Changes for Locomotive Fueling: On the Fast Track

Locomotive fuel spills can easily derail the bottom line for a railroad—not to mention their impact on the environment. Carcon Locomotive executive Robert Koeninger describes new equipment standards that promise to keep the railroad industry on the right track.

New standard coming in 1999

With this article, PE&T continues its quest to promote the use of sound technology and equipment to provide safe, efficient and environmentally sound systems for fueling America’s private and commercial vehicles, including passenger cars, trucks, watercraft, aircraft and other transportation media. In this case, the “other media” are railroad locomotives. Robert Koeninger provides firsthand knowledge and perspective on actions being taken to improve the efficiency, safety and environmental soundness of locomotive fueling systems and procedures. Robert is a working member of the AAR Locomotive Fueling System Task Force. He has 11 years experience designing controls for fueling and overfill detection equipment.

Locomotives getting checked out at the test fueling site at AAR’s Transportation Test Center in Pueblo Colorado. Courtesy of Carcon Locomotive Fueling Group.

Locomotive fueling technology is undergoing changes that will greatly improve efficiency, safety and environmental protection. These changes are motivated primarily by the costs, legal consequences and environmental concerns associated with spills during locomotive refueling.

Railroads, locomotives and fueling

For regulatory purposes, the nation’s railroads are classified into four general categories. They are:

- Class I
- Short-line
- Metro or regional passenger
- Museum

This article will focus on the fueling of Class I railroads, which are defined by the total ton/miles of freight hauled in a given year—typically 100 million tons or more per year. Typical Class I railroads are familiar companies like Union Pacific, Norfolk Southern, Illinois Central and Burlington Northern Santa Fe (BNSF). Through recent mergers, there are now eight Class I railroads in North America. The
mainline railroads used by passenger and freight trains are, for the most part, Class I railroads.

The diesel electric locomotives that pull (or push) these trains typically use a No. 2 Diesel with an alcohol additive during the winter months. Typically, a locomotive has a fuel capacity of 4,000 gallons of fuel and will be fueled twice per week.

Railroads own and manage their own fueling facilities. Fuel, when delivered by truck, is suction-pumped from the cargo tank into a fixed aboveground storage tank. Direct Truck to Locomotive (DTL) fueling is performed by a mix of railroad employees and contracted fuel jobbers. Fixed fueling facilities are located in every major switching yard with more than 2,000 fueling locations in North America.

A single Class I railroad fueling facility will transfer 500,000 to 1.2 million gallons of fuel per month. Fuel management is key to controlling cost of fuel inventory. These fuel management systems employ full SCADA-type (Supervisory Control and Data Acquisition) reporting. This graphical representation of inventory and the fueling process provides a method for railroads to charge fueling costs back to foreign locomotives that pass through for fueling.

A typical fueling system uses a pressurized manifold design in which the manifold is held at a constant pressure while the locomotive is fueled. A vacuum- or hydraulic-type shut-off nozzle acts as the primary control valve in the fuel delivery system. The locomotive is fitted with a fuel adapter threaded into the fill pipe. This adapter has either a vent tube, in the case of a vacuum-type shut-off, or a hydraulic tube, in the case of a hydraulic type shut-off.

Current spill prevention efforts focus on continuous operator training and equipment maintenance. The railroads continually stress the importance of fuel awareness with their operators. All facility fueling is done over collection pits where the spilled fuel is collected and stored for recycling. DTL fueling does not have this advantage; however, a growing trend is to use DTL because of its convenience. Although this can be done at various locations, they are unequipped with fixed fueling systems and spill prevention and containment. While convenient, DTL fueling can pose greater risks of uncontained spills.

Class I railroads consume about 3.5 billion gallons of diesel fuel each year—thus, railroads rank second only to the US military in diesel fuel consumption. And the 3.5 billion figure does not even include fuel consumed by short-line or regional railroads! The figure does, however, include fuel that was lost, either to theft, delivery discrepancies or spills.

The cost of diesel fuel varies depending on location and contracted delivery volumes. The average cost in 1998 was $.65 per gallon. As shown in Figure 1, fuel costs account for about 11 percent of a railroad’s operating expenses.

**Figure 1: Industry operating expenses (in millions of dollars)**

**Bills for spills**
By far, the number one problem for locomotive fueling operations is preventing, containing and cleaning up fuel spills. A significant part of the prevention and containment is focused on locomotive fueling. Although fuel spills occur during fuel delivery, this is far less of an issue than spills during locomotive fueling. This is because fuel transfer from the truck to storage tank is done by suction pumping, which limits fuel loss at the truck cargo tank.

