TECHNOLOGY DIGEST

Timely Technology Transfer

"TCFIRE: A COMPUTER MODEL THAT SIMULATES FIRE-INDUCED PRESSURE INCREASES IN TANK CARS"

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Summary

TCFIRE, a user-friendly computer model that simulates fire-induced pressure increases inside a tank car, is now available from the Association of American Railroads (AAR). This software was developed to support the Tank Car Committee's efforts to improve the design performance of tank cars in fires and reduce the frequency of hazardous materials releases. With TCFIRE, shippers and car suppliers can evaluate their car design options to maintain fire safety while minimizing hazardous materials releases.

Tank cars are fitted with pressure relief devices that extend tank survival when the car is exposed to fire in an accident. These devices occasionally leak during normal transportation; this phenomenon is the leading cause of non-accident caused releases (NAR) of hazardous materials from tank cars. There are potential alternatives to the standard pressure relief devices that may be less likely to leak; however, their effect on tank survival in a fire must be investigated.

It is not feasible to study these processes at the accident scene, and controlled, full-scale testing is difficult and expensive. TCFIRE allows rapid, low-cost analysis of tank car accident scenarios involving fire. This program simulates the rise of internal pressure and decreasing tank strength as the tank is heated by nearby fires. It allows the user to analyze the tank survival time achievable for a given lading with different choices of pressure relief device and tank insulation.

Suggested Distribution:

- ❑ Hazardous Materials Officers
- ❑ Casualty Prevention Dept.
- ❑ Mechanical Department

Association of American Railroads
Research and Test Department
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THE TCFIRE PROGRAM

TCFIRE is a personal-computer-based simulation program that models the behavior of a tank car's tank, lading, and pressure relief device in a fire. Its ease of use allows rapid, low-cost analysis of the effects of fire-induced pressure increases on tank survival. The user can investigate the fire safety performance of alternative safety vent designs meant to reduce the frequency of undesired releases in transportation. A reduction in leaks must be achieved without substantially curtailing tank survival in a fire. Suppliers of tank cars and shippers of corrosive materials have been interested in making various alterations to their safety vents, but had few tools to investigate these tradeoffs. TCFIRE fills that need.

Users of TCFIRE have considerable flexibility for describing the tank, safety relief device, lading, fire scenario, and simulation parameters to be used in a given analysis. Most common tank cars and safety relief devices can be modeled. The user may select from a list of commonly shipped materials; the relevant physical properties of these chemicals are built into the model. A derailed car can be tipped to any angle, so the effects of the safety relief device being near or under the surface of the lading can be investigated. The user can specify small time steps in the simulation for greater accuracy, or larger time steps for faster execution, and can terminate execution after a specified simulated time has elapsed. TCFIRE can be used to estimate the performance of the safety relief device, predict the elapsed time before failure of the tank, and generate time histories of the surface and internal temperatures, internal pressure, and the quantity of lading remaining in the tank.

Tank features that are accounted for include:

- Capacity
- Diameter
- Shell thickness
- Initial burst pressure
- Thermal insulation thickness
- Time- or temperature-dependence of tank and insulation conductance
- Initial and steady-state conductance
- Radiant energy emissivity

Variables describing safety vents include:

- Burst rating of the rupture disk
- Orifice area
- Vapor and liquid discharge coefficients

Safety relief valves are characterized by:

- Flow capacity
- Flow pressure
- Start-to-discharge pressure
- Vapor and liquid discharge coefficients

The user selects a lading from the following:

- 1,3-butadiene
- Corn syrup
- Ethylene oxide
- Hydrochloric acid
- Monomethylamine
- Phosphoric acid
- Potassium hydroxide
- Propane (one form of liquefied petroleum gas, or LPG)
- Propylene (another LPG)
- Propylene oxide
- Sodium hydroxide
- Sulfuric acid
- Super phosphoric acid
- Vinyl chloride
- Water

Shipment characteristics are specified by:

- Initial outage
- Initial concentration (for solutions)
- Initial temperature
- Padding gas

The scene is characterized by:

- Fire temperature
- Percent of car engulfed by flame
- Car attitude (angle from vertical)

Finally, the user defines the parameters of the simulation:

- Time step increment
- Duration of simulation
- Source of input and destination of output (terminal or file)

TCFIRE is written in Microsoft FORTRAN 5.0 for operation in a MS-DOS environment. Exhibit 1 is a flow chart depicting the TCFIRE computational process. AAR R&T Publication SD-053 contains the software and complete documentation. Contact Todd Treichel at (202) 639-2262 with questions or comments about this document.

