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Performance Testing of the AC Propulsion ELX Electric Vehicle

**W. E. Kramer
R. D. MacDowall
A. F. Burke**

*Work performed under
DOE Contract
No. DE-AC07-76ID01570*

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**W. E. Kramer
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**Prepared for the
U. S. Department of Energy
Assistant Secretary for Energy Efficiency and Renewable Energy (EE)
Under DOE Idaho Operations Office
Contract DE-AC07-76ID01570**

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ABSTRACT

Performance testing of the AC Propulsion ELX electric vehicle is described. Test data are presented and analyzed. The ELX vehicle is the first of a series of electric vehicles of interest to the California Air Resources Board. The test series is being conducted under a Cooperative Research and Development Agreement (CRADA) between the U.S. Department of Energy and the California Air Resources Board.

The tests which were conducted showed that the AC Propulsion ELX electric vehicle has exceptional acceleration and range performance. When the vehicle's battery was fully charged, the vehicle can accelerate from 0 to 96 km/h in about 10 seconds. Energy consumption and range tests using consecutive FUDS and HWFET Driving Cycles (the all-electric cycle) indicate that the energy economy of the AC Propulsion ELX electric vehicle with regenerative braking is 97 W·h/km, with a range of 153 km (95 miles). Computer simulations performed using the SIMPLEV Program indicate that the vehicle would have a range of 327 km (203 miles) on the all-electric cycle if the lead acid batteries were replaced with NiMH batteries having an energy density of 67 W·h/kg. Comparisons of FUDS test data with and without regenerative braking indicated that regenerative braking reduced the energy consumption of the ELX vehicle by approximately 25%.

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ACRONYMS

ABIR	Amps Battery In Recharge
ABOD	Amps Battery Out Discharge
CARB	California Air Resource Board
CRADA	Cooperative Research and Development Agreement
DCV	Discharge Cutoff Voltage
DR	Discharge Rate
DST	Dynamic Stress Test
EBIR	Energy in Battery In Recharge
EBOD	Energy Battery Out Discharge
ECT	Average Ending Charge Temperature
EDT	Average Ending Discharge Temperature
EV	Electric Vehicles
EVTL	Electric Vehicle Testing Laboratory
FUDS	Federal Urban Driving Cycle
HWFET	Highway Fuel Economy Driving Cycle
INEL	Idaho National Engineering Laboratory
LED	Light Emitting Diode
SAE	Society of Automotive Engineers
SOC	Battery State of Charge
TTOD	Total Time of Discharge
TTOC	Total Time of Charge
VDAS	Versatile Data Acquisition System
ZEV	Zero-Emission Vehicle

INTRODUCTION

A series of electric vehicles (EVs) will be performance-tested in the Electric Vehicle Testing Laboratory (EVTL) at the Idaho National Engineering Laboratory (INEL). These vehicles and their performance are of interest to the California Air Resources Board (CARB) as they track EV technology pursuant to their mandate for the sale of zero-emission vehicles (ZEV) starting in 1998. The EVTL work is being done under Task 2 of a Cooperative Research and Development Agreement (CRADA) between the U.S. Department of Energy (DOE) and CARB. The test plan for this work was approved by DOE. The INEL testing methodology and techniques are being transferred to the CARB vehicle testing laboratory.

The vehicles to be tested in this program are state-of-the-art. They also represent several driveline technologies and vehicle types. Table 1 is a tentative list of the vehicles to be tested. The time frame for the overall test program covers 1993, 1994, and 1995.

Table 1. Test Vehicle List

Vehicle	Battery
Cocconi CRX	Sealed Pb-Acid
Solectria GT Force	NiCd
Honda Prototype EV	Sealed Pb-Acid
Ford Ecostar	NaS
Solectria Force	Nickel Metal hydride
Chrysler TEVan	NiCd

VEHICLE AND SUBSYSTEMS DESCRIPTION

The AC Propulsion ELX electric vehicle (Figure 1) uses a high-performance AC powertrain and a sealed lead-acid traction battery pack in a converted 1992 Honda CRX chassis and body. The Honda CRX was retrofitted with an electric driveline by AC Propulsion, Inc., of San Dimas, CA, and is owned by South Coast Air Quality Management District (SCAQMD), Diamond Bar, CA. The mileage at the beginning of testing was 2,500 miles. The prototype EV has been used for demonstration purposes by SCAQMD. The vehicle conversion was completed in January 1993. The ELX's Power Electronics Unit comprises an inverter, battery charging circuitry (including regenerative braking), auxiliary 12 VDC power supply, and a nominal 336 V sealed-lead acid battery pack. The vehicle uses twenty-eight (28) 12 V OPTIMA 800S-SLI battery modules connected in series. The batteries are manufactured by Optima Battery, Inc., Denver, Colorado. The batteries are enclosed in a battery tunnel which is located down the center of the vehicle. A 100 kW, 4-pole, 3-phase induction motor, controlled by pulse-width modulation, powers the vehicle. The power semiconductors are MOSFETs.

The dash instrument cluster includes indicator lights for forward, neutral, and reverse gears; and battery voltage, motor voltage, and vehicle speed gauges. A battery meter is used to display amp-hours in charge and discharge and a trip battery meter is used to monitor the amp-hours or kilowatt-hours for individual trips. Temperature gauges monitor the temperatures of the motor, controller, and the batteries.

The on-board battery charger, which utilizes part of the inverter circuitry, has the capability for the user to set the maximum DC current and DC voltage to be used in charging the batteries. In addition, the user can select the maximum AC current delivered to the charger. AC line voltage and current are continuously displayed during the charging process. Individual battery module voltages are monitored through a single display. Battery module out-of-limit status is indicated through the use of 28 light emitting diodes (LEDs). If a module voltage falls below 11 V, or is above 14 V, a LED will light. The vehicle also uses LEDs to indicate low battery pack voltage in discharge, and over-voltage in charging.

Figure 1. ELX AC propulsion electric vehicle

The powertrain uses fixed-ratio gearing, eliminating all but one forward gear ratio from the original Honda transaxle. The system is rated for 100 kW, and the output power is not battery-limited. The vehicle is designed to permit operation at speeds in excess of 96 km/h (60 mph) and accelerate to 60 mph in less than 10 seconds. The ELX uses Goodyear Invicta GLR tires inflated to 65 psi. A detailed overview of the vehicle's components and operation is given in the Owner's manual (Reference 1) which is available from AC Propulsion Inc.

TEST PROGRAM AND DATA ACQUISITION

Chassis dynamometer tests were performed to determine the battery capacity, energy economy at constant speed, maximum effort acceleration, and vehicle energy consumption and range on the Federal Urban Driving Schedule (FUDS), the Federal Highway Test Schedule (FHWTS), and an all-electric cycle (FUDS + FHWTS) defined by CARB.

The vehicle test matrix thus was comprised of six different performance tests:

- Battery module capacity determination and verification of rated capacity
- Energy economy at constant speeds between 40 and 96 km/h.
- Maximum effort acceleration time.
- Energy consumption and range on FUDS and FHWTS.
- Energy consumption and range on the All-Electric Cycle.

A summary of the tests conducted at INEL and CARB are given below:

Cycle Tests	Location	Date Performed
Highway Driving Cycle	INEL	September 21, 1993
All Electric Range Test	INEL	September 23, 1993
Urban Driving Cycle	INEL	September 27, 1993
Highway Driving Cycle	INEL	September 28, 1993
All Electric Range Test	INEL	September 29, 1993
Urban Driving Cycle	INEL	September 29, 1993
LA92 Driving Cycle	INEL	September 30, 1993
All Electric Range Test	CARB	November 10, 1993
Constant Speed Tests	Location	Date Performed
88 km/h Constant Speed	INEL	September 28, 1993
64 km/h Constant Speed	INEL	October 1, 1993
Energy Economy Tests	Location	Date Performed
Energy Economy Test	INEL	September 23, 1993
Energy Economy Test	INEL	September 27, 1993
Energy Economy Test	INEL	September 30, 1993
Energy Economy Test	CARB	November 12, 1993
Energy Economy Test	CARB	November 16, 1993

A total of ten to fifteen test sequences are required to adequately characterize a candidate electric vehicle. The sequences are performed using the appropriate portions of Society of Automotive Engineers (SAE) Test Procedures J227a (Reference 2) and J1634 (Reference 3). Where modifications of the more recently defined, and largely untested, portions of J1634 were found to be required, they are identified, and the nature of the modification and the rationale for the change, discussed.

The dynamometers at the INEL and CARB were set based on vehicle coastdown data taken in Idaho Falls. The $C_D A$ and rolling resistance for the vehicle were determined from the coastdown times by the methods specified by SAE J1263 (Reference 3) and by using an iterative procedure using the SIMPLEV vehicle simulation program (Reference 5). Both approaches indicated the following road load values:

$$\begin{aligned} f_r &= 0.0067 \\ C_D A &= 5.75 \text{ ft}^2 (0.535 \text{ m}^2) \end{aligned}$$

The coastdown times measured in Idaho Falls (4800 ft) were then corrected for altitude effects to determine the coastdown curve (times vs. speed) for sea level, that was used to set the electro-mechanical dynamometers at the INEL and CARB. The test weight was 3,250 lbs (1477 kg).

