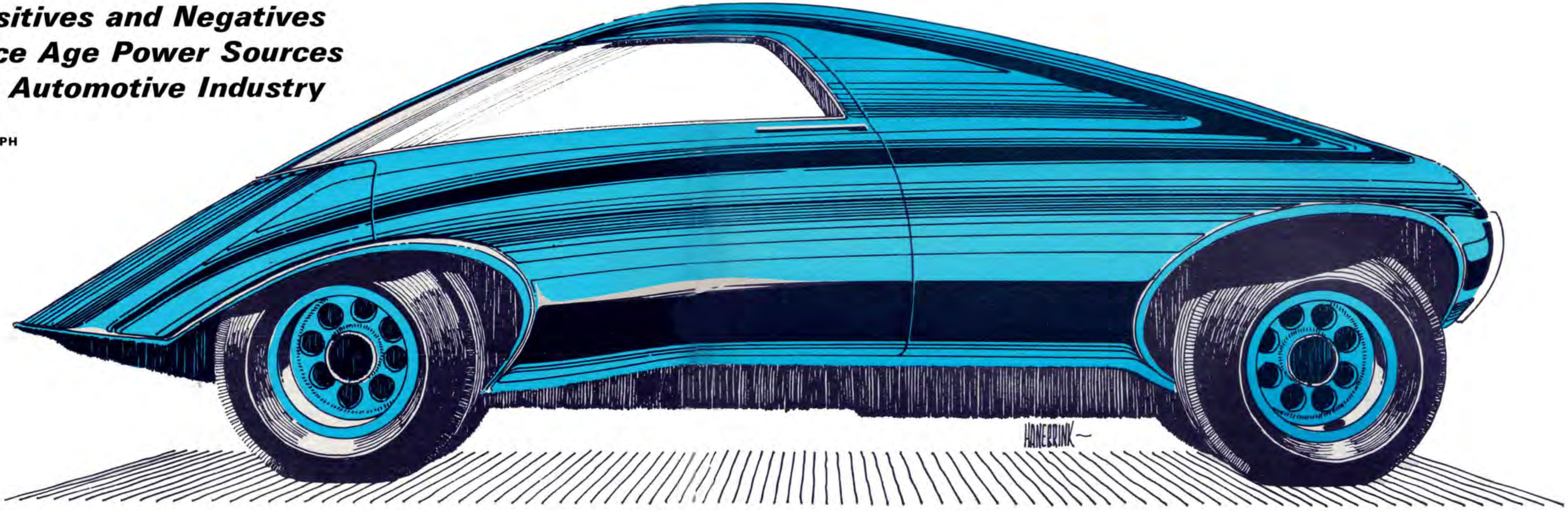
TOMORROWCARS: THE ELECTRICS

The Positives and Negatives Of Space Age Power Sources For the Automotive Industry

BY JAMES JOSEPH



IT WAS, says one Detroiter with unconcealed cynicism, "the week they held up a bottle full of fireflies and declared, 'We have seen the light!' "

More correctly, Detroit had struck sparks with a has-been idea that was born with Thomas A. Edison, reached its zenith in 1905 with Walter Baker's 100-mph Torpedo and short-circuited from public fancy in the 1920s: The electric car.

At a hastily convened press conclave in Dearborn, Ford's vice president in charge of science, Dr. Michael Ference Jr., made the terse announcement. Ford not only had developed a "revolutionary" ceramic-hearted sodium-sulfur battery (capable, said Ference, of powering a commuter electric compact at a respectable 40 mph, with 150 miles between recharges), but Ford would demonstrate a sized-down (only 6 ft. bumper to bumper) commuter electric early in 1967, powered with conventional lead-acid batteries. In perhaps two years, Ford would begin testing a Falcon-size electric, this time run on the new sodium-sulfurs.

Almost simultaneously, 14 electric utility companies made known they'd chipped in another $150,000 to help sizeable General Atomic (a division of General Dynamics) bring to prototype its new *zinc-air* battery which, claims GA, produces 50 watt-hours per pound—power enough, with 500 lb. of batteries, to push a commuter car 80-120 miles before recharging.

Earlier, Gulton Industries had announced yet another high-efficiency power candidate for any contemplated electric car, the firm's *lithium* battery.

Meantime, the highly touted *fuel cell*—dubbed a "battery with a gas tank" because, fuel fed, it never requires recharging—was making automotive news of its own. As long ago as 1959 Allis Chalmers powered tractors and industrial fork-lift trucks with crude fuel cells. In 1963, two General Electric scientists—hot on the track of something less volatile than hydrogen to fuel them—came up with cells fueled by safer (and lower cost) gasoline, Diesel oil and natural gas. Esso researchers, some months ago, announced a cell fueled with methanol (wood alcohol). Esso even unveiled a possible prototype for commuter car power, a 29-lb. cell that produced 100 watts of continuous power while wringing 40% efficiency from the methanol that fueled it. By comparison, most internal combustion engines do well to squeeze from gasoline even 20% of its potential power.

