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A closer look at LNG

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EMD 16-645E3 with LNG modifications for CN

Over its roughly 200 years of history, the North American railroad industry has been shaped by numerous technological milestones, among which are steel rail, automatic knuckle couplers, air brakes, signals, electrification, dieselization, CTC, radio communications, AC traction, gensets, and—still under development—ECP brakes and PTC. Add LNG (liquefied natural gas) to the list of potential evolutionary, if not revolutionary, technologies.

But don't expect a wholesale shift from diesel to LNG to occur overnight. The railroad industry just doesn't work that way.

How long might it take for significant adoption of LNG as a locomotive fuel? "The most recent huge increase in efficiency was the advent of the AC-traction locomotive," says consultant Jon T. Gabrielsen. "Yet as of now, only about 17% of the entire installed base is AC, and it has taken 20 years to build up to the 5,000-plus units that are AC, out of about 30,000 total—an average of adding 250 AC locomotives to the installed base over those 20 years. To their credit, during the period of 1994-1999, the railroads added over 500 AC locomotives per year. But those were very heady times in the macro economy, the roaring '90s. And even though the first AC locomotives were put into service in 1993, they had been developed and were being pushed by the OEMs as early as the late 1980s, when EMD licensed Siemens AC technology. If the adoption of AC locomotives is a valid proxy, railroads take about five years to decide if they want to go with a significantly changed technology and then adopt at a rate of about 0.8% to 1.0% per year of the total installed base thereafter. Even if they doubled that adoption rate for LNG, it would still take a very long time to be significant."

"The challenges of LNG are capital investment, the potential impact on maintenance costs, the LNG infrastructure costs, the logistics of getting LNG to a fueling site and into the tender car, and the possibility of compromising the fuel cost savings by over-investing," says Ricardo Strategic Consulting Principal Mark S. Kuhn.

Other significant challenges are the issues regarding integrating dual-fuel locomotives and fuel tenders in an increasingly interconnected network involving freight railroads serving three nations in North America, increasing amounts of run-through trains and locomotives among carriers, and the additional complication of distributed power locomotive consists within freight trains.

"The public policy issues are significant," BNSF chief executive Matt Rose told *Railway Age* in September. "LNG is the policy wonk's delight." Currently, the U.S. Environmental Protection Agency has no regulatory oversight on LNG locomotives. The Federal Railroad Administration, working presumably with the Department of Homeland Security, will need to establish safety regulations for LNG fuel tenders. The Surface Transportation Board will have to acknowledge the capital investment and ROI implications of LNG.

Programs to evaluate LNG as a locomotive fuel are expanding throughout the rail industry, led by such stakeholders as GE Transportation, Electro-Motive Diesel, BNSF, Union Pacific, CN, Clean Energy Fuels, Chart Industries, Westport Innovations, Waste Management, Gaz Métro, and many others. During two separate conferences in October—the 2013 GE Transportation/Norfolk Southern Railroad Sustainability Symposium, and the High Horsepower Summit in Chicago—industry experts delved into current LNG projects, and the potential of this (for railroads) relatively new alternative to diesel fuel.

In general, "there are huge environmental and economic benefits associated with going to LNG," said Association of American Railroads Assistant Vice President Environmental and Hazmat Bob Fronczak. "We believe that LNG's greenhouse gas emissions will be lower than diesel fuel, able to meet Tier 4 standards, though there is no data at present to support this." In terms of reduced fuel cost, a savings of up to $200,000 per year per locomotive (at current LNG prices) is estimated.

The cost of fuel drives everything. The industry currently spends about $9 billion on diesel fuel annually. Can LNG be hedged? Says Jon Gabrielson, "One can just as easily hedge the price of diesel as the natural gas that is made into LNG. Diesel hedging, like jet fuel hedging, already exists and has for a very long time. Hedging isn't free, and a gamble that when one loses is very costly. It is a bet on what the future price of what a commodity will be vs. what you pay for the futures now. The impact of changing natural gas prices is tiny because most of the cost is in the fixed cost of liquefying and in the logistics."

Development of an industry-standard fuel tender is under the auspices of the AAR Natural Gas Fuel Tender Technical Advisory Group (NGFT TAG), a joint effort of the AAR Locomotive, Tank Car, and Equipment Engineering Committees, Amtrak, BNSF, CN, Canadian Pacific, CSX, Kansas City Southern/KCS de México, Norfolk Southern and Union Pacific, with key support personnel from the AAR and Transportation Technology Center, Inc. (TTCI). This task force, which is chaired by UP General Director Car & Locomotive Engineering Michael Iden, is tackling regulatory and safety issues. For example, under current DOT Pipeline & Hazardous Materials Safety Admininstration (PHMSA) rules, LNG is not permitted to move by rail, unless there is an FRA waiver.

