



***U.S. Department of Energy
FreedomCAR & Vehicle Technologies
Advanced Vehicle Testing Activity***

***HYDROGEN-FUELED
MERCEDES SPRINTER VAN
OPERATING SUMMARY***

*Don Karner
James Francfort*

January 2003



*Idaho National Engineering and Environmental Laboratory
Bechtel BWXT Idaho, LLC*



**U.S. Department of Energy
FreedomCAR & Vehicle Technologies
Advanced Vehicle Testing Activity**

**Hydrogen-Fueled Mercedes Sprinter Van
Operations Summary**

**Don Karner¹
James Francfort²**

January 2003

**¹Electric Transportation Applications
Phoenix, Arizona**

**²Idaho National Engineering and Environmental Laboratory
Transportation Technology and Infrastructure Department
Idaho Falls, Idaho 83415**

**Prepared for the
U.S. Department of Energy
Assistant Secretary for Energy Efficiency and Renewable Energy
Under DOE Idaho Operations Office
Contract DE-AC07-99ID13727**

¹ Principal Investigator, Electric Transportation Applications

² Principal Investigator, Idaho National Engineering and Environmental Laboratory

Disclaimer

This document highlights work sponsored by agencies of the U.S. Government. Neither the U.S. Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the U.S. Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the U.S. Government or any agency thereof.

ABSTRACT

Over the past two years, Arizona Public Service, a subsidiary of Pinnacle West Capital Corporation, in cooperation with the U.S. Department of Energy's Advanced Vehicle Testing Activity, tested four gaseous fuel vehicles as part of its alternative fueled vehicle fleet. One vehicle operated initially using compressed natural gas (CNG) and later a blend of CNG and hydrogen. Of the other three vehicles, one was fueled with pure hydrogen and two were fueled with a blend of CNG and hydrogen. The three blended-fuel vehicles were originally equipped with either factory CNG engines or factory gasoline engines that were converted to run CNG fuel. The vehicles were variously modified to operate on blended fuel and were tested using 15 to 50% blends of hydrogen (by volume). The pure-hydrogen-fueled vehicle was converted from gasoline fuel to operate on 100% hydrogen. All vehicles were fueled from the Arizona Public Service's Alternative Fuel Pilot Plant, which was developed to dispense gaseous fuels, including CNG, blends of CNG and hydrogen, and pure hydrogen with up to 99.9999% purity.

The primary objective of the test was to evaluate the safety and reliability of operating vehicles on hydrogen and blended hydrogen fuel, and the interface between the vehicles and the hydrogen fueling infrastructure. A secondary objective was to quantify vehicle emissions, cost, and performance. Over a total of 40,000 fleet test miles, no safety issues were found. Also, significant reductions in emissions were achieved by adding hydrogen to the fuel.

This report presents results of testing conducted over 6,864 kilometers (4,265 miles) of operation using the pure-hydrogen-fueled Mercedes Sprinter van.

ACRONYMS

APS	Arizona Public Service
CNG	compressed natural gas
DOE	U.S. Department of Energy
ETA	Electric Transportation Applications
FTI	Fueling Technologies Inc.
HCNG	hydrogen blended with compressed natural gas

CONTENTS

ABSTRACT	iii
ACRONYMS	iv
CONTENTS	v
BACKGROUND	1
APS Program Description	1
OPERATING RESULTS	2
Vehicle History	2
Emissions Summary	2
Fuel Efficiency	2
Operating Costs	3
Operating Results Summary	4
CONCLUSIONS	4
Appendix A	5
Fuel Properties and gasoline gallon equivalents.....	5
Appendix B.....	6
Monthly Mileage Summary.....	6

BACKGROUND

APS Program Description

Several automobile manufacturers are developing fuel-cell vehicles. The fuel-cell power plants used in many of these vehicles operate using compressed hydrogen gas fuel. Arizona Public Service (APS), a subsidiary of Pinnacle West Capital Corporation, has designed and constructed its Alternative Fuel Pilot Plant to gain experience with the production and dispensing of gaseous hydrogen as a transportation fuel. In conjunction with operation of the Alternative Fuel Pilot Plant, APS operates a fleet of vehicles on pure hydrogen, and blends of hydrogen and compressed natural gas (CNG). The U.S. Department of Energy's Advanced Vehicle Testing Activity, through its Qualified Vehicle Tester, Electric Transportation Applications (ETA), has developed a cooperative agreement with APS to collect data from the operation of these vehicles.

The primary objectives for operating these vehicles were to provide hands on experience with the use of hydrogen, to determine the safety issues associated with dispensing hydrogen into motor vehicles, to evaluate the safety and reliability of operating vehicles on hydrogen and blends of hydrogen and CNG (HCNG), and to investigate the interface between the vehicles and the hydrogen fueling infrastructure. Secondary objectives were to measure the vehicle emissions, cost, and performance.

This report presents results of 6,864 kilometers (4,265 miles) of operation using the pure-hydrogen-fueled Mercedes Sprinter van. The testing results for the other HCNG and 100% hydrogen-fueled vehicles are reported separately. The APS Alternative Fuel Pilot Plant and the vehicle fueling interface operations will also be reported separately. The Idaho National Engineering and Environmental Laboratory manages the hydrogen and HCNG light duty internal combustion engine vehicle testing for the U.S. Department of Energy's Advanced Vehicle Testing Activity.