The ELX vehicle was tested at both the INEL and CARB. At the INEL, data was taken using the laboratory-based Laboratory Data Acquisition System (LDAS) and CARB data was taken using an on-board Versatile Data Acquisition System (VDAS). The intent was to compare VDAS and LDAS test data and reconcile any observed differences. The AC Propulsion ELX electric vehicle with VDAS was returned to CARB, after the INEL tests were completed, for dynamometer and road testing. A photograph of the vehicle in the dynamometer testing laboratory is given in Figure 2.

Figure 2. INEL dynamometer test setup.

TEST RESULTS AND ANALYSIS

A compilation of the test data taken at the INEL is given in Appendix A. Data from each of the test sequences is discussed in the following sections and where appropriate compared with computer simulations of vehicle performance using SIMPLEV (Reference 5).

Battery Module Tests

The vehicle utilizes twenty-eight (28) Optima 800S-SLI sealed, lead acid battery modules. The nominal voltage of each module is 12 V and the modules are connected in series to form a nominal 336 V battery pack. A single new 800S-SLI module supplied by Optima Battery, Inc. was tested in the INEL Battery Test Laboratory. Three constant current discharge tests at the $C/2$ rate, and three dynamic stress tests (DST) were performed on the module. A photograph of the battery module is given in Figure 3. After each test, the battery module was recharged using an initial constant current of 15 A to the clamp voltage of 14.1 V, after which the current was tapered to a finishing current of 0.3 A. The charging time was 4 to 5 hours with an overcharge of 2 to 5% based on ampere-hours. The new battery module test results are given in Table 2.

Figure 3. Optima 800S 12 volt battery module.

Table 2. Test data for the Optima 800 S-SLI sealed, lead-acid battery module.

DISCHARGE DATA								
Cycle	Date	Disch. rate	Out A·h	Energy Out kW·h	Cut-Off Volts (V)	Avg Temp (C)	Max Temp (C)	Discharge Time
1	09/27/93	20	39.7	.46	10.5	24.0	24.0	1h 59m
2	09/28/93	20	41.6	.48	10.5	22.5	22.5	2h 05m
3	09/29/93	20	41.5	.48	10.5	21.5	21.5	2h 05m
4	10/04/93	DST	38.5	.42	7.8	27.0	27.0	1h 34m
5	10/05/93	DST	38.7	.43	7.8	24.5	24.5	1h 34m
6	10/06/93	DST	38.7	.43	7.8	25.0	25.5	1h 34m
CHARGE DATA								
Cycle	Date	A·h in (A·h)	Energy In (kW·h)	Finishing Current (Amp)	Over Chrg. (%)	Avg Temp (C)	Max Temp (C)	Charge Time
1	09/27/93	43.1	.56	.30	8.6	22.5	23.0	5h 53m
2	09/28/93	42.4	.55	.60	1.9	24.0	24.5	4h 34m
3	09/29/93	42.2	.54	.30	1.7	24.0	25.0	4h 30m
4	10/04/93	40.8	.52	.30	6.0	25.0	27.0	4h 19m
5	10/05/93	39.5	.51	.30	2.1	25.0	27.0	4h 06m
6	10/06/93	39.4	.51	.30	1.8	24.5	26.0	4h 05m

The average capacity of the battery module at the C/2 rate was 40.9 A·h with an energy capacity of 0.473 kW·h. The cutoff voltage for the three C/2 tests was 10.5 V. The average capacity of the battery module for the Dynamic Stress Tests (DST) was 38.6 A·h with an average energy capacity of 0.426 kW·h. The DST test was terminated when the battery module voltage reached 7.8 V. A summary of the battery characteristics are given in Table 3.

Table 3. Summary of the characteristics of the Optima Battery

Module Weight	17.5 kg
Nominal Battery Voltage	12 volts
Battery Resistance	5 to 7 mohm/module up to 80% DOD
Recharge	4 hours, 2% A h Overcharge

Battery Capacity	Ampere hours	Kilowatt Hours	Watt hours/kg
C/2 rate	40.9	0.473	27.0
Dynamic Stress Test (DST)	38.6	0.426	24.3

Battery Pack Tests

Two constant speed tests were run on the dynamometer to determine the capacity of the battery pack in the AC Propulsion ELX electric vehicle as tested at the INEL. At a speed of 64 km/h, the vehicle battery pack delivered 4.62 kW·h before the pack reached a terminal battery voltage of 245.4 V. At 88 km/h the battery pack used 4.85 kW·h before the pack reached a terminal battery voltage of 245.8 V. The average currents measured for the 64 km/h and the 88 km/h tests were 13.5 A and 25.1 A, respectively. Based on these test results it was concluded that the battery pack in the vehicle had only about 35% of the capacity that would be expected of a new optima battery pack. No changes were made to the battery pack in the vehicle during testing at the INEL. Hence any range tests performed at INEL are not representative of the vehicle's range using the Optima 800S-SLI batteries, because of the poor condition of the batteries in the INEL tests. The battery pack was replaced before the tests at CARB, so the range tests done at CARB are meaningful.

Energy Economy (J227)

Five energy economy performance tests were performed at speeds between 40 and 96 km/hr. A typical speed vs. time profile for the energy economy test is shown in Figure 4. Three tests were conducted at INEL and two tests were conducted at CARB with only one of

Figure 4. Typical energy economy test.

the tests conducted at CARB yielding useable results. A summary of the results are given in Tables 4 and 5. As shown in Table 4, battery output power measured as a function of vehicle speed during the tests conducted at CARB was slightly higher than in the tests conducted at INEL. The differences range from 0.6% to 9% depending on speed.

Table 4. Battery output power as a function of speed.

	INEL Energy Economy Test 9/23/93		INEL Energy Economy Test 9/27/93		INEL Energy Economy Test 9/30/93		INEL AVG	CARB Energy Test
Speed (km/h)	Test #1^(a) (kW)	Test #2^(b) (kW)	Test #1 (kW)	Test #2 (kW)	Test #1 (kW)	Test #2 (kW)	(kW)	11/12/93 (kW)
40	2.279	2.120	2.163	1.914	2.455	2.025	2.159	2.264
48	2.876	2.896	2.795	2.498	3.148	2.658	2.812	3.072
56	3.767	3.730	3.519	3.224	3.921	3.465	3.604	3.916
64	4.811	4.673	4.368	4.140	4.657	4.264	4.485	4.903
72	5.944	5.853	5.455	5.269	5.603	5.565	5.615	6.112
80	7.495	7.209	6.722	6.623	7.075	6.735	6.971	7.388
88	8.996	8.804	8.208	8.106	8.524	8.357	8.529	8.981
96	10.754	10.308	9.850	9.759	10.347	10.122	10.19	10.135
(a) Test at 100% state-of-charge (SOC)								
(b) Test at 50% SOC								

The average speeds at CARB had a tendency to be slightly higher than the average speeds at the INEL which likely accounts for part of the difference in the battery power values.

The energy consumption results (W·h/km) are shown in Table 5, compared with the calculated values obtained using SIMPLEX. The comparison between the measured and calculated energy consumption values agree quite well with the differences ranging between -2% and +9%.

Table 5. Energy Economy Test Summary.

Speed (km/h)	INEL AVG Power (kW)	CARB 11/12/93 Power (kW)	INEL AVG Energy Consump Net (W·h/km)	CARB 11/12/93 Energy Consump Net (W·h/km)	SIMPLEV Prediction (W·h/km)
32	—	1.702	—	50.8	
40	2.159	2.264	54.0	55.6	55
48	2.812	3.072	58.6	62.8	59
56	3.604	3.916	64.4	69.0	66
64	4.485	4.903	76.6	75.6	75
72	5.615	6.112	78.0	83.8	83
80	6.971	7.388	87.1	91.2	95
88	8.529	8.981	96.9	100.4	106
96	10.19	10.135	106.1	104.1	118
104	No Data	11.338	107.6	107.6	

Maximum Effort Acceleration (J227A)

Maximum effort acceleration tests were conducted at INEL for five different battery state-of-charge (SOC) conditions¹ (100, 95, 85, 80 and 55% SOC). A graph of the results are given in Figure 5. The figure shows that at 100% SOC the vehicle accelerated from 0 km/h to 96 km/h in approximately 10.4 seconds. The maximum output power from the batteries during the INEL test was 108.8 kW with a minimum battery voltage of 274.4 V and a maximum battery current of 384 A. In comparison, on-the-road acceleration tests with gusty winds conducted at CARB showed that the vehicle can accelerate on an average from

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¹ Note that for the INEL tests the battery had only about 35% of its rated capacity so that 100% SOC for the INEL tests represents a low state-of-charge for a new battery pack.

0 km/h to 96 km/h in approximately 10.2 seconds.² Table 6 is a summary of the vehicle acceleration test results at the INEL and CARB. It should be noted that during the acceleration tests at INEL, the vehicle had a tendency to slip off the dynamometer, and so the tests were conducted in a conservative manner.

Table 6. Acceleration performance - test and SIMPLEV.

