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The Shocking Truth about Electric Vehicles

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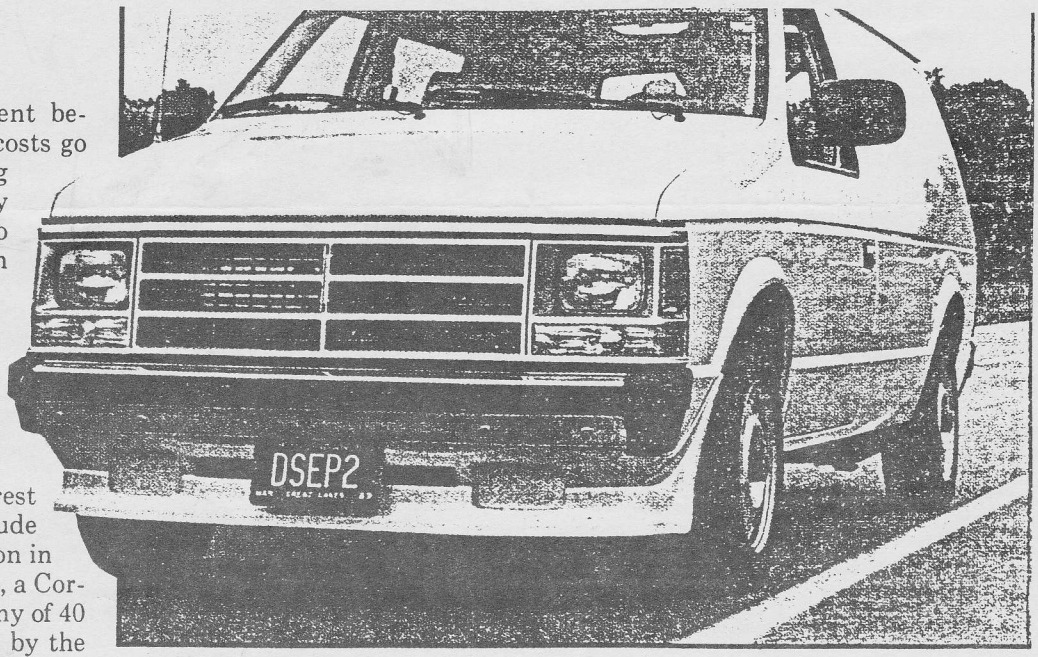
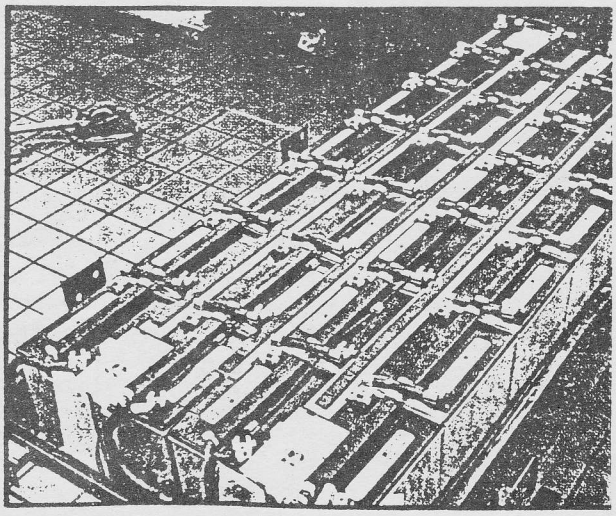
Staff Editor



Every time the environment becomes a hot topic, or fuel costs go up, engineers start thinking about electric vehicles. They are clean, efficient, and do not necessarily depend on imported fossil fuels. However, they also face hurdles such as a relatively short range that prevents their widespread acceptance. But ways are being found around these obstacles.

New events charging interest in electric vehicles (EVs) include efforts to reduce air pollution in congested urban areas. Also, a Corporate Average Fuel Economy of 40 to 50 mpg may be required by the year 2000. The Department of Energy has already indicated it would credit an electric van, through a complex formula, with a lofty mileage rating, about seven times that of standard gas-powered models.

But there is no need for auto dealers to brace themselves for the rush of EV buyers just yet. Only a few hundred will be produced by next year and they will be available only to utilities and fleet operators for evaluation. These users generally operate their vehicles for a limited mileage each day and return them to a central location at days' end. Hence, for the present, electric conversion in the U.S. has focused on vans rather than cars.



