Alternate Fuel Technology – Battery Electric Vehicles

This is another in a series of articles on alternate fuels. For comments or questions, contact ASE's Bob Rodriguez at 703-713-3086 or brodriguez@asecert.org.

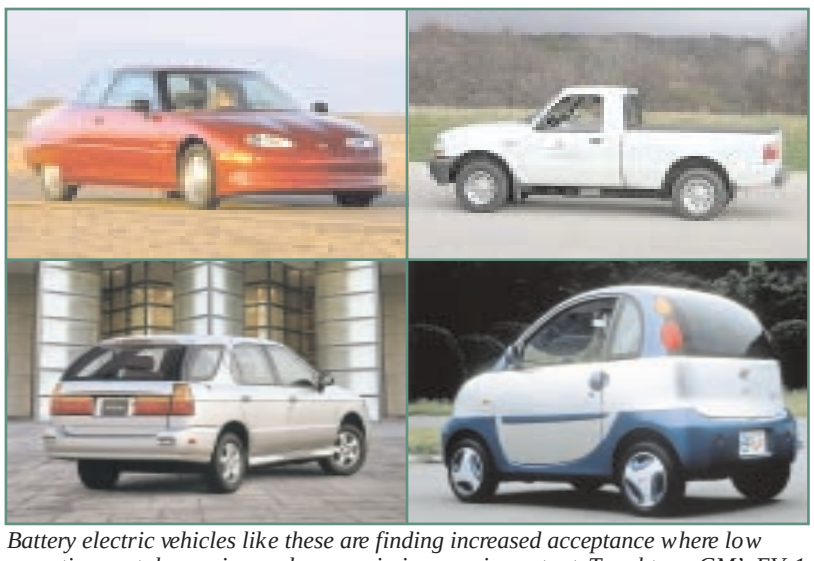
Electric vehicles on the road?… You've got to be kidding! Such is the reaction of most people who envision undersized, limited-range vehicles, with no place to charge them up. Despite that reputation, electric vehicle (EV) technology has progressed steadily, making EVs popular once more. But according to the U.S Department of Energy, owners of electric vehicles are faced with a lack of skilled EV service technicians. Interested in knowing more about EVS?… Read on.

Applications

Electric motorcars are hardly new: they were introduced in 1834. Electric "motor fuel" pre-dates gasoline and diesel, and offers strong benefits over fossil fuels and the internal combustion engine (ICE). Experts quickly agree however that battery EVs will not replace ICE vehicles. Environmental and technical drawbacks aside, the gasoline powered vehicle is our jack-of-all-trades, plus, quick fill ups and extended range are too *convenient* to give up. Conversely, we now recognize the value of using "niche" vehicles to efficiently fill *specific* needs. Obvious EV examples include well-known golf carts, shopping carts, forklifts and donkeys, aircraft tugs, parking meter-patrol vehicles and such, but also innovative battery EV applications like electric bicycles and scooters, and lawn and garden tractors. Also, watch for neighborhood (NEVs) and low-speed electric vehicles (LSVs), which make lots of sense for "gated" communities (campuses, resorts, business parks, retirement communities, boat clubs, military bases, zoos, etc.) desiring to reduce traffic, noise and pollution. In some cases, computers are used to track the whereabouts of loaner EVs and do the scheduling.

Battery-powered automobiles, pickups, vans and SUVs have been made available for sale or lease to fleet operators and car rental agencies. The U.S. Postal Service ordered 500 Ford Ranger EV chassis for use as mail delivery vehicles—the largest single procurement of EVs to date. With their ever improving range and faster charging batteries, EVs are becoming popular choices among municipalities for fleets of shuttle busses and vans.

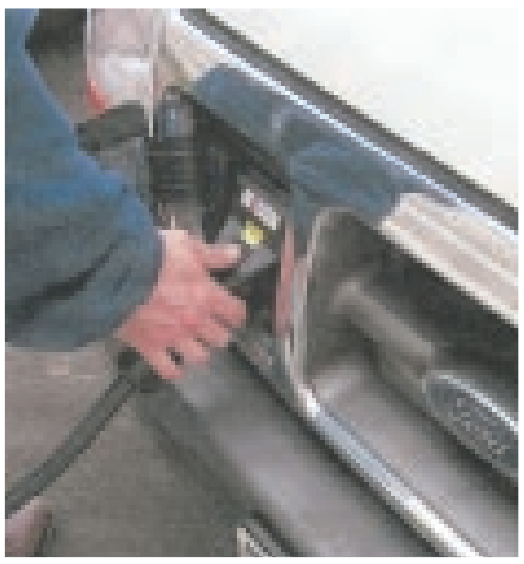
Sale of battery EVs to individuals will no doubt increase once charging stations are more widely available and purchase prices become comparable to ICE vehicles. Battery EVs are not intended for extended or long-range use; the better alternative would be the hybrid electric vehicle (HEV). Hybrids are powered by batteries, plus an ICE or fuel cell. (Hybrid EVs and fuel cells will be covered in future editions of *Tech News*).



