Eaton and Hybrid Electric Vehicle Powertrains- Past, Present, and Future

Eaton’s HEV Roots Go Deep

Eaton Corporation has been involved in the evolution of electric and hybrid vehicles for over 20 years. During the late 1970s and throughout the 1980s, Eaton was heavily engaged in electric vehicle research and development helping to pioneer important technological advances such as the migration from brush-type DC motors to brush-less induction motors. Early projects included the installation of complete electric traction drive systems into Ford and Chrysler passenger car and light truck applications. In the late 1980s, Eaton put its electric vehicle program on hold because of the gap in commercially viable battery technologies. This proved to be a wise decision, since most electric vehicle programs were dropped throughout the industry during the ‘90s and replaced with hybrid electric and fuel cell vehicle programs.

During this time, as Eaton continued to monitor these developments, they became convinced that battery technology for hybrid electric applications was approaching commercial viability. At the same time, forward-thinking end users and truck OEM customers were becoming more receptive to the idea of hybrid electric vehicles (HEV).

Eaton Forms HEV Business Unit- Sharpens Focus

In January 2000, Eaton launched itself into the HEV world with an internally funded R&D program aimed at building a Class 7 prototype hybrid truck. In March 2000, Eaton formed an HEV powertrain business unit within their Truck Electronic Systems Division, focusing human talent and resources toward the development of commercially viable hybrid powertrain systems. The successful demonstration of the Class 7 prototype in November 2000 paved the way for a second prototype, aimed at the urban P&D segment in the Class 4 range, to be built in 2001.

In late 2000, Eaton began to seek key partnerships with strategic fleets such as FedEx. During this time Eaton learned of FedEx Express’ plans to issue a Request for Information that was aimed at a Class 4 hybrid electric delivery step-van. Within just a few months, Eaton submitted a competitive proposal in response to an industry-wide Request for a Proposal issued by FedEx Express.

On February 26, 2002, FedEx Express announced that it had selected three finalists--including Eaton-- in its search for a prototype version of a hybrid electric Class 4 step-van. Eaton delivered its prototype to FedEx in September 2002, and that fall, was selected as the sole supplier of 18 HEV powertrain prototypes to be installed in FedEx vehicles for testing in four major metropolitan areas. At a press event in Washington D.C. in May 2003, FedEx Express proclaimed its leadership in the adoption of hybrid power in its fleet of Class 4 delivery vehicles, in cooperation with its powertrain supplier Eaton Corporation and advocacy group Environmental Defense.
Adding importance to the event were appearances by U.S. Senator Orin Hatch (R-Utah) and Environmental Protection Agency director Christine Todd-Whitman, both hailing the announcement as a real and positive step towards the adoption of fuel-saving and pollution-reducing technologies.

Meanwhile, in September 2002, Eaton was awarded a $7.1 million contract to lead a project in the Advanced Heavy Hybrid Propulsion System (AHHPS) Program sponsored by the U.S. Department of Energy. Through this program Eaton, in partnership with International Truck & Engine, will develop a heavy hybrid propulsion system designed to increase fuel efficiency and decrease emissions for commercial vehicles in the Class 4-7 weight range. Recently, a prototype UPS urban delivery vehicle was built using this new system and is currently in the testing stage.

On March 30, 2004, at a state capitol ceremony in Sacramento, CA, FedEx Express, in collaboration with Sacramento Metropolitan Air Quality Management District and Environmental Defense, placed the first of 18 Eaton hybrid electric powered delivery vehicles into service. The official rollout of the FedEx OptiFleet E700 took place on the capitol steps with California Governor Arnold Schwarzenegger in attendance. Since late February, two FedEx OptiFleet vehicles have been tested in the Sacramento area to demonstrate the commercial viability of the lower-emission powertrain in heavy-duty vehicles. Throughout the rest of 2004, Eaton will be placing an additional 16 trucks into service in selected cities. These trucks will endure real-world FedEx operating conditions to verify and prove their viability in commercial applications.

