EAA NEWS
Electric Auto Association

Vol XV No 2 Walter V. Laski, Editor February 1983

"Roadway Powered Electric Vehicles" are now being given Federal Attention!

Electrical energy can be transferred to vehicles traveling a highway by means of magnetic induction from an electric wire laid on top of the existing road surface. Then as the roads are resurfaced the wire and some iron are buried.

When the Federal Highway Reconstruction Program was being considered, EAA wrote to Senator John Glenn proposing an experimental prototype electrical "induction freeway" be installed near a large populated area as a part of the Highway Plan.

Senator Glenn wrote officials at the Department of Transportation. It was pointed out that induction systems are in use at the Walt Disney Experimental Prototype City of Tomorrow (EPCOT) and are being installed for buses in Santa Barbara, California. Federal Highway Administration's answer states, "In conclusion, we support EAA's view of promise in this area, although it is too premature to operationally implement at this time." They also sent a copy of an internal document, "Road Powered Electric Vehicle Final Report", from Transportation Systems Research dated September 30, 1982.

EAA has become increasingly confident that we can get some prototype "induction freeways" installed as a result of the following: (1) The conclusions of this research report are most encouraging to us and we quote, "No difficulties were uncovered which obviate the desirability of developing powered roadway for use in the U.S. transportation system. Powered roadways can reduce the dependence of transportation on petroleum." (2) EAA contacted the Federal Highway Administration as they suggested. The information received was not at all discouraging. Congressional authorization of funds is about all that is needed. (3) The Senator says please feel free to contact him again. EAA intends to pursue this actively. We believe this addition to resurfaced roads would broaden the Highway Plan's public benefits. It would certainly encourage more use of electric cars.

All of you realize, of course, what "induction freeways" could do for your electric cars. First, they would provide unlimited range since you already have the range to and from the freeways. Second, they would completely eliminate the exhaution of energy supplies on the freeway. Third, they would reduce the number of deep dischargings demanded from your batteries, thereby extending battery life and reducing your battery costs. Fourth, they would create a larger demand for electric cars, thereby encourage the mass production and reduced first costs of your electrics.

Contact your Congressman and inform him and others about this "induction freeway." Prepare him to support us in our attempts to implement this improvement which concerns us all. The time is most appropriate as our highways are being reconstructed. Do it NOW.

John B. Newell

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ELECTRIC CAR PERFORMANCE

HOW TO ESTIMATE ELECTRIC CAR CAPABILITY FOR RANGE, HILL CLIMBING, ACCELERATION AND SPEED

by BILL PALMER

If you are planning an electric car this method of estimating performance may help you improve the design before it is fixed in hardware. Or, if you have an electric car you can compare your actual performance with an estimate using this method and possibly find a way to improve performance. If your actual performance is better than your estimate you should write the next article telling the rest of us how you do it.

The purpose of this article is to describe an estimating method. The method consists of using car data to, first, calculate the propulsion forces required to produce the desired performance. Second, calculate the relationship between motor speed and car speed in each gear, and graphing motor characteristic curves scaled for each gear ratio. Finally, combine the motor curves with the propulsion force curves so we can visualize the limits of performance in each gear.

Car performance requires the motor, through the drive train and wheels, to apply propulsion force on the road to move the car against opposing forces such as friction, wind resistance, inertia and hills.

To calculate the values of these forces we need to establish some data about the car and to make some assumptions. Let's use a typical car with data such as these:

WEIGHT:	2500 POUNDS
WHEEL DIAMETER:	1.87 FEET
FRONTAL AREA:	20 SQUARE FEET
ROLLING RESISTANCE:	KRR = .015
AERODYNAMIC DRAG:	KAD = .0015
DIFFERENTIAL RATIO:	3:1
TRANSMISSION RATIOS:	3.33:1 FIRST
	1.67:1 SECOND
	1:1 THIRD
CONTROLLER CURRENT:	400 AMPS MAX.
BATTERIES, NUMBER:	12
BATTERY RATING:	6 V. 240 AH.

