Alternative Fuel Transit Buses

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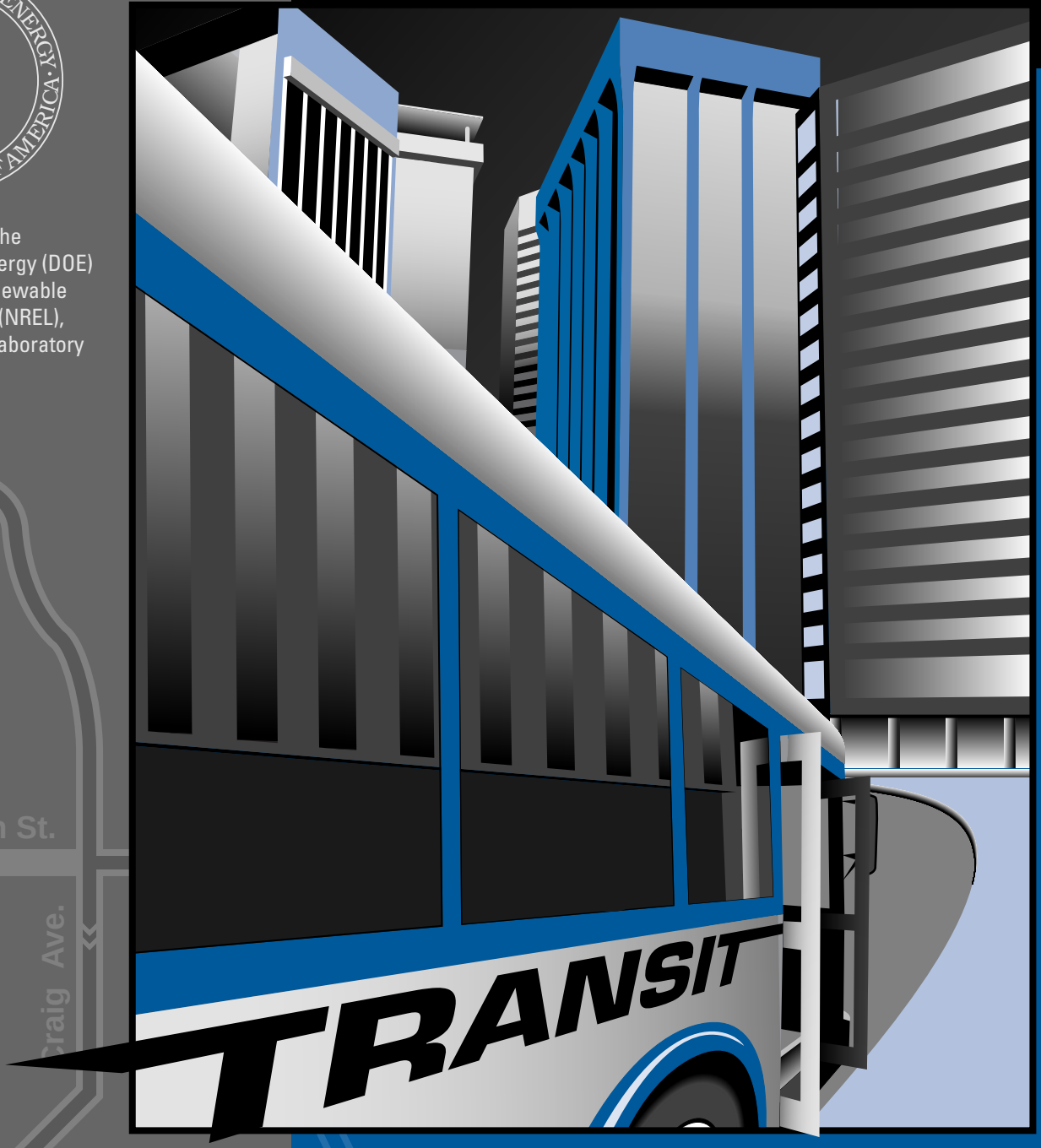

DART's LNG Bus Fleet

Start-Up Experience

When Dallas Area Rapid Transit (DART) announced the delivery of the first liquefied natural gas (LNG) bus to its Dallas, Texas, Northwest Bus Operations, the success of the alternative fuel program seemed inevitable. The DART Board of Directors had approved the multi-year purchase of alternative fuel buses in March 1997. The industry publication *Passenger Transport* had showcased DART's development activities, emphasizing the focused efforts of its four-year plan "to build one of the most modern and environmentally friendly bus fleets in the industry."

