

595

Volume II

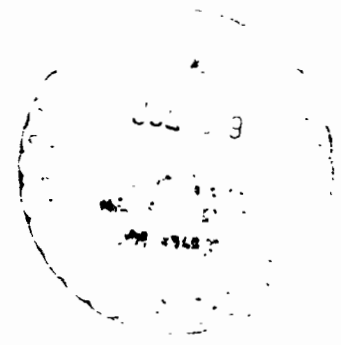
Three

State-of-the-Art

Individual Electric and

Hybrid Vehicle Test Reports

November 1978



Prepared For
U.S. Department of Energy
Assistant Secretary for Conservation
and Solar Applications
Division of Transportation Energy Conservation

Under Interagency Agreement No. EC-77-A-31-1011

(NASA-CR-162311) THREE STATE-OF-THE-ART
INDIVIDUAL ELECTRIC AND HYBRID VEHICLE TEST
REPORTS, VOLUME 2 (Jet Propulsion Lab.)
329 p HC A15/MF A01

N79-32130

Unclas
G3/85 37745

Volume II
Three
State-of-the-Art
Individual Electric and
Hybrid Vehicle Test Reports

November 1978

Prepared By
NASA/Jet Propulsion Laboratory
Pasadena, California

For
U.S. Department of Energy
Assistant Secretary for Conservation
and Solar Applications
Division of Transportation Energy Conservation
Washington, D.C. 20545

Under Interagency Agreement No. EC-77-A-31-1011

PREFACE

The Electric and Hybrid Vehicle Research, Development, and Demonstration Act of 1976 (Public Law 94-413) required that data be developed characterizing the state of the art of electric and hybrid vehicles. The Energy Research and Development Administration, now the Department of Energy (DOE), which was given the responsibility for implementing the Act, established the Electric and Hybrid Vehicle Research, Development, and Demonstration Project within the Division of Transportation Energy Conservation to manage the activities required by Public Law 94-413.

Specifically, the Act states that "Within 12 months after the date of enactment of this Act, the Administrator shall develop data characterizing the present state of the art with respect to electric and hybrid vehicles. The data so developed shall serve as baseline data to be utilized in order (1) to compare improvements in electric and hybrid vehicle technologies; (2) to assist in establishing the performance standards under subsection (b)(1); and (3) to otherwise assist in carrying out the purposes of this section." This report is intended, however, to give detailed information regarding the state-of-the-art assessment of electric vehicles in addition to the summary type information presented in HCP/M1011 already in print.

The National Aeronautics and Space Administration under an Interagency Agreement (Number EC-77-A-31-1011) was requested by ERDA (DOE) to develop data in support of the state-of-the-art characterization. The NASA/Jet Propulsion Laboratory was assigned the responsibility for the testing and reporting on the three vehicles included in this volume.

Since the purpose of the state-of-the-art survey was to characterize present electric vehicles and not to represent any particular vehicle technology, vehicles selected for test and evaluation were picked to provide a representation of the current state of the art. However, the number of vehicles selected was limited by the funding available and the time available to complete this phase of the work. Therefore, selection was based on: (1) ready availability of a vehicle; and (2) its technical representation and the apparent maturity of its construction. This report gives detailed information on three of the specific vehicles tested. A previous report, "Twelve State-of-the-Art Individual Electric and Hybrid Vehicle Test Reports," (Volume I, July 1978 - HCP/M1011-03/1), is also available.

This project was conducted under the overall direction of Dr. Robert S. Kirk and Mr. Walter J. Dippold of DOE. The NASA/JPL Project Manager was Mr. Thomas A. Barber. The reports represented were prepared by the Jet Propulsion Laboratory's Electric and Hybrid Vehicle Project Office whose members, through their technical skill, enthusiasm, and dedication, made it possible to complete this project.

TABLE OF CONTENTS

<u>Report #</u>	<u>Baseline Tests of the:</u>	<u>Section</u>
1	Fiat 850T Electric Van	I
2	Ripp Electric Passenger Car	II
3	Volkswagen Taxi Hybrid Passenger Vehicle	III

Report #1

Fiat 850T Electric Van

Section I

900-848

EVALUATION OF FIAT'S
ELECTRIC VAN

December 1977

Prepared by

D.B. Edwards, Ph.D.
Project Development Section

ACKNOWLEDGEMENT

I would like to recognize J. Solario and H. Callisen for their dedication and invaluable help in processing the data for this report. The instrumentation section was written by J. Solario and the overview of the data flow path, Appendix D, was written by H. Callisen. I would also like to acknowledge W. Rippel for his suggestions in writing this report.

PAGE BLANK NOT FILMED

PAGE BLANK NOT FILMED

TABLE OF CONTENTS

<u>Section</u>	<u>Title</u>	<u>Page</u>
1	INTRODUCTION	1-1
2	SUMMARY OF RESULTS	2-1
3	VEHICLE DESCRIPTION	3-1
4	INSTRUMENTATION	4-1
4.1	Introduction	4-1
4.2	Vehicle Speed and Distance	4-1
4.3.1	Current Sensors	4-2
4.3.2	Voltage Sensors	4-3
4.3.3	Motor Temperature Sensor.	4-3
4.4	Time and Weather	4-3
4.4.1	Time	4-3
4.4.2	Weather	4-4
4.5	Energy Measurements.	4-4
4.5.1	Energy into Battery Charger	4-4
4.5.2	Energy out of Battery Charger	4-4
4.5.3	Energy into and out of Battery.	4-5
4.5.4	Energy into and out of Motor, Excluding Shunt Field Energy.	4-5
4.5.5	Energy into Shunt Field	4-5
4.6	Energy Counters.	4-5
4.7	DAS Recorder	4-7
5	TEST RESULTS	5-1
5.1	Range at Steady Speed Tests.	5-1
5.2	Coast Down Test.	5-4
5.3	Acceleration Test.	5-23

TABLE OF CONTENTS (contd)

<u>Section</u>	<u>Title</u>	<u>Page</u>
	5.4 Driving Cycle Tests	5-51
6	ENERGY FLOW AND PERFORMANCE MODELS.	6-1
	6.1 Charger and Battery	6-2
	6.2 Controller.	6-5
	6.3 Motor	6-5
7	OBSERVATIONS AND CONCLUSIONS.	7-1

Appendices

A	COAST DOWN DATA	A-1
B	ACCELERATION DATA	B-1
C	B-CYCLE DATA.	C-1
D	DATA FLOW PATH OVERVIEW	D-1

SECTION 1

INTRODUCTION

This report is being written as part of ERDA's program in assessing the state of the art of electric vehicles. The vehicle tested was a small van made by Fiat. The Fiat van was shipped by air from Italy to Cleveland, Ohio, and the tests were conducted at the Transportation Research Center, TRC, in East Liberty, Ohio.

SECTION 2

SUMMARY OF RESULTS

The results of the tests are summarized in two tables. The energy to the various components as well as the distance traveled is given in Table 2.1. The second table, Table 2.2, lists the efficiency of the components. The efficiency calculations and the vehicle energy economy are based on the amount of energy used for a 150 amp-hr charge. The reason for using this figure instead of the true recharging energy is discussed in Section 6.

The velocity vs. corrected time curve for coast down is plotted in Figure 2.1 with the coefficient of rolling friction, viscous friction, and wind drag shown on the figure. The power and energy consumption is plotted against velocity in Figures 2.2 and 2.3, respectively. The acceleration curves are shown in Figure 2.4 for various levels of battery charge, and the gradeability vs. velocity figure is plotted in Figure 2.5.

Table 2.1. Energy Flow

Test	Date	Distance (Km) and Cycles	Energy to Charger (Kw-Hr)	Energy to Battery (Kw-Hr)	Energy to Controller (Kw-Hr)	Energy to Motor (Kw-Hr)	Regenerative Energy From Motor (Kw-Hr)	Regenerative Energy to Battery (Kw-Hr)
25 mph Range	5/19	68.9 (42.8 miles)	29.3 ¹	26.1 ¹	12.0	Total 10.94 Armature 10.8 Field 0.143	-	-
25 mph Range	5/21	73.1 (45.4 miles)	29.4	26.2	12.9	Total 11.86 Armature 11.7 Field 0.16	-	-
25 mph Range	5/26	71.1 (44.2 miles)	29.2	26.0	12.6	Total 11.43 Armature 11.2 Field 0.23	-	-
35 mph Range	5/23	57.8 (35.9 miles)	29.2	26.0	11.1	Total 10.1 Armature 10.1 Field 0.0	-	-
35 mph Range	5/25	58.1 (36.1 miles)	29.6	26.3	11.5	Total 10.6 Armature 10.6 Field 0.0	-	-
B-Cycle with regen. braking	5/31	40.2 (25. miles) 109 cycles	29.9	26.6	12.3	Total 10.7 Armature 9.9 Field 0.822	0.6	0.05
B-Cycle with regen braking	6/3	39.3 (24.4 miles) 116 cycles	29.2	26.0	11.9	Total 10.3 Armature 9.3 Field 0.977	0.6	0.02

¹The numbers are obtained by averaging the corresponding numbers of the other two 25 mph range tests.
The real data was lost because a strip chart recorder malfunctioned.