Time (Seconds)					
Acceleration ³	100% SOC	95% SOC	85% SOC	80% SOC	55% SOC
0 to 48 km/h, INEL Dyno	5.61	5.6	5.4	5.5	6.9
SIMPLEV	4.1	—	—	—	—
0 to 80 km/h, INEL Dyno	8.4	8.6	8.4	9.3	16.1
SIMPLEV	7.5	—	—	—	—
0 to 96 km/h, INEL Dyno	10.4	10.7	11.0	12.9	23.3
CARB On-the-Road ⁴	10.0	—	—	—	—
SIMPLEV	10.2	—	—	—	—

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² Note in Figure 4 that 100% SOC represents 35% SOC for a new battery

³ Note that battery pack in poor condition for tests conducted at INEL

⁴ Note new Optima 800S-DC batteries installed for CARB testing.

Figure 5. Acceleration times for the AC propulsion ELX.

FUDS Tests

Federal Urban Driving Cycle (FUDS) tests were performed at the INEL. One set of tests (four successive driving cycles) were conducted with the regenerative braking enabled at the recommended setting⁵ and a second set (two successive driving cycles) were conducted with the regenerative braking disabled.

When regenerative braking was enabled, the average energy consumption per kilometer for the four FUDS cycles was 101.4 W·h/km. The average energy consumption for each FUDS cycle was 1.227 kW·h. When regenerative braking was disabled, the average energy consumption per kilometer was 135.5 W·h/km. The average energy consumption for the two FUDS cycles without regenerative braking was 1.656 kW·h. The percent energy consumption reduction on the FUDS, using regenerative braking, was calculated to be 25.9%. Table 7 is a summary of the results for the FUDS tests which were conducted.

Table 7. Energy Consumption on FUDS cycle.

Test	kW·h/Cycle	Net W·h/km	Gross W·h/km
With Regenerative Braking	1.227	101	136
Without Regenerative Braking	1.656	136	136
SIMPLEV With Regenerative Braking	—	109	143

All Electric Cycle Tests

All-electric cycle tests were conducted at INEL and at CARB. The tests conducted at the INEL utilized the battery pack delivered with the vehicle, and as noted previously, that

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⁵ The regeneration in the ELX vehicle is adjustable using a knob on the dash. The setting for the FUDS tests was that recommended for general use by AC Propulsion. It was not the maximum setting.

pack had only about 35% of the manufacturer's rated capacity. The tests conducted at CARB utilized a new battery pack. During the testing at the INEL, regenerative braking was enabled. The All-Electric Cycle Test consists of consecutive FUDS and HWFET cycles with a ten minute break after each set of cycles. Typical speed and battery power vs. time traces for the all-electric cycle test are given in Figure 6, and typical voltage and current vs. time traces are given in Figure 7. The average energy consumption for the ELX vehicle on the all-electric cycle was measured to be 2.785 kW·h which yielded an energy consumption per kilometer of 97.2 W·h/km.

A second All-Electric Cycle Test was performed at CARB. Unlike the tests performed at INEL, the CARB tests utilized new Optima modules. The vehicle finished five complete cycles (FUDS and HWFET) and reached the test termination criterion during the 6th profile after 677 seconds. The vehicle completed a range of 152.6 km (94.8 miles) with a net energy out of the battery for the complete test of 15.23 kW·h. The average energy consumption for the completed five cycles was 13.696 kW·h which yields an energy consumption per kilometer of 99.4 W·h/km.

A simulation of the vehicle on the all-electric cycle was run using SIMPLEX. The simulation was run to predict the vehicle's energy economy and range with a new battery pack which met the manufacturer's rated capacity. The simulation predicted that the vehicle's range would be approximately 165 km (103 miles) on the All-Electric Cycle Test. Table 8 is a summary of the test and simulation results.

Table 8. All-Electric Cycle Test energy consumption and range summary.

Test Description	Location	Range (km)	Net Energy (kW·h)	Energy Consumption (W·h/km)
Dynamometer w/ Regen	INEL	—	4.59	97.2
Dynamometer w/Regen	CARB	152.6	15.23	99.4
SIMPLEX w/Regen		155.0	17.41	100.0

Figure 6. All electric cycle test speed and power vs. time.

Figure 7. All electric cycle test voltage and current vs time

LA-92 Driving Cycle Tests

LA92 Driving Cycle Tests were also performed at INEL. The energy use per kilometer was 128.4 W·h/km for the first cycle and 126.7 W·h/km for the second cycle. The average net energy for the two driving cycles conducted was 2.026 kW·h and the average gross energy used for the two cycles was 2.640 kW·h. The test results are given in Appendix A. Typical speed and power vs time profiles are given in Figure 8. A comparison of the energy consumption of the vehicle on the LA92 cycle with values for other driving cycles is shown in Table 9. Note that the energy consumption on the LA92 cycle is significantly higher than on the other cycles. Also, note that the SIMPLEV simulation results are in good agreement with test results, and that the energy recovery from regeneration braking is about 24% for the LA92 cycle.

Table 9. Comparison of energy economy (W·h/km) for various driving cycles - test and SIMPLEV.

Driving Cycle	Test		SIMPLEV	
	Net	Gross	Net	Gross
FUDS	101	136	109	143
Highway	96	100	100	112
LA92	127	167	129	175

Figure 8. LA-92 typical speed and power vs. time profile.

PROJECTIONS OF FUTURE ELECTRIC VEHICLE PERFORMANCE

The purpose of this section of the report is to estimate the range of a vehicle similar to the ELX if different vehicle and battery technologies were employed. The projections are based on vehicle computer simulation results obtained using SIMPLEV. The AC Propulsion ELX electric vehicle as tested utilized Optima Model 800S Pb-Acid batteries. Tests conducted at CARB indicated that the vehicle range for the All Electric Cycle Test was 152.6 km (94.8 mi). As indicated in Table 8, SIMPLEV predicts the range of a vehicle within approximately 2%. If the vehicle were to employ Ovonic NiMH batteries, SIMPLEV predicts that the vehicle range would be increased to 320 km (199 mi). If modifications were made to the vehicle to lower the drag coefficient and rolling resistance, SIMPLEV predicts that the vehicle range could be further increased to 375 km (233 mi) if NiMH batteries were employed. Table 10 is a summary of the performance projections obtained using SIMPLEV.

Table 10. Performance projections of the AC Propulsion ELX electric vehicle on the all-electric test cycle.

Vehicle	Battery Type	Test Weight (kg)	Drag Coef	Rolling Resist.	Range (km)	W-h/km
Existing AC Propulsion ELX electric vehicle	Optima Pb-Acid	1482	0.303	0.0067	152 (Actual)	100
Modified AC Propulsion ELX electric vehicle	Optima Pb-Acid	1339	0.240	0.0055	184	87
AC Propulsion ELX electric vehicle	SAFT NiCd	1482	0.303	0.0067	188	100
Modified AC Propulsion ELX electric vehicle	SAFT NiCd	1339	0.240	0.0055	240	87
AC Propulsion ELX electric vehicle	OVONICS NiMH	1482	0.303	0.0067	320	100
Modified AC Propulsion ELX electric vehicle	OVONICS NiMH	1339	0.240	0.0055	375	87

SUMMARY AND CONCLUSIONS

Tests of the AC Propulsion ELX electric vehicle were performed at the INEL and CARB. The tests showed that the ELX vehicle has exceptional acceleration, energy consumption, and range performance. The conversion of a 1992 Honda CRX was professionally done with only minor impact on the passenger compartment. The vehicle operated very reliably and had excellent dash instrumentation, including LEDs indicating the condition of each of the modules in the 336 V battery pack. The ELX used Optima sealed lead-acid batteries (12 V, 46 A·h).

Energy consumption and range tests on the all-electric driving cycle (FUDS + highway) indicated that the energy consumption of the ELX vehicle is 97 W·h/km with a range of 152 km (95 miles) using new Optima batteries. A summary of test data for various other driving cycles is given in Table 11. Tests were conducted on the FUDS cycle with the ELX vehicle with and without regenerative braking. The results indicated that the net energy consumption was decreased by 25% using regenerative braking. This percentage of decrease is nearly double that found in previous tests of electric vehicles at the INEL.

Table 11. Energy economy and range test results for various driving cycles.

Driving Cycle	Net W·h/km	Gross W·h/km	Maximum Range on Driving Cycle (km)	Source
FUDS	101	136	—	INEL Test
HIGHWAY	97	100	—	INEL Test
LA92	127	165	—	INEL TESTS
ALL ELECTRIC (FUDS + highway)	100		152	CARB TESTS

Maximum effort acceleration tests were performed both at the INEL and CARB. The ELX vehicle accelerated to 30 mph in 5 seconds and to 60 mph in 10 seconds. Peak battery output power as high as 108 kW was measured in the acceleration tests on the dynamometer at the INEL.

Calculations of the range performance of the ELX vehicle using the Ovonic nickel-metal-hydride (NiMH) batteries were made using the SIMPLEV computer simulation program. The NiMH batteries have an energy density of 67 W·h/kg at C/2. The results of the calculations indicate a range of 320 km (199 mi) for the ELX vehicle on the all-electric test cycle. If the vehicle were modified to reduce its weight by about 145 kg (315 lb), its drag coefficient from 0.3 to 0.24, and rolling resistance coefficient from 0.0067 to 0.0055, the range using the NiMH batteries would be 375 km (233 mi). The projected acceleration times for the modified ELX would be 4 seconds to 30 mph and 9 seconds to 60 mph.