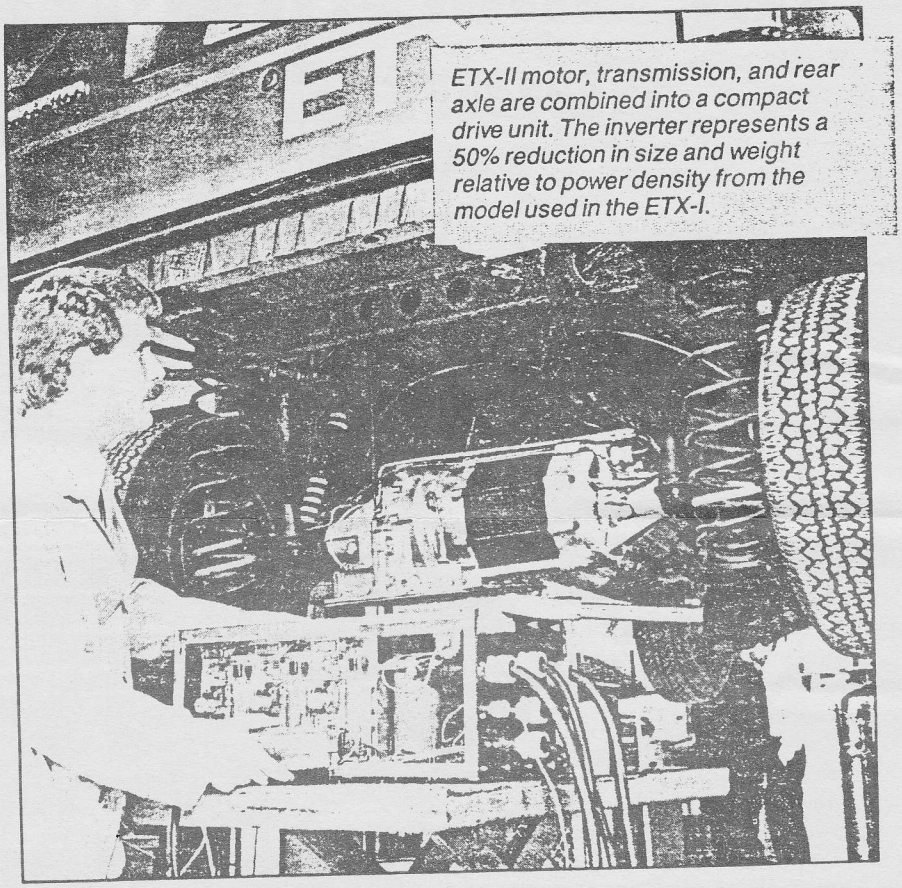
The next wave of EVs is likely to be fleet-operated vans where daily mileage is limited and vehicles return to a central location at night. Eaton's test vehicle, the DSEP, is capable of an 50 to 80-mile range, depending on how driven. It reaches 50 mph in less than 20 s and gets up to 70 mph for short bursts. Its nickel-iron batteries can be recharged in as little as 4 h.

Ford's ETX-II is an Aerostar van powered by a 70-hp ac motor capable of 65 mph, 100 miles between charges, and climbing 30% slopes. Like a diesel-powered vehicle, it accelerates to 50 mph in less than 20 s, and costs about the same to operate. At present, Ford has no plans to take the proof-of-concept van into production.

The electric challenge

The primary challenge for developers is raising EV performance. To this end, the Department of Energy and the Electric Power Research Institute in Palo Alto, CA, are jointly funding several projects. Most goals for EV performance for acceleration, handling, and operating costs, are to match those of similar gasoline-powered vans. Range, however, is not as critical to fleet operators. In fact, studies show that about 90% of all vehicles are driven less than 60 mile/day.

Eaton, Ford, Chrysler, and Vehma International in Canada have each responded to the EV challenge with working prototype vans. Furthermore, Vehma in Richmond Hill, Ont., is going one step further than its counterparts by planning limited production for later this year. Chrysler is waiting to see how the technology is accepted before deciding on production. In any case, each of the four companies is using a different technological mix to meet performance goals.



ETX-II motor, transmission, and rear axle are combined into a compact drive unit. The inverter represents a 50% reduction in size and weight relative to power density from the model used in the ETX-I.

Eaton's DSEP

Eaton Corp. engineers in Southfield, MI, are mounting an ac motor on an axis parallel to a 2-speed mechanical automatic transmission to electrically propel a Chrysler minivan. The arrangement, called dual-shaft electric propulsion, or DSEP, is easily air cooled and eliminates the torque converter common to other automatic transmissions. The motor-transaxle unit can also be mounted for rear drive, and positioned horizontally or vertically for best use of space.

The stretched van's structure

AC VERSUS DC

One significant difference between the latest batch of EVs and their predecessors is that half of the prototypes are powered by ac rather than dc motors. Proponents from both camps suggest good reasons for their drive selection.

Those who selected ac motors say ac is more easily combined with other drive components such as a transmission and axle in one unit, and they require less maintenance. They say a brushed dc motor requires cleaner cooling air which is likely to draw some dirt through the motor and compromise efficiency. Also, ac motors weigh less and are readily available from existing sources. Finally, ac motors have a marginal efficiency advantage.

Controllers also are a factor. A unit for an ac motor is more sophisticated because its current is three phase. Speed is usually controlled by modulating frequency. On a dc motor, controls are chopping types. Voltage is divided into discrete on-off pulses. And while ac control logic is more complex, it is not much more expensive. Overall drive-efficiency, however, is a tossup.

