APPENDICES

TESTS AND SUPPORTING DOCUMENTS

Actual Test Runs

All tests were performed on a 2.2 mile oval track, measured surface roughness number of better than 0.75 (standard highway requirements). All tests having occurred on an oval track opposite wind affects were cancelled.

Hours	M.P.H.	Distance
2.2	50	110 miles
1.5	50	105 miles
1.5	20	
1.0	50	110 miles
3.0	20	

I. AERODYNAMIC LOSS

At low speeds, the chassis is the primary source of energy consumption; at high speeds, the aerodynamic losses become the dominant energy loss. The proportion of net power output used in overcoming an air resistance at 50 MPH is approximately equal to that of chassis losses. Therefore, one main objective is to minimize weight and aerodynamic drag. The aerodynamics of our vehicle and the horsepower required to overcome that resistance can be expressed in the following formula:

$$D = .002558 \ C_D \ A \ V^2 \text{ (Lbs.)}$$

$$HP = \frac{D \ V}{375}$$

Combining the first two equations:

$$HP = \frac{C_D \ A \ V^3}{146,625}$$

Where D = Aerodynamic drag (Lbs.)

A = Frontal area ($Ft.^2$)

V = Air speed relative to the car (MPH)

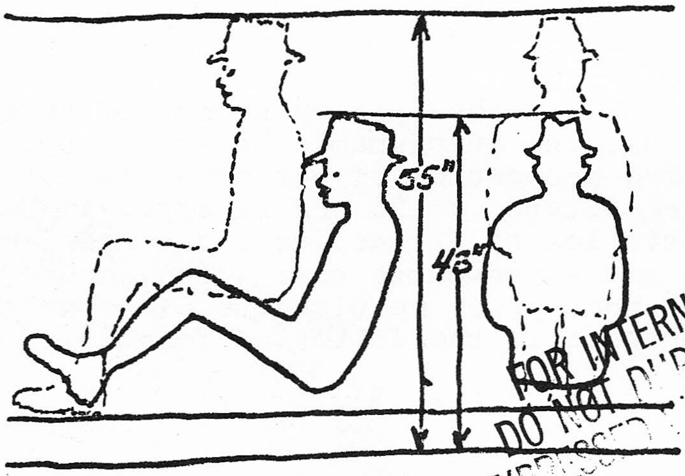
C_D = Drag coefficient

It is obvious that as the speed is doubled, the required horsepower, due to air resistance, is eight times as great. The horsepower required to overcome the air resistance increases by the cube of velocity. By reducing either the frontal area (A) or the drag coefficient (C_D), or preferably both, the consumption of the stored energy to overcome aerodynamic drag will be reduced.

(Continued)

A. Frontal Areas

Cause of Distance Reduction	Remedies to Increase Distance
The frontal area as concerns resistance consists primarily of two factors: one is the heighth of the car and two is the width of the vehicle. Such factors as ground clearance, visibility for the driver, car visibility to other drivers, ease of entry and exit and the use of the vehicle are secondary factors that influence horsepower loss.	The frontal area of our present vehicle is considerably larger than most large automobiles. Two improvements could be made in order to decrease the resistance caused by frontal area: by lowering the roof of the car and changing the seating characteristics, as shown in Figure I,



A. Frontal Areas - Continued

Cause of Distance Reduction	Remedies to Increase Distance
	and by reducing the width of the car, as shown in Figure II, substantial reduction in frontal area could be reduced if necessary. We have chosen the larger of these two in order to accommodate the primary concern of most drivers, which is comfort and safety.

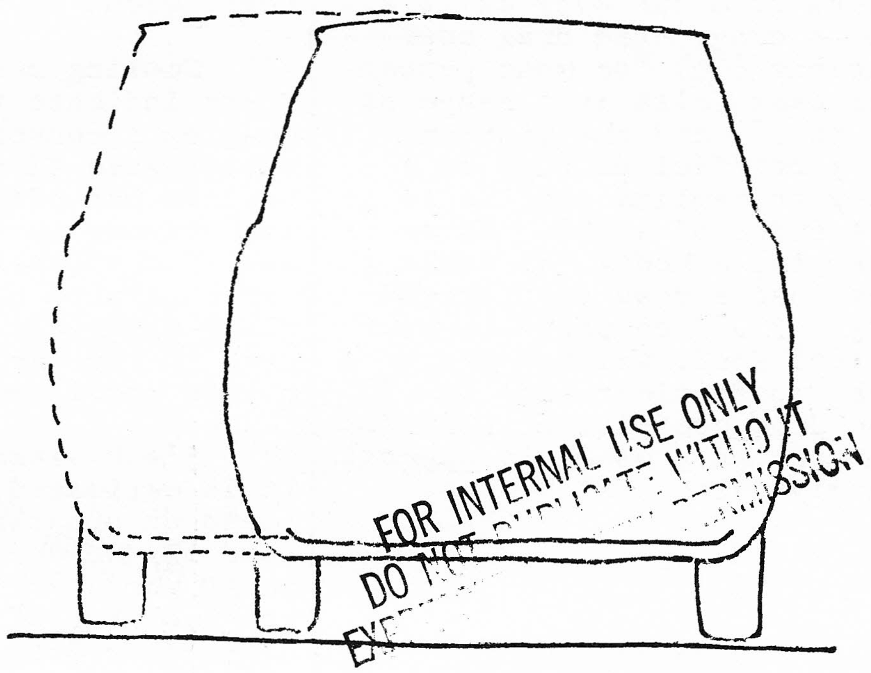


Figure II

There are many compromises between the minimums and maximums that relate to frontal area which would be utilized.

