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BASELINE TESTS OF THE EVA CHANGE-OF-PACE COUPE ELECTRIC PASSENGER VEHICLE

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16 Abstract

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The Electric and Hybrid Vehicle Program was conducted under the guidance of the then Energy Research and Development Administration (ERDA), now part of the Department of Energy.

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SUMMARY

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The EVA Change-of-Pace Coupe is a four-passenger American Motors Pacer that has been converted to an electric vehicle. It is powered by twenty 6-volt traction batteries through a silicon-controlled-rectifier chopper controller actuated by a foot throttle to change the voltage applied to the series-wound, direct-current motor. Braking is accomplished with a vacuum-assist hydraulic braking system. Regenerative braking is also provided.

All tests were run at the gross vehicle weight of 2086 kilograms (4600 lbm). The results of the tests are as follows:

Test speed or driving schedule		Type of test						
		Range		Road power, kW	Road energy		Energy consumption	
km/h	mph	km	mile		MJ/km	kWh/mile	MJ/km	kWh/mile
40	25	85	53	3.4	0.31	0.14	[a]0.94	[a]0.42
56	35	70	44	6.2	40	.18	1.1	.45
72	45	55	34	11	.54	.24	1.1	.50
82	51	51	31	[b]14	[b].60	[b] 27	1.4	.61
B[c]		48	30	-----	----	----	-----	-----
B[d]		53	33	-----	----	----	1.6	.70
C[c]		48	30	-----	----	----	[a]1.9	[a].85
C[d]		47	29	-----	----	----	[a]2 0	[a].87

[a]110-Volt AC NASA charger used.

[b]Extrapolated data point.

[c]Without regenerative braking.

[d]With regenerative braking.

The EVA Change-of-Pace Coupe was able to accelerate from 0 to 32 kilometers per hour (0 to 20 mph) in 8 seconds and from 0 to 48 kilometers per hour (0 to 30 mph) in 18 seconds.

Measurements were made to assess the performance of the vehicle components. The performance was as follows:

Charger power efficiency, percent	.93
Battery efficiency with 49-percent overcharge, percent	.58
Controller efficiency, percent	<94

INTRODUCTION

The vehicle tests and the data presented in this report are in support of Public Law 94-413 enacted by Congress on September 17, 1976. The law requires the Energy Research and Development Administration (ERDA) to develop data characterizing the state-of-the-art of electric and hybrid vehicles. The data so developed are to serve as a baseline (1) to compare improvements in electric and hybrid vehicle technologies, (2) to assist in establishing performance standards for electric and hybrid vehicles, and (3) to help guide future research and development activities.

The National Aeronautics and Space Administration (NASA), under the direction of the Electric and Hybrid Research, Development, and Demonstration Office of the Division of Transportation Energy Conservation of ERDA, has conducted track tests of electric vehicles to measure their performance characteristics and vehicle component efficiencies. The tests were conducted according to ERDA Electric and Hybrid Vehicle Test and Evaluation Procedure described in appendix E of reference 1. This procedure is based on the Society of Automotive Engineers (SAE) J227a procedure (ref. 2). Seventeen electric vehicles have been tested under this phase of the program, 12 by NASA, 4 by MERADCOM, and 1 by the Canadian government.

The assistance and cooperation of Warren Harhay, the president of Electric Vehicle Associates, is greatly appreciated. The Energy Research and Development Administration provided funding support and guidance during this project.

U.S. customary units were used in the collection and reduction of data. The units were converted to the International System of Units for presentation in this report. U.S. customary units are presented in parentheses. The parameters, symbols, units, and unit abbreviations used in this report are listed here for the convenience of the reader.

Parameter	Symbol	SI units		U.S. customary units	
		Unit	Abbreviation	Unit	Abbreviation
Acceleration	a	meter per second squared	m/s^2	mile per hour per second	mph/s
Area	---	square meter	m^2	square foot; square inch	ft^2, in^2
Energy	---	megajoule	MJ	kilowatt hour	kWh
Energy consumption	E	megajoule per kilometer	MJ/km	kilowatt hour per mile	kWh/mile
Energy economy	---	megajoule per kilometer	MJ/km	kilowatt hour per mile	kWh/mile
Force	P	newton	N	pound force	lbf
Integrated current	---	ampere hour	Ah	ampere hour	Ah
Length	---	meter	m	inch; foot; mile	in., ft; ---
Mass, weight	W	kilogram	kg	pound mass	lbm
Power	P	kilowatt	kW	horsepower	hp
Pressure	---	kilopascal	kPa	pound per square inch	psi
Range	---	kilometer	km	mile	---
Specific energy	---	megajoule per kilogram	MJ/kg	watt hour per pound	Wh/lbm
Specific power	---	kilowatt per kilogram	kW/kg	kilowatt per pound	kW/lbm
Speed	V	kilometer per hour	km/h	mile per hour	mph
Volume	---	cubic meter	m^3	cubic inch; cubic foot	in^3; ft^3

OBJECTIVES

The objectives of these tests were to measure vehicle maximum speed, range at constant speed, range over stop-and-go driving schedules, maximum acceleration, gradeability, road energy consumption, road power, indicated energy consumption, battery charger efficiency, battery characteristics, and controller efficiency for the EVA Change-of-Pace Coupe (the EVA Pacer).

TEST VEHICLE DESCRIPTION

The EVA Change-of-Pace Coupe, also referred to as the EVA Pacer, is a converted American Motors Pacer two-door sedan that is powered by twenty 6-volt traction batteries. A silicon-controlled-rectifier (SCR) chopper speed controller actuated by a foot throttle changes the voltage applied to the series-wound direct-current (DC) motor. A standard transmission with four forward and one reverse gear is provided. The vehicle is shown in figure 1 and described in detail in appendix A. The 110-volt alternating-current (AC) battery charger on board the vehicle charges both the traction batteries and the accessory battery. Regenerative braking was provided on this vehicle.

INSTRUMENTATION

The EVA Change-of-Pace Coupe was instrumented to measure and record vehicle speed and distance traveled, battery current and voltage, motor current and voltage, energy into the charger, battery capacity removed during the test, and battery capacity restored during charging. (A schematic diagram of the electric propulsion system with the instrumentation sensors is shown in fig. 2.) A Nucleus Corporation Model NC-7 precision speedometer (fifth wheel) was used to measure vehicle velocity and distance traveled. Auxiliary equipment used with the fifth wheel included a Model ERP-X1 electronic pulser for distance measurement, a Model NC-PTE pulse totalizer, a Model ESS/E expanded-scale speedometer, a Model NC-RSD digital speedometer, and a programmable digital attenuator. Vehicle speed and distance were recorded on an on-board Honeywell 195 Electronik two-channel, strip-chart recorder. The fifth wheel system and the recording system were calibrated periodically. An electronic pulse generator was used to simulate the rotation of the fifth wheel. Comparing the simulated speed and distance to that indicated by the expanded-scale speedometer, digital speedometer, pulse totalizer, and strip-chart recorder showed an error of less than ± 1.6 kilometers per hour (± 1 mph) in speed and less than ± 1 percent in distance.

The integrated battery current was measured for the battery pack with a current shunt and an on-board current integrator. It was recorded manually after each test. The current integrator is a Curtis Model SHR-C3 current integrator and was calibrated periodically to within ± 1 percent of reading.

Battery and motor current and voltage were recorded on two on-board Honeywell 195 Electronik two-channel, strip-chart recorders. The currents were measured with 500-ampere shunts, and the voltages were measured with appropriate voltage-sensing leads (fig. 2). In addition, battery electrolyte temperatures and specific gravities were measured manually before and after the tests.

The battery current and voltage during charge and the energy into the battery charger were measured. The battery current and voltage were recorded on a Honeywell 195 Electronik two-channel, strip-chart recorder (fig. 2). The energy delivered to the charger was measured with a General Electric 1-50A single-phase residential kilowatt-hour meter (fig. 2).

In tests designed to measure the charger power efficiency, a laboratory-type wattmeter with Hall-effect current sensors was used. The wattmeter was manufactured by Ohio Semitronics, Inc.

Power for the fifth-wheel system was provided from a 12-volt starting, lighting, and ignition (SLI) instrumentation battery. A Tripp Lite 500-watt DC/AC inverter, also powered from the SLI battery, provided the AC power to the current integrator and to all on-board strip-chart recorders.

All instruments were calibrated periodically. The integrators and strip-chart recorders were calibrated with a Hewlett-Packard Model 6920 B meter calibrator, which has an accuracy of 0.2 percent of reading and a usable range of between 0.01 and 1000 volts.

TEST PROCEDURES

The tests described in this report were performed at the Transportation Research Center Test Track, a 12-kilometer (7.5-mile) multilane test track located in East Liberty, Ohio. A complete description of the track is given in appendix B. When the vehicle was delivered to the test track, the pretest checks described in appendix C were conducted. The first test was a formal shakedown to familiarize the driver with the operating characteristics of the vehicle, to check out all instrumentation systems, and to determine the vehicle's maximum speed (appendix C). All tests were run in accordance with ERDA Electric and Hybrid Vehicle Test And Evaluation Procedure ERDA-EHV-TEP (appendix E of ref. 1) at the gross weight of the vehicle, 2086 kilograms (4600 lbm).

Range Tests at Constant Speed

The vehicle speed for the highest constant-speed range test was determined during checkout tests of the vehicle. It was specified as 95 percent of the minimum speed the vehicle could maintain on the test track when it was traveling at full power. This speed was 82 kilometers per hour (51 mph) for the EVA Change-of-Pace Coupe.

Range tests were run at constant speeds of 40, 56, 72, and 82 kilometers per hour (25, 35, 45, and 51 mph). The speed was held constant within $\pm$1.6 kilometers per hour (1 mph), and the test was terminated when the vehicle could no longer maintain 95 percent of the test speed.

Range Tests under Driving Schedules

Schedule B and C stop-and-go driving cycles, shown in figure 3, were run with and without the regenerative braking system operative. A complete description of cycle tests is given in appendix E of reference 1. A special instrument, called a cycle timer, was developed at the Lewis Research Center to assist in accurately running these tests. Details of the cycle timer are given in appendix C. The cycle tests were terminated when the cruise speed could not be attained in the time required under maximum acceleration.

Acceleration and Coast-Down Tests

The maximum acceleration of the vehicle was measured on a level road with the battery fully charged and 40 and 80 percent discharged. Four runs were made at each of the battery states of charge, two on each side of the oval test track, in order to average out track abnormalities. Depth of discharge was determined from the number of ampere-hours removed from the batteries. Coast-down data were taken after the acceleration test with the transmission in neutral and with fully charged batteries in order to start the coast-down run from the maximum attainable vehicle speed.

Braking, Tractive Force, and Handling Tests

The braking and tractive force tests described in appendix E of reference 1 were not performed. The period of time the vehicle was available for testing was limited, and a higher priority was placed on determining the range of the vehicle and the acceleration and coast-down characteristics. The handling tests were omitted at the request of ERDA.

Charger Efficiency Tests

Charger efficiency was measured with a 50-kilowatt power meter and a Hall-effect current probe. To minimize errors, the same meter and current probes were used for both the input measurement and the output measurement. The average power measured was about 4 percent of full scale. The batteries were removed from the vehicle and reconnected in series with pressure clamps. The ratio of input and output charger power was determined at only one point in the charging phase. As a result, only the power efficiency was determined.

TEST RESULTS

Range

The data collected from all the range tests are summarized in table I. Shown in the table are the test

date, the type of test, the environmental conditions, the range attained, the number of cycles completed, the capacity into and out of the battery, the energy into the charger, and the calculated indicated energy consumption.

The maximum speed of the vehicle was measured during the checkout tests. Maximum speed is defined as the average speed that could be maintained on the track under full power. The measured maximum speed was 90 kilometers per hour (56 mph) for this vehicle. This differs from the maximum speed used in the range tests.

Nineteen range tests were performed with the EVA Change-of-Pace Coupe. Five of these tests were invalid or aborted due to various vehicle failures. These data are not reported. These five failures included three speed controller failures, a fractured clutch linkage, and shorted motor leads. One range test was performed with high-pressure truck tires in place of the standard tires on the vehicle. No significant difference was observed between the results of this test and the results from similar tests with standard tires.

The results of the 14 useful range tests are shown in table I. The measured vehicle range varied from an average of 84.6 kilometers (52.6 miles) at 40 kilometers per hour (25 mph) to 50.5 kilometers (31.4 miles) at 82.1 kilometers per hour (51 mph). Regenerative braking effects were determined for the schedule B and C tests. The average ranges measured under schedule C were 45.9 kilometers (28.5 miles) without regenerative braking and 47.8 kilometers (29.7 miles) with regenerative braking, for a 5-percent improvement in range. The range extension due to regenerative braking during the schedule B tests was somewhat larger - 47.9 kilometers (29.8 miles) without regenerative braking and 52.8 kilometers (32.8 miles) with regenerative braking, for a 10-percent improvement. Only one schedule B test in each configuration was run, so the accuracy of the schedule B regenerative braking results is somewhat in doubt.

Maximum Acceleration

The maximum acceleration of the vehicle was determined with the batteries fully charged and 40 and 80 percent discharged. The vehicle speed and acceleration at the three states of battery charge are presented in figures 4 and 5 and tabulated in table II. The average acceleration $\bar{a}_n$ was calculated for the time period t_{n-1} to t_n, where the vehicle speed increased from V_{n-1} to V_n, from the equation

$$\bar{a}_n = \frac{V_n - V_{n-1}}{t_n - t_{n-1}}$$

and the average speed of the vehicle $\bar{V}$ from the equation

$$\bar{V} = \frac{V_n + V_{n-1}}{2}$$

Gradeability

The maximum specific grade, in percent, that a vehicle can climb at an average vehicle speed $\bar{V}$ was determined from maximum acceleration tests by using the equations

$G = 100 \tan (\sin^{-1} 0.1026\ \bar{a}_n)$ for V in km/h

in SI units

or

$G = 100 \tan (\sin^{-1} 0.0455\ \bar{a}_n)$ for $\bar{V}$ in mph

in U.S. customary units

where $\bar{a}_n$ is average acceleration in meters per second squared (mph/sec). The maximum grades the EVA Change-of-Pace Coupe can negotiate as a function of speed and battery state of charge are shown in figure 6 and table II. At a speed of 20 kilometers per hour (12.4 mph), the gradeability varied from 16.1 percent for a fully charged battery to 12.6 percent for an 80-percent-discharged battery. The gradeability is less than 5 percent at speeds greater than 42 kilometers per hour (26.1 mph) at all states of charge.

Road Energy Consumption

Road energy is a measure of the energy consumed per unit distance in overcoming the vehicle's aerodynamic and rolling resistance plus the energy consumed in the differential drive shaft and the portion of the transmission rotating when in neutral. It was obtained during coast-down

tests, when the differential was being driven by the wheels, and thus may be different than the energy consumed when the differential is being driven by the motor. Figure 7 and table III show the vehicle speed as a function of time during the coast-down period. The vehicle coasted down from a speed of 80 kilometers per hour (49.7 mph) in 145.7 seconds.

Road energy consumption E_n was calculated from the following equations:

$$E_n = 2.78 \times 10^{-4} W \frac{V_{n-1} - V_n}{t_n - t_{n-1}}, \text{ MJ/km}$$

or

$$E_n = 9.07 \times 10^{-5} W \frac{V_{n-1} - V_n}{t_n - t_{n-1}}, \text{ kWh/mile}$$

where

W vehicle mass, kg (lbm)

V vehicle speed, km/h (mph)

t time, s

The results of the road energy calculations are shown in figure 8 and table III. At 2.0 kilometers per hour (1.2 mph) the road energy was 0.188 megajoule per kilometer (0.084 kWh/mile). At 78 kilometers per hour (48.5 mph) the road energy was 0.519 megajoule per kilometer (0.232 kWh/mile).

Road Power Requirements

The calculation of road power is analogous to that of road energy. Road power is a measure of the power necessary to overcome vehicle aerodynamic and rolling resistance plus the power losses in the differential, the drive shaft, and a portion of the transmission. The road power P_n required to propel a vehicle at various speeds is also determined from the coast-down tests. The following equations were used:

$$P_n = 3.86 \times 10^{-5} W \frac{V_{n-1}^2 - V_n^2}{t_n - t_{n-1}}, \text{ kW}$$

or

$$P_n = 6.08 \times 10^{-5} W \frac{V_{n-1}^2 - V_n^2}{t_n - t_{n-1}}, \text{ hp}$$

The results of road power calculations are shown in figure 9 and table III. At 2.0 kilometers per hour (1.2 mph) the road power was 0.105 kilowatt (0.14 hp). At 78.0 kilometers per hour (48.5 mph) the road power was 11.26 kilowatts (15.095 hp).

Indicated Energy Consumption

The vehicle indicated energy consumption is defined as the energy required to recharge the battery after a test, divided by the vehicle range achieved during the test, where the energy is the input to the battery charger.

During the testing of the EVA Change-of-Pace Coupe, three different chargers were used: a 110-volt AC full-wave rectifier originally supplied with the vehicle; a 110-volt AC NASA-supplied charger used after the original charger failed; and a 208-volt AC, single-phase charger supplied by the vehicle manufacturer for the last few range tests. The type of charger used after each test is shown in table I.

The indicated energy consumptions reported herein are for the two 110-volt AC chargers only. The energy input to the 208-volt AC, single-phase charger was not measured. The average indicated energy consumptions for the constant-speed and cycle tests are shown in table IV.

During the testing program the battery was overcharged to assure a fully charged and equalized battery. In many cases the overcharge exceeded 10 percent, which would be desirable in actual field use conditions. Correcting the charger input energy to a 10-percent overcharge reduces the energy consumption. The actual total charge energy and the corrected energy consumption for an overcharge of 10 percent are shown in table IV for the constant-speed and cycle tests.

COMPONENT PERFORMANCE AND EFFICIENCY

Battery Charger

Three different traction battery chargers were used: the original 110-volt AC, full-wave rectifier; a 110-volt AC NASA charger; and a 208-volt AC single-phase charger.

The original 110-volt AC charger was unable to charge the traction battery in the 18 hours between tests. The charger was to be replaced because of this deficiency but failed before a replacement arrived. Since this charger was a simple bridge rectifier, it was very sensitive to input voltage. An increase in input voltage would increase the current delivered to the battery to a point where the charger components were operating beyond design points. A decrease in input voltage would reduce the current delivered to the battery to a point where the charge could not be completed overnight. This sensitivity necessitated constant attention to the filter chokes used in series with the charger. When the battery current exceeded 20 amperes, it was assumed that the input charger voltage exceeded the nominal value of 110-volt AC. The number of chokes in series with the charger had to be increased to reduce the battery current. When charging times were in excess of 16 hours and/or battery current levels were less than 15 amperes, the number of series chokes was decreased, thereby increasing the battery current. These chokes were adjustable from 0 to 2.4 millihenries in 0.6-millihenry steps.

The original 110-volt AC charger failed and a NASA-supplied, 110-volt AC charger was used until a new charger could be obtained from the vehicle manufacturer. The auxiliary NASA charger was a 110-volt AC, full-wave bridge using a variable resistor for control. The new charger supplied by the vehicle manufacturer was an upgraded version of the original charger but required a three-wire 208-volt AC, single-phase input voltage. This charger was much more stable and performed well during the latter phases of testing. The new charger was designed to terminate charge when the battery voltage reached 150 volts.

