Issued: February 2006

S.15 Specialty Trucks Study Group Information Report: 2006-2

Hybrid Work Trucks: Preparing for Market Introduction

Developed by the Technology & Maintenance Council's (TMC) Hybrid Powertrains Task Force Under the Auspices of the S.15 Specialty Trucks Study Group

ACKNOWLEDGMENT
TMC acknowledges the valuable contributions of the following organizations in preparing the information contained in this report:

- The Hybrid Truck Users Forum (HTUF), sponsored by WestStart-CALSTART, Inc.
- The members of the S.15 Speciality Trucks' Hybrid Powertrains Task Force.
- University of Michigan

ABSTRACT
One of the most promising new technologies emerging to meet fuel efficiency and environmental challenges for medium- and heavy-duty vehicles is the hybrid drive system. Hybrid drive systems offer the potential both to increase vehicle fuel efficiency and at the same time to reduce actual vehicle emissions below the level of the engine certification. Hybrid systems also offer the possibility of reduced noise, in some cases electrical power generation, and the promise of reduced maintenance due to lowered brake wear, extended maintenance intervals and reduced engine load or operation time.

Over the last few years, hybrid systems have risen from a little known technology to an emerging trend in medium- and heavy-duty vehicles, specifically in key vocational applications that have city, stop-and-go and high idling duty cycles. As the volumes increase with more hybrid vehicles on the road in a greater variety of applications, the higher initial incremental cost will drop but still be a factor for many years. However, indications are this hybrid premium can be offset by operational cost savings and early hybrid incentives now proposed or already in place.

Fleets that have already started to explore or use hybrids can provide real-world insight on the advantages and challenges to expect. A growing number of hybrid meetings and briefings are appearing on the calendar to help fleets assess the current status of the technology and its application to their vehicles. Finally, fleets can take part in organized, multi-user working groups defining performance needs to guide developers. Such working groups are a component of the HTUF program and help build a better understanding the business case by application for hybrid vehicles for both users and suppliers.

Technology & Maintenance Council (TMC)
2200 Mill Road • Alexandria, VA 22314 • Ph: (703) 838-1776 • FAX: (703) 684-4328
tmc@trucking.org • http://tmc.truckline.com

INTRODUCTION

Several key industry and societal drivers are creating opportunities for the use of new technologies in commercial truck applications. These drivers include:

- steadily increasing fuel prices and the reality of a new, higher plateau for oil prices,
- the U.S. EPA's 2007-2010 stringent heavy-duty emission regulations,
- idle reduction regulations emerging in communities nationwide, and;
- concerns over diesel engine efficiencies decreasing to meet emissions requirements.

One of the most promising new technologies emerging to meet these challenges for medium- and heavy-duty vehicles is the hybrid drive system. A hybrid drive system offers the potential both to increase vehicle fuel efficiency and at the same time to reduce actual vehicle emissions below the level of the engine certification. The potential for significant fuel economy gains in the face of rising fuel prices is currently one of the most attractive features of the hybrid. However, hybrid systems also offer the possibility of reduced noise, in some cases electrical power generation, and the promise of reduced maintenance due to lowered brake wear, extended maintenance intervals and reduced engine load or operation time.

Another force supporting the emergence of hybrids has been the interest and needs of the U.S. military, particularly the U.S. Army. The U.S. Army sees an opportunity to cut back the crushing logistics burden of supplying huge amounts of fuel to vehicles at the front. At the same time, it needs increased capabilities from vehicles, including electrical power generation in the field and "silent watch" (engine off operation of equipment and electronics). The military, through the U.S. Army National Automotive Center (NAC), U.S. Air Force and other agencies, has provided early investment to develop and test the core prototype drive systems for military use. These investments have provided much of the early work making commercial hybrid applications more viable.

WHAT IS A HYBRID VEHICLE?

