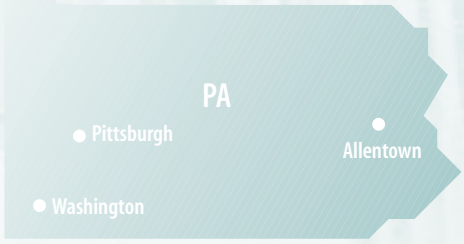
Waste Management's LNG Truck Fleet

Start-Up Experience

Alternative Fuel Truck Evaluation Project

Washington, Pennsylvania, with a population just under 16,000 and a land area of 3 square miles, is located at the crossroads of Interstates 70 and 79 at the state's western edge. In 1998, Waste Management, a municipal waste contractor, assumed operation of Washington's primary landfill, then operated by William H. Martin, Inc. (formerly Chambers Development). Waste Management wanted to ensure a seamless transition of refuse collection and disposal for the 120,400 residential customers and 4,500 commercial and industrial accounts in the 250-mile, five-county operating radius. Waste Management also was committed to continuing an innovative liquefied natural gas (LNG) demonstration project undertaken nearly seven years before.



This report highlights the site's start-up experience, describing the program, the vehicles and engine technology, the fueling station, and operations. Members of the project team also share their views of the start-up experience, offering some lessons learned to fleet operators who may be considering alternative fuel technologies.

Visitors to Waste Management's Washington site may not readily identify the unique characteristics of this operation tucked against a green, hilly backdrop in the Allegheny Mountains. It looks like any other landfill operation, with refuse trucks moving across the lot and the noise of heavy equipment just over the hill.

A closer look, however, reveals some interesting features: a couple of the refuse trucks heading toward the landfill do not have the lingering odor of diesel fuel or the distinct chatter of the diesel engine.

Perhaps the most unusual feature of this municipal disposal site, however, is the hidden LNG storage tank, buried 8.5 feet underground on Waste Management's lot.

Origin of the Program

In 1991, Chambers Development Company, now Waste Management, began exploring the possibility of using the site's landfill as an energy source to fuel its refuse trucks. Technological developments supported its interest in converting landfill gas (LFG) to usable natural gas (NG) fuel, but the capability of the technology at that time did not produce fuel clean enough for the Washington vehicles. Trace components in the LFG, such as heavy hydrocarbons (aliphatics and aromatics) and chlorinated hydrocarbons, can damage engines if contained in the fuel. Further analysis of the process and the site showed that LFG conversion was not the appropriate technology for the site at that time.

A strong commitment to finding an alternative to diesel fuel for both environmental and economic reasons led William H. Martin, Inc., to explore on-site natural gas fueling, with the hope of expanding to LFG conversion in the future.

Building on a $333,000 grant from the Pennsylvania Department of Environmental Protection Alternative Fuels Incentive Grants Program and support from the Gas Research Institute (GRI), Southwest Research Institute (SwRI), and Mack Trucks, Inc., William H. Martin began developing its alternative fuel project. Early supporters of the project also included the U.S. Department of Energy's National Renewable Energy

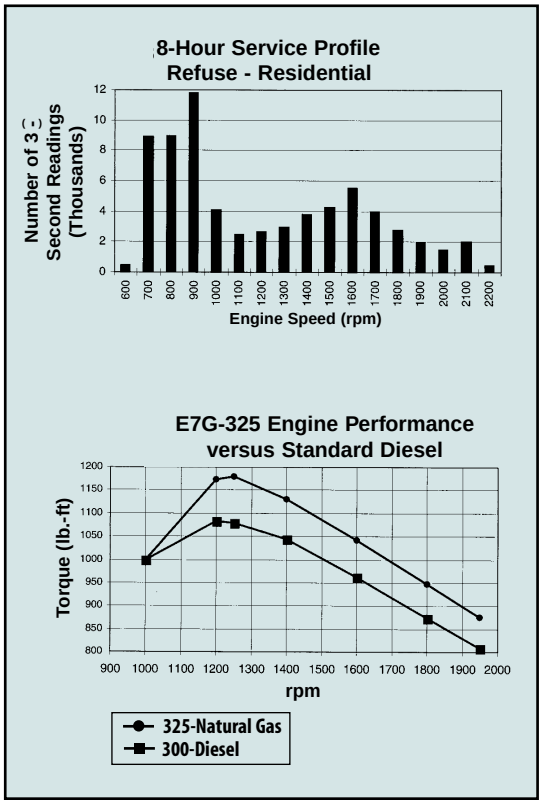
Laboratory, the American Trucking Association, Columbia Gas of Pennsylvania, and CVI, Inc.