Let's also establish some performance goals for use in our estimate calculations:

CRUISING SPEED, LEVEL	55 MPH.
ACCELERATION:	3 MPH/SEC.
HILL CLIMBING:	10% GRADE
RANGE PER CHARGE	50 MILES

PROPULSION FORCES:

Next, we should evaluate the opposing forces, the loads, which must be overcome to make the car move. The conventional load, or propulsion force, components, mentioned above by slightly different names, are: Rolling Resistance, Aerodynamic Drag, Accelerating Force and Grade Force. Let's look at what causes each one and how to evaluate it.

ROLLING RESISTANCE "RR" is caused by tires flexing and scrubbing, and by drag of bearings and gears. Rolling resistance is proportional to car weight and is independent of car speed. It runs roughly 1% to 2% of car weight. Rolling resistance can be calculated by assuming a value for the RR factor "KRR" such as 1.5% and using it in the following equation:

RR = WEIGHT X KRR
= 2500 x .015 = 38 pounds

The actual value of RR for a specific car can be measured easily by pulling the car with a force measuring device, such as a spring fish scale, rated fifty pounds or more, or by pushing the car with a bathroom scale. Be sure your pulling or pushing force is horizontal and measure in two directions to cancel any road slope. Average the readings.

AERODYNAMIC DRAG "AD" is caused by the car displacing its volume of air as it moves and by car surface roughness and protrusions causing air turbulence. AD is proportional to the car's frontal area, the square of the speed and an AD factor: KAD. KAD is difficult to measure without a wind tunnel, but tunnel tests have shown that it runs about .001 for a smooth, streamlined car to .003 for a rough, boxy car.

AD = frontal area x spd. sqd. x KAD
= 20 x 55^2 x .0015 = 91 pounds

ACCELERATING FORCE "AF" is simply the "force = mass x acceleration" we learned in high school physics. Remember that mass is weight divided by acceleration due to gravity.

AF = 2500/32.2 x 3 = 233 pounds

GRADE FORCE "GF" is the extra force required to move the car up a hill, lifting the car using the hill as an inclined plane.

GF = CAR WEIGHT x % GRADE
= 2500 X .1 = 250 pounds

Let's review the values we have just calculated:

RR = 38 pounds AD = 91 pounds
AF = 233 pounds GF = 250 pounds

Note that RR and AD are small compared to AF and GF. That means we can cruise with considerably less force than we need to accelerate or climb hills. Since AF and GF are both proportional to weight, any efforts to improve performance should include reducing weight.

SPEED VS PROPULSION FORCE CURVES:

The values we calculated above were for the loads imposed by the maximum speed, acceleration and grade goals. If we did the same calculations for a range of values for car speed and each load and plotted them on a graph of car speed vs propulsion force we would get FIGURE 1. This graph shows the relative magnitudes of propulsion forces required to move the car at various speeds, rates of acceleration and grade steepness.

Note how the RR curve is vertical, indicating that the force required to overcome rolling resistance is the same for any speed. The CRUISE curve starts at the rolling resistance force and bends up to the right as speed increases showing the increasing force required to overcome aerodynamic drag as speed increases. The other curves show the forces to accelerate or climb at various rates or grades. To accelerate uphill add AF to GF.