DART was working hard to achieve this goal and demonstrate its forward-thinking transportation philosophy in a well-crafted plan. In addition to the alternative fuels program, DART planned construction and operation of 53 miles of light rail, 37 miles of commuter rail, and 98 miles of high occupancy vehicle (HOV) lanes along congested Dallas highways. The American Public Transit Association (APTA) recognized DART's efforts, naming DART Transit Agency of the Year in 1997. In one year, DART ridership increased nearly 45%.

1997 Transit Agency of the Year

In 1997, the American Public Transit Association presented DART with the Outstanding Achievement Award for Large Transit Systems. This award recognized DART for its accomplishments during its 13-year operation.

Specific achievements cited for the award included establishing the first light rail and commuter rail systems in the southwestern United States and building new high occupancy vehicle lanes to promote ridesharing. The award also recognized DART's Trinity Railway Express commuter rail line.

In December 1997, DART increased its order for LNG buses with the manufacturer and supplier, Nova BUS of Roswell, New Mexico. In January 1998, Nova BUS delivered the first of 139 LNG-fueled buses. This first LNG bus began with limited operations in the Dallas region, preparing the way for the full delivery of the advanced technology buses later in the year. In November 1998, the first of the LNG buses joined the DART fleet, and the program was officially under way.

However, less than a year later, on July 23, 1999, the direction of the program took a different turn. The *Dallas Morning News* reported the cancellation of DART's LNG bus orders. "DART is canceling the purchase of 60 buses powered by cleaner-burning natural gas and instead will return to buying buses that run on diesel fuel," the newspaper stated, citing poor performance and reliability as key factors in the decision.

What happened to change DART's path, and how dramatic is the change? The following report, based on interviews and site visits conducted in October 1999, describes the start-up activities of the DART LNG bus program, identifying problem areas, highlighting successes, and capturing the lessons learned in DART's ongoing efforts to remain at the forefront of the transit industry.

What happened to change DART's path, and how dramatic is the change?

DART's 989 buses and vans include 141 natural gas transit buses.

"One point should be made clear," says DART's Maintenance Vice President Mike Hubbell. "We are not canceling our commitment to natural gas. We have imposed a moratorium on purchasing additional LNG buses. We have 141 natural-gas buses in our fleet–139 LNG buses and two older CNG (compressed natural gas) buses. We have the first ULEV (ultra-low emissions vehicle) certified heavy-duty natural gas engines in the U.S. We have 200 CNG paratransit vans, and 148 CNG automobiles and trucks. Forty-one percent of DART's motor fuel fleet is natural gas. We've invested $16 million in this program in the last five years, but we have some issues we need to resolve before we invest any more."

The partnership that supports this effort is strong, Hubbell said. "We've had very good success with the infrastructure needed for the program. The mobile side has been disappointing. There are lots of things pulling at the success of this program." Hubbell emphasizes that no single partner in this team is at fault. Every supplier has remained involved.

Current DART Operations

- Serves Dallas, Texas, and 12 suburban cities
- 130 local and express routes
- 989 buses and vans
- 141 natural gas transit buses
- 20 CNG trolleys
- 200 CNG paratransit vans
- 148 CNG automobiles and trucks
- 700 square-mile area
- Approximately 200,000 passengers daily
- 2 LNG fueling facilities

PIX 09175

PIX 09176

However, the size of the DART fleet seems to have strained the LNG industry's ability to support the program. A transit operation like DART needs to have problems resolved in a day or two, not a week and certainly not a month. A common understanding in the alternative fuels industry is that a program can realize economies of scale if it incorporates a large number of vehicles in a fleet (several hundred units rather than a dozen). This prediction of economy may be premature, however, if the industry does not invest in the support infrastructure technology development and/or refinement needed to maintain the fleet. DART's experience indicates that the alternative fuel industry—designers, manufacturers, suppliers—is not ready to respond to a large LNG fleet operation in a day or two.