B. Drag Coefficient

Cause of Distance Reduction	Remedies to Increase Distance
There is very little latitude in the frontal area (A) reduction of the passenger space is to be maintained; therefore, our main concern is the drag coefficient (C_D). The drag coefficient (C_D) is a dimensionless figure of merit for judging the form and proportions of a car body as it affects drag. The drag coefficient (C_D) for most passenger cars falls in a range of .4 to .6, and the minimum drag coefficient (C_D) of a very streamline profile is in the order of a .05. As an example, a Model "A" would have had a drag coefficient (C_D) of .83 compared to say a 1955 Ford, which would be a drag coefficient (C_D) of .50. The drag coefficient (C_D) for our car at present is approximately .41.	Some of the areas to which particular attention can be given for the reduction of our drag coefficient (C_D) to .25 or less are as follows: (1) Underbody Enclosing the underbody with a flush pan can reduce the drag coefficient as much as 17%. (2) Cooling and Ventilation Tests indicate that the cooling drag on a conventional vehicle varies some 4% to 10%. Our vehicle can offer significant improvement in this area by the use of preformed, smooth body parts made of the acrylic fiberglass materials, which will be used in the car and the production model vehicle. (3) Flush Glass It is estimated that the flush glass on our car reduces drag by some 5%. However, since all parts were handmade, improved streamlining of glass to body can reduce drag by as high as 10%. (4) Lift Drag The force necessary to produce lift drag requires energy from the vehicle. By reducing the vehicle lift, the aerodynamic drag, due to lift, will be minimized. The improvements to be made in our production model can be set at zero lift, as required by the anti-lift formula, developed by the late Andreau in 1938. This can only be maximized under controlled production circumstances.

(Continued)

B. Drag Coefficient - Continued)

Cause of Distance Reduction	Remedies to Increase Distance
	(5) Defined Contours A further improvement in the use of machinery to form the smooth curved contours of our automobile are far superior to the handwork in our present body, where tolerances of thicknesses and wave differences, which are not quite of the equation of the third order, will further improve drag coefficient.

II. CHASSIS LOSS

The force (Lbs.) required to overcome the tire rolling resistance and the front wheel bearing and power train resistances of our electric car at 1 MPH has a road load of some 82 Lbs. Approximately 85% of this road load can be attributed to the rolling resistance of the tires, and the remaining 15% is due to the front wheel bearings and power train losses.

A. Power Train and Wheel Bearing Losses

Cause of Distance Reduction	Remedies to Increase Distance
An extremely low rolling resistance could be achieved by using steel wheels on steel rails. The pneumatic tire is essential for handling, riding and traction.	
(1) Our current belted radial tire causes a loss of some 4.8 horsepower.	(1) By the use of a low aspect ratio tire, special compounding, gauge reduction, reduced deflection, the total horsepower loss could be reduced to 2.5 horsepower or almost a 50% reduction in rolling resistance.
(2) The comfort rating is approximately 80%. Wear, stability and traction are all exceptional on our present tires.	(2) While the ride of the tire would be reduced to 65%, wear, stability and traction again being exceptional, the noise, vibration and harshness problems

(Continued)

A. Power Train and Wheel Bearing Losses - Continued

Cause of Distance Reduction	Remedies to Increase Distance
	have already been designed out of our present suspension system. Therefore, while ridability has been reduced by the use of a tire of such greatly reduced rolling resistance, the passenger will not be affected by this factor in our electric automobile as he would be affected in a standard Detroit designed vehicle.

Goodyear has presented us with four tires and a set of criteria to test in our current vehicle. The reduction in rolling resistance to be tested with these tires is approximately 4% to 34%, based on different perimeters to be injected at the time of testing. This will improve our current range and provide us with some sufficient data to allow Goodyear to use whatever method of either materials or design to give us a total horsepower loss of some 2 to 2.5 horsepower rather than the present 4.8 horsepower loss.

III. INERTIAL LOSSES

Cause of Distance Reduction	Remedies to Increase Distance
Although aerodynamic and chassis losses consume a large portion of available stored energy at higher constant speeds, energy is also required to accelerate the vehicle. At present, our vehicle is some 25% overweight; therefore, the inertial losses are increased considerably under our present test circumstances.	By mass producing the body under controlled circumstances where thickness can be controlled to thousandths of an inch and weight per square foot to fractions of an ounce and the replacement of many steel and heavy material components could be replaced, the resultant weight savings could cause a minimum of some 25% energy savings. An example of this would be the 3/8" x 11 1/2" steel disc brakes presently being used. Under maximum production the brake system which currently weighs approximately 85 Lbs. could be reduced (and still maintain its current integrity) by some 30 Lbs.