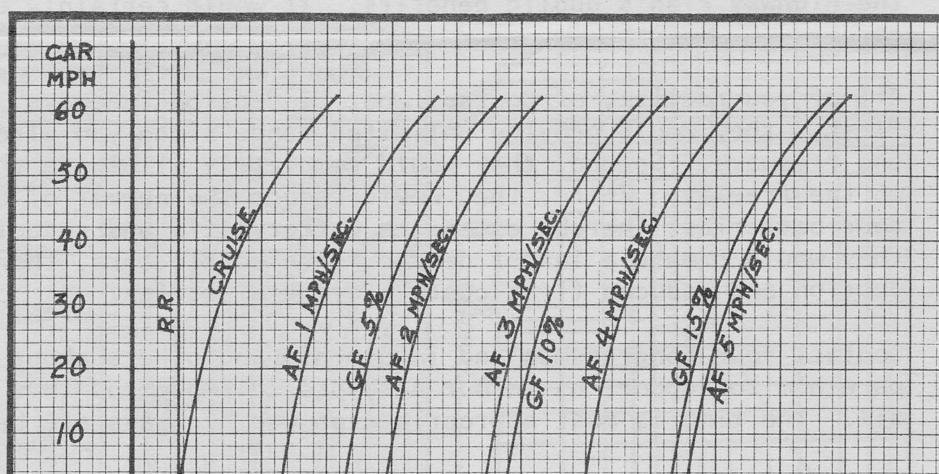


FIGURE 1. REQUIRED PROPULSION FORCES VS SPEED

GEAR RATIOS:

Now that we have determined the forces we need at the pavement to make our car perform, we need to relate those forces to the motor through the wheels, and drive train. We need to relate wheel and axle speed to car speed, which we can do with the following calculation: Wheel revolutions per mile = feet per mile/ wheel diameter x 3.1416 = 5280/1.87 x 3.1416 = 900 revs per mile. Wheel revolutions per minute at 1 mile per hour = revs per mile/60 minutes per hour = 900/60 = 15 wheel RPM per car MPH.

Now we can relate wheel RPM to motor RPM by multiplying the differential ratio by the individual gear ratios which gives us overall ratios of 10:1 in first gear, 5:1 in second and 3:1 in third. With these ratios we can build a table of car speeds, wheel or axle speeds and motor speeds for each gear such as TABLE 1.

CAR MPH	AXLE RPM	MOTOR RPM GEAR: 1	2	3
10	150	1500	750	450
20	300	3000	1500	900
30	450	4500	2250	1350
40	600	6000	3000	1800
50	750	7500	3750	2250
60	900	9000	4500	2700

TABLE 1

FIGURE 2 is a typical speed-torque curve for a motor with a shunt field separately excited at full field strength. For a series motor the lower current lines would be farther to the left indicating less torque per ampere at the lower currents due to the weaker field. Some manufacturers plot these curves with torque on the left and speed at the bottom, but the data are the same. You can reverse the axes by turning the graph over and tracing it on the back with speed on the left and torque at the bottom, using a light box or window.

On the Speed-Torque graph, FIGURE 2, notice how each successively higher voltage line intersects the speed scale, on the left, at a higher speed. This shows that motor speed is roughly proportional to applied voltage. Also notice the current scale, across the top, and how each line of higher current intersects the torque scale, at the bottom, at a higher torque value, indicating that torque is roughly proportional to current.

The motor curves show that our maximum voltage of 72, from our twelve-6 volt batteries, will produce a maximum motor speed of about 4500 RPM. Also, remember that our controller is rated to carry 400 amperes maximum. The Speed-Torque curves show that the most motor torque we can expect 400 amps to produce is 40 lb-ft. at 72 volts and 4500 RPM. If you refer back to FIGURE 1, the Propulsion Force curves, you will see that we need over 270 lb. of propulsion force to accelerate at our goal of 3 MPH/SEC. If our wheel radius were an even one foot, it would take 270 lb-ft of axle torque to produce the 270 pounds of force on the road. Fortunately, our first gear ratio (including differential) is 10:1. So, the 40 lb-ft of motor torque, times the 10:1 ratio, will produce 400 lb-ft of axle torque, more than enough for our acceleration goal in first gear. Actually, the available propulsion force is a little more than 400 lb. because our wheel radius is a little less than one foot. In the curve scale conversion calculations I have rounded the radius to an even foot to keep the numbers simple.