At its simplest, a hybrid vehicle uses more than one source of producing, storing and delivering power to increase overall efficiency. In systems currently under advanced development, the "primary" source is a diesel or gas engine, and the "secondary" or "hybrid" source is electrical or hydraulic. Many, but not all, hybrids can deliver this combined power directly to the drive wheels. A hybrid can capture and store energy during braking that otherwise would be lost as heat through frictional wear on the brakes. It then can reuse this energy for driving demands such as launch and acceleration. The ability to capture energy and reuse it creates much of the efficiency in a hybrid vehicle. A hybrid might combine the energy from a main internal combustion engine with stored energy from a second source and deliver both to the driveline and wheels as needed. In this way, the hybrid system can cause both sources to operate most of the time near their optimum conditions rather than pushing either source's capacity limits during high-demand or wasting energy during low-demand excursions.

HYBRID POWERTRAIN VARIATIONS

Hybrid systems can be characterized in many different ways. The main pairs of alternatives in emerging hybrid systems are:

- electric vs. hydraulic.
- "mild" vs. "full."
- "series" vs. "parallel."

Every emerging system uses one or the other alternative from each of these pairs, and selected alternatives can be used in any combination. For the purpose of this paper the following definitions will be used in reference to

medium- and heavy-duty applications.

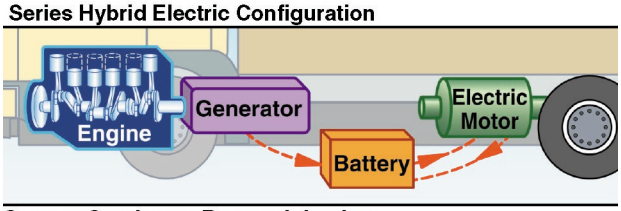
- **Hybrid-Electric—**Primary engine is diesel or gas; secondary motor is electric.
- **Hybrid-Hydraulic—**Primary engine is diesel or gas; secondary motor is hydraulic.
- **Mild Hybrids—**An electric motor/generator or hydraulic motor/pump assists the engine (usually a diesel) in acceleration or launch of the vehicle, regenerative braking and start/stop of the engine. Mild hybrids are not intended to operate in pure electric or hydraulic mode.
- **Full Hybrids—**In addition to the functionalities of mild hybrids, the electric or hydraulic motor can operate without the primary engine to propel the vehicle, typically during launch. Full hybrid systems usually require more powerful secondary motors and more energy storage to support this function.
- **Series Hybrids—**In this case, the primary engine propels the vehicle through the secondary motor. The primary engine does not power the drive train directly.
- **Parallel Hybrids:** Primary or secondary power source can propel the vehicle, independently or in combination.

Most consumers have some familiarity with hybrid-electric vehicles (HEV) now in production, which combine internal combustion engines with electric motors and store energy in batteries or capacitors. When the vehicle is starting off or requires rapid acceleration, it can pull energy from the batteries to power the electric motor. When the vehicle is braking, the electric motor serves as a generator, driven by the wheels in the forward motion of the vehicle. The motor/generator returns electricity to the batteries as the work it does applies resistance to the forward motion of the vehicle, slowing the vehicle down. In many designs, the engine can also turn the motor/generator to charge the batteries. The range of current production models includes both series and parallel, and both mild and full configurations.

Hybrid-Electric: Both Series and Parallel Configurations

In a series hybrid-electric vehicle (see **Figure 1**), an internal combustion (or other) engine powers a generator that in turn feeds electricity to an electric motor powering the vehicle's wheels. The conventional engine is not directly connected to the wheels in a series design. Hybrid-electric and hybrid-hydraulic systems can both be designed as series systems.

Series Hybrid Electric Configuration

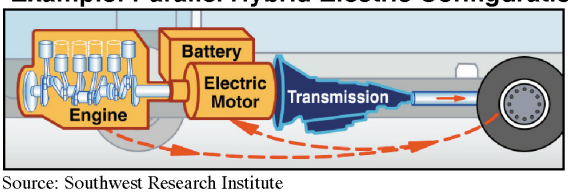


Source: Southwest Research Institute

Figure 1

A "parallel" hybrid (see **Figure 2**) has two sources that can send power to the wheels independently, or they can be used together, in "parallel." Both hybrid-electric and hybrid-hydraulic systems can be designed as parallel systems. The term "parallel" refers to the ability to operate on primary or secondary power independently or in combination.