Alissa Oppenheimer, a GRI technology manager and early advocate of the Waste Management project, emphasized the significance of the Washington, Pennsylvania, site. "This project was initiated in 1991, and over the years many individuals worked diligently to make this project a reality. What has come together at Waste Management is not only unique in terms of heavy-duty, LNG vehicle technology and equipment, but it is also a working example of an environmentally sound heavy truck and waste services operation."

Natural Gas Refuse Truck

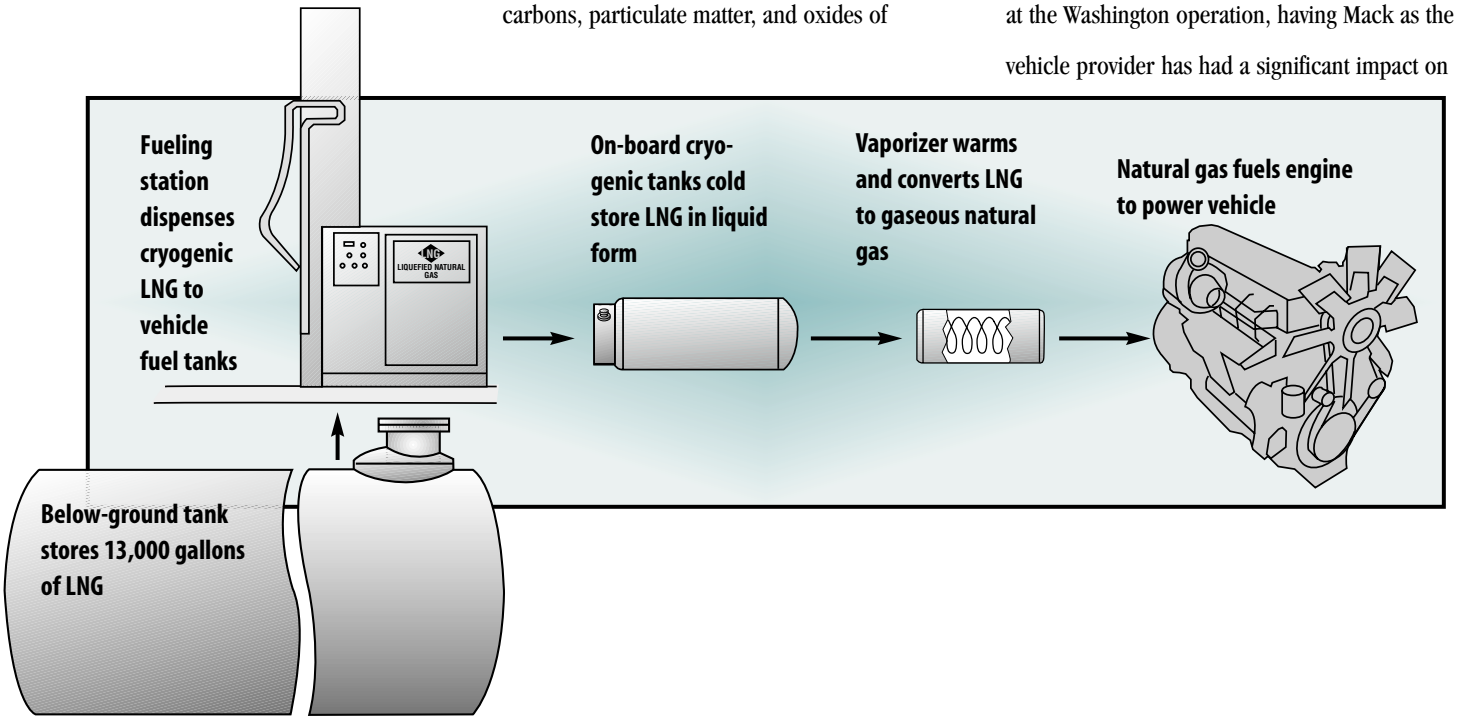
GRI and SwRI had worked together in an earlier project with Mack to develop and test a natural gas version of the Mack E7 heavy-duty diesel engine. SwRI had been examining conversion of compression-ignition engines to natural gas and developed a compressed natural gas (CNG) fuel system that was installed on a prototype refuse truck. However, the size and weight of tanks required for storing CNG on board the vehicles proved a serious disadvantage. Mack believed that natural gas still offered the most effective fuel, however, and continued to develop its natural gas refuse truck. Working with CVI, Inc., and MVE, Inc., Mack has developed an effective LNG fuel system for the truck.