According to railroad estimates, fuel spills alone account for about one-half of one percent of the 3.5 billion gallons of diesel fuel consumed annually. While a small amount percentage-wise, this figure actually amounts to about 17.5 million gallons. At $.65 per gallon, this comes to $11.4 million—and the cost doesn’t stop there.

The cost of spill containment and collection equipment can reach roughly around $1 million per facility. Additionally, reclaiming fuel from containment areas—which involves separating, treating, transporting and disposing of water—can increase the cost of spilled fuel by more than $4 per gallon. For spills that occur where there are no containment devices, the cost of reclamation or remediation (including controlling the spill, removing and treating soil and disposing of waste) can reach $100 per gallon. And, if a spill occurs on a mainline section of track—requiring a disruption of service—the cost can be many times more than these remediation costs.

Given both the environmental and monetary costs incurred, the railroad industry is taking positive steps to improve the effectiveness of its prevention and containment of spills during locomotive refueling. Railroad companies are committed to protecting the environment and controlling expenditures for fueling operations, including losses, reclamation and cleanup. Under federal regulations (CFR 40, Volume 19, Parts 300-399), the US Environmental Protection Agency (EPA) can take action to penalize groundwater polluters and force them to clean up contaminated soil and water.

Figure 2: Fuel level tank on grade

Answering the challenge

Most railroad companies have significant personnel and financial resources dedicated to reducing fuel losses and improving environmental protection. The companies are acting through their association, the Association of American Railroads (AAR), to develop and adopt standards to prevent and contain spills. About three years ago, AAR established the Locomotive Fueling Systems Task Force (LFSTF), with the following objectives:

- To analyze locomotive fueling methods and equipment to identify causes of spills;
- To research hazardous liquid-handling methods and equipment in other industries; and
- To develop and test a new locomotive fueling standard.

The LFSTF was comprised of management representatives from the Class I railroads, AAR project managers, fuel systems suppliers and consulting engineers from ARINC Engineering, Inc. of Annapolis
Maryland. In its analysis of locomotive fueling systems, the LFSTF identified the following as the main causes of spills during the locomotive fueling cycle:

- Nozzles tend to “fail permissive.” This means that the nozzles tend to allow fuel to flow after sensing the locomotive’s fuel tank is full. This malady was found to be related to the passive vacuum or hydraulic shut-off circuits used in most locomotive fueling nozzles. The functions of the shut-off circuit are to detect the fuel level in the tank and cause the nozzle lever to trip, thus stopping the flow of fuel before the tank is over-filled. Any malfunction, such as a failure in a diaphragm or a leak in the sensing tube, would cause the system to fail permissive.
- Restrictions in fuel tank vents cause the tank to pressurize and (1) blow fuel out the fuel inlet when the nozzle is removed or (2) force fuel to leak out of the fuel inlet on the opposite side of the locomotive. Locomotive fuel tanks have inlets on both sides. The tanks and vents are under the locomotive. During winter months, the under carriage can become packed with ice and snow that block the vent pipe. Since the inlet tubes extend to the bottom of the tank, any tank pressure will force fuel out both fuel inlets.
- Fueling locomotives positioned on a track with a side-to-side grade can cause the fuel inlet on the low side to overflow before the nozzle senses the fuel level on the high side. (See Figure 2.)
- Failed or unreliable nozzles are frequently “defeated” or bypassed by the nozzle operator. Bypassing forces the nozzle valve to stay open, with no automatic shut-off protection. This usually results in a fuel spill through the locomotive tank’s vent piping. Operators defeat the nozzle shut-off feature by tying off the nozzle control lever, often as a way of “force-fueling” with nozzles that tend to shut off prematurely or to “top-off” a fuel tank. This practice is easily done using a shop rag or rope and usually results in a fuel spill. I saw one fuel operator use a rope with a slip knot that he tugged quickly to stop the fuel flow.
- The use of adapters in connection with incompatible fueling system components defeats the automatic shut-off feature.

- Poor visibility of sight gauges can contribute to spills when an automatic shut-off feature is not used. All locomotive fuel tanks have some type of fuel level sight glass or gauge. Any sight glass that has been in use for two years or more is coated with a dark varnish, which makes the fuel level nearly impossible to see. For manual nozzles or nozzles with shut-off bypasses, inability to see the fuel level means that a spill is the first indication that the tank is full.
- Fuel retained in the nozzle spout can spill during disconnection from the locomotive fuel tank inlet.
- Direct Truck to Locomotive (DTL) fueling is vulnerable to spillage when an automatic shut-off system is not used. DTL fueling is used when a locomotive needs fueling in a remote area or in a switching yard not equipped with a fixed fueling system. DTL fueling costs are higher, but permit the locomotive to be fueled on the mainline or remote area without removing the locomotive from the train. DTL is a valuable option for any railroad trying to improve locomotive utilization. However, DTL fueling typically does not use spill containment of a sufficient capacity. Also, this method of fueling relies on the operator to remain observant and prevent any fuel spills. Cleaning up a significant fuel spill from DTL fueling on a mainline can mean lost revenue, in addition to the normal cleanup costs.
Railroads attempt to deter fuel spills by transferring the cost of remediation to the DTL servicing company, by way of language in the fuel supply contract. In reality, the inadequacies in fuel nozzle technology had prevented even the most well-intentioned operator from avoiding spills (see photo on Top).