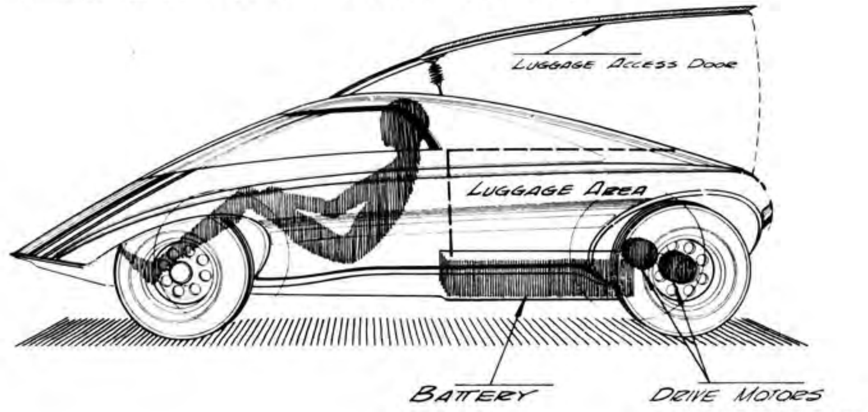
Clearly, both in and out of Detroit, wheels were spinning—some of them electrically powered. Researchers were aiming to do what few of the amps/volts fraternity had ever seriously hoped, much less dreamed, of doing. The goal was an electric drive "town car" with performance akin, if not the match, of a standard combustion-engined compact.

Oddly, Ford half-concealed its real intent—a comparable to compact/performance electric—by announcing that its upcoming sodium-sulfur drive prototype would, initially at least, be in the 40-mph/150-mile range class.

More significant was the "comparative performance" chart accompanying this article which Ford released, comparing its own 170-cu. in./105-bhp combustion-engined Falcon with three projected "Falcon class" electrics, each powered by different battery systems—lead-acid, silver-zinc and Ford's own sodium-sulfurs.

The sodium-sulfur "Falcon" that Ford envisages—and which its researchers plainly aim to build—would weigh only 360 lb. more (all accounted for in its battery system) than a combustion-engined Falcon. In town, at least, the electric would nearly match Falcon performance. And, in some cases, it would perform better. The electric would accelerate quickly—approximately 10% faster from the start—because electric motors produce "instant torque." Even after 10 sec., the electric would not fall far behind the ▶

DESIGNER Dan Hanebrink has speculated graphically on how the electric runabout of the future may appear. His proposal features maximum usefulness of minimum space with far-forward seating, large battery and motor compartment, and huge, easily reached luggage/utility area. Construction would be ultra-light.



WEIGHT COMPOSITION OF ELECTRIC AUTOMOBILES

COMPONENT	WEIGHT RATIO	ALTERATIONS POSSIBLE FROM CONVENTIONAL COUNTERPART	WEIGHT REDUCTION FRACTION	FINAL WEIGHT RATIO
Body structure	.25	Gauge reductions in frame and chassis allowed by redistribution of concentrated weights. Elimination of mid-floor transmission hump and driveline tunnel.	1/6	.21
Trim	.13	Reduction of acoustical and thermal insulation. Simplification of dashboard furnishings and instruments. Elimination of air intake grillwork.	1/8	.115
Glass	.035	No alterations	0	.035
Front suspension	.03	Equal front/rear weight distribution. Low CG battery pack clustered near spring-body junction points.	1/6	.025
Rear suspension	.025	Same as above	0	.025
Wheels	.023	No change	0	.023
Tires	.025	No change	0	.025
Steering	.013	Lighter steering mechanism from low CG, equal front and aft weight, 4-wheel traction.	1/10	.012
Electric motors	—		—	X
Energy storage	—		—	Y
				SUM: 1.00 = 0.47 + X + Y

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combustion Falcon in getup and sustained go.

Only a week previously, Dr. George A. Hoffman of UCLA's Institute of Government and Public Affairs, and one of the nation's leading electric car authorities, had come close to corroborating Ford's projected performance figures.

"Electric cars," Dr. Hoffman told the first National Intersociety Energy Conversion Conference, "will have better-than-conventional performance up to 15 mph, comparable performance from 0-30 mph, and somewhat less-than-conventional performance for 0-60 mph acceleration."

Dr. Hoffman then set the parameters for such a town electric. The car would weigh about 3000 lb. (49% of this weight in batteries, 4% in electric traction motors). It would be able to manage a short duration top speed of 100 mph, but would average 30 mph around town and travel 150 miles between rechargings or refuelings, in the case of fuel cells. Though initially higher priced than comparable compacts, the electric, because of lower operational costs, over the long run would return its owner something of a bonus. For this kind of performance, its batteries would require an energy density of 50-60 watt hr./battery lb. and a storage capacity of 80-90 kilowatt hr./lb. Both of these power figures are within reach, perhaps in the next few years at the least, by the early 1970s at latest, say some of the electrical experts.

The compact of Dr. Hoffman's calculations might match a Falcon's performance with electric motors rated at only 25 bhp or so. By reason of greater efficiency, torque characteristics and overload capabilities, electric motors need have horsepower ratings of 20-25% that of piston engines for the same service.

One motor might power a front-wheel drive electric compact, or two might drive both front and rear wheels. Were four smaller motors used, they would provide either external or internal drive for each wheel. A recently designed experimental army truck employs in-the-wheel motors, the axles of which are the armatures and the wheels are the fields. One type of in-wheel motor now weighs but 2 lb./bhp, thus 40 lb. of motor could produce 20 bhp. Engineers say, however, they can accomplish even more. In-wheel motors capable of producing 1 bhp/lb. are in the realm of probability.