The efficiency of the 208-volt AC charger was determined from data gathered during a charging sequence with the battery removed from the vehicle. The 50-kilowatt power meter used on the AC and DC sides of the charger indicated a power efficiency of 93 percent at 20 amperes DC.

Battery

Manufacturer's data. - The battery supplied with the EVA Change-of-Pace Coupe consisted of 20 Globe-Union GC-2-19 golf car battery modules. The manufacturer delivered the vehicle to NASA for testing with 18 of the batteries under the hood and in the trunk. The remaining two batteries were located on the floor in front of the rear seat, reducing the seating capacity to three. The GC-2-19 is a 6-volt, three-cell module that provides an average of

131 ampere-hours when discharged in 105 minutes at a current of 75 amperes to a voltage cutoff of 1.75 volts per cell. Battery characteristics as supplied by the manufacturer are shown in table V, and battery discharge data are presented in figures 10 and 11. Discharge current as a function of discharge time is shown in figure 10. The capacity of the battery varies with discharge current. The battery is capable of delivering 205 ampere-hours at 10 amperes, or 131 ampere-hours at 75 amperes.

Battery specific power as a function of the specific energy available for a three-cell module is shown in figure 11. At a low specific power of 2 watts per kilogram (0.9 W/lbm) the available energy is 0.15 megajoule per kilogram (41.7 Wh/kg). At a higher specific power of 20 watts per kilogram (9 W/lbm), the available energy decreases to 0.08 megajoule per kilogram (22.2 Wh/kg). At the manufacturer's rated discharge rate of 75 amperes, which is equivalent to 14.8 watts per kilogram the available specific energy is 0.093 megajoule per kilogram (25.8 Wh/kg).

Battery acceptance. - Prior to track testing, the battery supplied by the vehicle manufacturer was checked for capacity and terminal integrity as specified in appendix E of reference 1.

The 300-ampere terminal qualification test was run with a constant-current electronic load bank. The battery voltage decreased from 107 volts to 105 volts (1.75 VPC) when it was discharged at a rate of 300 amperes (fig. 12). After a 5-minute discharge at the 300-ampere rate, the terminal temperature as measured by thermocouples ranged from 52° to 82° C (125° to 180° F). As this was less than 60 degrees Celsius above ambient, the battery system was within specifications.

The capacity check was performed using the same load bank. The capacity check was run twice, once immediately after the 300-ampere terminal test without a recharge and once after a subsequent recharge. In both tests the battery was discharged at 75 amperes until the battery voltage reached 105 volts (1.75 VPC). The results of both tests are shown in figure 12. In the first capacity test (which included the 300-ampere test) the measured capacity was 127 ampere-hours. In the second test the capacity was 123 ampere-hours. The average capacity of 125 ampere-hours is 95 percent of the manufacturer's specification, which is within the 80-percent criterion for passing the test.

Battery performance at constant vehicle speed. - During the track tests, battery current and voltage were recorded.

The battery current and voltage for four constant-speed tests are shown in figures 13 and 14 and table VI. Average data are presented for the first 25 percent and the last 25 percent of the range at their respective speeds.

Battery current and voltage tended to decrease toward the end of the test, suggesting that the power required to propel the vehicle at a constant speed decreases as the test proceeds. This effect has also been reported in reference 1. It is probably due to a reduction in road load as the mechanical components, lubricants, and tires heat up.

Battery performance over a driving schedule. - During the two stop-and-go schedule tests (schedules B and C with and without regenerative braking), battery voltage and current were recorded. These battery data are presented in figure 15 and table VII. Regenerative braking should return current to the battery when the brakes are applied at about 42 seconds from the start of driving schedules B and C, 46 seconds for schedule C (fig. 3). A negative current pulse results when regenerative braking is operative. The current returned to the battery is small. Only 0.03 ampere-hour was returned to the battery during a typical cycle (fig. 15(h)); the battery was discharged 1.7 ampere-hours during the same test. During the schedule B tests, even less capacity was returned to the battery.

Battery performance during maximum acceleration tests. - Battery current and voltage as a function of gradeability and depth of discharge are shown in figure 16 and table VIII. The calculation procedure used to obtain gradeability from maximum acceleration test data is discussed under gradeability. The transmission gear (first, second, third, or fourth) that the vehicle was being driven in when data were recorded is also shown in figure 16. The peak current drains occurred while shifting into a higher gear and reached 277 amperes at a battery voltage of 108.7 volts with a fully charged battery.

General battery performance. - Battery data for representative tests are shown in table IX. The battery electrolyte specific gravities ranged from 1.273 to 1.280 for the fully charged battery and from 1.110 to 1.149 for the fully discharged battery. The ampere-hour overcharge varied from 11 percent to 51 percent.

The battery temperature increased more during the driving schedule tests than during the constant-speed tests. During the constant-speed tests, battery temperatures increased an average of 3 degrees Celsius, during the driving schedule tests they increased 17 degrees Celsius.

Charging and battery efficiency. - Battery energy efficiency is calculated from measurements of charger input and battery output. Since the EVA Change-of-Pace Coupe employs an SCR chopper speed controller and only average battery and current were recorded, simple multiplication of battery current and voltage to obtain power is inaccurate. This inaccuracy may be minimized if battery efficiency is calculated for tests where the chopper control is full on or nearly full on throughout the test. This situation occurred during the constant-high-speed test.

The charge sequence and the test results for the 82-kilometer-per-hour (51-mph) test on 6/24/77 were analyzed to determine battery energy efficiency. The charging battery current, voltage, and power for this test are shown in figure 17. The total energy restored to the battery was 72 megajoules (20 kWh). The energy removed from the battery during this speed test was 42 megajoules (11.6 kWh). Thus, the calculated battery energy efficiency is 58 percent. The battery overcharge during this test was 49 percent (table IX). Correcting this excess overcharge to 10 percent increases the battery energy efficiency to 79 percent.

Controller

The controller for the EVA Change-of-Pace Coupe is a commercially available SCR Cableform chopper. An off-the-shelf controller was modified by Cableform, enabling the controller to initiate and maintain regenerative braking. Figure 18 is a schematic of the electrical drive and the controller showing the operation in the normal and regenerative modes.

During normal operation the speed controller, actuated by the foot pedal, varies the power to the motor. Also during normal operation, contactors C1, C2, and C5 are closed and C3 and C4 are open. Current then flows from the battery into the motor. During the regenerative mode, which is actuated by the brake pedal, contactors C1, C2, and C5 are opened and C3 and C4 are closed. Current then flows from the motor armature into the batteries.

The power efficiency of the controller can be determined from battery and motor data recorded during the maximum acceleration tests. During these tests, the speed controller is full on, so average current and voltage can be multiplied to determine average power. This technique was applied to a random sample of battery and motor current and voltage given in tables VIII and X. The resultant ratio of battery and motor power gives an average controller power effiency of 94 percent. The power efficiency of the speed

controller will decrease when it is operating in other than the full-on condition.

Motor

The motor used in the EVA Change-of-Pace Coupe is a DC series-wound motor specifically manufactured for EVA. The available data for the motor are included in appendix A. Motor input current and voltage data for maximum acceleration tests are shown in figure 19 and table X. The current and voltage are presented as a function of gradeability, similar to the battery data discussed earlier. The transmission gear the vehicle was driven in during the test is also shown for reference in figure 19. At the shift points the peak motor current was 272.4 amperes and motor voltage was 95.3 volts during the 80 percent battery discharge tests.

The input parameters to the motor during the various cycle tests are shown in figure 20 and table XI. Regeneration occurs during the braking phase of the test and in some cases reaches 250 to 300 amperes for a short period of time.

The efficiency of the motor could not be determined because torque/speed characteristics were not available for the motor.

VEHICLE RELIABILITY

The initial tests demonstrated a need for a motor adjustment. Due to a misalignment of the motor brushes, a component in the SCR speed controller failed. After the motor brushes were rotated to a more optimum position and the failed component in the speed controller was replaced, it was found that the vehicle's maximum speed was reduced from 87 kilometers per hour (54 mph) to 82 kilometers per hour (51 mph). As a result, all range tests completed prior to this repair were not representative of the vehicle performance and are not included in this report.

Testing was resumed after the adjustments and repairs described above had been made. Two subsystem failures resulted in an aborted test: another SCR speed controller failure on 7/5/77, and a fractured clutch linkage on 7/14/77. During two range tests conducted on 7/1/77 and 7/8/77, intermittent speed controller outages occurred. During one charging sequence on 6/27/77 the original 110-volt AC charger failed. An auxiliary NASA 110-volt AC charger was used until a new charger was supplied by the vehicle manufacturer on 7/8/77.

DRIVER REACTION AND VEHICLE SERVICEABILITY

The vehicle was comfortable and handled well. The transmission coupled with the SCR speed controller system allowed effortless and smooth gear changes.

The operation of the charger is sensitive to line input voltage. Longer charge times are required if line voltage is low. The batteries were all relatively easy to service (i.e., in respect to adding water and servicing the terminals), except for the two 6-volt modules located temporarily in the back seat.

APPENDIX A

VEHICLE SUMMARY DATA SHEET

1.0 Vehicle manufacturer: Electric Vehicle Associates, Inc.
Valley View, Ohio

2.0 Vehicle: EVA Change-of-Pace Coupe

3.0 Price and availability: $10 500; immediate

4.0 Vehicle weight and load

4.1	Curb weight, kg (lbm)	1810 (3990)
4.2	Gross vehicle weight, kg (lbm)	2086 (4600)
4.3	Cargo weight, kg (lbm)	141 (310) with two passengers
4.4	Number of passengers	[1] 4
4.5	Payload, kg (lbm)	277 (610)

5.0 Vehicle size

5.1	Wheelbase, m (in.)	2.54 (100)
5.2	Length, m (in.)	4.3 (170.2)
5.3	Width, m (in.)	1.96 (77)
5.4	Height, m (in.)	
5.5	Head room, m (in.)	0.98 (38.3)
5.6	Leg room, m (in.)	1.03 (40.7)
5.7	Frontal area, m^2 (ft^2)	
5.8	Road clearance, m (in.)	
5.9	Number of seats	2 front; 1 rear

6.0 Auxiliaries and options

6.1 Lights (number, type, and function): 2 head; 2 park and tail; 2 brake; 2 front parking

[1] Limited to three on test vehicle because two batteries were installed on floor of rear passenger compartment.

6.2 Windshield wipers 2 on front windshield

6.3 Windshield washers yes

6.4 Defroster yes, from heater

6.5 Heater yes, gas fired

6.6 Radio optional

6.7 Fuel gage voltmeter, expanded scale

6.8 Amperemeter yes

6.9 Tachometer no

6.10 Speedometer yes

6.11 Odometer yes

6.12 Right- or left-hand drive left

6.13 Transmission 4-speed manual

6.14 Regenerative braking yes

6.15 Mirrors rearview, inside and out

6.16 Power steering no

6.17 Power brakes yes

6.18 Other

7.0 Battery

7.1 Propulsion battery

7.1.1 Type and manufacturer lead-acid golf car; Globe-Union GC-2-19

7.1.2 Number of modules twenty 6-V modules[2]

7.1.3 Number of cells 60

7.1.4 Operating voltage, V 120

7.1.5 Capacity, Ah 131.3 (105 min at 75 A)

7.1.6 Size of each module, m (in.) height, 0.22 (8.62); width, 0.17 (6.83); length, 0.30 (12.04)

7.1.7 Weight, kg (lbm) 508 (1120)

7.1.8 History (age, number of cycles, etc.) new; uncycled

7.2 Auxiliary battery

7.2.1 Type and manufacturer UI case garden tractor battery; NAPA

7.2.2 Number of cells 6

[2]In the test vehicle, 18 were installed under the hood and in the trunk and the remaining two on the rear floor of the passenger compartment.

7.2.3 Operating voltage, V 12

7.2.4 Capacity, Ah 23

7.2.5 Size, m (in.) height, 0.187 (7.38); width, 0.133 (5.25); length, 0.198 (7.80)

7.2.6 Weight, kg (lbm)

8.0 Controller

8.1 Type and manufacturer SCR controller; Cableform, Inc.

8.2 Voltage rating, V 188

8.3 Current rating, A 100

8.4 Size, m (in.) height, 0.13 (5); width, 0.25 (10); length, 0.61 (24)

8.5 Weight, kg (lbm) 10 (35)

9.0 Propulsion motor

9.1 Type and manufacturer DC series; Electric Vehicle Associates

9.2 Insulation class H

9.3 Voltage rating, V 150

9.4 Current rating, A 300 for 3 min

9.5 Horsepower (rated), kW (hp) 15 continuous

9.6 Size, m (in.) diameter, 0.30 (12); length, 0.30 (12)

9.7 Weight, kg (lbm) 107 (235)

9.8 Speed (rated), rpm 3500 (4500 max.)

10.0 Battery charger

10.1 Type and manufacturer full-wave bridge rectifier; impedance snubbing; Electric Vehicle Associates

10.2 On- or off-board type on board

10.3 Input voltage required, V 110 AC

10.4 Peak current demand, A <30

10.5 Recharge time, h 16

10.6 Size, m (in.) height, 0.13 (5.22); width, 0.21 (8.22); length, 0.30 (11.75)

10.7 Weight, kg (lbm) 8.6 (19)

10.8 Automatic turnoff feature no

11.0 Body

11.1 Manufacturer and type American Motors two-door Pacer sedan

11 2 Materials unitized construction with subframe

11.3 Number of doors and type 2

11.4 Number of windows and type 6; glass

11.5 Number of seats and type 2 bucket (front); 1 bench (rear)

11.6 Cargo space volume, m^3 (ft^3) 0.84 (29.5)

11.7 Cargo space dimensions, m (ft)

12.0 Chassis

12.1 Frame

12.1.1 Type and manufacturer welded; American Motors

12.1 2 Materials steel

12.1.3 Modifications battery-retaining members added

12.2 Springs and shocks

12.2.1 Type and manufacturer rear, leaf; front, coil; tubular shocks

12.2.2 Modifications strengthened rear leaf springs; sway bar; heavy-duty shocks

12.3 Axles

12.3.1 Manufacturer American Motors

12.3.2 Front unequal length A-arms

12.3 3 Rear

12.4 Transmission

12.4.1 Type and manufacturer 4-speed standard

12.4.2 Gear ratios 3.51; 2.21; 1.43; 1.00

12.4.3 Driveline ratio 3.58

12.5 Steering

12.5.1 Type and manufacturer rack and pinion

12.5.2 Turning ratio six turns lock to lock

12.5.3 Turning diameter, m (ft) 10.3 (37)

12.6 Brakes

12.6.1 Front hydraulic disk (vacuum assisted)

12 6.2 Rear hydraulic drum (vacuum assisted)

12 6.3 Parking mechanical (on rear wheels)

12.6.4 Regenerative yes

12.7 Tires

12.7.1 Manufacturer and type Goodyear radial

12.7.2 Size DR78-14

12.7.3 Pressure, kPa (psi):

Front 220 (32)

Rear 220 (32)

12.7.4 Rolling radius, m (in.)

12.7.5 Wheel weight, kg (lbm):

Without drum

With drum

12.7.6 Wheel track, m (in.):

Front

Rear

13.0 Performance

13.1 Manufacturer-specified maximum speed (wide-open throttle), km/h (mph) 97 (60)

13.2 Manufacturer-recommended maximum cruise speed (wide-open throttle), km/h (mph) 80 (50)

13.3 Tested at cruise speed, km/h (mph) 40 (25); 56 (35); 72 (45); 82 (51)

APPENDIX B

DESCRIPTION OF VEHICLE TEST TRACK

All the tests were conducted at the Transportation Research Center (TRC) of Ohio (fig. B-1). This facility was built by the State of Ohio and is now operated by a contractor and supported by the state. It is located 72 kilometers (45 miles) northwest of Columbus along U.S. route 33 near East Liberty, Ohio.

The test track is a 12-kilometer (7.5 mile) continuous loop 1.6 kilometers (1 mile) wide and 5.6 kilometers (3.5 miles) long. Three concrete lanes 11 meters (36 ft) wide in the straightaways and 13 meters (42 ft) wide in the curves make up the high-speed test area. The lanes were designed for speeds of 129, 177, and 225 kilometers per hour (80, 110, and 140 mph) with zero lateral acceleration in the curves. The 3-kilometer- (1.88-mile-) long straightaways are connected to the constant 731-meter- (2400-ft-) radius curves by a short variable-radius transition section. Adjacent to the inside concrete lane is a 3.66-meter- (12-ft-) wide asphalt berm. This berm is only banked slightly to provide a drainage slope. An additional asphalt lane 3.66 meters (12 ft) wide is located adjacent to the outside lane on the straightaways. The constant-speed and cycle tests were conducted on the inside asphalt lane because all tests were at relatively low speeds. The acceleration and coast-down tests were conducted on the straight outside asphalt lanes because these were more alike than the two inside asphalt lanes and because it was the portion of the track least likely to encounter traffic interference. The track has a constant 0.228 percent north-to-south downslope. The TRC complex also has a 20-hectare (50-acre) vehicle dynamics area and a 2740-meter- (9000-ft-) long skid pad for the conduct of braking and handling tests.

APPENDIX C

VEHICLE PREPARATION AND TEST PROCEDURE

Vehicle Preparation

When a vehicle was received at the test track, a number of checks were made to assure that it was ready for performance tests. These checks were recorded on a vehicle preparation check sheet, such as the one shown in figure C-1. The vehicle was examined for physical damage when it was removed from the transport truck and before it was accepted from the shipper. Before the vehicle was operated, a complete visual check was made of the entire vehicle including wiring, batteries, motor, and controller. The vehicle was weighed and compared with the manufacturer's specified curb weight. The gross vehicle weight (GVW) was determined from the vehicle sticker GVW. If the manufacturer did not recommend a GVW, it was determined by adding 68 kilograms (150 lbm) per passenger plus any payload weight to the vehicle curb weight.

The wheel alignment was checked, compared, and corrected to the manufacturer's recommended alignment values. The battery was charged and specific gravities taken to determine if the batteries were equalized. If not, an equalizing charge was applied to the batteries. The integrity of the internal interconnections and the battery terminals was checked by drawing either 300 amperes or the vehicle manufacturer's maximum allowed current load from the battery through a load bank for 5 minutes. If the temperature of the battery terminals or interconnections rose more than 60 degrees Celsius above ambient, the test was terminated and the terminal was cleaned or the battery replaced. The batteries were then recharged and a battery capacity check was made. The battery was discharged in accordance with the battery manufacturer's recommendations. To pass this test, the capacity must be within 20 percent of the manufacturer's published capacity at the published rate.

The vehicle manufacturer was contacted for his recommendations concerning the maximum speed of the vehicle, tire pressures, and procedures for driving the vehicle. The vehicle was photographed head-on with a 270-millimeter telephoto lens from a distance of about 30.5 meters (100 ft) in order to determine the frontal area.

Test Procedure

Each day, before a test, a test checklist was used. Two samples of these checklists are shown in figure C-2.