A close-up of the side of a locomotive with a typical DTL fuel spill. The gauge is broken. Courtesy of Carcon Locomotive Fueling Group

In with the new, and out with the old
In December 1996, the AAR held a conference that was open to all suppliers and railroad officials. The purpose of the meeting was to distribute and answer questions on a “Statement of Need” memorandum that outlined the fundamental system requirements. AAR–LFIS Locomotive Fueling Interface Standard, July 27, 1998, 8th Draft, is currently under testing by the Union Pacific, BNSF and Illinois Central railroads. It is expected that the standard will be released by the end of 1999. The standard is known as the AAR-LFIS. Any equipment built to this standard must be labeled “AAR-LFIS” and must have passed a qualification testing spelled out in the standard. Testing of components designed to meet the standard are ongoing so that systems and components will be available when the specification is released.

AAR-LFIS is a recommended practice, and railroad implementation is voluntary. The benefits of the system are clear: “Not one fuel spill has been reported to date.” The standard addresses the problems identified by the task force. AAR-LFIS is based principally on the established standards used in aviation fueling and the bottom loading of petroleum cargo tanks, both of which use dry disconnect nozzles and electronic fluid level or pressure control.

This “home-brewed” DTL nozzle has no automatic shut-off. Courtesy of Carcon Locomotive Fueling Group.

AAR and the railroad industry in general view the American Petroleum Institute’s API RP-1004 Bottom Loading and Vapor Recovery of Tank Motor Vehicles, September 1983, for cargo tanks as the standard most adaptable to locomotive fueling. Other advantages of the API 1004 standard are its: familiarity to DTL fueling operators; 20 years of reliability data; higher speed fueling; and availability from competitive suppliers.

API RP-1004 defines the mechanical and electrical interface of liquid and electronic components. As mentioned above, the API method of bottom loading has demonstrated 20 years of “spill free” and reliable operation. AAR task force tours of petroleum and aviation terminals found clean and safe operations.

The AAR-LFIS standard incorporates two proven API 1004 technologies. A spill-free system is achieved through the combination of a dry disconnect nozzle and a fail-safe automatic shut off electronic optic sensing system. The AAR-LFIS system contains six key components:

• Dry disconnect nozzle
• Dry disconnect fuel adapter n Liquid level sensor
• Communication plug and socket
• Fueling control monitor
• Solenoid control valve

The dry disconnect nozzle and fuel adapter—An AAR-LFIS nozzle is a three-inch dry disconnect nozzle. The nozzle must have a maximum flow of 600 gpm with a maximum pressure drop of 10 psi. An interlocking feature prevents nozzle disconnection while the internal dry disconnect poppet assembly is open. A dry disconnect fuel adapter is fitted to the fuel inlet pipe on the locomotive.


The AAR-LFIS standard requires the combination to have a maximum leakage of five milliliters throughout the fueling cycle. This equates to .005 liters, compared to pints or gallons with existing nozzles. The dry disconnect feature addresses fuel spills resulting from any leakage or blow back from the fuel adapter.

Ergonomics were considered in the specification requiring a push-on, pull-off coupling feature and a maximum weight of 10 pounds. This is less than half the weight of some nozzles in use today.

Automatic shut-off system—The automatic shut-off system consists of four parts: a liquid level sensor mounted in the locomotive fuel tank; a communications plug-and-socket connection; a fueling control monitor; and a solenoid control valve.


The liquid level sensor is designed to resist fuel agitation, frosting and the tar buildup typically found on fuel-tank sight glasses. An optical transducer detects the level of fuel with a repeatability of one-sixteenth of an inch.

Two sensors are mounted on the locomotive fuel tank. Sensors are positioned so that one is towards the front and the second is towards the rear of the locomotive. Sensor depth is set to two inches, or 200 gallons, of outage space. This is done to ensure thermal expansion does not cause fuel to spill out the venting system. The sensor communicates to the mounted fueling control monitor through an electrical plug-and-socket connection.