Example: Parallel Hybrid Electric Configuration



Source: Southwest Research Institute

Figure 2

Figure 2 shows the electric motor assisting in launching the vehicle. During braking, the motor is used to regenerate energy that is stored in the batteries.

Recall that mild hybrids are not intended to operate in pure electric or hydraulic mode. This is because the secondary power source (in **Figure 2**, electric), isn't sized large enough to power the vehicle on its own. Hence, the engine drives the wheels at all times. The secondary source (electric motor) assists in providing power during launch or acceleration of the vehicle.

Hybrid-Hydraulic

In addition to hybrid-electric designs, the medium- and heavy-duty market is also seeing promise from hybrid-hydraulic systems. In a hybrid-hydraulic system, an internal combustion engine is combined with hydraulic pumps, which can serve as motors when fluid is pushed through them.

Energy is stored in a hydraulic accumulator instead of a battery. When the vehicle is launched, pressurized gas in the accumulator forces the hydraulic fluid through a hydraulic motor providing power to the vehicle's driveshaft. The fluid then collects in a low-pressure reservoir. (See **Figure 3**.)

When the vehicle brakes, the hydraulic motor turns into a hydraulic pump, utilizing the energy of the vehicle's forward motion to force the fluid from the low-pressure reservoir back to the high-pressure accumulator. (See **Figure 4**.)

Hybrid-hydraulic systems are very good at quickly capturing braking energy, and quickly releasing it.

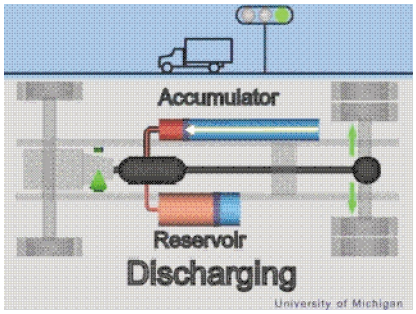


Figure 3: Hybrid-Hydraulic–Launch Mode

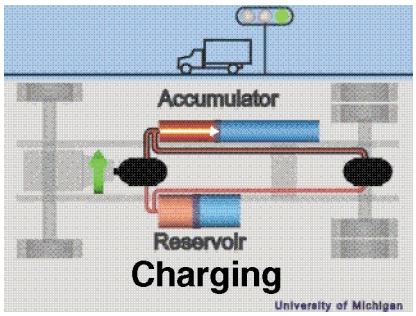


Figure 4: Hybrid-Hydraulic–Braking Mode

They are being looked at for several heavy-duty, extreme stop-and-go duty cycles.

HYBRID BENEFITS TO COMMERCIAL USERS

In most cases, hybrids offer significantly increased fuel economy over the vehicles they replace, particularly in a duty cycle that includes city, stop-and-go, or high-idling modes. Savings increase when a demanding stop-and-go cycle can be made more efficient with a hybrid system's regenerative braking, or when the hybrid system allows an engine that otherwise would be idling to be shut off instead. Vehicles that make significant stationary use of power takeoff (PTO) devices in their duty cycle may benefit greatly from some hybrid-electric designs where, instead of a lightly loaded engine, the electric motor provides the takeoff power.

The duty cycle of the vehicle is a major factor when determining the value a hybrid vehicle can provide. It is not yet clear whether trucks that drive mostly in high-speed freeway conditions will benefit greatly from a hybrid system. However, most vocational or work trucks drive a mixed duty cycle that involves a combination of highway, stop-and-go and city driving. Many have portions of the day when they idle. Hybrids provide greatest value when they can smooth out the energy demands on the conventional engine. As the vehicle gets up to speed, the second energy source does some of the work in place of the conventional engine. As the vehicle slows down, the hybrid system captures energy for future use that would have been lost. Hybrid-electrics can also provide tremendous value to vehicles that need to idle to use PTOs, because they can be designed to shut off the main engine and provide PTO power from the hybrid system, which can save significant fuel and reduce emissions.