LNG is colorless, odorless, non-toxic, non-corrosive, and non-carcinogenic. LNG is burned as a gas when used as a fuel, and it can provide significant reductions in carbon monoxide, reactive hydrocarbons, particulate matter, and oxides of nitrogen. Natural gas has an octane rating of 130 and excellent properties for spark-ignited internal combustion engines. The second-generation Mack natural gas engine was released in production in 1995 and installed in the refuse haulers being demonstrated in Washington. The Mack refuse hauler has two on-board LNG fuel tanks with a combined capacity of 150 gallons (usable LNG), which will allow about 13 hours of operation before refueling.



Mack Trucks, Inc., data indicate that the refuse haulers have a harsh duty cycle. Data also show the LNG-fueled engines performing slightly better than standard diesel-fueled vehicles.

According to Jerry Simmons, fleet manager at the Washington operation, having Mack as the vehicle provider has had a significant impact on



the project's success. Mack is an integrated manufacturer of heavy-duty engines and chassis. The E7G engines are built and tested at the Mack Hagerstown, Maryland facility. The Mack Macungie Assembly Operations builds the natural gas-powered MR and LE models in Macungie, Pennsylvania (near Allentown). The Macungie operations conduct the final performance tests and ship the fully warranted chassis to the customer.

Steve Ginter, vocational product manager for Mack, emphasizes the significance of the integrated approach: "Our natural gas series is built on the same assembly lines as our other chassis. Customers appreciate the consistent high quality that our skilled technicians produce, and when it comes to resolving a vehicle problem, our customers know Mack will respond. Integrated means being responsible to keep our customer's trucks producing."

John Bartel, senior staff engineer for Natural Gas Engines at Mack's Hagerstown, Maryland, facility, underscores Ginter's point. "The natural gas engine started out as a pilot-production vehicle, but now it is in the Mack lineup. We continue to refine and test the engine, but it's a Mack product, ready for daily use."

The primary difference in the diesel and natural gas engines is the ignition. The E7G natural gas engine has different pistons and cylinder heads, and the bottom end is the same as the diesel. The Mack engine uses a lean-burn, turbo-charged natural gas fuel operation for optimum combustion. The lean-burn natural gas engine eliminates the diesel odor and reduces the noise usually associated with heavy trucks.

