F.V.E.A.A. NEWSLETTER

AUGUST 1986

MEETING NOTICE

The next meeting will be friday AUGUST 20th, at *CRAGIN FEDERAL SAVINGS & LOAN* 333 W. Wesley St. Wheaton, Illinois. - Time - 7:30 P.M. *sharp*. Guests are welcome and need not be members to attend the meeting.

THE PRES SAYS

EXXON MONEY "No money for electric car work" according to my unofficial information. When the allocation is released, I will contact the Governor and inquire the reasons for his dicision. It was still worth the try.

RAFFLE CAR The raffle car becomes more important in our plans with the denial of Exxon money. According to Paul Harris' report at the last meeting, if we can wait another few weeks, we can avoid the $75 inspection fee. The members voted to increase the allocation of our funds for this project from $250 to $800 to buy batteries and get the car running. Members also thought it would be a good idea to get a few miles on the car before proceeding with the cooperative raffle.

SANTA FE HAMFEST Faithful member Dana Mock was at the Santa Fe Hamfest on Aug. 10th to sell some of the material in his garage. Vladimir Vana & Jack Cahill volunteered to help him sort out the stuff and were also at the event. We would have liked to have some of our cars at the meeting but it seems like many are having battery problems. We should discuss this.

NEXT MEETING We will continue the discussion started at the July meeting on just what are the positive attributes of an electric car with the performance characteristics developed thus far. This discussion can have an important influence on our future activities. I hope we will have a good attendance on August 15.

F.V.E.A.A.

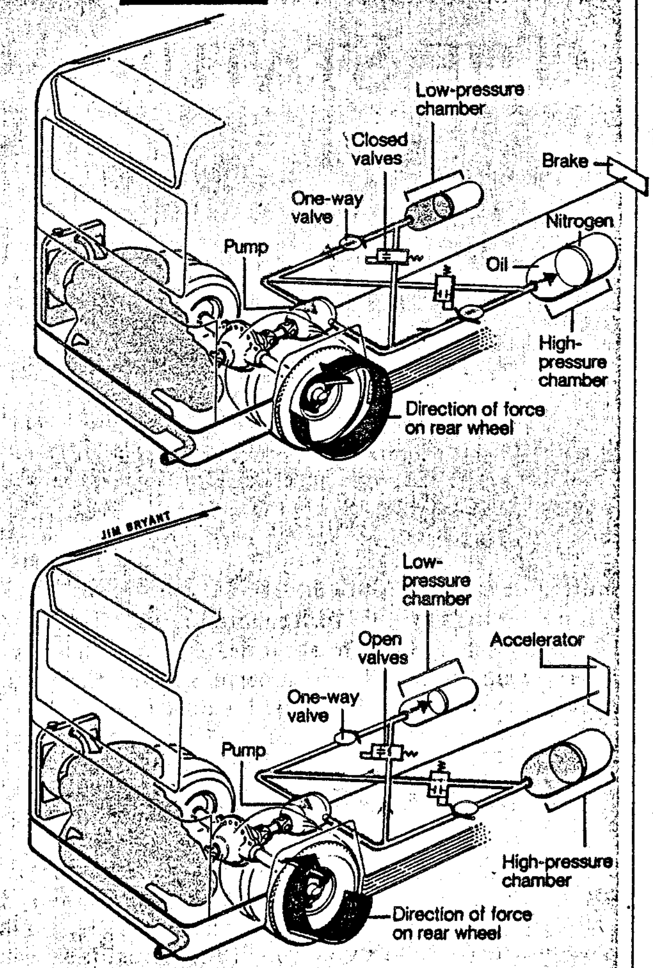
FOX VALLEY ELECTRIC
AUTO ASSOCIATION
624 PERSHING ST. WHEATON, ILL. 60187

FIRST CLAS

ADDRESS CORRECTION
REQUESTED

BRAKING

1. Brake is applied, closing two valves.
2. The pump, driven by the rear axle, injects oil into the high-pressure chamber.
3. Oil fills the chamber, compressing nitrogen. The pressure in the chamber causes the oil flowing through the pump to resist the pump's rotation, exerting drag on the rear axle and slowing the bus.



ACCELERATING

1. When the accelerator is applied, the two valves open, allowing pressurized oil to flow back through the pump toward the low-pressure chamber.
2. As the oil passes through the pump, it turns the rear axle, moving the bus forward.

USING YOUR BRAKES CAN HELP YOU GET GOING

The stop-and-go progress of a city bus does more than send standees reeling. It wastes fuel, fouls the air, and, of course, wears down the brakes. "Getting the bus up to speed takes a large amount of energy," says mechanical engineer Tony Davies, "and when you put the brakes on, you throw it away."