Ford revealed its labs already have designed an electric motor "which weighs one-fourth that of the best commercially available direct-current motor of equivalent power rating."

"Further development will be required," acknowledged Ford, "but initial studies indicate that this motor will be low in cost and extremely rugged."

Recently—and secretly—Detroit has been speed-testing prototype electrics, usually, production cars with battery systems substituted for their engines. In one recent test, a production-standard car, turned electric, clocked more than 80 mph on the straightaway, but not for long. As yet, no battery or fuel-cell has sufficient "electrical density"—the capacity to store sufficient wattage per pound—for anything approaching sustained range at speeds in excess of 60 mph.

THIS IS WHY, at present, the most enthusiastic electric car visionaries will speak only in terms of "commuters"—in-town cars, designed as an urban family's second or third vehicle, and one used by dad for the home-to-work shuttle and by mom, for shopping and car-pooling the kids to school.

Smog free, operating on pennies per day, perhaps as little as $1 a week in electrical recharge costs, the noiseless electrics' performance could equal compact or small car performance. These factors would have certain consumer appeal, say marketing experts.

Battelle Memorial Institute researchers recently estimated that an electric commuter with "small foreign car performance and economy," meaning a commuter the match of the Volkswagen, might sell at the rate of 250,000 per year, strictly for town service.

All this presupposes electrics with far and away better performance and range than those of the past, which the public, with rare unanimity, has repeatedly and enthusiastically rejected.

The brief 1959-1961 electric flurry died aborning. As others like it, the California-designed Charles electric, a Karmann-Ghia stuffed with batteries, expired of kilowatt failure. So did Electric Storage Battery Company's much-publicized Henney Kilowatt. The Henney, a rebuilt Renault Dauphine loaded with 12 lead-acid batteries, performs nicely in traffic. However, the performance is of short duration. The car manages only 35 miles before recharging is necessary. Battery rejuvenation requires about 12 hours.

RANGE FOR such a commuter is not the handicap it might seem. An American Automobile Association survey shows the average New Yorker drives only 26 miles daily. In Los Angeles, where home-to-work distances approach 60 miles, town electrics could be expected to operate for two days between recharges. Recharging would not necessarily have to wait until a driver wheeled into his own garage. At least one parking meter designer has on the boards a "recharge meter." Slip a quarter in the slot and the electric car owner could purchase two hours' worth of recharge while going about his business.

What, then, are the probable power sources for tomorrow's "high performance" electrics? Here is a searching look at the contenders, the "electric engines" which are most likely to power the commuter electrics:

Lead-Acid Battery: Strengthened with special electrolytes, or otherwise treated for greater power production, the venerable lead-sulphuric acid battery, despite its bulk and low energy density, remains a prime contender as a power source for the commuter electric.

"Exotic electrolytes might just do the trick," concedes UCLA's Dr. George A. Hoffman.

It would admittedly take some doing to judge by an analysis of motive power battery systems recently compiled by the Edison Electric Institute:

ENERGY DENSITY

Battery	Theoretical watt-hr./lb.	Achieved watt-hr./lb.	Achieved watt-hr./cu. in.
Lead-acid	115	12	0.9
Nickel-iron	215	11	0.8
Zinc-silver	220	40-70	2.0-3.5
Zinc-air	400	45-55	2.0-3.0

Yet, no less an authority than Battelle Memorial Institute, in its 1965 survey, "Energy Sources for Electrically Powered Automobiles," concluded that of the batteries its researchers had studied, including fuel cells, but not Ford's new sodium-sulfur battery, the lead-acid seemed the surest and most quickly available energy source for commuter cars.

The relatively low cost lead-acid, (S-L-I, now used in cars only for Starting, Lighting and Ignition) needs some improvement, however.

For the S-L-I lead-acid to become a serious candidate for commuter electric power, said Battelle's report, it must:

1) Be capable of 500 deep-discharge cycles, equivalent, in average electric-powered driving, to about 75,000 miles, or approximately 2.5 times the present recycle life of most S-L-I batteries; 2) produce 0.1 bhp/lb., or about five times the power density of present lead-acid batteries; 3) pack 5 bhp hr. into every cu. ft. of battery, about twice the present volume density of S-L-I batteries; and 4) cost no more than $10 per horsepower output,