(Continued)

HCP/M1011-01

STATE-OF-THE-ART ASSESSMENT OF ELECTRIC AND HYBRID VEHICLES

January 1978

Prepared for
U.S. DEPARTMENT OF ENERGY
Division of Transportation Energy Conservation
Under Interagency Agreement EC-77-A-31-1011

TABLE 3-15. -

(b) U.S.

Manufacturer	Vehicle	Number of passengers	Year	Dimensions, in.			Curb weight, lbm	Pay-load, lbm	Battery		
				Length	Width	Height			Weight, lbm	Type	Voltage, V
Amectran Co.	Exar-1	4	1976	180	74	--	4360	—	1700	TRO244	144
Anderson Electric Power Equipment	Third generation	2	1972	146	65	68	2520	—	750	Pb-acid	72
Braunlich-Roessle Co.	Braun Electric	2	1976	—	--	--	1800	300	——	Pb-acid	—
Christianson, M.B.	Renault R-10[c]	—	1975	165	60	56	2250	—	535	Pb-acid	—
Copper Development Association	CDA Town Car	2	1976	145	60	55	3100	370	1062	GC-21A	—
Die Mesh Corp.	Electra Spider[c] (Fiat 850)	↓	1973	—	—	—	2850	—	——	Pb-acid	—
Dow, Douglas	(d)		1973	176	65	70	1250	—	276	EFP	—
3E Vehicles	Sportster[c] 1+1 EP 10B		1977	86	52	33	565	210	285	Pb-acid	—
Electric Dynamics Corp.	X-2		1976	144	62	50	1900	—	——	Pb-acid	72 ↓
Electric Engineering	Datsun 1200	4	1972	156	60	53	2100	—	780	GC-2H	
	Kelmark, CT	—	——	167	72	43	2500	—	828	SGL	
	VW Beetle	4	——	160	61	59	2300	—	780	EV-106	
Electric Fuel Propulsion Corp.	Transformer I	5	1975	212	77	54	5850	750	2400	EFP ↓	180
	Electricar	4	1970-71	181	71	--	5200	300	2200		144
	Mars II[c]	5	1966-70	173	60	55	4100	550	1840		120
	Electro-Sport (Hornet station wagon)	—	1972	—	--	--	5180	800	2200		144
Electric Passenger Cars, Inc.	Hummingbird	4	1976	155	63	56	2570	600	830	TR) 217	72
Electric Vehicle Associates	Electric luxury sedan	4	1975-77	174	65	57	3150	—	1040	Pb-acid	96
Electric Vehicle Engineering	Islander	4	1971-76	125	76	60	2500	—	850	Pb-acid	84
Ford Motor Co.	City car (Pinto)	—	——	—	--	—	3200	300	956	Pb-acid	—
	Cortina Estate car	5	1970	174	65	55	3086	—	900	Ni-Cd	113
General Electric Co.	Delta	2	——	130	56	59	2300	—	864/57	Pb-NiCd	72
General Motors Corp.	512 urban car	2	1969	86	56	52	1250	—	330	Pb-acid	84
	512 Zn-Ni urban car	2	1969	85	56	52	1257	435	270	Ni-Zn	94

[a]S denotes series; P denotes shunt; C denotes compound; PM denotes a motor with a permanent magnet; B denotes brushless.

[b]SCHP denotes a silicon-controlled rectifier (SCR) chopper; TCHP denotes a transistor chopper; BSW denotes battery switching; R denotes resistance; E denotes electronic.

Continued.

customary units

Motor			Controller[b]	Transmission	Maximum speed, mph	Range at constant speed, miles	Range test speed, mph	Acceleration from standing start	
Power, hp	Type[a]	Maximum voltage, V						To speed, mph	Time, s
13	DC	96	E	Direct drive	70	100	55		
20	S DC	72	SCHP	2 Speed; automatic	55	60	45	—	—
11	DC	36	BSW	4 Speed; manual; belt drive	58	35	35	58	30
———	P DC	—	BSW	4 Speed; manual	50	30	25	—	—
9	P DC	108	R; BSW	Fixed	59	103	40	30	9
Three motors at 3.2 hp each			———	Continuously variable; cone drive	55	—	—	—	—
1.5	P DC	36	BSW	Chain drive	25	—	—	—	—
8	DC	—	BSW	Direct drive	45	—	—	—	—
Two DC motors at 8 hp each			E	———————————	50	—	—	—	—
20	P DC	36	R	4 Speed; manual	70	36	45	30	11
20	P DC	36	R	4 Speed; manual	75	35	45	↓	11
20	P DC	36	R	4 Speed; manual	65	35	45	↓	11
32	S DC	—	SCHP	3 Speed; automatic	75	60	55	↓	8
20	S DC	144	SCHP	3 Speed	80	55	60	60	30
20	S DC	—	BSW	4 Speed; manual	60	100	40	40	20
20	C DC	144	———	3 Speed; manual	69	87	30	30	10
15	S DC	36	TCHP	4 Speed; manual	52	50	40	—	—
13.4	P DC	—	SCHP	3 Speed; automatic	>55	50	30	30	13
10	DC	—	E	Direct drive	30	—	—	—	—
40	DC	—	———	———————————	80	39	40	—	—
40	S DC	100	SCHP	Fixed	70	40	25	30	7
10.9	S DC	—	↓	4 Speed; manual	55	110	30	30	6
8.4	DC	—	↓	Fixed	45	47	30	30	12
8.4	S DC	—	↓	Fixed	47	92	31	31	12

[c]Regenerative braking.