The dc-drive proponents, in this case Chrysler and Vehma, say the dc controls are lighter and simpler with fewer power components, and less expensive. Also, sophisticated designs are now available. But the real winner in the ac-dc duel is more likely about 10 years down the road.

A sire with a pedigree, the Griffon is the conceptual father of a new herd of U.S. born EVs. The van is produced by General Motors in the U.K. and carries a GM warranty. While its 60-mile range seems limited, it works well in fleet duty.

has been modified slightly to maintain standard ground clearance and stiffness, and to carry a 1,600-lb battery pack. To accomplish this, the cargo-area floor is raised 4 in. The modification makes for easier loading and unloading of cargo from the back door because the floor depression is eliminated.

A 64-hp (5,640 rpm at 60 lb-ft) 88-lb motor mated to a two-speed transmission pulls up to 70 mph. Power comes from a bank of twenty-eight 6-V nickel-iron batteries from Eagle-Picher, Joplin, MO. Eaton engineers claim that the DSEP is the best performing EV ever. A test drive of Eaton's EV is described in the box *Behind the wheel of the electric vehicles*.

Ford's electric entry

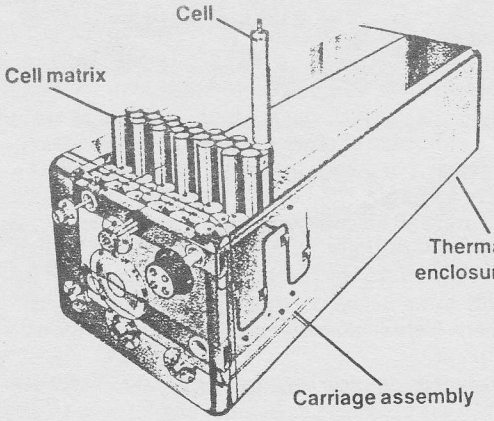
Ford Motor Co. and General Electric have collaborated to electrify a stock Aerostar with one rear-mounted package consisting of an ac motor, 2-speed automatic transmission, and drive axle. Power for the ETX-II (Electric TransaXel — second generation) test vehicle, comes from industrial lead-acid batteries, but these will be replaced with a sodium-sulfur pack later in the year.

The 1,270-lb battery pack rides under the cargo compartment along with a 79-lb inverter that changes dc to ac. No structural changes were made to the vehicle to accommodate the battery pack and

SIZING UP THE NEW BREED OF BATTERIES

Power for the latest crop of electric-charged vehicles comes from technology that was showing promise just a decade ago. A few are near or in production and some may need another decade before finally reaching battery compartments.

Sodium sulphur is a top contender as a widespread vehicle power supply because it stores up to four times the energy in the same weight as a lead acid. Also, it is made of materials that are inexpensive and plentiful. Furthermore, its life may be longer than standard batteries. Chloride Silent Power, a U.K.

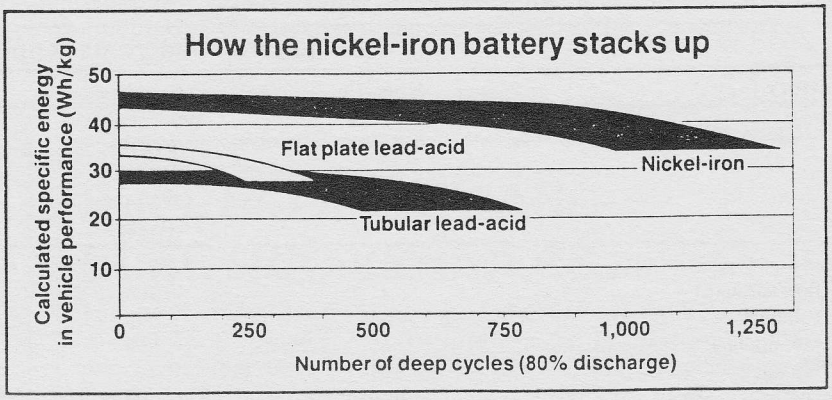


A sodium-sulphur cell holds molten sodium in a ceramic-electrolyte container that conducts sodium ions. Sulphur blocks then surround the ceramic and the unit is encased in an aluminum container. The cell is further protected in a carriage assembly and thermal enclosure.

company, claims to have cells that have operated for six years and survived more than 6,000 charge-discharge cycles.

Because the battery operates between 572 to 626°F, it has an onboard heating system, it is well insulated (warm to the touch), sealed for life, and it is maintenance free. In fact, another battery manufacturer, Powerplex Technologies Inc., Toronto, Canada, claims that winter weather will have little effect on performance because of the insulation. Once both companies begin volume production, about 1993, energy costs are expected to be $200/kWh.