Table 2.2. Component Efficiencies

Test	Date	Energy Efficiency of Charger	Energy Efficiency of Batter	Energy Efficiency of Contrcller.	Energy Efficiency of Motor	Overall Energy Efficiency	Amp-Hr Efficiency of Battery	Energy Economy (Kw-Hr)/Km
25 mph Range	5/19	89%	46%	91%	80%	29%	58%	0.43
25 mph Range	5/21	89%	49%	92%	77%	31%	61%	0.40
25 mph Range	5/26	89%	48%	90%	78%	30%	60%	0.41
35 mph Range	5/23	89%	43%	91%	89%	31%	54%	0.51
35 mph Range	5/25	89%	44%	91%	85%	30%	56%	0.51
B-Cycle with regen braking	5/31	89%	46%	87%	63%	22%	60%	0.74
B-Cycle with regen braking	6/3	89%	46%	87%	50%	18%	60%	0.74

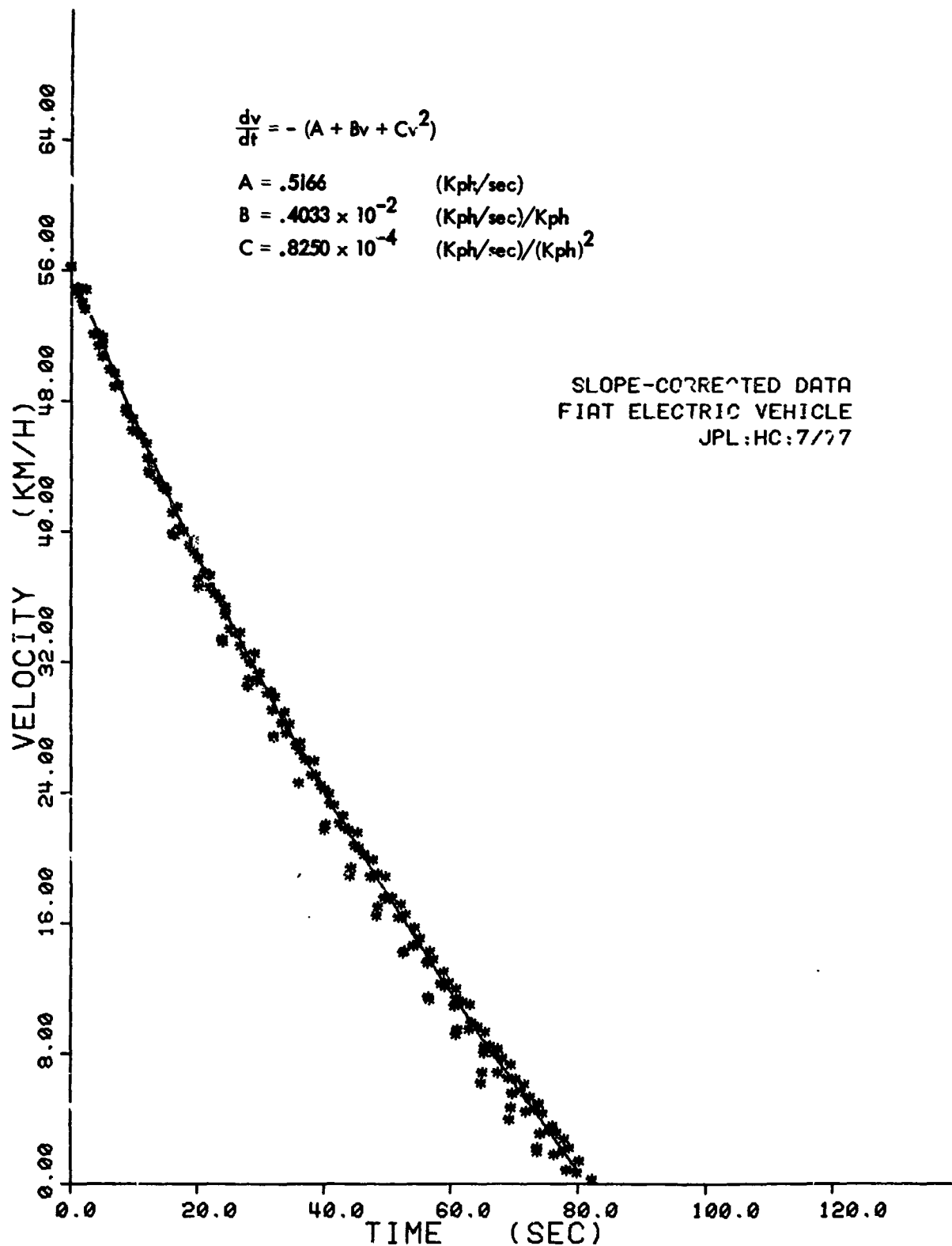


Figure 2.1. Coast Down Curve

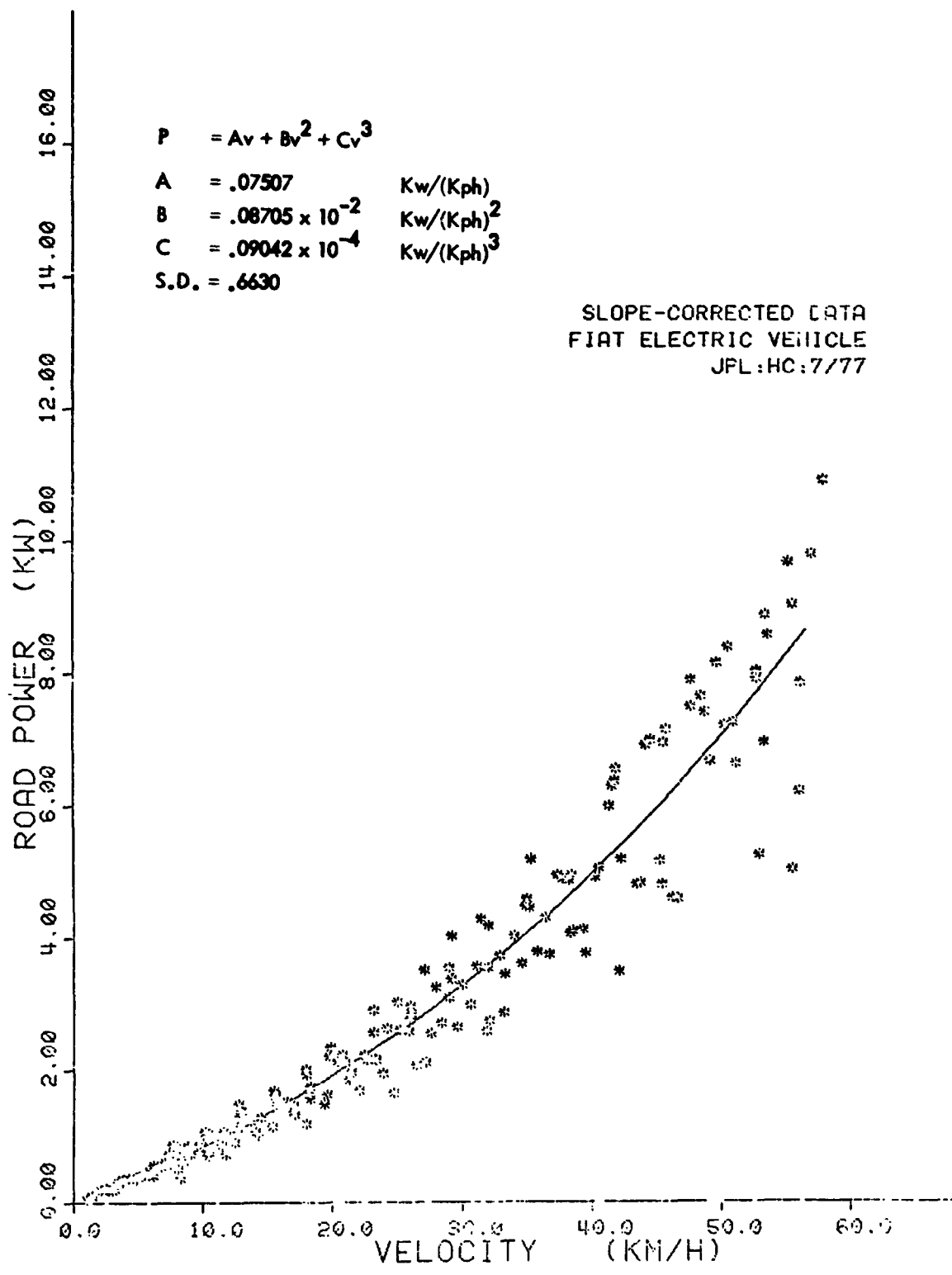


Figure 2.2 Road Power Consumption

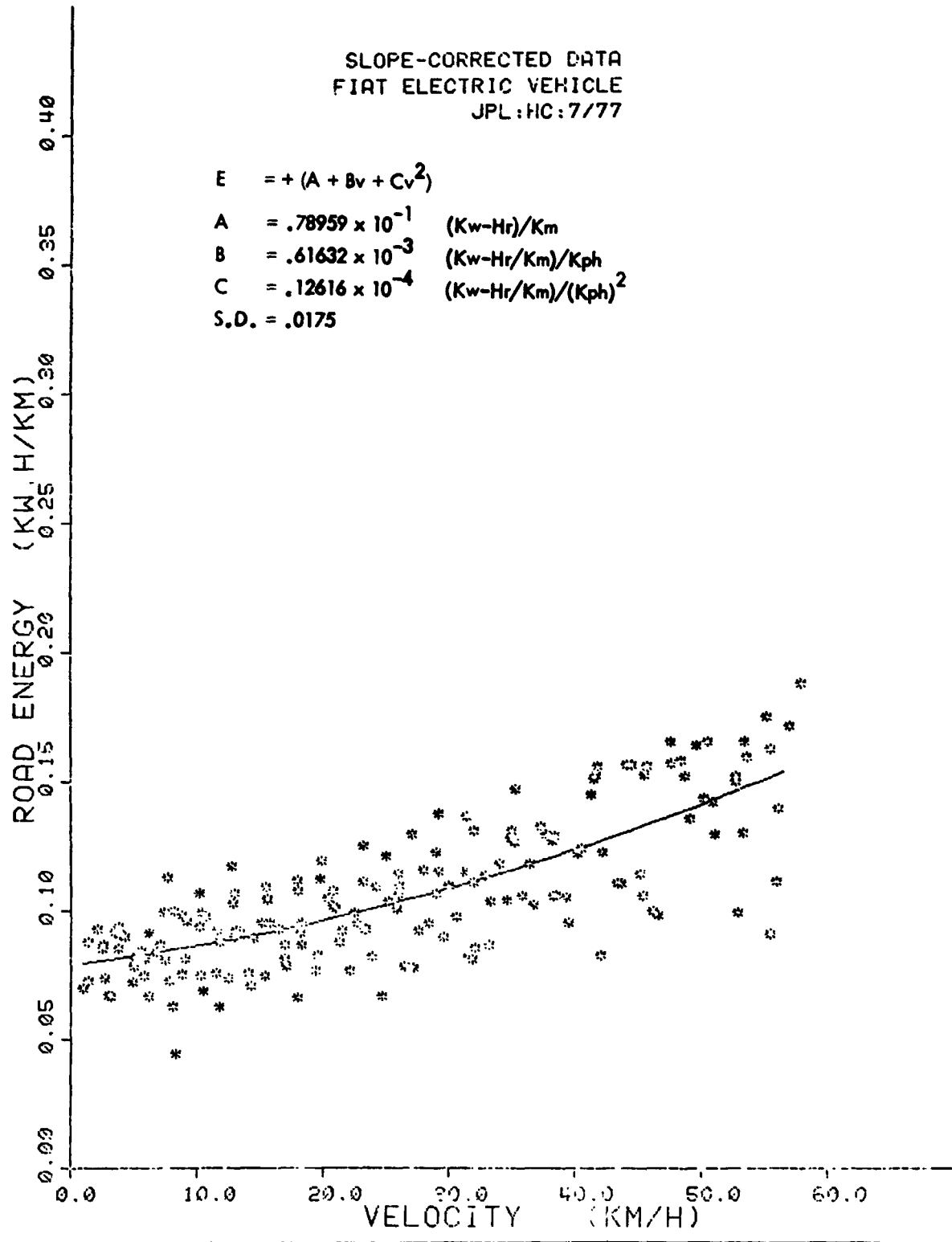


Figure 2.3 Road Energy Consumption

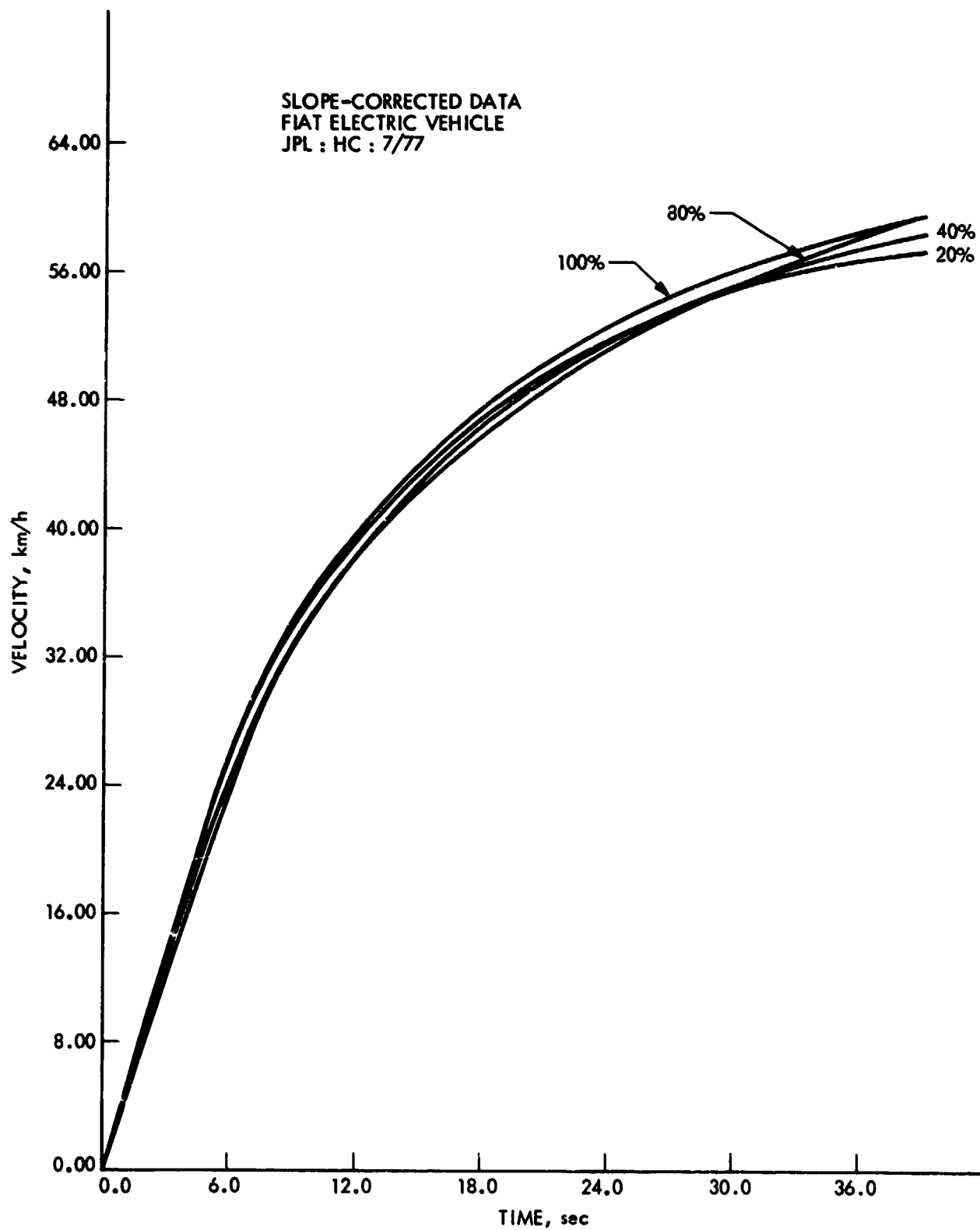


Figure 2.4 Acceleration Curves

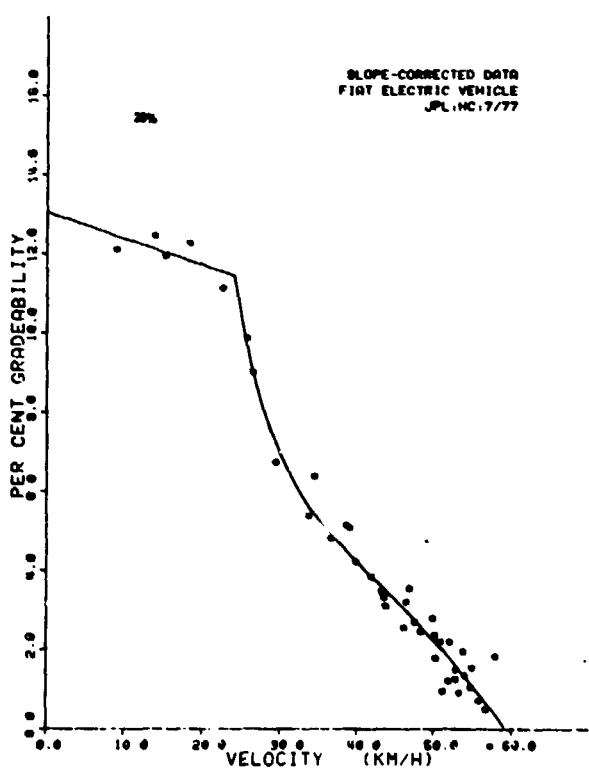
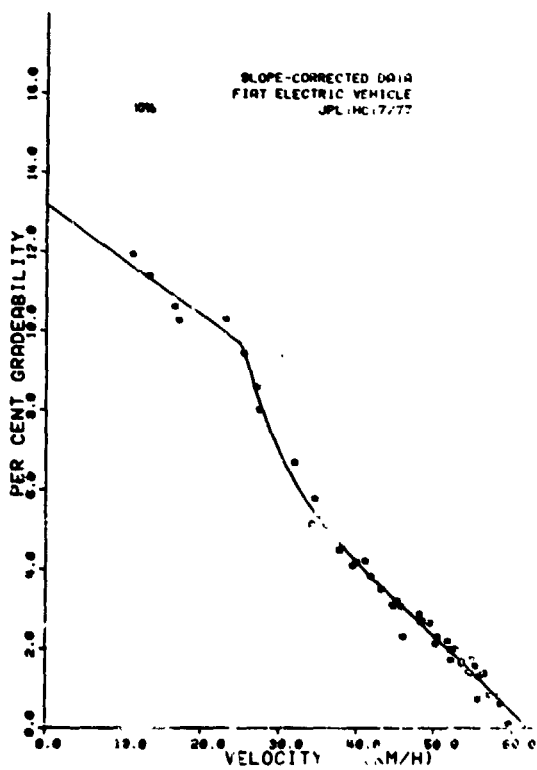
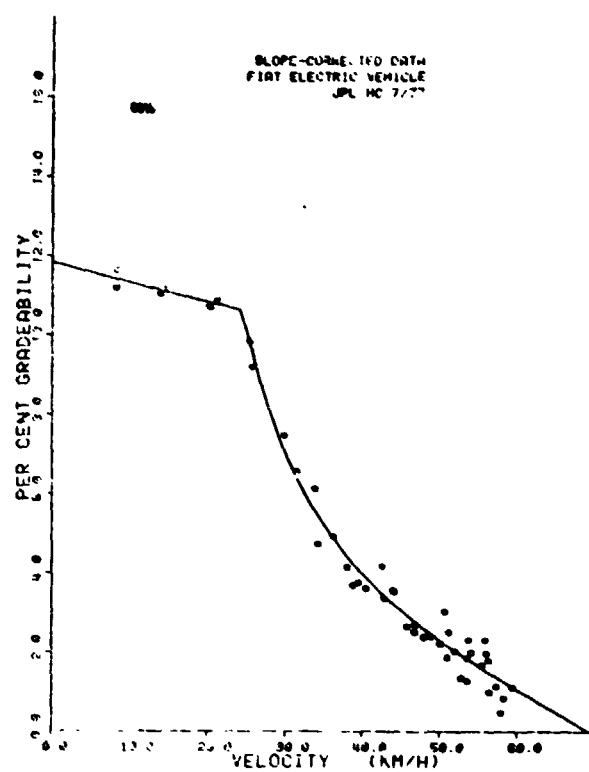
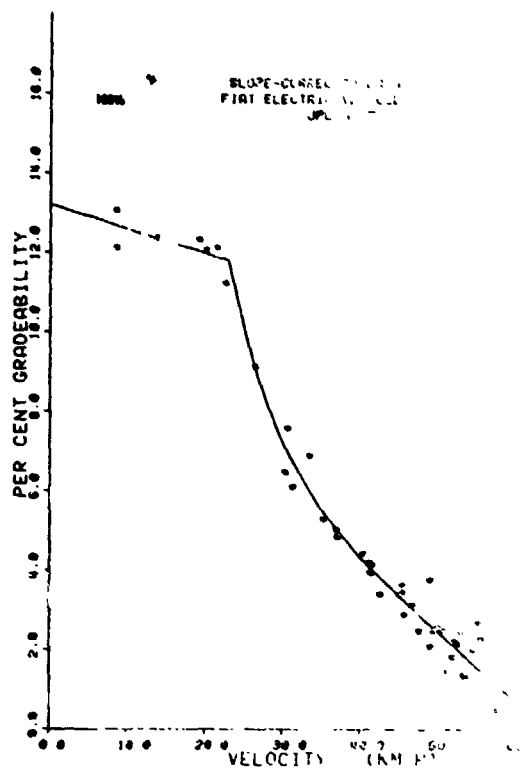