[d]Two steerable lightweight front wheels; one rear drive wheel.

TABLE 3-15. -

(b)

Manufacturer	Vehicle	Number of passengers	Year	Dimensions, in.			Curb weight, lbm	Payload, lbm	Battery		
				Length	Width	Height			Weight, lbm	Type	Voltage, V
General Motors Corp.	xep-1a (Opel Kadett)	4	1970-71	—	—	—	2957	—	648/250	Zn-air + Pb-acid	160
	Electrovairs 1 and 2[c]	4	1964-67	—	—	—	3400	—	680	Ag-Zn	530
Globe-Union, Inc.	Endura	4	1977	184	72	—	3200	—	1300	Pb-acid	240
Howes, Paul	VS dune buggy	—	—	—	—	—	1900	—	800	Pb-acid	72
Hughes, Max	NSU Prinz	—	—	—	—	—	1640	—	—	Pb-acid	48
Jausel, Virgil W.	Renault	—	—	—	—	—	2420	355	—	Pb-acid	96
Kesling, Dr. H.D.	YARE[e]	5	1977	168	72	52	2300	—	—	Pb-acid	72
Korff Electrics	Tailwind 3[f]	2	1977	130	71	46	1506	400	584	TRO244	48
Linear Alpha Corp.	Falcon	—	—	—	—	—	—	—	360	Li-NiF	—
	Seneca Electric	4	1975-76	169	50	69	—	—	—	Pb-acid	—
Mallon, Richard G.	VW sedan[c]	4	1959	—	—	—	2100	—	750	TRO217	66
McKee Engineering Corp.	McCulloch electric car	2	—	166	68	46	2760	360	1260	Pb-acid	108
	Sundancers 1 and 2	2	1970-72	120	—	—	1614	400	750	Exide EV-106	72
Mechanix Illustrated	Urba Electric[c]	2	—	126	60	43	[g]1700	—	584	TRO244	48
National Union Electric	Henny Kilowatt (Renault Dauphine)	—	1959-62	—	—	—	2135	—	792	Pb-acid	72
Newell, John	VW fastback	—	—	—	—	—	1900	—	—	Ni-Cd	48
Paine, Donald	Datsun 410	4	1974	156	59	55	2500	—	1040	EV-108	96
Rippel, Wally E.	Ripp-Electric[c]	4	—	151	59	55	2950	338	1300	LEV-115	120
Sears, Roebuck & Co.	XDH-1[c]	2	1977	151	61	52	3110	—	—	Sears EV	120
Sebring-Vanguard, Inc.	CitiCar	2	1974-76	94	55	60	1300	500	530	EV-106	48
Stamant, Andy	Miny Dune Buggy	—	—	—	—	—	1781	819	—	Pb-acid	72
Steinfeld, Robert	NSU Prinz	—	1964	—	—	—	1700	—	520	Pb-acid	48

[a]S denotes series; P denotes shunt; C denotes compound; PM denotes a motor with a permanent magnet; B denotes brushless.

[b]SCHP denotes a silicon-controlled rectifier (SCR) chopper; TCHP denotes a transistor chopper; BSW denotes battery switching; R denotes resistance; E denotes electronic.

[c]Regenerative braking.

Continued.

Continued.

Motor			Controller[b]	Transmission	Maximum speed, mph	Range at constant speed, miles	Range test speed, mph	Acceleration from standing start	
Power, hp	Type[a]	Maximum voltage, V						To speed, mph	Time, s
Two S DC motors at 14 hp each			SCHP	Fixed	60	150	30	30	10
115	AC	120	SCHP	Fixed	75/80	40	75	60	17
20	S DC	120	SCHP	Fixed	60	115	35	30	9
—	P DC	—	BSW	4 Speed; manual	60	60	30	—	—
—	P DC	30	BSW	Chain drive	40	—	—	—	—
6.3	S DC	96	—	4 Speed; manual	52	50	30	—	—
12	DC	—	—	—	55	—	—	50	12
Two motors @ 4 hp each	DC; PM	48	TCHP	Chain drive	58	75	30	30	12
25	AC	—	—	—	60	75	25	—	—
—	DC	—	—	E	57	50	25	30	8
—	S DC	—	—	Fixed	>55	30	40	—	—
15	DC; PM	108	SCHP	2 Speed; manual chain drive	75	125	30	—	—
8	S DC	—	1 - BSW 2 - SCHP	2 Speed; manual	62	100	30	30	10
10	P DC	30	BSW	Continuously variable[h]	55	—	—	—	—
7	DC	—	BSW	—	40	—	—	—	—
—	DC	—	TCHP	4 Speed; manual	65	—	—	—	—
27	P DC	—	BSW	↓	62	25	35	30	10
15	S DC	120	TCHP	↓	61	85	30	30	7
27	C DC	120	BSW	↓	75	90	47	—	—
6	S DC	48	BSW	Direct drive	38	—	—	30	15
39	C DC	72	BSW	4 Speed; manual	70	100	35	30	8
—	S DC	—	—	4 Speed; manual	60	—	—	—	—

[e]Two side drive wheels; one front and one rear wheel, both steerable; built to demonstrate safety features.