WHY TCFIRE WILL HELP PREVENT HAZARDOUS MATERIALS LEAKS

Tank cars are fitted with pressure relief devices designed to extend tank survival when the car is exposed to fire in an accident (Figure 1). However, the frequency with which these devices discharge lading during normal transportation has focused the industry's concern on the prevention of these undesired releases.

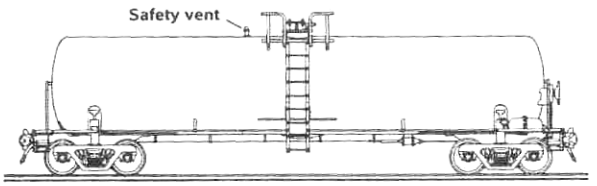

Figure 1. Tank Car With Safety Vent

Courtesy of General American Transportation Corporation; Modified by AAR With Permission

Three promising options for reducing these leaks are (1) use of frangible disks with higher pressure ratings, (2) reducing the size of the opening within the safety vent, and (3) eliminating the safety vent entirely (an approach referred to as "total containment"). The benefits of these options must be weighed against their effect on pressure relief capacity and possibly tank survival in a fire.

Tank Cars and Fires

Rail accidents are occasionally accompanied by fires, and tank cars may be exposed to or engulfed in these flames. As heat is transferred through the tank shell into the product, pressure inside the tank rises at the same time the tank steel is weakening. When the tank's rising internal pressure equals its falling burst pressure, the tank fails and the commodity is released. Under some conditions, this failure can result in an explosion.

To delay this type of tank failure and allow emergency responders time to cool the car or put out the fire, tank cars are equipped with pressure relief devices. These are designed to function at a particular internal tank pressure, called the start-to-discharge pressure. When the car is heated and the start-to-discharge pressure is reached inside the tank, the pressure relief device opens and releases vapor and/or product, relieving pressure and cooling the car's interior.

Safety Vents and Leaks

There are two common forms of safety relief device: valves and vents. Vents are less expensive and are commonly used for a small group of relatively nonvolatile commodities. These materials are much less likely to cause a violent tank failure than gases or volatile liquids. And if released, they are likely to create only a limited hazard area. Among the most common products shipped in tank cars equipped with safety vents are corrosive materials such as acids and caustic soda.

The safety vent uses a frangible disk (or "rupture disk") designed to contain the product during transportation but to rupture at the start-to-discharge pressure (Figures 2 and 3). Unfortunately, these disks occasionally crack or burst in ordinary transportation due to momentary pressure surges or improper installation and maintenance. The car may then travel many miles with the vent open to the atmosphere, potentially contaminating or spilling the contents. Switching activities can cause sloshing within the tank, resulting in splashes from the open vent.

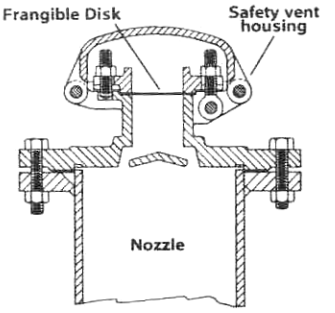

Figure 2. Side View Of Safety Vent

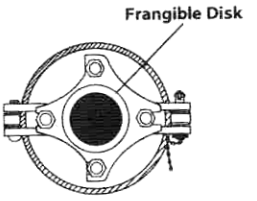

Figure 3. Cross Section Of Safety Vent

Despite a variety of measures taken to eliminate releases from safety vents in transportation, the releases are still occurring over 300 times a year. A number of protective alternatives that may reduce or eliminate rupture disk leaks have been given service trials. However, accidents in which tank cars are in fires are relatively rare events. Consequently, the small group of modified cars in service has not provided empirical evidence concerning the performance of these alternatives in fires. Tank car owners and operators must be confident in the fire safety performance of alternative approaches before they will implement them on a wide scale. TCFIRE allows users to simulate accidents involving fire and predict its effects. This will accelerate the evaluation and implementation of the most appropriate leak prevention systems in the tank car fleet.

