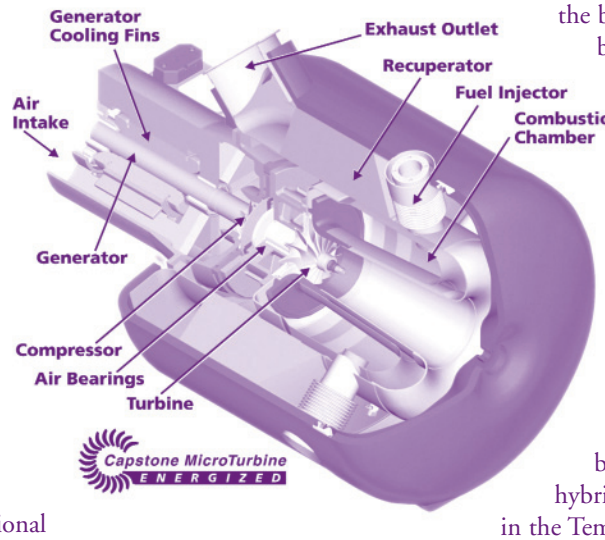
Tempe Transportation Division

LNG Turbine Hybrid Electric Buses

TEMPE, ARIZ.'S TRANSPORTATION PLANNING AND TRANSIT DIVISION, also known as Tempe in Motion (TIM), purchased the first fleet of buses in the world that uses a new engine system fueled by electricity and liquefied natural gas (LNG). The Transportation Planning and Transit Division is responsible for long-range planning and the implementation of alternative transportation modes. The new LNG turbine hybrid electric buses are quieter and produce oxides of nitrogen at a level 70% cleaner than the U.S. Environmental Protection Agency's year 2004 requirements.

THE NEW TURBINE HYBRID ELECTRIC BUSES are part of Tempe's Free Local Area Shuttle (FLASH) service, which is funded by the city and the Federal Transit Administration, and connects neighborhoods with major destinations in Tempe (i.e., Arizona State University and downtown Tempe neighborhoods). The neighborhood shuttle operates 13 hours a day and runs every 15 minutes, seven days a week.



Tempe's FLASH service also connects with the Valley Metro, which is the regional fixed route bus service. Fixed route buses serve the Phoenix metropolitan area and will eventually connect to the new light rail system. The Valley Metro service area covers 183 square miles and carries about 31 million riders annually. In Tempe, more than 4.5 million riders used the fixed route bus system in calendar year 2000, including FLASH routes. Tempe's FLASH buses are operated and maintained under contract with ATC-Tempe.

ADVANCED VEHICLE SYSTEMS (AVS), INC., of Chattanooga, Tenn., manufactures the hybrid electric buses (AVS-22), which have advanced sealed-gel, lead-acid batteries and an on-board battery charging system. These buses are 22 feet long, 102 inches wide, and have a kneeling position of approximately 11 inches above ground. The buses have 22 passenger seats, one wheelchair position, and aisle room for 12 standing passengers. The AVS hybrid electric buses in Tempe are equipped with a Direct Drive Propulsion System developed by AVS. The hybrid system is monitored and controlled by the Battery Control Unit (BCU), manufactured by PEI Electronics, Inc., of Huntsville, Ala. The BCU controls the thermal management systems and power demand for the Capstone MicroTurbine™ to regulate battery environment, equalization, and state of charge (SOC). Thermal management is provided through insulated battery boxes and forced-air cooling systems for the batteries and electric control systems, which were designed for providing optimum performance.

A MICROTURBINE manufactured by Capstone Turbine Corp. of Chatsworth, Calif., recharges the batteries. The microturbine is fueled by LNG and produces electricity to charge the batteries via an integral generator (see diagram). This system has just one moving part and uses no lubricants, no coolants, and has no gearbox. This design is compact, lightweight, and requires minimal maintenance. The propulsion system incorporates regenerative braking to slow the vehicle while producing additional power and reducing brake wear. The range of the AVS hybrid electric buses is 250 to 300 miles in the Tempe service environment.

At the end of each operating day, the hybrid buses are fueled and washed. The microturbine is left on until the batteries are at 80% SOC. The buses are then plugged into the electrical grid system to equalize the batteries for extended battery life and to bring the batteries to 100% SOC for the next operating day.

