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Testimony of

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Chairman Lampson, Ranking Member Inglis, thank you for the opportunity to appear today. My name is Eric Smith and I am the Chief Engineer for Medium Duty Hybrid Electric Powertrains for the Eaton Corporation. Eaton is a diversified industrial manufacturer headquartered in Cleveland, Ohio. We have over 79,000 employees worldwide, including over 28,000 employees in over 100 locations in over 40 states. Our 2007 sales were over $13 billion, and we sold products in more than 125 countries.

Eaton has five main business groups that manufacture highly-engineered components:

- Hydraulics, which manufactures hydraulic components, hoses and connectors;
- Aerospace, which manufactures fuel systems, motion control systems, propulsion sub-systems and cockpit interface and circuit protection applications for commercial and military programs;
- Electrical, which manufactures residential and commercial power distribution equipment;
- Automotive, which manufactures engine valves, lifters and superchargers; and
- Truck, which manufactures transmissions and hybrid systems for heavy and medium duty trucks.

Eaton Hybird Truck Power Systems

Following years of successful development and extensive real-world testing, Eaton has emerged as a market leader in the development and production of hybrid power systems for commercial vehicle fleets. Eaton is currently offering hybrid electric products for commercial vehicles applications and our hybrid hydraulic products will enter the market this year. Our hybrid power systems are being tested and used in the United States by companies such as FedEx, UPS, Coca-Cola and Pepsi Cola. Eaton's diesel-electric hybrid power system is currently engineered as a production option in North America for Peterbilt, Kenworth, International and Freightliner and we are working with leading

European manufacturers like DAF Trucks and Daimler Trucks for potential introduction in Europe.

Eaton has invested in three separate hybrid power solutions for commercial vehicles:

- Hybrid Electric Vehicles (HEV)
- Hybrid Hydraulic Vehicles (HHV)
- Plug-In Hybrid Vehicles (PHEV)

Eaton believes that all of these technologies have a place in the truck market. We will continue to develop these technologies to create a portfolio of hybrid power systems for a wide variety of vehicles and applications.

Eaton's hybrid power systems can provide significant fuel savings and reduce vehicle emissions. Hybrid power is particularly appealing for Class 5/6 vehicles (Pickup and Delivery), Class 7 vehicles (Utility), and Class 8 vehicles (Over the Road Trucks) – all large trucks with weights exceeding 16,000 pounds, especially in stop-and-go applications.

Hybrid power provides further savings through engine-off operations and power take-off operations at a worksite. Whatever the application, hybrid power can provide significant fuel savings, increased functionality, quieter operation, and improved performance.

Currently, the U.S. stands poised to lead the world in hybrid power for trucks. Our Hybrid Drive Systems are being developed and engineered at our facilities in Michigan and Minnesota and then our systems are produced in Indiana and Iowa.

Eaton is the first Tier One Supplier of Truck components to produce for sale HEV systems to the Truck OEM market. We are the only hybrid power system to be certified by the IRS for the medium and heavy duty hybrid tax credit that was enacted in the Energy Policy Act of 2005.

Our medium-duty hybrid electric vehicles are achieving between 20% and 70% fuel economy gains depending upon the truck application.

Early this year, Eaton Corporation agreed to sell 207 diesel-electric hybrid power systems to Guangzhou Armada Development Corporation to be installed in new buses for operation in the city of Guangzhou, China. This purchase adds to the initial sales of 30 Eaton hybrid-powered buses announced in January as part of the U.S. Department of Commerce Clean Energy Trade Mission to China.

It is Eaton's largest single hybrid power systems order to date. Additionally, Eaton Corporation recently received orders from United Parcel Service for 200

units while Coca Cola Enterprises ordered 120 hybrid units. These sales make Eaton Corporation the world leader in hybrid power sales in the commercial truck market.

Hybrid Electric Vehicles (HEV)

To produce Eaton's patented parallel hybrid electric system; we couple a vehicle's diesel engine with an electric motor/generator, power electronics and batteries.

Hybrid electric systems have much higher energy storage capacity, and generally have low to moderate power capabilities compared to hydraulic hybrids. Hybrid electric systems can provide engine off PTO capability for applications needing worksite hydraulic operations and an auxiliary electric power source from the vehicle. This is valuable in vehicles whose workday takes them off the highway and to a jobsite, where the truck's power is used to operate other tools and equipment.

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

The hybrid electric system maintains conventional drivetrain architecture – such as Eaton's Fuller® UltraShift® automated transmissions – while adding the ability to augment engine torque with electrical torque. The system recovers energy normally lost during braking and stores the energy in batteries. When electric torque is blended with engine torque, the stored energy is used to improve fuel economy and vehicle performance for a given speed or used to operate the vehicle with electric power only.

This integrated system delivers a number of benefits, including:

- Up to 60 percent reduction in fuel consumption
- Up to 87 percent reduction in idle times
- Reduced maintenance and lower life cycle costs
- Reduced emissions
- Quieter operations and better acceleration

The system can also be designed to provide energy for use during engine-off worksite operations. As an additional benefit of the parallel architecture, should the hybrid system go off-line, conventional engine-powered operation continues.

Hydraulic Hybrid Vehicles (HHV) – Parallel and Series

In a parallel hybrid hydraulic system, the conventional vehicle powertrain is supplemented by the addition of the hydraulic system. The system is best suited for vehicles that operate in stop-and-go duty cycles, including refuse vehicles, pickup and delivery vehicles, and buses, where fuel economy improvements between 20% and 30% are typical. Eaton plans to commercialize its parallel hybrid hydraulic system in refuse trucks in 2008. Other applications will soon follow.