One potential benefit now being assessed in field trials is the expected reduced maintenance in hybrids. Because it can recover braking energy, a hybrid system can extend brake life by reducing brake wear. During regenerative braking, a hybrid system slows the vehicle by converting its kinetic energy into stored electrical or hydraulic energy, via a generator or pump, reducing the need to use the conventional brakes to stop. Hybrid systems have been shown in some demonstrations to extend maintenance intervals for service brakes by several hundred percent. Reducing the number of brake jobs over the life of the vehicle would significantly affect life cycle cost. Hybrid systems also have no clutch or torque converter. They generate less heat in the engine and gears by requiring smaller RPM excursions. Less heat reduces the burden on the cooling system; reduces the destructive effect on hoses, wiring, and other ancillaries in the engine compartment; and causes slower degradation of the lubricant thereby extending engine life.

Hybrids may also extend the maintenance intervals of trucks when the interval is based on either engine hours or fuel throughput. Hybrid strategies that shut the engine down during times it would normally idle will reduce engine hours for the same work period. Sharing of peak power demands and taking on PTO functions will reduce conventional engine fuel throughput. Some hybrid systems may extend maintenance intervals by 30 percent or more.

Hybrids can also offer an advantage in reduced engine noise. Less conventional engine power, and therefore less noise, is required during launch and acceleration. A hybrid-electric truck could provide power generation in the field for lighting and tools and even for a building with little or no operation of the conventional engine, reducing or eliminating that noise source.

One of the advantages of a series hybrid concept is the flexibility offered to the vehicle designer on the placement of the drive components. The engine can be located anywhere on the vehicle since the motive power is obtained exclusively from the secondary motor. The “driveline” is simply an electric power cable or a hydraulic line. The engine, for example, can be installed backwards to gain packaging benefits and to allow greater flexibility in configuration of a vocational vehicle.

Hybrids will also reduce emissions below the level of the engine certification; however, the amount will vary by duty cycle. Early tests show reductions of all regulated emissions in hybrid systems, as well as reductions in the emissions of gases that cause global warming. The global warming emission reductions generally equal the reduction in fuel use; the regulated emissions reductions do not always show so direct a link. Comparing the emission reduction benefits of hybrids with conventional vehicles can also be difficult because current certification methods for medium- and heavy-duty vehicles were designed for conventional engines only. In order to quantify the emissions benefits of hybrids, the emissions of the entire system need to be measured. Test protocols exist, but to date the U.S. Environmental Protection Agency (EPA) has not established a national test standard. A standard is under consideration and may be adopted some time in 2006.

Early test results have been promising. Emission tests of early hybrid buses by the California Air Resources Board showed significant emissions reductions over conventional diesel buses. For example, 1999 Allison diesel-electric buses reduced NOx by 55 percent and PM by 96 percent, while the BAE Systems Orion VI bus reduced NOx emissions by over 50 percent, PM by over 90 percent, and greenhouse gases by 35 percent. Fuel economy was increased by 50 percent compared to conventional diesel drivetrains.

Federal Express and Environmental Defense collaborated to develop a delivery truck for Federal Express that met rigorous environmental, fuel economy, and price standards. Using many of the strategies described above, including a downsized engine due to lower peak power demands, the hybrid-electric delivery truck reduced NOx by 54 percent; PM by 93 percent, and improved fuel economy by 45 percent compared to the vehicle it replaced.

Most current hybrids use existing fuel infrastructure. In the future, hybrids may also use alternative fuels. Indeed, this may ultimately be one of the most efficient designs to address energy security.

FIRST COMMERCIAL HYBRID APPLICATIONS

Applications that involve a mixed driving cycle —city, stop-and-go, and idling modes—gain the fullest benefits of hybrid systems. Hybrids are not currently a good commercial fit for long haul, over-the-road, freeway-speed driving. For these reasons, the focus for first hybrid applications has been on vocational work trucks and urban transit buses. These vehicles generally have the duty cycles that can benefit most from hybridization.