Fueling Station

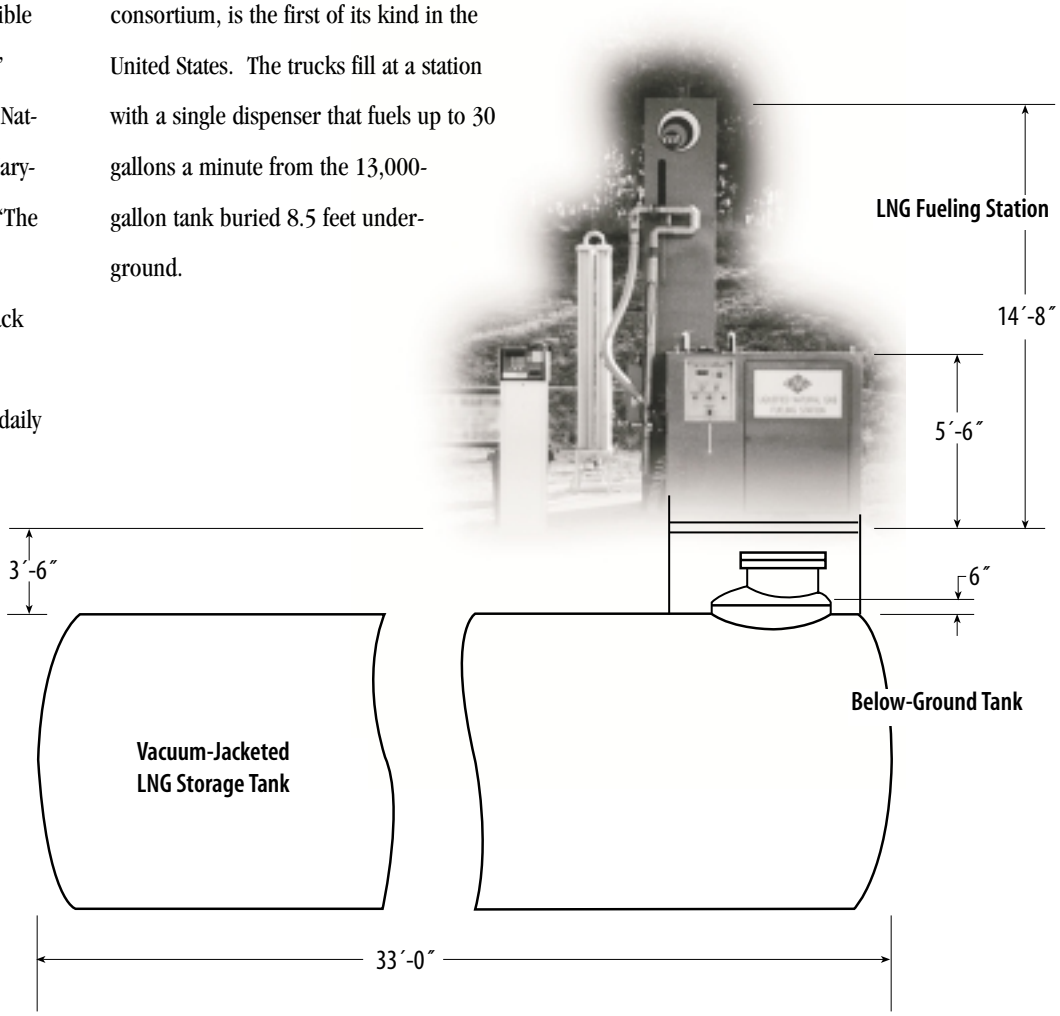
Natural gas consists primarily of methane, with other hydrocarbon gases such as ethane, propane, and butane. Natural gas also contains trace amounts of carbon dioxide, nitrogen, and water. Cooling natural gas to approximately -260°F at atmospheric pressure condenses the gas to LNG. LNG must be cold to remain liquid, and is stored in double-walled, vacuum-insulated containers.

On the refuse trucks, the LNG is stored in two containers, a tank that holds 90 gallons (usable), and a second tank that holds 60 gallons (usable). The fueling station, which was installed at the Washington site and funded by the consortium, is the first of its kind in the United States. The trucks fill at a station with a single dispenser that fuels up to 30 gallons a minute from the 13,000-gallon tank buried 8.5 feet underground.

Although LNG is actually safer than diesel in many respects, such as volatility, there are benefits in using underground storage tanks, as *LNG Express* has reported:

- Shorter piping runs, no containment dike, and compactness of the facility reduce installation time.
- The soil protects the tank from thermal radiation, eliminating fire risk from the tank.
- Reduced vapor dispersion and thermal radiation zones make it easier to install tanks in densely populated areas.
- Reduced exposure minimizes vandalism, accident, and sabotage.