The reason: brakes are deliberate energy-wasting devices. They convert the kinetic energy of a moving vehicle into heat, friction, and, sometimes, screeching sound, thereby slowing it down. The loss is greatest on a vehicle like a bus, which is heavy and stops often.

But Davies and his colleagues at the Canadian National Research Council in Ottawa say they've found a way to reduce that loss. They've designed a system that stores energy when the driver steps on the brake pedal, and then uses it to get the bus moving again when he steps on the accelerator.

The system works like this: pressing on the brake pedal causes a hydraulic pump geared to the rear axle to begin pumping oil from a low-pressure chamber into a high-pressure chamber, thereby putting a drag on the axle and slowing the bus. The oil is stored at pressures of up to 5,000 pounds per square inch until the accelerator is depressed. Then the oil squirts back through the pump, causing it to act like a motor and turn the rear axle. This hydraulic assist gets the bus going about 15 m.p.h.

The bus Davies is testing is designed to use 30 per cent less fuel than a standard vehicle, produce 35 per cent fewer emissions, and suffer 80 per cent less brake wear. The system would add some $14,000 to the $112,000 (in U.S. dollars) cost of a Canadian city bus, he says, but it would save as much as five per cent in operating costs each year.

Happily, it would also cut another sort of pollution. Says Davies, "You hear much less noise."

FVEAA CLUB ITEMS FOR SALE

BATTERIES

2 6 volt 7" x 12" wet $5.00 ea.
1 6 volt 7" x 12" dry $10.00 (new)
1 6 volt 7" x 16" wet $5.00

OTHER STUFF

Solid brass battery connectors #00 & 000 pos. or neg.	$ .75 ea.
Steel laminated choke core for shunt motors.	$5.00 ea
Black heat shrink tubing 3/4" shrinks to approx. 1/2"	$ .50 foot
200 Amp relay 24-28 volt coil Only 2 left.	$15.00 ea.
400 Amp relay 12 volt coil Limited supply.	$45.00 ea. 2

Above items may be purchased at the meetings or place your order with me to ship U.P.S. JOHN EMDE 968-2692

PUTTING PERFORMANCE IN YOUR ELECTRIC CAR-PART IV

The June meeting discussion defined the project battery to be a 72-volt, single-string, series-connected arrangement using twelve 6-volt golf-cart type batteries. In this paper, we will calculate the range expected from this battery system.

A golf-cart battery is given an industry designation of type GC-2; 10.4" long, 7.2" wide, and 11" high. Each unit weighs 57-67 pounds and is designed to deliver a constant 75 amps for 75-130 minutes.

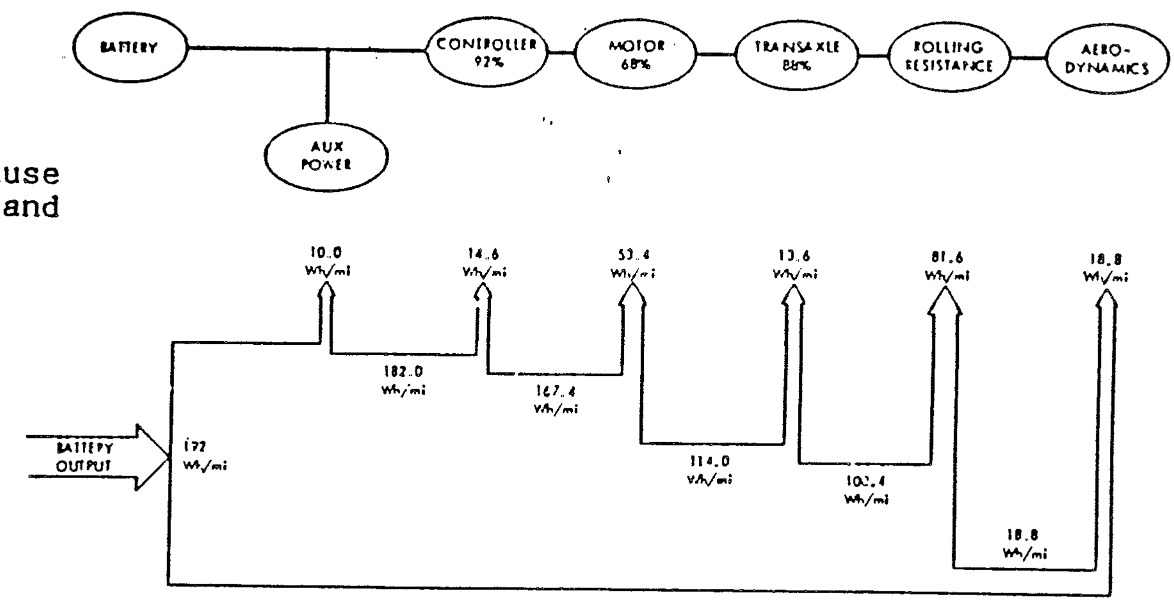
Golf-cart batteries power an off-the-road, specialized vehicle through one round of golf on one charge. Carts are usually managed by club pro shop personnel having little battery knowledge. As long as a cart will make one round and can be profitably rented, there is little incentive for the operator to perform more than minimal maintenance. When the cart won't make one round, the batteries are replaced. Golf-cart batteries must be rugged. This is a plus when they are used for an electric car.