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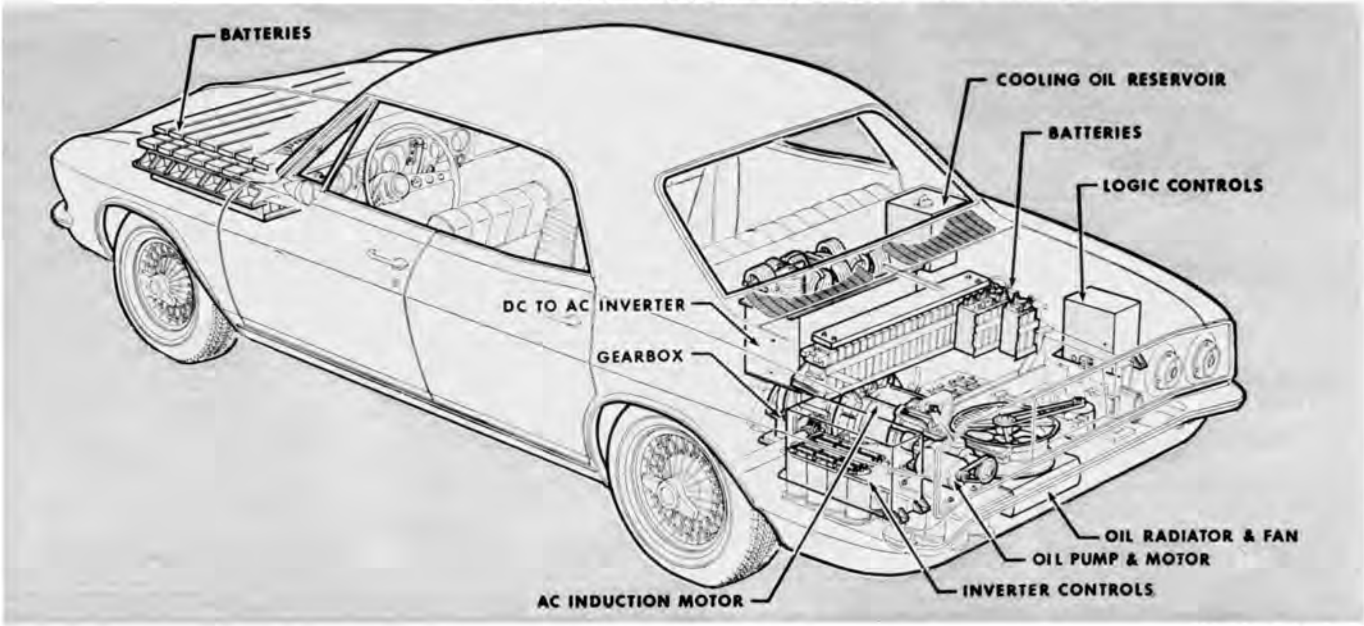
ELECTROVAIR II is second generation battery-powered car by General Motors Research. With a trunkful of batteries in front, and more batteries, the motor and controls (above) in the rear, the car weighs over 4000 lb. Range of the silver-zinc battery pack (value $25,000) is only 40–80 miles between recharges.



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though the majority of S-L-Is today sell for about twice this or a $20/-bhp equivalent.

Zinc-Air Battery: Under development by the General Atomic Division of General Dynamics, the zinc-air battery is perhaps the most exotic of the "metal-air" batteries. An all-out effort is in progress to develop the zinc-air battery into a practical high energy density electric propulsion system for cars and trucks.

Potentially, the zinc-air, which uses atmospheric oxygen as a reactant, offers energy density of the highest order, a calculated 400 watt hr./battery lb.

Though still far short of theoretical levels, experiments show the zinc-air can store and deliver an amazing 50 watt-hr./lb., enough to give a compact commuter electric an 80-160-mile range. Today, 60 watt-hr. seem close to achievement. This would power a commuter car 180-210 miles before recharging in normal, but battery draining, stop-go city traffic.

On the freeways, ranges would dramatically increase because steady driving extracts far less power from a battery than does stop-and-go traffic.

Powered by a 60 watt-hr. zinc-air, and cruising at 55 mph, the same car would approach normal gas tank range, perhaps 250-300 miles. And, gas tank range is the avowed goal of commuter car designers. At a steady 90 mph, range would be cut to 150 miles, far better than any system except the fuel cell can claim today.

The zinc-air battery, using air as a reactant and continuously circulating electrolyte (potassium hydroxide), makes electricity by converting zinc to zinc oxide.

THE ACCOMPANYING diagram shows the zinc-air battery in action. During discharge (electrical output), air from a pressurized chamber is bubbled through a porous nickel cathode and into the liquid electrolyte, which continuously circulates through the zinc cell stack—the anode. The oxygen absorbed by the electrolyte combines with the dissolving zinc to form zinc oxide. The reaction produces electricity which is taken from the cell across its terminals (+ and −). Waste air and unused nitrogen are continuously swept from the cell by the circulating electrolyte, as is excess zinc oxide, which is stored in the zinc separator for later reuse.

Charging reverses the reaction. Voltage is applied across the cell at the terminals while the electrolyte is circulating. The stored zinc oxide is carried back to the cells where it is replated on the anodes from which it was dissolved. The remarkable zinc-air battery, recharged, is ready once again to power the commuter electric.

A goodly amount of "plumbing" is involved. The basic electrolyte circuit requires a pump for circulating electrolyte, a small electrolyte reservoir and an air separator to remove spent air captured in the cell. All is enclosed in the insulated, temperature controlled cell structure. Outside the cell are located two other accessories, an air compressor, a zinc oxide separator and storage container.

COMPLEX THOUGH the zinc-air battery may be, it operates at normal air temperatures, unlike Ford's fiery new sodium-sulfur batteries.