The first item under driver instructions on the test checklist is to complete the pretest checklist (fig. C-3).

Data taken before, during, and after each test were entered on the vehicle data sheet (fig. C-4). These data include

(1) Average specific gravity of the battery

(2) Tire pressures

(3) Fifth-wheel tire pressure

(4) Test weight of the vehicle

(5) Weather information

(6) Battery temperatures

(7) Time the test was started

(8) Time the test was stopped

(9) Ampere-hours out of the battery

(10) Fifth-wheel distance count

(11) Odometer readings before and after the tests

The battery charge data taken during the charge cycle were also recorded on this data sheet. These data include the average specific gravity of the battery after the test, the kilowatt-hours and ampere-hours put into the battery during the charge, and the total time of the charge.

To prepare for a test, the specific gravities were first measured for each cell and recorded. The tire pressures were measured and the vehicle was weighed. The weight was brought up to the GVW by adding sandbags. The instrumentation was connected, and power from the instrumentation battery was applied. All instruments were turned on and warmed up. The vehicle was towed to the starting point on the track. If the data were being telemetered, precalibrations were applied to both the magnetic tape and the oscillograph. The fifth-wheel distance counter and ampere-hour integrator counter were reset to zero, and thermocouple reference junctions were turned on. The test was started and was carried out in accordance with the test checklist. When the test was terminated, the vehicle was brought to a stop and the post-test checks were made in accordance with the post-test

checklist (fig. C-5). The driver recorded on the vehicle data sheet the time, the odometer reading, the ampere-hour integrator reading, and the fifth-wheel distance reading. The post-calibration steps were then applied to the magnetic tape and the oscillograph. At the end of the test, weather data were recorded on the vehicle data sheet. All instrumentation power was turned off, the instrumentation battery was disconnected, and the fifth wheel was raised. The vehicle was then towed back to the garage, the post-test specific gravities were measured for all cells, and the vehicle was placed on charge.

After the test, the engineer conducting the test completed a test summary sheet (fig. C-6). This data sheet provides a brief summary of the pertinent information received from the test. Another data sheet, the engineer's data sheet (fig. C-7), was also filled out. This data sheet summarizes the engineer's evaluation of the test and provides a record of problems, malfunctions, changes to instrumentation, etc., that occurred during the test.

Weather data. - Wind velocity and direction and ambient temperature were measured at the beginning and at the end of each test and every hour during the test. The wind anemometer was located about 1.8 meters (6 ft) from the ground near the southern straight section of the track. The ambient temperature readings were taken at the instrumentation trailer near the west curve of the track. During most of the test period the winds were variable and gusty.

Determination of maximum speed. - The maximum speed of the vehicle was determined in the following manner. The vehicle was fully charged and loaded to gross vehicle weight. After one warmup lap, the vehicle was driven at wide-open throttle for three laps around the track. The minimum speed for each lap was recorded and the average was calculated. This average was called the vehicle maximum speed. This speed takes into account track variability and maximum vehicle loading. This quantity was then reduced by 5 percent and called the recommended maximum cruise test speed.

Cycle timer. - The cycle timer (fig. C-8) was designed to assist the vehicle driver in accurately driving SAE schedules B, C, and D. The required test profile is permanently stored on a programmable read-only memory (PROM), which is the heart of the instrument. This profile is continuously reproduced on one needle of a dual-movement analog meter shown in the figure. The second needle is connected to the output of the fifth wheel and the driver

"matches needles" to accurately drive the required schedule.

One second before each speed transition (e.g., acceleration to cruise or cruise to coast), an audio signal sounds to forewarn the driver of a change. A longer duration audio signal sounds after the idle period to emphasize the start of a new cycle. The total number of test cycles driven is stored in a counter and can be displayed at any time with a pushbutton (to conserve power).

REFERENCES

1. Sargent, Noel B., Maslowski, Edward A.; Soltis, Richard F.; and Schuh, Richard M.: Baseline Tests of the C. H. Waterman DAF Electric Passenger Vehicle. NASA TM-73757, 1977.

2. Society of Automotive Engineers, Inc.: Electric Vehicle Test Procedure - SAE J227a. Feb. 1976.

TABLE I. - SUMMARY OF TEST RESULTS FOR EVA CHANGE-OF-PACE COUPE

(a) SI units

Test date	Test condition (constant speed, km/h, or driving schedule)	Wind velocity, km/h	Temperature, °C	Range, km	Cycle life, number of cycles	Capacity out of batteries, Ah	Capacity into batteries, Ah	Energy into charger, MJ	Indicated energy consumption, MJ/km	Type of charger	Remarks
6/17/77	40	6 - 23	30	83.8	———	144	356	179	2 1	110 V AC	———
6/21/77	82	10	18	49 7	———	100	140	65 9	1 3	↓	———
6/22/77	72	8 - 16	21	54 5	———	102	124	60 8	1 1		———
6/23/77	56	0 - 13	21	67 6	———	95	143	68 4	1 0		———
6/24/77	82	6	22	51 2	———	110	164	73 1	1 4		———
6/27/77	B[a]	0 - 16	27	52 8	145	140	165	82 4	1 6	↓	———
6/28/77	C[a]	16 - 24	24	47 1	[b]73 (75)	124	126	91 4	1 9	110 V AC + NASA	110 V AC charger failed
6/30/77	C[c]	13 - 31	25	40 5	62	112	146	77 0	1 9	NASA	Premature termination of test
7/1/77	B[c]	6 - 35	22	47 9	133	140	201	99 7	2 1	NASA	———
7/6/77	40	8 - 19	31	85 2	———	142	168	79 6	94	NASA	New controller
7/8/77	56	6	22	73 2	———	125	170	——	——	208 V AC	High-pressure tires light transmission oil
7/11/77	C[a]	6	23	48 4	82	128	173	——	——	208 V AC	Light transmission oil
7/13/77	C[c]	6 - 19	30	48,1	83	127	179	——	——	208 V AC	Light transmission oil
7/15/77	C[c]	———	—	47.8	82	126	——	——	——	———	Light transmission oil

(b) U S customary units

Test date	Test condition (constant speed, mph, or driving schedule)	Wind velocity, mph	Temperature, °F	Range, miles	Cycle life, number of cycles	Capacity out of batteries, Ah	Capacity into batteries, Ah	Energy into charger, kWh	Indicated energy consumption, kWh/mile	Type of charger	Remarks
6/17/77	25	4 - 14	86	52,1	———	144	356	49 7	0 93	110 J AC	———
6/21/77	51	6	65	30 9	———	100	140	18 3	59	↓	———
6/22/77	45	5 - 10	70	33 9	———	102	124	16 9	50		———
6/23/77	35	0 - 8	70	42.0	———	95	143	19 0	.45		———
6/24/77	51	4	71	31 8	———	110	164	20.3	64		———
6/27/77	B[a]	0 - 10	80	32 8	145	140	165	22.4	70	↓	———
6/28/77	C[a]	10 - 15	80	29.3	[b]73 (75)	124	126	25 4	87	110 V AC + NASA	110 V AC charger failed
6/30/77	C[c]	8 - 19	77	25 2	62	112	146	21 4	85	NASA	Prerature termination of test
7/1/77	B[c]	4 - 22	71	29 8	133	140	201	27 7	93	NASA	———
7/6/77	25	5 - 12	88	53 0	———	142	158	22 1	42	NASA	New controller
7/8/77	35	4	72	45 5	———	125	170	——	——	208 V AC	High-pressure tires, light transmission oil
7/11/77	C[a]	4	73	30 1	82	128	173	——	——	208 V AC	Light transmission oil
7/13/77	C[c]	4 - 12	86	30 5	83	127	179	——	——	208 V AC	Light transmission oil
7/15/77	C[c]	———	—	29 7	82	126	——	——	——	———	Light transmission oil

[a]With regenerative braking

[b]Last two cycles may have not met schedule

[c]Without regenerative braking

TABLE II. - MAXIMUM ACCELERATION AND GRADEABILITY FOR EVA CHANGE-OF-PACE COUPE

(a) At full battery charge

Vehicle speed		Time to reach designated vehicle speed, s	Vehicle acceleration		Grade-ability, percent
km/h	mph		m/s^2	mph/s	
0	0	0	0	0	0
2.0	1.2	.7	1.07	2.39	11.0
4.0	2.5	1.1	1.60	3.58	16.6
6.0	3.7	1.4	2.18	4.88	22.9
8.0	5.0	1.7	3.08	6.90	33.3
10.0	6.2	1.8	2.87	6.43	30.8
12.0	7.5	2.1	2.52	5.64	26.8
14.0	8.7	2.3	2.72	6.10	29.1
16.0	9.9	2.5	2.36	5.29	25.0
18.0	11.2	2.7	2.02	4.53	21.2
20.0	12.4	3.0	1.55	3.47	16.1
22.0	13.7	3.5	1.14	2 55	11.8
24.0	14.9	4.0	.94	2.11	9.7
26.0	16.2	4.7	.75	1.69	7.7
28.0	17.4	5.5	.54	1.20	5.5
30.0	18.7	6.9	.53	1.18	5.4
32.0	19.9	7.7	.53	1.18	5.4
34.0	21.1	9.1	.55	1.24	5.7
36.0	22.4	9.9	.66	1.48	6.8
38.0	23.6	10 0	.62	1.38	6.3
40.0	24.9	11.7	.54	1.20	5.5
42.0	26.1	12.8	.44	.99	4.5
44.0	27.4	14.2	.40	.89	4.1
46.0	28.6	15.6	.32	.72	3.3
48.0	29.8	17.8	.28	.62	2.8
50.0	31.1	19.7	.34	.76	3.5
52.0	32.3	21.2	.40	.89	4.1
54.0	33.6	22.5	.41	.92	4.2
56.0	34.8	23.9	.37	.82	3.8
58.0	36.1	25.6	.32	.71	3.2
60.0	37.3	27.4	.29	.64	2.9
62.0	38.5	29.5	.25	.57	2.6
64.0	39.8	31.8	.22	.49	2.2
66.0	41.0	34.6	.19	.43	2.0
68.0	42.3	37.7	.21	.47	2.1
70.0	43.5	40.0	.28	.62	2.8
72.0	44.8	41.8	.27	.60	2.7
74.0	46.0	44.3	.22	.50	2.3
76.0	47.2	46.8	.21	.47	2.2
78.0	48.5	49.5	.18	.41	1.9

(b) At 40-percent battery discharge

Vehicle speed		Time to reach designated vehicle speed, s	Vehicle acceleration		Grade-ability, percent
km/h	mph		m/s^2	mph/s	
0	0	0	0	0	0
2.0	1.2	.7	1.19	2.67	12.3
4.0	2.5	1.0	1.99	4.45	20.8
6.0	3.7	1.3	3.32	7.44	36.3
8.0	5.0	1.4	4.33	9.69	49.6
10.0	6.2	1.5	4.22	9.43	47.9
12 0	7.5	1.7	3.40	7.60	37.1
14.0	8.7	1.9	2.88	6.45	30.9
16.0	10.0	2.1	2.47	5.53	26.2
18.0	11.2	2.3	1.77	3.96	18.5
20.0	12.3	2.7	1.49	3.34	15.5
22.0	13.7	3.1	1.20	2.69	12.4
24.0	14.9	3.6	.93	2.09	9.6
26.0	16.2	4.3	.76	1.70	7.8
28.0	17.4	5.1	.52	1.16	5.3
30.0	18.7	6.6	.50	1.11	5.1
32.0	19.9	7.5	.68	1.51	6.9
34.0	21.1	8.3	.73	1.63	7.5
36.0	22.4	9.0	.70	1.57	7.2
38.0	23.6	9.9	.60	1.35	6.2
40.0	24.9	10.9	.51	1.13	5.2
42.0	26.1	12.1	.44	.99	4.5
44.0	27.4	13.5	.37	.84	3.8
46.0	28.6	15.1	.30	.67	3.1
48.0	29.8	17.3	.33	.74	3.4
50.0	31.1	18.6	.47	.04	4.8
52.0	32.2	19.7	.50	.11	5.1
54.0	33.6	20.9	.44	.99	4.5
56.0	34.8	22.2	.39	.87	4.0
58.0	36.1	23.7	.34	.75	3.5
60.0	37.3	25.5	.28	.64	2.9
62.0	38.5	27.7	.23	.51	2.3
64.0	39.8	30.5	.24	.53	2.4
66.0	41.0	32.5	.28	.62	2.9
68.0	42.3	34.5	.29	.66	3.0
70.0	43.5	36.3	.30	.68	3.1
72.0	44.8	38.2	.27	.61	2.8
74.0	46.0	40.5	.23	.51	2.3
76.0	47.2	43.1	.19	.42	1.9
78.0	48.5	46.4	.16	.35	1.6

TABLE II. - Concluded.

(c) At 80-percent battery discharge

Vehicle speed		Time to reach designated vehicle speed, s	Vehicle acceleration		Grade-ability, percent
km/h	mph		m/s^2	mph/s	
0	0	0	0	0	0
2.0	1.2	.5	1.5	3.45	16.0
4.0	2.5	.8	3.28	7.34	35.7
6.0	3.7	.9	4.01	8.96	45.0
8.0	5.0	1.1	3.71	8.30	41.1
10.0	6.2	1.2	3.38	7.57	37.0
12.0	7.5	1.4	2.96	6.62	31.9
14.0	8.7	1.6	2.64	5.91	28.2
16.0	9.9	1.8	2.00	4.48	21.0
18.0	11.2	2.1	1.63	3.66	17.0
20.0	12.4	2.5	1.22	2.73	12.6
22.0	13.7	3.1	.98	2.20	10.1
24.0	14.9	3.7	.84	1.89	8.7
26.0	16.2	4.4	.68	1.53	7.0
28.0	17.4	5.3	.52	1.17	5.4
30.0	18.7	6.6	.42	.95	4.3
32.0	19.9	8.0	.50	1.13	5.2
34.0	21.1	8.9	.60	1.35	6.2
36.0	22.4	9.8	.58	1.30	6.0
38.0	23.6	10.8	.51	1.15	5.3
40.0	24.9	12.9	.44	.99	4.5
42.0	26.1	13.3	.38	.85	3.9
44.0	27.4	15.0	.29	.64	2.9
46.0	28.6	17.3	.28	.62	2.8
48.0	29.8	19.1	.37	.83	3.8
50.0	31.1	20.4	.40	.90	4.1
52.0	32.3	21.8	.36	.81	3.7
54.0	33.6	23.5	.31	.70	3.2
56.0	34.8	25.4	.29	.64	3.0
58.0	36.1	27.3	.26	.58	2.7
60.0	37.3	29.8	.23	.52	2.4
62.0	38.5	32.1	.21	.46	2.1
64.0	39.8	35.3	.24	.53	2.5
66.0	41.0	37.1	.31	.69	3.1
68.0	42.3	38.9	.28	.62	2.9
70.0	43.5	41.2	.24	.53	2.4
72.0	44.8	43.6	.20	.46	2.1
74.0	46.0	46.8	.16	.35	1.6
76.0	47.2	50.8	.13	.29	1.3
78.0	48.5	55.5	.11	.25	1.1

TABLE III. - ROAD ENERGY AND ROAD POWER FOR EVA

CHANGE-OF-PACE COUPE

[Coast-down data.]

Vehicle speed		Test time, s	Road energy		Road power	
km/h	mph		MJ/km	kWh/mile	kW	hp
80.0	49.72	0	0	0	0	0
78.0	48.48	2.1	.52	.23	11.26	15.10
76.9	47.23	4.4	.49	.22	10.43	13.99
74.0	45.99	6.7	.53	.24	10.86	14.56
72.0	44.75	8.8	.54	.24	10.88	14.59
70.0	43.51	10.9	.52	.23	10.04	13.47
68.0	42.26	13.3	.49	.22	9.28	12.41
66.0	41.02	15.6	.49	.22	8.97	12.03
64.0	39.78	18.0	.48	.21	8.47	11.35
62.0	38.53	20.5	.44	.20	7.63	10.23
60.0	37.29	23.2	.45	.20	7.43	9.96
58.0	36.85	25.6	.43	.19	7.00	9.39
56.0	34.80	28.5	.39	.17	6.03	8.08
54.0	33.56	31.6	.38	.17	5.74	7.70
52.0	32.32	34.5	.40	.18	5.79	7.77
50.0	31.08	37.3	.39	.17	5.39	7.22
48.0	29.83	40.4	.36	.16	4.85	6.50
46.0	28.59	43.6	.35	.15	4.42	5.92
44.0	27.35	47.1	.33	.15	4.00	5.36
42.0	26.10	50.7	.32	.14	3.68	4.93
40.0	24.86	54.4	.31	.14	3.40	4.56
38.0	28.62	58.2	.30	.13	3.13	4.20
36.0	22.37	62.1	.30	↓	3.00	4.03
34.0	21.13	65.8	.20	↓	2.80	3.76
32.0	19.89	69.9	.28	↓	2.50	3.35
30.0	18.65	74.0	.27	.12	2.22	2.97
28.0	17.40	78.6	.26	.11	1.99	2.67
26.0	16.16	83.0	.26	.11	1.84	2.47
24.0	14.92	87.6	.23	.10	1.56	2.10
22.0	13.67	92.8	.22	.10	1.37	1.84
20.0	12.43	97.8	.24	.11	1.34	1.80
18.0	11.19	102.4	.24	.11	1.19	1.60
16.0	9.94	107.5	.22	.10	.99	1.33
14.0	8.70	112.7	.23	.10	.91	1.22
12.0	7.46	117.4	.22	.10	.73	.98
10.0	6.22	123.3	.20	.09	.57	.76
8.0	4.97	128.7	.20	↓	.45	.61
6.0	3.73	184.6	.20	↓	.34	.46
4.0	2.49	189.9	.21	↓	.23	.31
2.0	1.24	145.7	.19	.08	.11	.14

TABLE IV. - ENERGY CONSUMPTION FOR EVA CHANGE-OF-PACE COUPE

Test condition (constant speed or driving schedule)		Indicated energy consumption		Amount of overcharge, percent	Corrected energy consumption	
km/h	mph	MJ/km	kWh/mile		MJ/km	kWh/mile
40	25	[a]0.94	[a]0.42	11	[a]0.92	[a]0.41
56	35	1.0	.45	--	-----	-----
72	45	1.1	.50	22	1.0	.45
82	51	1.4	.62	40 - 49	1.1	.47
B[b]		[a]2.1	[a].93	44	[a]1.6	[a].71
B[c]		1.6	.70	18	1.5	.65
C[b]		[a]1.9	[a].85	30	1.6	[a].72
C[c]		2.0	.87	--	-----	-----

[a]110-Volt AC NASA charger used.

[b]Without regeneration.

[c]With regeneration.

