor of safety currently cushions the rail car design from the known, but not quantified, deviations in the actual operating environment from the expected environment (i.e., accidental loads). To more closely understand the actual risk which must be considered in the operation and maintenance of rail cars—as well as to minimize that risk, a better understanding of the rail car operating environment must be obtained. The environment, including variations due to train make up, track and truck conditions, temperature, as well as train handling, must be studied and documented.

- **Track/Train Dynamics**
  Track/Train dynamics (or track/vehicle dynamics) refers to the interaction of railroad vehicles (locomotives and cars) with the track as affected by operating practices, terrain and environmental conditions. The study of track/train dynamics has been particularly useful in determining the causes for combination-caused derailments where several factors contribute to the derailment, but each factor, if considered independently, would not normally result in derailment. Track/Train dynamics has also been used to establish design and safety standards for both equipment and track and has been used to determine proper operating practices (e.g. train handling).

  Current research on empty-load distribution may lead to a better understanding of the forces experienced in an actual train movement and the optimal location to place cars. Further research is needed to understand the effects of Track/Train Dynamics on the car structure, such as accelerated fatigue due to vibration.

- **Empirical Data Collection and Quantitative Risk Analysis**
  Ongoing empirical data collection efforts by the Federal Railroad Administration (FRA), Research and Special Programs Administration (RSPA), Association of American Railroads (AAR), and the Railway Progress Institute-Association of American Railroads (RPI-AAR) Cooperative Railroad Tank Car Safety Research and Test Project have been instrumental in helping to identify and prioritize railroad and tank car safety advances for over twenty years. Used appropriately, empirical data can complement theoretical modeling and engineering approaches to estimating system performance by reflecting the performance of similar systems in the actual operating or accident environment. Current data collection efforts will continue to have value, and additional opportunities to take advantage of actual experience should be carefully considered.

  Qualitative Risk Analysis (QRA) refers to a family of techniques for using empirical data to estimate the risk (i.e., the frequency or likelihood of various undesired events) associated with the transportation of hazardous materials by rail. Many hazardous material release scenarios occur very infrequently due to the high level of safety of normal operations. Indeed, many consequences that are possible have never occurred, so simple empirical analysis alone cannot estimate their likelihood. However, the potential consequences should there be a release might be very large, and even if rare, such possibilities cannot be disregarded in managing risks. QRA techniques develop quantitative information about such low frequency events, as well as more routine types of incidents, and thereby allow the risk manager to make the most cost-effective safety investments.

- **Reliability Assessments:**
  The reliability of a tank car is the probability that, when operating under stated environmental conditions, the tank car will perform its intended function adequately for a specified interval of time. Assumptions are made that there is a possibility of failure of a welded joint or the shell material, as strength, ductility, and wall thickness deteriorate with time. In assessing tank car reliability, modes of failure are defined and categorized (fatigue, corrosion) and procedural constraints, such as preventative maintenance and repairs, are established.

- **Damage-Tolerance Analysis**
  The dynamic nature of the rail environment—including variable cyclic loading, normal and accidental impacts and varying exposure to corrosive environs, makes it difficult to perform a realistic evaluation of the expected life of a railroad tank car. However, DTA allows analysts to deterministically consider the important loading and environmental variables which drive tank car reliability. Evaluations performed using DTA are ideally suited to allow tank car owners to tailor inspection and maintenance programs for their individual fleets. Validation testing of one owner's DTA is currently

under way and will be utilized to refine the DTA methodology to be applied to tank designs.

C **Full-Structural Analysis of Car Designs and Modifications**
Once a railroad tank car has undergone modifications or repairs to the tank or sill, the load paths through the sill and tank may have been altered from those of the original tank car design. A change in structural response may be significant and may require changes in the inspection and maintenance plans for the modified tank car. A detailed analysis of the tank car as designed--and with the proposed modifications to the design--is necessary to fully understand new requirements for the maintenance and use of a modified tank car. DTA analysts are currently evaluating what structural variations will result in a "different" design.