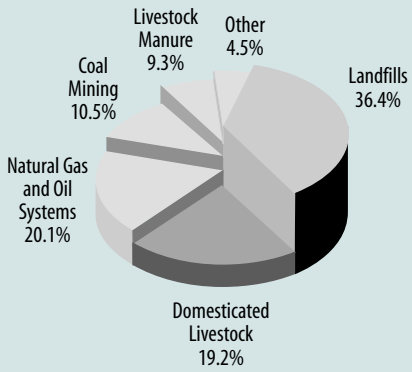
The buried tank also reduces the visual impact of an above-ground LNG tank, which may cause concern for new users of the fuel. With the tank below ground, the station looks like any



Landfill Gas

The decomposition of organic waste material in landfills produces a gas rich with methane, carbon dioxide, and volatile organic compounds (VOCs). Left alone to escape into the atmosphere, LFG has a significant environmental and safety impact. However, the methane gas that composes 55% of LFG has valuable potential. The U.S. Environmental Protection Agency (EPA) has established the Landfill Methane Outreach Program to show companies, utilities, and communities how to capture landfill gas and convert it to energy. Recent EPA data indicate that more than 150 landfills in the United States are using LFG as an energy source. You can find out more about the program at **www.epa.gov/methane.**

U.S. Methane Emissions From Principal Anthropogenic Sources (1996)



Source: U.S. EPA Inventory, 1998

Recent technological advances are making it easier to see methane from landfills as a resource. For example, Acrion Technologies of Cleveland, Ohio, recently completed an LFG field demonstration supported by the U.S. Department of Energy. This project tested an innovative process for cleaning LFG. "CO_2 Wash" reduced the VOCs in raw landfill gas by 100%, leaving only methane and carbon dioxide. Cleaned and processed methane can be used as pipeline natural gas and as a transportation fuel. The CO_2 has commercial applications, such as dry ice production. **(www.fetc.doe.gov/publications/press/1998/tl_acrion.html)**

other fueling facility. As Jerry Simmons pointed out, the underground station also seems much safer. "With this many trucks moving around on this lot, it makes a lot of sense to have the tank underground."

The fueling system is also unique because it vents gas back from the station to a Columbia Gas pipeline. The process ensures that this premium fuel is not wasted, and that methane is not vented to the environment.

Operations

Waste Management's LNG trucks operate in the same duty cycle as the rest of the fleet, which is daily, city, and suburban refuse pick-up service. The fleet includes 150 trucks, and Waste Management is operating seven Mack LNG refuse trucks. According to Ben Woods, district manager for Waste Management, the trucks do the same work—if not more—as the diesels. "They are right in the thick of it," he says, "900-1000 houses each day." Woods cannot convert the whole fleet because of range issues. Some of the fleet travel nearly 350 miles roundtrip to reach Waste Management customers and return to the landfill.

The vehicles have a tough duty cycle—continuous stops and starts and lots of engine revving. Recent data indicate that 50% of the engine hours of the Waste Management diesel- and LNG-fueled refuse trucks are spent operating at 0 to 5 mph. "It's the worst duty cycle imaginable," says John Bartel, "but they still are getting decent fuel mileage." Data analysis indicates that the LNG fuel economy is only 18% lower than that of diesel on an energy equivalent basis, even with the LNG trucks having a lower average speed (10 mph [LNG] versus 14 mph [diesel]). Spark-ignited engines are inherently less efficient than diesel at low speeds. However, historical data indicate that heavy-duty vehicles using natural gas usually have anywhere from 20% to 30% lower fuel economy than diesel on an energy equivalent basis.