The results of the tests of the AC Propulsion ELX indicate that technology currently exists to design 4-passenger electric vehicles having good acceleration, top-speed performance, and a range of about 100 miles using sealed lead-acid batteries, and about 200 miles using NiMH batteries. These designs could be implemented using available vehicle chassis such as the Honda CRX.

REFERENCES

1. AC Propulsion ELX Owners Manual.
2. SAE J1634, Electric Vehicle Energy Consumption and Range Test Procedure, May 1993.
3. SAE J1263, Road Load Measurement & Dynamometer Simulation Using Coastdown Techniques, May 1984
4. SAE J227, Electric Vehicle Test Procedure Draft, May 1986.
5. Cole, G.H., "*SIMPLEV: A Simple Electric Vehicle Simulation, Version 2.0*", EG&G Report No. DOE/ID-10293-2, April 1993.

APPENDIX A

Compilation of Test Data
For
The AC Propulsion ELX Electric Vehicle

PART I:

**Testing on the Dynamometer at the Idaho National
Engineering Laboratory**

Dynamometer Setting: Coastdown curve based on

Test Weight: 3,250 lbs

$C_D A$: 5.75 ft²

fr: 0.0067

TESTS COMPLETED ON THE COCCONI ELECTRIC VEHICLE
PERFORMED AT THE IDAHO NATIONAL ENGINEERING LAB

<u>Cycle Tests</u>	<u>Date Performed</u>
Highway Driving Cycle	September 21, 1993
All Electric Range Test	September 23, 1993
Urban Driving Cycle	September 27, 1993
Highway Driving Cycle	September 28, 1993
All Electric Range Test	September 29, 1993
Urban Driving Cycle	September 29, 1993
LA92 Driving Cycle	September 30, 1993

<u>Constant Speed Tests</u>	<u>Date Performed</u>
88 km/h Constant Speed	September 28, 1993
64 km/h Constant Speed	October 1, 1993

<u>Energy Economy Tests</u>	<u>Date Performed</u>
Energy Economy Test 9/23	September 23, 1993
Energy Economy Test 9/27	September 27, 1993
Energy Economy Test 9/30	September 30, 1993

**COCCONI CRX ELECTRIC VEHICLE TEST RESULTS
PERFORMED AT THE IDAHO NATIONAL ENGINEERING LAB**

HIGHWAY FUEL ECONOMY TEST 9/21/93 CYCLE 1

Distance	16.5516 km
Battery Amp Hours Out	6.6404 AH
Battery Amp Hours In	0.0009 AH
Battery Amp Hours Net	6.6404 AH
Battery Energy Out	2.3109 KWh
Battery Energy In	0.0003 KWh
Battery Energy Net	2.3109 KWh
Watt Hours per Kilometer	139.6203 Wh/km

Driving Cycle Discharge Information:

Minimum Battery Voltage	340.2260 Volts
Maximum Battery Current	110.8400 Amps
Maximum Battery Power	37.7410 KW

Driving Cycle Regen Information:

Maximum Battery Voltage	363.4020 Volts
Maximum Battery Current	0.8057 Amps
Maximum Battery Power	-0.1912 KW

Test Performed on September 21, 1993

**COCCONI CRX ELECTRIC VEHICLE TEST RESULTS
PERFORMED AT THE IDAHO NATIONAL ENGINEERING LAB**

HIGHWAY FUEL ECONOMY TEST   9/21/93   CYCLE 2

Distance	16.5569	km
Battery Amp Hours Out	6.3376	AH
Battery Amp Hours In	0.0000	AH
Battery Amp Hours Net	6.3376	AH
Battery Energy Out	2.1846	KWh
Battery Energy In	0.0000	KWh
Battery Energy Net	2.1846	KWh
Watt Hours per Kilometer	131.9496	Wh/km

Driving Cycle Discharge Information:

Minimum Battery Voltage	334.8350	Volts
Maximum Battery Current	113.6340	Amps
Maximum Battery Power	38.4664	KW

Driving Cycle Regen Information:

No regen observed for second cycle.

Test Performed on September 21, 1993

**COCCONI CRX ELECTRIC VEHICLE TEST RESULTS
PERFORMED AT THE IDAHO NATIONAL ENGINEERING LAB**

HIGHWAY FUEL ECONOMY TEST   9/21/93   CYCLE 3

Distance	16.5469	km
Battery Amp Hours Out	6.3863	AH
Battery Amp Hours In	0.0000	AH
Battery Amp Hours Net	6.3863	AH
Battery Energy Out	2.1686	KWh
Battery Energy In	0.0000	KWh
Battery Energy Net	2.1686	KWh
Watt Hours per Kilometer	131.0594	Wh/km

Driving Cycle Discharge Information:

Minimum Battery Voltage	330.7050	Volts
Maximum Battery Current	131.6050	Amps
Maximum Battery Power	43.3529	KW

Driving Cycle Regen Information:

No regen observed for third cycle

Test Performed on September 21, 1993

**COCCONI CRX ELECTRIC VEHICLE TEST RESULTS
PERFORMED AT THE IDAHO NATIONAL ENGINEERING LAB**

HIGHWAY FUEL ECONOMY TEST 9/21/93 CYCLE 4

Distance	9.9674 km
Battery Amp Hours Out	4.4916 AH
Battery Amp Hours In	0.0207 AH
Battery Amp Hours Net	4.4914 AH
Battery Energy Out	1.2772 KWh
Battery Energy In	0.0068 KWh
Battery Energy Net	1.2771 KWh
Watt Hours per Kilometer	128.1295 Wh/km

Driving Cycle Discharge Information:

Minimum Battery Voltage	245.4660 Volts
Maximum Battery Current	129.8440 Amps
Maximum Battery Power	31.8930 KW

Driving Cycle Regen Information:

Maximum Battery Voltage	338.8690 Volts
Maximum Battery Current	0.5962 Amps
Maximum Battery Power	-0.1986 KW

NOTE: NOT a complete cycle.

Test Performed on September 21, 1993

Speed and Power vs Time
First Cycle from Highway Test 9/21/93

Voltage and Current vs Time
First Cycle from Highway Test 9/21/93

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Net Amp Hours and Net Kilowatt Hours
First Cycle from Highway Test 9/21/93

**COCCONI CRX ELECTRIC VEHICLE TEST RESULTS
PERFORMED AT THE IDAHO NATIONAL ENGINEERING LAB**

ALL ELECTRIC RANGE TEST 9/23/93 CYCLE 1

Distance	28.7243 km
Battery Amp Hours Out	12.7314 AH
Battery Amp Hours In	0.0007 AH
Battery Amp Hours Net	12.7313 AH
Battery Energy Out	4.3665 KWh
Battery Energy In	0.0002 KWh
Battery Energy Net	4.3664 KWh
Watt Hours per Kilometer	152.0130 Wh/km

Driving Cycle Discharge Information:

Minimum Battery Voltage	328.8650 Volts
Maximum Battery Current	136.5990 Amps
Maximum Battery Power	44.9665 KW

Driving Cycle Regen Information:

Maximum Battery Voltage	362.1470 Volts
Maximum Battery Current	1.6964 Amps
Maximum Battery Power	-0.1899 KW

Test Performed on September 23, 1993

COCCONI CRX ELECTRIC VEHICLE TEST RESULTS
PERFORMED AT THE IDAHO NATIONAL ENGINEERING LAB

ALL ELECTRIC RANGE TEST   9/23/93   CYCLE 2

Distance	21.4575	km
Battery Amp Hours Out	9.4252	AH
Battery Amp Hours In	0.0000	AH
Battery Amp Hours Net	9.4251	AH
Battery Energy Out	2.9891	KWh
Battery Energy In	0.0000	KWh
Battery Energy Net	2.9891	KWh
Watt Hours per Kilometer	139.3052	Wh/km

Driving Cycle Discharge Information:

Minimum Battery Voltage	245.6830	Volts
Maximum Battery Current	159.3970	Amps
Maximum Battery Power	42.8615	KW

Driving Cycle Regen Information:

Maximum Battery Voltage	344.7780	Volts
Maximum Battery Current	0.3597	Amps
Maximum Battery Power	-0.0957	KW

NOTE: This is not a complete cycle. Test was
terminated after completing 1180 seconds
of the second cycle.

