Summary of Pilot Test of Prototype Hybrid Shuttle with Hybrid Booster Drive™

The Hybrid Shuttle diesel-electric hybrid prototype, equipped with Hybrid Booster Drive™, has undergone pilot testing on the campus of Bowling Green State University (BGSU) in Bowling Green, Ohio. The BGSU Campus Shuttle Service commissioned the hybrid prototype for service in the middle of June 2005 through the middle of September. The prototype still provides periodic service on routes and special charters although the pilot test has ended.

As of September 19, 2005, the bus has logged approximately 3,600 hybrid miles (over 400 running hours). Service hours per day ranged from 8 to 16 and rider-ship reached upwards of 500 passengers per day at times. The researchers at the Electric Vehicle Institute are pleased to report that the hybrid system performed well without technical difficulty over the 40 days of service.

From a technical standpoint, the major system components have performed as designed. The mechanical, electrical, and electronic control components have shown to be durable enough to withstand the shock and vibration of on-road vehicle testing. The control system proved to be stable and reliable. No mechanical, electrical, or electronic control system component has failed. Temperatures of the motor, inverter, and ultracapacitors have remained within normal operating limits with ambient air temperatures above 95 degrees Fahrenheit. The driveline characteristics of the standard bus in terms of noise and vibration have remained unchanged. Two minor issues were experienced during the testing however. A few of the lid fasteners of one ultracapacitor enclosure had loosened a bit but maintained their functional integrity. A bit of oil from the transfer case and some coolant from the motor escaped the seals.

At vehicle speeds above 40 miles per hour (mph), the hybrid drive mechanically disengages from the driveline of the vehicle and lies dormant. When the vehicle speed falls below approximately 35 mph following the disengagement, the hybrid drive will re-engage and become active again. During the pilot test the hybrid drive experienced a couple of hundred disengagement/engagement events without incident.

Five drivers from the shuttle service participated in the pilot test. The drivers did not undergo special training as the hybrid system was configured for automatic operation and provided standard driver controls. Each of the drivers were rather impressed with the system and found the hybrid bus intuitive and comfortable to drive. They cited the electric regenerative braking as exceptionally smooth and capable and the engine noise reduced.

A portion of the pilot test program coincided with the summer academic session. Typically, demand for shuttle service during the summer is reduced compared with Fall and Spring. Consequently, only one shuttle bus, the hybrid prototype, was provided during this period running primarily the Main campus route and a special route for University Admissions. In addition to the standard routes several out-of-town charters were run. Such charters included trips to Detroit, Michigan for example.

The Main route on campus consists of 12 shuttle stops in addition to the posted stop signs and traffic lights. According to the shuttle drivers, however, it is uncommon that all 12 stops are made during the summer. Perhaps only half of the stops are made on average. The Main route covers about 2.8 miles in typically less than 14 minutes. The posted speed limits of the campus and city streets on the route are 25 and 35 MPH. About a quarter of the route includes side streets and parking lots with speeds under 15 MPH. Top speed is usually just over 32 MPH.

A measure of baseline economy and emission improvement of the hybrid system has been against the White Book Central Business District (CBD) drive cycle. This drive cycle is a standard in the transit bus industry which specifies a particular route that vehicles of this type must follow for performance characterization. The researchers of the HBD have adopted a modified CBD cycle (MCBD) that more closely approximates a true drive cycle of a shuttle bus similar to the Hybrid Shuttle. The MCBD is a 1.6 mile course with approximately 9 stops. One stop is part of an arterial route with a top speed of 35 MPH. The rest are CBD stops with a top speed of 30 MPH. The Shuttle Service Main campus route, cited above, has about the same stop density as the MCBD but with several stops having a lower top speed. Fuel economy improvement of the prototype hybrid bus on the MCBD route has shown to be between 20 and 35 percent with similar reduction in exhaust emissions.

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A data logger was equipped in the prototype shuttle bus to record performance of the bus while in operation. Performance relevant to the base vehicle systems was recorded in addition to data from the hybrid components. There are nearly 25 data parameters that were monitored and recorded several times each second. This equated to over 250 data elements stored per second.

Some of the key data parameters included:

- Accelerator pedal position
- Brake pedal position
- Vehicle speed
- Engine torque contribution
- Fuel rate
- Transmission gear
- Capacitor voltage
- Capacitor current
- Hybrid torque contribution
- Motor temperature
- Capacitor temperature

The drive cycle in the summer session of the HBD pilot test has shown to not be ideal in demonstrating maximum potential of the parallel electric hybrid system. The parallel electric hybrid system shines with vehicles that are frequently in transition, that is, vehicles that make frequent starts and stops with little idle and cruising time. The drive cycle of the summer session has long periods of engine idle while the vehicle is parked. In fact, on some occasions the time spent idling has reached over 50% of the day's activity. While the vehicle is parked and the engine idles, fuel is being consumed. For the Hybrid Shuttle, fuel spent at idle can be greater than 0.7 gallons per hour. When the vehicle is stopped the miles per gallon fuel economy is zero by definition. Long periods of idle can dramatically lower the overall fuel economy of the day. The Hybrid Booster Drive does not lower fuel consumption at engine idle by design. Therefore, no savings can be achieved in these instances.

Despite the non-ideal demonstration route, the hybrid system performed well as designed and provided electric boost and regenerative braking consistently with each transition event. The hybrid system supplemented the engine fuel-derived power with electric power derived primarily from the recovery of vehicle braking energy. Acceleration boost of the electric drive commonly reached peaks of 40 kW (54 HP) and regenerative braking during deceleration with peaks of 80 kW (107 HP). At times, peak acceleration power reached 70 kW (94 HP) and regenerative braking power 150 kW (200 HP).

The initial pilot testing of the prototype Goshen Euroshuttle with Hybrid Booster Drive™ was successful in many respects. The pilot testing has demonstrated that the diesel-electric hybrid system of this design is an able and attractive alternative to traditional engine-only busses. Feedback from drivers and passengers has been positive. In fact, the supervisor of the Campus Shuttle Service, Fred Smith, has expressed a desire to make the prototype hybrid Euroshuttle a permanent addition to the fleet.

For more information

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