A locomotive fuel adapter, socket and sensor— all AAR-LFIS compliant. Courtesy of Carcon Locomotive Fueling Group.

Sensor communications use a defined digital pulsed signal sent to the sensor from the control monitor. When dry and operational, the sensor receives the signal, modifies the signal and echoes the modified pulsed signal back to the control monitor. When the sensor is wetted, no signal is returned to the control monitor.

Sensor communications are documented in the standard to ensure compatibility between manufacturers. Mounting of the socket is typically on the locomotive fuel tank near the fuel adapter inlet. Design of the plug-and-socket connection conforms to mechanical and electrical requirements.
defined in the AAR-LFIS specification. The plug and socket use a push-and-twist motion to make the electrical connection.

Communication between the sensor and control monitor uses a unique “fail-safe, handshaking” signal format. Any failure in the sensor, wiring, plug-and-socket connection or in the fueling monitor will result in a loss of this handshaking signal—thus, causing the system to stop fueling.

The fail-safe nature of this system is the primary defense against fuel spills. The electronic components are small and easily installed in almost any style of fuel tank. System operation is similar to overfill prevention equipment found at API petroleum bottom loading terminals, and is very familiar to any DTL operator. Equipped with start, stop and status controls, the fueling control monitor is available for fixed fueling sites and DTL mobile fueling.

The New Standard in Action

An important factor in the development of the AAR-LFIS specification has been to address the concerns centered on DTL fueling in the many cases in which spill containment is unavailable.

Typical DTL suppliers use standard petroleum DOT-406 cargo tanks or fuel delivery tank wagons. These tanks perform a variety of fuel delivery services and typically do not permit modification, thus limiting their use to single customers. Here is where the flexibility of the AAR-LFIS standard shows its ability to be applied in any fueling application.

Smaller nozzles and mobile fuel control monitors are available to permit a tank wagon to provide fueling service compatible with AAR-LFIS, yet permit transfer of equipment between tanks. An electric over-air PTO (electrically controlled air-operated power take off) solenoid valve is installed on any truck providing DTL service and the nozzle; the hand-held control monitor may then be moved to any tractor equipped with the PTO valve. A mobile system limits the cost of DTL conversion and maintains flexible management of the tank fleet.

The most measurable value to the DTL fuel supplier comes in the form of liability management. Investment in an AAR-LFIS system will greatly reduce exposure to significant clean-up costs and possible loss of a key customer.

This tank truck is fitted with an AAR-LFIS system. Courtesy of Carcon Locomotive Fueling Group.

Several Class I railroads are testing the AAR-LFIS technology to evaluate equipment performance and build real-life experience into their installations and operations. Changeover of a railroad’s fueling system is no small project and much needs to be learned through the testing process.

Testing is under way at Burlington Northern, Santa Fe, Union Pacific and the Alaska Railroad. Initial prototype systems were tested at AAR’s Transportation Technical Center in Pueblo, Colorado. Testing to date has been very successful—with not a single fuel spill recorded since the test began!

Short-line railroads and DTL servicing companies have already taken advantage of the AAR-LFIS system. The Class I railroads are testing and developing conversion plans for the coming years. Tests
are underway for DTL and fixed fueling facilities. Early testing has proven to solve fuel spill problems. This early data was sufficient for some railroads to make the commitment and install AAR-LFIS equipment in areas where spills have been a historical problem. Fueling contracts now specify the use of an AAR-LFIS system for DTL fueling.

What should a DTL operator do if the railroad has not converted to AAR-LFIS? One possibility is to use an AAR-LFIS-compatible DTL fueling system designed for use on non-AAR-LFIS locomotives. Carcon, for instance, has developed a system that consists of a mobile control/alarm module and temporary mounted fuel level sensor. Fueling is done through the existing nozzle. A sensor is mounted in a special fuel inlet adapter that detects when the tank is full and automatically stops the flow of fuel. Equipment is transferable between tanks, and no modification of the locomotive fuel tanks is needed. The integrated sensor plug-and-socket connection is compatible with the AAR-LFIS standard so the system will not become obsolete.

Final thoughts
Fuel management is a big expense; environmental remediation is an even bigger expense. Thus, a small percentage saving in fuel costs transfers a lot of money to a railroad’s bottom line.

Any railroad executive responsible for managing the cost of fuel or environmental policy should become well informed on the benefits of the AAR-LFIS fueling specification. Environmental law will drive its implementation; railroad CEOs will demand the cost savings. In today’s environmentally aware world, key executives can find themselves criminally liable for neglecting environmental protection law. AAR-LFIS is a fueling standard that’s time has come.

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