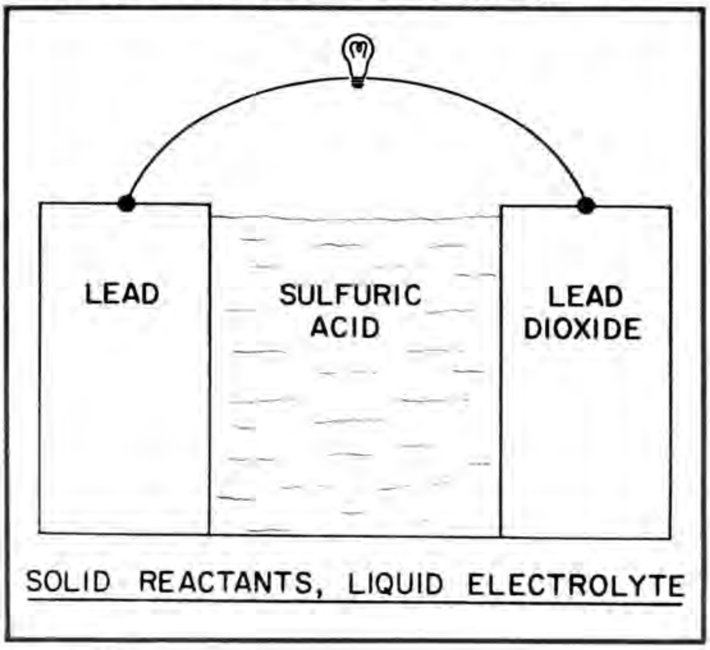
Sodium-Sulfur Battery: If Ford's new sodium-sulfur battery lives up to the energy density projected by its Dearborn designers, 150 watt-hr./lb., it would be far and away the most powerful and longest ranged of existing commuter electric power sources.

Privately, many experts are skeptical of the sodium-sulfur battery. They doubt whether Ford, in practice, can deliver. One reason for skepticism is the 500° F temperature at which the sodium-sulfur battery's crystalline ceramic heart must operate.

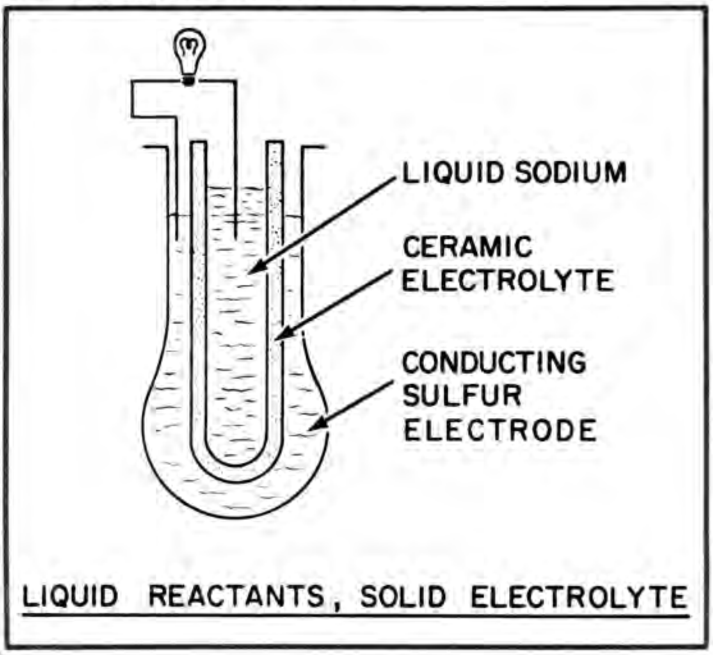
Shrugs a battery technologist, "The sodium-sulfur idea has been around a long while. What's new is anybody seriously proposing a 'hot battery' as a practical automotive power source."

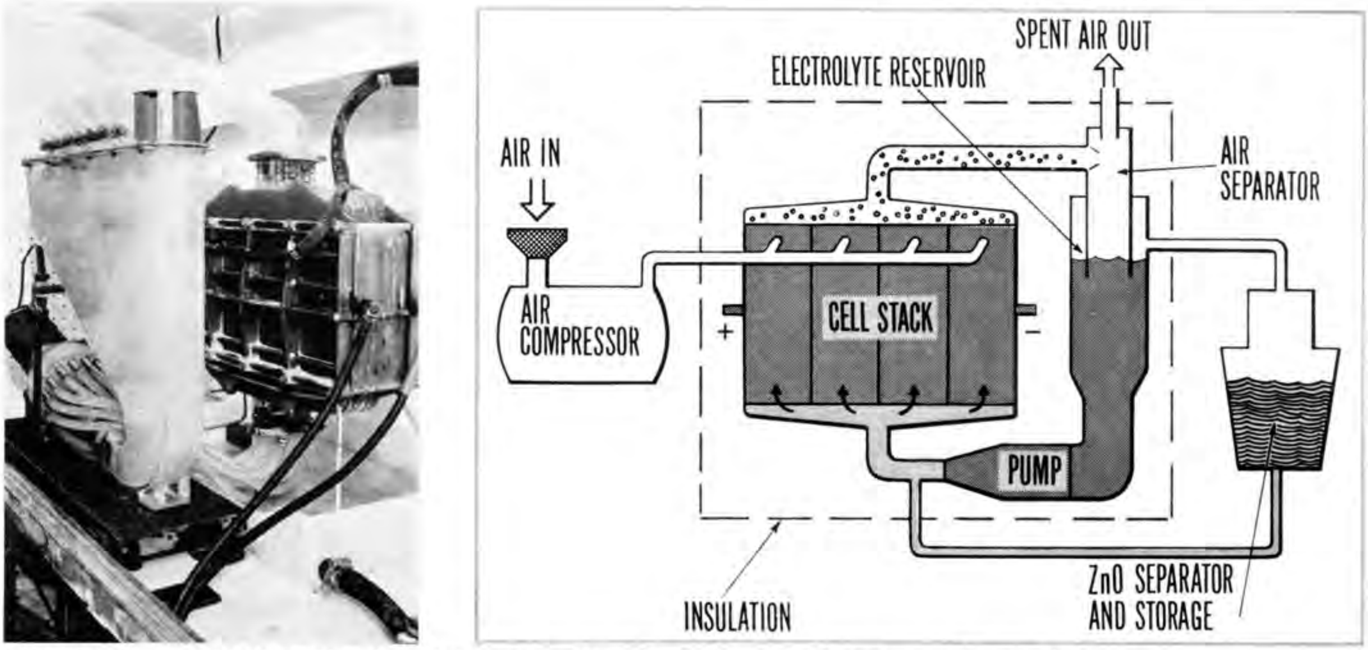
That the sodium-sulfur battery is hot was confirmed by Ford, though the