Success of the earliest hybrids, however, depends on more than just duty cycle. The best first markets for hybrids would combine an appropriate duty cycle, relatively high fuel use, sufficient yearly volumes to justify manufacturer investment and the ability to accommodate the high early incremental costs of hybrid systems. Because hybrid trucks are still produced in low volume, the incremental costs will be high on the first systems. Therefore, work trucks that are already relatively expensive because of body and tool customization can be good candidates because the incremental cost of the hybrid system is a smaller percentage of the total vehicle cost. Alternately, vehicles that accumulate high mileage or whose owners focus on total cost of ownership over the life cycle of the vehicle are also good candidates.

The Hybrid Truck Users Forum (HTUF), a program operated by WestStart and the U.S. Army National Automotive Center (NAC), determined the top potential first applications for hybrid commercialization based on these considerations. These are not the only applications for hybrids, but they showed the best promise to be the first markets. Once commercialization begins in these segments, hybrids can start to penetrate additional applications as volumes increase and prices drop.

The five markets HTUF identified were: buses (particularly transit buses); refuse collection trucks; parcel delivery trucks; utility and specialty work trucks; and beverage and regional delivery trucks. In most of these categories, initial hybrid efforts are underway, and some have reached pre-production or early market phases. See **Table 1**.

Fleets in several of these applications have formed Working Groups through HTUF to develop their performance requirements, to assess the business case for a hybrid in their applications, and to work with manufacturers and suppliers to determine if a hybrid system can meet their needs. The next step for several of these groups, for whom prototypes already exist, is to commit to a purchase and assessment of pre-production trucks.

HYBRID BUSINESS CASE

The business case for commercial hybrids depends heavily on duty cycle in each fleet application. It is, therefore, critical that fleets understand their duty cycle to assess the viability of hybrid systems in their trucks. Several elements, however, play in the business case for all fleets. These core elements are:

Operational Savings—Commercial work trucks stand to benefit, in some cases significantly, from a hybrid's ability to reduce fuel consumption and some maintenance costs.

TABLE 1		
Application	**Description**	**Status**
Buses -urban transit buses -shuttle buses -paratransit	Can be extreme stop and go urban duty cycles, emission reductions important, transit platforms already high cost; lighter buses and paratransit vehicles based on truck chassis	Hybrid urban transit buses are already in early commercial status with over 2,000 on the road or ordered; Hybrid shuttle and paratransit work is just beginning
Class 7/8 Refuse collection trucks	Extreme stop and go, urban cycle; high fuel use; operate in neighborhoods; already expensive vehicles; noise and emissions important	Prototypes under development; fleet performance requirements under development; strong fleet interest
Class 4-6 Urban delivery trucks -package/parcel delivery	Stop and go duty profile; operate in urban regions; fuel use savings; best for companies with desire for high environmental image; low cost of existing trucks a concern	18 or more pre-production hybrids in service, 75 more expected in 2006; major fleets agreeing to performance requirements for separate group purchase
Specialty Truck Applications Class 5-7 utility "bucket" trucks telecom/cable Other speciality/PTO applications	Generally higher cost trucks; high idling time at work sites; heavy use of PTO; some value in on-board energy generation; duty-cycle involves stop and go and other "cycling" duties	30 utility and other fleets nationwide have set performance requirements; 14 fleets purchasing pre-production hybrids for evaluation in 2005/2006
Class 5-8 Urban delivery trucks -beverage, food and water delivery -regional delivery	Can be heavy-duty but operated only in urban, repetitive duty-cycles; not long haul; image concerns can be a factor; warehouse to store delivery; concerns over price	Growing interest from fleets in this segment, some prototypes developed

Fuel—By far the biggest cost benefit will come from fuel savings. As fuel has topped $3 per gallon in some regions during 2005, the cost and risk of rising fuel prices has come into sharp relief. Hybrid systems have been shown to increase fuel efficiency up to 50 percent, and in some duty cycles, even more. Where fuel is a large portion of the cost of vehicle operation (including fuel delivery costs), a hybrid can provide substantial savings. Fleets whose operations include substantial idling can also realize fuel savings if a hybrid system can reduce or eliminate this fuel burden.

Engine Downsizing—Additional fuel savings may be possible as new hybrid designs allow the use of downsized engines, which also reduces initial system cost.

