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Future Energy Sources for Commercial Vehicles

Developed by the Technology & Maintenance Council's (TMC)
Future Energy Conservation Task Force

ABSTRACT
Today's heavy-duty truck manufacturers are increasing their focus on more efficient management of all types of energy in commercial vehicle (e.g., combination vehicle, straight truck, etc.). This position paper explores industry efforts at attaining alternate energy sources and what steps should be taken to implement such alternatives successfully for commercial vehicle operations.

TMC believes the next step in vehicle energy conservation is to investigate the usage of the fuel energy once it is burned and develop strategies for efficient recovery and subsequent usage where possible and feasible. At the same time, this effort should include using 'free' energy, specifically solar, as part of the overall energy mapping process.

The time is now to begin laying out an electrical system architecture that will accommodate the energy efficient tractor and trailer of the future. TMC's study groups and task forces should play a leading rolle in developing this architecture, working with other industry groups and organizations as needed.

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INTRODUCTION

Today's heavy-duty truck manufacturers are increasing their focus on more efficient management of all types of energy in commercial vehicle (e.g., combination vehicle, straight truck, etc.). This position paper explores industry efforts at attaining alternate energy sources and what steps should be taken to implement such alternatives successfully for commercial vehicle operations.

Clearly, the primary source of energy for today's commercial vehicles is fuel — diesel, gasoline, CNG, LPG, etc. For decades, the drive to conserve energy has reduced fuel consumption by improving fuel mileage. A variety of tactics [e.g., policies, training, and devices to optimize miles per gallon (MPG)] have been developed and implemented. Significant progress has taken place in fuel economy or MPG improvement using a wide-ranging approach to the problem. Methodologies include tire design and pressure monitoring systems, airflow improvement, fairings, drivetrain improvements, engine size/efficiency, and weight reduction, to name a few.

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ENERGY SOURCES VS. ENERGY CONSUMERS

The obvious energy source in the truck is fuel. Once the engine is running and the truck is underway, energy from the burned fuel results in a significant amount of secondary energy (beyond that used for propulsion) that is generally lost or wasted. Heat is by far the major form of secondary energy that is lost (via the radiator and exhaust gases). Lagging far behind heat are vibrational energy losses.

Technology now exists that can recover these types of lost/wasted energy:

- Waste heat from radiator and exhaust gases
- Regenerative braking energy (currently dissipated as heat in brake drums)
- Energy from suspension system motion (currently dissipated as heat)
- Energy from engine, chassis, and trailer vibration

Once recovered from these secondary sources, energy can be stored or re-used immediately by energy-consuming components in the truck. Energy consumers in the truck can be any of the following:

- Propulsion motors (hybrid vehicle)
- Driver comfort (heat, air-conditioning, sleeper loads)
- Lighting (internal and external)
- Engine accessories (e.g., electric fan/ water pump, electric power steering, electric fuel pump, etc.)
- Driver accessories (e.g., radios, computers, telematics, liftgates, etc.)

What is clearly missing at this point is the strategy for seamlessly integrating *energy sources* in the truck with *energy consumers*. Presently available are a variety of aftermarket energy recovery devices that effectively collect secondary energy, convert it to electrical form, and make it available for immediate use or storage. Some manufacturers of these devices offer only the collection/recovery device. Examples are energy recovery from suspension and vibration motion, and solar energy collection. Manufacturers of regenerative braking systems offer:

- the recovery/generation portion,
- the storage portion (via ultracapacitors or lead-acid batteries), and;
- the consumption portion (motive force or energy)

while manufacturers of waste heat recovery offer energy recovery and immediate re- use via a turbine coupled into the drivetrain.

Below is a summary of the various types of energy recovery devices and systems currently available as aftermarket options along with proposed goals/positions for each.

A. Waste Heat Recovery (WHR)
Waste heat is significant but cannot be fully recovered. The strategy of recovering waste heat depends on the quantity and quality of the heat.

The Organic Rankine Cycle (ORC) operates with organic fluids with a lower boiling point and higher vapor pressure. It allows working with the lower heat temperatures found in trucking. Efficiency is around five percent of the total waste heat.