Another significant aspect of the alternative fuel vehicles used at the Washington site stands out for Woods and Simmons: Drivers like the trucks. Although they expressed some expected uncertainty at first because the new technology required specialized training for fueling and safety, they actually prefer the LNG trucks. "It's not a matter of encouraging or persuading them," Woods says. "We can't get them out of the trucks." The workers on the trucks cite clear differences—no diesel smoke, no diesel smell, low noise level, less offensive exhaust, and more

power for heavy payloads (the LNG vehicles have a 325 hp engine and the diesel vehicles 300 hp). And because the drivers fuel their own vehicles, they also like not having to wait in line for diesel fuel.

Lessons Learned

As with any new technology and new operation, the Waste Management demonstration project had its difficulties. Here are some of the key lessons that the project participants learned:

- Communication is the most significant aspect of the program. Get everyone on the same page from the beginning, Jerry Simmons emphasizes. Every participant needs to understand what is going on—"This isn't proven yet. We must work together to make it happen."

  Mack Godfrey of Columbia Gas agrees. "I am convinced there will be glitches. This is new technology," he says. "But with good partners, good communication, and good understanding of the technology upfront, it's a win-win situation. Everybody is involved: this will make it work. There will be problems *other* than technologies *unless* you have good partners."

  As Simmons points out, his company has changed ownership several times recently, but through it all, they have managed to keep the focus and the commitment of the program. "We are not just a bunch of nice guys doing a good thing," he says. "We are looking to the future. We are committed to the environmental aspect of the project—this is central, the number one priority—but bottom line issues drive a lot of our effort, and we have the commitment to see it through."
- Bartel, Woods, and Simmons all agree that the project must have a champion, a nucleus for the project to work. Both Mack and Waste Management clearly have made exceptional efforts to ensure the project's success. Simmons believes that Mack is the real champion. "Working with them has been a good experience. They have provided continuous, valuable support."
- The commitment of the fleet manager makes all the difference. When the manager of the fleet makes a commitment, it will work, Bartel says. And it needs to be someone who has an interest *and* control of resources. "There may be a small number of trucks in the fleet," he says, "but it will be a large percentage of attention to start-up issues, such as fueling infrastructure, training, etc. This is an investment, and it needs to be treated as significant."
- Bartel emphasizes the importance of recognizing that although the natural gas vehicles can work the same duty cycle as the diesel vehicles, the trucks are not going to mix immediately with the diesel fleet. These are not diesel trucks; they *are* different. "Not difficult," Bartel says. "But different. There must be someone like Jerry Simmons to see to the trucks, to troubleshoot. Jerry has worked to understand the system, and he knows the engines. It's easy to blame any problem on the LNG, but it isn't always a fuel problem. Jerry knows this. If he calls me, I know it's not going to be a simple problem."
- There needs to be a focal point for the drivers also. They need a "go-to guy," someone they

Mack E7G Natural Gas Engine Specifications

Rated power bhp @ rpm		
	E7G-325	325 hp @ 1950 rpm
	E7G-350	350 hp @ 1800 rpm
Peak torque		
	E7G-325	1180 lb-ft @ 1250 rpm
	E7G-350	1260 lb-ft @ 1250 rpm
Torque rise		
	E7G-325	35%
	E7G-350	23%
Number of cylinders		6, inline
Bore and stroke, mm		4.875 x 6.50
Piston displacement, (L)		12
Compression ratio		11.5:1
Cylinder head		4 valve
Electronic management system		Closed loop lean burn
Air management		Full authority drive-by-wire
Ignition		Inductive direct fire
Diagnostics		Comprehensive electronic
Fuel		LNG or CNG
Weight, dry		Approx. 2090 lb

