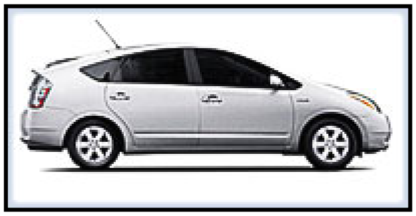

HYBRID VEHICLES

Today there are 800 million motor vehicles sharing the world's roads. If lined up bumper to bumper, they would circle the globe nearly 100 times. Ninety five percent of these vehicles are fueled by petroleum and currently 25% of all carbon emissions in the atmosphere are a result of exhaust from these machines. If that were not bad enough, it is estimated that by 2050, there will be 2 billion vehicles on the road, two and a half times as many as today.

Twenty five percent of all the oil consumed in human history has been consumed in just the past 10 years. Our appetite for petroleum is rising at an astronomic rate.

In the United States, people expect their cars and trucks to be reliable, practical, and safe. They also expect them to be comfortable, roomy, and fast. Only now that gasoline has reached four dollars a gallon are many beginning to think of fuel economy as an important factor in selecting their vehicles.

The worldwide automotive industry has always been at the forefront of technology. Ever since the first horseless carriage appeared on the scene in the 1890's, technical innovation has been the name of the game. The introduction of Hybrid vehicles has not changed the role of the auto manufacturers. In fact, innovation and complexity have accelerated in recent years.

HYBRID TECHNOLOGY: Standard hybrids are a step in the right direction, but not the ultimate solution. They are characterized by a small gasoline engine and an electric motor. Either prime mover is capable of powering the vehicle and the engine is also capable of charging a battery bank. The battery bank in turn provides much of the energy to drive the electric motor.

There are three features in most current hybrids that are that are most responsible for their remarkable fuel economy: engine shutdown, regenerative braking, and initial acceleration by electric motor.

Engine shutdown is simply a programming issue which shuts off the engine when the vehicle is motionless as long as the batteries are approximately 80% charged. If the overall charge falls below a specific threshold with the vehicle standing still, the engine starts to charge them back up and then shuts back off. In stop-and-go city traffic, engine shutdown produces a significant improvement in miles per gallon since fuel is not being consumed while the vehicle is standing still.

Regenerative braking is a method of reducing speed by converting some of the vehicle's kinetic energy into electrical power. When hybrid vehicles are coasting or slowing down, as their kinetic energy carries the vehicle along, the wheels drive the electric motor's shaft. This causes the motor to act as a generator, charging the batteries, and producing mechanical resistance, thereby slowing the vehicle. Traditional friction braking takes over when the speed slows to the point that regenerative braking disappears, brings the vehicle to a full stop, and holds it in place. Friction braking also serves as a backup in case the regenerative system fails or if the batteries are fully charged and cannot accept additional charging energy.

The friction and regenerative braking effects must be matched by one of the onboard computers to produce the desired total braking output. The GM EV-1 Electric Car was the first commercial car to do this.

The largest use of energy needed to move a body through space is that used to change its velocity or direction. For a car or truck, the energy to get it started moving consumes a significant percentage of the fuel expended. Some hybrid models use the electric motor to overcome the inertia of starting from a dead stop, with the gasoline engine kicking in after one or two revolutions of the wheels.

One of the most popular hybrids is the Prius by Toyota. It is a 5 passenger car with a standard weight of about 2,900 pounds, a 106 inch wheelbase, a width of 68", and a height of 58". The Prius' power plant is actually a large 4 cylinder motorcycle engine of 90 cubic inches. Toyota has recently announced that total sales of the Prius has passed the one million mark since it's inception in Japan in 1997.

The overall result of the hybrid performance including engine shutdown on stop, regenerative braking, and electric motor take-off is a gasoline consumption rate of approximately 44 miles per gallon in mixed city and open road driving.

ENERGY STORAGE – Batteries:

Nickel-Metal Hydride:

Many hybrid manufacturers use nickel-metal hydride batteries (abbreviated NiMH). The NiMH is a rechargeable battery similar to a nickel-cadmium (NiCd) battery but using a different alloy for the negative electrode (cathode). A NiMH battery can have two to three times the capacity of an equivalent size NiCad. However, compared to the lithium-ion battery, the energy density of the NiMH is lower and the self-discharge (internal leakage) is higher.

Nickel-metal hydride battery made by Varta Company in Germany

Applications of NiMH type batteries includes all-electric plug-in vehicles such as the Toyota RAV4 EV, Honda EV Plus, and Ford Ranger EV. Hybrid vehicles such as the Toyota Prius, Honda Insight, and Honda Civic Hybrid also use them. NiMH technology is also used extensively in rechargeable batteries for consumer electronics.