Over 1.6 million golf-cart batteries were manufactured in 1985 (SLI production was over 72 -million units). The availability and reasonable cost of golf-cart batteries is a plus when they are used for an electric car application. The disadvantages are the size, weight, and 6-volt configuration of these units.

Each GC-2 unit can store and deliver about 1.2 kilowatt-hour (kwH) of electrical energy at 75 amps. Twelve units store about 14.5 kwH. This energy is used in several ways. Probably the best data on electric car energy use is provided by ETV-1 test data. Although this car had a 3350 lb. curb weight, the design features it included should make its test data applicable to our 2500 lb conversion car which is not optimized for electric drive.

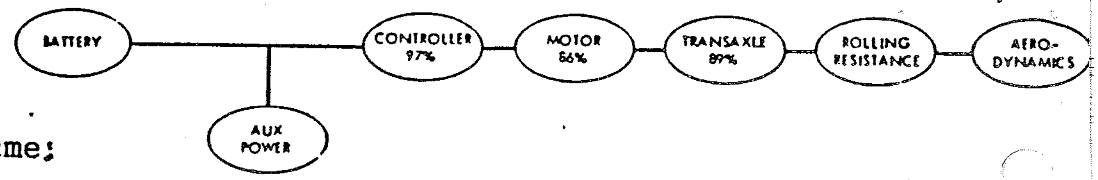
At a steady 25 mph, the ETV-1 required 192 watt-hours/mile of energy, which was distributed as the following diagram illustrates:

Range-not tested because of motor and controller overheating.

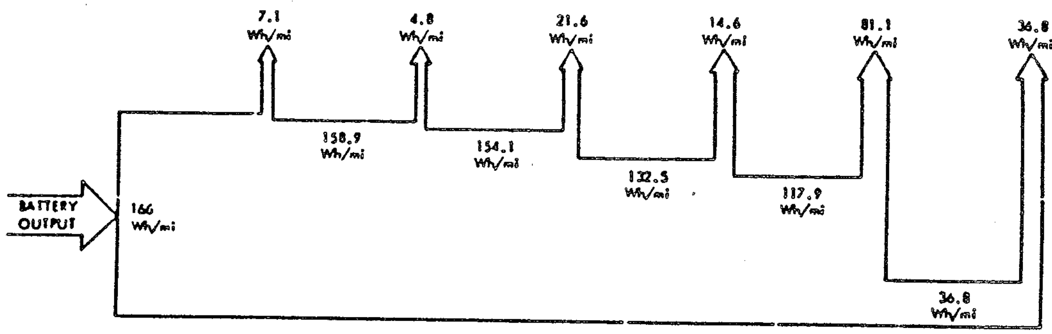


ETV-1 Energy Flow Distribution at a Steady 25 mph Speed

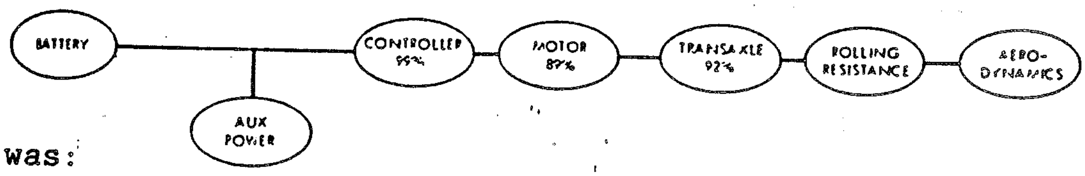
At 35 mph, it became:



Range-100 miles

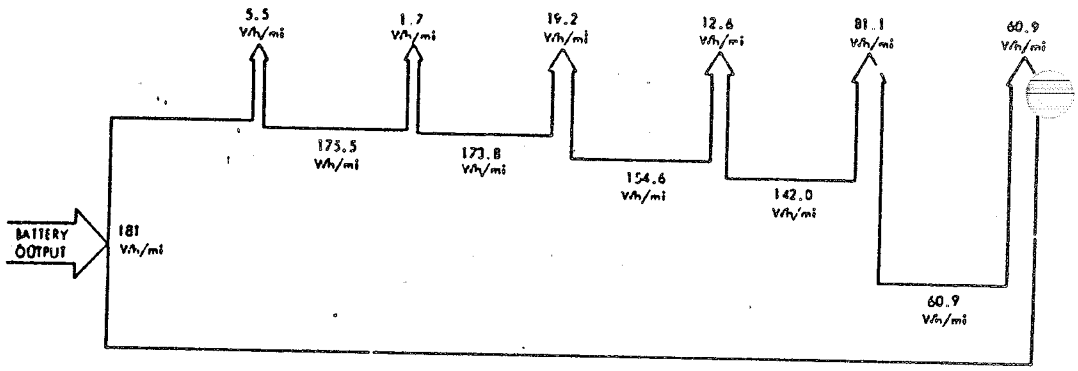


ETV-1 Energy Flow Distribution at a Steady 35 mph Speed

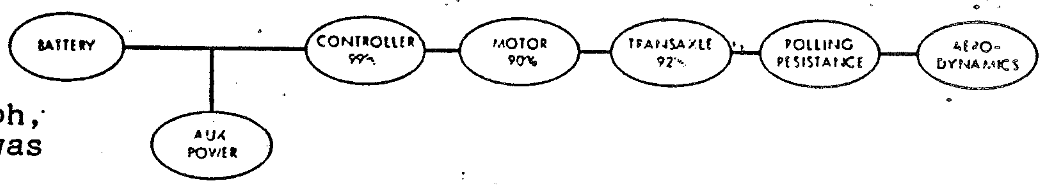


And at 45 mph, it was:

Range-75 miles

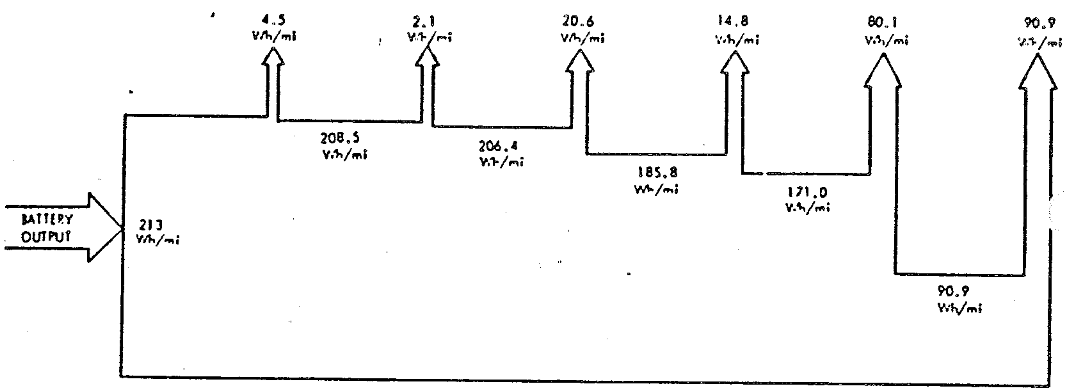


ETV-1 Energy Flow Distribution at a Steady 45 mph Speed



Finally, at 55 mph, the battery output was distributed as shown:

Range-55 miles



ETV-1 Energy Flow Distribution at a Steady 55 mph Speed

Constant-speed driving is fine for test purposes, but it is hardly the way a car is used. For this, the SAE J.227a"D" test driving cycle contained in Part III is used. For this condition, the ETV-1 battery output was 190 Wh/mile and the range dropped from 50 miles @ 55 mph to 42 on the "D" cycle.

Because of the many dynamic variables involved in the "D" cycle, the expected range of our converted car cannot be easily calculated. Based on the ratio of 12 batteries for our project to 18 in the ETV-1, and a ETV-1 "D": cycle tested range of 42 miles, our project car should have a 25-30 mile range to an 80% discharge depth for new batteries. Building and testing our project cars will be necessary to verify the estimates summarized by this table:

Speed (MPH)	Road & Drag Force (Lbs)	Required HP	Required KW	Current (AMPS)	Battery Energy (kwH)	Energy Required (Kwh/Mile)	Estimated Range (Miles)
25	67	4.46	3.3	46	16	.20	80
35	87	8.12	6.1	84	14	.18	77
45	112	13.44	10.1	140	9	.20	46
60	160	25.60	19.1	265	6	.30	20

There is no simple, direct answer to the range question. Promoters have quoted a 100 mile range for their car. What they don't say is this is at a constant 25 mph speed. When asked how fast their car will go, they will say 60 mph, leaving the misleading impression that it will travel 100 miles while moving at 60 mph.

A realistic reply to the range question for our project car would be to say we expect a 25-mile range in urban driving and a top speed capability of 60 mph.