The NGFT TAG has met with locomotive builders and other stakeholders, and is working with the FRA to develop fuel tender performance standards. More than 100 potential failure modes have been identified and submitted to FRA and Transport Canada. "We have had numerous 'town hall' meetings with locomotive and engine technology manufacturers and freight and tank car manufacturers at which the locomotive and engine manufacturers were also present," says Iden. "FRA, PHMSA, and Transport Canada have been present at several of the TAG meetings, and one meeting was held specifically with FRA, Transport Canada and PHMSA at the AAR in Washington D.C. Additional TAG meetings and town hall meetings are being planned."

Unlike household natural gas, the odorants (mercaptans) that assist in the detection of a leak cannot be used in a locomotive application. Instead, methane detectors must be in place to detect an LNG leak, because LNG is colorless and odorless. The most vulnerable spots for a leak would be the connection from the fueling facility to the fuel tender, and from the fuel tender to the locomotive.

There are several methods to deliver LNG fuel to the locomotive prime-mover. All require the LNG, which is cryogenic methane chilled to –260 degrees F with other elements (water, propane butane, etc.) removed, to be vaporized (heated to a gas). This process takes place on the fuel tender. In the engine's power assemblies (cylinders), diesel fuel, which ignites under high compression, is used to ignite the natural gas. ("All of the technologies current being promoted pass gaseous methane, not LNG, onto the dual-fuel locomotive and into the engine cylinders," says Iden. "Technology does not currently exist to inject LNG directly into engine cylinders and properly combust it.") This method provides some operational flexibility, depending upon the LNG/diesel ratio. High pressure direct injection (HPDI, at 5,000 to 8,000 psi), and low pressure (125 psi) fuel delivery methods are being looked at. HPDI fuel delivery requires port or direct injection at the cylinder; this method is purported to save anywhere from 40% to 60% in fuel costs.

The mission of the AAR NGFT TAG is "to develop performance standards for future natural gas fuel tenders for the railroad industry to support the use of LNG as an alternative locomotive fuel."

"The AAR creates and maintains performance standards for many facets of the railroad industry and is the logical organization to take on the challenge of creating industry standards that offer homogeneity for fuel tender designs in support of industry and regulatory requirements," says Iden. "Also, the TAG is not ruling out the use of compressed natural gas (CNG) and hence the possibility of CNG fuel tenders. However, the majority of the TAG's effort at this time is on LNG fuel tenders as LNG is the logical form of natural gas fuel to support long-distance line-haul locomotives. There are four existing tank-car-style prototype tenders from the 1980s and 1990s and several new yet-to-be-operated well-car style tenders."

The NGFT TAG, which serves as an AAR/industry interface, is working on:

• Safety, crashworthiness, and environmental protection.

• Tender design and construction.

• Tender-to-locomotive interfaces and connections.

• Tender-to-refueling infrastructure interfaces and connections.

• Tender interoperability and interchangeability between railroads.

• Maintainability.

• Development of dual-fuel and gas-fuel locomotives and tenders.

• Soliciting feedback from relevant suppliers.

• Communicating and updating the NGFT TAG standards process to suppliers.

Class I tests ramping up

LNG test programs at BNSF and Union Pacific are expected to start in the fourth quarter and last at least one to two years. EMD Director, Engine Systems Martha Lenz reports that an HPDI stationary test is up and running. EMD is supplying three test locomotives to BNSF, and with fuel tender supplier Westport and Gaz Métro (one of the largest natural gas distributors in Canada), is participating in a demonstration on CN.

CN's current LNG development program, which began in 2012, uses two EMD 3,000hp SD40-2s equipped with modified 16-645E3 engines. The engines have been converted to LNG using available kits. A 27,000-gallon LNG tender (built in 1992 for UP and on lease from UP) was modified for this program, which Transport Canada approved. The tender was outfitted with a locomotive coolant loop for gasification, filling, and purging arrangements; a power supply; and other equipment.

CN in 2014 will be taking its demonstration program one step further with main line testing beginning in 2014. It will evaluate:

• LNG thermal efficiency with a high-horsepower locomotive.

• Mileage range reliability.

• Fuel tender operations flexibility with CN's fleet operations productivity requirements.

• EPA and Transport Canada emissions compliance.

• LNG substitution ratio capital cost control.

• Maintenance cost controls and maintenance facility impact.

• Safety and regulatory AAR interchange standards.

• Tender design and construction.

• LNG supply logistics.

• LNG long term price forecasts.

• LNG refueling efficiency.

According to GE Transportation Locomotive Business Operations Executive Graciela Trillanes and Dual-Fuel Engine System Leader Eric Dillen, GE Transportation's LNG technology (currently under test at its Erie, Pa., plant) is based upon a mix of 80% LNG, 20% diesel, using an existing EVO™ engine. This ratio allows the engine to revert to 100% diesel in the event of an LNG-related failure or the unavailability of an LNG stationary or mobile refueling station. At a 95% LNG/5% diesel ratio, reverting to 100% diesel is not possible. A 100% LNG engine would require a spark at the cylinder (and major modifications to existing engine technology), since LNG does not ignite under compression. Thus, the “dual fuel” engine appears the way to go, at least until LNG fueling solutions can be deployed industry-wide.