TABLE V. - BATTERY CHARACTERISTICS FOR EVA CHANGE-OF-PACE COUPE

Length, m (in.)	0.30 (12.04)
Width, m (in.)	0.17 (6.83)
Height, m (in.):	
To top of case	0.20 (7.90)
To top of terminals	0.22 (8.62)
Weight, kg (lbm)	25.4 (56)
Specific gravity of fully charged electrolyte	1.265 (+0.010, -0.015)
Number of plates per cell	19

TABLE VI. - CONSTANT-SPEED BATTERY PERFORMANCE FOR EVA CHANGE-OF-PACE COUPE

Vehicle speed		Test date	First 25 percent of range		Last 25 percent of range	
km/h	mph		Current, A	Voltage, V	Current, A	Voltage, V
40	25	6/17/77	79	120	83	112
56	35	6/23/77	106	118	101	108
72	45	6/22/77	143	116	138	107
82	51	6/24/77	168	115	163	107

TABLE VII. - BATTERY PERFORMANCE OVER DRIVING SCHEDULES FOR EVA CHANGE-OF-PACE COUPE

(a) Schedule B without regenerative braking, cycle 29, July 1, 1977

Test time, s	Vehicle speed, km/h	Current, A	Voltage, V
0	0	0	125 5
1	3 3	59.7	122 7
2	5 4	65 5	122 0
3	6 9	88.7	120.8
4	8 8	82.9	120 2
5	9 9	79.2	120.4
6	10 9	91.4	120.1
7	12.3	118.3	118.7
8	13.6	118.3	118 3
9	14.6	128.9	117 8
10	15.9	134.2	117.3
11	17.1	156.9	116 0
12	19.5	164.3	115 8
13	21.0	157 9	116.0
14	22.0	150.0	116.2
15	23 1	153.2	116.4
16	23.9	148.4	116.2
17	25.5	149.5	116.0
18	26 5	162.7	115 1
19	28 5	183.3	114.4
20	29 7	175.9	114 4
21	30 6	172.2	114.6
22	31 2	121.5	117 6
23	32 3	62.3	120.6
24	31 9	75 0	120.4
25	31 7	89.3	119.5
26	31 6	102.5	118.8
27	31 7	89.8	119 4
28	31 7	88 7	119.5
29	31.7	89.8	119.5
30	31 9	88.7	119.4
31	31.6	89.8	↓
32	↓	88.7	↓
33	↓	88.7	↓
34	↓	85.6	119.5
35	31.4	85.0	↓
36	31 4	85.6	↓
37	31 6	86 6	↓
38	31 7	85 0	119.7
39	31.6	84.5	119.7
40	31.0	.5	123.8
41	30 5	0	124.8
42	29 7	↓	124.8
43	28 9	↓	124.5
44	27 6	↓	124.5
45	22.1	↓	124.6
46	16.6	↓	↓
47	12 2	↓	↓
48	7 8	↓	↓
49	.3	↓	124.8

(b) Schedule B without regenerative braking, cycle 79, July 1, 1977

Test time, s	Vehicle speed, km/h	Current, A	Voltage, V
0	0	0	121 0
1	1 7	37.5	120 6
2	3 1	49.1	118 5
3	5 4	64 4	118 0
4	7.5	88.2	115.7
5	8.9	90.8	115 0
6	10.3	97.2	114 4
7	11.8	110.4	114.1
8	13.5	113.6	113.6
9	14 3	123.6	113.0
10	15 2	121 5	112 9
11	16.4	127 8	112.1
12	17 3	161.6	110.6
13	18.7	155 8	110.6
14	20.0	151 6	118 7
15	21 1	148.9	110 7
16	22.1	147 4	110.7
17	23.1	197 5	103 5
18	25.6	268 3	104.8
19	27 2	237 1	107 7
20	28.6	151 1	110.4
21	30 3	117 3	112 7
22	31 2	98 5	113 7
23	↓	100.4	113 6
24	↓	107 2	113 2
25	↓	112.0	112.9
26	31.3	112 5	112.9
27	31.6	114.1	112 7
28	31 9	106 7	113 0
29	32 0	103.8	113.0
30	32.2	88.7	113.4
31	32 6	81.3	113.9
32	33 0	70.8	114.8
33	33 4	68.9	115.5
34	33.6	64.4	115 7
35	33.3	65 5	115.7
36	33.3	70 2	115 5
37	33.1	↑	115.5
38	33.0	↓	115.7
39	32.7	↓	115 5
40	32.3	-1.1	119.4
41	32.2	-1.1	119 5
42	32.0	-1 6	119 5
43	31.2	↓	119 5
44	30.7	↓	119 7
45	30.0	↓	119.9
46	29 3	↓	↓
47	28 2	↓	↓
48	26 6	↓	↓
49	18.1	↓	↓
50	8.4	↓	↓

TABLE VII - Continued.

(c) Schedule B with regenerative braking, cycle 3, June 27, 1977

Test time, s	Vehicle speed, km/h	Current, A	Voltage, V
0	0 1	0	119 9
1	1 4	16 4	125.0
2	2.4	25 4	125 4
3	4 4	33 8	125 5
4	5 8	58.1	125.5
5	7 9	90 8	125.5
6	11.2	131 5	127 1
7	13.3	131 0	126 6
8	16 0	132 0	126.4
9	17 6	140 0	126.4
10	19.3	143 1	126 2
11	21.1	142 6	126.4
12	22.9	139.4	↓
13	24.4	139.4	
14	25.1	134.2	
15	26 3	132.0	
16	27 6	129.4	
17	28 3	125 7	
18	29.5	156.9	126 6
19	30 7	155.3	126 4
20	31.9	146.8	126 6
21	33.0	142 1	↓
22	38 9	138.9	
23	34 8	133 6	
24	35.4	129 9	
25	36.1	127 3	126 8
26	36.4	105.1	126 6
27	36 7	96 1	126 6
28	36 8	91 7	126 8
29	37 0	91 9	↓
30	36 8	81 9	
31	36.8	↓	
32	36 8		
33	36 7		
34	↓		126.6
35			125.7
36			125.0
37			124.1
38			122 9
39	36.8		120.8
40	36 4	82 4	119.0
41	35.7	1 1	118 3
42	34.7	.5	100.0
43	33 9	0	117 6
44	33 0	.5	117.4
45	30.9	10.6	↓
46	26.2	-5 3	
47	21.1	-4.8	
48	16 1	-4.8	
49	10.6	-3.7	
50	3.8	.5	↓

(d) Schedule B with regenerative braking, cycle 131, June 27, 1977

Test time, s	Vehicle speed, km/h	Current, A	Voltage, V
0	0	0	116 4
1	2 3	43.3	113 0
2	4 2	113 0	107.2
3	6 9	128 3	107 7
4	8 5	102.5	108 5
5	10 2	93 5	108 8
6	11.8	92.4	108.6
7	12.9	101.9	108 5
8	14 4	100 4	108.3
9	15.3	100 4	108.3
10	16.3	108 3	104.8
11	17 7	154 8	104.4
12	19.0	144.7	104.8
13	20.1	137 3	105.1
14	21.3	134 2	105 3
15	22.5	150 5	103.0
16	24.2	179 6	101.9
17	25 1	169 5	102.1
18	26 6	174 8	100 4
19	28.3	209.7	104.2
20	29 9	96.1	108 1
21	31.2	89.8	108.5
22	31.3	88.7	108.6
23	31 4	87.1	108 8
24	31.6	85.0	109.2
25	31 7	82 9	109 2
26	32 0	80 3	109 3
27	32 2	79.8	109 3
28	32 3	79.2	109 2
29	32 3	↓	109 3
30	32 3		109 3
31	32 4		109 5
32	32.7		109 5
33	32.4		109 3
34	32.6		109 5
35	32.7	↓	109.5
36	32.7	78.7	109.3
37	32.9	78.7	109.5
38	32.9	76.6	109.5
39	32.9	76.1	109.7
40	32.7	.5	115 0
41	31.9	.5	115.1
42	31.3	0	115.3
43	30.7	0	115 5
44	27.5	3.2	114.8
45	22.8	-4.8	116.7
46	17.6	-4.8	116.4
47	12.0	-4.8	116.0
48	8 4	-2.1	115 8
49	0	-.5	115.7

TABLE VII - Continued

(e) Schedule C without regenerative braking, cycle 3, June 30, 1977

Test time, s	Vehicle speed, km/h	Current, A	Voltage, V
0	0	1 1	127 3
1	2.7	48 1	125 2
2	5 5	104 6	121 7
3	8.9	126 2	119 5
4	11 2	160 0	118 3
5	13.9	180 6	117 1
6	16 9	198 6	115.8
7	19 3	220.8	114 8
8	22 8	232 9	113 7
9	25.4	248 8	112 9
10	27.5	260 9	112 0
11	30 0	272 0	111 4
12	32.3	285 2	110 6
13	34 8	296 3	109 7
14	36 8	302.1	108 8
15	39 2	302.6	108 3
16	42.6	302.6	107.4
17	44.9	302 1	108.6
18	46 5	283 6	109.3
19	47.6	266 7	110 4
20	48 3	249 3	110 9
21	48 3	77.1	120 6
22	48 2	85 0	120 6
23	48 0	115 7	119 2
24	48 2	126 2	118.7
25	↓	134 7	118.7
26		125 2	118 7
27		112 0	119 2
28		108.8	119.5
29	48.3	108 3	119 5
30	48 3	108.3	119.7
31	48.3	108.8	119 7
32	48.2	108 8	119.7
33	48 2	108 3	119 9
34	48 0	102 5	120 1
35	48 0	102 5	120 1
36	47 9	105.1	119 9
37	47 9	107 2	119 7
38	48 0	110.9	119.5
39	47.9	113.0	119.5
40	47.9	112 5	119 9
41	47 0	0	125.4
42	46.2	0	125.5
43	45.2	.5	125 7
44	44 3	-.5	125.9
45	43.9	0	125 9
46	43.2	0	125 9
47	42 2	- 5	126.1
48	40 4	↓	126 2
49	38 0		126.2
50	34 7		126 4
51	30 2		↓
52	22 0	↓	
53	16 6	0	
54	8 2	0	126 6
55	1 8	- 5	126 6

(f) Schedule C without regenerative braking, cycle 62, June 30, 1977

Test time, s	Vehicle speed, km/h	Current, A	Voltage, V
0	0	0	117.4
1	2 7	79.2	111 3
2	6 5	129 9	108 3
3	9 3	160 6	106 3
4	11 3	177.5	104 2
5	14 4	200 7	102 5
6	17.3	220.8	101.6
7	19.7	237.1	100.2
8	22.2	255 1	99.1
9	24 4	268 8	97.9
10	26.2	279 4	96.7
11	28 6	287 3	96 0
12	31 7	292.1	95.4
13	33 7	298.9	94.0
14	36 1	302 6	95 4
15	39 0	283 1	96.1
16	39 9	264 1	96 8
17	40.6	249 3	97 5
18	42 3	239 3	98.1
19	44 3	231.3	98 6
20	45 3	223 4	98 9
21	46 0	217 6	99.3
22	46 9	211 3	99.5
23	47.6	206 5	108 1
24	47 7	145 8	107 9
25	↓	75 5	110 2
26		132.0	106 3
27		114 1	107.2
28	47 9	103 0	108 1
29	47 9	102 5	108.1
30	47 7	103 0	107 7
31	47.6	113 0	107 6
32	47.6	112 5	107 7
33	47 7	106.2	107 9
34	47 6	105 6	108.1
35	47 6	95 6	108 6
36	47.4	90 3	109 2
37	47.2	88 7	109 3
38	47 2	88 7	109 0
39	47.0	106.7	108 3
40	46 9	96 7	113.6
41	46.5	- 5	115 5
42	46.0	-1 1	115 7
43	45 5	-1 1	115 7
44	44 8	- 5	115 8
45	43 8	↓	116 0
46	43 2		↓
47	42.6		
48	42 1	-1 1	116 2
49	40.4	-1.1	116 2
50	36 1	-.5	116.2
51	33 1	↓	116.4
52	26.3		116 4
53	21 4	↓	116 5
54	16.1	-1 1	116 5
55	11.0	-1.6	116.4
56	6 5		

TABLE VII - Concluded

(g) Schedule C with regenerative braking, cycle 2, June 28, 1977

Test time, s	Vehicle speed, km/h	Current, A	Voltage, V
0	0	-1.3	126.9
1	1 6	31 1	125 4
2	3.5	41.0	124.6
3	5.9	48.7	124.3
4	9 6	171.3	118.8
5	12 0	161.4	117.8
6	15 4	166.3	117.1
7	19.7	229 7	113 7
8	23 5	260 0	112 3
9	26 8	254.4	111.8
10	28 9	232 5	112.3
11	31.4	230 4	112.5
12	33 3	235.4	111 8
13	36 3	234.6	111.6
14	37 4	217.0	112.3
15	38 7	207 2	112.9
16	40.4	199.4	113 4
17	41 6	192.4	113.9
18	42 8	186.1	114 3
19	43 8	179.7	114 6
20	44.8	174.8	114.8
21	45 5	172.7	115.1
22	46 0	169.2	115 3
23	46.7	166 3	115 5
24	47.2	162.8	115.7
25	46.5	35 4	122.9
26	46.3	112 8	120.2
27	46.5	129.0	118 3
28	46.7	128 3	118 0
29	46 9	127 6	118.0
30	47 2	126 9	118 0
31	47.2	112 1	118 7
32	47.0	111.4	118 7
33	47 0	107 9	119.0
34	47 0	104.4	119.0
35	46 9	102.3	119.4
36	46 7	100.8	119.4
37	46.6	98 7	119.7
38	46.3	98 0	119 7
39	46.3	97 3	119.9
40	46 2	97 3	119.9
41	45.3	-1.3	125 2
42	44.2	-2.0	125 4
43	43.5	↓	125 7
44	42.5	↓	125.7
45	41 6	↓	125 7
46	40 9	↓	125 9
47	39.9	↓	125 9
48	39 1	↓	126 L
49	38.0	1	126.1
50	35 4	11 4	125 4
51	31.3	-40 7	128 9
52	26 1	-19 6	128.0
53	20 3	-11.1	127.6
54	15.7	-6 2	127 5
55	10.1	-3.4	127 1
56	4.4	-2.7	126 8

(h) Schedule C with regenerative braking, cycle 71, June 28, 1977

Test time, s	Vehicle speed, km/h	Current, A	Voltage, V
0	0	-0.6	118.1
1	2.8	86 1	110.9
2	6 1	136.1	108.6
3	8.8	169'9	107.0
4	11 3	191 7	105 5
5	13.9	217 0	103.7
6	17.0	233 2	102.3
7	18 8	248.0	101.1
8	21 4	262.8	99 6
9	23.9	274.1	98 8
10	26.6	281.8	97 9
11	28.9	284.6	97.4
12	31 0	286 1	97.2
13	32 3	289.6	96.7
14	34.6	305.1	95.1
15	36 7	279.0	96.7
16	38.8	262.1	97.7
17	40 8	252.3	98.6
18	41.9	241 0	99.1
19	43 5	233 9	99.5
20	44.5	226.9	99.8
21	45.6	222 0	100 0
22	46 3	214 9	100.5
23	47 3	210.7	100.9
24	47.7	117 7	107.9
25	47 9	122.0	107 7
26	48.0	139.6	106.7
27	48.0	138.9	↓
28	48 3	138.2	↓
29	48 4	136 8	↓
30	48 6	114 9	108.1
31	48.6	109 3	108 8
32	48 7	100.1	109 5
33	48.7	98 7	109.5
34	48.6	98 7	109.7
35	48 6	100 1	109.5
36	48 4	101.5	109.3
37	48.3	103 0	109 2
38	48 2	106 5	109 0
39	48 2	112 1	108 6
40	47.7	1	115 7
41	47.2	- 6	116 2
42	46 6	↓	116.4
43	46 0	↓	116 5
44	45.3	↓	116 5
45	44 0	↓	116 5
46	43 5	↓	116 7
47	42 6	↓	116 9
48	41 8	5.8	116.4
49	38.3	-13 9	118.1
50	34.3	-11 1	118 3
51	29 0	-7.6	117 8
52	25 4	-4 8	117.8
53	20 8	-3 4	117 6
54	16.0	-2 0	117 6
55	9 1	-1 3	117 6
56	4.4	- 6	117 4
57	7	-1.3	117 4.

TABLE VIII. - BATTERY PERFORMANCE DURING MAXIMUM ACCELERATION TESTS FOR EVA CHANGE-OF-PACE COUPE

(a) At full battery charge

Gradeability, percent	Current, A	Voltage, V
0	233.2	110.8
.4	234.9	110.7
.8	237.5	110.6
1.3	239.9	110.5
1.7	242.3	110.3
1.9	244.7	110.2
1.8	247.8	110.1
2.1	250.4	110.0
2.2	253.3	109.8
2.3	260.9	109.5
2.5	265.5	109.3
2.7	270.2	109.0
2.8	277.0	108.7
2.0	195.3	112.7
2.1	200.3	112.4
2.2	203.2	112.2
2.4	206.5	112.1
2.5	209.7	111.9
2.7	213.4	111.8
2.9	217.6	111.5
3.0	221.8	111.3
3.2	227.6	111.0
3.4	233.7	110.7
3.8	241.2	110.5
3.0	174.7	116.0
3.3	179.7	113.6
3.6	187.0	113.2
4.2	193.7	112.8
4.5	202.9	112.3
5.2	215.6	111.8
6.1	231.3	111.2
6.9	213.9	112.3
9.8	256.8	110.0

(b) At 40-percent battery discharge

Gradeability, percent	Current, A	Voltage, V
0	232.8	108.6
1.0	234.9	108.4
1.8	240.4	108.1
1.6	243.1	108.1
2.0	245.9	107.9
2.2	253.9	107.4
2.4	258.0	107.2
2.5	262.2	107.1
2.8	266.9	106.8
2.4	205.1	110.2
2.5	209.0	109.9
2.9	213.4	109.8
3.1	218.0	109.5
3.4	223.3	109.3
3.7	229.8	109.0
4.1	237.0	108.6
4.5	246.3	108.1
3.1	176.3	112.7
3.8	181.6	111.4
4.1	189.1	111.0
4.6	198.3	110.6
5.2	209.2	110.1
6.1	224.2	109.5
7.2	242.0	108.8

(c) At 80-percent battery discharge

Gradeability, percent	Current, A	Voltage, V
0	210.9	105.0
.5	211.9	105.0
.9	213.2	104.9
1.1	214.7	105.0
1.3	219.9	104.8
1.4	222.2	104.6
1.6	227.9	104.4
1.7	230.7	104.3
1.9	232.9	104.1
2.0	235.8	103.9
2.2	239.1	103.7
2.3	241.9	103.6
2.5	246.1	103.4
2.7	249.7	103.2
2.8	255.0	103.0
3.0	260.7	102.7
3.1	263.8	103.7
2.6	199.5	106.4
2.7	202.7	106.2
2.9	206.5	105.8
3.0	211.3	105.6
3.2	216.9	105.3
3.4	222.9	105.0
3.7	229.4	104.7
4.0	237.7	104.2
2.9	171.4	108.1
3.5	177.1	107.8
4.0	183.1	107.4
4.5	192.0	107.0
5.2	203.5	106.4
5.8	218.7	105.7
6.2	235.7	104.8
4.8	167.7	108.5
5.9	184.5	108.0
7.9	212.9	106.9

TABLE IX - GENERAL BATTERY PERFORMANCE FOR EVA CHANGE-OF-PACE COUPE

Test condition (constant speed or driving schedule)		Test date	Current into battery, Ah	Current out of battery, Ah	Amount of overcharge, percent	Specific gravity		Battery temperature, °C	
km/h	mph					Before test	After test	Before test	After test
40	25	7/6/77	158	142	11	1 274	1 135	34	45
56	35	6/23/77	95	143	51	1 273	1 110	31	32
72	45	6/22/77	102	124	22	1 275	1 137	32	32
82	51	6/24/77	110	164	49	1 278	1 149	32	35
B[a]		7/1/77	140	201	44	1.274	1.110	27	45
B[b]		6/27/77	140	164	18	1.280	1.130	30	54
C[a]		6/30/77	112	146	30	1 280	1 110	27	43
C[b]		6/28/77	124	126	--	1 278	1 110	34	45

[a]Without regenerative braking

[b]With regenerative braking.