Battery electric vehicles like these are finding increased acceptance where low operating cost, low noise, and zero emissions are important. Top, l to r: GM's EV-1 sports coupe and Ford's Ranger EV pickup; bottom: Nissan's Altra SUV/wagon and Toyota's E-Com neighborhood EV (prototype).

Why drive a battery powered EV?

For one, BEVs are clean: The Electric Vehicle Association of Canada reports that, depending on power plant source emissions (from coal, gas, nuclear, etc.), a 55% to 99.9% improvement in CO_2 emissions takes place when driving a battery EV over an ICE vehicle. According to the American Council for an Energy Efficient Economy, GM's EV-1 and Nissan's Altra battery electric vehicles (see above) scored the highest in "green" ratings. The California Air Resources Board mandates that by the year 2003, at least 10% of new car purchases there be *zero-emission vehicles* (ZEVs) such as battery EVs. Densely populated and polluted cities may one day end up banning all vehicles except ZEVs from operating within their beltways. Where charging sites are available, consumers are using battery EVs for commutes to malls and metro stations; some suggest that a battery EV (BEV) is a logical second-car choice for suburban households.



The jury is still out on which of these SAE-approved charging connectors will be accepted by users: inductive "paddle" (l) or conductive connector (r).

BEVs are less expensive to operate and maintain: "Fuel" costs less. Based on seven cents per KW hour compared to 22 mpg @ $1.25 per gal. for gasoline, the DOE calculates a battery powered EV will travel 43 miles for a dollar; a gasoline vehicle will travel 18. At $1.60 per gallon of gas, you'll go under 14 miles/dollar, or only one third the distance of a battery EV.

Unlike the hybrid EV with *two* drive systems or the ICE vehicle, battery EVs have far fewer parts to wear out, and they're less complicated—once you've had the training. Maintenance costs are slashed driving a battery EV (not counting "advanced battery" replacement costs).

And let's not forget that EVs are fun to drive. Acceleration is quick to the point that top speed must be regulated. A survey by the California's Mobile Source Air Pollution Reduction Review Committee (MSRC) found that 80% of those surveyed are more satisfied with their EV than with their current gasoline-powered vehicle, and that 70% of owners and leaseholders use their EV as their primary vehicle.

The Real World

If EVs are so great, why aren't battery electric vehicles more widely used? The act of "plugging in" to recharge is more than most want to deal with. But the most obvious reason is that motorists won't tolerate the typical limited range of 50–150 miles; anything less than 200–250 miles per "fill-up" is not acceptable to motorists. Also, the relatively long charging time required for sustained use is a handicap. Most battery EV manufacturers advertise a full-charge time of 6-8 hours or more. In short, nothing now beats gasoline as a fast-fill, high energy-density fuel. The challenge is to store enough kilowatts for practical range, with a quick-charge.

Also, the bulk and weight of on-board traction batteries work in opposition to extended EV range, yet advanced battery research has yielded promising results (see Nuts and Bolts). While motor and controller manufacturers are now claiming 90-95% efficiency of components, better computerized management of overall systems is still needed (see below).

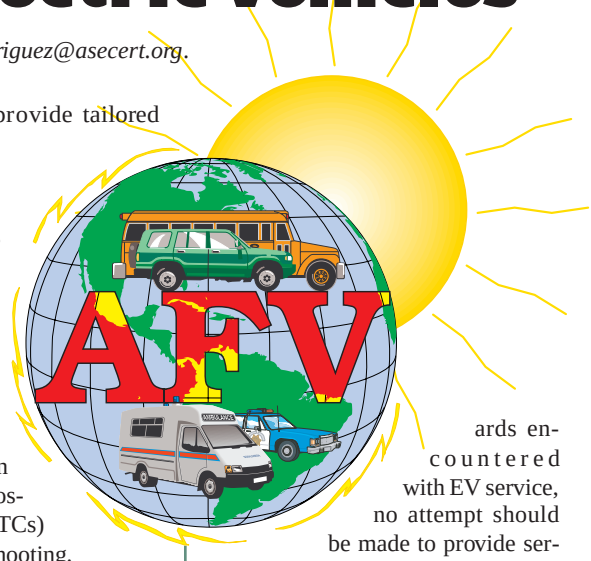
Until then, what may convince commuters to "think green" and make the switch to EVs will be vehicles which meet their needs, conveniently located charging stations, off-peak electric utility rates and lucrative tax incentives to offset vehicle cost.