[f]Two steerable front wheels; one rear drive wheel; two permanent magnet motors.

[g]Gross vehicle weight.

[h]Electronically controlled, continuously adjustable belt drive and fixed-ratio roller chain drive with a differential.

ENERGY CONSERVATION

RECOMMENDED PERFORMANCE STANDARDS FOR ELECTRIC AND HYBRID VEHICLES

FINAL REPORT FOR THE PERIOD
JANUARY – OCTOBER 1977

Bradford B. Underhill – Project Leader

Date Published – October 1977

Work Performed Under Contract No. EY-76-C-03-1335

ARTHUR D. LITTLE, INC.
25 Acorn Park
Cambridge, MA. 02140

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

Division of Transportation Energy Conservation

TABLE II-7 (Continued)

SUMMARY OF PERFORMANCE – 4 PASSENGER ELECTRIC VEHICLES

		C.H. Waterman (Volvo-DAF)	EVA Metro Sedan	EVE Islander	Dianatsu Lt. Wt. Experimental	Electric Vehicle Association (Renault Contractor)	Ripp Electric	Electric Passenger Car EPC Hummingbird	C.H. Waterman (Renault)	City Car (Pinto Ford)	Comet '74 Ford	Commuter '74 Ford	Cortina '74 Ford	Linear Alpha (Falcon)	Pargo Laser Multi-purpose Delivery Van	Amectran Exar-I	Linear Alpha Seneca Electric	Globe Union Endura	EFP Corporation Mars II	Marathon Model 300	Sebring Vanguard Citi-Van	General Electric/ERDA
GVW	(kg)	1354	1687		1132	1667	1572	1451	1431	1576	1915								1917			1323
Payload	(kg)	139	270			270	270	270	270	136	205											270
Curb Mass	(kg)	1215	1417	990	912	1417	1302	1181	1161	1440	1710	540	1388			1962		1440	1845		612	1600
Cargo Volume	(m³)																					
Size (LxWxD)	(m)					.9x1.0x5																
Payload	(kg)			225																		
Maximum Speed	(km/h)	53	84		89		88	56	56	80	112	64	96	96		112		96		56		96
Cruise Speed	(km/h)	40	56		38		56	56	56	64		64	40	48		80	64	56			60	
Cruise Range	(km)	94	54	48	128		129	43	128			40	64	120	64	176	80	160		80	80	
Range J227A	A			80				32														
	B	67				52	105	32	129						80							
km	C		33			44	94															
	D																					
Acceleration (0-X km/h)		32	48		28	48	48	48	48												48	48
Time in Sec.		14	27		4	16.5	14	21.6	34.3												15	9
Gradeability	(%)		25		6																	
Speed	(km/h)		8		38																	
Regenerative Braking						Y	Y												Y			
Energy Consumption																						
Cruise (MJ/km) @ km/h		.8/48	1.1/40	.42/64		1.3/56	.59/56	1.5/56	.73/56								.73				.71	
Stop & Go (MJ/km) @ cycle		1/B				1.6/C	1/C	2/B	.78/B													
Battery Charger																						
On Board		Y	Y		Y				Y							Y	Y	Y		Y	Y	Y
115	(time/h)	10			10													1416			8-9	6-8
230	(time/h)				6													7				
Off Board								Y														
115	(time/h)																					
230	(time/h)																				.84	1.4
Battery Type		Pb	Pb		Pb	Pb			Pb	Pb	Na/S	Pb	Ni/Cd	Pb					Pb			
Voltage		6	6		4	6		6	6										30			
Number		16	16	10		16		12	16							24			4			
Total Voltage		96	96	78	96	96	120	72	96			48							120			
Cost		$5995-2dr. $6395-Sta. wgn.		$5000											$4500	$4600			$4000-6000			
Test Agency		NASA	NASA			NASA	NASA	NASA	NASA							NTA						
Date			75-76			1/1-3/21/77	3/23-4/26/77	4/6-4/26/77														
Source		AC	ABCDE	A	BD	ABC	AC	AC	AC	A	A	A	A	A	A	AD	A	ABD	A	A	AB	ABD

Y = Yes
PB = lead acid

TABLE II-7 (Continued)