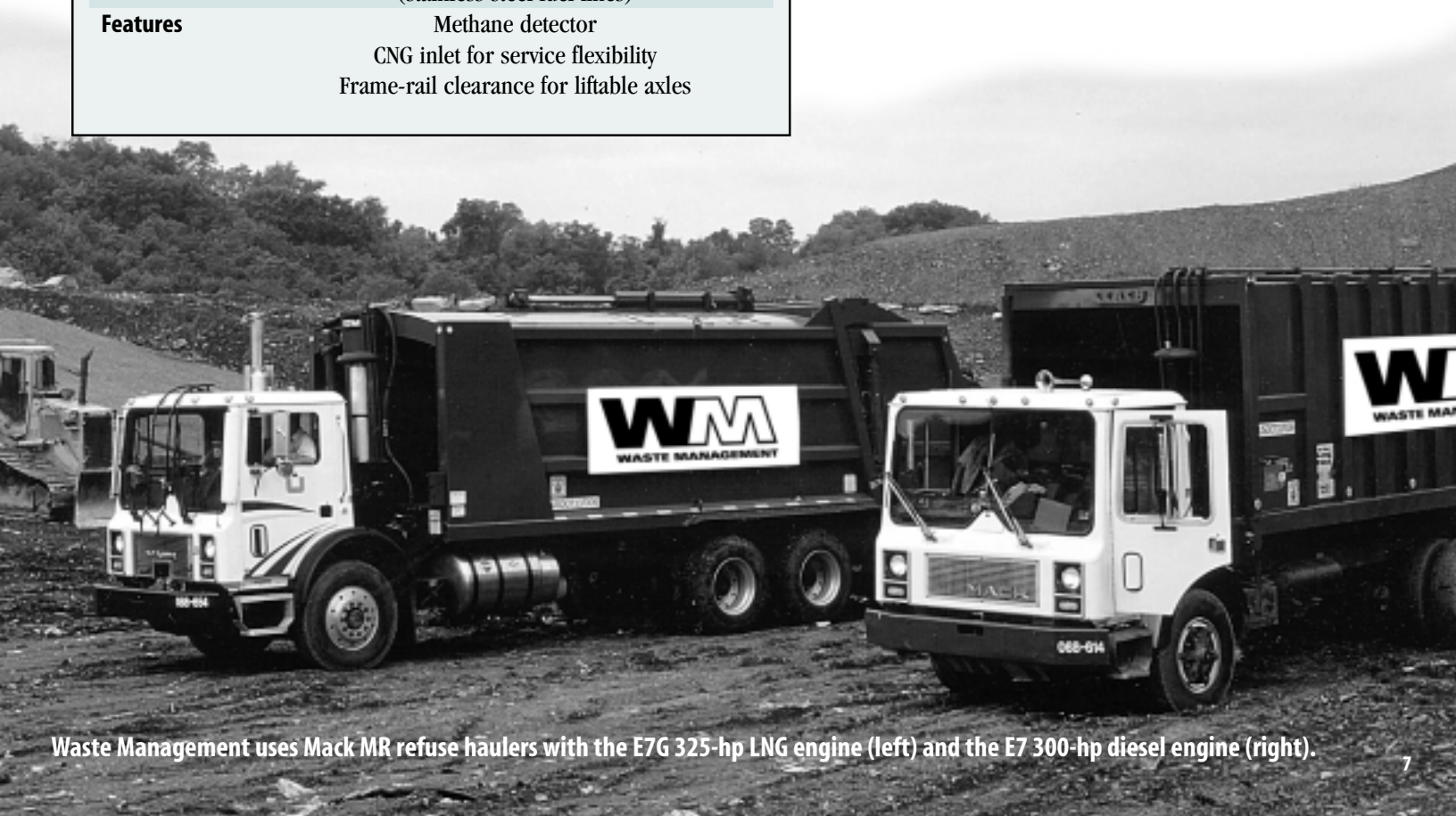
can talk to about the trucks, someone to whom they will tell anything. Drivers may sense that something is wrong with a vehicle, but because the technology is new, they may not know whether it is a problem. They must have the opportunity to express concerns. Drivers spend more time with the trucks than anyone else, and their input is valuable.

- Patience is essential, and troubleshooting is mandatory, according to John Bartel. LNG is not odorized, so it was difficult to figure out problems sometimes. He has had to develop creative methods for figuring out problems, such as stuck injectors.
- Woods and Simmons also agree that starting with a few trucks is the best way to introduce the technology into a fleet operation. Getting to know the trucks and the technology and troubleshooting problems on a smaller scale increases the possibility of expanding the number of trucks in the fleet after the start-up period.
- Installing the fueling infrastructure before purchasing the trucks is a key lesson learned. The station is a limited production item—whether above or below ground—and difficulties are likely.