Test Performed on September 23, 1993

Speed and Power vs Time
First Cycle from All Electric 9/23/93

Voltage and Current vs Time
First Cycle from All Electric 9/23/93

Net Amp Hours & Net Kilowatt Hours
First Cycle from All Electric 9/23/93

**COCCONI CRX ELECTRIC VEHICLE TEST RESULTS
PERFORMED AT THE IDAHO NATIONAL ENGINEERING LAB**

88kmh Constant Speed Test Summary

Average Speed	88.6809	kmh
Maximum Speed	90.1427	kmh
Minimum Speed	87.5224	kmh
Average Battery Current	25.0963	amps
Average Battery Voltage	337.5325	volts
Average Battery Power	8.4264	KW
Distance (Range)	51.4094	km
Battery Amp Hours Out	14.5466	AH
Battery Amp Hours Net	14.5466	AH
Battery Energy Out (KWh)	4.8848	KWh
Battery Energy Net (KWh)	4.8848	KWh
Net Amp Hours per Kilometer	0.2829	AH/km
Net Kilowatt Hours per Kilometer	0.0950	KWh/km

Test Performed on September 28, 1993

Net Amp Hours vs. Distance for 88kmh Test
Performed on September 28, 1993

Net KWh vs. Distance for 88kmh Test
Performed on September 28, 1993

Speed vs. Distance for 88kmh Constant Speed Test
Performed on September 28, 1993

**COCCONI CRX ELECTRIC VEHICLE TEST RESULTS
PERFORMED AT THE IDAHO NATIONAL ENGINEERING LAB**

MAXIMUM ACCELERATION TEST AT 100% STATE OF CHARGE

0kmh to 16kmh (10mph)	2.6060 sec
0kmh to 32kmh (20mph)	4.1060 sec
0kmh to 48kmh (30mph)	5.6060 sec
0kmh to 64kmh (40mph)	7.2060 sec
0kmh to 80kmh (50mph)	8.4060 sec
0kmh to 96kmh (60mph)	10.4110 sec
Average Battery Power	71.9313 KW
Maximum Battery Power	108.8640 KW
Minimum Battery Voltage	274.4490 Volts
Maximum Battery Current	384.2950 Amps
Distance (0-96kmh)	0.1306 km

Test Performed on October 20, 1993

Maximum Acceleration Test at 100% SOC 10/20/93
Speed and Power vs. Elapsed Time

Maximum Acceleration Test at 100% SOC 10/20/93
Battery Voltage and Current vs. Elapsed Time

**COCCONI CRX ELECTRIC VEHICLE TEST RESULTS
PERFORMED AT THE IDAHO NATIONAL ENGINEERING LAB**

MAXIMUM ACCELERATION TEST AT 95% STATE OF CHARGE

0kmh to 16kmh (10mph)	1.8000 sec
0kmh to 32kmh (20mph)	3.9010 sec
0kmh to 48kmh (30mph)	5.6360 sec
0kmh to 64kmh (40mph)	7.1460 sec
0kmh to 80kmh (50mph)	8.5460 sec
0kmh to 96kmh (60mph)	10.7060 sec
Average Battery Power	71.2528 KW
Maximum Battery Power	103.0740 KW
Minimum Battery Voltage	262.4800 Volts
Maximum Battery Current	383.5820 Amps
Distance (0-96kmh)	0.1429 km

Test Performed on October 20, 1993

Maximum Acceleration Test at 95% SOC 10/20/93

Maximum Acceleration Test at 95% SOC 10/20/93
Battery Voltage and Current vs. Elapsed Time

**COCCONI CRX ELECTRIC VEHICLE TEST RESULTS
PERFORMED AT THE IDAHO NATIONAL ENGINEERING LAB**

MAXIMUM ACCELERATION TEST AT 85% STATE OF CHARGE

0kmh to 16kmh (10mph)	2.0000 sec
0kmh to 32kmh (20mph)	3.7990 sec
0kmh to 48kmh (30mph)	5.4490 sec
0kmh to 64kmh (40mph)	7.0000 sec
0kmh to 80kmh (50mph)	8.4050 sec
0kmh to 96kmh (60mph)	11.0050 sec
Average Battery Power	73.3032 KW
Maximum Battery Power	99.7693 KW
Minimum Battery Voltage	255.2640 Volts
Maximum Battery Current	382.5450 Amps
Distance (0-96kmh)	0.1518 km

Test Performed on October 20, 1993

Maximum Acceleration Test at 85% SOC 10/20/93
Speed and Power vs. Elapsed Time

Maximum Acceleration Test at 85% SOC 10/20/93

**COCCONI CRX ELECTRIC VEHICLE TEST RESULTS
PERFORMED AT THE IDAHO NATIONAL ENGINEERING LAB**

MAXIMUM ACCELERATION TEST AT 80% STATE OF CHARGE

0kmh to 16kmh (10mph)	2.1040 sec
0kmh to 32kmh (20mph)	2.9350 sec
0kmh to 48kmh (30mph)	5.4550 sec
0kmh to 64kmh (40mph)	6.7550 sec
0kmh to 80kmh (50mph)	9.3100 sec
0kmh to 96kmh (60mph)	12.9090 sec
Average Battery Power	60.1060 KW
Maximum Battery Power	86.3080 KW
Minimum Battery Voltage	251.9420 Volts
Maximum Battery Current	341.3210 Amps
Distance (0-96kmh)	0.1972 km

Test Performed on October 20, 1993

Maximum Acceleration Test at 80% SOC 10/20/93
Speed and Power vs. Elapsed Time

Maximum Acceleration Test at 80% SOC 10/20/93
Battery Voltage and Current vs. Elapsed Time

**COCCONI CRX ELECTRIC VEHICLE TEST RESULTS
PERFORMED AT THE IDAHO NATIONAL ENGINEERING LAB**

MAXIMUM ACCELERATION TEST AT 75% STATE OF CHARGE

0kmh to 16kmh (10mph)	2.6500 sec
0kmh to 32kmh (20mph)	4.4540 sec
0kmh to 48kmh (30mph)	5.9400 sec
0kmh to 64kmh (40mph)	8.5050 sec
0kmh to 80kmh (50mph)	12.0100 sec
0kmh to 96kmh (60mph)	16.8100 sec
Average Battery Power	45.7834 KW
Maximum Battery Power	68.1879 KW
Minimum Battery Voltage	250.4660 Volts
Maximum Battery Current	280.6460 Amps
Distance (0-96kmh)	0.2624 km

Test Performed on October 20, 1993

**COCCONI CRX ELECTRIC VEHICLE TEST RESULTS
PERFORMED AT THE IDAHO NATIONAL ENGINEERING LAB**

MAXIMUM ACCELERATION TEST AT 55% STATE OF CHARGE

0kmh to 16kmh (10mph)	2.0500 sec
0kmh to 32kmh (20mph)	3.9610 sec
0kmh to 48kmh (30mph)	6.9060 sec
0kmh to 64kmh (40mph)	10.8100 sec
0kmh to 80kmh (50mph)	16.1010 sec
0kmh to 96kmh (60mph)	23.3150 sec
Average Battery Power	31.9398 KW
Maximum Battery Power	35.4159 KW
Minimum Battery Voltage	248.3200 Volts
Maximum Battery Current	142.3120 Amps
Distance (0-96kmh)	0.3975 km

Test Performed on October 20, 1993

COCCONI CRX ELECTRIC VEHICLE TEST RESULTS
PERFORMED AT THE IDAHO NATIONAL ENGINEERING LAB

ENERGY ECONOMY TEST 9/27/93 CYCLE 1

Target Speed	Average Speed	Average Power	Net AH per km	Net KW hrs per km
40 km/h	40.329	2.163	0.152	0.053
48 km/h	48.311	2.795	0.164	0.057
56 km/h	56.364	3.519	0.178	0.062
64 km/h	64.337	4.368	0.194	0.067
72 km/h	72.458	5.455	0.217	0.075
80 km/h	80.643	6.722	0.242	0.083
88 km/h	88.672	8.208	0.271	0.092
96 km/h	96.727	9.850	0.302	0.102

NOTE: Average Power is in Kilowatts

Test Performed on September 27, 1993

COCCONI CRX ELECTRIC VEHICLE TEST RESULTS
PERFORMED AT THE IDAHO NATIONAL ENGINEERING LAB

ENERGY ECONOMY TEST 9/27/93 CYCLE 2

Target Speed	Average Speed	Average Power	Net AH per km	Net KW hrs per km
40 km/h	40.350	1.914	0.138	0.047
48 km/h	48.377	2.498	0.150	0.051
56 km/h	56.321	3.224	0.167	0.057
64 km/h	64.411	4.140	0.188	0.064
72 km/h	72.341	5.269	0.213	0.072
80 km/h	80.606	6.623	0.242	0.082
88 km/h	88.679	8.106	0.272	0.091
96 km/h	96.709	9.759	0.302	0.101

NOTE: Average Power is in Kilowatts

Test Performed on September 27, 1993

Complete Energy Economy Test run on 9/27/93

First Cycle from Energy Economy Test run 9/27/93

Second Cycle from Energy Economy Test run 9/27/93

COCCONI CRX ELECTRIC VEHICLE TEST RESULTS
PERFORMED AT THE IDAHO NATIONAL ENGINEERING LAB

ENERGY ECONOMY TEST 9/23/93 CYCLE 1

Target Speed	Average Speed	Average Power	Net AH per km	Net KW hrs per km
40 km/h	40.066	2.279	0.159	0.056
48 km/h	48.134	2.876	0.168	0.059
56 km/h	56.268	3.767	0.190	0.067
64 km/h	64.278	4.811	0.212	0.075
72 km/h	72.219	5.944	0.233	0.081
80 km/h	80.634	7.495	0.265	0.092
88 km/h	88.684	8.996	0.290	0.101
96 km/h	96.678	10.754	0.320	0.111