Figure 2.5 Percent Gradeability vs Velocity

SECTION 3

VEHICLE DESCRIPTION

The side and rear view of the Fiat van, which had a total weight of 1986 Kg (4370 lbm), is shown in Figure 3.1 and Figure 3.2 respectively. The van is powered by 12 series-connected, 12 volt batteries manufactured by Magnetti-Marelli (6TS 17T). The batteries are located beneath the van, Figure 3.3, in a container which can be raised and lowered hydraulically. The hydraulic lift, Figure 3.4, makes servicing and replacing the batteries very easy. The batteries are rated at 135 amp-hr for a 5 hr discharge time (27 amps for 5 hr), and the total battery weight is 461 Kg (1014 lbm). The batteries were about three months old when the vehicle was tested and had not been deep cycled.

The vehicle is propelled by a D.C. separately excited compound electric motor manufactured by Fiat. The rated continuous power of the motor is 14 Kw (19 hp), and the motor can deliver 29 Kw (39 hp) for three minutes. The rated speed is 2600 rpm, and its maximum speed is 6700 rpm. The motor weighs 55 Kg (121 lbm).

The power to the series connected armature and field is controlled by an SCR chopper while the shunt field power is controlled with a transistor chopper. The SCR chopper has a current rating of 320 amps, and the transistor chopper has a current rating of 10 amps. A schematic of the Fiat's power system is shown in Figure 3.5. The weight of the controller is 79 Kg (173.8 lbm) which includes a 30 Kg (66 lbm) inductor.

The off-board battery charger operated from a 240 V, 3-phase outlet. The charger supplied was not the charger usually used by Fiat. The charger normally used was delayed in the U.S. Customs