Jerry Simmons stresses the significance of the project for Waste Management: "The trucks are great. It's not something that I have to put up with—I think it's a privilege to work on this project. This is cutting-edge, exciting technology, and it is making a difference."

Mack Chassis Specification

	MR Model Low cab-over engine Truck or tractor	LE Model Dual-steer dedicated refuse collection vehicles
Wheel base	210 in.	197 in.
Platform	320 in.	286 in.
Engine	E7G-325 hp	
Transmission	Allison automatic	
Front axle	20,000 lb Mack	
Rear axle	46,000 lb Mack	
Suspension	46,000 lb Mack SS462 Camelback	
Fuel tank system	MVE, Inc., super-insulated stainless steel tank Left side–72 gal., right side–100 gal. (stainless steel fuel lines)	
Features	Methane detector CNG inlet for service flexibility Frame-rail clearance for liftable axles	



Waste Management uses Mack MR refuse haulers with the E7G 325-hp LNG engine (left) and the E7 300-hp diesel engine (right).

The Alternative Fuel Truck Evaluation Project

The Alternative Motor Fuel Act of 1988 requires the Department of Energy (DOE) to demonstrate and evaluate alternative fuels usage in the United States. DOE's National Renewable Energy Laboratory (NREL) is conducting the Alternative Fuel Truck Evaluation Project to compare alternative fuel and diesel fuel trucks. Information for the comparison comes from data collected on the operational, maintenance, performance, and emissions characteristics of alternative fuel trucks currently being used in vehicle fleets and comparable diesel fuel trucks serving as controls within the same fleet. In 1993, NREL began a similar program to evaluate transit bus use. The defined and proven data collection and analysis system from the bus study has been adapted for the heavy truck project. The sites in the program are selected according to the type of trucks and engines used, the availability of control vehicles, and site interest in participating. Specific criteria must be met, such as vehicle class (Class 6, 7, or 8 trucks with a gross vehicle weight of at least 19,500 lb) and number of alternative fuel trucks (at least five).

This report highlights the start-up experience of Waste Managaement, a refuse hauling company in Washington, Pennsylvania. 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 LNG truck program, its components, alternative fuel vehicles, or incentive programs, contact any of the following:

Waste Management
Ben Woods, Jr.
District Manager
200 Rangos Lane
Washington, PA 15301
724/228-4200

Waste Management
Jerry C. Simmons
Fleet Manager
200 Rangos Lane
Washington, PA 15301
724/228-4200

Waste Management
Chuck Vleck
Fleet Director, Eastern Area
Park West Two, Suite 420
2000 Cliff Mine Road
Pittsburgh, PA 15275
412/490-0168

Mack Trucks Inc.
John B. Bartel
Senior Staff Engineer
13302 Pennsylvania Avenue
Hagerstown, MD 21742
301/790-5762

Mack Trucks Inc.
Steve C. Ginter
Marketing Manager
2100 Mack Blvd.
Allentown, PA 18105
610/709-3259

Gas Research Institute
Alissa Oppenheimer
Technology Manager
8600 West Bryn Mawr Avenue
Chicago, IL 60631-3562
773/399-4616

NREL
Paul Norton
Senior Project Engineer
1617 Cole Blvd.
Golden, CO 80401
303/275-4424

Columbia Gas
Mack V. Godfrey
Engineering Consulting
650 Washington Road
Pittsburgh, PA 15228
412/572-7124

Battelle
Kevin Chandler
Project Manager
505 King Avenue
Columbus, OH 43201
614/424-5127

For more information and for copies of program reports, visit the Alternative Fuels Data Center on the World Wide Web at **http://www.afdc.doe.gov,** *or call the Alternative Fuels Hotline at* **1-800-423-1DOE.**

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