SCHEMATIC OF a typical lead acid battery shows that on discharge energy is extracted in external circuit while both electrodes and electrolyte undergo chemical change. Charging reverses process.



FORD SODIUM battery: Current is carried by sodium atoms which give up electrons to external circuit, traverse solid ceramic electrolyte and react with sulfur.





ZINC-AIR battery is one of the most sophisticated power sources under development, has an enormous potential for high energy density. General Atomic's experimental prototype model undergoes testing sequence, left. Cell stack is at right, zinc oxide separator in middle. Right, a schematic of the ZnO battery and necessary components.

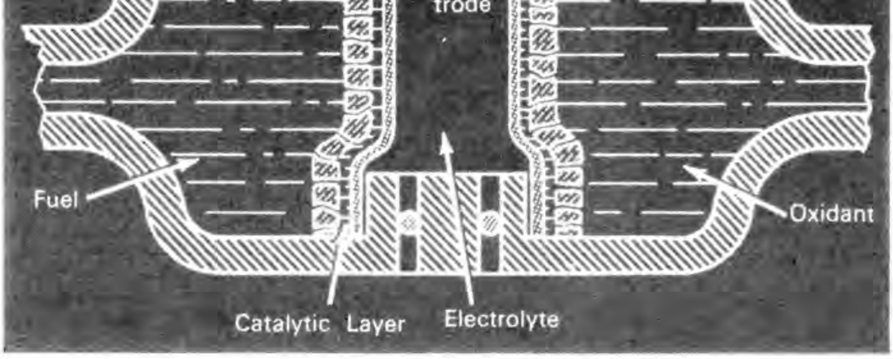
point was missed by the majority of automotive reporters. Speaking of the battery's ceramic electrolyte, Ford's Dr. Ference discussed its great "conductivity at operating temperatures—250 to 300° C." On the Fahrenheit scale, that is 482° to 572°.

What turns some experts chary isn't the sodium-sulfur battery's fiery temperature. After all, the internal combustion engine is a pretty fiery character itself. The experts questions are: "Where will the energy come from to pre-heat the battery to operational temperature? What will keep it hot?"

Because the sodium-sulfur battery is virtually dead when cold, its solid electrolyte must forever be maintained at operating temperature. Overnight parking would mean plugging the battery into an electrical outlet, say some technologists. Even were glow plugs or an auxiliary "warming battery" installed underhood to heat the ceramic core, start-up would hardly be a turn-the-key-and-go proposition.

"I'd guess that from cold start to go it would take anywhere from 30 seconds to maybe a minute to fire up the electrolyte," reckons one expert. The goggles-and-gloves Stanley Steamer crowd may not have chafed at the wait, but today's commuter undoubtedly would.

FUEL CELL is similar in construction to battery, but must have constant interaction of oxidant and fuel on the catalytic layer to generate electricity. Byproducts sometimes pose problems.



Ford yet may have the last laugh, but to do it, some think Dearborn must work considerable magic.

Still, Ford's sodium-sulfur battery is an ingenious power source which, claim its designers, can store 15 times the electrical energy of today's lead-acid batteries.

Basically, Ford's sealed and airtight "hot" cell consists of a reservoir of liquid sodium (the anode), enclosed within the solid, hot, porous aluminum-oxide ceramic electrolyte, which in turn is immersed in highly conductive liquid sulfur (the cathode). While containing the liquid sodium, Ford's unique "hot ceramic" electrolyte acts as a conductor of sodium ions that pass through it. These react with electrons in the liquid sulfur to form sulfide ions to produce an electric current. During recharging, the process is reversed and the battery is restored to its essentials—sodium, sulfur, alumina and soda.

Fuel Cell: Strange though fuel cells may seem, they already have come a long way. Fuel cells have gone into space with the Gemini spacecraft, where they powered elaborate life-support systems. Soon they may come down to earth to give the commuter electric what no battery can, a continuous peak-level power punch.

Unlike batteries, fuel cells never require recharging because neither their electrolyte or electrodes are exhausted in the process of making electricity.

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Fuel cells "burn" fuel fed to them from an external source—as do today's combustion engines. Fueled by low-cost hydrocarbons, such as Diesel fuel, gasoline or vaporized kerosene, a fuel cell converts its easily replenishable fuel directly into electrical energy.