NOTE: Average Power is in Kilowatts

Test Performed on September 23, 1993

COCCONI CRX ELECTRIC VEHICLE TEST RESULTS
PERFORMED AT THE IDAHO NATIONAL ENGINEERING LAB

ENERGY ECONOMY TEST 9/23/93 CYCLE 2

Target Speed	Average Speed	Average Power	Net AH per km	Net KW hrs per km
40 km/h	40.283	2.120	0.149	0.052
48 km/h	48.279	2.896	0.170	0.059
56 km/h	56.342	3.730	0.189	0.066
64 km/h	64.374	4.673	0.208	0.072
72 km/h	72.589	5.853	0.233	0.081
80 km/h	80.521	7.209	0.259	0.089
88 km/h	88.639	8.804	0.289	0.099
96 km/h	96.537	10.308	0.312	0.106

NOTE: Average Power is in Kilowatts

Test Performed on September 23, 1993

Complete Energy Economy Test run on 9/23/93

First Cycle from Energy Economy Test run on 9/23/93

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Second Cycle from Energy Economy Test run 9/23/93

**COCCONI CRX ELECTRIC VEHICLE TEST RESULTS
PERFORMED AT THE IDAHO NATIONAL ENGINEERING LAB**

URBAN DRIVING CYCLE TEST 9/29/93 CYCLE 1

Distance	12.1044 km
Battery Amp Hours Out	4.8002 AH
Battery Amp Hours In	0.0029 AH
Battery Amp Hours Net	4.7976 AH
Battery Energy Out	1.6718 KWh
Battery Energy In	0.0009 KWh
Battery Energy Net	1.6710 KWh
Watt Hours per Kilometer	138.0511 Wh/km

Driving Cycle Discharge Information:

Minimum Battery Voltage	335.2260 Volts
Maximum Battery Current	125.6620 Amps
Maximum Battery Power	42.6647 KW

Driving Cycle Regen Information:

Maximum Battery Voltage	357.6850 Volts
Maximum Battery Current	0.6067 Amps
Maximum Battery Power	-0.0841 KW

Test Performed on September 29, 1993

**COCCONI CRX ELECTRIC VEHICLE TEST RESULTS
PERFORMED AT THE IDAHO NATIONAL ENGINEERING LAB**

URBAN DRIVING CYCLE TEST 9/29/93 CYCLE 2

Distance	12.1056 km
Battery Amp Hours Out	4.7736 AH
Battery Amp Hours In	0.0006 AH
Battery Amp Hours Net	4.7729 AH
Battery Energy Out	1.6407 KWh
Battery Energy In	0.0002 KWh
Battery Energy Net	1.6404 KWh
Watt Hours per Kilometer	135.5101 Wh/km

Driving Cycle Discharge Information:

Minimum Battery Voltage	332.0260 Volts
Maximum Battery Current	117.7040 Amps
Maximum Battery Power	38.5284 KW

Driving Cycle Regen Information:

Maximum Battery Voltage	357.6850 Volts
Maximum Battery Current	0.6067 Amps
Maximum Battery Power	-0.0841 KW

Test Performed on September 29, 1993

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Speed and Power vs Time First Cycle from Urban Test 9/29/93

Voltage and Current vs Time
First Cycle from Urban Test 9/29/93

A-60

A-61

Net Amp Hours and Net Kilowatt Hours First Cycle from Urban Test 9/29/93

**COCCONI CRX ELECTRIC VEHICLE TEST RESULTS
PERFORMED AT THE IDAHO NATIONAL ENGINEERING LAB**

URBAN DRIVING CYCLE TEST 9/27/93 CYCLE 1

Distance	12.0629 km
Battery Amp Hours Out	4.8014 AH
Battery Amp Hours In	1.1827 AH
Battery Amp Hours Net	3.6408 AH
Battery Energy Out	1.6768 KWh
Battery Energy In	0.4387 KWh
Battery Energy Net	1.2459 KWh
Watt Hours per Kilometer	103.2879 Wh/km

Driving Cycle Discharge Information:

Minimum Battery Voltage	336.3180 Volts
Maximum Battery Current	115.8870 Amps
Maximum Battery Power	38.7969 KW

Driving Cycle Regen Information:

Maximum Battery Voltage	399.2320 Volts
Maximum Battery Current	53.8224 Amps
Maximum Battery Power	-21.4566 KW

Test Performed on September 27, 1993

**COCCONI CRX ELECTRIC VEHICLE TEST RESULTS
PERFORMED AT THE IDAHO NATIONAL ENGINEERING LAB**

URBAN DRIVING CYCLE TEST 9/27/93 CYCLE 2

Distance	12.1153 km
Battery Amp Hours Out	4.7336 AH
Battery Amp Hours In	1.1972 AH
Battery Amp Hours Net	3.5598 AH
Battery Energy Out	1.6388 KWh
Battery Energy In	0.4379 KWh
Battery Energy Net	1.2093 KWh
Watt Hours per Kilometer	99.8204 Wh/km

Driving Cycle Discharge Information:

Minimum Battery Voltage	335.6040 Volts
Maximum Battery Current	103.8680 Amps
Maximum Battery Power	33.4201 KW

Driving Cycle Regen Information:

Maximum Battery Voltage	384.8390 Volts
Maximum Battery Current	62.1593 Amps
Maximum Battery Power	-24.0636 KW

Test Performed on September 27, 1993

**COCCONI CRX ELECTRIC VEHICLE TEST RESULTS
PERFORMED AT THE IDAHO NATIONAL ENGINEERING LAB**

URBAN DRIVING CYCLE TEST 9/27/93 CYCLE 3

Distance	12.1122 km
Battery Amp Hours Out	4.8285 AH
Battery Amp Hours In	1.1873 AH
Battery Amp Hours Net	3.6618 AH
Battery Energy Out	1.6530 KWh
Battery Energy In	0.4272 KWh
Battery Energy Net	1.2330 KWh
Watt Hours per Kilometer	101.8050 Wh/km

Driving Cycle Discharge Information:

Minimum Battery Voltage	331.2700 Volts
Maximum Battery Current	102.2050 Amps
Maximum Battery Power	34.4642 KW

Driving Cycle Regen Information:

Maximum Battery Voltage	368.5720 Volts
Maximum Battery Current	64.6652 Amps
Maximum Battery Power	-23.3319 KW

Test Performed on September 27, 1993

**COCCONI CRX ELECTRIC VEHICLE TEST RESULTS
PERFORMED AT THE IDAHO NATIONAL ENGINEERING LAB**

URBAN DRIVING CYCLE TEST 9/27/93 CYCLE 4

Distance	12.0753 km
Battery Amp Hours Out	5.2609 AH
Battery Amp Hours In	1.2105 AH
Battery Amp Hours Net	4.0793 AH
Battery Energy Out	1.6448 KWh
Battery Energy In	0.4362 KWh
Battery Energy Net	1.2187 KWh
Watt Hours per Kilometer	100.9270 Wh/km

Driving Cycle Discharge Information:

Minimum Battery Voltage	246.0360 Volts
Maximum Battery Current	125.2570 Amps
Maximum Battery Power	41.5607 KW

Driving Cycle Regen Information:

Maximum Battery Voltage	381.2390 Volts
Maximum Battery Current	57.6804 Amps
Maximum Battery Power	-20.6420 KW

Test Performed on September 27, 1993

Speed and Power vs Time
First Cycle from Urban Test 9/27/93

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Voltage and Current vs Time
First Cycle from Urban Test 9/27/93

A-69

Net Amp Hours and Net Kilowatt Hours First Cycle from Urban Test 9/27/93

**COCCONI CRX ELECTRIC VEHICLE TEST RESULTS
PERFORMED AT THE IDAHO NATIONAL ENGINEERING LAB**

64kmh Constant Speed Test Summary

Average Speed	64.610	kmh
Maximum Speed	66.177	kmh
Minimum Speed	63.896	kmh
Average Battery Current	13.506	amps
Average Battery Voltage	338.560	volts
Average Battery Power	4.538	KW
Distance (Range)	65.795	km
Battery Amp Hours Out	13.759	AH
Battery Amp Hours Net	13.759	AH
Battery Energy Out (KWh)	4.624	KWh
Battery Energy Net (KWh)	4.624	KWh
Net Amp Hours per Kilometer	0.209	AH/km
Net Kilowatt Hours per Kilometer	0.070	KWh/km

Test Performed on October 1, 1993

Net Amp Hours versus Distance for 64kmh Test
Performed on October 1, 1993

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Net KWH versus Distance for 64kmh Constant Speed Test
Performed on October 1, 1993

A-75

Speed versus Distance for 64kmh Constant Speed Test

Test Performed on October 1, 1993

Speed versus Distance for 64kmh Constant Speed Test

Test Performed on October 1, 1993

Speed versus Elapsed Time for 64kmh Test
Performed on October 1, 1993

**COCCONI CRX ELECTRIC VEHICLE TEST RESULTS
PERFORMED AT THE IDAHO NATIONAL ENGINEERING LAB**

ALL ELECTRIC RANGE TEST 9/29/93 CYCLE 1

Distance	28.6467 km
Battery Amp Hours Out	9.6901 AH
Battery Amp Hours In	1.5350 AH
Battery Amp Hours Net	8.1844 AH
Battery Energy Out	3.3390 KWh
Battery Energy In	0.5641 KWh
Battery Energy Net	2.7853 KWh
Watt Hours per Kilometer	97.2292 Wh/km