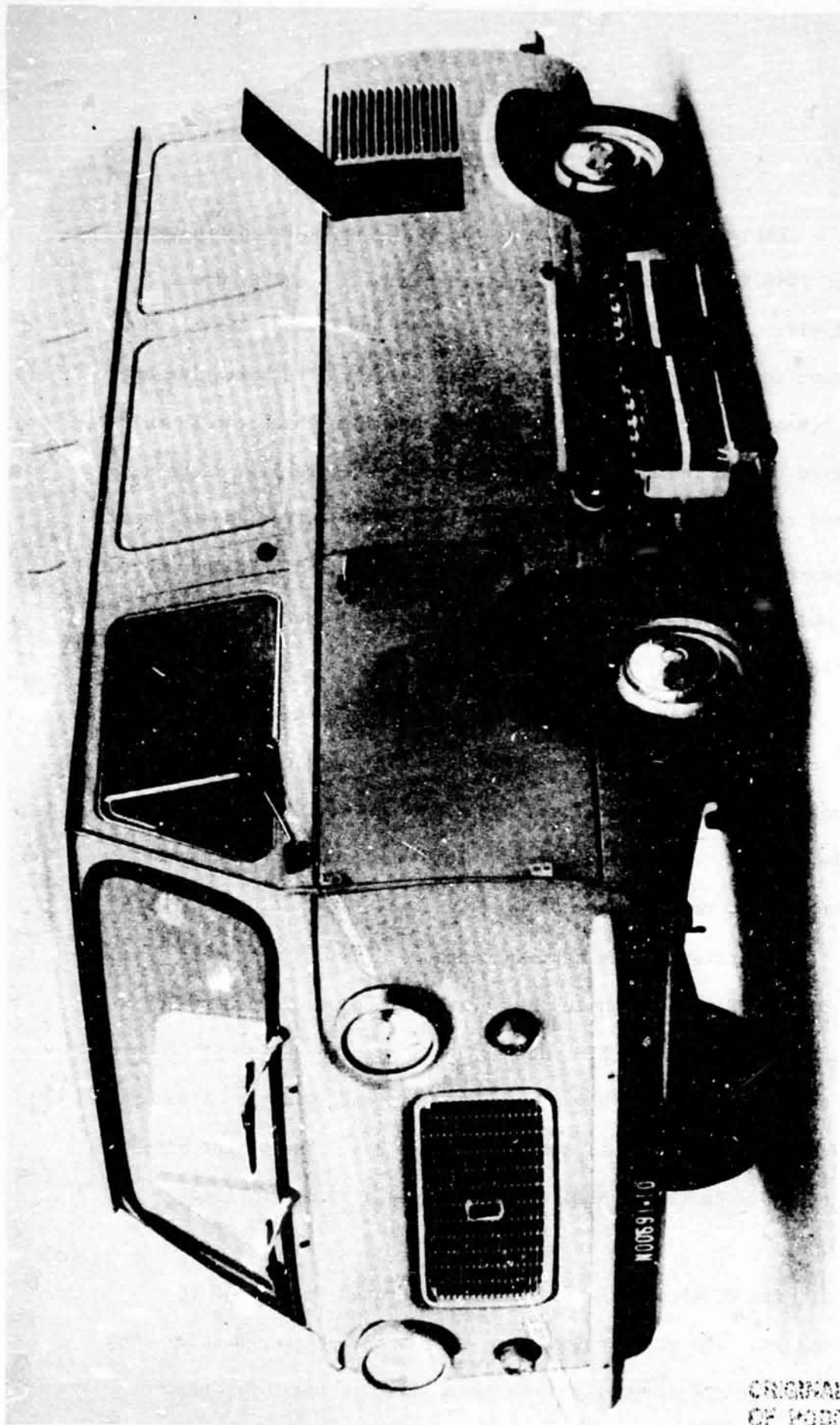


Figure 3.1. Side View of Fiat Van

ORIGINAL PAGE IS
OF POOR QUALITY



Figure 3.2. Rear View of Fiat Van

ORIGINAL PAGE IS
OF POOR QUALITY

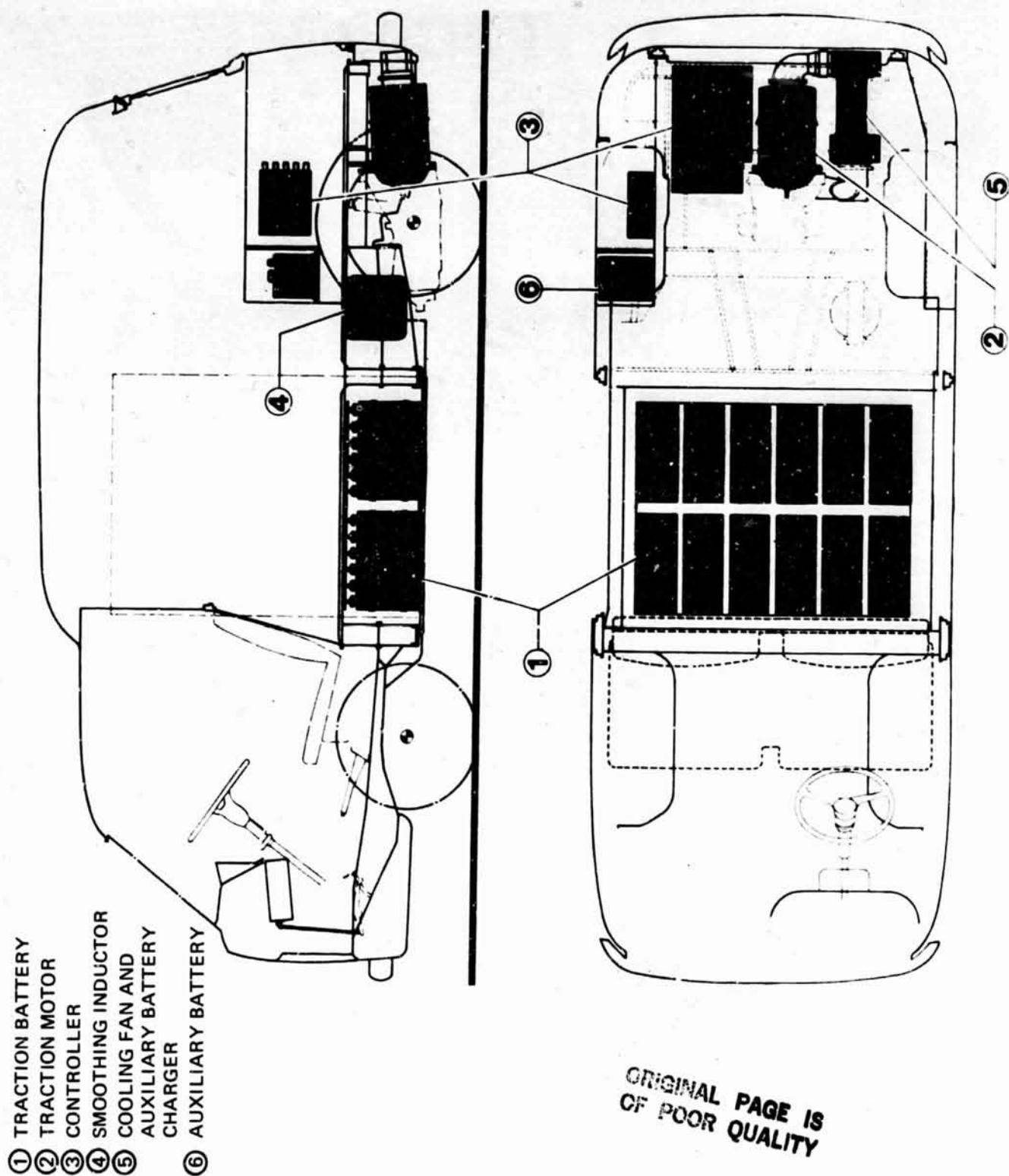
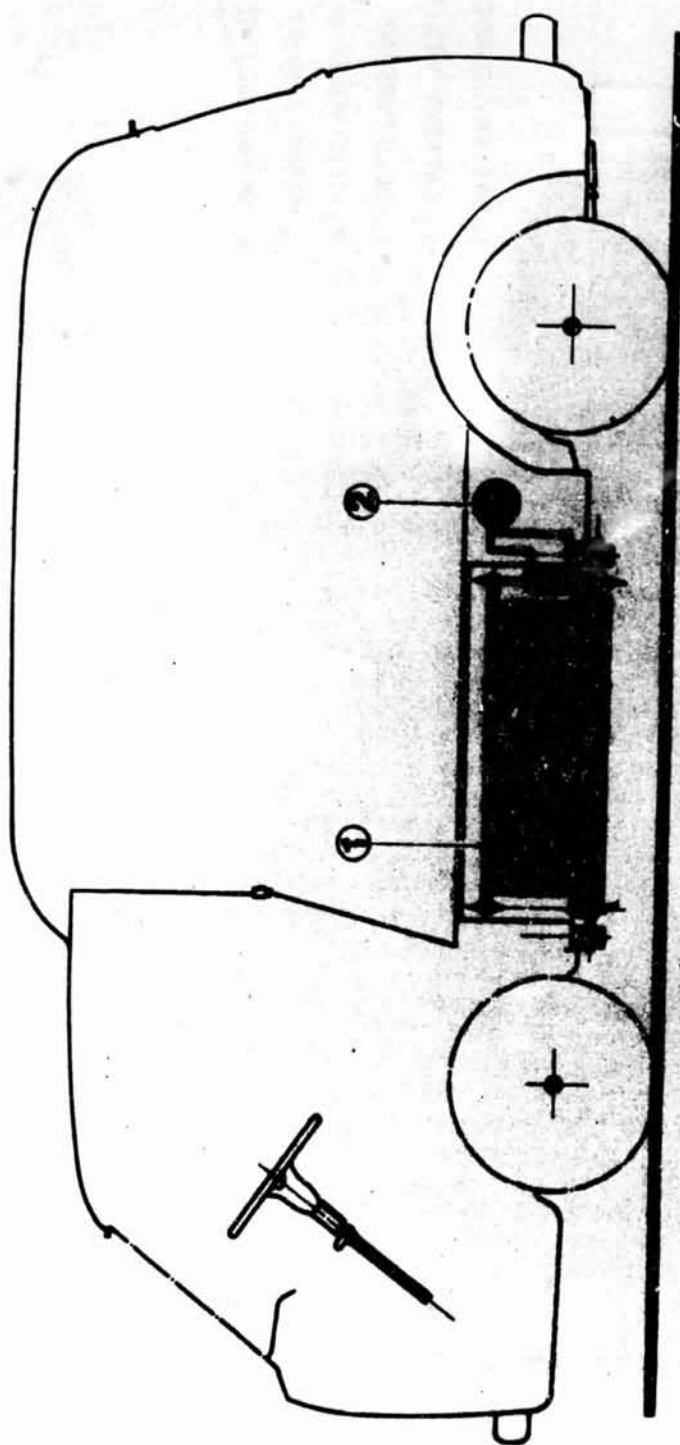


Figure 3.3. Cross-Sectional View of Fiat Van



- ① TRACTION BATTERY
114 V 135 AH
- ② HYDRAULIC PUMP
- ③ HYDRAULIC PISTON

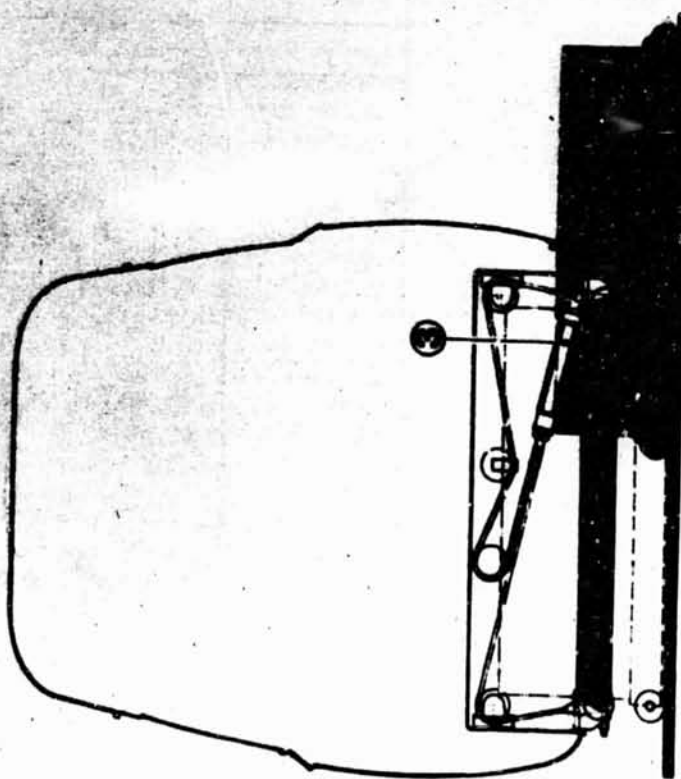


Figure 3.4. Hydraulic Lift

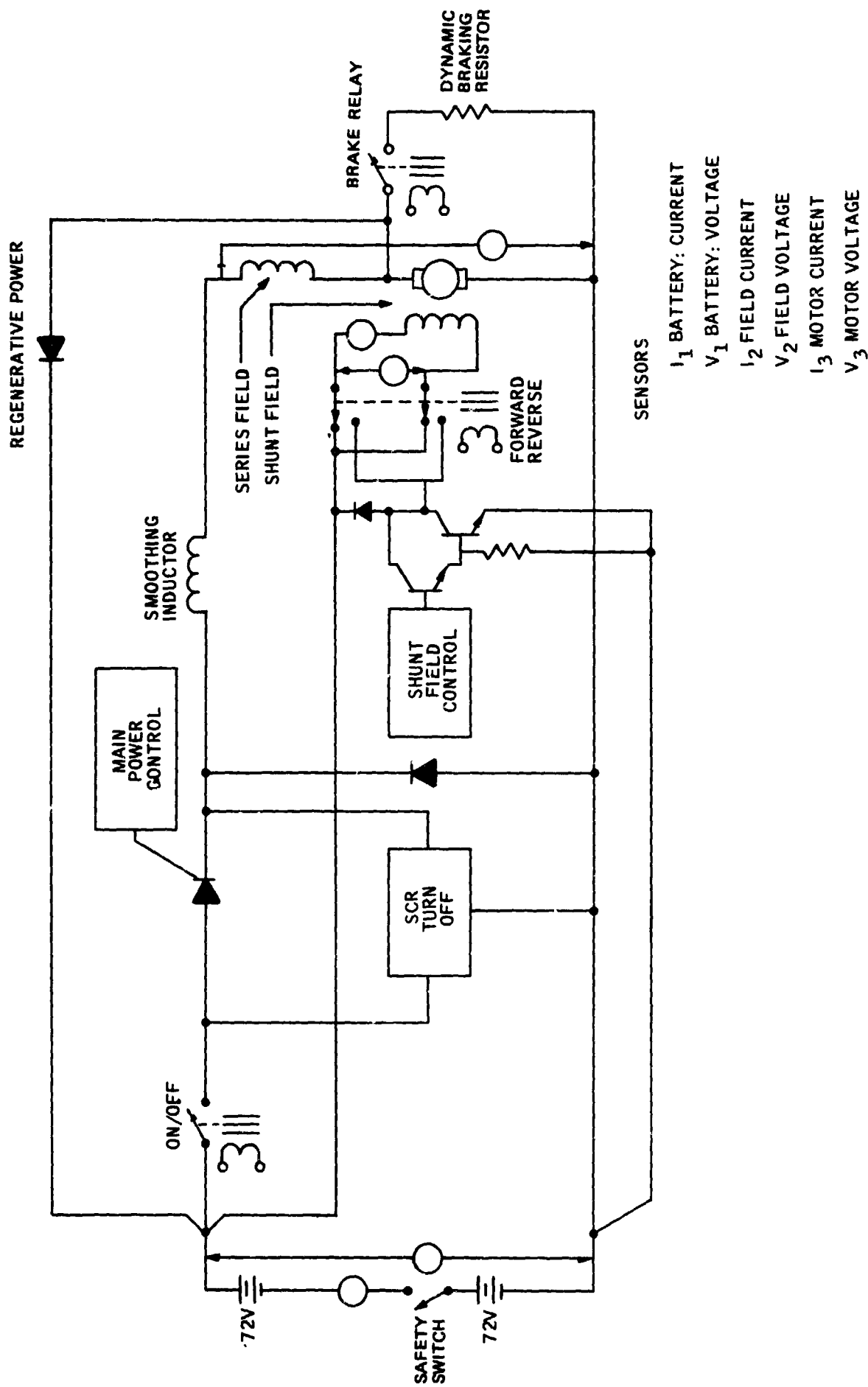


Figure 3.5. Schematic of Power System

Office long enough to prevent it from being tested. The charger supplied by Fiat had to be hand operated during the charging cycle, and it appeared to have an efficiency of about 89%.