Transit Operation Use of LNG in the United States

Agency and Number of Vehicles

City of Phoenix PTD (Phoenix, AZ)	**157**
Dallas Area Rapid Transit (Dallas, TX)	**139**
City of Tempe Transportation Division (Tempe, AZ)	**67**
El Paso Mass Transit Department (El Paso, TX)	**35**
Regional Public Transportation Authority (Phoenix, AZ)	**22**
Tri-County Metro Transportation District (Portland, OR)	**10**
Gary Public Transportation Corp. (Gary, IN)	**6**
Metropolitan Transportation Authority—Harris County (Houston, TX)	**5**
Lompoc Transit (Lompoc, CA)	**4**
Mass Transit Administration of Maryland (Baltimore, MD)	**4**

Source: American Public Transit Association (APTA), 1999

The issues Hubbell refers to have haunted the DART LNG program, says Darryl Spencer, Fleet Systems Engineer. "The program has faced difficulties, both in reality and in perception," Spencer said. "A negative cloud seems to hang over the program." Darryl Parham, Senior Manager of Bus Services, ticks off the difficulties with a sigh: range, mileage, reliability. Fueling problems, particularly with fuel hose nozzles, also are industry-wide issues. DART has experienced problems with parts availability as well.

Less-than-expected fuel economy contributes to DART's problems with the range capability of the LNG buses. The fuel economy is approximately 1.6 mpg. Nearly 2.5 mpg would be required to meet DART's range requirement. However, 1.6 mpg for the LNG engine is the industry average for the rough transit duty cycle, which is nearly 50% idle time and very low average speed. This fuel economy puts extreme pressure on the vehicle range based on how DART dispatches buses. DART's buses need a range of 380 miles minimum (DART's target was 400 miles). DART dispatches most buses on two runs during a standard operating day, with no refueling. Refueling in the middle of the day would be expensive for DART. DART's strategy for overcoming this problem was to add a fourth LNG tank to the buses. The most recent fuel economy test showed that the four-tank system has a range of 380 miles. The first buses in the fleet were retrofitted with the fourth tank, and the remaining buses were fitted with the tank at the factory before delivery to Dallas.

A second contributor to the range was difficulty in fully fueling the buses. To get the desired maximum range from a bus, DART needs to ensure that each bus is filled completely with fuel before it begins its route. Getting the full fill has been difficult with the on-board LNG tanks. The problem, as Parham describes it, is that one of the tanks would get "hot" and have higher pressure than the others. This would cause two of the tanks to get refilled during fueling, but not the third "hot" tank. The fueler needs to rely on the fuel gauge for the LNG, Parham says, and the gauge was not always accurate. Fuel gauge inaccuracy resulted in unfilled tanks, and that led to road calls for out-of-fuel buses.

The impact of a road call can go beyond the obvious operational interruption. One DART bus driver noted that although customers often do not really know or care about the kind of fuel the buses are using, "they do start to draw their own conclusions when they see another one of those new buses down on the side of the road," he said. Reliability is the key operational issue, according to Rocky Rogers, DART's Assistant Vice President of Technical Services, and the impact is significant. If reliability issues lead to reduced ridership, then that means more


PIX 07850

Two 30,000-gallon tanks supply LNG to the fueling island through above-ground insulated piping, which runs under the canopy.

PIX 09177

Lone Star's computerized monitoring system provides fuelers with real-time information for troubleshooting.

PIX 09180

DART installed fuel indicators on board the buses to monitor LNG levels and ensure a full fill.


PIX 09178


PIX 09179

This docking station stores the LNG nozzles when not in use and serves as pre-cool circuit for the station. The liquid fill nozzle supplies 50 gpm.

vehicles on the road, and that means more emissions, says Rogers. "And the biggest benefit we can provide to the community is getting people out of cars and into buses."

DART has alleviated the "hot" tank scenario by installing fuel gauges on the individual tanks. Fuelers are now able to monitor "hot" tank conditions. A "hot" tank does not receive fuel, and when the fuelers see this, they can begin the fueling process again.

In March 1998, DART commissioned Lone Star Energy to develop an LNG fueling station at the Northwest Bus Operations. The fueling facility consists of two 30,000-gallon storage tanks; three 60-gpm, 110-psig pumps; and three LNG dispensers. Each of the three fuel lanes has an LNG and a diesel dispenser. Lone Star is responsible for both the station and the fuel.