Driving Cycle Discharge Information:

Minimum Battery Voltage	332.7410 Volts
Maximum Battery Current	105.0190 Amps
Maximum Battery Power	35.1337 KW

Driving Cycle Regen Information:

Maximum Battery Voltage	399.0870 Volts
Maximum Battery Current	74.7097 Amps
Maximum Battery Power	-24.4759 KW

Test Performed on September 29, 1993

COCCONI CRX ELECTRIC VEHICLE TEST RESULTS
PERFORMED AT THE IDAHO NATIONAL ENGINEERING LAB

ALL ELECTRIC RANGE TEST 9/29/93 CYCLE 2

Distance	18.7318 km
Battery Amp Hours Out	6.4111 AH
Battery Amp Hours In	0.6574 AH
Battery Amp Hours Net	5.8694 AH
Battery Energy Out	1.9956 KWh
Battery Energy In	0.2366 KWh
Battery Energy Net	1.8006 KWh
Watt Hours per Kilometer	96.1298 Wh/km

Driving Cycle Discharge Information:

Minimum Battery Voltage	245.6550 Volts
Maximum Battery Current	83.3159 Amps
Maximum Battery Power	26.3285 KW

Driving Cycle Regen Information:

Maximum Battery Voltage	388.9430 Volts
Maximum Battery Current	93.1053 Amps
Maximum Battery Power	-31.3480 KW

NOTE: This is not a complete cycle. Test was
terminated after completing 1000 sec. of
the second cycle.

Test Performed on September 29, 1993

A-81

Speed and Power vs Time
First Cycle from All Electric 9/29/93

Voltage and Current vs Time
First Cycle from All Electric 9/29/93

..... voltage — current

A-83

Net Amp Hours & Net Kilowatt Hours First Cycle from All Electric 9/29/93

COCCONI CRX ELECTRIC VEHICLE TEST RESULTS
PERFORMED AT THE IDAHO NATIONAL ENGINEERING LAB

ENERGY ECONOMY TEST 9/30/93 CYCLE 1

Target Speed	Average Speed	Average Power	Net AH per km	Net KW hrs per km
40 km/h	40.232	2.455	0.170	0.060
48 km/h	48.329	3.148	0.185	0.065
56 km/h	56.342	3.921	0.198	0.069
64 km/h	64.340	4.657	0.208	0.072
72 km/h	72.199	5.603	0.226	0.078
80 km/h	80.582	7.075	0.250	0.087
88 km/h	88.646	8.524	0.280	0.096
96 km/h	96.727	10.347	0.313	0.108

NOTE: Average Power is in Kilowatts

Test Performed on September 30, 1993

COCCONI CRX ELECTRIC VEHICLE TEST RESULTS
PERFORMED AT THE IDAHO NATIONAL ENGINEERING LAB

ENERGY ECONOMY TEST 9/30/93 CYCLE 2

Target Speed	Average Speed	Average Power	Net AH per km	Net KW hrs per km
40 km/h	40.207	2.025	0.144	0.050
48 km/h	48.329	2.658	0.158	0.055
56 km/h	56.309	3.465	0.176	0.061
64 km/h	64.248	4.264	0.191	0.066
72 km/h	72.324	5.565	0.222	0.076
80 km/h	80.266	6.735	0.244	0.084
88 km/h	88.655	8.357	0.277	0.094
96 km/h	96.736	10.122	0.310	0.104

NOTE: Average Power is in Kilowatts

Test Performed on September 30, 1993

A-87

Complete Energy Economy Test run on 9/30/93

First Cycle from Energy Economy Test run 9/30/93

Second Cycle from Energy Economy Test run 9/30/93

**COCCONI CRX ELECTRIC VEHICLE TEST RESULTS
PERFORMED AT THE IDAHO NATIONAL ENGINEERING LAB**

HIGHWAY FUEL ECONOMY TEST 9/28/93 CYCLE 1

Distance	16.5459 km
Battery Amp Hours Out	4.9880 AH
Battery Amp Hours In	0.4010 AH
Battery Amp Hours Net	4.7803 AH
Battery Energy Out	1.7425 KWh
Battery Energy In	0.1519 KWh
Battery Energy Net	1.6634 KWh
Watt Hours per Kilometer	100.5335 Wh/km

Driving Cycle Discharge Information:

Minimum Battery Voltage	341.9370 Volts
Maximum Battery Current	89.4574 Amps
Maximum Battery Power	30.4469 KW

Driving Cycle Regen Information:

Maximum Battery Voltage	398.4290 Volts
Maximum Battery Current	96.2223 Amps
Maximum Battery Power	-37.0736 KW

Test Performed on September 28, 1993

**COCCONI CRX ELECTRIC VEHICLE TEST RESULTS
PERFORMED AT THE IDAHO NATIONAL ENGINEERING LAB**

HIGHWAY FUEL ECONOMY TEST   9/28/93   CYCLE 2

Distance	16.5358 km
Battery Amp Hours Out	4.7793 AH
Battery Amp Hours In	0.3821 AH
Battery Amp Hours Net	4.5905 AH
Battery Energy Out	1.6520 KWh
Battery Energy In	0.1399 KWh
Battery Energy Net	1.5836 KWh
Watt Hours per Kilometer	95.7676 Wh/km

Driving Cycle Discharge Information:

Minimum Battery Voltage	337.7270 Volts
Maximum Battery Current	79.1030 Amps
Maximum Battery Power	26.8150 KW

Driving Cycle Regen Information:

Maximum Battery Voltage	375.3810 Volts
Maximum Battery Current	66.6906 Amps
Maximum Battery Power	-24.4509 KW

Test Performed on September 28, 1993

**COCCONI CRX ELECTRIC VEHICLE TEST RESULTS
PERFORMED AT THE IDAHO NATIONAL ENGINEERING LAB**

HIGHWAY FUEL ECONOMY TEST 9/28/93 CYCLE 3

Distance	16.5176 km
Battery Amp Hours Out	4.8483 AH
Battery Amp Hours In	0.4058 AH
Battery Amp Hours Net	4.6380 AH
Battery Energy Out	1.6521 KWh
Battery Energy In	0.1463 KWh
Battery Energy Net	1.5771 KWh
Watt Hours per Kilometer	95.4818 Wh/km

Driving Cycle Discharge Information:

Minimum Battery Voltage	327.9160 Volts
Maximum Battery Current	76.6366 Amps
Maximum Battery Power	25.8004 KW

Driving Cycle Regen Information:

Maximum Battery Voltage	371.7350 Volts
Maximum Battery Current	103.0030 Amps
Maximum Battery Power	-37.6167 KW

Test Performed on September 28, 1993

**COCCONI CRX ELECTRIC VEHICLE TEST RESULTS
PERFORMED AT THE IDAHO NATIONAL ENGINEERING LAB**

HIGHWAY FUEL ECONOMY TEST 9/28/93 CYCLE 4

Distance	6.3911 km
Battery Amp Hours Out	2.1611 AH
Battery Amp Hours In	0.2544 AH
Battery Amp Hours Net	2.0205 AH
Battery Energy Out	0.6168 KWh
Battery Energy In	0.0946 KWh
Battery Energy Net	0.5647 KWh
Watt Hours per Kilometer	88.3612 Wh/km

Driving Cycle Discharge Information:

Minimum Battery Voltage	245.6750 Volts
Maximum Battery Current	74.9518 Amps
Maximum Battery Power	25.2386 KW

Driving Cycle Regen Information:

Maximum Battery Voltage	395.2650 Volts
Maximum Battery Current	76.7801 Amps
Maximum Battery Power	-29.7478 KW

NOTE: This is not a complete cycle. Test
was terminated before completion of
this cycle.