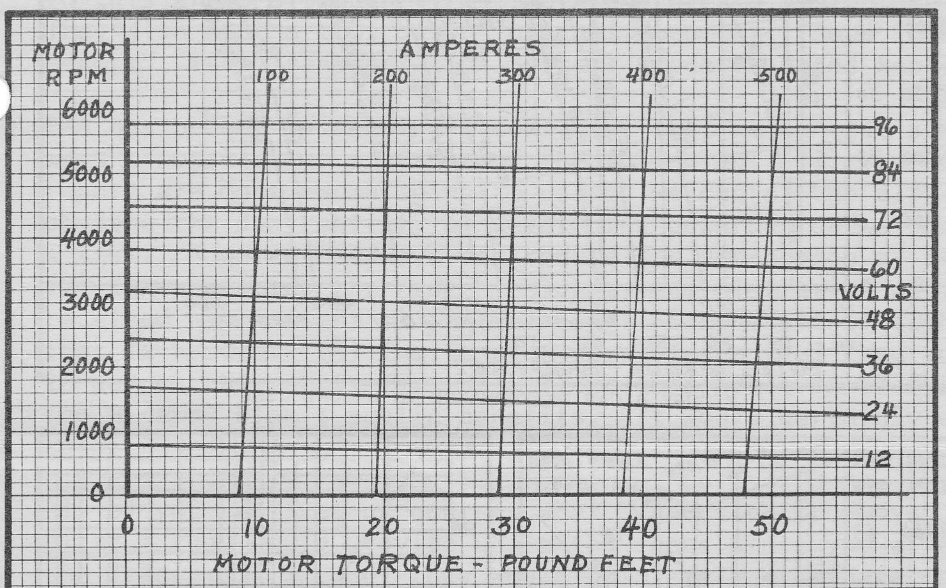


FIGURE 2. MOTOR SPEED-TORQUE-VOLTAGE-CURRENT CHARACTERISTICS

MOTOR CHARACTERISTICS:

The next thing we need to look at is the motor. We need to know at what speeds the motor will run when various voltages are applied, how much torque it will produce and what current it will draw to produce that torque. We must have the manufacturer's curves or run extensive tests to develop equivalent data. The motor manufacturer can furnish a "Speed-Torque" curve for your motor. But, if it is an aircraft generator, the curves probably won't extend above about 48 volts and you will need to extrapolate. Do it more accurately than I did.

CAR PERFORMANCE VS GEAR RATIO:

FIGURES 3, 4 and 5 are the car's Propulsion Force curves from FIGURE 1 with the motor Speed-Torque curves from FIGURE 2 re-scaled for each gear ratio and superimposed on them. Note that the motor and car speeds are from TABLE 1 for each gear ratio and that the scales for Propulsion Force and Motor Torque are related by the gear ratio.

FIRST GEAR:

Refer to FIGURE 3, the combined curves for first gear. Note the heavy lines along the 72 volt and 400 amp curves. These define the theoretical limits of operation in first gear due to our voltage and current limitations. This graph shows that you can, but you don't have to, accelerate up the 400 amp line at over 4 MPH/SEC. Whatever acceleration rate you use, you will press the accelerator farther down as speed increases, to maintain enough voltage on the motor to keep pushing enough current through it to maintain enough torque to continue accelerating at that rate. At some point, short of the 72 volt line, you will have the controller full-on but the motor's back-emf will have increased, due to increased motor speed, so that 72 volts will not be enough to maintain your acceleration rate. From that point current and torque begin to decrease, as speed increases, causing the rate of acceleration to decrease. Actual acceleration follows a path like the dashed line with acceleration rate continuing to decrease until a constant speed balance point is reached at the CRUISE curve. In practice you shift to second gear soon after the acceleration rate begins to decrease.