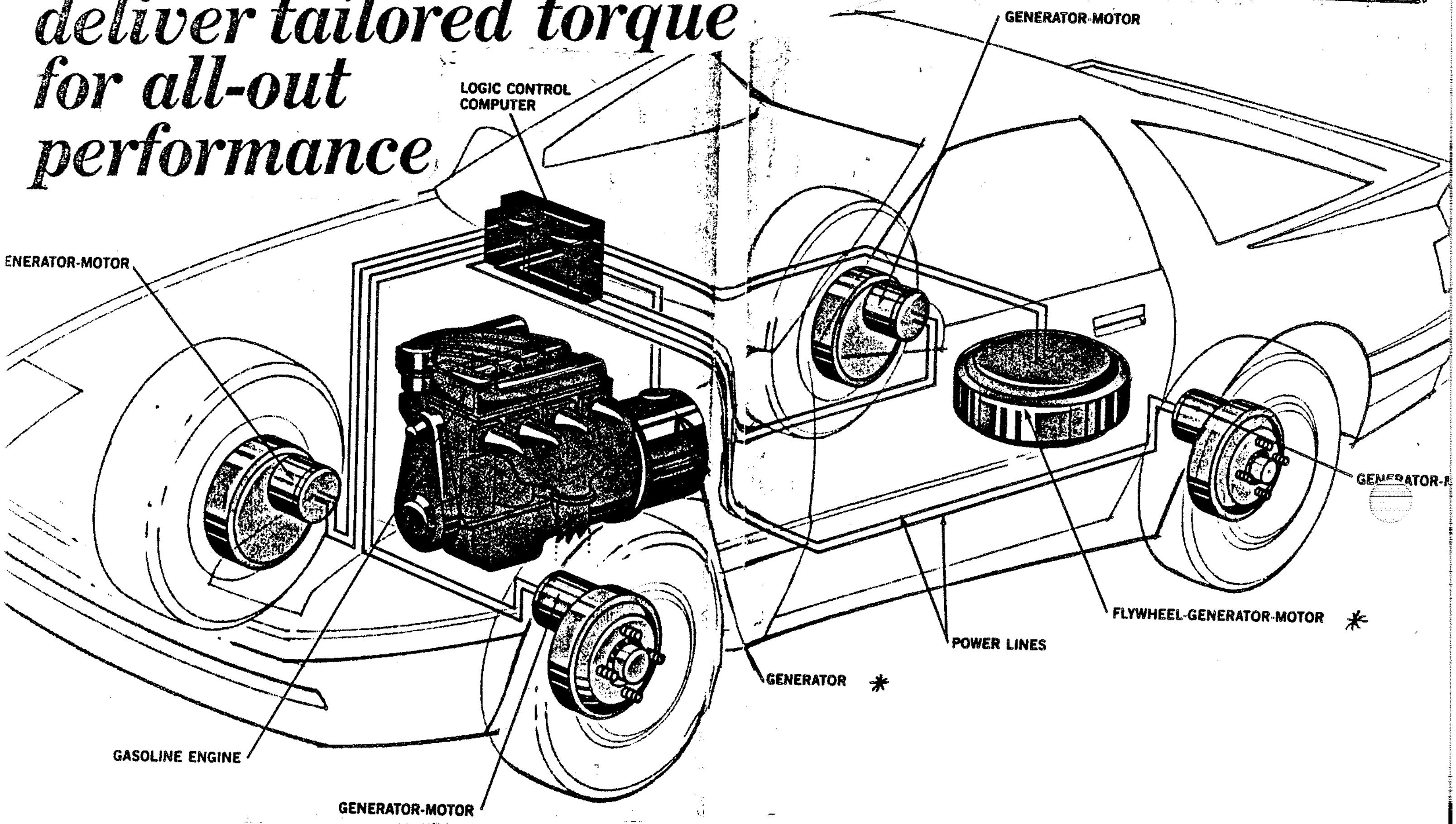
An electric car with the performance developed thus far can be useful with a daily driving pattern of about 20 miles. The electric has a particular advantage for the 1-5 mile trips where a gasoline engine must cold-start and hardly gets to operating temperature. In these circumstances, the wear on a gasoline engine is severe, mileage is reduced, and maintenance must be more-frequent. We will discuss electric car usefulness at a future meeting.

In the next paper, we will consider some characteristics of lead-acid batteries and their effects on project car design.

W. H. Shafer
July 8, 1986

Gasoline/electric sports car

electric motors at each wheel deliver tailored torque for all-out performance



DRAWING BY RUSSELL VON SAUERS

Hybrid drive's main power sources are an engine-driven generator and an energy-storage flywheel. At constant speeds, the generator will power small electric motors at each wheel. During peak power demands, an on-board computer will pull power from the flywheel for the wheel motors.