Although the station is operating effectively, DART faced start-up issues with it also. The LNG fueling facility requires a minimum number of buses to be fueled daily to keep the storage tank pressures low enough to prevent venting of natural gas. The amount of piping used in the facility also created problems with the cooldown cycle. Lone Star solved the fuel facility problem with an advanced, computerized system that allows the fuelers to monitor the cooldown cycle.

DART has also experienced a problem with the fuel hose nozzles. Mating the LNG fuel hose to the bus sometimes allows leakage around the nozzle during fueling, which causes ice to form on the seal. The ice formation compounds the problem, damaging the seal and increasing the amount of time for fueling. Additionally, the nozzles used on the LNG fuel hoses do not incorporate a breakaway feature, which is common for diesel fuel hoses. If a driver pulls away with a diesel hose attached, the hose simply breaks away from the dispenser, which minmizes damage to the bus and the dispenser. A driveaway is a driver error, not a technology problem, but technology has reduced the impact of this human performance issue for diesel fueling.

DART is considering adding a switch that removes the ability to start the bus if the fuel door is open, thus keeping the bus from pulling away from the fueling island with a fuel hose attached. However, this feature presents potential for vandalism, so it is essential that opening the fuel door should not shut off the engine.

Other issues, such as out-of-calibration methane sensors used to detect fuel leaks, have presented challenges for the maintenance

personnel. The mechanics received training to work with the technology, and Parham says some of the mechanics really like the troubleshooting. "They dig into the problems. They've jumped right in. It keeps them interested and makes them want to know more about it." From a strictly technical perspective, the challenges of the new technologies such as methane detectors, LNG tanks, and the fueling process are interesting, Parham says. Some of the problems with the fire suppression system, some of the electronics, and the multiplexing system are inherent in the LNG and diesel fleets, as mechanic Mauricio (Max) Rodriquez pointed out. But as he also made very clear, working on the LNG buses does have unique difficulties that are not technology related, such as getting parts.

"It is interesting—LNG is a different animal," says Anthony Verhovshek, DART's Maintenance Supervisor. Verhovshek emphasized that understanding the LNG-fueled buses means learning about the whole bus, not just the engine. "You really have to understand the whole system to make it work," he said. Parham's interest in the technology does take a more cautionary note when he addresses these problems within the context of day-to-day operations. "We are surviving. We are running the business. There are 192 vehicles at this facility, and there are 168 pullouts every day. My job," Parham said, "is to get the buses on the street. LNG is making this difficult, but we are solving the problems."

Q: Did DART approach this program with expectations higher than those supported by other industry experiences?

A: "Absolutely not," Spencer stressed. "We went into this program embracing the technology, but we knew it would be challenging. DART did it by the book: We started 18 months in advance with an LNG steering committee. We ran the scenarios. We identified possible obstacles. And we ended up experiencing 50% of what we tried to avoid." Hubbell agrees that DART worked to understand what the program involved. "We knew that the technology wasn't in its infancy," he said, "but we thought it was more advanced than it is. Managing our expectations has been difficult," Hubbell said.

Jason Ruble of Cummins Engine Company knows that DART personnel are disappointed with the bus. "It is difficult," he said, "because often the expectation is that the natural gas engine will perform the same as a diesel. This may not be a realistic expectation. The technology is evolving, and the current technology may not be able to meet expectations." And Ruble points out that realizing that current natural gas engines require more maintenance is often the greatest disappointment for fleet operators. LNG engines are more sensitive to duty cycle than diesel. "If you want to look at emission numbers," Ruble said, "natural gas provides a great solution. But you are not going to get a great fuel economy and ultra-low emissions. Not yet, anyway."

Q: What has DART learned during the two-year start-up of the LNG bus program?

A: "We've certainly learned a lot about LNG," Spencer said. "We've learned you have to go in embracing it. You can't go in kicking and screaming." Transit property operators should require engineering design validation and/or performance tests on critical vehicle systems. The test results will reveal where problems lie in overall vehicle design and expected performance.

DART personnel are ready to share what they have learned because they are committed to the concept. "We are committed to making the vehicles run," Rogers said. "We are committed to natural gas. We operate a zero-emission light rail system. All of our non-revenue vehicles use natural gas. DART needs to be recognized for this as well as the ongoing commitment to maintaining the existing LNG vehicles. But reliability is an issue, and we cannot invest in additional vehicles until we resolve this."

