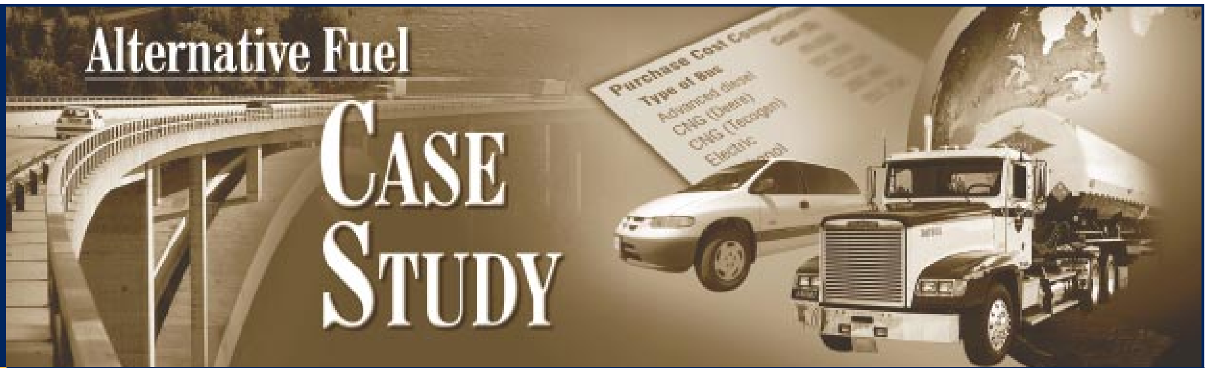
Clean Cities
Alternative Fuel Information Series



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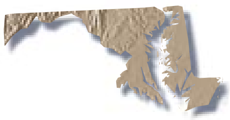


UPS Delivers with Alternative Fuels

Introduction

For UPS, efficiency and resource conservation are synonymous, both on the ground and in the air. Based on this philosophy, the company has pioneered several environmental initiatives over the years. From delivering packages with electric-powered vehicles in the 1930s, to operating one of the largest private fleets of alternative fuel vehicles now, UPS has learned that operating efficiently and using resources responsibly go hand-in-hand.

In the fall of 1994, the UPS fleet in Landover, Maryland, began operating 20 vehicles on CNG. UPS selected CNG because natural gas is an abundant domestic resource that is available in almost every city in the United States, and it also generally costs less than other fuels.

On average, natural gas is 82% to 98% methane with smaller percentages of ethane, propane, and butane. The relatively simple molecular structure gives natural gas the potential to emit very low levels of exhaust pollutants. Plus, it has a high octane rating (120-130), which allows it to be used at higher compression ratios (relative to gasoline) without damaging the engine.

The UPS project, funded by DOE through NREL and managed by TRI, was designed to test the feasibility of using CNG in a "medium-duty" pick-up and delivery fleet. NREL's AFDC has logged data on the fuel use and maintenance requirements of the CNG trucks along with those of similar gasoline-powered trucks.

What Does That Stand For?

AFDC	Alternative Fuels Data Center
CFFP	Clean Fuel Fleet Program
CNG	compressed natural gas
CO	carbon monoxide
DOE	U.S. Department of Energy
g/bhp-hr	grams per brake horsepower-hour
gge	gasoline gallon equivalent
GMC	General Motors Corporation
HCHO	formaldehyde
ILEV	inherently low-emission vehicle
LEV	low-emission vehicle (under federal or California standards)
NMHC	non-methane hydrocarbons
NO_x	oxides of nitrogen
NREL	National Renewable Energy Laboratory
PM	particulate matter
psi	pounds per square inch
TRI	Trucking Research Institute
ULEV	ultra low-emission vehicle
UPS	United Parcel Service
ZEV	zero-emission vehicle

Twenty-five vehicles were used in the development project: 20 CNG vehicles and 5 gasoline control vehicles. The GMC chassis had a gross vehicle weight rating of 20,000 pounds. They ranged in age from the 1987 model year to the 1990 model year. The special purpose bodies are built for package delivery and UPS calls them "package vehicles." Five vehicles were type