TABLE X. - MOTOR INPUT DURING MAXIMUM ACCELERATION TESTS FOR EVA CHANGE-OF-PACE COUPE

(a) At full battery charge

Gradeability, percent	Current, A	Voltage, V
0	231.9	103.7
.4	233.2	103.5
.8	234.4	103.4
1.3	235.3	103.5
1.7	236.9	103.4
1.9	238.2	103.2
2.1	241.0	102.9
2.2	242.4	102.6
2.3	246.1	102.4
2.5	249.0	102.2
2.7	251.8	101.9
2.8	254.8	101.6
2.0	197.4	105.2
2.1	199.9	105.1
2.2	202.8	105.0
2.4	205.7	104.8
2.5	209.2	104.8
2.7	212.7	104.5
2.9	217.2	104.3
3.0	221.6	104.0
3.2	227.5	103.7
3.4	233.5	103.6
3.8	238.1	103.2
3.2	179.6	106.5
3.6	186.7	106.2
4.2	194.1	105.7
4.5	201.6	105.2
5.2	213.9	104.7
6.1	229.2	104.0
6.7	232.9	100.8

(b) At 40-percent battery discharge

Gradeability, percent	Current, A	Voltage, V
0	233.8	102.4
1.0	235.8	102.3
1.7	238.6	102.2
2.0	246.8	101.7
2.2	254.3	101.3
2.4	258.4	101.1
2.5	263.2	100.8
2.8	267.4	100.7
2.9	269.6	99.3
2.4	206.1	104.3
2.5	209.6	104.0
2.9	214.2	103.8
3.1	219.2	103.5
3.4	224.5	103.2
3.7	229.8	102.9
4.1	238.1	102.3
4.5	245.3	101.9
4.9	253.7	100.5
3.1	177.6	106.0
3.8	182.9	105.7
4.1	189.1	105.3
4.6	198.2	104.9
5.2	209.9	104.4
6.1	222.9	103.5
7.2	241.8	101.9
7.3	209.2	88.3
7.3	209.2	88.3

(c) At 80-percent battery discharge

Gradeability, percent	Current, A	Voltage, V
0	213.4	98.7
.5	214.8	98.6
.9	215.9	98.5
1.1	216.8	98.4
1.3	222.9	98.2
1.4	225.5	98.1
1.6	231.6	97.7
1.7	234.0	97.6
1.9	236.2	97.5
2.0	239.5	97.2
2.2	242.7	97.1
2.3	246.3	96.9
2.5	250.6	96.8
2.7	255.0	96.7
2.8	260.0	96.2
3.0	267.1	95.7
3.1	272.4	95.3
2.5	190.3	99.8
2.6	202.2	99.9
2.7	206.3	99.8
2.9	210.7	99.5
3.0	216.2	99.2
3.2	221.6	98.9
3.4	228.0	98.4
3.7	235.4	98.0
4.0	228.4	98.6
2.9	168.7	102.4
2.9	173.9	102.2
3.5	179.7	101.8
4.0	186.3	101.3
4.5	194.8	100.7
5.2	205.5	100.1
5.8	223.3	99.2
4.8	169.3	102.8
5.9	187.0	102.2
7.9	215.2	100.3

TABLE XI. - MOTOR INPUT OVER DRIVING SCHEDULES FOR EVA CHANGE-OF-PACE COUPE

(a) Schedule B without regenerative braking; cycle 29, July 1, 1977

Test time, s	Vehicle speed, km/h	Current, A	Voltage, V
0	0	0	50 0
1	3.3	297 9	50 0
2	5 4	252 5	50 0
3	6.9	259.3	49 8
4	8.8	220 2	49 8
5	9.9	197.0	49 8
6	10.9	198.8	49.8
7	12 3	223 9	50.0
8	13 6	218 7	50.0
9	14 6	227.6	51.9
10	15.9	229.2	56.7
11	17.1	233.5	62.7
12	19.5	237.7	68 0
13	21.0	221 3	69 7
14	22 0	210.7	70.4
15	23 1	206 0	73.6
16	28.9	198 1	75 0
17	25.5	198 1	78 2
18	26 5	214 4	87 5
19	28 5	211 8	92.6
20	29.7	197.5	93 5
21	30.6	193.8	94 9
22	31.2	148.4	87.0
23	32.3	94.5	50 2
24	31.9	116 2	55 1
25	31.7	138.9	64 6
26	31.6	138 9	69 7
27	31.7	128 3	63 6
28	31.7	127 3	63 2
29	31.7	127 8	63,2
30	31.9	↓	63.2
31	31 6	↓	63 0
32	31.6	↓	63.2
33	31.6	↓	63 2
34	31.6	126 2	62.5
35	31.4	↓	61 8
36	31 4	↓	62 3
37	31 6	↓	62.3
38	31 7	↓	62.3
39	31 6	125 7	62 0
40	31 0	.5	49 8
41	30 5	0	49 8
42	29.7	↓	50 0
43	28 9	↓	↓
44	27 6	↓	↓
45	22 1	↓	↓
46	16 6	↓	↓
47	12 2	↓	↓
48	7.8	↓	↓
49	3	↓	↓

(b) Schedule B without regenerative braking, cycle 79; July 1, 1977

Test time, s	Vehicle speed, km/h	Current, A	Voltage, V
0	0	0	50.0
1	1.7	259.9	49 8
2	3 1	234 5	50 0
3	5 4	250 9	49.8
4	7.5	257.7	50 0
5	8.9	218.7	↓
6	10.3	213.9	↓
7	11.8	211.3	↓
8	13 5	218.1	↓
9	14.3	220.8	↓
10	15 2	216.5	51 6
11	16 4	236 1	58.6
12	17.3	231.3	64 1
13	18 7	215.5	65.7
14	20 0	207 0	66.7
15	21 1	199 1	69.0
16	22 1	284.7	72.4
17	23.1	267.3	101.1
18	25.6	232.4	103.9
19	27.2	191.2	103.7
20	28 6	153 7	85 6
21	30.3	142 1	74.1
22	31.2	127.8	66 2
23	↓	140 0	60.2
24	↓	144.7	54 2
25	↓	143.7	53 5
26	31.3	148.4	53 7
27	31 6	140 5	67.4
28	31 9	137 3	72 5
29	32.0	135 7	72 5
30	32 2	123 1	66 5
31	32 6	116.2	64 3
32	33.0	103.5	64 1
33	33 4	95 1	63 6
34	33 6	96 1	54 4
35	33 3	103.5	49 6
36	33 3	109 9	50.0
37	33 1	110 4	54.2
38	33 0	111 4	54.2
39	32.7	110 9	53.0
40	32.3	0	50.2
41	32 2	↓	49.8
42	32.0	↓	50 0
43	31.2	↓	↓
44	30 7	↓	↓
45	30 0	↓	↓
46	29 3	↓	↓
47	28 2	↓	↓
48	26 6	↓	↓
49	18 1	↓	↓
50	8 4	.5	

TABLE XI - Continued.

(c) Schedule B with regenerative braking; cycle 3; July 27, 1977

Test time, s	Vehicle speed, km/h	Current, A	Voltage, V
0	0.1	0	50.0
1	1.4	160.0	↓
2	2.4	191.2	
3	4.4	178.0	
4	5 8	216.0	50.2
5	7.9	298.9	56.2
6	11.2	183 3	62 3
7	13 3	160 6	63 2
8	16 0	158 5	63 6
9	17.6	159 0	63 9
10	19.3	210 2	69 4
11	11 1	202.8	92 8
12	22 9	198.6	103 0
13	24 4	179.6	113 9
14	25 1	164.8	114 8
15	26.3	153 2	114 6
16	27.6	145 2	109 2
17	28.3	142 1	109 5
18	29 5	141 5	111.3
19	30.7	136 3	116.7
20	31 9	132 6	117.1
21	33 0	129.9	117.1
22	33 9	126.8	117.3
23	34 8	119.9	115 8
24	35.4	118.3	86.3
25	36.1	117.8	86 4
26	36.4	↓	↓
27	36 7		
28	36.8	↓	↓
29	37.0	119.4	
30	36.8	121 5	86.6
31	36.8	122 5	86.8
32	36.8	122 5	87.5
33	36 7	122 5	89.1
34	↓	119 4	88 9
35		121 5	88 9
36		125 7	88 9
37	↓	125 7	89 3
38		122 0	89 6
39	36 8	111.4	91 2
40	36 4	109.3	93 5
41	35 7	6.9	81 9
42	34 7	-.5	49 8
43	33 9	-1 1	↓
44	33 0	- 5	
45	30.9	- 5	
46	26.2	169 0	
47	21 1	134.2	↓
48	16.1	86.6	50 0
49	10.6	54.4	49 8
50	3 8	-1.1	49 8

(d) Schedule B with regenerative braking; cycle 131; July 27, 1977

Test time, s	Vehicle speed, km/h	Current, A	Voltage, V
0	0	0	49.8
1	2.3	189 6	↓
2	4.2	272 0	
3	6 9	302 1	↓
4	8.5	240.3	49.6
5	10.2	206.5	49 6
6	11.8	187.5	49 8
7	12 9	191.7	↓
8	14 4	185 9	
9	15 3	181.2	↓
10	16 3	176 9	60 0
11	17 7	235 6	61.6
12	19 0	218 7	62.5
13	20.1	203 3	63 4
14	21.4	192 3	66 2
15	22.5	187.0	79.2
16	24 2	217.6	80 6
17	25.1	209.7	82.0
18	26 6	200.7	95.4
19	28.3	207.6	63.9
20	29.9	174.3	61 6
21	31.2	133.6	60.9
22	31 3	128 3	60.6
23	31 4	127.8	59.3
24	31 6	125 2	58.5
25	31.7	123 6	57 2
26	32.0	122 0	57 2
27	32.2	121.0	57 4
28	32.3	120.4	57 4
29	32.3	120 4	57 2
30	32.3	120.4	57.2
31	32.4	119.9	57 4
32	32.4	↓	57 2
33	32.4		57.4
34	32.6	↓	57 2
35	32.7	119 4	57.4
36	32 7	118.8	57 2
37	32 9	118 8	57 0
38	32 9	118 3	56 2
39	32 9	117 8	49.6
40	32 7	1.1	↓
41	31 9	.5	
42	31 3	↓	↓
43	30.7		49 6
44	27.5		49 8
45	22.8	155 8	↓
46	17 6	124.1	
47	12.0	107 2	↓
48	8 4	91 4	
49	0	73 9	49.6

TABLE XI. - Continued.

(e) Schedule C without regenerative braking, cycle 3, June 30, 1977

Test time, s	Vehicle speed, km/h	Current, A	Voltage V
0	0	0	50 0
1	2.7	297.4	50 2
2	5 5	297.4	
3	8.9	297 4	
4	11.2	297 9	
5	13.9	297 4	
6	16.9	297 4	
7	19 3	297.9	53.3
8	22 8		58 5
9	25.4		68.2
10	27 5		70.4
11	30.0	297.4	77.1
12	32 3		80.6
13	34 8		87 5
14	36 8		93.7
15	39.2		98 8
16	42 6	297.9	106.3
17	44.9	297 4	107.6
18	46 5	282 6	108.8
19	47 6	266.7	109.5
20	48 3	122 5	110.0
21	48.3	122 5	53.5
22	48.2	137.9	61.1
23	48.0	159 5	69.9
24	48.2	169 0	71.8
25		178.0	77 6
26		163.7	73.7
27		154.2	69.4
28		152.6	68.5
29	48.3	152 6	68.3
30	48.3	153 2	68.5
31	48.3	153 7	68.8
32	48.2	153 2	68 8
33	48.2	151 6	68 5
34	48.9	149.5	66 0
35	48.0	149.5	65 8
36	47.9	150.0	66 0
37	47.9	152.1	67 4
38	48.0	154.2	69 4
39	47.9	156 9	69 4
40	47 9	156 9	69 4
41	47.0	0	50 2
42	46.2		50.0
43	45.2		50 2
44	44.3		50 0
45	43.9		50 0
46	43.2	- 5	50 2
47	42.2		50 0
48	40.4		
49	38.0		
50	34.7		
51	30.2		
52	22.8	-1 1	50 2
53	16 6	-1 1	50 2
54	8.2	-.5	50 0
55	1.8	-.5	50 2

(f) Schedule C without regenerative braking, cycle 62, June 30, 1977

Test time, s	Vehicle speed, km/h	Current, A	Voltage, V
0	0	0	50 0
1	2 7	298 9	50 2
2	6.5		
3	9.3		
4	11.3		
5	14.4		
6	17.3		
7	19.7	298.4	53.9
8	22.2		59.0
9	24.4		64.3
10	26.2		70.8
11	28.6		75.0
12	31.7		81.0
13	33.7	298.9	85.2
14	36.1	298 9	90.5
15	39.0	282.0	94.0
16	39.9	267 8	95.2
17	40 6	251 9	95.8
18	42.3	240 8	96.5
19	44.3	232.4	97.2
20	45.3	225.0	97 9
21	46.0	219 2	98 2
22	46 9	214 4	98 6
23	47.6	208 6	98.9
24	47.7	156 9	65.5
25		115.1	82 9
26		161 6	53.7
27		146 3	78.0
28	47.9	137 3	69.4
29	47.9	137 3	67.1
30	47.7	137 3	66.7
31	47 6	147 4	68.5
32	47.6	143.1	70 6
33	47.7	140.0	69.0
34	47 6	138.0	67.6
35	47.6	133.1	66.0
36	47.4	125 7	62.7
37	47 2	125 7	61.6
38	47 2	127 3	60.7
39	47 0	141.0	66 9
40	46 9	123.6	65 8
41	46 5	0	49 8
42	46.0		50 0
43	45 5		50 0
44	44.8		50 0
45	43 8		49 8
46	43 2		49 8
47	42 6	5	49.8
48	42 1	0	50 0
49	40 4		
50	36.1		
51	33 1		
52	26 3		
53	21 4		49 8
54	16 1		49 6
55	11 0	:5	50 0
56	6 5	5	49 8

TABLE XI - Concluded.

(g) Schedule C with regenerative braking; cycle 2; June 28, 1977

Test time, s	Vehicle speed, km/h	Current, A	Voltage, V
0	0	0	50.0
1	1 6	248 2	49 6
2	3 5	236 1	49.6
3	5.9	223 4	49 8
4	9 6	298 9	49 8
5	12.0	298 9	50 0
6	15 4	298 4	62 1
7	19.7	298.4	75 4
8	23 5	298.9	84 0
9	26 8	298.4	90 7
10	28.9	269.9	95 1
11	31 4	255 1	100 9
12	33.3	251.4	108.1
13	36.3	244 5	112.1
14	37.4	223 4	113.0
15	38.7	213 9	113.7
16	40.4	203.3	114.3
17	41.6	193.8	114.8
18	42.8	188.0	115.1
19	43.9	184.3	115.3
20	44 8	179.0	115.5
21	45.5	175.4	115 8
22	46 0	172 2	115.8
23	46.7	169 0	116.0
24	47 2	166 4	116 2
25	46 5	60 2	60 0
26	46.3	143 1	94.7
27	46.5	149 5	99.6
28	46.7	148.9	99.6
29	46.9	147 9	99.6
30	47 2	146 3	99 5
31	47 2	137 3	92.6
32	47.0	136 3	91 4
33	47 0	135 2	90 0
34	47.0	133 1	88.7
35	46.9	131.0	87.3
36	46 7	129 4	85.7
37	46 6	128.3	84.5
38	46.3	126.8	83.6
39	46 3	126.2	82 9
40	46 2	126.2	83.1
41	45.3	-.5	50 0
42	44 2	↓	50 0
43	43.5		49.8
44	42.5		49.8
45	41.6	-1 1	49.6
46	40.9	-1 1	49.8
47	39.9	-.5	50 0
48	39.1	-.5	49.8
49	38.0	- 5	↓
50	35 4	196.0	
51	31 3	150.0	
52	26 1	130.5	
53	20 3	113 0	50 0
54	15.7	97 2	49.8
55	10 1	80 3	49 8
56	4.4	57 0	49 8

(h) Schedule C with regenerative braking, cycle 71, June 28, 1977

Test time, s	Vehicle speed, km/h	Current, A	Voltage, V
0	0	0	50.0
1	2 8	302 1	50 0
2	6 1	302 1	49 8
3	8 8	↓	49 6
4	11.3		49 6
5	13.9	↓	50 5
6	17 0	301.6	53.3
7	18.8	↓	59.5
8	21.4		64.4
9	23.9	↓	70.4
10	26 6		75 4
11	28 9	302.1	81 0
12	31.0	↓	84 5
13	32 3		89.4
14	34.6	↓	94.5
15	36.7	282.6	96.1
16	38.8	265 7	97.4
17	40 8	254 0	97.9
18	41 9	241 9	98 6
19	43 5	232.4	99 1
20	44.5	226.6	99 6
21	45.6	221.8	100.0
22	46.3	217.1	100.4
23	47.3	206.9	100.5
24	47 7	153.7	74.1
25	47.9	167 4	78 5
26	48.0	169 0	80.8
27	48 0	168 0	80.8
28	48 3	167 4	80 6
29	48 4	164 3	80 6
30	48 6	144 2	71 1
31	48 6	140 0	68 3
32	48.7	136.8	66 0
33	48 7	136.3	65.8
34	48.6	137 3	66.2
35	48 6	138.4	66.5
36	48.4	138.9	67.4
37	48.3	140.0	67 6
38	48 2	145 8	69 9
39	48 2	147 9	71 3
40	47.7	.5	49.6
41	47.2	0	49.8
42	46.6	0	49.8
43	46.0	.5	49.6
44	45 3	0	49.6
45	44.0	0	49 6
46	43 5	.5	49 8
47	42 6	.5	49 6
48	41 8	151 1	↓
49	38 8	132.6	
50	34.3	110.9	
51	29.0	99.8	49.8
52	25 4	90.3	49.8
53	20.8	79 8	49.8
54	16 0	71.3	49.6
55	9 1	62 3	49 6
56	4 4	5	49 6
57	.7	0	50 5

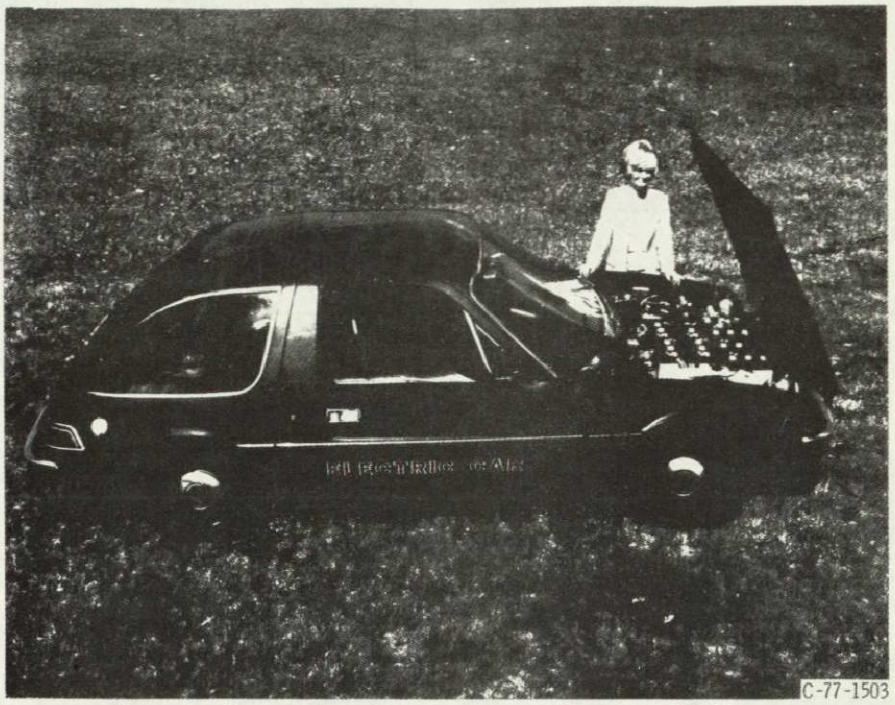


Figure 1. - Electric Vehicle Associates Change-of-Pace Coupe (EVA Pacer).