Every fleet has start-up issues. However, Hubbell makes it clear that DART has learned some things that have industry-wide implications. "We made the commitments that were needed. We committed the energy, and we committed the infrastructure, and we committed the money. Our challenges were at a different level, at a higher level." Rogers emphasizes that: "You really have to look at the size of the fleet. This is complicated, and our industry hasn't addressed this yet. How do you implement new transportation technologies in a large organization?"

Did DART approach this program with expectations higher than those supported by other industry experiences?

The industry needs to hear about DART's experience. "We need to work with industry representatives to resolve the issues associated with natural gas in large-scale heavy duty operations," said Hubbell. "It is particularly important to look at the context of the operation. Reliability, range, and economics are issues." The DART program has successfully implemented a significant number of alternative fuel buses. It has not been a particularly smooth process, but the program is operating. "You have to be patient," said Spencer. "The lesson is being patient with the whole fleet and looking at the overall successes. Yes, there are problems, as would be expected with new technology such as LNG. But the buses are making pull out."

What emerges clearly from this program is a need to integrate fully the systems required to make the program work. Independently, each element has succeeded in the industry: Cummins engine, MVE tanks, Nova BUS chassis, Lone Star Energy fueling station, and DART's daily operations. DART is using the LNG-fueled vehicles in its fleet. The primary issue of range has been resolved with the fourth LNG tank. However, this was not an issue of poor technology. The other known issues—low fuel economy, fuel nozzle leak, fuel gauge inaccuracy, parts availability, contractor-dependent system maintenance, and breakaway fuel hose connection—are manageable now that they are identified.

As Hubbell has pointed out, the industry can learn from this program, and the primary lesson may well be the need for these systems to fully integrate. The need for strong communications and accurate information underlies many of the lessons voiced at DART.

Although the start-up may be rough, Rogers emphasizes that if a site intends to use alternative fuels, investment and commitment are the keys to success. "You have to make enough of an investment to make it work and enough of a commitment to resolve problems. If you have only a few buses and you have a problem or hit an obstacle, you just park the buses. When you have a large number, you cannot just park them. You have to resolve the problems."

STATUS: As of June 2000, nearly all the problems with the LNG buses reported here have been resolved through the lessons learned from start-up. The LNG buses have been operating on nearly all routes at the Northwest facility except for a few very long routes. The only remaining issues are to finish optimizing the power train to increase the fuel economy on the LNG buses and to resolve a problem of premature head failures in the engine. Cummins is pursuing a resolution to the engine problem.

DART released its latest request for proposal with a requirement to bid an order of 160 buses as all diesel or all LNG. The response to this request is not complete without the LNG bid.

Vehicle Specifications for DART LNG Buses

Chassis Manufacturer/Model	Nova BUS, 40 foot
Chassis Model Year	1998
Engine Manufacturer/Model	Cummins L10-280G
Engine Ratings	
Max. Horsepower	280 hp @ 2100 rpm
Max. Torque	900 lb-ft @ 1300 rpm
Fuel System Storage Capacity	4 LNG MVE, Inc. tanks*
	221 LNG gallons (132 diesel equivalent gallons)
Transmission Manufacturer/Model	ZF 5HP590
Catalytic Converter Used	Yes
Curb Weight	30,920 pounds
Gross Vehicle Weight (GVW)	39,500 pounds

*Retrofit of the fourth tank was completed in summer 1999.

PIX 09147

The Alternative Fuel Transit Bus Evaluation Project

This report is part of an ongoing Department of Energy (DOE) program to study heavy-duty alternative fuel vehicles in the United States. DOE's National Renewable Energy Laboratory (NREL) is conducting the Alternative Fuel Transit Bus Evaluation Project to compare alternative fuel and diesel fuel buses. Information for the comparison comes from data collected on the operational, maintenance, performance, and emissions characteristics of alternative fuel buses currently being used in vehicle fleets and comparable diesel fuel buses serving as controls within the same fleet. Other results from this project were released in 1996 in a report entitled Alternative Fuel Transit Buses, Final Results from the National Renewable Energy Laboratory (NREL) Vehicle Evaluation Program.

This report highlights the start-up experience of the Dallas Area Rapid Transit in Dallas, Texas. After collecting 12 months of data from the site, NREL and Battelle, NREL's support contractor for the project, will prepare a formal report and analysis. If you want to know more about this transit bus program, its components, alternative fuel vehicles, or incentive programs, contact any of the following:

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