Nickel-iron batteries are within a few months of production, according to engineers at Eagle-Pitcher Inc. The advantages of this design are that its energy density is about 30% more than that of similar voltage lead-acid batteries and it operates at room temperature. Hence, it needs no special heaters or insulation. Also, its voltage curve is almost flat over about 95% of its discharge cycle and the nickel, iron, and electrolyte are recyclable with current technology.



Developers also say the 28-module battery will withstand 1,200 to 1,400 charge cycles to propel a vehicle about 100,000 miles over 8 years. In one prototype, the batteries have endured over 900 cycles and are still in operation. Basic 6-V modules measure about 7 × 10.5 × 10 in. and weigh 54 lb.

The Ni-Fe battery can be trickle charged over 8 h or quick charged in about 3 h. Researchers also suggest this figure might soon drop to 1.5 h. Efficiency estimates are 68 to 85% while charging, and 75 to 85% while discharging.

Lithium alloy-iron sulfide is a high-temperature molten-salt electrolyte

battery (internal temperature about 850°F) that promises 200 miles between charges. For the battery to operate during charge and discharge cycles it must be maintained at a temperature above the melting point of the lithium salt electrolyte. But researchers estimate that the battery can self-sustain its operating temperature for about a week and still propel a vehicle over a limited range. If longer periods of inactivity are anticipated, a simple resistance heater plugged into the electric utility will maintain the battery's operating temperature. During charge and discharge cycles, the chemistry maintains a working temperature of about 850°F. Again, insulation techniques will produce little operating difference from summer to winter.

One advantage of this design is that the battery is easily shaped to fit available space. While prototype cells show promise, the cycle life needs improvement to be acceptable for the electric vehicle user. However, researchers at Westinghouse Naval Systems, Chardon, OH, say that recent changes to the electrode formulations are expected to boost cycle life.

Zinc air holds promise as a near-term battery capable of powering an EV for 150 to 200 miles, according to researchers at Dreisbach ElectroMotive Inc., (DEMI), Santa Barbara, CA. While the battery pack for this task may only weigh 1,000 lb, its life will be admittedly short before replacement is necessary, about 6 months to 1 year. While researchers work to lengthen that period, the chemistry offers other benefits. For example, the battery needs no liquid electrolyte, operates at room temperature, and all components are recyclable.

Lithium air is predicted to be the ultimate EV battery, with better than three times the energy density of gasoline. Researchers at DEMI predict EV ranges stretching to an amazing 400 miles in city driving and 1,000 miles on the highway. Later this year, a Southern California Edison Li-air-powered EV will begin road testing to prove the concept.

However, the chemistry here is more complex because lithium-air batteries are not recharged. Instead, electricity is produced as lithium combines with air to produce lithium carbonate. To refuel a Li-air battery, the lithium carbonate, formed in a removable pack, will be replaced with fresh lithium in about a 5-min operation. Later, in a complex operation, lithium will be electrically separated from the compound for reuse. In this way, lithium is not consumed, but recycled.

Advanced lead-acid batteries will be sealed, need no maintenance, and produce no gas by-products when charging. Also, they may cost less than more sophisticated designs to develop, and can be put into production sooner.

Ensci Inc., Woodland Hills, CA, is working on two advanced lead-acid designs, a monopolar or advanced conventional battery and a bipolar design. Both systems improve on the energy density of standard lead-acid designs. In addition, the bipolar battery eliminates standard battery items such as grids or inner-cell connects that hold the active material and transfer current between cells. Researchers claim that energy density in bipolar battery is equivalent to that of nickel-iron designs.

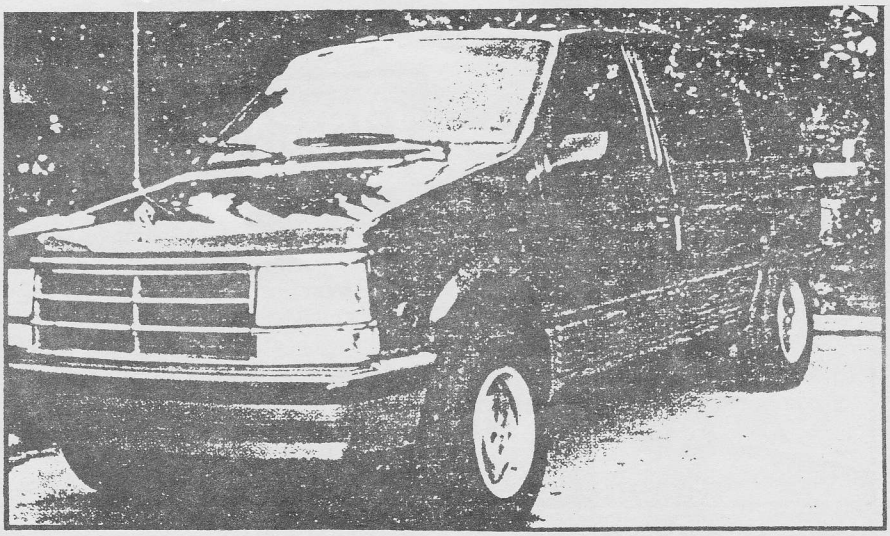
Vehma International is overseeing the production of the G (Griffon) Van for sale to U.S. utilities. Drivers report that this EV rides quieter and smoother than its petrol-powered twin. A 60-hp dc motor accelerates the van from 0 to 30 mph in 12 s and it can hit 55 mph for 5 min. Range with lead-acid batteries is 60 miles but will extend with improved models. Operating costs are about $0.045/mile, half that for a standard van.