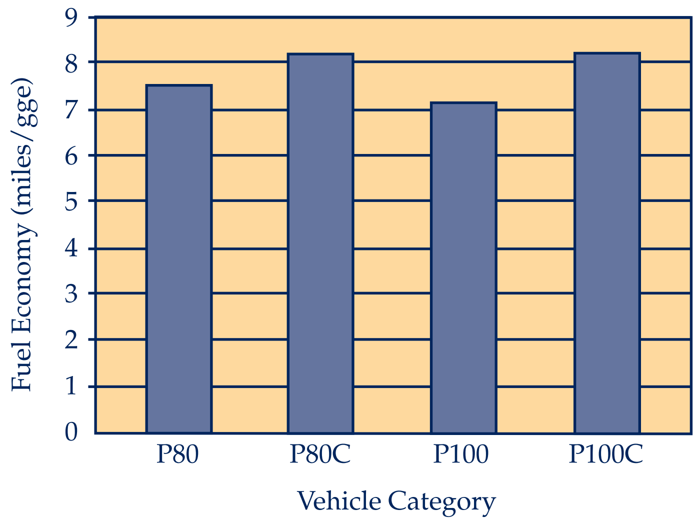
P100 and 15 were P80s. These are UPS designations, the number denoting the cubic foot capacity, in tens, of the cargo body (i.e., 80 = 800 cubic feet). The vehicles with the CNG engines have the suffix "C" added to the designation (P80C, for example). The 20 CNG vehicles accumulated 554,575 miles during the demonstration.

Chassis:	GMC P4T042
Fuel:	CNG
Gross Vehicle Weight:	20,000 pounds
Engine:	Tecogen Tecodrive 4300 (12:1 compression ratio)
Displacement:	4.3 liters
Power:	150 horsepower
Torque:	140 foot-pounds
Gas Cylinders:	Brunswick composites
Capacity:	15.8 gge at 3600 psi

Fuel Economy and Range

Both the natural gas and gasoline (control) engines feature closed-loop air-fuel ratio systems and operate at stoichiometric conditions. An oxygen sensor in the exhaust indicates whether the engine is operating on the rich or lean side of stoichiometric, and also provides a signal for adjusting the fuel system to achieve the desired air-fuel mixture. However, because natural gas has a significantly higher octane rating, the natural gas engine can operate at a higher compression ratio than the gasoline version (12.0:1 compared to 9.3:1). Operating at a higher compression ratio, the natural gas engines were able to achieve better fuel efficiency than the gasoline engines on a gge basis. A gge is the amount of CNG that has the same energy content as a gallon of gasoline. On average, the P80C achieved 9% better fuel economy than the P80 gasoline vehicle, and the P100C achieved 15% better fuel economy than the P100 gasoline vehicle. The graph on the following page compares the average fuel economy of the package trucks.

Average Fuel Economy of Trucks



Although the CNG vehicles achieved better fuel economy, their range was significantly less than the gasoline vehicles. The gasoline vehicles have a 30-gallon fuel tank capacity. At 7.3 mpg (combined average fuel economy of the P80 and P100), the theoretical range is roughly 220 miles. The CNG vehicles have a 15.8 gge capacity—at 8.2 mpgge, the theoretical range is 130 miles. The gasoline vehicles could travel about 100 miles farther on a full tank of fuel. The gasoline vehicles are typically fueled every other day, but the CNG vehicles are fueled daily to make sure they have enough fuel to complete their routes.

Cost

Fuel cost accounts for a significant portion of the overall cost of operating a delivery truck fleet. In the 3 years that UPS collected data, the natural gas cost has ranged from $0.597 to $0.873 per gge, and gasoline costs have ranged from $1.043 per gallon to $1.25 per gallon. The UPS package vehicles in Landover travel between 30 and 45 miles per day and use 5 to 6 gallons of fuel per day. After the fuel cost differential between CNG and gasoline is applied, UPS realized worst-case savings of $1.82 per vehicle per day and best-case savings of $4.64 per vehicle per day. These savings translate into $455 to $1,160 per vehicle per year or, for the fleet of 20 CNG trucks, savings of $9,100 to $23,200 per year.