One manufacturer has steadily invested in this area and is now on its fourth generation of prototypes. Indications are this manufacturer is ready to start field testing with a customer and could have it in production “as early as” 2020. If the manufacturer does accomplish this, it would be at lower volume and higher cost than average engines without WHR; however, it would be a start to proving the technology rather than having it introduced in high volume before it is ready.

Positions:

- The primary goal of a waste heat recovery system is to increase the overall efficiency of the fuel combustion process and convert heat energy into mechanical propulsion energy. The ability to efficiently collect the waste heat energy and reuse it is primary to any practical system. The benefit is measured directly in MPG improvement.
- The use of the collected waste heat energy as motive power should always be the primary goal.
- The economics of waste heat recovery must make economic sense. That is to say, that once implemented and offered by an vehicle manufacturer, the increased cost of the tractor with the WHR option (over the same tractor without) must be recovered in fuel savings within a generally accepted time period. In trucking, this typically must be within a year or less.

B. Regenerative Shock Absorber
A regenerative shock absorber is a type of shock absorber that converts parasitic intermittent linear motion into useful energy, such as electricity. Conventional shock absorbers simply dissipate this energy as heat. Both hydraulic and electric systems have been demonstrated.

- ***Electric***—Preliminary data suggests 20-70 percent of the energy normally lost in the suspension can be recaptured with this system.
- ***Hydraulic***—A system developed at the Massachusetts Institute of Technology (MIT) uses hydraulic pistons to force fluid through a turbine coupled to a generator.[1] The system is controlled by active electronics which optimize damping, which the inventors claim also results in a smoother ride compared to a conventional suspension. In addition to the MIT study, there are designs and studies showing that hydraulic systems in conjunction with accumulators (versus generators) can be used quite efficiently in vehicles that do a lot of stop and start operations. The technology was available in 2009/2010 ---- they may (still) be in use in garbage haulers, etc. This is discussed in detail in TMC's Future Truck Committee Information Report 2015-3, “Exploring the Potential for 48-Volt Commercial Vehicle Electrical Systems.”

Positions:

- The primary goal of a suspension energy harvesting or collection system is

1. Avadhany, Shakeel N, “Analysis of hydraulic power transduction in regenerative rotary shock absorbers as function of working fluid kinematic viscosity,” 2009 Massachusetts Institute of Technology Citable URL: http://dspace.mit.edu/handle/1721.1/58375

to design practical systems in terms of system cost and weight. The ability to efficiently collect the energy, store it and then reuse it is primary to any practical system.

- There are two challenges:
  - Regenerative shock absorbers can be installed on tractors and trailers. There must be standardization between the two, so that trailers are not dedicated only to tractors with the same system installed.
  - Once captured, it is not clear where the energy is stored or used. If the harvested energy is immediately used for motive power, then appropriate means of interfacing to a motorized axle system or equivalent is paramount.

- Again, once implemented and offered by a vehicle manufacturer, the increased cost of the tractor/trailer with the regenerative shock absorbers (over the same tractor/trailer without) must be recovered in fuel savings within a generally accepted time period.

C. Piezo-Electric Vibration Energy Recovery

One major original equipment manufacturer (OEM) is currently looking to use renewable energy from noise/sound emitted from vehicle, which is to be converted to electrical energy with the help of piezo-electric technology and stored in ultracapacitors. Automotive OEMs have discovered piezo-electric vibration energy recovery as a way to capture vibration energy which is otherwise lost.

Unfortunately, the energy output from the piezo is very low and cannot be directly used to power another electrical device (i.e., a motor); however, it is sufficient to charge a battery. For this to be efficient, the conversion efficiency of the piezo device and the charge acceptance of the battery are typically monitored.

Positions:

- This technology should be monitored in the future for any significant breakthroughs in cost or energy produced.

D. Regenerative Braking

Two manufacturers are now offering regenerative braking for commercial trailers. A third offers a system for medium-duty straight trucks.