Also, as an initial step, deploying 80% LNG locomotives would be an easier, more cost-effective solution for the railroads, according to Waste Management Sustainability Services Director Tom Carpenter.

Fuel tenders can be configured in two forms: a 10,000-gallon ISO tank, or a 20,000 to 30,000-gallon (approximate) tender that closely resembles a tank car. “Gallon figures are not iron clad,” says Iden “I don't believe anyone has established firm capacity numbers for future tenders because there are many variables that railroads will be contending with in matching fuel tenders, locomotives, trains, operating speeds, corridor geography, refueling locations, etc.”

An LNG-powered freight train using 25,000-gallon LNG fuel tenders could be able to operate, for example, between Los Angeles and Chicago one-way without a refueling stop, improving locomotive utilization, according to GE’s Trillanes. The ISO LNG tank, though of lower capacity, offers more operational flexibility and potentially lower cost. At 40 feet in length and enclosed in a steel frame, the ISO tank can be mounted in a modified well (doublestack intermodal) car, and can be easily removed when empty and replaced with a full tank transported by truck, thus eliminating the cost and logistical constraints of a dedicated LNG fueling station.

For a purpose-built fuel tender, for which the AAR is developing performance standards that will support safety, interoperability, interchangeability, regulatory needs, maintainability, and dual-fuel locomotive operation, among other requirements, the most modern refueling equipment will provide a refueling time of 30 to 45 minutes, about 400 gallons per minute, according to Clean Energy Fuels Assistant Vice President LNG Production & Rail Koby Knight—longer than a diesel refueling stop, but required less frequently.

Fuel tender safety is of course a prime consideration. In general, LNG is safer than diesel or gasoline, since it does not ignite in liquid form. If it spills, it vaporizes instantly (at –100 degrees F) and dissipates. Dissipation is affected by such factors as humidity and wind. In gaseous form, LNG will ignite only under very specific temperature conditions (at least 1,000 degrees F) and oxygen concentrations. LNG cryogenic tanks, supplied by companies like Chart Industries and Westport Innovations, are highly crashworthy, and must, under 49 CFR 179.400-13, be built to withstand 7 Gs of longitudinal impact force, and 3 Gs of transverse and vertical impact force. They are constructed as a double tank—an inner tank (typically stainless steel, though aluminum is sometimes used) encased in a flexible material, and enclosed in a carbon-steel or stainless steel outer tank. A vacuum is created in the space between the inner and outer tanks.

Historical perspectives

LNG has been in use in the transportation industry (mainly trucks and buses) since the mid-1990s, and was tested on the Burlington Northern Railroad and the Union Pacific in the 1980s and 1990s. (The fuel tenders being prepared for BNSF's current tests with GE and EMD locomotives are BN's original tenders from those years, rebuilt and modernized.) Union Pacific sponsored developments at EMD and GE between 1992 and 1998, using two EMD SD60s and two GE Dash 8s and two fuel tenders. These units were tested at the OEMs, but the final engine technology was not completed, and the project was shelved in the late 1990s. BN had a development program with ECI (Energy Conversions Inc.) from 1988 to 1996, using two EMD SD40-2s with two tenders. These units operated in Powder River Basin coal service from 1991 to 1996 between Wyoming and Wisconsin. The LNG hardware is still marketed by ECI.

In 1994, Morrison-Knudsen (now the MotivePower Industries division of Wabtec Corp., Boise, Idaho) built four LNG-fueled MK1200G switchers, two each for BN and UP. These 1,200-hp, 100% LNG units were equipped with a 16-cylinder Caterpillar 3516 natural gas spark ignition engine that delivered a 25% to 35% BTU/HP savings over a diesel-fueled GP38-2. All four eventually went to BNSF; they worked in Southern California over the past decade, and were refueled by LNG tank trucks.

LNG, said Clean Energy's Knight, "is a sustainability and energy security initiative. The way to make LNG work for the rail industry is through state-of-the-art engine technology and the expertise required for it. The engine technology has come of age. What needs to be carefully looked at is the business aspect: What is the cost per hour of operating an LNG locomotive?"

CN says the estimated cost of a fuel tender is $1 million—"a potential complication. The economic analysis lies with the tender." Operationally, "unit coal trains are a tight operational process and may make the most sense, at least initially, for LNG. And the fastest way to refuel a tender is with an LNG truck. Adding an LNG plant is costly and doesn't make sense. Using a truck lessens local community concerns, as it does not require pipes, etc. And how many people will be needed for switching and refueling operations?"

LNG locomotives could be in widespread use by 2016 or 2017. Whether that comes to pass will depend upon all the variables discussed above.

Editor's note: This article originally was published in the October 2013 issue of Railway Age. It is re-published here with several clarifications, corrections, and additions. Railway Age thanks Union Pacific's Michael Iden for his input.