Maintenance and Repair Issues

Although the UPS development project proved the viability of using CNG in a pick-up and delivery fleet, some operational issues are inevitable with any new technology. This project was no exception.

The natural gas pressure regulators, the fuel injectors, and the spark plug and spark plug wires presented most of the maintenance and repair issues.

Fuel pressure regulators failed without warning, stranding vehicles by the roadside. Because these are relatively low volume components, replacements can be in short supply, and the price is high at $428 each. When several regulators were needed at once, UPS experienced delays of up to 14 days. This problem reoccurred throughout the project.

Although several concerns about the fuel injectors surfaced during the project, the main problem was that the injectors would stick shut, keeping fuel from flowing to the engine. Initially it was thought that the fuel station compressor was passing oil to the fuel. However, further inspection revealed that the oil was a residue from the manufacturing process.

The CNG vehicles also experienced problems with the durability of the spark plugs and the spark plug wires. These components required replacement at twice the rate of those on the gasoline-powered vehicles. Because the natural gas requires more energy to ignite than gasoline, the natural gas ignition system uses higher voltage, which wears out the components twice as fast.

A comprehensive comparison of maintenance costs is unavailable because many of the components replaced during the project were covered under warranty. The UPS maintenance and repair tracking system did not capture warranty repairs.

Emissions

The Tecogen Tecodrive 4300s were production engines and were emissions-certified to the federal ULEV standard. The category on the following page shows the CFFP's federal standards. The test procedure for the CFFP standards is the EPA Transit Test Procedure.

CFFP for Heavy-Duty Spark Ignition and Compression Ignition Engines

Emission Category[a]	CO (g/bhp-hr)	NMHC + NO_x (g/bhp-hr)	PM (g/bhp-hr)	HCHO (g/bhp-hr)
LEV (Federal Fuel)		3.8		
LEV (California Fuel)		3.5		
ILEV	14.4	2.5		0.050
ULEV	7.2	2.5	0.05	0.025
ZEV	0	0	0	0

[a] The standards apply to 1998–2003 model year engines on vehicles that weigh more than 8,500 pounds. Beginning in 2004, the new emission standards for heavy-duty highway engines will apply. In addition to CFFP standards, vehicles must comply with applicable conventional standards for heavy pollutants. Additional information is available at: http://www.epa/gov/omswww or http://www.arb.ca.gov

Lessons Learned

Fueling Frequency and Vehicle Range
At the beginning of the project, the CNG vehicles' shorter range, along with coarse fuel gauge accuracy, led to the vehicles running out of fuel. Training drivers to do a pre-trip inspection of both the dash fuel gauge and the system pressure gauge before leaving the building resolved the problem.

Fuel System Freezing
During cold weather (below 25°F), moisture in the fuel would occasionally cause the CNG fuel systems to freeze. The freezing would typically occur in the regulator or the pressure-relief devices. After a thorough review of various solutions, the option to drain coalescing filters more often during cold weather was the most viable alternative. This process was implemented with positive results. Infrastructure changes could also alleviate this problem; the refueling site could be equipped with dryers to eliminate the moisture from the natural gas before it gets into the vehicle tanks.

Natural Gas Parts Availability
CNG vehicle downtime during the project was exacerbated by the limited availability of replacement parts. Where it was practical, UPS inventoried its own components. UPS also worked with local suppliers who agreed to stock specific problematic components.

What's Next?

Battelle Memorial Institute is working with UPS to collect data on and evaluate 13 Freightliner Custom Chassis vehicles in the UPS fleets operating in Hartford and Waterbury, Connecticut. The vehicles are equipped with 1997 Cummins B5.9G CNG engines. Battelle is tracking 10 CNG trucks and 3 diesel (control) trucks. Because the vehicles are already in operation, Battelle is collecting back data (up until May 1999) and then analyzing the information. Emissions testing on these vehicles is slated for the spring of 2000.

Disclaimer

This study is intended only to illustrate approaches that organizations could use in adopting AFVs into their fleets. The data cited here, although real experience for the fleet discussed in this study, may not be replicated for other fleets.

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