In May 2004, Eaton, in collaboration with International Truck and Engine, submitted a proposal to build a hybrid electric drive system for heavy-duty utility trucks. The proposal was submitted in response to a Request for Proposal from the HTUF Utility Hybrid Truck Working Group (Hybrid Task Force). Before submitting their proposal Eaton and International conducted several “Day-in-the-Life” sessions with members of the HTUF Utility Task Force Fleets. These sessions were held to better understand how the equipment is used in the field and have directly impacted the proposed design. In August 2004, the HTUF Working Group notified Eaton and International that their proposal had been selected.

In October 2004, Eaton will host the fourth annual national meeting for the Hybrid Truck Users Forum (HTUF) in Kalamazoo, MI. In addition to hosting the event, Eaton will showcase several HEV commercial vehicle prototypes of varying vocations with a “ride-and-drive” at the Eaton Proving Grounds in Marshall, MI.
Eaton’s Hybrid Mission & Strategy

Hybrid electric systems are critical to the automotive and truck industry’s technological roadmap that ultimately leads to fuel cell powertrains and beyond. The successful introduction of electric motor drives, inverters, energy storage devices and advanced power management controls on HEVs will pave the way for future migration to fuel cell powertrains.

Eaton recognizes that in order to be commercially viable, hybrid electric vehicles will need to deliver significant fuel savings and environmental benefits. They are convinced that the most successful hybrid products will have the lowest price premiums compared to conventional vehicles as well as demonstrate exceptional reliability “out-of-the-box.” These objectives are what drives Eaton’s commitment to develop a hybrid electric system that will enable truck OEMs and engine manufacturers to comply with strict emissions regulations, reduce fuel consumption, improve drivability and increase functionality by providing on-board electrical power generation.

By combining their successful automated manual transmission and clutch products with electric motor drives and related components, Eaton will be able to create integrated hybrid drivetrain units that are attractive to various commercial truck segments.

Product Strategy: Series Vs. Parallel

When building an HEV powertrain there are two basic configurations: series and parallel.

- A “series” configuration has a generator mounted directly to the engine. All power from the engine is converted directly into electrical energy, which is then used to drive traction motors at the axle or wheel ends. In this type of design there is no mechanical drive path between the engine and the drive wheels.

- A “parallel” configuration maintains conventional mechanical drivetrain architecture, but adds the ability to augment engine torque with electrical horsepower. A parallel system provides operating redundancy not found in a series system, whereby the conventional power can continue to operate in the event of an electrical power malfunction.

Eaton is focused on developing parallel-hybrid drivetrain systems that provide the best cost-benefit balance for many commercial truck applications. Most hybrid suppliers began working on series-hybrid systems and have since transitioned to parallel hybrid architecture for similar reasons.

Eaton’s first prototype truck featured a Full Hybrid system that made it possible to operate the engine independently from the vehicles’ road load conditions. This freedom was accomplished by combining a CVT-like device with an electric motor used to fill the gap between the most desirable engine operating conditions and the vehicle operating demands. The Full Hybrid...
architecture provides the maximum potential for reducing fuel consumption and exhaust emissions of commercial trucks.

Eaton’s second prototype truck features a Direct Hybrid system that incorporates an electric motor/generator located between the output of an automated clutch and the input to the AutoShift® transmission. This architecture makes it possible to recover energy normally lost during braking and store that energy in batteries or other devices. Electric torque can be blended with engine torque to improve vehicle performance and to operate the engine in the most fuel-efficient range for a given speed or to operate the vehicle with electric power only. In addition, this configuration creates a built-in power generator function into the vehicle for applications where remote power may be critical. Finally, this design provides a level of redundancy by enabling the vehicle to operate in electric-only or engine-only modes if the other system experiences a failure.

**Product and Technology Development**

Hybrid electric vehicles require an unprecedented level of integration and partnership between truck OEMs, the engine manufacturer, and the suppliers of the drivetrain and major electrical components. Eaton’s strategy includes early and significant collaboration with truck OEMs, engine manufacturers and key technology/component suppliers.