SECOND GEAR:

So, let's look at the similar graph for second gear, FIGURE 5. Since the gear ratio is half that of first gear, torque multiplication is decreased by half. Our 400 amps of current still produces about 40 lb.ft. of motor torque but only 200 pounds of propulsion force, now that the gear ratio is 5:1. The heavy lines again show the operating area, which starts on the 400 amp line at about 25 MPH because that's where we shifted gears. Our rate of acceleration is less than 2 MPH/SEC. and decreases to less than 1 MPH/SEC. as we approach the maximum cruising speed of 58 MPH. at our maximum voltage of 72. The dashed curve again shows the tapering-off of current, torque and acceleration as motor speed increases with the controller full-on. We can cruise in second gear at 55 MPH drawing about 250 amps (point A on the graph).

THIRD GEAR:

If we shift to third gear to further increase speed, the reduction in torque multiplication due to the lower gear ratio requires more motor torque and more current. But, with our maximum current of 400 amps we have only enough torque to cruise at about 51 MPH. That is the intersection of the CRUISE curve and the 400 amp curve, point C. Please notice also that, due to the lower motor speed in third gear, it only takes about 38 volts to push 400 amps through the motor. The accelerator pedal is at half throttle. You have experienced similar situations, starting up hills in high gear or overdrive in a marginally-powered car. You can't maintain speed even with the accelerator on the floor. This illustrates how critical gear ratios are. The more gears the better.

RANGE:

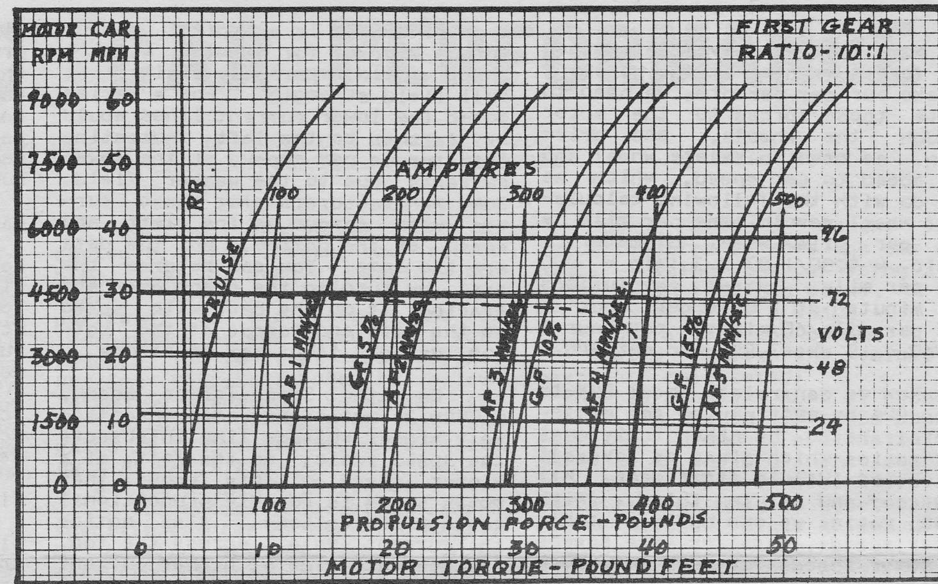
Electric car range varies widely for the same reasons miles per gallon do in an engine-powered car. But let's estimate range. Refer to FIGURE 4. At point A we are cruising at 55 MPH, drawing about 250 amperes. Our batteries have an ampere-hour rating of 240, but the fine print says that is at the 20 hour rate, which is 12 amperes. The battery discharge curve, FIGURE 6, shows they will be discharged in only 20 minutes at 250 amps. At 55 MPH that is 18 miles.

Let's try 35 MPH. On FIGURE 4 start at point A and move down the CRUISE curve to point B halfway between 30 and 40 MPH. The current lines indicate about 160 amperes to cruise at 35 MPH in second gear. The battery curve shows 40 minutes at 160 amperes. That will take us 23 miles at 35 MPH. So, it appears that our cruising range goal of 50 miles was not realistic for our car weight, number of batteries and motor current, at least in second gear. I suspect the motor current curves lost some accuracy in extrapolating them above 48 volts.