Additional information on the van is listed below:

(1) Body

(a)	Type and Manufacturer	Fiat 850T Van
(b)	Modifications	Expanded cargo area by removal of part of I.C. engine housing
(c)	Space for Cargo	3 m ³ (106 ft ³)
(d)	Modifications	Heavy Rear Springs
(e)	Frontal Area	2.14 m ² (23 ft ²)

(2) Axles

(a)	Type and Manufacturer (rear)	Slip Joint, Half Axle Swing Shafts
(b)	Driveline Ratio	Direct Drive 11.35/1

(3) Tires

(a)	Type and Manufacturer	Firestone Brema Deluxe F7
(b)	Size	5.60-12
(c)	Pressure	42 psi Front, 45 psi Rear
(d)	Rolling Distance per revolution	1.70 m (5.58 ft)
(e)	Weight	11.1 Kg (24.5 lbm)

SECTION 4

INSTRUMENTATION

4.1 INTRODUCTION

A specifically designed data acquisition system (DAS) was developed at JPL to aid in the testing of electric and hybrid vehicles.

The DAS, as configured, had eight inputs:

- 1) Speed
- 2) Battery volts
- 3) Battery current
- 4) Motor volts
- 5) Motor current
- 6) Field volts
- 7) Field current
- 8) Motor temperature

The system was electrically floating. The currents were isolated by using hall-effect current sensors; the voltages were isolated by using iso-opamps (Figure 3.5).

4.2 VEHICLE SPEED AND DISTANCE

A Nucleus Corporation Model NC5 fifth wheel generated a voltage signal proportional to speed. This signal was filtered and fed to the DAS, where it was digitized and recorded. The fifth wheel was equipped with a digital readout head, which proved to be a source of error. The digital readout drifted considerably and fluctuated so much that the driver was unable to maintain a true constant speed. Later and during the B cycle tests, the fifth wheel output was fed to a H/P Model 1700B chart recorder. This analog speed indicator proved to be much better than the digital readout.

Speed was also periodically checked, using a Kurtom Electronics Radarspeed gun, Model HR8. The gun, however, was sensitive to aiming angle and rounded to a lower integer value.

Average speed was calculated from the time required for the test and distance traveled.

Distance traveled was shown by two indicators: the fifth wheel distance totalizer, and markers located one-tenth-mile apart on the track.

Calibration of the fifth wheel was checked by timing the duration of steady speed runs over a measured distance. The fifth wheel output was recorded on the DAS and a chart recorder, and measured with a DVM.

4.3 SENSORS

4.3.1 Current Sensors

Manufacturer - American Aerospace Controls

Model Number - 924A-300

Scale Factor - 5V = 300 AMPS

Rated Accuracy - $\pm 1\%$ of Full Scale (± 6 amps)

Temperature Coefficient - $\pm 0.08\%$ of Full Scale/ $^{\circ}\text{C}$ (± 0.48 amp/ $^{\circ}\text{C}$)

Response - 100 μsec

The greatest single source of error in testing can be traced to the current sensors. Environmental temperature effects caused offset errors to be introduced. These errors were especially noticeable at very low current levels, such as at the end-of-battery charging.

4.3.2 Voltage Sensors/Iso-Opamp

Manufacturer - Burr Brown

Model Number - 3452

Scale Factor (Set) - 5V = 200V

Isolation - ± 2000 VPK

Response (-3db) - 2.5 KHZ

Nonlinearity (Max) - $\pm 0.025\%$ of output (1.25 m volts)

Temperature Coefficient - ± 50 ppm/ $^{\circ}$ C

The iso-opamps were useful in reducing groundloops, and especially in allowing the shunt field voltage measurements to be made.

4.3.3 Motor Temperature Sensor

The voltage signal at the node between a 2K 1% resistor and a 2K thermistor supplied by a precision 5-volt source is inversely proportional to temperature. This signal was digitized and recorded.

The relationship between voltage and temperature is

$$T = \frac{3887}{\ln \frac{V}{5-V} + 13.04} - 273$$

where

V = volts

and T = degrees centigrade.

4.4 TIME AND WEATHER

4.4.1 Time

The DAS used a 1 megahertz crystal as the timing element for all recording.

A stopwatch was used for lap time. A wristwatch was used for battery charging time.

4.4.2 Weather

Weather Information

Wind Velocity

Wind Direction

Barometric Pressure

Humidity

This information was supplied by the Transportation Research Center of Ohio. This data was recorded at one-half-hour intervals during tests.

4.5 ENERGY MEASUREMENTS

4.5.1 Energy Into Battery Charger

The energy to the charger was measured by means of a standard power-company-type watt-hour meter, Westinghouse Model No. 246C700G37. The smallest division on this meter was 10 KWH, so readings were approximated to ± 1 KWH. This was a source of considerable error, since the total energy drawn from the wall was in the range of 25 to 35 KWH/charge cycle.

4.5.2 Energy Out of Battery Charger

The charger output was measured in several ways.

- 1) Periodically - output voltage and current (across a calibrated shunt) using a H/P Model 960 DVM.
- 2) Continuously - using a H/P Model No. 7100B chart recorder with Model 17501A amplifiers. The chart recorder tended to drift, so it was periodically recalibrated, using the DVM. Offsets were noted and recorded. The resultant chart was integrated to show watt-hours.

3) Continuously - watt-hours, using the DAS. This measurement was not too accurate over long time periods and temperature ranges due to the sensitivity of the Hall effect current sensor.

4.5.3 Energy Out of and Into Battery

Battery voltage and current were continuously monitored. This data was fed to the DAS which computed the elapsed watt-hours.

The weak link in this measurement, again, was the current sensor. However, the results were consistent and the percentile error was lower than battery charge data because the current was higher, and temperatures were not as extreme.

4.5.4 Energy Into and Out Of the Motor, Excluding Shunt Field Energy

Monitoring of motor energy was performed with the DAS, in a manner similar to that used in para 4.5.3. Again, the current levels were high and the percentile error was low.

4.5.5 Energy Into Shunt Field

The DAS digitized and recorded the voltage and current. The current levels were low so the percentile error was high.

The energy was computed from this data by means of a digital computer.

4.6 ENERGY COUNTERS

The iso-opamps and the current sensors supply voltage signals that are proportional to voltage and current. These signals are fed to scaling opamps and then to a four-quadrant multiplier.

The multiplier output is proportional to instantaneous watts; the polarity is correct, i.e., positive for positive-voltage positive current, and negative for positive-voltage negative current.

The multiplier output signal is fed to two voltage-to-frequency converters: one responds to positive signals, the other to negative signals.

The voltage-to-frequency converters integrates the multiplier output to give pulses proportional to watt-hours.

The pulses drive mechanical totalizers and a digital-to-analog converter which outputs a voltage proportional to the sum of the input number of pulses. When the number of pulses reaches 255, the output is 5 volts. The next pulse resets the converter to 0 volts output, where it steps upward at the rate of 0.01953 volts per pulse till it again resets. The converter output is then fed to the DAS, where it is digitized and recorded.

The mechanical counters are used as field indicators of energy flow, so there are four records of energy for each voltage and current sensor pair:

- 1) Positive energy flow counter
- 2) Positive energy flow recorder
- 3) Negative energy flow counter
- 4) Negative energy flow recorder

The calibration graph shown in Figure 4.1 was generated at JPL under ideal conditions. The voltages were sensed with the iso-opamps, but the current sensor output was simulated.

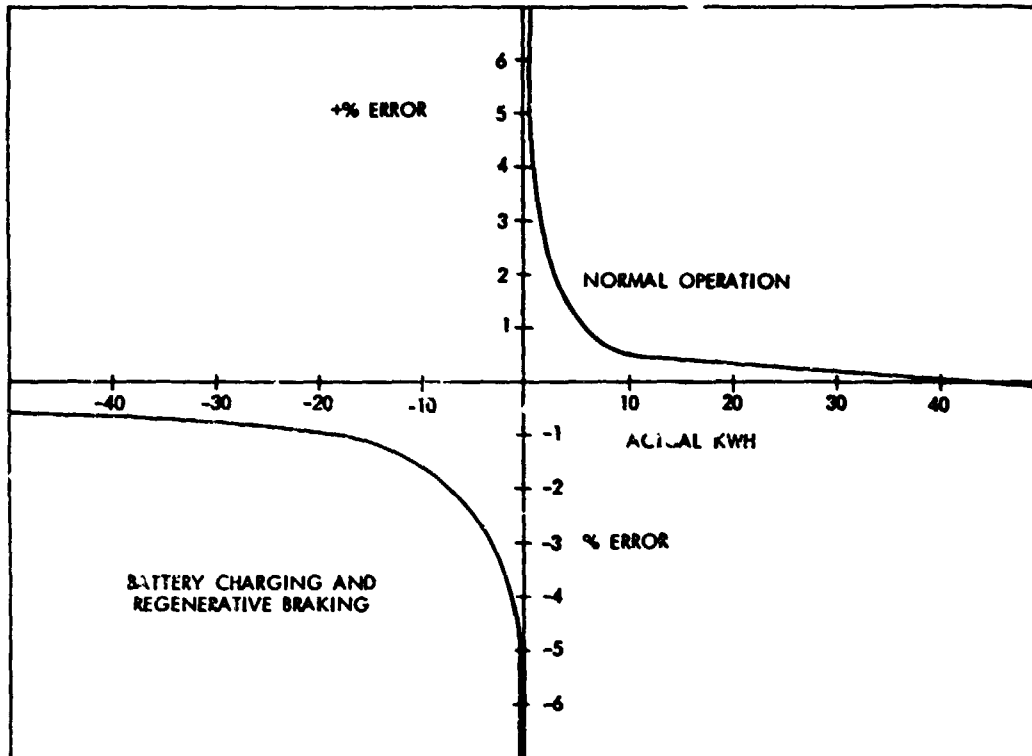


Figure 4.1. Analog Power Computer Excluding Current Sensor

4.7 DAS RECORDER

The recorder (Figure 4.2) consists of 7 blocks.