The conversion is remarkably efficient. Fuel cells generate more electricity per pound of fuel than any other non-nuclear method. Even today's crude cells manage to turn 50% of their fuel into power. Advanced cells, designers believe, will extract 80-90% of fuel energy potential.

The two fuel cells (each 2-ft. long and 1-ft. dia.) used aboard the Gemini spacecraft weigh only 145 lb. (not counting fuel), yet produce up to 2000 watts of power. Based on Gemini experience, cell designers now think they can, perhaps by the early 1970s, develop a cell system weighing 400-500 lb. that would produce 500-2000 watts and have a life of 10,000 hours. This system would give a commuter car all but unlimited power.

Major problems remain, however. One is that low-temperature cells aren't as efficient as hot ones. Some cells, using methane or hydrogen operate at upwards of 1800° F. The problem isn't how to warm them because the fuel does that. Rather, the most efficient, hottest cells are fueled with hydrogen, a volatile gas. Mixed with oxygen, as in some experimental cells, the volatility increases. Present day high efficiency fuel cells are veritable time bombs. The average motorist wouldn't want one under the hood of his car. Another problem is cost, especially the cells' platinum electrodes.

BASICALLY, HOWEVER the fuel cell is simple. It is a mechanism that, astonishingly, creates electricity from water. Fuel, such as hydrogen or various hydrogen-containing hydrocarbons, and oxygen from the air are fed to the cell where they produce water. In the process, they generate energy.

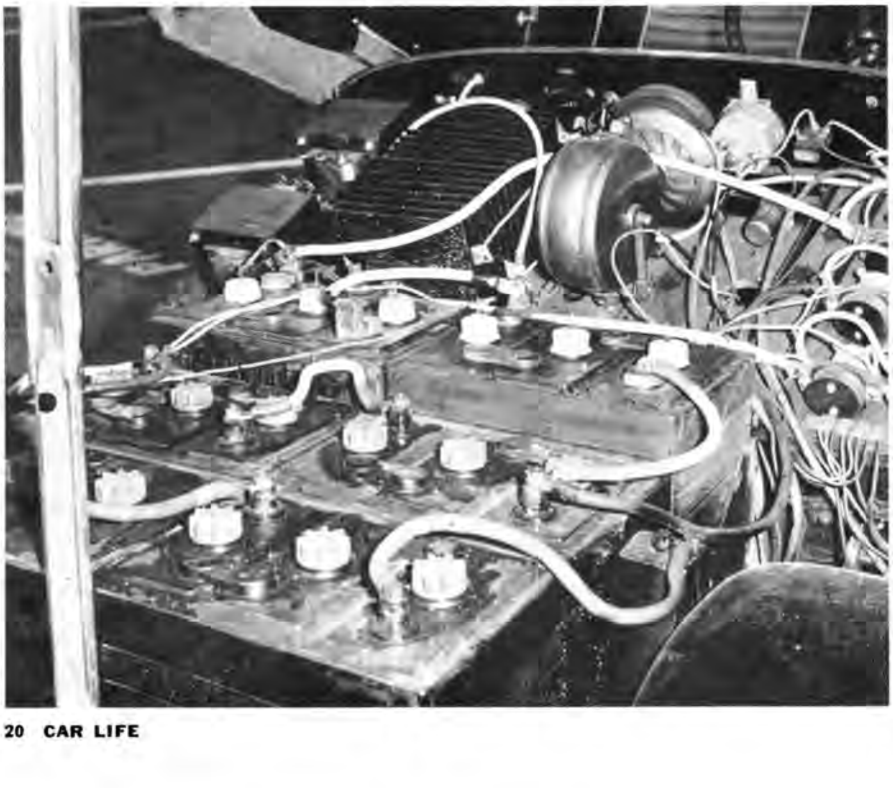
In a typical cell, fuel is fed to one porous electrode (the anode) where it is absorbed. Air is supplied to the other porous electrode (the cathode) and is likewise absorbed. The oxygen flows through the electrolyte which separates the two electrodes and combines with the anode's fuel, oxidizing it. Electricity and also waste products are produced. Water and, in the case of hydrocarbon fuels, carbon dioxide are the waste products.

This brief review of potential commuter car power sources leads to an obvious conclusion: High-efficiency electric cars may be on their way, but they are still not on the road—and won't be for some time.

Paradoxically, the industry's giants —Ford among them—champion the commuter electric with vague promises of "something on wheels—maybe by 1967 or '68." ■

VOLTSWAGEN

This Cross-Town Car Has an Electrifying Future



FORD'S REVELATION that an electric commuter car is in the works brought a galvanic reaction from the press, but at least one person got a big charge out of all the flap and fanfare. This man is the owner of a here and now commuter electric—a scaled down prototype mayhap, but nevertheless on the road daily. The performance of this car, however, may be short of the giant manufacturing firm's hopes for the future.

The battery-powered commuter is the BMW, no relation to the German car clan of similar name.