Looking back at FIGURE 3, we can cruise in first gear at 30 MPH drawing only 70 amps. That will give us about 110 minutes and 55 miles. That's better, if 30 MPH is fast enough for urban cruising.

These range estimates illustrate that our best current utilization occurs at the highest motor speeds we can attain. In general, the higher the voltage, the faster the motor will run and the lower the current because higher gear ratios multiply motor torque and thereby divide the current necessary to move the car. If we increase the number of batteries to 16 to get 96 volts, we could cruise at 35 MPH with 60 amperes. That would give us 106 minutes, and 62 miles.

Ideally, to optimize current utilization at the most frequently used speeds, our gear ratios, if we could select them, would be such that the controller would be full-on and the motor running at maximum speed during cruising. Maybe someday an efficient, continuously variable speed reducer will be invented.



FIRURE 3. CAR PERFORMANCE IN FIRST GEAR

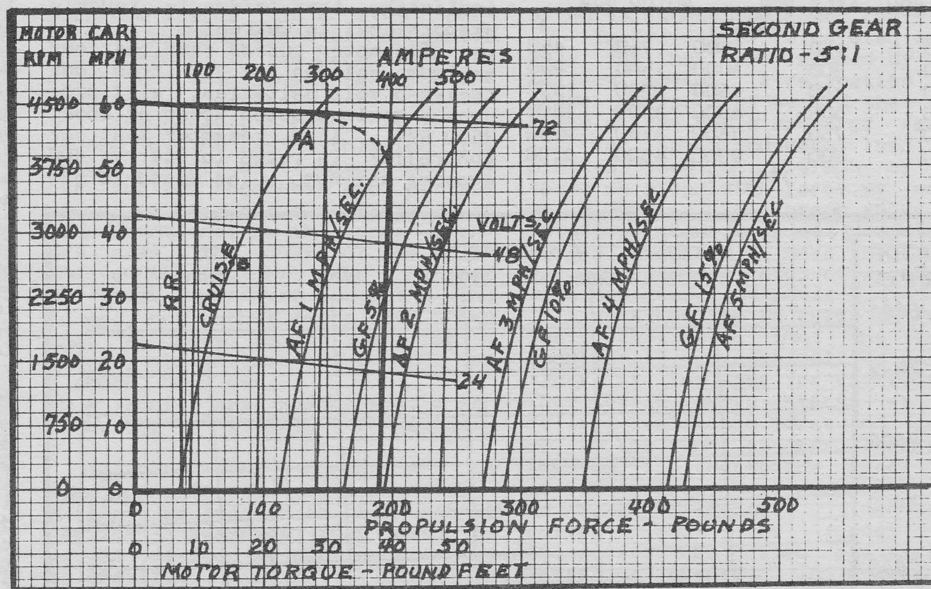


FIGURE 4. CAR PERFORMANCE IN SECOND GEAR

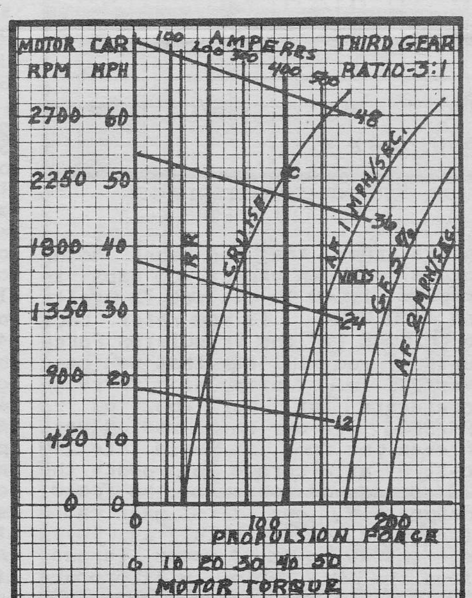


FIGURE 5. CAR PERF. THIRD GEAR

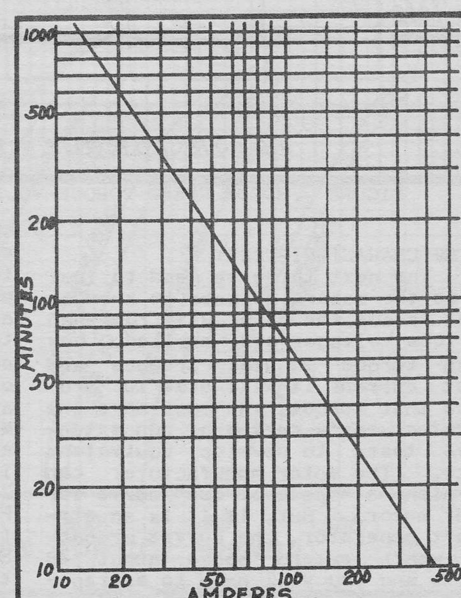


FIGURE 6. BATTERY DISCHARGE RATE

FOR SALE

1981 & 1982 E.A.A. RALLY WINNER

1981

E.A.A. Santa Clara Chapter

First Place Overall Endurance Trophy Winner!

1982

E.A.A. East Bay Chapter

First Place Overall

E.A.A. Santa Clara Chapter

First Place Stock Endurance Trophy Winner!

SAAB MODEL 96 ELECTRIC VEHICLE

SPECIFICATIONS & FEATURES

Curb Weight - 3000 lbs.; Maximum Speed - 75 mph; Acceleration - 0 to 30 mph -- 10 seconds; Range-Maximum - 118.9 miles at 1982 E.A.A. Santa Clara Rally; Range-Highway - 100 miles at constant 45 mph at 75 Amps. (San Jose to San Francisco and return); Range-City - 60 to 70 miles, depending on traffic and acceleration. Capacity - four passengers in comfort, five if absolutely needed; Motor - Prestolite MTC-4001 series wound - 20 Hp continuous - 40 Hp intermittent; Controller - Electric Vehicles Inc. (Skokan), two Motorola