SUMMARY OF PERFORMANCE

		4 PASSENGER ELECTRIC VEHICLES																TAXIS			
		Seneca Linear Alpha	Elcar Model 200	Elcar Wagonette or Delivery Van	Udylite Corp. Test Bed Vehicle	University of Colorado, Mars IIG	C.H. Waterman Electricar (Datsun 1200)	Yardney Passenger Car	Toyota EV-2 Hybrid Battery System	Transformer (5 passengers)	EFP Corporation Electricar (70-71)	Electro-Sport EFP 72	Exide ESB 68	Electric Vehicle Association (1968 Pinto)	Electric Vehicle Association Metro Sedan (73-76)	Mazda Electric Family Van	Theu No. 2 (Taiwan)	Lucas Limo/ Delivery Van (7 passengers)	Lucas Electric Pullman (10 passengers)	Lucas Electric Proto	VW Hybrid
GVW	(kg)								1475	2970					1687	1345	1400	3465	3070	2640	
Payload	(kg)								220	337					270	335	200	712	770	400	
Curb Mass	(kg)		515	675		1305			1255	2632	2340	2331	1125	1557	1417	1070	1200	2752	2300	2240	
Cargo Volume	(m^3)			1.5																	
Size (LxWxD)	(m)															.9x2.0x?	1.0x.9x.8				
Payload	(kg)								w/3 pass 300							200					
Maximum Speed	(km/h)	91	52	64	105	64	80-96	88		112	126		64	80	92	70	90	80	80	96	Elec 69 ICE 102
Cruise Speed	(km/h)	40			80			40		88	95		64	48	56	30	45	64	48	40	
Cruise Range	(km)	112	48	64	243	64	64-80	128		96	88		40	112	96	70	160	121	128	320	
Range J227A	A		53																40	160	
	B																120				
km	C																	77			
	D																				
Acceleration (0-X km/h)		48	46			40					96					48	96	48	48	48	99
Time in Sec.		8	27.5			25				8	30			8-10	13	5.5	12	15	11	10	31
Gradeability	(%)								6	20						17	18	16.5	20	20	
Speed	(km/h)								38	1.6									Restart	Restart	
Regenerative Braking																		Y	Y	Y	
Energy Consumption																					
Cruise (MJ/km) @ km/h						1.1										.71	.83	1.6/72			
Stop & Go (MJ/km) @ cycle																		2/C			
Battery Charger																					
On Board		Y	Y							Y	Y				Y						
115	(time/h)									8					12						
230	(time/h)														6						
Off Board			Y				Y			Y				Y		Y	Y	Y	Y	Y	
115	(time/h)						8-12									12	3		10	10	
230	(time/h)									4											
Battery Type			Pb	Pb	Zn/Cl			Ag/Zn	Zn/air Pb	Pb	Pb	Pb				Pb	Pb	Pb	Pb		
Voltage			12	12	200	6	6		12	6	6	6						6	6		
Number			8	12		12	16		16		24	24					16	36	36	36	
Total Voltage			84	144		72	96		192	180	144	144					192	216	216	216	
Cost			$3475							28,500					$9500						
Test Agency										NTA	NTA							NASA			
Date																		9/24-9/30/76			
Source		A	A	A	A	A	A	A	ABD	ABDE	A	A	AB	A	ABD	E	E	BGE	BDE	BDE	A

Y = Yes
Pb = lead acid

HS Form 121 (Rev. 11/78)

DEPARTMENT OF TRANSPORTATION
NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

UNITED STATES GOVERNMENT

memorandum

19800702
NRD-12-CC-80045

SUBJECT: PLANS FOR THE TESTING AND FURTHER INVESTIGATIONS WITH THE AMECTRAN ELECTRIC CAR

FROM: CARL CLARK, OFFICE OF PASSENGER VEHICLE RESEARCH NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

TO: CHARLES PATTERSON, TRUSTEE OF THE DALLAS COURT

YOU HAVE READ TO ME BY TELEPHONE THE DALLAS COURT ORDER DESIGNATING THAT I SHALL SPECIFY AND DIRECT THE CARRYING OUT OF TESTS OF THE AMECTRAN ELECTRIC CAR TO DETERMINE WHETHER THE EXPENSE OF TIME AND MONEY TO BRING THE CAR TO MARKET IS JUSTIFIED. YOU NOTED THAT A LETTER WILL BE SENT TO THE SECRETARY OF TRANSPORTATION REQUESTING THAT I BE AUTHORIZED TO TRAVEL TO LOS ANGELES DURING THE PERIOD OF JULY 14-19, AT COURT EXPENSE, TO PREPARE FOR AND CARRY OUT THESE TESTS OF THE AMECTRAN PRE-PRODUCTION ELECTRIC CAR. MY MEMORANDUM NRD-12-CC-80043, ATTACHED, GIVES THE BACKGROUND OF MY INVOLVEMENT, AS INVENTOR CONTACT OF THE NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION, WITH THE AMECTRAN WORK.