inverter. Consequently, the EV's 550-lb payload is one-half that of a gas-powered van.

The ETX-II sports innovations such as electric power steering and a drive-by-wire control system. That substitutes an electric signal for mechanical-control linkages. For the EV to perform like a gasoline-powered van, the control computer triggers the electric motor to duplicate the torque charac-

How the new batterys stack up

Battery type	Specific energy (Wh/kg)	Specific peak power at 80% depth of discharge (W/kg)	Projected operating cost (1986 $/kWh)	Cycle life (Cycles to 80% depth of discharge)
Lead acid types				
(flow through)	47	105	72	181 +
(tubular)	36	80	—	800 to 1,000
(monopolar)	35	200	63	600
(bipolar)	57	—	—	1,200 (estimated)
Nickel-iron	49	103	125	2,000
Nickel-cadium	44	110	72	700
Zinc-bromide	55	88	75	50 +
Lithium aluminum-iron sulfide	83	100	91	350 to 1,000
Sodium-sulfur	136	180	91	810 +
Iron-air	70	83	91	48 +
Zinc-air	200 to 300	—	—	6 to 12 mos
Lithium air	800 to 1,200	—	—	Does not recharge
Gas-engine power train	400 to 500	—	—	—



Development engineers at Chrysler want the TE (T-115, Electric) Van to be identical to a gasoline-powered van in operation and performance. To accomplish this, a 70-shaft-hp dc motor is front mounted to a 2-speed automatic transmission. An 1,800-lb battery pack provides a 120-mi range in an SAE simulated urban driving cycle.

teristics of an internal combustion engine.

The motor transmission is integrated into the rear axle to avoid the cost of constant-velocity joints on front-drive units and to conserve weight. The 70-hp interior permanent-magnet motor (81 lb-ft in the constant-torque region) is a significant development for its size and boasts a 96% efficiency.

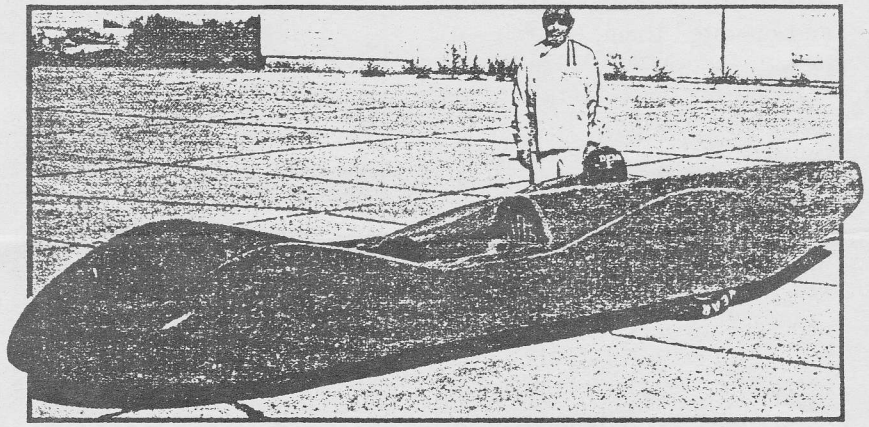
From the driver's seat, dash-mounted controls are similar to the gas-powered model. The van is started by turning a key to "on" and then "start." A Ford spokesman says that one project goal is to minimize any discernible differences between the electric van and its conventional counterpart, other than the electric van's quieter and smoother riding.

The G-Van

Working EVs have been on U.S. roads for the last few years. One make, Griffon, a lead-acid battery-powered van, was built in the U.K.

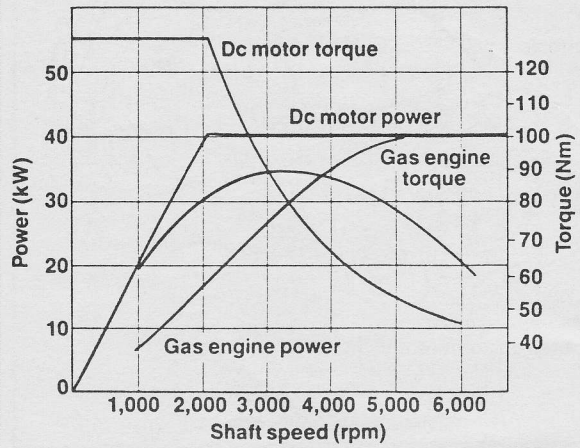
BUT THEY ARE NOT VERY FAST

Not necessarily. To show the capability of an EV, Santa Barbara-based DEMI built the X-1, an electric drag racer. This red bullet reaches 100 mph in 17 s and is capable of about 210 mph.