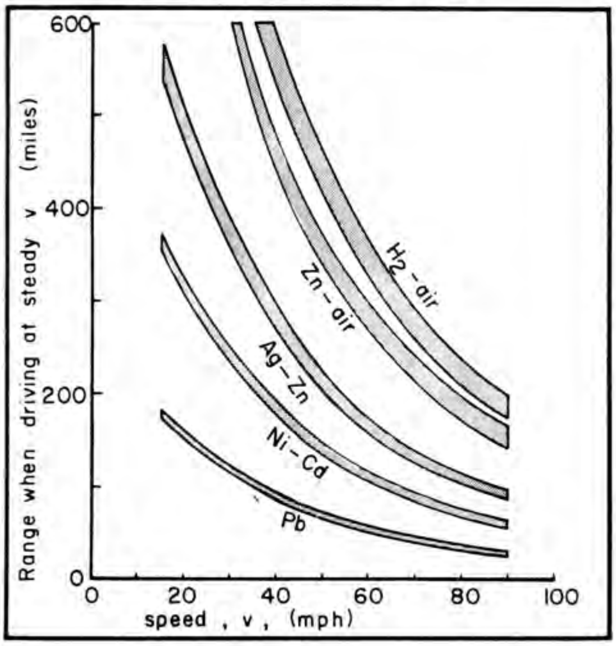
Brainchild of its designer-builder, battery vehicle expert Leslie Perhacs, a BMW has been skittling around Los Angeles for nearly a year, virtually unnoticed.

If local folk have been oblivious to what may well be the forerunner of the first practical commuter electric, others have been more cognizant: A top U.S. industrialist reportedly has pledged an initial two million dollars toward production of a compact-sized town car that likely will sell for a modest $2300 or so.

Foreign emissaries, too, have been beating a path to designer Perhacs' door. One group of businessmen from India already has plunked down "earnest money" for the rights to build the BMW.

As for the single car produced, unlike its more highly touted competitors, the BMW is owned and driven daily by Los Angeles City College professor Dorothy A. Stapleton. Mrs.

PROJECTED RANGE in miles for various batteries in electric cars at steady speeds. From top to bottom are: Hydrogen-air, zinc-air, silver-zinc, nickel-cadmium and lead-acid.



CALCULATED ELECTRIC VEHICLE CHARACTERISTICS

FALCON CLASS – PASSENGER CAR

Vehicle	Standard Falcon with (170 CID engine)	Electric "A"	Electric "B"	Electric "C"
Batteries	—	Lead-acid	Silver-zinc	Sodium-sulfur
Weight (lb.)	—	500	500	500
Total Powerplant Weight (lb.)	620	980	980	980
Vehicle Test Weight (lb.)	2960	3320	3320	3320
Range in Miles:				
40 mph const. speed	425	21	68	134
60 mph const. speed	333	0	43	70
City Traffic Cycle	250	10	37	82
Performance				
0–4 sec. dist., ft.	89	86	98	98
0–10 sec. dist., ft.	436	355	408	408
Pass 50 mph car, sec.	12.2	*	22	22

* Insufficient power to pass.

PRACTICAL battery-powered electric already is in use on Los Angeles streets. It has eight automobile batteries.

Stapleton's husband, Douglas, a magazine editor, heard of inventor Perhacs' battery-electric system, asked him to fashion a car, paid $1800 for the first model and promptly turned the car over to his wife to drive.

"It handles beautifully," says Mrs. Stapleton, of the 10-ft. long 2-seater.

More significant is the little BMW's town performance. Governed to a top of 45 mph from the 70 mph Perhacs claims it can do and has done in tests, the BMW gets an easy 100 miles between recharges, zips in and around traffic and, in almost year-long daily use, has cost the Stapletons almost nothing to run.

"A couple of times a week," says Mrs. Stapleton, "I plug the dash's pull-out charge cord into my garage's 110-volt electric socket. That's all there is to it."

The Stapletons say they've carefully studied their electric bill every month, but haven't yet detected even a few cents rise, despite those twice-weekly rechargings.

"Maybe," shrugs Stapleton, "we're spending $1 to $1.50 a month for electricity, as the inventor says we should be, but I can't see it in our electric bills."

The only other cost has been the $10 annual "road tax" the state of California placed on the electric in an attempt to recoup something for road use, because the state wouldn't get it the usual way via gasoline taxes.

Under its something less than sleek fiberglass body, the BMW carries eight lead-acid storage batteries, six forward, two in the rear. Boosted by what Perhacs dubs his "secret formula electrolyte," they produce 195 amperes at 48 V. to power 16 speed solenoids, for four speeds forward and reverse, and two off-the-shelf 2-bhp Baldor electric motors which, through Bendix 2:1 gearing, drive the rear wheels. A built-in recharger also is located forward.

So far, the Stapletons have recharged their battery about 100 times. Inventor Perhacs claims one of his special electrolyte batteries was recycled 3800 times before it expired. Even at a conservative 1000 recharges before no-voltage death, the Stapletons' batteries should produce current for upward of 8–10 years. All eight batteries can be replaced for about $256. As for Perhacs' special electrolyte, each of the batteries requires 1 qt. of the liquid each year. Perhacs supplies the formula at $2 a quart, for an annual cost of about $16.

THERE'S NO doubt that this single-copy midget is a performer. The question remaining to be answered is whether the compact-sized, 4-wheel drive "big car" Perhacs and his backers plan will, given the added weight, perform equally as well as the prototype. Perhacs expects to be turning out 1000 units per month, perhaps by late 1967.

The Stapletons' BMW handles well and has surprising power and acceleration. Yet, given a compact-size production model with equal or better performance, would one plunk down hard cash for a town electric?

That is a question thousands of commuters soon may be asking themselves. Their answers will decide the electric cars' future. —*James Joseph*