Because no gases are released during charging, NiMH batteries are able to remain sealed in normal operation and to be maintenance-free.

Care must also be taken during discharge to ensure that one or more cells in a series-connected battery pack do not become completely discharged and reverse polarity. Cells are never absolutely identical, and inevitably one will be completely discharged before the others. When this happens, the "good" cells will start to "drive" the discharged cell in reverse, which can cause permanent damage to that cell.

NiMH batteries are commonly considered to have lower environmental impact than NiCd batteries, due to absence of toxic cadmium. Most industrial nickel is recycled, due to the relatively easy retrieval of the metal from scrap, and to its high value.

Lithium-ion batteries:

Lithium-ion batteries (commonly referred to as Li-ion) are a type of rechargeable battery which uses lithium ions for current flow. This type of battery is used in several hybrid vehicles as well as many popular types of portable electronic devices. They have several advantages, such as one of the best energy-to-weight ratios, no memory effect, and a slow loss of charge when not in use. However, care must be excercised since certain kinds of mistreatment may cause Li-ion batteries to explode.

The three primary functional components of any battery are the anode, the cathode, and the electrilyte. Commercially, the most popular material for the lithium ion anode is graphite. The cathode is generally made from cobalt oxide, lithium iron phosphate, or manganese oxide. Depending on the choice of material for the anode, cathode, and electrolyte, the voltage, capacity, life, and safety of a lithium ion battery can change dramatically.

Lithium-ion batteries came into reality in 1991 at Bell Labs. The first commercial model was released by Sony. These batteries have revolutionized consumer electronics.

Advantages of Lithium-ion batteries are:

- They can be formed into a wide variety of shapes and sizes so as to efficiently fill available space in the devices they power.
- Li-ion batteries are lighter than other equivalent secondary batteries.
- Li-ion batteries do not suffer from the memory effect.
- They also have a low internal leakage rate when compared to nickel metal hydride and nickel cadmium batteries.

Disadvantages of Lithium-ion batteries are:

- Life span begins at time of manufacturing, not just on the number of charge/discharge cycles. So, unlike other batteries an older battery, even though unused, will not last as long as a new battery due solely to its age. This drawback is not widely published.
- At a 100% charge level, a typical Li-ion laptop battery at room temperature that is full most of the time will irreversibly lose up to 20% capacity per year. Higher temperatures will result in higher percentages of capacity loss, while lower temperatures will prolong battery life.
- As Li-ion batteries age, their internal resistance rises. This causes the voltage at the terminals to drop under load, reducing the maximum current that can be drawn from them. Eventually they reach a point at which the battery can no longer operate the equipment for an adequate period.
- A stand-alone Li-ion cell must never be discharged below a certain voltage to avoid irreversible damage. Therefore, all Li-ion battery systems are equipped with a circuit that shuts down the system when the battery is discharged below the predefined threshold. It should thus be impossible to "deep discharge" the

battery in a properly designed system during normal use. This is also one of the reasons Li-ion cells are rarely sold as such to consumers, but only as finished batteries designed to fit a particular system.

- When the voltage monitoring circuit is built inside the battery (a so-called "smart" battery) rather than the equipment, it continuously draws a small current from the battery even when the battery is not in use; furthermore, the battery must not be stored fully discharged for prolonged periods of time, to avoid damage due to deep discharge.
- Li-ion batteries are not as durable as nickel metal hydride or nickel cadmium designs and can be extremely dangerous if mistreated. They are usually more expensive.
- Li-ion chemistry is not as safe as nickel metal hydride or nickel cadmium and a Li-ion cell requires several mandatory safety devices to be built in before it can be considered safe for use outside of a laboratory. These are: shut-down separator (for overtemperature), tear-away tab (for internal pressure), vent (pressure relief), and thermal interrupt (overcurrent/ overcharging). These devices take away useful space inside the cells, and add an additional layer of unreliability.

Supercapacitors: A promising technology that might serve as a replacement for the nickel metal-hydride or lithium-ion battery is the “Supercapacitor” or “ultracapacitor”. These are electrical energy storage devices that can store as much as 10,000 times as much electrical energy as standard capacitors.

Standard capacitors typically can be thought of as a roll of two layers of aluminum foil separated by a layer of dielectric, such as mylar. They are charged by impressing a DC voltage between the foil layers. This develops a negative charge on one layer of foil by driving electrons to that layer and a positive charge on the other foil layer due to an absence of electrons. When the impressed voltage source is removed, the charge difference created maintains a potential difference on the plates across the dielectric. This charge difference can later be used as an electrical source by allowing electron flow through an electrical circuit, such as the drive motor of a hybrid vehicle.