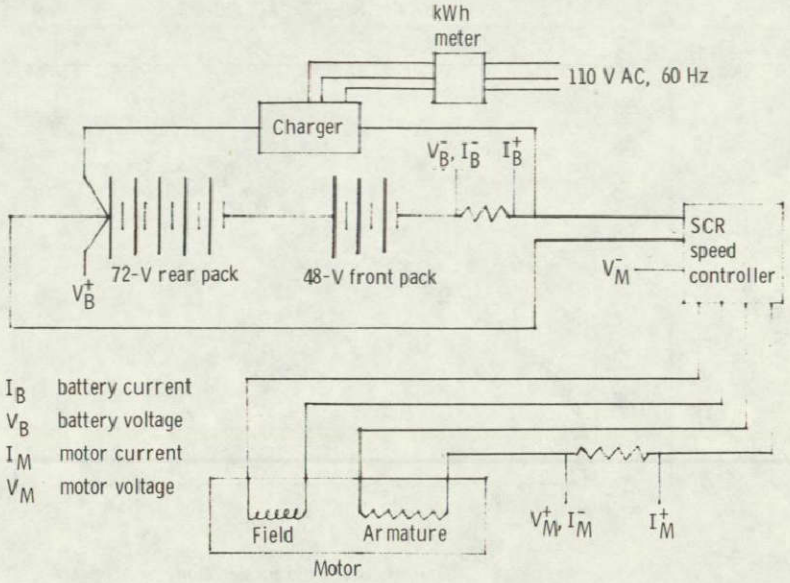
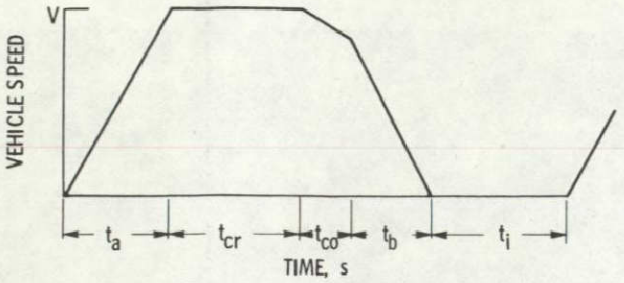


Figure 2. - Schematic diagram of instrumentation for EVA Change-of-Pace Coupe.



TEST PARAMETER	SAE SCHEDULES		
	B	C	D
MAX. SPEED, V, mph	20	30	45
ACCEL. TIME, t_a, s	19	18	28
CRUISE TIME, t_{cr}	19	20	50
COAST TIME, t_{co}	4	8	10
BRAKE TIME, t_b	5	9	9
IDLE TIME, t_i	25	25	25

Figure 3. - SAE J227a driving cycle schedules.

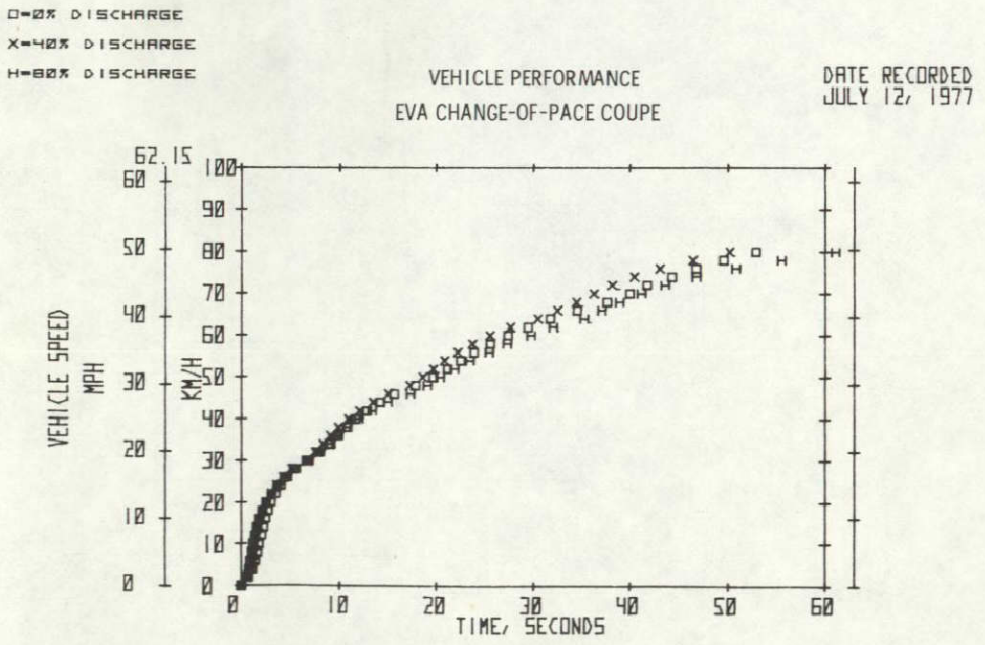


Figure 4. - Vehicle acceleration.

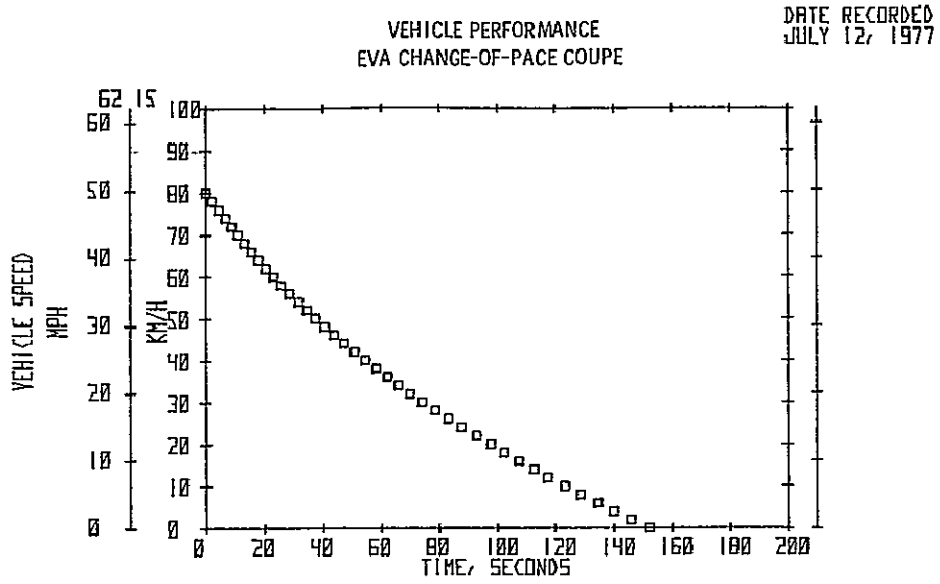


Figure 7. - Vehicle deceleration.

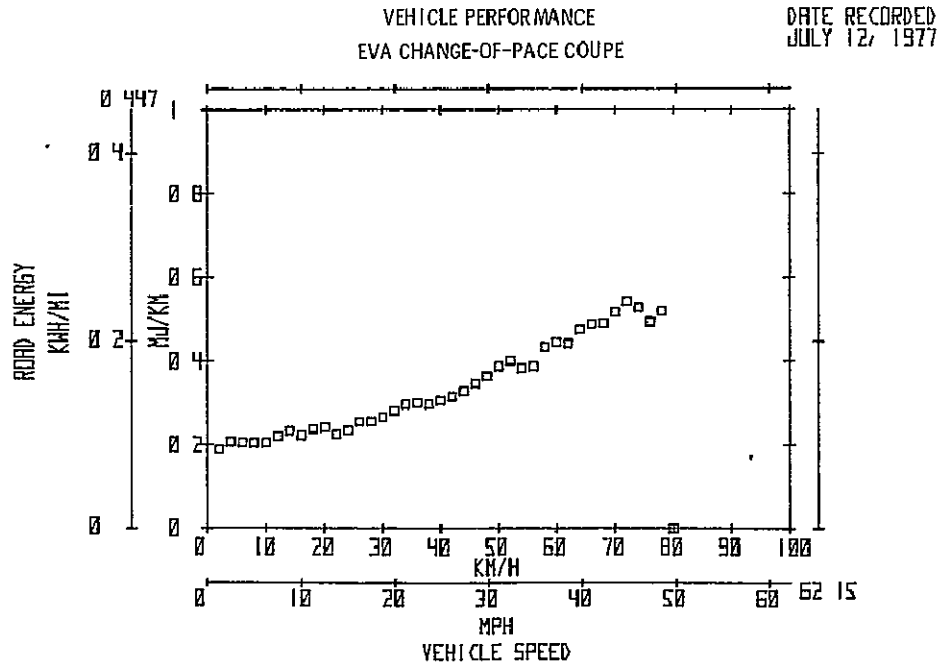


Figure 8. - Road energy as a function of speed

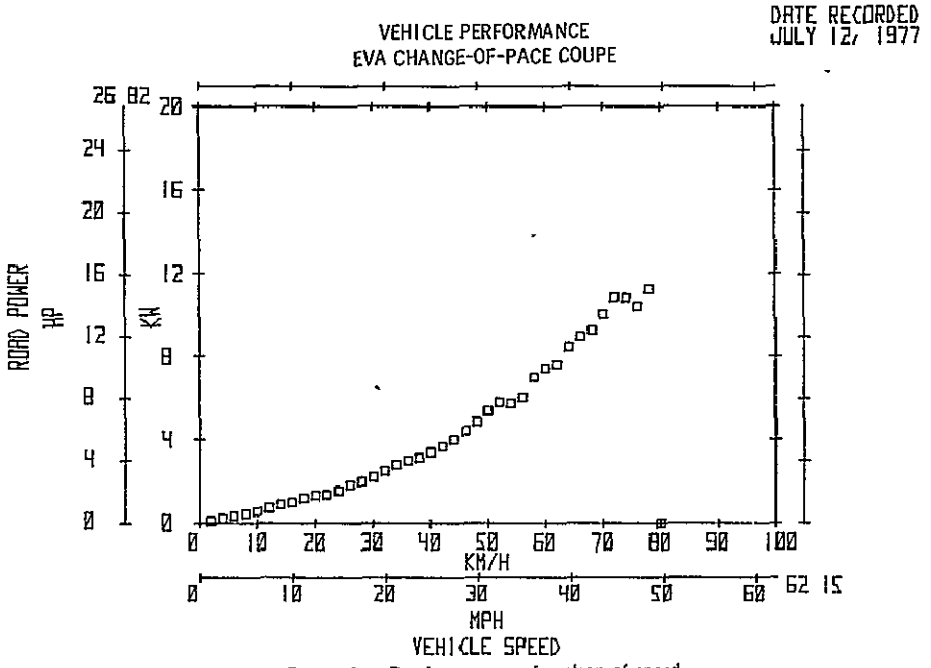


Figure 9. - Road power as a function of speed

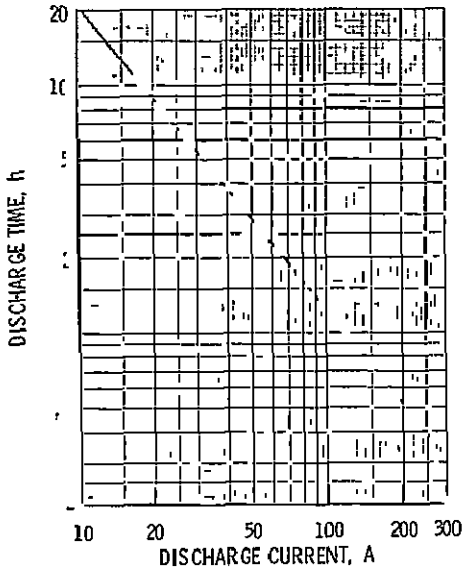


Figure 10 - Globe-Union GC-2-19 battery discharge data.

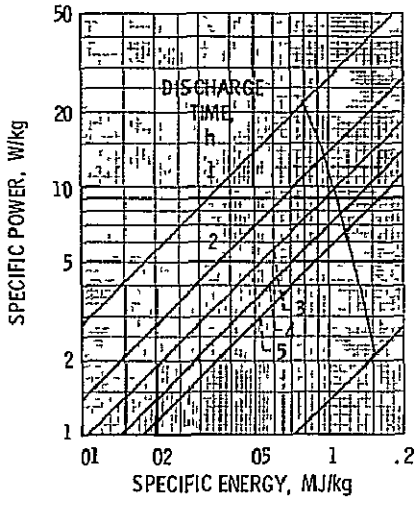


Figure 11 - Battery energy/power relationship for Globe-Union GC-2-19 three-cell module

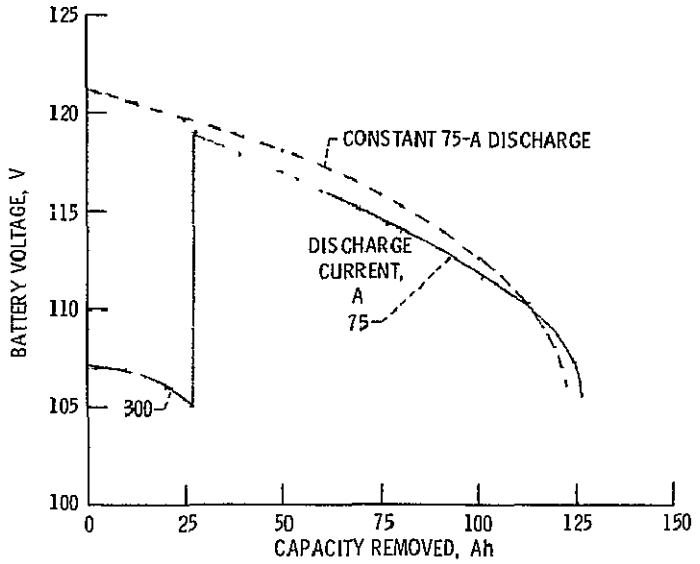


Figure 12. - Battery qualification test data for EVA Change-of-Pace Coupe.