A small development company in Denver is working to eliminate the automobile's transmission, gears, and drive shaft. With this totally new system, the engineers hope to achieve sports-car-like performance with 100-mpg fuel economy.

By DAN McCOSH
Detroit Editor

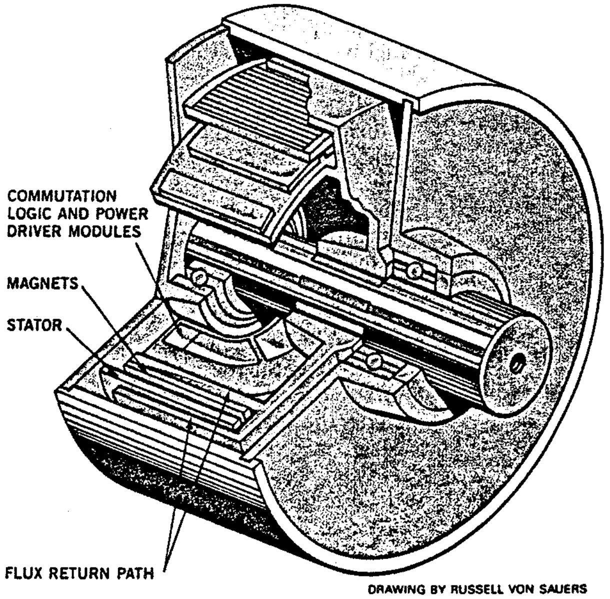
If Ray A. Geddes has his way, the street racer of the future will no longer rev his engine in noisy preparation for a stoplight blastoff. Instead, he'll sit quietly while his tiny constant-speed engine powers up an energy-storage flywheel in near silence. Then, as the light changes and he snaps his foot down on the accelerator, a flywheel/generator will release a massive surge of power to electric motors located at each wheel. Within seconds, the hybrid-drive racer will be a small dot on the horizon.

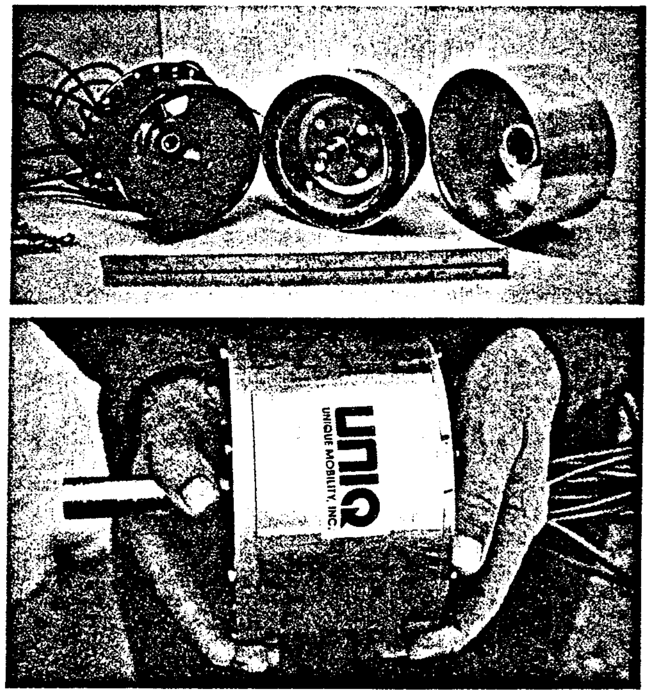
Since the beginning of the automobile age, power has been transferred from engine to wheels through drive shafts and transmissions. The goal with the new system is to break with that tradition entirely and convert the raw energy of an internal combustion engine—still the lightest, most efficient source of on-board power for a car—into electricity that powers a motor at each wheel. Such a system, if it can be made to work, would produce a host of benefits:

- Nearly infinite torque control, applying precise amounts of power at each wheel according to demand and road surfaces.
- Outstanding economy—in the range of 100 mpg—both at highway speeds and in stop-and-go driving.
- Regenerative braking, in which the energy now dissipated as heat would be used instead to rev up a flywheel, and then be extracted again for the next acceleration cycle.

But if there are potential benefits, there are also big problems. Among them: Conventional electric motors are massive and heavy, and the electronics to control the relatively high currents with the necessary precision doesn't exist.

So is this another automotive fantasy, an idea to be shelved along with the car that runs on water and the James Bond specials? I recently visited a small development company called Unique Mobility, run by a couple of former Detroit heavyweights, which just may have come close to solving the problems and converting the idea into reality. And more: Rather





Unique Mobility's 8-lb., 40-hp traction motor is shaped like a cake pan turned on edge. It's actually two cups that nest inside each other. One holds a row of neodymium permanent magnets on its rim. The other cup carries a belt-shaped wound armature. Conventional motors of equal power weigh between 240 and 255 lbs.

than pursuing a fantasy, Unique Mobility may be running only slightly ahead in a race to apply recent breakthroughs in high-strength magnets, electric motor design, and power semiconductors to a new generation of power transmission.