In a series hybrid hydraulic system, the conventional vehicle driveline is replaced by the hybrid system. The conventional transmission and driveline are replaced by the hybrid hydraulic powertrain and energy is transferred from the engine to the drive wheels through fluid power. The system is suited to a broader number of applications than parallel hydraulic hybrids, though - as with all hybrids - benefits will be highest in vehicles that operate in stop-and-go duty cycles.

Eaton is working with the Environmental Protection Agency (EPA), under a Cooperative Research and Development agreement, to develop a series hydraulic hybrid power system that combines a high-efficiency diesel engine and a unique hydraulic propulsion system to replace the conventional drivetrain and transmission.

The series hybrid engine continually operates at its “sweet spot” of fuel consumption facilitated by the continuously variable transmission (CVT) functionality of the series hybrid system and by regenerative braking. The vehicle uses hydraulic pump/motors and hydraulic storage tanks to recover and store energy, similar to what is done with electric motors and batteries in hybrid electric vehicles.

These vehicles can achieve a fuel economy improvement between 50 and 70 percent by:

- braking energy that normally is wasted is recovered and reused;
- the engine is operated more efficiently; and
- the engine can be shut off when not needed, such as when stopped or decelerating.

Currently, Eaton is engaged in a program supported by the US Army to militarize this drive train to provide power and fuel efficiency to military vehicle drive trains.

Plug-In Hybrid Electric Vehicles (PHEV)

Eaton is currently working with the Electric Power and Research Institute (EPRI) to develop commercial PHEV trucks. However, plug-in Hybrid technology is in the very early stages of development for heavy duty trucks.

PHEV vehicles require a notably higher energy storage capability then current medium or light duty production systems in order to maximize benefits of plug in capability. Higher energy storage battery systems facilitate the on vehicle energy storage necessary to move towards full electric vehicle capability (critical for zero emission and noise restriction areas). This would also require work on electrifying the accessories inside the vehicle (e.g. steering, brakes, HVAC).

In addition, we are working with members of the Hybrid Truck Users Forum (HTUF) such as Southern California Edison, Pacific Gas and Electric, and Florida Power and Light to develop a PHEV for use in utility truck applications. We are also working with Navistar on a proposal for a Department of Energy funded PHEV truck project.

Needed Enabling Technologies

Successful deployment of hybrid vehicles is dependant on the availability of high power output and high energy storage devices. Today, the Lithium Ion battery represents the most promising technology for hybrid electric vehicles. However, these types of batteries significantly increase the complexity and cost of the system. Additionally, robust battery management systems are needed to ensure safe and reliable operation.

Managing the charge and discharge process within the battery pack to optimize service life and reliability, as well as monitoring, predicting, diagnosing and mitigating potentially unsafe conditions, are challenges that must be overcome. The use of high voltage DC batteries (400-600 Volts) in vehicles poses a set of challenges not normally seen on commercial vehicles.

For Hydraulic Hybrid Vehicles, the Accumulator provides the same energy storage function as a battery. Today's accumulator technology is adequate for certain applications. But to achieve widespread adoption of hybrids, an increase in the energy storage capacity is needed.

Challenges and Opportunities

The U.S. is far behind in the development and commercialization of state of the art, "plug and play" lithium ion battery systems for HEV and PHEV applications that are affordable, reliable and safe. The assembly and manufacturing methodologies need to be modular and flexible, in order to cater to a range of vehicle size and configuration needed in the world of medium and heavy duty trucks. Unfortunately, there isn't a one-size-fits-all solution for trucks.

The benefits of hybridization apply equally to cars and trucks, although implementation and use in commercial trucks is significantly more complex. For example, the battery packs are larger, often must be located on the exterior of

trucks (exposed to the elements) and the duty cycles are much more demanding, since commercial vehicles are typically driven for 12-16 hours a day versus cars that are normally used for commuting and hence driven only a few hours a day.

Phasing in the next generation lithium ion batteries to make PHEV's a reality will require significantly more effort. Any significant effort towards accelerating the market appeal and penetration of hybrid vehicles in the US by developing state-of-the-art technologies and systems will provide huge impetus to the endeavor towards energy conservation and pollution reduction.

A major threat to the widespread adoption of hybrid vehicles (particularly the PHEV's) is the high cost of implementation of the fairly large battery systems needed, as well as the reliability and life of the energy storage systems. Developing a flexible and robust system to leverage multiple cell suppliers and reach the necessary economies of scale will go a long way toward reducing implementation costs. (Dr. Giorgio Rizzoni, Center for Automotive Research, The Ohio State University)

Conclusion

The hybrid truck market is in its infancy and the jury is still out as to who will lead the world in this space. Investment in Research and Development will help reduce our dependence on foreign oil, help truck fleets big and small mitigate the cost of fuel and reduce emission here at home. In fact, these are the types of technologies that can lead to a leadership position for the United States in the manufacture of hybrid truck technologies. We can provide these same benefits and solutions to truck fleets around the globe.

As the committee debates funding research and development for hybrid vehicles, we would urge that electric hybrid, hydraulic hybrid, and plug-in hybrid systems be included in such a program. Battery and accumulator technologies need to be developed specifically for commercial vehicles because their size, weight, duty cycle and energy storage requirement are unique from those storage systems being developed for passenger vehicles. It only makes sense to include commercial trucks in the mix. With proper investment, the United States could lead the world in these new and exciting technologies.