Test Performed on September 28, 1993

Speed and Power vs Time
First Cycle from Highway Test 9/28/93

A-95

Voltage & Current vs Time
First Cycle from Highway Test 9/28/93

A-97

**COCCONI CRX ELECTRIC VEHICLE TEST RESULTS
PERFORMED AT THE IDAHO NATIONAL ENGINEERING LAB**

LA92 DRIVING CYCLE TEST 9/30/93 CYCLE 1

Distance	15.9377 km
Battery Amp Hours Out	7.7066 AH
Battery Amp Hours In	1.6749 AH
Battery Amp Hours Net	6.0636 AH
Battery Energy Out	2.6622 KWh
Battery Energy In	0.6285 KWh
Battery Energy Net	2.0461 KWh
Watt Hours per Kilometer	128.3860 Wh/km

Driving Cycle Discharge Information:

Minimum Battery Voltage	324.5530 Volts
Maximum Battery Current	171.1980 Amps
Maximum Battery Power	55.5876 KW

Driving Cycle Regen Information:

Maximum Battery Voltage	398.2670 Volts
Maximum Battery Current	95.5958 Amps
Maximum Battery Power	-37.5508 KW

Test Performed on September 30, 1993

**COCCONI CRX ELECTRIC VEHICLE TEST RESULTS
PERFORMED AT THE IDAHO NATIONAL ENGINEERING LAB**

LA92 DRIVING CYCLE TEST 9/30/93 CYCLE 2

Distance	15.8376 km
Battery Amp Hours Out	8.4342 AH
Battery Amp Hours In	1.7212 AH
Battery Amp Hours Net	6.7290 AH
Battery Energy Out	2.6181 KWh
Battery Energy In	0.6229 KWh
Battery Energy Net	2.0058 KWh
Watt Hours per Kilometer	126.6482 Wh/km

Driving Cycle Discharge Information:

Minimum Battery Voltage	245.7720 Volts
Maximum Battery Current	171.4620 Amps
Maximum Battery Power	53.5139 KW

Driving Cycle Regen Information:

Maximum Battery Voltage	390.0060 Volts
Maximum Battery Current	101.6830 Amps
Maximum Battery Power	-39.0739 KW

Test Performed on September 30, 1993

A-101

Speed and Power vs Time
First Cycle from LA92 9/30/93

A-102

A-103

Net Amp Hours & Net Kilowatt Hours
First Cycle from LA92 9/30/93

APPENDIX B

Compilation of Test Data For The AC Propulsion ELX Electric Vehicle

PART II:

**Testing on the Dynamometer at the California Air
Resources Board**

Dynamometer Setting: Coastdown curve based on

Test Weight: 3,250 lbs

$C_D A$: 5.75 ft²

fr: 0.0067

COCCONI CRX ELECTRIC VEHICLE TEST RESULTS
PERFORMED FOR CALIFORNIA AIR RESOURCES BOARD

ENERGY ECONOMY TEST 11/12/93

Target Speed	Average Speed	Average Power	Net AH per km	Net Watt hrs per km	-
32 km/h	32.966	1.702	0.143	50.811	
40 km/h	40.817	2.264	0.157	55.630	
48 km/h	48.908	3.072	0.177	62.774	
56 km/h	56.872	3.916	0.196	68.973	
64 km/h	64.840	4.903	0.215	75.549	
72 km/h	73.151	6.112	0.239	83.840	
80 km/h	81.140	7.388	0.261	91.194	
88 km/h	89.361	8.981	0.289	100.492	
96 km/h	97.375	10.135	0.300	104.058	
104 km/h	105.553	11.338	0.312	107.589	

NOTE: Average Power is in Kilowatts

Test Performed on November 12, 1993

Speed vs Time from Energy Economy Test Dynamometer Test at CARB

B-6

Test run 11/12/93

**COCCONI CRX ELECTRIC VEHICLE TEST RESULTS
PERFORMED FOR CALIFORNIA AIR RESOURCES BOARD**

ALL ELECTRIC RANGE TEST   11/10/93   Complete Test

General Test Information:

Distance	152.6100 km
Watt Hours per Kilometer	99.8218 Wh/km
Battery Amp Hours Net	47.1772 AH
Battery Energy Net	15.2339 KWh

Driving Cycle Discharge Information:

Minimum Battery Voltage	245.6000 Volts
Maximum Battery Current	209.0000 Amps
Maximum Battery Power	64.7900 KW

Driving Cycle Regen Information:

Maximum Battery Voltage	398.2000 Volts
Maximum Battery Current	-125.0000 Amps
Maximum Battery Power	-46.2300 KW

Test Performed on November 10, 1993

**COCCONI CRX ELECTRIC VEHICLE TEST RESULTS
PERFORMED FOR CALIFORNIA AIR RESOURCES BOARD**

ALL ELECTRIC RANGE TEST   11/10/93   First Highway Cycle

General Test Information:

Distance	16.0300 km
Watt Hours per Kilometer	97.3504 Wh/km
Battery Amp Hours Net	4.5451 AH
Battery Energy Net	1.5608 KWh

Driving Cycle Discharge Information:

Minimum Battery Voltage	332.4000 Volts
Maximum Battery Current	143.6000 Amps
Maximum Battery Power	48.2200 KW

Driving Cycle Regen Information:

Maximum Battery Voltage	398.2000 Volts
Maximum Battery Current	-83.0000 Amps
Maximum Battery Power	-31.2500 KW

*****NOTE*****

CARB Coastdown Curves did NOT
match the INEL Coastdown Curves

Test Performed on November 10, 1993

COCCONI CRX ELECTRIC VEHICLE TEST RESULTS
PERFORMED FOR CALIFORNIA AIR RESOURCES BOARD

ALL ELECTRIC RANGE TEST   11/10/93   First Urban Cycle

General Test Information:

Distance	11.5827 km
Watt Hours per Kilometer	103.4387 Wh/km
Battery Amp Hours Net	3.5232 AH
Battery Energy Net	1.1981 KWh

Driving Cycle Discharge Information:

Minimum Battery Voltage	331.1000 Volts
Maximum Battery Current	139.6000 Amps
Maximum Battery Power	46.2216 KW

Driving Cycle Regen Information:

Maximum Battery Voltage	371.8000 Volts
Maximum Battery Current	-61.5000 Amps
Maximum Battery Power	-22.6997 KW

*****NOTE*****

CARB Coastdown Curves did NOT
match the INEL Coastdown Curves

Test Performed on November 10, 1993

B-11

Speed & Power vs Time CARB Test First Highway Cycle from All Electric

B-12

Voltage & Current vs Time CARB Test First Highway Cycle from All Electric

NOTE: CARB Coastdown Curves did NOT match INEL Coastdown Curves

..... voltage — current

Test run 11/10/93

Voltage & Current vs Time CARB Test First Urban Cycle from All Electric

..... voltage — current

Test run 11/10/93

AC Propulsion (Cocconi) Honda 11-15-93 0 to 60 On-Road w/Gusty Winds

11/15/93	Steady State Data									
		Series 1		Series 2		Series 3		Series 4		Series 5
	Start Odo	0	Start Odo	13.4	Start Odo	28.2	Start Odo	36.7	Start Odo	39.05
	Start AH	0	Start AH	11.59	Start AH	22.5	Start AH	31.5	Start AH	36
		time		time		time		time		time
	West	10.35	West	9.92	West	10.11	West	10.00	West	10.42
	East	10.32	East	10.05	East	10.25	East	10.42	East	10.00
	West	10.28	West	10.24	West	10.33	West	10.28	West	10.17
	East	10.09	East	10.19	East	10.25	East	10.17	East	10.28
			East	10.02						
	End Odo	2.8	End Odo	14.9	End Odo	29.8	End Odo	38.2	End Odo	40.6
	End AH	5.4	End AH	14.8	End AH	26.7	End AH	35.3	End AH	40
	Act Miles	2.8	Act Miles	1.5	Act Miles	1.6	Act Miles	1.5	Act Miles	1.55
	Act AH	5.4	Act AH	3.21	Act AH	4.2	Act AH	3.8	Act AH	4
	Act AH/Mi	1.93		2.14		2.63		2.53		2.58
	Avg AH/Mi	2.30								
	Avg East	10.21	Avg East	10.04	Avg East	10.25	Avg East	10.30	Avg East	10.14
	Avg West	10.32	Avg West	10.08	Avg West	10.22	Avg West	10.14	Avg West	10.30
	% chg E/W	-1.08%	% chg E/W	-0.45%	% chg E/W	0.29%	% chg E/W	1.51%	% chg E/W	-1.53%

CARB Coastdown Curve #1

CARB Coastdown Curve #2

CARB Coastdown Curve #3

COCCONI CRX ELECTRIC VEHICLE TEST RESULTS
PERFORMED FOR CALIFORNIA AIR RESOURCES BOARD

ROAD ENERGY ECONOMY TEST 11/16/93

Target Speed	Average Speed	Average Power	Net AH per km	Net Watt hrs per km
32 km/h	36.031	1.101	0.332	28.258
40 km/h	40.824	3.619	0.630	88.643
48 km/h	50.292	4.335	0.493	86.066
56 km/h	56.575	5.178	0.579	92.453
64 km/h	64.213	3.073	0.329	46.331
72 km/h	71.744	6.038	0.558	84.108
80 km/h	79.608	4.851	0.411	61.462
88 km/h	87.532	5.743	0.398	64.867
96 km/h	95.388	8.110	0.524	84.934

NOTE: Average Power is in Kilowatts

*****NOTE*****

CARB Coastdown Curves did NOT
match INEL Coastdown Curves

Test Performed on November 16, 1993

Energy Economy Road Test 11/16/93
CA Data Graph #5 1400<time<1750

Energy Economy Road Test 11/16/93
CA Data Graph #6 1750<time<2150

Energy Economy Road Test 11/16/93
CA Data First 400 seconds

Energy Economy Road Test 11/16/93
CA Data Graph #8 2500<time<2900

Energy Economy Road Test 11/16/93
CA Data Graph #10 3300<time<3700

Energy Economy Road Test 11/16/93
CA Data Graph #12 4150<time<4600

Energy Economy Road Test 11/16/93
CA Data Graph #13 4600<time<5100

Energy Economy Road Test 11/16/93
CA Data Graph #14 5100<time<5500