The moving force behind Unique Mobility is chairman Ray A. Geddes, who draws confidence from a 28-year automotive background that includes a stint at Ford supervising the team of Shelby Cobras that unseated Ferrari for the world championship in 1965. Geddes later worked with specialty-car programs, including the Ford GT 40 race cars that swept LeMans, and the original Shelby Mustang GT 350. His former mentor, Carroll Shelby, today is a major stockholder in Unique Mobility and sits on the board of directors.

The essential concept Geddes has been working on is an engine-driven generator powering electric motors at the wheels. Engineers call the concept "hybrid drive." It's not a new idea; a car called the Gas-A-Lec was on the market in 1905 that used an engine-driven generator coupled to an electric motor at the wheels. An automotive hybrid-drive system is basically a shrunken version of the diesel-electric drive used on locomotives and big earthmoving equipment. Hybrid drive promises numerous benefits—mainly near infinite control of speed, torque, and power at the wheels, while a small engine providing power runs steadily at a constant and efficient speed.

Today's on-board computer controls promise a whole series of benefits from hybrid systems. Even the simplest possible hybrid drive—an engine-driven generator coupled to a drive motor —becomes a promising route to a lightweight, infinitely controllable automatic transmission.

Geddes is staking his dream on an extremely lightweight, powerful new permanent-magnet electric motor developed by Unique Mobility that produces up to 40 hp in an eight-pound package. It's one of a new generation of small, powerful permanent-magnet motors. Coupled to power logic systems that allow the motors to be directly controlled by computers, the hybrid-drive system, Geddes says, can substitute for conventional mechanical and hydraulic transmission systems. Potential applications of hybrid drive in automobiles range from powering engine accessories to one of the most flexible, efficient, and responsive transmission systems ever conceived.

In an operating system, a computer senses the torque and speed demands of the car, feeding power to the driving motor on demand. It's a kind of electronic version of a standard automatic transmission, which uses a hydraulic torque converter and hydraulic logic to accomplish the same task.

"It's the ultimate constant-velocity transmission," says Geddes. "The drive motors start at zero from a standing start, and are controllable over the full range of vehicle speed. No mechanical system even comes close."

Geddes sees even further possible benefits to hybrid drive in an automobile: eliminating conventional gearing altogether. "A separate motor driving each wheel would allow you to control torque individually under all driving conditions. Say in a high-speed corner, when the car loads up the outside wheels, torque is applied to the wheels with the most traction," he says. More sophisticated traction control would cut power to a wheel spinning on ice, directing it to a wheel on dry pavement.

The full program Geddes envisions includes an energy-storing flywheel that accumulates energy from regenerative braking and low-demand periods, to release on demand for acceleration. Taking advantage of an electric motor's ability to act as either a generator or motor, Geddes proposes a flywheel that consumes electricity to wind up to speed, and then generates current when the electricity is needed.

With the car at speed, tapping electricity at the wheels to spin up the flywheel makes the wheel motors act as brakes—completely controllable with anti-lock sensors. The spinning flywheel then supplies short bursts of power to accelerate from a standing stop. Saving the energy normally dissipated as braking heat increases the overall efficiency of the car; theoretically, stop and go should consume no more fuel than steady highway speed.

→

In addition, with the flywheel accommodating power surges, only a small engine is needed to supply the average power to the system—a boon to overall fuel economy.

Now the problems

But what works on a locomotive has been impractical for passenger cars. Three key problems have held this system back: the electrical inefficiency of today's best motor-generator sets, the sheer bulk and weight of today's electric motors, and compact high-power electronics to handle the motor-control requirements.

"One problem is that the average efficiency of a reasonable size motor is only about eighty percent," explains Dr. Victor Wouk, a New York-based consultant on hybrid drive. "That means with the losses in a motor and generator, you start losing about a third of the advantage—unless you use very big engines and very big motors."

In addition to the problem of electrical inefficiency, the weight of a motor-generator set powerful enough to propel an automobile has limited its practicality. One of the best commercial 32-hp DC traction motors on the market today weighs some 240 pounds. Conventional AC motors cut the weight to 75 pounds or so, but still represent considerable bulk. Anyone with a standard ¼-hp motor driving a grinding wheel in the home workshop can appreciate how bulky an electric motor can be.