OPERATING RESULTS

Vehicle History

A 1998 Mercedes Sprinter van was operated using pure hydrogen fuel in the APS alternative fuel vehicle fleet. The Sprinter was originally equipped with a 2.4 liter gasoline internal combustion engine. The German government in Hamburg, Germany converted the engine to operate using pure hydrogen. The modifications include adding three hydrogen tanks (115 L), CV injection, and a spark ignition modification. When APS received the vehicle, a WEH 5,000 psi inlet was installed to make the vehicle compatible with the APS Alternative Fuel Pilot Plant. The fuel storage tanks installed on the Sprinter operate at 3,600 psi.



Figure 1. Mercedes Sprinter hydrogen-powered van.

Emissions Summary

Inasmuch as this vehicle operates using pure hydrogen, its only potential emission is nitrogen oxide. No testing for nitrogen oxide was performed on the Sprinter.

Fuel Efficiency

From the time that the van arrived at APS until June 2, 2002, it was fueled directly from a hydrogen tube trailer. No accurate fuel measurement was available from this system, and, thus, no fuel economy data are available for the time period. After June 2, 2002, the van was fueled using dispensers made by Fueling Technologies Inc. (FTI). The FTI dispensers, shown in Figure 2, are

equipped with an accurate fuel measuring system. The FTI dispensers receive compressed hydrogen (99.9997% purity by volume)³ from the APS Alternative Fuels Pilot Plant.

Between June 2 and June 23, 2002, the van used 22.9 gasoline gallon equivalents (gge's) of hydrogen and accumulated 739 kilometers. The fuel economy over this time period is 20 miles per gge. This fuel economy appears to be unrealistically high. As the fuel economy was computed over a very short time period, more data should be collected to confirm these results. See Appendix B for monthly mileage reports.



Figure 2; FTI Hydrogen Dispenser.

Operating Costs

The Sprinter van had no mechanical problems during its operation at APS, and, therefore, incurred no repair-related expenses. One of the goals of the APS program was to determine if oil change intervals could be extended by using hydrogen fuel. During its operation at APS, the Sprinter had one oil change (odometer reading 6,719 kilometers) at a cost of \$90.00. This translates to an operating cost of 2 cents per mile. Mobil 1 Synthetic oil was used in the oil

³ The purity test was conducted by Air Liquide America Corporation on 8/7/2002.

change. An oil analysis was performed on the drained engine oil to serve as a baseline for future oil analysis.⁴ Additional testing will be required to determine actual oil change intervals.

Operating Results Summary

The Sprinter experienced only minor mechanical problems during its 6,864 kilometers of operation in the APS fleet. Drivers of the hydrogen van reported rough operation: “It sounds like a diesel engine.” Drivers also reported a dead spot in the accelerator. The only operational problem occurred when the vehicle failed to start after refueling. It was determined that a failure to fully shut the fuel door caused the fueling interlock switch not to release. This was, therefore, an operator error. No safety problems were observed during the Sprinter’s operation.

As shown in Appendix B, limited fuel-use data indicate that the Mercedes Sprinter operates at 20 miles/gallon. Based on German experience with this vehicle, this would appear to be an unrealistically high fuel economy. It is believed that the short period over which fuel use measurement was available significantly reduced the reliability of the fuel economy measurement.

CONCLUSIONS

The pure hydrogen Mercedes Sprinter operated 6,864 kilometers in the APS fleet. The vehicle was operated to gain experience in fueling pure hydrogen. No safety problems were encountered during operation of the Mercedes Sprinter in the APS fleet. The vehicle appears to have a good fuel economy. However, this was based on very limited data and more data needs to be collected to validate the results.

⁴ Oil analysis was performed by Schaeffer Lubricants.

APPENDIX A

FUEL PROPERTIES AND GASOLINE GALLON EQUIVALENTS

The gasoline gallon equivalent (gge) is a simple metric to compare the energy content in any given fuel to the energy in one gallon of gasoline. The gge values used for various fuels/fuel mixtures are given in Table 1. The value of 5.66 lb CNG is defined by the National Conference on Weights and Measures to be equal to one gge. However, no similar standard exists for hydrogen or various blends of HCNG. The listed gge's were derived from the properties given in Table 1.

Table 1. Fuel properties and gge's.

	Energy Content (kWh/Kg)	Energy Content (kWh/gal)	GGE (lbm)	GGE (kg)
Gasoline	–	34.5	–	–
CNG	13.44	–	5.66	2.57
Hydrogen	33.90	–	2.28	1.04
15% H ₂ blend	13.85	–	5.49	2.49
30% H ₂ blend	14.32	–	5.31	2.41
50% H ₂ blend	15.56	–	4.89	2.22

APPENDIX B

MONTHLY MILEAGE SUMMARY

Mercedes Sprinter Van		Fuel and Mileage Summary									
Date	11/1/01	12/1/01	1/1/02	2/1/02	3/1/02	4/1/02	5/1/02	6/1/02	6/23/02	7/1/02	8/1/02
Odometer (km)	6,764	6,884	8,306	11,044	11,792	11,895	12,035	12,328	13,067	13,440	13,628
Monthly mileage (km/mo)	120	1,422	2,738	748	103	140	293	739	373	188	
Monthly fuel (gge)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	22.9	N/A	N/A	
Fuel economy (mi/gge)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	20.01	N/A	N/A	