Powered by 4 to 12 24-V NiCd jet-engine-starter batteries and one to four 80-hp dc motors, the X-1 has set world records for electric vehicle acceleration in ¼-mile, ½-km, and 1-km two-way courses. Admittedly, at full blast, its endurance is limited to 2 min. But it is streamlined enough so that at 60 mph it requires only 3 kW, and has a range of 150 mile at slower speeds.

Comparing dc to ic motors

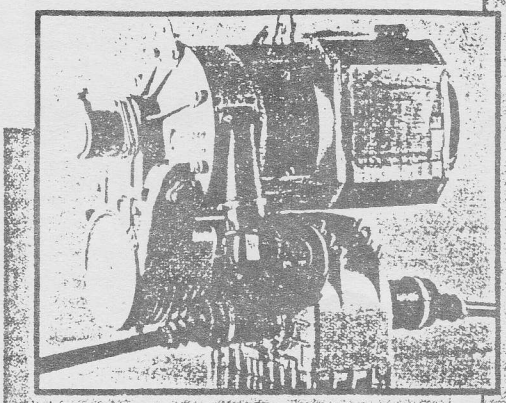


FUEL ECONOMY AND ELECTRIC VEHICLES

For 1990, the Department of Transportation has raised the Corporate Average Fuel Economy, or CAFE to 27.5 mpg. In other words, the average mile/gal figure for each motor, transmission, and model combination offered by an automobile manufacturer must be 27.5 mpg to avoid fines.

Electric vehicles complicate CAFE a bit because they do not directly consume fossil fuels, the resources CAFE is meant to help preserve. Through a complicated formula that includes factors such as electricity produced from petroleum sources and vehicle efficiency, electric vehicles are included in the average by crediting them with about 200 mpg for an automobile and 150 mpg for a van.

Different organizations suggest that CAFE requirements for the year 2000 will be 40 mpg. If 10% of 14-million new cars sold that year are electrics, then a CAFE of 40 mpg is possible with 1989 technology.



BMW combines motor and 2-speed manual transmission into one unit. The first gear is for starting up or climbing hills. Second gear is for cruising.

and distributed here for evaluation. Eleven utilities bought 31 Griffons and operated them, to their satisfaction, for over 300,000 miles.

Based on the Griffon's success, Vehma International is converting General Motors full-sized vans to electric drive. Twenty-five G (Griffon) Van prototypes are in production, and 500 are scheduled for completion by January 1990. Most of these EVs will be sold to utility companies for further studies and to encourage public acceptance. Unit costs have not been set.

Power for the Vehma van comes from a 60-hp rear-mounted dc motor coupled to a fixed ratio drive. This arrangement, Vehma engineers say, is the simplest and best developed for current use. Initially, lead-acid batteries provide a 60-mile range. However, that will improve when the sodium-sulphur battery is available in a few years. Drivers report that it rides quieter and smoother than gas-powered versions.

TEVan

Chrysler's overall goal with its TEVan (T-115, Electric) project is to produce an electric-powered vehicle that performs much like a conventional van with a 2.5-l engine. But unlike the conventional version, the electric model will be nearly maintenance free.

Drivers will notice some differences, such as the state-of-charge gage that replaces the gas gage. New dashboard information in-

BEHIND THE WHEEL OF THE ELECTRIC VEHICLES

Several companies have made their vehicles available for test drives. Reports on the BMW and Eaton vehicles revealed positive driver responses.

Bavarian Motor Works is testing a fleet of eight electric 325iX sedans. This model, usually a 4-wheel drive, was chosen for its front-drive feature. Bill Siuru, a contributor to MACHINE DESIGN, visited the Bavarian automaker and provided these details.

To house the battery and allow adequate passenger and luggage room, BMW removed the driveshaft and differential from the 325iX. Power for the test car came from an advanced-technology 360-cell sodium-sulphur battery. It produces 170 to 200 V at idle, and measures about 56 × 19 × 14 in.

The car has clutch, brake, and accelerator pedals like other autos but the clutch is used only to put the car in gear. After that, only the throttle and brake are required.

The two-speed transmission has a high-ratio first gear for hill climbing and a low-ratio second gear for moderately hilly and flat terrain. The dc motor's characteristic high torque, even at standstill, allows acceleration from 0 to maximum of 62 mph without shifting.