At Unique Mobility's Denver headquarters, Gene Fisher, vice president of research and development, tossed me the guts of a 1-hp motor he had designed; I caught it with one hand. I was holding what looked like an empty toilet-paper roll with fine wires imbedded in the surface. Fisher calls it a "shell," or "cup," motor. It weighs less than a pound, can produce 1 hp, and can rev to 2,500 rpm in 0.5 milliseconds.

Fisher developed the motor to power a high-speed computer tape drive. Now he is expanding on the concept to build motors large enough to power cars. Unique Mobility's eight-pound 40-hp traction motor is considerably shorter and fatter than the tape-drive motor.

"You can spend forever trying to improve existing designs ten percent," says Unique Mobility president John S. Gould. "We took the basic principles of motor design and started from scratch. That improved everything—even simplified the controller design."

"The breakthrough is the ability to use very high-strength permanent magnets," says Wouk. "They have a very high flux density, producing larger force, greater torque, and higher speed. But there are a few tricks to using very high-strength magnets," he adds. The permanent magnets used in the motor are neodymium—one of a new generation of supermagnets that are 10 to 40 times as strong as ferrite magnets, the most common in use today.

Fisher says several engineering features contribute to the motor's power: Extremely thin armature windings are located far from the center shaft, increasing their effective torque. The close spacing of each winding to the permanent magnets means the propulsive force is maximized. Also the thin windings help dissipate heat.

Smooth control of high horsepower is a problem with most motors, which would rather be "off" or "on." The new design actually has three sets of windings in layers—one on top of another—each powering the motor at certain speed range. The controller "shifts gears" by going from one winding set to another. "We should be able to develop the forty horsepower at about 2,500 rpm. It's not strictly a high-speed motor," says Geddes.

Like most permanent-magnet motors, the Unique Mobility system functions efficiently as either a generator or motor. "To make the flywheel, we weight the 'cup' of the motor, make it wider and flatter, and it becomes a flywheel storage system, about the size of a mini spare tire," says Gould. An early prototype weighed 250 pounds, but Gould notes most of that weight was heavy shielding installed to catch pieces if it broke.

"We were running it over 25,000 rpm and we thought it might explode," he explains. Later generations will be lighter and slower. "A small flywheel would store about one-sixth kilowatt-hour of energy, a real wheel-burner a full kilowatt-hour," Gould says.

What's a MOSFET?

The third major obstacle to automotive hybrid drive has been affordable and compact control electronics for the complicated switching duties. Fortunately, the new on-board computers promise a whole series of benefits, including smooth motor control. Electronic controls for the motor are based on a new generation of semiconductors called a Metal Oxide Semiconductor Field Effect Transistor (MOSFET).

"MOSFETs can switch high power at high frequency, while being controlled by low voltages," Geddes says. "They were developed in the 1970s, but just recently there have been major increases in power handling capability." The Unique Mobility motor uses four MOSFETs in parallel to handle its 120-amp/200-volt demand. Each MOSFET is about the size of a one-inch cube.

Controlling the MOSFET is the job of the microprocessor. It's programmed to respond to throttle position and sensors signaling engine power loads, wheel spin, and torque requirements.

Today, the pieces that would make the "supercar" work exist, but only on the workbenches at Unique Mobility. The development program to get the sports car project on the road would mean taking the basic pieces—the motor, flywheel, and controller—that are still in Unique Mobility's lab and developing them to where they could stand up in automotive use.

The full potential of the new motor has not yet been achieved, Gould says. Sustained tests have been run at about 20 hp, half its theoretical rating. But this is still an impressive output. A control system is also in the development stage.

Possibilities for Geddes include support by a major British sports-car manufacturer, underwriting a three-year project to develop a 130-mph sports car and put his dream on the road.

But first, hybrid drive is likely to show up in less ambitious roles than a full-drive system. One potential application is direct electric drive and control of engine accessories, including the water pump, camshaft, and power steering.

The second place we can expect to see hybrid drive is in military vehicles. Recently the U.S. military became interested in the potential of hybrid drive for all its vehicles.

"They're merging control electronics with power transmission. We call it 'smart power,'" says Patrick McCleer, assistant professor of electrical engineering at the University of Michigan, who recently completed a study on smart power transmissions for military vehicles ranging from tanks to light trucks.

The study indicated that even hybrid drives using currently available technology promise smaller size and lighter weight than today's mechanical and hydraulic transmissions. General Dynamics Corp. (Troy, Mich.) recently completed a prototype medium-truck chassis using a motor-generator set as a transmission, based on the new permanent-magnet motors. Several similar projects are in the research stage.

Development is expected to accelerate quickly, however, as other major manufacturers rush to develop the new generation of electric motors. General Motors launched a new plant manufacturing its Magnequench ["Mighty Magnet," PS, Feb. '85] magnetic material in production volumes only a few months ago, the first volume source in the U.S.

The era of smart power is here. PS