transistor design; Traction Batteries - twenty Globe-Union EV-1000 Oearly production - good ones) for nominal 120 Volt system; Accessory Battery - one 12 Volt Sears 9650 - only 85 cycles total on all batteries, not yet up to 100 cycle peak performance area; Drive Train - original Saab 4-speed transaxle and clutch - all newly rebuilt, including halfshafts and joints, upgraded brakes and suspension for the added weight; Tires - 250 miles on the very latest and ultimate in low rolling resistance Pirelli P8 185/65-SR15; Saab factory air dam; Fully enclosed belly pan; All power cables of Cornish 4/0 welding cable and soldered on brass connectors, 300 degree movement custom built meters to match factory instruments; Commercial duty 500 Amp break Emergency-Off switch.

All components for this vehicle selected for best quality available without regard to cost. A 10,000 lb. tow bar and custom designed self-limiting battery charger included. This vehicle has 2,300 miles since conversion and has never had a failure of any kind. Over $7,500 invested in electrical components and chassis, plus who knows how many hours of design and labor.

Priced at $7,000. Serious inquiries only to:

JACK HIGGINS
811 Jansen Avenue, San Jose, CA 95125
(408) 998-8288 after 6:00 PST

ATTENTION: Santa Clara Members will meet on February 12, instead of February 18, due to lack of room availability at Hewlett-Packard, Cupertino. Next months as usual.

ELECTRIC CAR SUPPLIES, PARTS, ETC.

Electric Vehicles Inc., Northern California EV Dealership offers Year-End Clearance. Cars: Jet 600 Minivan, new $10,995 - Jet 600 used 2K miles $8,995 - Jet 600 22K miles $5,995 - Jet Electrica (Escort) demo 9K miles $9,995 - Jet Electrica 007 (Omni 024) new demo $5,995 - Honda Civic Automatic, used $5,995. EV Conversion Components: Prestolite MTC 4001 DC Series Motors, new $795 - Transistor Speed Controllers EVI-82 400 Amps/up to 110V $695 - Electric Engine$_{TM}$ complete conversion unit $2,200 (EAA members discount). Write to EVI, 2736 Winfield Dr., Mountain View, CA 94040 or call (415) 964-3974.