Maintenance—To a lesser extent, hybrids also show the promise of reducing some maintenance costs, particularly for brake replacement, oil change and routine scheduled engine maintenance. The full extent of the maintenance impact needs more evaluation; however, maintenance intervals might be extended 10 to over 100 percent in some designs.

Extended Engine Life—Most hybrid systems provide a less-demanding engine operation regime or actually reduce total engine hours, leading to expectations of increased engine life. This component of the hybrid business case still needs to be better understood through field evaluation.

Productivity Gains—This possibility varies by application, and can be large or small depending on the specific duty cycle and hybrid design. Generally, fleets desire that hybrid trucks perform as well as the trucks they are replacing. But in many criteria they can perform better. Specifically, a hybrid truck can allow faster launches and more effective braking than a comparable conventional truck. In some applications, this ability can mean performing more work (such as refuse collection stops) in a given period of time while still saving fuel. Some hybrid-electric vehicles can generate utility electricity on board in addition to supplying the drive system with energy. These systems can accommodate increased electrical accessory needs, cooling systems for bodies or trailers, emergency lighting and tools, or even in some cases power restoration for buildings.

Emissions Reductions—Since a hybrid requires less power and/or less operating time from the conventional engine, a hybrid vehicle will typically deliver performance better than the certification level of the vehicle's engine. For fleets in EPA non-attainment regions these additional reductions can be important for air quality improvement, company image, customer relations or offsets of other emissions. The emissions reductions could qualify the hybrid for incentive or support funding. Hybrids also reduce global warming gases (by burning less fuel); as that becomes an increasingly important issue it may become another component of the business case.

Idle Management—Certain duty cycles, particularly those that involve truck idling and/or the use of PTOs at work sites, can benefit from hybrid designs that allow the conventional engine to be shut down and work to continue using stored energy or the hybrid drive system. These benefits can be in the form of reduced fuel consumption, reduced engine wear from idling, reduced emissions, reduced noise, and ability to comply with anti-idling ordinances.

Incentives—Because of the emissions and energy security benefits of hybrids, there are some emerging incentives to assist with hybrid purchase and use. On the national level, the Energy Policy Act of 2005 includes tax credits for medium- and heavy-duty hybrids that range from $1,500 -12,000, depending on the weight of the vehicle and the level of fuel efficiency gain (see **Table 2**). Some states and regions also have incentive programs available to fleets to help offset the incremental cost of a hybrid system.

In the early years of hybrid introduction, hybrid systems will be expensive and will likely cost more than what can be recovered simply through operational cost savings over the expected life of the vehicle. Therefore, cost recovery aspect of the business case should

TABLE 2
Energy Policy Act of 2005 Heavy-Duty Hybrid Tax Credits

Vehicle Weight	Max Tax Credit for 30% FE Increase*	Max Tax Credit for 40% FE Increase*	Max Tax Credit for 50% FE Increase*
8,501 - 14,000 LB	$1,500	$2,250	$3,000
14,001 - 26,000 lb	$3,000	$4,500	$6,000
>26,000 lb	$6,000	$9,000	$12,000

* based on maximum qualified incremental cost

include a package of benefits, costs savings and incentives.

HYBRID CHALLENGES AND BARRIERS

Cost is the key critical factor that can either encourage or discourage the acquisition of hybrid vehicles. The incremental capitalization costs are still in the multiple tens of thousands of dollars for early systems that are not yet in manufacturing volume. This cost is expected to decrease steadily, possibly to a purchase premium level of perhaps ten to thirty percent over a conventional vehicle's cost. However, an important consideration for hybrids is to evaluate their total cost of ownership, or life cycle cost. In this case the question is whether the lower cost of fuel, potentially lower or extended maintenance and incentives will recoup the incremental capital cost. Fleets that know their operational and life cycle costs will be in a good position to evaluate hybrids as they start to enter the market.

Energy Storage for Hybrid-Electric Systems

Among the technical challenges to hybrid-electric systems remain weight, cost and lifetime of the energy storage batteries. Battery storage capacities have steadily increased over the past two decades and their weights have greatly decreased. The most advanced batteries are still very expensive, limiting the amount of energy storage that can be carried economically in a hybrid. However, hybrid system designers are finding that parallel hybrid systems do not require large amounts of energy storage; their "power" abilities (ability to deliver and receive energy quickly) are more important. The passenger car hybrid market has accelerated development of this attribute.