The unit of capacitance is the farad. Standard capacitors about the same size as a D-cell battery can hold a charge of several millionths of a farad. A supercapacitor of the same size can hold several farads, up to 10,000 times as much charge as a standard type.

In supercapacitors, the dielectric is sometimes composed of activated charcoal. Thicknesses are on the order of nanometers (1 one millionth of a millimeter). However, due to the exceedingly thin separation between the plates, only low levels of 2 or 3 Volts can be used. This means that many supercapacitors connected in series are necessary to match the operating voltages used in hybrids. Current development includes efforts in discovering improved energy density and higher useable voltages.

Advantages of supercapacitors over batteries are:

- Higher power density. This means the combined effects of energy density and the speed that power can be withdrawn are better than batteries.
- Higher efficiency.
- Faster charging time.
- Less heat generated during operation.

- Operation and disposal are safer and do not involve hazardous materials, since none are used in manufacture or emitted during operation.
- 1,000 times as many charge/discharge cycles.

As the energy density of electric double-layer capacitors is bridging the gap with batteries, it is hoped that in the near future the automotive industry will start to deploy ultracapacitors as a replacement for chemical batteries.

PLUG-IN HYBRIDS:

The idea seems simple enough: Just add a cord and a plug to a Hybrid so you can charge its battery on ordinary household electric current overnight. Then, use only the battery power to make the short round-trips to work, school or the store. That would save lots of gas, and the charging could be done mainly at night, when utility rates are cheaper. When driving longer distances, the engine kicks in and the vehicle operates on gasoline, much like today's Hybrid vehicles. This inspiring idea has caught the public's attention as an energy-security measure that uses domestic and potentially renewable resources. Not surprisingly, it has prompted questions to automakers about when the first commercial plug-in hybrid can be expected.

Some say that this idea merely moves the pollution from the tailpipe to the power plant. But many experts say that charging vehicle batteries from the utility electric grid is more efficient and less polluting than by the on-board engine and generator.

At present, however, plug-in hybrid vehicles are not considered commercially feasible by most auto manufacturers. Reaching this goal will require breakthroughs in battery technology, including size, weight, performance, durability and cost. Depending on electric power sources, they may offer reductions in both emissions and fuel consumption.

At the 2008 North American International Auto Show held in Detroit in January, 2008, Toyota announced a wide-ranging environmental agenda which includes delivery of a significant fleet of plug-in hybrid electric vehicles by 2010, powered by lithium-ion batteries to the U.S and a wide variety of global commercial customers.

General Motors announced at the Detroit Auto Show that production of a Saturn SUV plug-in model may start as early as 2010.

MILD HYBRIDS:

A second type of hybrid, called a Mild hybrid, is essentially a conventional vehicle with an oversized starter motor. This allows the engine to be turned off whenever the car is coasting, braking, or stopped, yet restart quickly as soon as it is needed. The electrical system will continue to operate accessories while the engine is turned off. The larger starter motor is used to spin the engine up to operating rpm before injecting fuel or initiating ignition.

Many people do not consider these to be hybrids at all since the electric motor does not technically drive the vehicle, they don't have battery storage, and do not achieve the fuel economy of full hybrid models. A major example of a Mild hybrid is the 2005 Chevrolet Silverado Hybrid, a full-sized pickup truck. Chevrolet was able to get a 10% improvement on the Silverado's fuel efficiency by shutting down and restarting the engine on demand.

Many Mild hybrids use 48 volt starters rather than the conventional 12 volts to supply the power needed for the more frequent startups.

Compared to a "full" hybrid vehicle, however, mild hybrids provide some of the benefits of full hybrid technologies, with less of the cost/weight penalty incurred by the parallel electric hybrid drivetrain. Fuel savings are generally less than that of a full hybrid vehicle. This is because Mild hybrid design does not normally allow regenerative braking or the use of smaller, lighter, or more efficient gasoline engines. BMW, however, succeeded in combining regenerative braking with the mild hybrid "start-stop" system in one of their current models. GM's "Belt Alternator Starter" (BAS) mild hybrid system also utilizes regenerative braking by back-spinning the electric motor during coasting and deceleration to generate electricity used to charge the system's conventional battery.

General Motors followed the Silverado hybrid with their BAS system used in the2007 Saturn Vue Green Line. It operates in much the same manner as the "start-stop" system in the pickup truck, but the electric motor can also provide modest assist under acceleration.

Hybrid vehicles are a great leap forward in the fight to preserve the earth and it’s environment for future generations. In order to make a difference, however, they, and their improved descendents, must be sold, not by the hundreds or the thousands, but by the hundreds of millions.