The former are intelligent systems involving two control units: one on the tractor and one on the trailer. Two of the three use ultracapacitors to store the recovered braking energy. In the case of the tractor/trailer, the trailer also has a propulsion motor/generator. In all three cases, during braking the motor/generator recovers kinetic energy that would otherwise be lost as heat and stores it in ultracapacitors or batteries. During acceleration, the tractor control unit communicates with the trailer control unit to manage the motive energy provided through a motorized axle with power stored in the ultracapacitors or batteries.

Although regenerative braking is growing in popularity in passenger cars, few if any of these systems are yet in operation in heavy duty trucks. Primary limitations are:

- Cost – particularly retrofit (approximately $25,000)
- Weight – particularly when batteries are used (can be as high as 550 lbs.)
- Requirement for tractor and trailer to be compatible (and/or dedicated)
- Not yet available on new trucks

Positions:

- There are two challenges:
  - Regenerative braking systems can be installed on tractors and trailers. There must be standardization between the two, so that trailers are not dedicated only to tractors with the same system installed.
  - Once captured, it is not clear where or how the energy is stored and

used. If the harvested energy is immediately used for motive power, then appropriate means of interfacing to a motorized axle system or equivalent is paramount.

- The use of the collected energy as motive power should be a primary goal.
- As with waste heat recovery the payback or ROI must be acceptable. The increased cost of the tractor/tractor with the regenerative braking system option (over the same tractor/trailer without) must be recovered in fuel savings within a generally accepted time period. Also, this system will require cooperation between the manufacturers of tractors and trailers.

F. Solar Energy

Solar is here now and well understood. Due to surface area requirements, collection panels must be installed on the roof of the trailer; there simply isn't sufficient square footage on the tractor. (This topic is addressed in greater detail in TMC RP 177, *Solar Power for Commercial Vehicles*.)

As noted earlier, the availability of energy recovery devices is creating a need for storage of recovered energy that can't be instantly re-used. The type of energy to be stored falls into three primary categories:

- High current, high burst power for cranking and starting
- Moderate to high current motive power for tractor/trailer propulsion. Rapid charging and discharging are key demands.
- Low power, high energy storage requirements for operation of sleeper loads, lighting, global positioning satellite/geofencing, computers, telematics, etc., when the engine is switched off.

The industry OEMs presently depend on lead-acid battery technology to satisfy nearly all of the above energy and power needs. The shortcomings of battery technology are becoming apparent as the new energy capture technology creates new requirements for storage. Commercial automotive and bus manufactures globally are deploying several technologies today with various energy storage means.

Goals:

- Recognize different energy storage needs in the truck and trailer based on:
  - Charge/discharge rate
  - Total energy vs power required
  - Weight
  - Lifetime charge/discharge cycles required
- Increasing the operating voltage of the electrical/electronic systems is receiving growing attention and discussion. This is an ideal opportunity to consider multiple voltages in the truck and trailer. At the same time, different energy storage requirements can be incorporated into a new standardized system truck electrical architecture.
- Investigate and recommend storage technologies that are well suited to the current, charge, and discharge characteristics.

Summary/Call to Action

As various energy recovery products and systems are brought to market, there is an increasing challenge to design, layout and connect such equipment in a logical and consistent manner. Since there is as yet little OEM involvement in energy recapture and recovery, there are few industry standards or guidelines for utilization of such equipment. The industry will become increasingly laden with conflicting designs and installation configurations that will require some level of standards to be implemented. Examples are as follows:

- Tractor/trailer interface and interconnection standards for solar, regen braking, and suspension energy and interconnection.

- Standards for interconnection of solar panels to the electrical systems of the tractor and trailer.
- Energy storage configurations and interconnection strategy for various storage technologies: lead-acid, nickel- cadmium, lithium-ion, and ultracapacitor.
- Cost reduction of the various technologies to allow wide spread implementation by the OEMs.

The time is now to begin laying out an electrical system architecture that will accommodate the energy efficient tractor and trailer of the future. TMC's study groups and task forces should play a leading rolle in developing this architecture, working with other industry groups and organizations as needed. ❏