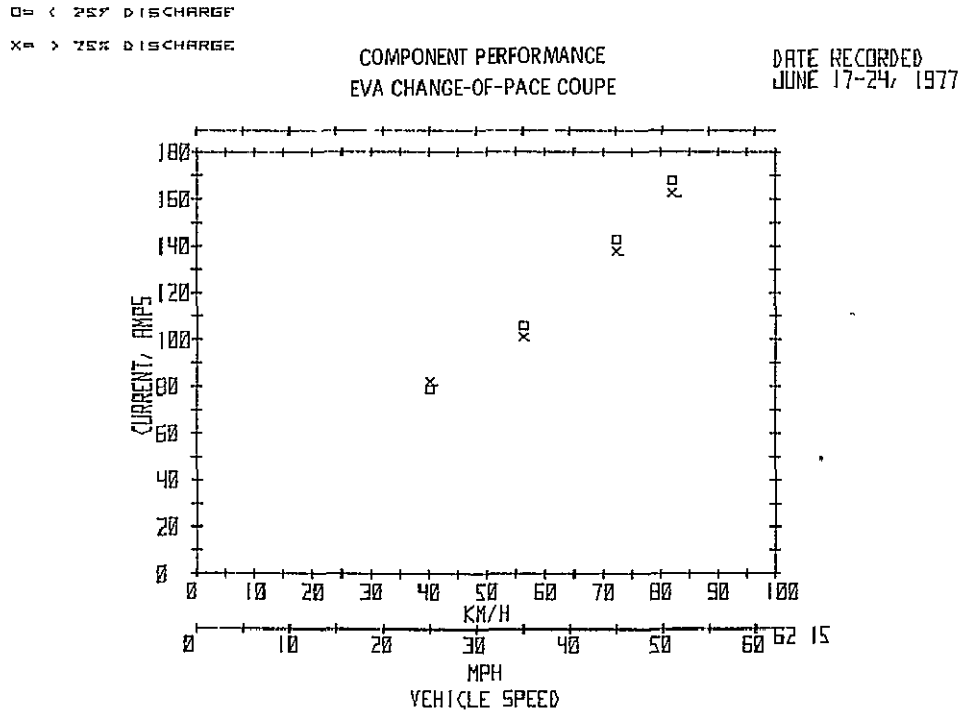


Figure 13. - Current as a function of speed

□=< 25% DISCHARGE

X= > 75% DISCHARGE

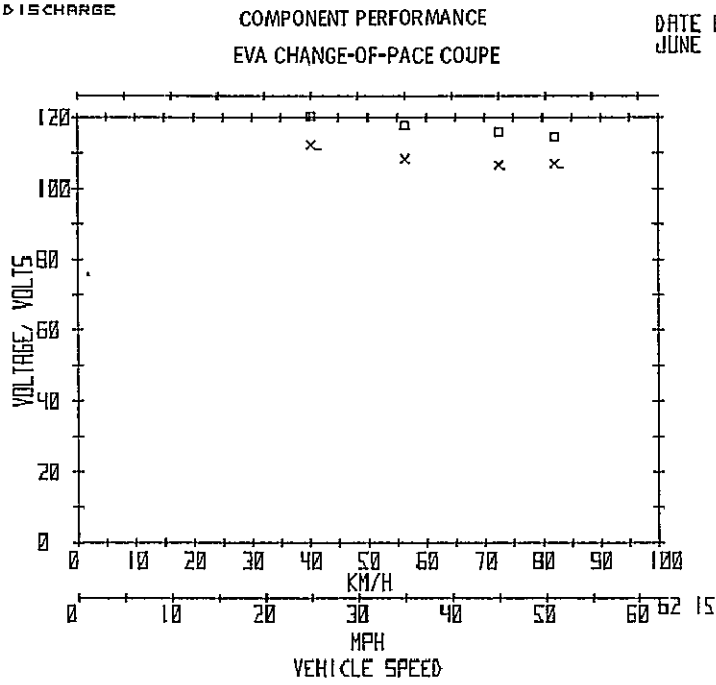
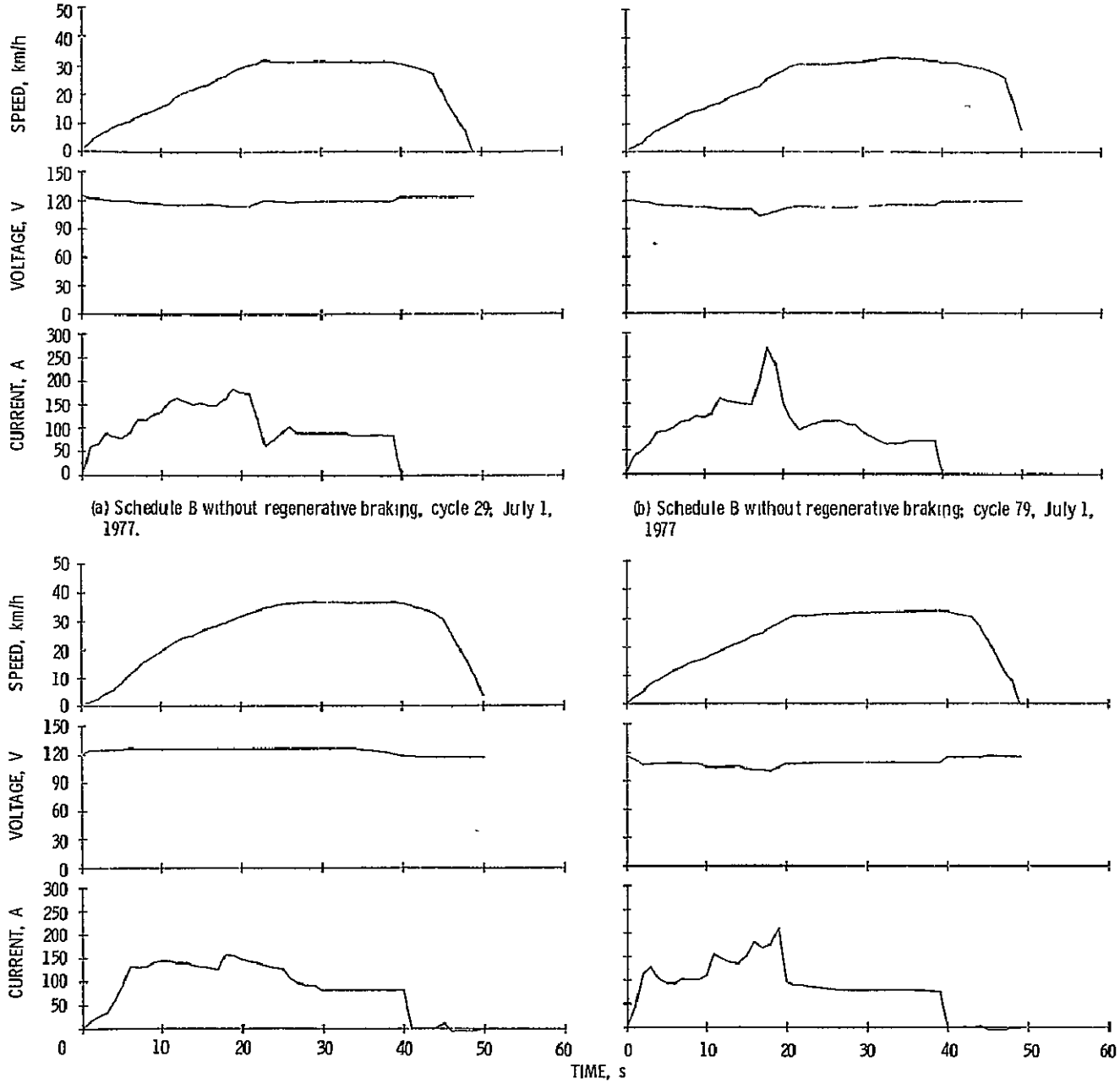


Figure 14. - Voltage as a function of speed.



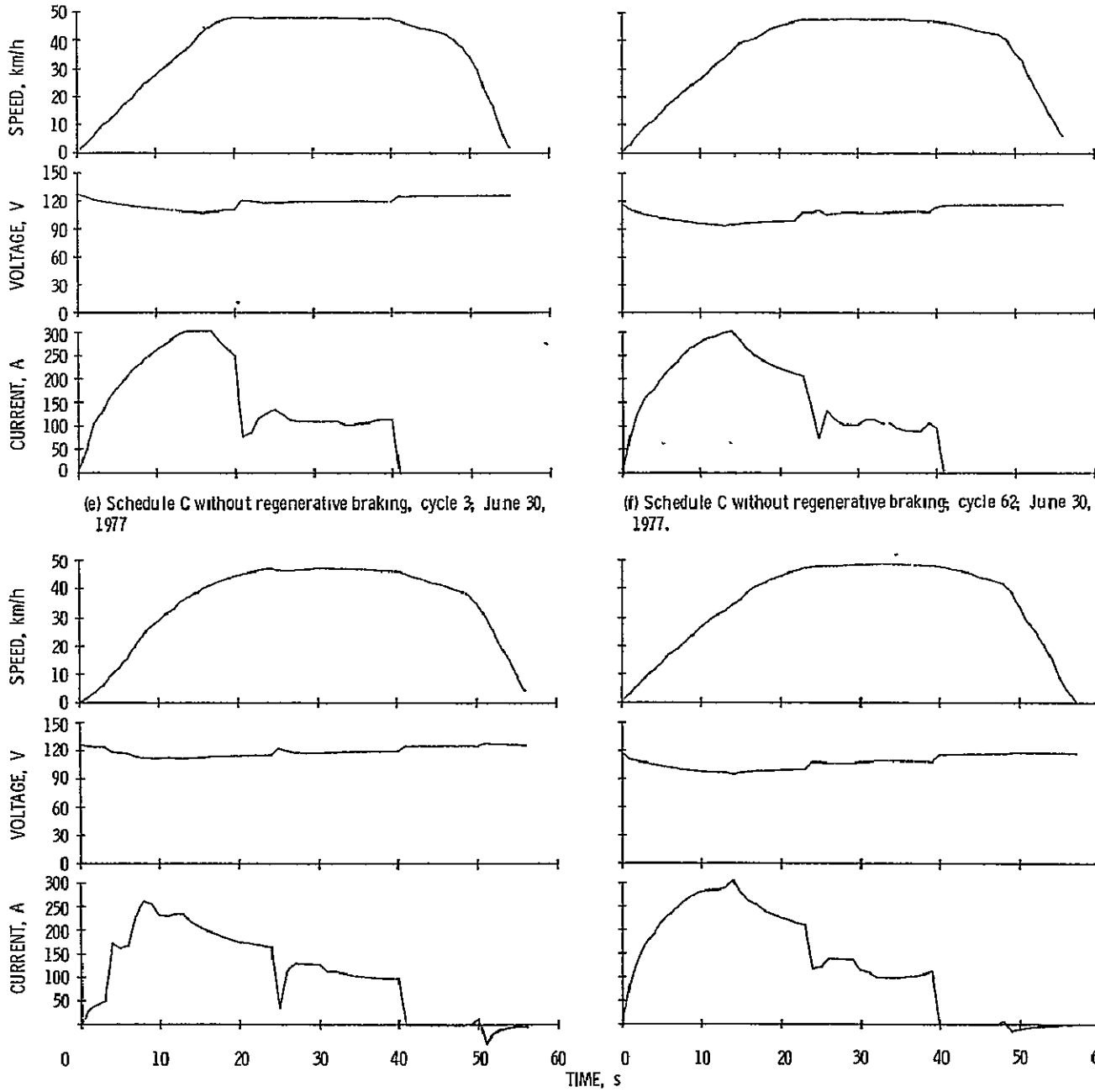
(a) Schedule B without regenerative braking, cycle 29; July 1, 1977.

(b) Schedule B without regenerative braking; cycle 79, July 1, 1977

(c) Schedule B with regenerative braking; cycle 3; June 27, 1977.

(d) Schedule B with regenerative braking, cycle 131, June 27, 1977

Figure 15 - Battery output as a function of time for EVA Change-of-Pace Coupe



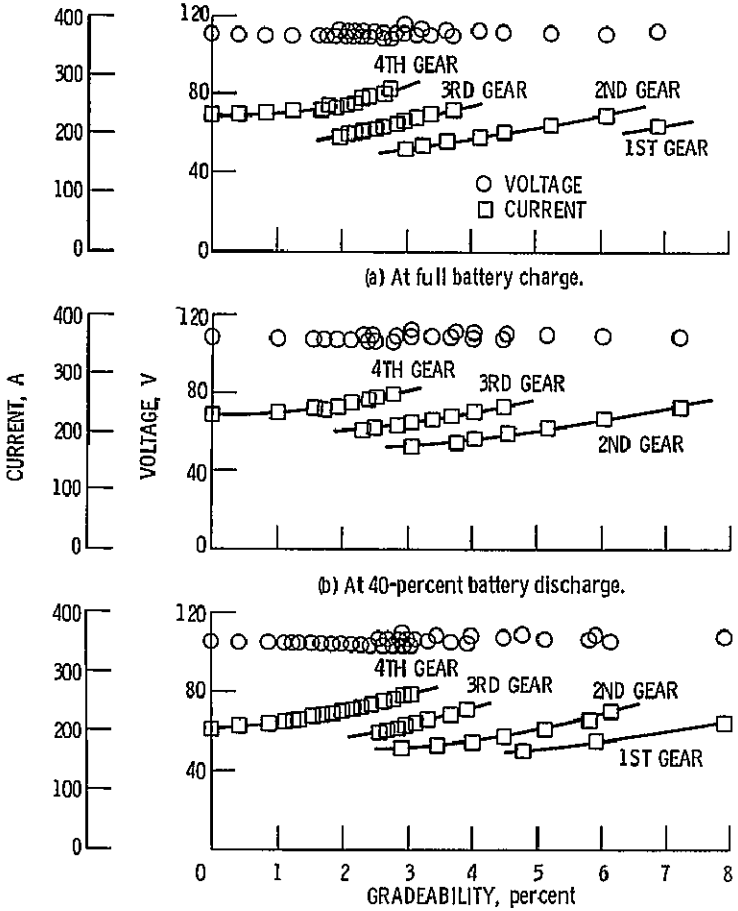
(e) Schedule C without regenerative braking, cycle 3; June 30, 1977

(f) Schedule C without regenerative braking; cycle 62; June 30, 1977.

(g) Schedule C with regenerative braking; cycle 2; June 28, 1977.

(h) Schedule C with regenerative braking, cycle 71, June 28, 1977

Figure 15 - Concluded.



(a) At full battery charge.

(b) At 40-percent battery discharge.

(c) At 80-percent battery discharge.

Figure 16. - Battery output during acceleration for EVA Change-of-Pace Coupe.

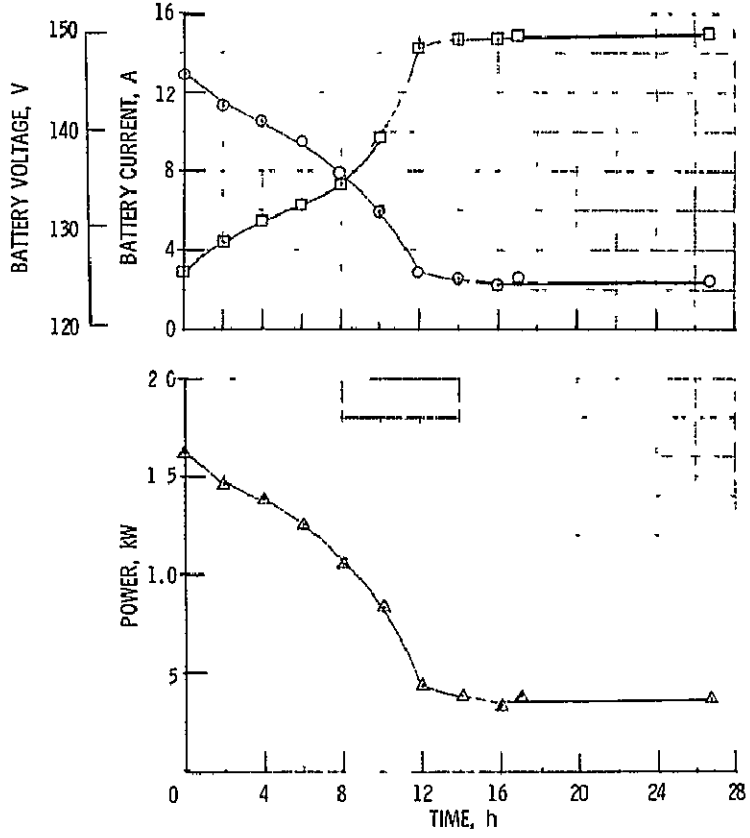


Figure 17. - Charger output for EVA Change-of-Pace Coupe, after 82-km/h test on June 24, 1977

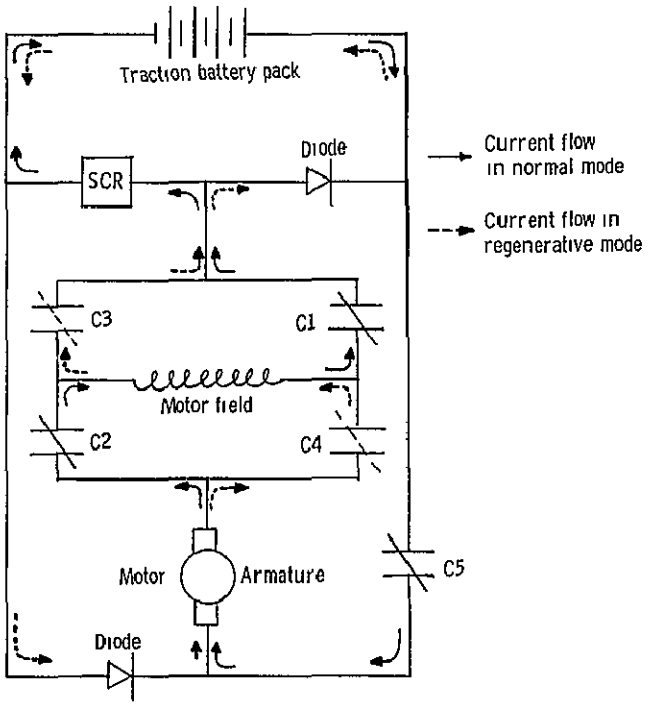
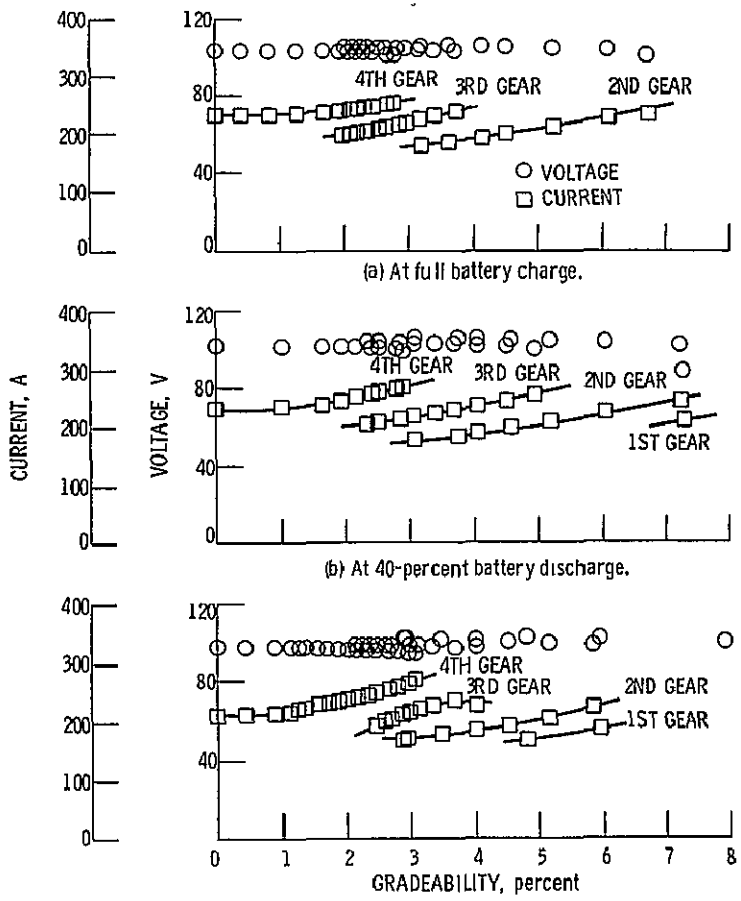


Figure 18 - Schematic diagram of speed controller and regeneration system for EVA Change-of-Pace Coupe.

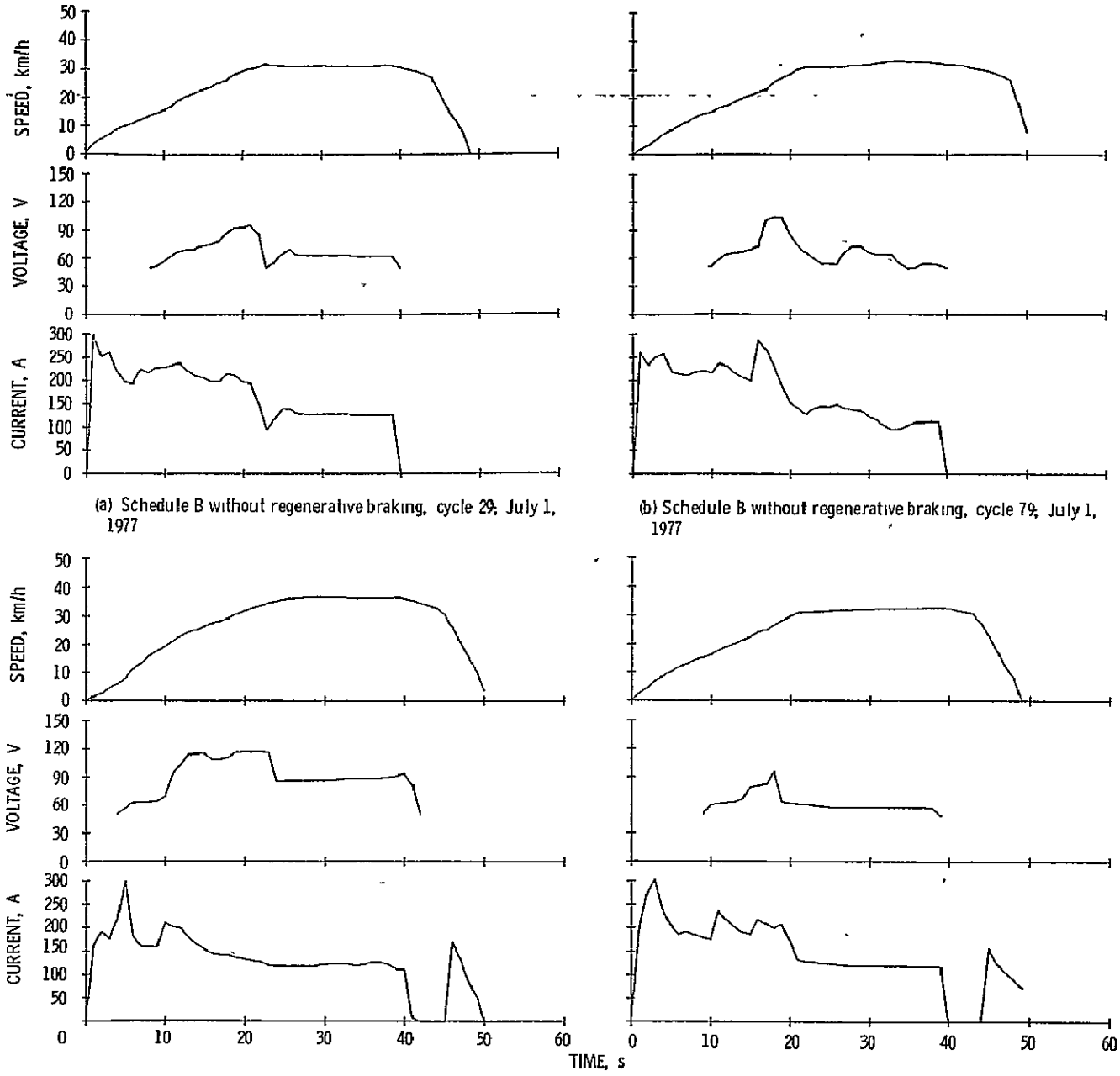


(a) At full battery charge.