- 1) 16-channel input multiplexer
- 2) Sequencer
- 3) Sample and hold
- 4) 12-bit analog to digital converter
- 5) Formatter and tape control
- 6) Tape transport electronics
- 7) Tape transport

The multiplexer has 16 channels of 0 to 5 volt range, common ground and 100 megohm input impedance. The sequencer was a MOS

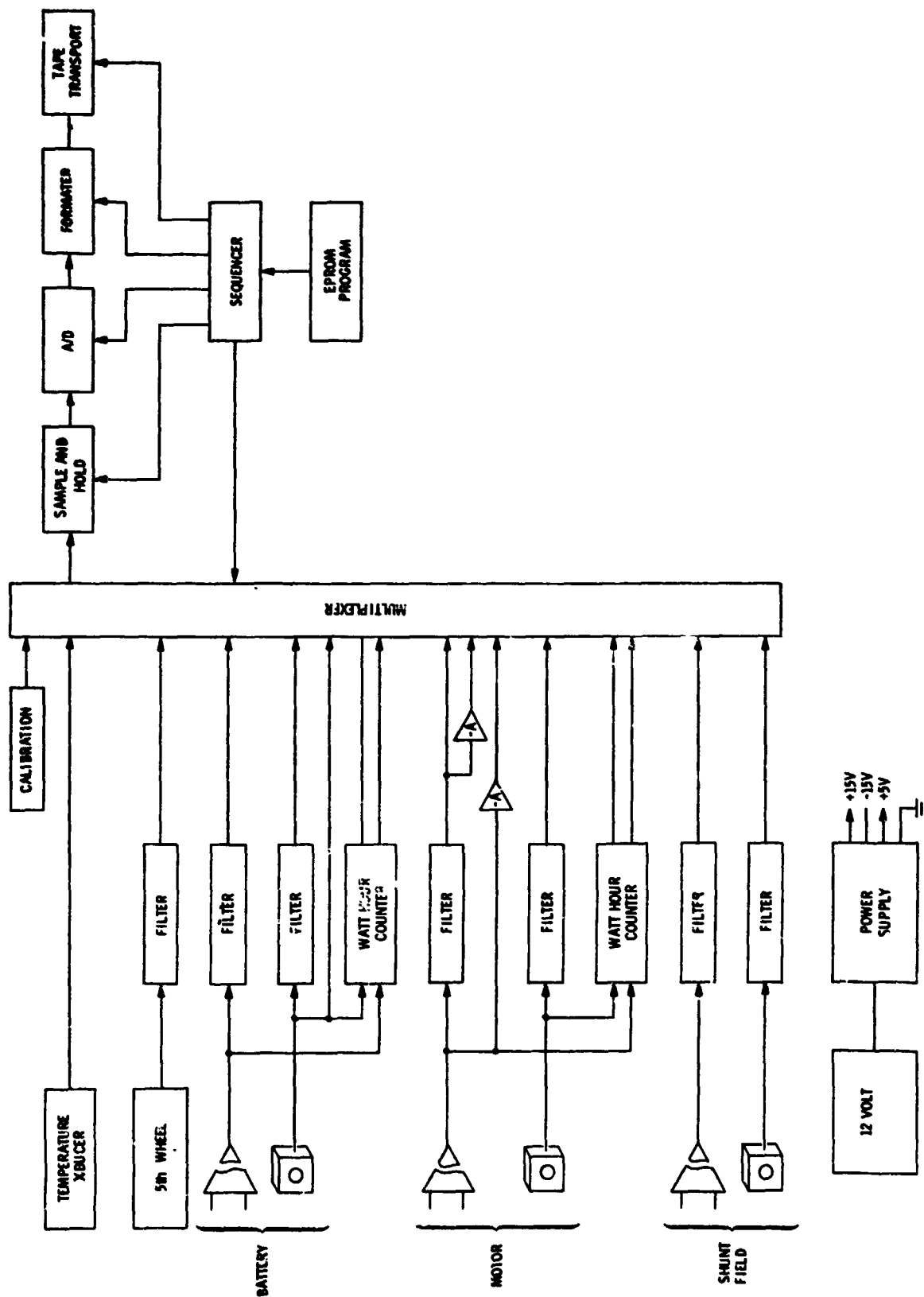


Figure 4.2. DAS Configuration

Technology 6502, microprocessor based control board which supplied all the timing and control functions to the DAS.

The sample-and-hold circuit has a window time of 150 μ sec.

The 12-bit analog-to-digital converter is a successive approximation type.

The tapes used had a continuous four-hour recording capability. During this time, 62,000 data points of 12-bit data words plus channel number were recorded. Tapes are available with a 120,000 data point storage.

The DAS recorder specifications are

System Accuracy - $\pm 0.025\%$ of full scale $\pm 1/2$ LSB

(Least Significant Bit)

System Linearity - $\pm 1/2$ LSB

A/D Resolution - 12 bits

System Aperture Time - 50 nanosec

Operating Temperature Range - -10°C to $+60^{\circ}\text{C}$

Relative Humidity - 10% to 95%, without condensation

Shock and Vibration - 1g @ 0-50 cps, all 3-axis

The watt-hour counters calibration was checked in situ during battery charging (Table 4.1). The output voltage and current of the Battery Chargers were accurately measured by means of a DVM, a precision current shunt, and a stop-watch. Watt-hours out of the charger were calculated and compared with the watt-hour counters.

Table 4.1. Data System Accuracy Check

Date	I (amps)	V (Volts)	T (Seconds)	Watt-Hours Calculated	Watt-Hour Counters	% Difference
5/17	21.5	156	60	55.9	59	+5.5%
5/19	23.8	153	132	138.6	137	-1.13%
5/25	24.5	160	122	132.8	137	3.13%
6/7	25.1	162	119	134.9	124	-7.77%

SECTION 5

TEST RESULTS

The tests conducted on the Fiat van were done in accordance with ERDA's document entitled "Electric and Hybrid Vehicle Test and Evaluation Procedure" (ERDA-EHV-TEP). If the test conducted differed in any manner from the test described in the document, then the difference is noted and an explanation given. An overview of the data flow path is given in Appendix D by H. Callisen.

5.1 RANGE AT STEADY SPEED TESTS

The range at constant speed tests were conducted at 40 Kph (25 mph) and 56 Kph (35 mph), which was the top speed of the vehicle. The range for each speed is recorded in Table 2.1 with the end of range being determined when the vehicle cannot maintain 95% of the specified speed.

In Figure 5.1.1 the range is plotted against the vehicle speed. Since only two range tests were performed, the shape of the curve is difficult to ascertain. The curve was drawn as a straight line for lack of further information. A range test at 24 Kph (15 mph) was attempted but was terminated because of control problems. The brake relay of Figure 3.5 is activated at about 25 Kph (15.5 mph) which caused the vehicle to behave erratically.

The battery and motor information at the first half-mile and at a point one-half mile from the end of range is given in Table 5.1.1.