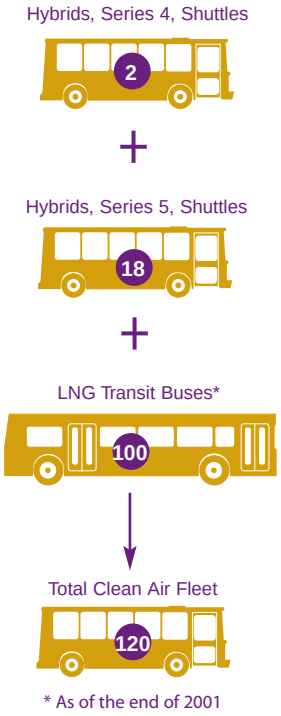
As of December 2001, the City of Tempe had two AVS Series 4 and one AVS Series 5 hybrid electric buses in its fleet. AVS will deliver the remaining 17 Series 5 hybrid buses to Tempe between December 2001 and April 2002, bringing the fleet's total number of hybrid buses to 20. Tempe opted for the Series 5 for most of its order (18 of 20 buses) because a more robust (heavier-duty) front axle and braking system will better meet its requirements of operation. The new LNG turbine hybrid electric buses will share the fueling station with Tempe's clean burning fleet, which consists of 100 LNG buses.

The fleet of hybrid electric buses will participate in an evaluation project conducted by the U.S. Department of Energy's (DOE) Field Operations Program. Information will be collected on operation, maintenance, performance, and emissions to provide comprehensive, unbiased evaluations of currently available advanced technology. NREL's Fleet Test and Evaluation Team supports the Field Operations Program in evaluating fleets of alternative fuel trucks and buses, including New York City's hybrid electric transit buses. For more information, visit www.ott.doe.gov/otu/field_ops.

Buses	**AVS-22 Series 5**
Model Years	2001, 2002
Length/Width/Height	22 ft /102 in./107 in.
GVWR/Curb Weight	27,000/19,050 lbs.
Seats/Standees	22/12
Service	Tempe, Ariz.
Turbine-Generator	**Capstone Model 330 MicroTurbine™, Natural Gas**
Rating	30 kW, 250V-700V DC
LNG Fuel Storage	71 gallons
Hybrid Propulsion	**AVS Direct Drive Propulsion System**
Traction Motor	2-AC55 Solectria wheel mounted
Traction Batteries	2 tubs, 24 cells each, sealed gel lead acid
Regenerative Braking	Yes
Emissions Results *	**Natural Gas, No Catalyst**
NO_X	0.26 g/bhp-hr
HC	0.42 g/bhp-hr
CO	0.41 g/bhp-hr
PM	0.004 g/bhp-hr

* Actual emissions results certified by the California Air Resources Board.

Tempe's Clean Air Fleet



* As of the end of 2001


PIX 10900

Tempe FLASH bus


PIX 10832

LNG fueling station


PIX 10830

ATC-Tempe facility

FOR FURTHUR INFORMATION, CONTACT

Tempe Transportation Planning and Transit Division
Carlos de Leon, Transit Manager
Transportation Division
Public Works
20 East 6th St.,Tempe, AZ 85281
Phone: 480-350-8527
Fax: 480-858-2097
E-mail: carlos_deleon@tempe.gov

National Renewable Energy Laboratory
Kenneth Proc, Project Engineer
1617 Cole Blvd.
Golden, CO 80401
Phone: 303-275-4424
Fax: 303-275-4415
E-mail: kenneth_proc@nrel.gov

Web Sites
Tempe Transportation Planning and Transit Division: www.tempe.gov/tim • Advanced Vehicle Systems, Inc.: www.avsbus.com • DOE/FOP: www.ott.doe.gov/otu/field_ops
Capstone Turbine: www.microturbine.com/hev

Sponsored by the
U.S. Department of Energy, Energy Efficiency and Renewable Energy Office of Transportation Technologies

Produced by the
National Renewable Energy Laboratory (NREL)
NREL is a U.S. Department of Energy National Laboratory
Operated by Midwest Research Institute • Battelle • Bechtel

This report was written and designed by Battelle for DOE and the NREL Field Operations Program

NREL/FS-540-31594 • February 2002

Printed with a renewable-source ink on paper containing at least 50% wastepaper, including 20% postconsumer waste.