THE AMECTRAN ELECTRIC CAR IS REPRESENTED TODAY BY ONLY THE PRE-PRODUCTION PROTOTYPE. THIS CAR HAS MUCH OF THE APPEARANCE OF THE PRODUCTION CAR, BUT HAS A STEEL BODY (WHICH WILL BE USED AS THE MOLD FOR THE PRODUCTION PLASTIC BODY) GIVING A VEHICLE CURB WEIGHT SOME 1800 POUNDS I AM TOLD OVER THE PRODUCTION CAR WEIGHT, AN ELECTRIC MOTOR AND TRANSMISSION WHICH ARE NOT PRECISELY THOSE TO BE USED IN THE PRODUCTION CAR, BEARINGS AND BRAKES WHICH ALSO WILL BE MODIFIED, 24 MAGNETTI-MORELLI BATTERIES I AM TOLD - WHEREAS DIFFERENT BATTERIES (TROJAN?) ARE PLANNED FOR THE PRODUCTION CAR, AND DIFFERENT GOODYEAR TIRES AND TIRE PRESSURES NECESSITATED BY THE 5200 POUNDS OR SO OF THE PRE-PRODUCTION VEHICLE GROSS WEIGHT. HENCE THIS CAR MUST BE VIEWED AS A DEMONSTRATION CAR AND NOT A TEST CAR STRICTLY REPRESENTATIVE OF THE PRODUCTION CAR. BECAUSE OF EACH OF THESE FACTORS, THE PERFORMANCE OF THIS CAR IS EXPECTEDLY LESS THAN THE PERFORMANCE WE CAN EXPECT OF THE PRODUCTION CAR. THE MOST IMPORTANT DIFFERENCE IS THE INCREASED WEIGHT OF THE PRE-PRODUCTION VEHICLE. A SIMPLISTIC CORRECTION FOR THIS WEIGHT DIFFERENCE WOULD BE THAT THE PRODUCTION CAR WOULD HAVE A RANGE AND ACCELERATION OF THE PRE-PRODUCTION CAR TIMES THE RATIO OF DRIVING WEIGHTS OF THE PRE-PRODUCTION CAR TO THE PRODUCTION CAR, A RATIO OF ABOUT 1.6.
IN ACTUAL PRACTICE, THE ENERGY REQUIRED TO MOVE A CERTAIN WEIGHT AT A CERTAIN SPEED FOR A PARTICULAR ELECTRIC CAR MAY BE QUITE NON-LINEAR WITH WEIGHT NEAR TRANSMISSION GEAR CHANGES OR THE ENGINE RPM DESIGN LEVEL. IT IS EMPHASIZED THAT MR. RAMIREZ HAS NOT HAD THE OPPORTUNITY SINCE THE PRE-PRODUCTION CAR HAS BEEN RETURNED FROM ITALY TO QUANTITATIVELY ASSESS AND FINE TUNE THE CAR CHARACTERISTICS AND EFFICIENCY. HE IS BEING ASKED TO TEST A CAR THAT IS NOT DESIGNED FOR TESTING, NOR GIVEN THE OPPORTUNITY TO TUNE THE CAR FOR OPTIMUM PERFORMANCE BEFORE IT IS TESTED.

M E M O R A N D U M

DATE: September 8, 1980

TO: The Honorable John C. Ford, Bankruptcy Judge

FROM: Dr. Richard A. Jenner, Director, Business Incentive Program, The City of Berkeley

SUBJECT: REPORT OF THE TEST RESULTS FOR THE AMECTRAN EXAR-1

In response to an order issued by your court on July 11, 1980, between July 14, 1980, and July 16, 1980, at Ontario Motor Speedway, I supervised a test of the electric vehicle, known as the Frua-Exar-1 developed by the Amectran Corporation of Dallas, Texas. A previous court order had placed this vehicle under the supervision of Dr. Carl Clark, of the United States Department of Transportation, for transportation, testing, and protection at a mutually agreeable testing facility, which was determined to be the Ontario Motor Speedway in Ontario, California. When Dr. Clark was prohibited from participating in this test, my name was substituted for his, with the exception that the responsibility for shipping the car would remain with the President of Amectran, Edmond X. Ramirez.

The court order of July 11 further stipulated that the proposed test of the car should follow an outline of the testing procedures that had previously been prepared by Dr. Clark. Although the specific memorandum in which this outline was contained was not identified in the court order, I assume that the memorandum in question was from Dr. Clark to Mr. Charles Patterson, Trustee of the Dallas Court, Reference Number NRD-12-CC-80045. I received a copy of this memorandum, and generally agreed that the proposed testing procedures would provide adequate information and data to assist me with my activities on behalf of the City of Berkeley; that is, it would assist me to prepare a financial loan application package for the California licensee of this car, the California Electric Car Company, which has proposed to construct its first production and sales facility in the City of Berkeley. As a city officer, of course, my obligation and involvement with this project is to promote business development in the City.

Therefore, after consulting with engineers and local authorities in the field of electric vehicle technology and research, my staff and I designed a program or plan for testing the Exar-1, that in every way was compatible with that outline by Dr. Clark. This testing procedure was very closely adhered to during the three days of the actual conduct of the test, July 14 through July 16, 1980.

All three days of tests were physically conducted at the Ontario Motor Speedway in Ontario, California. This speedway, at which the "Ontario 500" race is conducted every year, is a race track of professional dimensions, with photoelectric instrumentation that specifically and accurately counts the time in seconds for each lap around the track, which is measured at precisely 2.5 miles at the center strip. In addition, the race track provides an electronic weighing devise and a crew to operate all equipment. Furthermore, in conducting this test, I engaged the services of an international authority in the field of electric vehicle research, who is a head of the electric vehicle testing program at Jet Propulsion Laboratory in Pasadena, California, to supervise all of the technical characteristics of the tests itself. This person is preparing a final report of his observations. In addition, I engaged the services of a manufacturer of specialized instrumentation for conducting vehicular tests, who provided a fifth wheel connected to a computer that measures such factors as velocity, acceleration, drag, etc., second-by-second, throughout the test. Finally, the batteries were checked by a totally independent person, the president of a battery manufacturing firm whose batteries were not used in this production prototype car. The individuals who provided technical anaylsis of the car's performance were not paid through City of Berkeley funds, but through the California licensee, the California Electric Car Company. It is my opinion that the test was professionally conducted and monitored, under strictly scientific and objective conditions, and as free from bias as possible.