Some technology providers have shifted their focus to ultra- or super-capacitors due to their promise of lower costs and their ability to meet much more demanding charge and discharge cycles. Aggressive drive cycles as seen in buses and refuse vehicles can drive very large charge and discharge power requirements hundreds or thousands of cycles a day. Most current battery technologies cannot handle these aggressive requirements while lasting long enough to meet the life cycle cost requirements. Ultra/super capacitors may prove superior to the battery technologies in some of these niche applications.

Energy Storage for Hybrid-Hydraulic Systems

Hybrid-hydraulic systems are a generally robust technology with the potential to cost less than hybrid-electric systems. Challenges remain, however, as hydraulic systems are less technically advanced today than the electric types. Work continues on reduction of the size and weight of the hydraulic accumulator. Location of the accumulator in the vehicle and choice of an optimal size for the expected operational demands require special, sometimes case-by-case design effort. Substantial fieldwork must follow to develop and prove system reliability and to assure hoses and fittings are suited to the necessary high pressures.

Other Important Concerns

While the outlook for maintenance cost savings is good for hybrids in general, the case is still being demonstrated in first field trials. These trials will also address the level of fleet training required and the adequacy of service support systems. While most commercial hybrid trucks are intended to operate in as similar a manner as possible to conventional vehicles, that functionality needs additional validation.

Finally, safety issues remain concerning high voltage wiring systems in hybrid-electric vehicles and high pressures in hybrid-hydraulic systems. Substantial advancement in electric and hybrid-electric passenger cars and long experience with high pressure hydraulic systems give developers confidence they can

ensure the safety of operators, maintainers, and emergency response providers. The Society of Automotive Engineers (SAE) already has protocols for identifying cabling and power shut-off points for hybrid-electric heavy-duty vehicles.

NEXT STEPS

Over the last few years, hybrid systems have risen from a little known technology to an emerging trend in medium- and heavy-duty vehicles, specifically in key vocational applications that have city, stop-and-go and high idling duty cycles.

As the volumes increase with more hybrid vehicles on the road in a greater variety of applications, the higher initial incremental cost will drop but still be a factor for many years. However, indications are this hybrid premium can be offset by operational cost savings and early hybrid incentives now proposed or already in place. Fleet users interested in hybrids need first to understand their units' duty cycles, including miles driven per day, speed range and excursions, number of stops, percentage of time spent idling or powering accessories, and fuel consumption. This fleet characterization is necessary to determine if the vehicles might benefit sufficiently from a hybrid design. For the simplest analysis, fleets can compare their general duty cycles and truck sizes to those applications showing first promise and for which prototype and pre-production models exist, as these will likely represent the first commercially available hybrid chassis.

Fleets that have already started to explore or use hybrids can provide real-world insight on the advantages and challenges to expect. A growing number of hybrid meetings and briefings are appearing on the calendar to help fleets assess the current status of the technology and its application to their vehicles. Finally, fleets can take part in organized, multi-user working groups defining performance needs to guide developers. Such working groups are a component of the HTUF program and help build a better understanding the business case by application for hybrid vehicles for both users and suppliers.

For more information, please consult the following Web sources and publications:

Heavy-Duty Hybrids 2003: Challenges & Opportunities
www.calstart.org/info/publications/hybrid2003/index.php?p=news
Hybrid Truck Users Forum (HTUF) –
www.htuf.org
Federal Express Hybrid Trucks
www.fedex.com/us/about/responsibility/environment/hybridelectricvehicle.html
Environmental Alliance hybrid information
www.environmentaldefense.org/partnership_project.cfm?projectID=3
U.S. Department of Energy – FreedomCar and Vehicle Technologies
www.eere.energy.gov/vehiclesandfuels/technologies/systems/index.shtml
U.S. Army National Automotive Center
www.tacom.army.mil/tardec/nac/index.htm
Oshkosh Truck Corporation
www.oshkoshtruck.com/defense/technology