Eaton plans to offer complete, integrated Hybrid Drive Units to truck OEMs that include automated clutch, electric motor/generator, motor controller/inverter, energy storage, automated manual transmission, and an integrated supervisory Hybrid Control Module.

Eaton’s HEV vision includes the Hybrid Drive Unit, which includes an automated clutch, a motor/generator, automated transmission and inverter/controls, as well as the supervisory Hybrid Control Module.
HEV: Commercial Status

Many industry observers believe that hybrid electric technology is readily available. They point to the increasing popularity of passenger cars like the Toyota Prius and the Honda Insight as examples of successful passenger car applications. Recent moves by the transit departments in New York City and Seattle to purchase hundreds of hybrid electric transit buses are cited as examples of successful heavy hybrid vehicle application. Since most commercial trucks fall between the gross vehicle weights of these two hybrid examples, shouldn’t commercial trucks be an easy next step?

Eaton, in partnership with International Truck & Engine, was recently selected by WestStart’s Hybrid Truck Users Forum (HTUF) to manufacture more than 20 advanced, pre-production hybrid-electric work trucks for national deployment and assessment. This is the first announcement by a U.S. truck OEM regarding production plans for Class 4-8 (light, medium and heavy-duty) hybrid vehicles. Unlike city buses and passenger cars, commercial trucks are subject to unique durability, reliability and operating requirements and expectations. For example, a typical passenger car’s useful life of 100,000 to 125,000 miles is not even close to being acceptable for commercial truck applications. Many commercial fleets put 100,000 miles or more on a truck in a single year. Other fleets may keep their trucks for 10 years or more.

Today, the use of hybrid electric technology in commercial trucks faces many challenges. From a technological standpoint, these challenges include hybrid electric systems being able to create the increased torque and horsepower required in medium or heavy-duty trucks. The durability and reliability of battery systems and motor/inverter components must be proven in hybrid applications where battery cycles and operating environments are consistent with actual commercial truck field conditions before truck OEMs will invest in product development programs leading to production release. Furthermore, the production volumes of commercial trucks are much smaller than passenger cars, making it more difficult to recover the R&D and tooling investment. Thus, strong business cases from both the fleet operator and OEM manufacturer’s perspectives must be demonstrated before truck OEMs will commit to large investments.

For these and other reasons, successful commercialization of hybrid electric trucks will require government support of initial technological development and demonstration of reliability in the field. In 2000, four federal government departments and 16 industrial partners, including Eaton, formed the 21st Century Truck Partnership to address these issues. The 21st Century Truck Partnership was formed to bring industry and the government together in research and development efforts and share the associated costs. The role of the federal agencies is to build on existing research and to assign priority to major new research identified by the Partnership. These research efforts will address concerns specific to all trucks, tractor-trailers, transit buses and military vehicles.

Currently, Eaton is engaged in planning discussions with certain truck OEMs, engine manufacturers and key early adopter fleets. Increasingly, these discussions focus on characterizing sales volume forecasts and component cost structures required for successful commercialization.
Eaton Hybrid In The News

Eaton’s rapid progress in hybrid power technology over the last two years has earned visibility not only in its own market, but by the general public as well. In addition to being featured in trucking industry news and environmental journals for its groundbreaking efforts, Eaton has also been featured along with its teammates FedEx Express and Environmental Defense on CNN and CNN Headline News, as well as CNBC, MSNBC, the New York Times and other national and international media.

Summary

Eaton has established a Hybrid Electric Powertrain business unit and is investing aggressively in the technology and product development necessary to develop commercially attractive solutions for cost effective, reliable hybrid drive systems. At present, Eaton is optimistic that battery durability, reliability and cost will improve to the point where these systems are attractive for commercial fleet customers. In the meantime, aggressive government R&D funding and purchasing incentives are essential to bridge the gaps between today’s technology and a significant hybrid penetration in the future.

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