It should be noted that the Amectran Electric Car that was tested at the Ontario Speedway was the pre-production prototype, and not a test vehicle itself. It was clear that this vehicle had not been intended nor designed for performance testing; although it has the appearance of the production car, its heavy eleven-gauge steel body (which will be used as the mold for the final production car, to be made from Kevlar plastic), weighed 4,715 pounds--approximately 1,700 pounds more than the final production car is scheduled to weigh. Moreover, because of this overweight, the tires used in the test were different in many respects from the specially-made Goodyear tires that will be used on the final production car, tires which I am told will have 40% less rolling friction than standard production tires. In addition, the batteries in this test car, which were aging Magnetti-Morelli batteries (except for one even older Trojan that was inserted to replace one that had been dropped) are not the batteries that will be used in the production car, nor are they ideally suited for any type of performance testing. Finally, other differences should be noted between this test car and the final production version:

> The electric motor, the transmission, the bearings, and brakes will all be somewhat different in the final production automobile. As Dr. Clark has put it: ". . . this car must be viewed as a demonstration car and not a test car strictly representative of the production car." My personal observation, as well as that provided by the independent test consultants, verified that this statement by Dr. Clark was accurate. According to Dr. Clark's memorandum, the test should basically be focused on determining whether "the expense of time and money to bring the car to market is justified." This determination will rest upon four "qualitative and semi-qualitative tests." They are:

1) Is the pre-production car capable of expressway speed (55 m.p.h.)?
2) Does it have an acceleration in the range of accelerations of acceptable cars now in use on the highway?
3) Does the pre-production car with its extra weight and used lead acid batteries have a driving range of greater than 21 miles?
4) Is the pre-production car marketable?

Results of the Test:

1) Is the pre-production car capable of expressway speed (55 m.p.h.)? It was clearly demonstrated at the test that this pre-production car, despite its excess weight, is clearly capable of driving at expressway speeds: i.e., 55 m.p.h. Despite this excess weight--and carrying four fairly heavy passengers--the car traveled many times at 55 m.p.h. without difficulty. The highest speed recorded on the computer printout for the acceleration test was 66 m.p.h. However, Jay Colombatto, an employee of the Business Incentive Program, and I observed during one run, the automobile operating at 73 m.p.h., as measured by the automobile's speedömeter. On other tests, the car was tracked by another car at comparable speeds. By adjusting for the excess weight, for the weak batteries, and less than adequate tires, it seems reasonable to infer that this car could drive between 75 and 80 m.p.h. As it is now, however, all evidence and information that I have been able to obtain points quite graphically that the pre-production prototype Exar-1, despite its current weight and other handicapps, exceeds both the cruise and top speeds of all existing electric vehicles, and even those that have been proposed or are planned for production within the next five years.

2) Does the car have an acceleration that would make it capable of highway travel? In my opinion, the test results confirm that, indeed, the production prototype Exar-1 is capable of freeway accessibility. Dr. Clark specified that, for the pre-production

car to be freeway accessible, it should have an acceleration of between 0-30 m.p.h. within 9 seconds, and between 25 and 55 m.p.h. within 18 seconds. According to our computer data, the best recorded 0-30 acceleration was 6.55.

3) The final test that Dr. Clark specified was the determination of its driving range. This test I was intimately involved with, since I was the communication point via walkie-talkie, with Mr. Ramirez, who was driving the car for its range test. I received from the crew monitoring the photo-electric cell at the speedway, the elapsed lap time in seconds, converted this to lap time m.p.h. and average total m.p.h., and communicated this to Mr. Ramirez. In this way, he kept the average and the actual lap time speed to approximately 55 m.p.h. The results of this range test exceeded 72 miles. In fact, the range of the actual production prototype car, despite its excessive weight, equals or exceeds the range of any production electric car or any electric car proposed for production so far as I, my staff, or any authority that I have consulted are aware.

4) The most difficult question, of course, to answer is whether the pre-production car is sufficiently attractive, roomy, safe, and competitively priced to assure a sufficient market. Partly, I can draw on my own experience in advertising, management consulting, loan and financial packaging, production planning, and marketing, to attest to my personal conviction that this car eminently meets all of these requirements. A number of business executives, federal officers, and a senior executive of a bank in California which has expressed an interest in providing the loan to the California

Electric Car Company to construct the Berkeley production facility attended one or more days of the tests at Ontario at my request. The information, verbal exchanges, and communications that I and my staff have received, attest to the opinion by these authorities that the Exar-1 is highly marketable. Moreover, the people connected with the California Electric Car Company have been directed to proceed with plans for the financing of their Berkeley faciltiy. These people, who are all seasoned and successful businesspeople, are clearly satisfied that the product they observed at Ontario Motor Speedway is a marketable product. I concur in this opinion.

RAJ/jw