Zero to 31 mph takes a leisurely 9 s; and the range in city driving is about 93 miles. But to anyone who has driven a normal BMW, running out of "oomph" at 60 mph is an odd feeling. Despite this, BMW has done a good job simulating the throttle response of an internal combustion engine. Performance in city driving is quite adequate, especially considering the motor is rated at only 22.7 hp. The car does not have the golf-cart feel found in previous EVs.

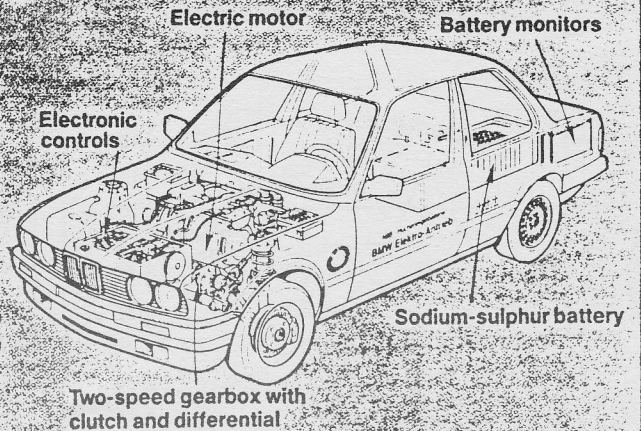
Eaton's DESP looks like a conventional van on the outside. But once in the driver's seat, the volt, amp, and state-of-charge meters suggest a departure from familiar.

Eaton engineers want new electric-van drivers to be able to operate the vehicle the same way as a gas-powered model. With the ignition key in the Run position, the dashboard meters come alive and a battery-cooling fan hums quietly under foot. Turning the key one notch more to Start enables the selector lever and power train.

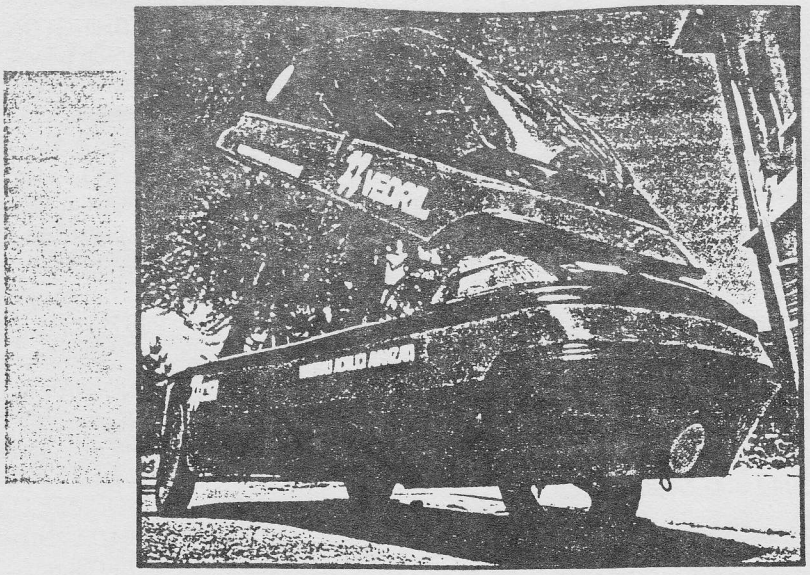
While equivalent performance to a gas-powered van is a goal, the DESP may be a notch better. Putting the selector lever into drive, the van creeps forward, just like a standard one. Push on the "gas" petal, and the van accelerates quite nicely. Motor whine is noticeable, but it fades as road noise increases.

During a quick spin around the block, handling and ride quality showed improvement over standard models because the EVs heavy battery lowers the center of gravity and damps bumps. On a Detroit freeway with two others aboard, the EV easily kept pace with the 55-mph-plus rush-hour traffic.

Power brakes brought the vehicle to quick and sure stops. The EV brakes even have an edge over conventional brakes. When the brake pedal is touched, the ac traction motor is brought on line as a generator to return some electrical energy, about 10% of the lost kinetic, to the battery.



The electric BMW carries 584 lb of batteries to juice a 22.7-hp front-mounted motor. A dc motor was chosen because the controls are simpler. Battery life is estimated at 1,000 electrical cycles, 10 years, or about 100,000 miles.



Mini-el makes extensive use of plastic for structural strength. Power for the 628-lb auto, built by El-Trans A/S in Denmark, (Montedison USA, New York, NY) comes from three 12V lead-acid batteries. Top speed is about 25 mph and range is 45 miles.

cludes a temperature reading for the controls, battery, and motor. A range predictor gives the driver a reading of how far he can go based on the previous 6 or 7 miles. The most noticeable indication that the driver is not in a gas-powered van is that ride quality is better and there is no motor noise.

Chrysler is also opting for a dc rather than an ac drive. It claims the dc is simpler and requires less development cost.