Batteries and Technology

The mainstay wet cell 12 volt lead-acid (PbA) battery has progressed over the years, but is being replaced by advanced design batteries. Even so, one company claims that battery efficiency still peaks at around 65%, typically much less, severely limiting BEV range. With modern "load control technology" applied to controller design, factors like weather, traffic conditions and driving style are monitored along with individual cell state-of-charge, temperature, and electrical load to provide tailored charging.

EV service

In many ways, EVs are like cars and trucks you already service. Just as with today's ICE vehicles, the malfunction indicator lamp (MIL) provides the technician with specific diagnostic trouble codes (DTCs) to facilitate troubleshooting. As always, safety precautions published by manufacturers must be adhered to. This doubly applies when working on high voltage wiring or components like batteries, motor, controller, etc., or when jacking or lifting the vehicle. Insulated rubber gloves are required for servicing high voltage systems, which are recognized by orange-colored insulation or convolute wire wrap (in general, anything over 50 volts is considered dangerous). Because of the "potential" hazards encountered with EV service, no attempt should be made to provide service without having received specialized training.



Summary

Battery electric vehicles are not suited for every driving purpose, but they are very efficient and emission free. We're sure to see more neighborhood commuter EVs and low speed EVs as the charging infrastructure develops and as gasoline prices continue to soar. Are you ready and willing to provide the service needed?

Nuts and Bolts – BEVs

Auto shop instructors often teach EV basics to students by having them convert VWs, pickups and kit cars into EVs. Wet-cell, lead-acid batteries and a DC motor are commonly used, with designs not unlike those familiar to us who tinkered with model electric trains or remote controlled cars. But things are different today.

Today's EVs are masterpieces of sophisticated engineering. A new generation of lead-acid (non-flooded) 8- and 12-volt batteries are used for improved range and cold weather performance. Some OEs use "advanced" batteries like 6-volt nickel-cadmium (NiCad), the 12-volt nickel metal hydride (NiMH), or the 3.6 volt lithium-ion (Li-Ion) batteries in their EVs. Other types include the lithium sulfide or the space-saving/conformable lithium polymer type battery. Such advanced batteries don't come without a penalty, as they may require liquid cooling or forced air cooling and heating, along with sophisticated computer-controlled load and charging algorithms.

Traction batteries are wired in series to produce anywhere from 150 to over 500 volts DC; they are not grounded to the EV chassis. Individual cells form batteries, and batteries are assembled into packs or modules which are stored in one or more battery trays/tubs under the vehicle. A battery tray typically weighs 1000 to 1400 pounds or more, thus R&R requires a special lift table to be used under the vehicle. The added weight of batteries affects payload, handling and ride height, so low-resistance tires and a stiffer suspension are used.

Normal (level two) charging typically requires 240 volt 40–60 amp service depending on the vehicle, and is delivered from wall or post-mounted chargers. At least one OE supplies a 110 volt (level one) charger with its vehicle for emergencies, and one supplier offers (level three) 440 volt equipment for a 50–85% capacity charge in 10 minutes for quick vehicle turnaround. Another company lays claim to a new charging algorithm for decreasing charging time to less than one-half of present requirements. An on-board "fuel gauge" tells the driver the traction battery voltage/percent of charge or distance to empty. Despite improvements in range (sometimes to over 200 miles), studies show that most EV drivers tend to recharge sooner than required for fear of running low.

Charging also occurs during coasting and (regenerative) braking; drag of the motor-turned-generator slows the vehicle and helps extend vehicle range by as much as 15%–20%. A DC – DC converter supplies charging current for the 12-volt auxiliary system and battery used for non-traction related functions like lighting and entertainment. Since there's no engine vacuum or belt drives, EVs use electricity for power steering, power brakes and a resistive or heat pump HVAC system.

Assuming that charging stations are conveniently located for EV "refueling," charging port *design* still varies. Presently, directly connected "conductive", and indirect, magnetically-coupled "inductive" charging systems are recommended by the SAE and are used; both are safe in all weather. The market must decide which charging port standard will prevail (just as with the 8-track/compact-cassette debate of the '70s). In both designs, the external charger and the vehicle communicate via an RF or IR communications link to determine battery charging parameters, to perform fault detection, and to control charger activation and deactivation and other functions.

AC motors require a DC to AC traction inverter module; improved efficiency DC motors are also used for traction. The motor is typically coupled directly to a single speed transaxle; final drive ratios are lower than for ICE vehicles. Reverse "gear" is actuated by either reversing DC motor polarity or the phase sequence of the 3-phase AC motor. Batteries may pack over 500VDC, while the traction motor pulls anywhere from 50 to over 400 amps from the batteries to deliver 60–150 horsepower.

The controller is the brain of the vehicle, providing management of all vehicle functions. It not only contains power contacts and connectors for the traction motor, but manages charging, regenerative braking, auxiliary systems functions and on-board diagnostics. Improved controller design is one of the keys for unlocking extended EV driving range; watch for improved designs which continue to be made available.