New Controller Company - PMC and Siskiyou Energy Systems have joined forces to form a new Controller Company. PMC Energy Systems, Inc. in Berkeley, CA. The company plans to manufacture an advanced line of EV Controllers for use in commercial EVs. Controllers will be available to hobbyists via distribution outlets such as Electro Automotive and Flight Systems.

Electro Automotive presents the complete, efficient EV System, consisting of: Willey 9 Controller - The China Motor - Alco Batteries - and all necessary components for a complete conversion. For details call Mike Brown at (408) 438-3606.

Brewer Associates - Exclusive producer of Willey Solid State Controller Kits (to 450A and 120V), designed for easy assembly and big savings, with top quality components and a manual. We also stock blowers, contactors, meters, testing equipment, fuses, etc. Write or phone for our catalog: 21511 Deerpath Lane, Malibu, CA 90265 - (213) 456-6236.

AA Electracar, Inc. has reduced its business and moved to 1085 Tasman Drive #732, Sunnyvale, CA. For information in the Aquila, Electric Engine Kit, Batteries, etc., call Alfred Hardage at (408) 734-8385. Al will be handling the Alco batteries at $65 each for six or more, delivered with a 50 mile radius. He will also provide a vehicle moving service for $30 within a 30 mile radius.

FOR SALE

'80 Electric Bradley
Like new - needs Batteries
Asking $5,000/offer
Pat Owens (408) 742-6067

'79 Electra Van 600 - Driven only 2,500 miles - $9,000
Ivans Marts (415) 752-0880
Will finance or Lease

'81 Bradley GT II Electric
4,000 miles - CA registered
On board Charger - $10,200
Dynamic American
(619) 453-6755

(2) Battronic Minivans with 42 Hp Motor, (2) 56V Batts.
Built-in Charger - $2,500/ea
3530 Durfee Ave., Pico Rivera, CA 90660 (213) 699-0536

FOR SALE

Fiat 600 - Solid State Controller - J&H G-29 Motor - 10 Batts. - Asking $1,300
N.Rogers (408) 426-5975

Flight Systems Catalog-$3.00
EV Conversion Plans for VWs, Pinto, Chevette, Hybrids-$17.50
VTS, 1816 25th Avenue NE
Puyallup, WA 98371

'59 MGA - $4,500/offer
Willey Model 8 Control
Prestolite 20 HP Motor
72V EV 1000 Batteries
John (408) 624-7132

'80 Comuta Car - Driven 2,000+ miles by original owner
Asking $3,500
(415) 524-0223

FOR SALE

12 Trojan Batts. J-244 & T-135 used, excellent condition - only $350
(408) 867-5930

Lester Dual 84/12V Charger - $295. H.Wheelwright
4036 N. 900, Ogden, UT 84404
(801) 782-5792 evenings

MG 1100, Hydraulic Suspension
2CM76 Motor, Transistor Speed Controls, Berg Gibson Charger
All/part - $900
(415) 658-6586

GE EV-1 Motor, GE SCR Control
Accelerator Switch, Batt.Cables
Instruments, Lestronic Batt.Chg.
$1,700 delivered price
Dynamic American (619) 453-6755

"Guide to Electric Auto Conversion" - Fourth Edition. A clearly written 76-page Conversion Manual with an emphasis on practical techniques, using latest technology. Plans include several PROVEN Diagrams and Schematics, as well as a comprehensive Parts Procurement Directory. Separate Chapters thoroughly cover Expected Conversion Cost/Performance, Electric Motors, Adaptor Plates, Controllers, Batteries, Chargers, Maintenance, System Test/Integration Safety and Wiring Capacity. A real bargain for only $19.95 from Bill Williams, Dept. EAAN, Box 1548, Cupertino, CA 95015.