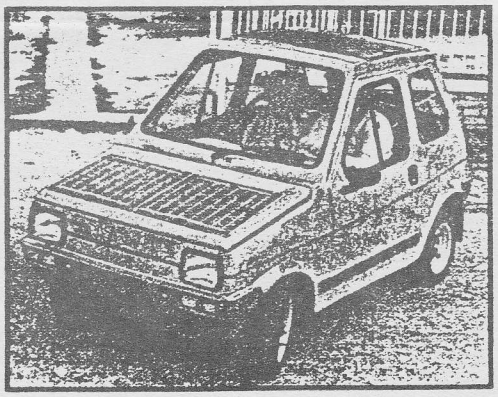
The only driver maintenance required will be to fill the battery-water reservoir level once every 2 to 3 weeks, and to connect the charger when necessary. But even the latter item can be eliminated. A coil on the garage floor can inductively recharge the batteries without a physical connection. All the driver has to do is park over the coil. A fully automatic charger then "refills" the batteries at the most efficient rate and turns off when the job is done.

Where are the E-cars?

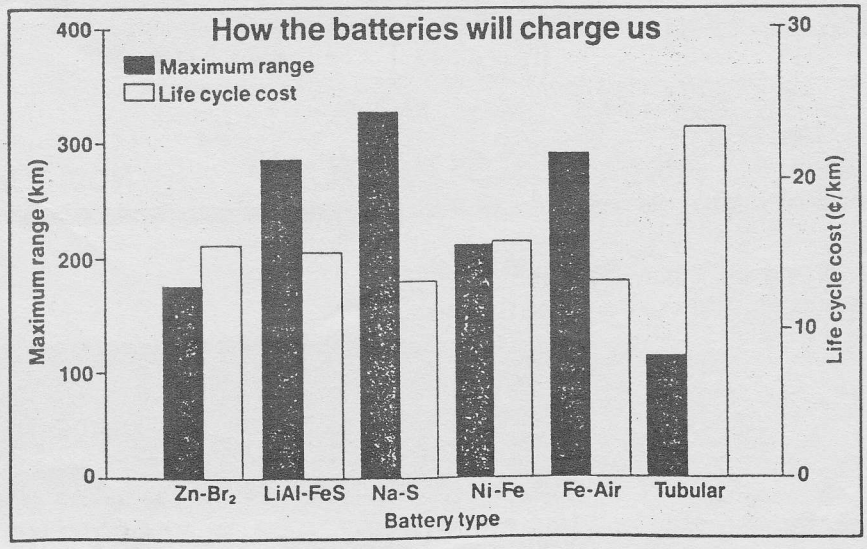
Development of electric cars has been more fragmented than that of vans. With funding from the U.S. Energy Department, Ford built an electric two-seater, the ETX-II, capable of 60-mph top speed and 0 to 50 mph in less than 20 s. Although the project ended in 1985, it demonstrated the possibility of a low-cost, lightweight power train.

In Europe, where gasoline can approach $4/gal, smaller electric cars have been receiving attention more recently. In Denmark, the Mini-el features a plastic body and tricycle design to keep weight below 700 lb. The Italian Micro-Vett has a tubular-steel frame and a fiberglass body. A 4.7-kW dc motor drives its rear wheels through a 2-speed automatic transmission. Four solar panels each provide 18.5 W to a 48-V battery for extended range and charging away from home.

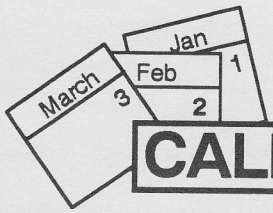
The Hoskyns Duo, a proof-of-concept car, is a two-seat auto made in England. It uses a minicar chassis with roll bar and a fiberglass body. Top speed is limited to about 40 mph with a range of 55 miles. Finally, in Germany, BMW is experimenting with an electrified 325iX sedan. A firsthand driving report on how this one handles is in the box *Behind the wheel of the electric vehicles*. ■



Micro-Vett is a "2-place" electric minicar with a top speed of about 30 mph. A 2-speed transmission drives the rear wheels with a 4.7-kW dc motor. The solar modules are from Solarex Corp., Rockville, MD. MicroVett S.r.l. (Italy) plans mass production and worldwide distribution for later this year.



Source: Marr et al., Analysis of Life Cycle Cost for Electric Vans with Advanced Battery Systems, SAE Technical Paper 890819



CALENDAR

Nov. 6 Symposium for Solar Car Builders in Boston at Wentworth Institute. Contact James Worden

Western Electric Show and Convention - Wescon '89 (Los Angeles, San Francisco Bay Area Concils); Nov. 14-16; Moscone Center, Brooks Hall, Civic Auditorium, San Francisco; Electronic Conventions Management, 8110 Airport Blvd. Los Angeles, Ca. 90045; 213-772-2965 or 800-421-6816

Conference on Magnetism and Magnetic Materials (MAG); Nov. 28-Dec. 1; Sheraton Boston Hotel, Boston; Courtesy Associates Inc., 655 15th St., N.W., Suite 300, Washington, D.C. 20005; 202-639-5088

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