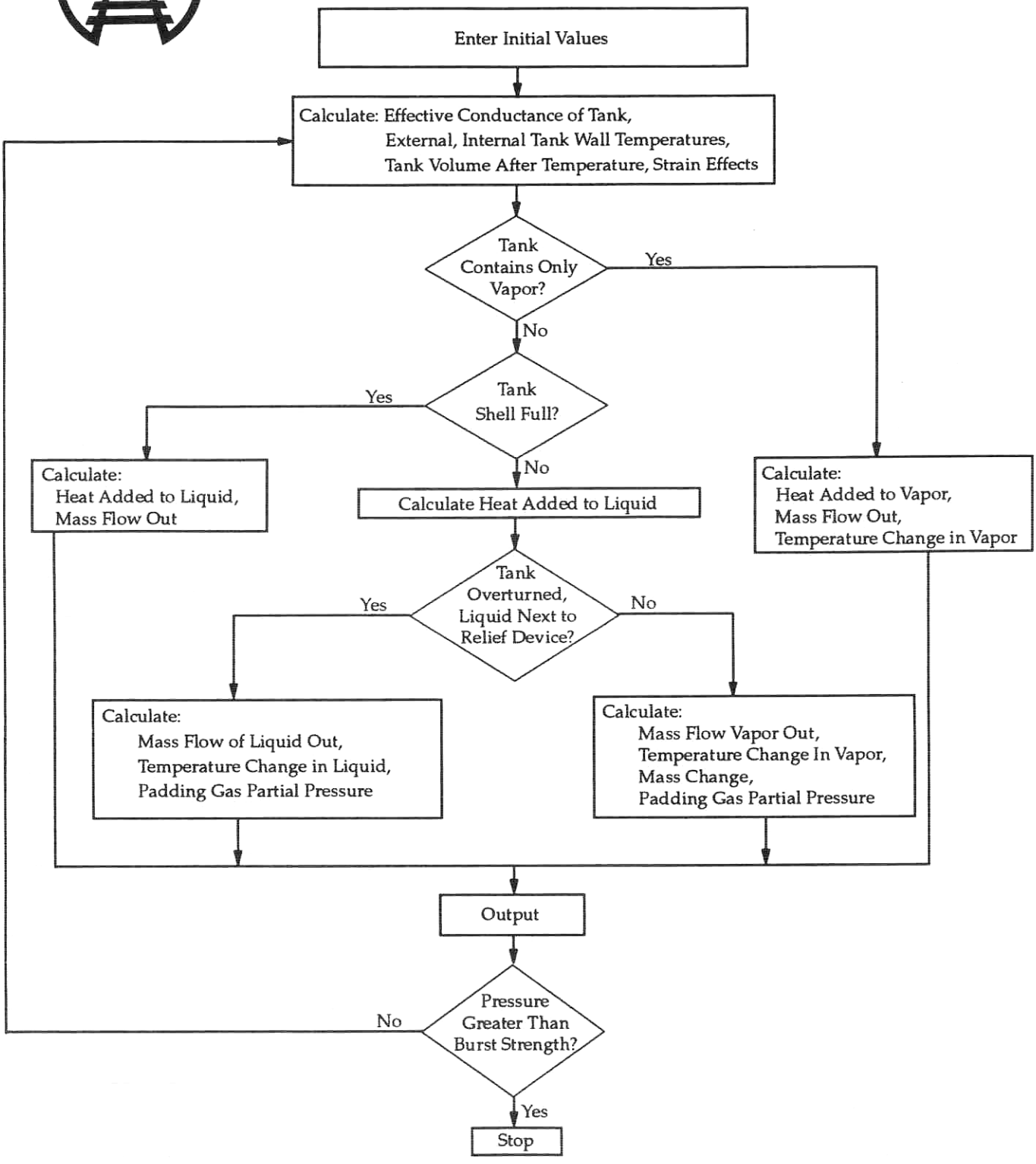

Exhibit 1. Simplified Flow Chart of TCFIRE Computational Procedure

A MORE DETAILED REPORT ENTITLED "TCFIRE: A MODEL FOR PREDICTION OF FIRE EFFECTS ON TANK CARS" (SD-053) IS AVAILABLE FROM: AAR, PUBLICATION ORDER PROCESSING, 50 F STREET, NW, 5TH FLOOR, COG, WASHINGTON, D.C. 20001