C **Design Criteria to Reduce Structural Fatigue**
Good engineering designs optimize desirable design features. With tank car design, as in the past, empirical data may be used to optimally reduce structural fatigue. However, new engineering tools are becoming available to the railroad industry—such as DTA and newly available nondestructive stress monitoring methods.

C **Weld Quality, Technology, Techniques and Stress Relieving**
The reliability of a welded joint depends on the chemistry of the weld (combination of filler and base materials), the fluxing action of the slag, the condition of welding materials, the welding technique (including qualifications of the welder), heat input, interpass temperature, post-weld heat treatment (stress relieving), and the depth of penetration and fusion. The "mix" of these variables determines the soundness of the finished weld. To improve the inherent reliability and safety of a welded joint, government and industry must study the interrelationship between these variables and optimize the mix that produces a weld that is free of the defects that may reduce the intended service life of the welded joint.

C **Inspection of Tank Cars Involved in Derailments and Over-Speed Impacts**
Rule 95 of the Association of American Railroads' Interchange Rules applies to any handling carrier that has knowledge of damage or loss to any car resulting from unfair usage. This rule, and others, is not specific with respect to the inspection of stub sill tank cars involved in a train derailment or an over speed impact. When a tank car experiences a derailment or an over speed impact, a mandated inspection of the sill structure and tank attachment welds could ensure that any damage is detected before such damage can grow to a critical size. Stub sills that are "home shopped" due to an accident or derailment are currently required to be inspected; however, there is no provision at the present for inspection following an over speed impact.

C **Life-Cycle Maintenance Plans for Tank Cars**
Since a car owner has an obligation to ensure for the continued qualification or maintenance of a tank car, it logically follows that the owner must develop a set of procedures that cover design, maintenance, and repair. Recognizing the effects of

fatigue and corrosion on a tank structure, the plan should set specific qualification or maintenance intervals to achieve maximum in-service reliability and to ensure timely inspection and maintenance. In detail, the plan should identify the areas to inspect, the inspection and test method, the acceptance criteria, and the inspection and test frequency. The DTA methodology will provide a technical basis for such plans.

C **Nondestructive Evaluation**
The regulations were recently amended to replace the periodic hydrostatic test with nondestructive evaluation methods that are adequate to inspect for flaws. Of importance is the comparability of the methods with respect to the probability of defect detection. It is forecast that the existing Transportation Technology Center's nondestructive evaluation (NDE) project will be extended to accommodate additional applicable test procedures. New NDE methods will continue to be monitored for applicability.

C **Pressure Relief Devices (Liquid, Vapor, and Two-Phase Flow)**
Current Federal and industry safety codes require the use of a pressure relief device that have adequate flow capacity under vapor flowing conditions. Often, the orientation of a pressure relief device on a transportation container involved in an accident lies below the plane of the liquid level of the cargo. In this orientation and under fire conditions, the saturated liquid (two-phase flow) will flow through the pressure relief device causing the liquid to flash. A flashing liquid will cause a decrease in the required flow capacity of the pressure relief device. Research is needed to study the two-phase flow through a pressure relief device and its affects on a pressure vessel.

In addition, further research is needed to study the vapor pressure for certain commodities under fire conditions, e.g., materials that polymerize or decompose at elevated temperatures. In fire conditions, the high-vapor pressure of the cargo may require the use of a pressure relief device (PRD) that has greater flow capacity than prescribed under current rules. Under this research program, the contractor will determine the proper flow capacity required for these materials.

6. **Performance-Oriented Standards**
Performance-oriented standards are generally preferred to engineering or design-specific standards because they allow the regulated parties to achieve the regulatory objective in the most cost-effective way. In general, a performance standard should be preferred when the performance can be measured or reasonably imputed, and the standard should be so written that there is more than one way to meet it. Examples of performance standards include coupler vertical restraint systems (shelf couplers), thermal protection systems (fire protection systems), and head puncture resistant systems (head protection). Examples of design-specific standards include tank shell thickness, pressure relief device flow capacity, and insulation requirements.