(b) At 40-percent battery discharge.

(c) At 80-percent battery discharge.

Figure 19 - Motor input during acceleration for EVA Change-of-Pace Coupe



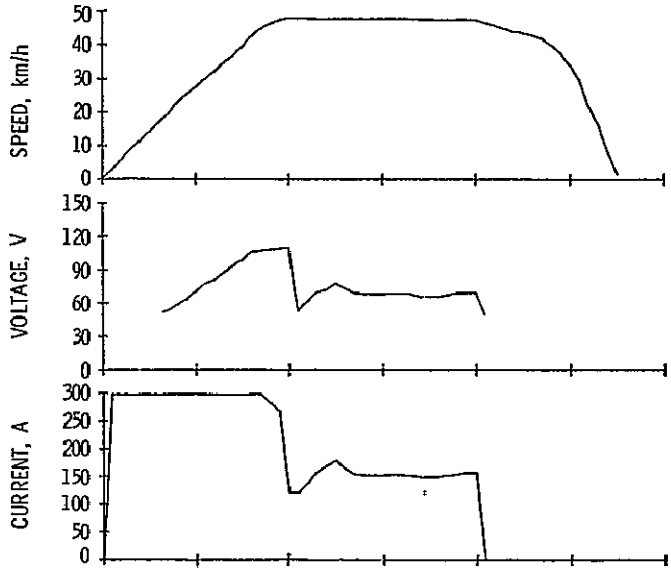
(a) Schedule B without regenerative braking, cycle 29, July 1, 1977

(b) Schedule B without regenerative braking, cycle 79, July 1, 1977

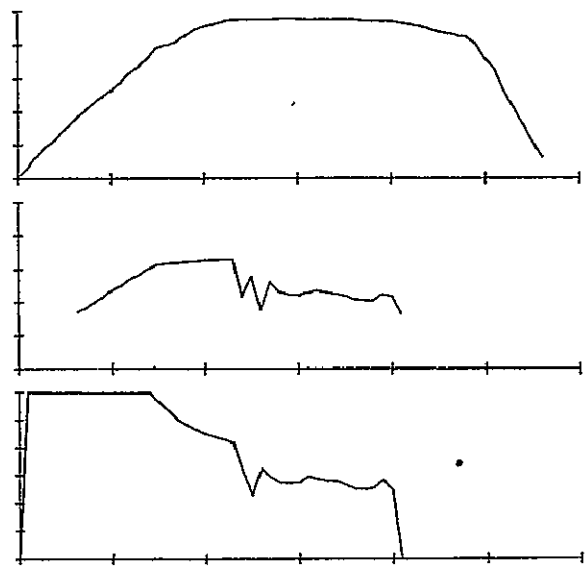
(c) Schedule B with regenerative braking, cycle 3, June 27, 1977

(d) Schedule B with regenerative braking, cycle 131, June 27, 1977

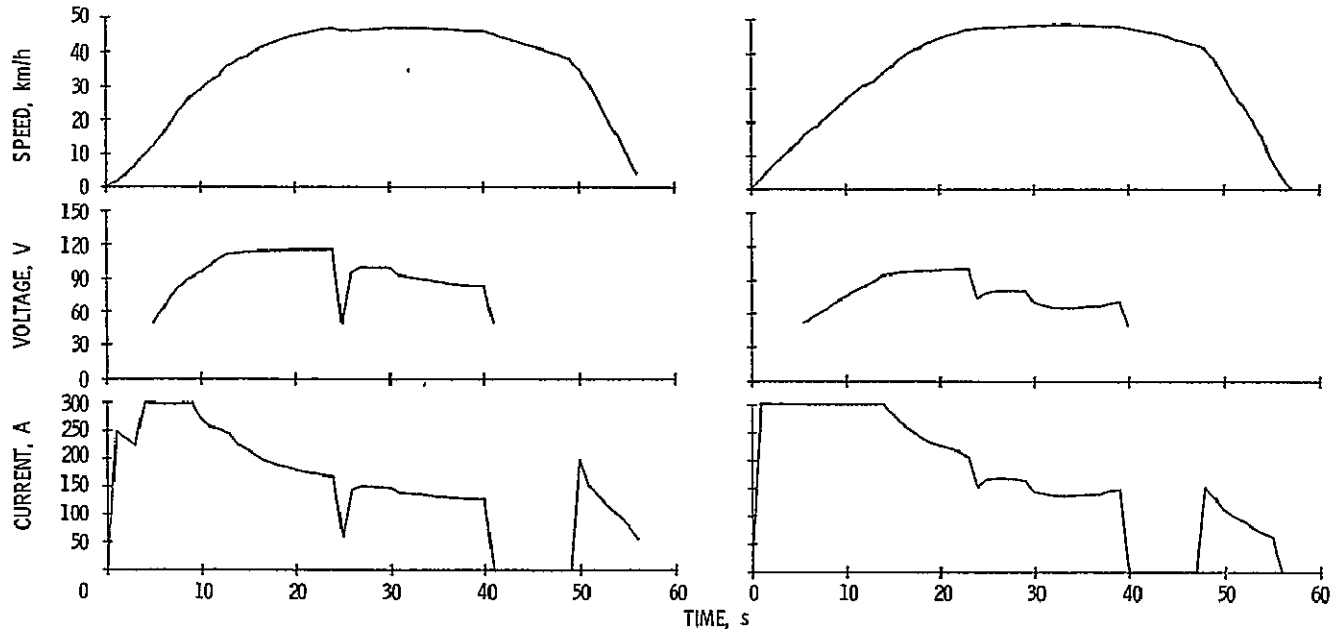
Figure 20 - Motor input as a function of time for EVA Change-of-Pace Coupe.



(e) Schedule C without regenerative braking, cycle 3; June 30, 1977



(f) Schedule C without regenerative braking, cycle 62; June 30, 1977



(g) Schedule C with regenerative braking, cycle 2; June 28, 1977

(h) Schedule C with regenerative braking, cycle 71, June 28, 1977.

Figure 20. - Concluded.

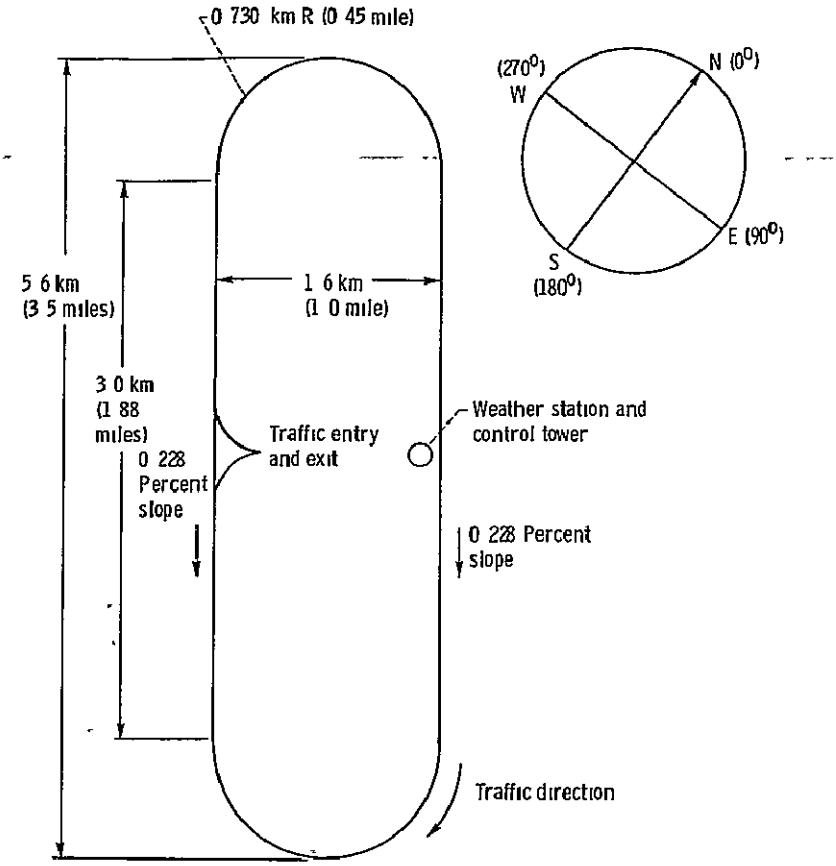


Figure B-1 - Characteristics of Transportation Research Center Test Track, East Liberty, Ohio

1. Vehicle _____
2 Date received _____
3 Checked for damage - date _____
4 Wheel alignment - date _____
5. Battery checked and equalized - date _____
6 Curb weight determined, lbm _____ Date _____
7. Gross vehicle weight, lbm _____
8 300-Ampere test - date _____
9 Manufacturers recommendations
Maximum speed, mph _____
Tire pressures, psi Front _____, Rear _____
Driving procedures _____

Figure C-1 - Vehicle preparation check sheet.

Vehicle _____, _____ mph range test, _____ gear

Driver Instructions·

1 Complete pretest checklist.

2 While on track recheck
Integrator - light on, in "operate" position, zeroed
Speedometer - set on ____ mph center
Distance - on, reset, lighted
Attenuator - on, reset, lighted

3. At signal from control center accelerate moderately to ____ mph.

4 Maintain ____ ±1 mph with minimal accelerator movement.

5. When vehicle is no longer able to maintain ____ mph, brake moderately to full stop

6. Complete post-test checklist and other documentation

Recording

1 Set oscillograph zeros at.

Channel	Zero, in.
3	3.0
4	4 5
6	5 0
10	75
12	1.1
13	1 2
14	2 0

2 Record all channels on magnetic tape. Check inputs at beginning of test to verify recording

3. Run cals on all channels

4 Remove all channels from oscillograph except 3 and 4

5 Start recording 15 s before start of test at oscillograph speed of 0 1 in/s and tape speed of _____ in/s.

6 After 15 min into test connect channels 6, 10, 12, 13, and 14 to oscillograph and record a burst at 100 in/s while vehicle is in chopper mode.

7. Remove channels 6, 10, 12, 13, and 14 from oscillograph and continue test at 0 1 in/s with channels 3 and 4 only.

8 Document all ambient conditions at beginning, once every hour, and at the end of the test Items recorded shall include temperature, wind speed and direction, significant wind gusts, and corrected barometric pressure

(a) Constant-speed test.

Vehicle _____, _____ cycle test, _____ gear

Driver Instructions

1 Complete pretest checklist.

2. While on track recheck.
Integrator - light on, in "operate" position, zeroed
Speedometer - set on ____ mph center
Distance - on, reset, lighted
Attenuator - on, reset, selector on 100
Cycle timer - verify scheduled timing with stop watch

3 At signal from control center, perform cycle test using cycle timer as basis for determining length of each phase of performance cycle Use programmed stop watch as backup device Cycle consists of

Accelerate to _____ mph in _____ s

Cruise at _____ mph for _____ s

Coast for _____ s

Brake to complete stop in _____ s

Hold in stop position for _____ s

Repeat entire cycle until vehicle is unable to meet acceleration time Moderately brake to a complete stop

4 Complete post-test checklist and other documentation.

Recording

1 Record all channels on magnetic tape at _____ in/s Check all channels to verify input at beginning of test

2 Record speed and distance on oscillograph at _____ in/s.

3 Start recording data 15 s before beginning test

4. Document ambient conditions at beginning, once every hour, and at the end of the test Items recorded shall include temperature, wind speed and direction, significant wind gusts, and corrected barometric pressure

(b) Driving cycle test

Figure C-2. - Test checklists.

1. Record specific gravity readings after removing vehicle from charge, and disconnect charger instrumentation Fill in charge data portion of data sheet from previous test Add water to batteries as necessary, recording amount added Check and record 5th wheel tire pressure and vehicle tire pressure.

2 Connect. (Connect alligator clips to instrumentation battery last)
   (a) Inverter to instrument battery
   (b) Integrator input lead
   (c) Integrator power to inverter
   (d) Starred (*) 5th wheel jumper cable
   (e) Cycle timer power and speed signal input cables. Check times
   (f) Spin up and calibrate 5th wheel

3. Record test weight - includes driver and ballast with 5th wheel raised

4 Turn on
   (a) Inverter, motor speed sensor, thermocouple reference junctions, integrator, and digital voltmeter Set integrator on "Operate "
   (b) Fifth wheel readout and switching interface units (2) (Select distance for expanded scale range.)

5 Tow vehicle onto track with 5th wheel raised
   Precalibrations.
   Tape data system
   Oscillograph
   Reset.
   5th wheel distance
   Ampere-hour meter
   Thermocouple readout switches on "Record"
   Turn on thermocouple reference junctions
   Lower 5th wheel. Set hub loading.

6 Be sure data sheet is properly filled out to this point Check watch time with control tower

7 Proceed with test

Figure C-3 - Pretest checklist.

Vehicle _____ Battery system _____

Test _____ Date _____

Track data

Driver _____ Navigator _____

Average pretest specific gravity _____

Open-circuit voltage, V _____

Tire pressure before test, psi

Right front ___ Left front ___ Right rear ___ Left rear ___

Tire pressure after test, psi

Right front ___ Left front ___ Right rear ___ Left rear ___

Fifth-wheel pressure, psi _____ (calibrated) _____ psi)

Weather	Initial	During test	Final
Temperature, °F			
Wind speed, mph			
Wind direction			
Pressure, in Hg			

Battery temperature, °F Before _____ After _____

Motor temperature, °F. Before _____ After _____

Time Start _____ Stop _____

Odometer reading, miles Start _____ Stop _____

Current out, Ah _____ Current in (regenerative), Ah _____

Fifth wheel _____

Basis for termination of tests _____

_____

Charge data

Average post-test specific gravity _____

Open-circuit voltage, V _____

Charger used _____

Charger input voltage, V _____

Battery temperature, °F Before charge ___ After charge ___

Power, kWh Start _____ End _____ Total _____

Time Start _____ End _____

Total charge time, min _____

Current input, Ah _____

Average specific gravity after charge _____

Approval _____

Figure C-4 - Track and charge data

1. Record time immediately at completion of test. Turn off key switch.
2. Complete track data sheet:
   (a) Odometer stop
   (b) Ampere-hour integrator
   (c) 5th wheel distance
   (d) Read temperature
   (e) Calibrate data system
   (f) Record weather data
3. Turn off inverter, thermocouple reference junctions.
4. Disconnect 12-volt instrument battery red lead.
5. Raise 5th wheel.
6. Tow vehicle off track.
7. Start charge procedure (specific gravities).
8. Check specific gravity on instrument battery. If less than 1.220, remove from vehicle and charge to full capacity.
9. Check water level in accessory batteries. Add water as necessary.

Figure C-5. - Post-test checklist.

Vehicle _____ Test _____ Date _____

Test conditions:

Temperature, °F _____ Wind speed, mph _____ at _____

Barometer reading, in. Hg _____; Other _____

Test results:

Test time, h _____

Range, miles _____

Cycles _____

Current out of battery, Ah _____

Current into battery, Ah _____

Charge time, h _____

Power into battery, kWh _____

Magnetic tape:

No. _____; Speed, in/s _____

Comments _____

Figure C-6. - Test summary sheet.

Vehicle _____ Test _____ Date _____

Engineer _____

Reason for test (checkout, component check, scheduled test, etc.) _____

_____

Limitation on test (malfunction, data system problem, brake drag, etc.) _____

_____

Changes to vehicle prior to test (repair, change batteries, etc.) _____

_____

Other comments _____

_____

Evaluation of test:

Range, miles _____

_____

Current out, Ah _____

_____

Current in, Ah _____

_____

Power in, kWh _____

Energy consumption, kWh/mile _____

Was planned driving cycle followed? _____

_____

General comments _____

_____

_____

_____

_____

_____

_____

Figure C-7. - Engineer's data sheet.

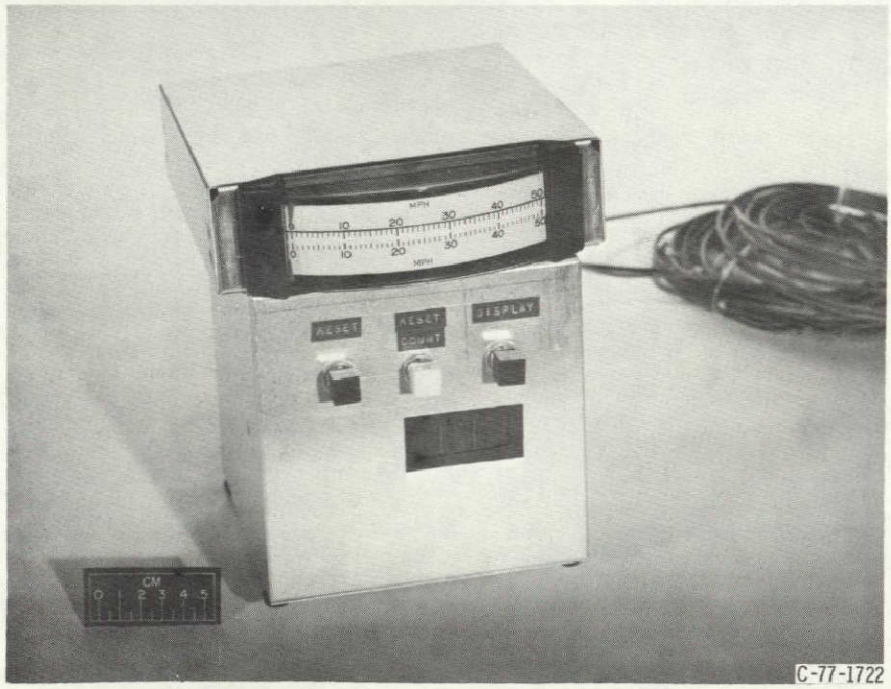


Figure C-8. - Cycle timer.

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