7. **Negotiated Rulemaking**

To achieve improvements in railroad transportation safety requires both coordination and cooperation by both government and industry when establishing Federal safety rules. As a means to authorize Federal agencies to use the collective knowledge of industry, Congress enacted the Negotiated Rulemaking Act of 1990, establishing a statutory framework for Federal agencies to formulate rules by bringing together representatives of the agency with affected interest groups. The process provides value to both government and industry in learning about the issues at hand, and provides for a rule that is less likely to receive judicial review.

8. **Railroad Operating Practices (Human Factors)**

Since 1985, human factors accidents have accounted for approximately one-third of all railroad accidents. The reduction of human factors accidents requires examination of current railroad operating practices and anticipation of the future safety of current practices given industry trends. This program targets human factors in yard and terminals and in mainline train operations.

Work proposed by the FRA over the next five years includes an evaluation of injuries in yards, terminals, and maintenance-of-way operations, as well as ergonomic issues associated with them. Work will be done to assess training for employees handling hazardous materials.

Other projects will focus on gaining an enhanced understanding of fatigue in locomotive engineers, dispatchers, and other operating personnel and identifying mitigation strategies such as napping and vigilance monitoring. Studies will be done for incorporating new information display technology into the railroad environment and for the formation of effective team among operating personnel. The effects of boredom and inactivity on operator performances will be investigated.

9. **Public Workshops, Information Meetings, and Lessons Learned**

By "partnering" with labor and management, tank car operators (owners, lessors, and lessees), and car manufacturing and repair facilities, solutions to safety issues are found and unified policy decisions are made. The involvement of all parties in this process ensures that the most appropriate business decisions are made early and that key safety areas are not overlooked. The essence of government and industry partnerships will further lead to an effective and efficient Government, since less government resources will be spent arbitrating labor and management disagreements over safety concerns.

Public workshops and meetings that provide either information or lessons learned from practical experience are excellent vehicles for all parties to understand the applicability of a rule in question. Such meetings provide an interactive process for clarifying key elements in a final rule or for gaining knowledge about governmental safety concerns and industry limitations prior to adoption of a proposed rule.

Where a final rule may seem logically planned on paper and agreed to by all parties, the true test of the rule is in its implementation. For example, does the current rule recognize the limitations of car repair facilities to inspect a required area of observation? Will the industry actively promote the sensitivity and reliability of testing equipment at an acceptable level? Can nondestructive examination personnel interpret acceptable and non-acceptable findings (e.g., minimum and maximum detectable flaw size)? What is the minimum qualifications for non-destructive testing personnel? The answer to these questions relies not only on the interaction between government and industry, but more importantly on the electiveness of an individual car owner to accept responsibility for establishing a qualification and maintenance plan to ensure for the reliability of an in-service tank car (i.e., maintaining failure rates below an acceptable level). It is for these reasons that the promotion of meetings that focus on lessons learned in the qualification and maintenance of tank cars will further the knowledge base of the entire industry.

10. **286,000 Gross Weight on Rail**

The railroad industry is moving rapidly in the construction and operation of railcars with gross rail loads of up to 286,000 lbs. Tank car builders and owners are presently submitting applications to the Department of Transportation for the use of these heavy gross weight cars. Fatigue analysis is performed for these cars using scaled-up FEEST-1 and FEEST-2 loading spectrum data to account for the increase in the longitudinal and vertical coupler loads. However, before considering such a requirement, the Department must study the appropriate scaling factors. A more thorough understanding of changes in the in-train forces with changes in gross weight may be developed by review of past FRA research involving the Train Operations and Energy Simulator (TOES) and ADAMS computer models (translating those studies to include the heavier weight cars). The issue of buckling of larger tank cars will also be investigated.

11. **Safety of Intermodal Portable Tanks Transported by Railroad**

In a 1994 Transportation Research Board report on Ensuring Tank Car Safety (Special Report 243), the Board voiced concerns with respect to the transportation of intermodal portable tanks by rail. Because the use of intermodal portable tanks is relatively new in the United States, experience in ensuring their safety in the rail environment is limited. The Board recommended that the DOT conduct a thorough review of tank container safety.

Because the design and maintenance of tank containers are subject to international regulations, there is a need for all international trading partners, including government agencies, to review the safety aspects and to promote the development of an international data base on tank container failures.