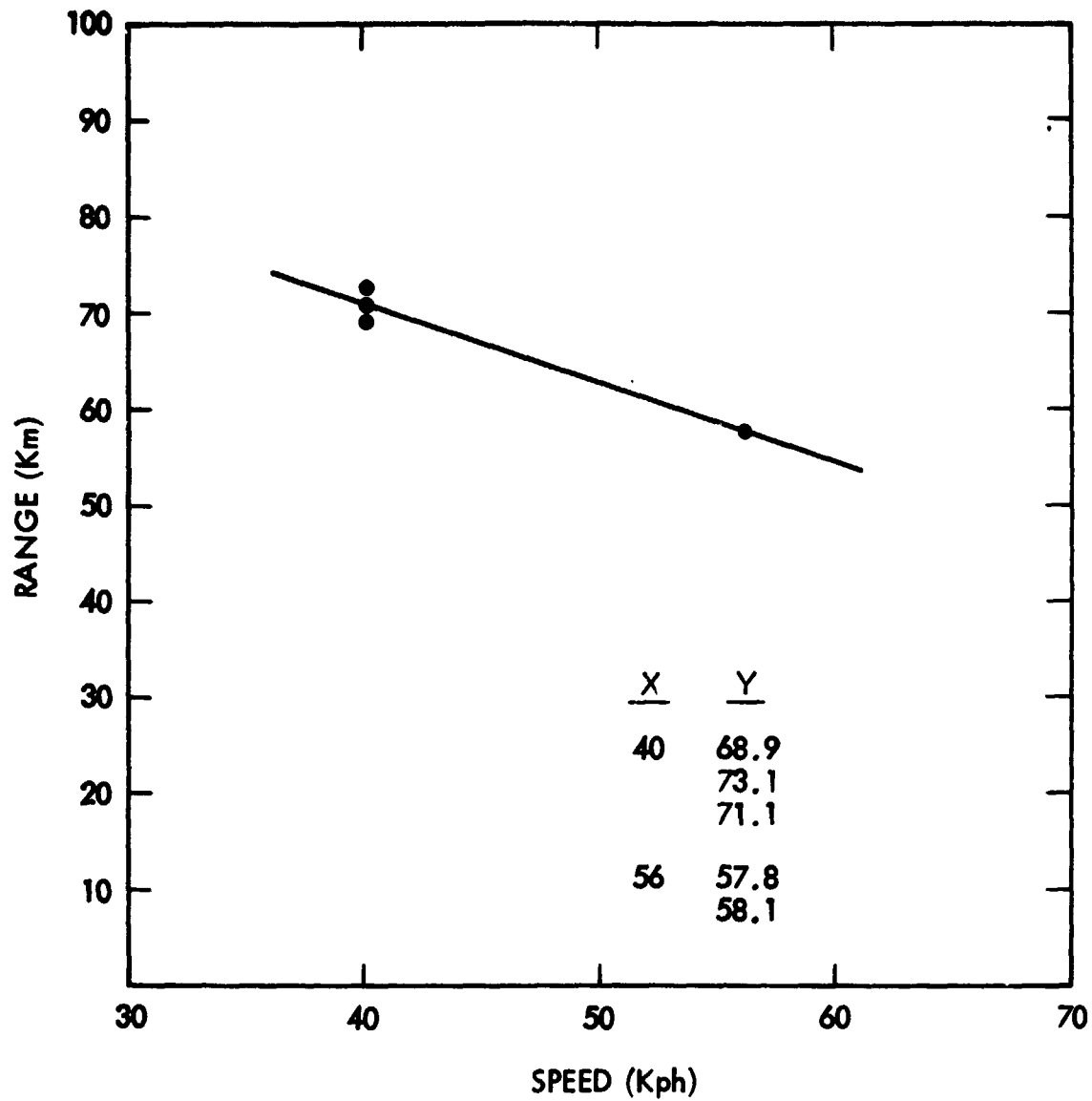


Figure 5.1.1. Range at Constant Speed

Table 5.1.1.1. Battery and Motor Information

Range Test	Battery		Motor Armature		Motor Field							
	Voltage (Volts)		Current (Amps)		Current (Amps)							
	Start	End	Start	End	Start	End						
25 mph (40 Kph) 5/19	141.5	110.3	69.2	53.6	139.3	108.7	66.6	49.4	27.9	12.2	2.4	1.6
25 mph (40 Kph) 5/21	144.2	110.2	56.6	53.6	142.3	108.1	49.1	49.7	38.3	11.0	4.2	1.8
25 mph (40 Kph) 5/26	146.6	117.4	50.0	58.6	144.5	115.3	45.2	54.3	39.5	19.1	2.9	1.8
35 mph (56 Kph) 5/23	142.1	112.9	89.2	65.8	138.4	113.9	83.8	71.1	11.18	6.84	0.7	0.1
35 mph (56 Kph) 5/25	141.3	113.2	103.3	80.3	138.2	110.6	101.5	75.5	9.08	2.78	0.3	0.4

5.2 COAST DOWN TEST

The coast down test was conducted on that portion of the test track shown in Figure 5.2.1. The track has a grade which varies from +.500% to -.440% over its length. The Fiat van was towed to a velocity of approximately 64 Kph (40 mph) and then released. The easiest way of disconnecting the motor from the wheels was by disconnecting the half axes (Figure 5.2.2), and this necessitated towing the vehicle for the test.

The raw velocity data is shown in Figure 5.2.3. The difference in the amount of time it takes for the vehicle to come to a stop is attributable to the slope of the track. The longer time is associated with the vehicle going downhill while the shorter time occurs when the vehicle is going uphill. Since most of the runs occurred over the portion of the track with a +.500% grade, the velocity vs time curve was corrected by calculating the time difference, Δt_i , it would have taken the vehicle's velocity to change from v_{i-1} to v_i if there was no slope.

$$\Delta t_i = \frac{v_i - v_{i-1}}{Ac_i}$$

where

$$Ac_i = Ar_i \pm g \sin \theta \quad \left(\begin{array}{l} + \text{ for uphill} \\ - \text{ for downhill} \end{array} \right)$$

with

Ar_i = raw acceleration

Ac_i = slope-corrected acceleration

$$\theta = \tan^{-1} (.5\% \text{ grade}/100) = .283^\circ$$

g = acceleration due to gravity

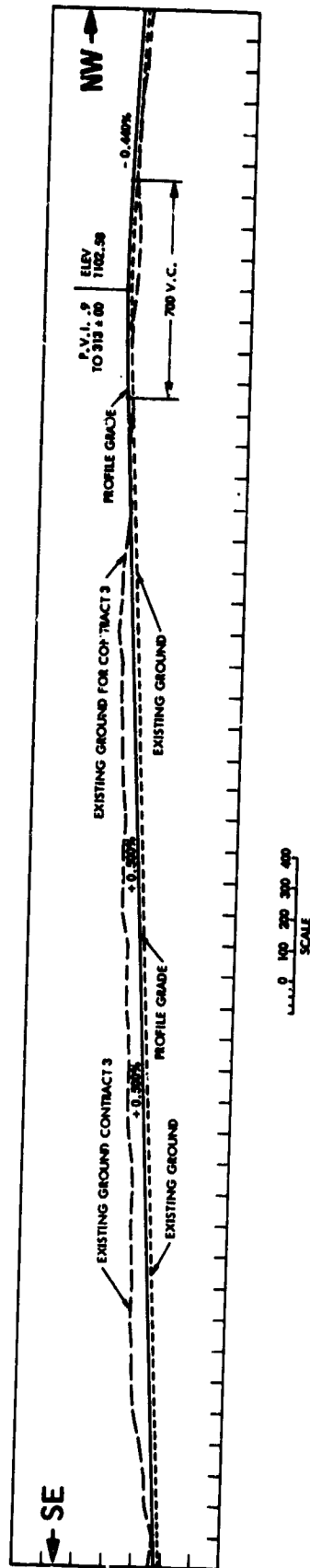


Figure 5.2.1. Test Track for Coast Down and Acceleration Tests

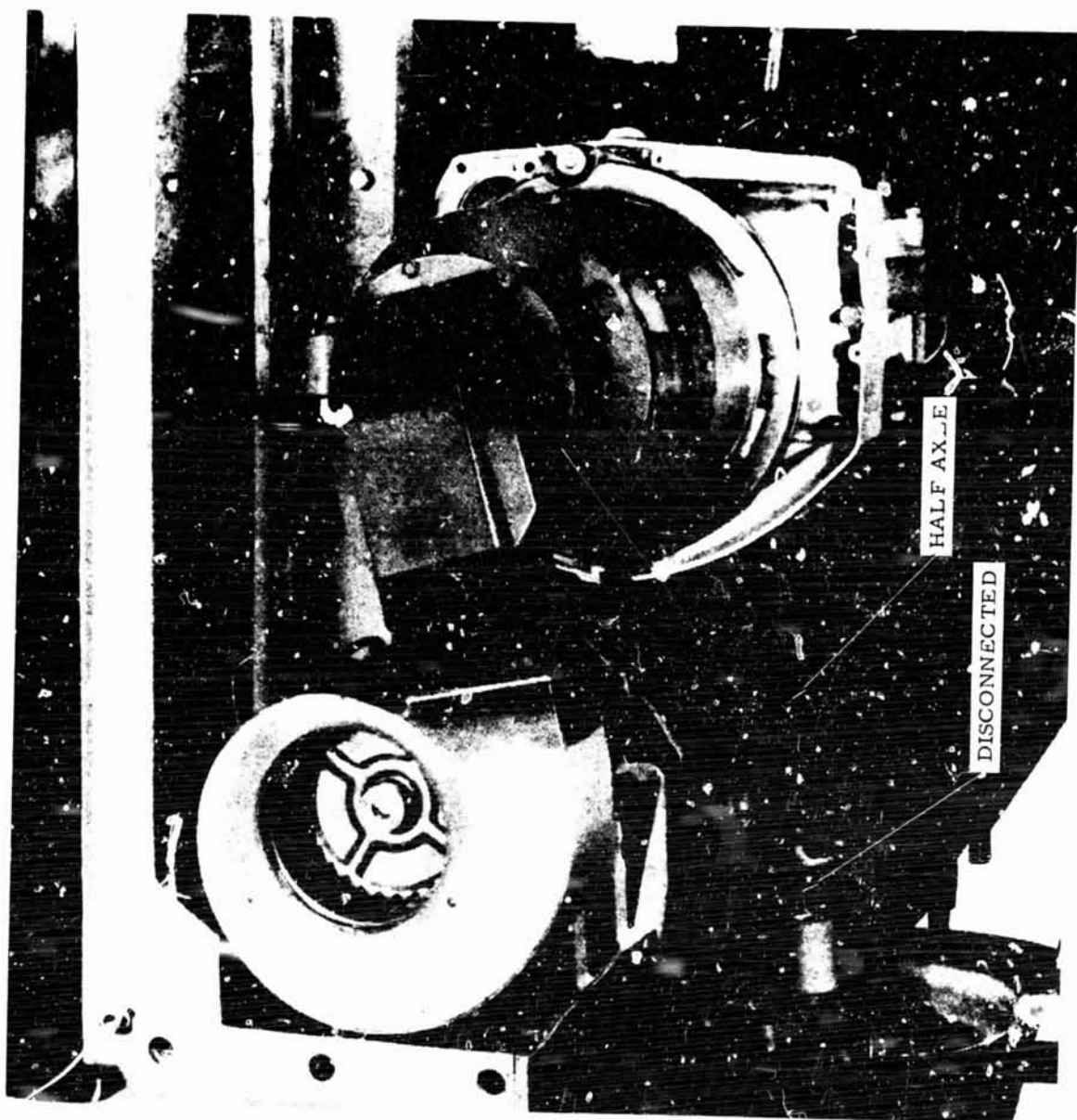


Fig. 5.2.2. View of Half Axle

PAGE IS
QUALITY

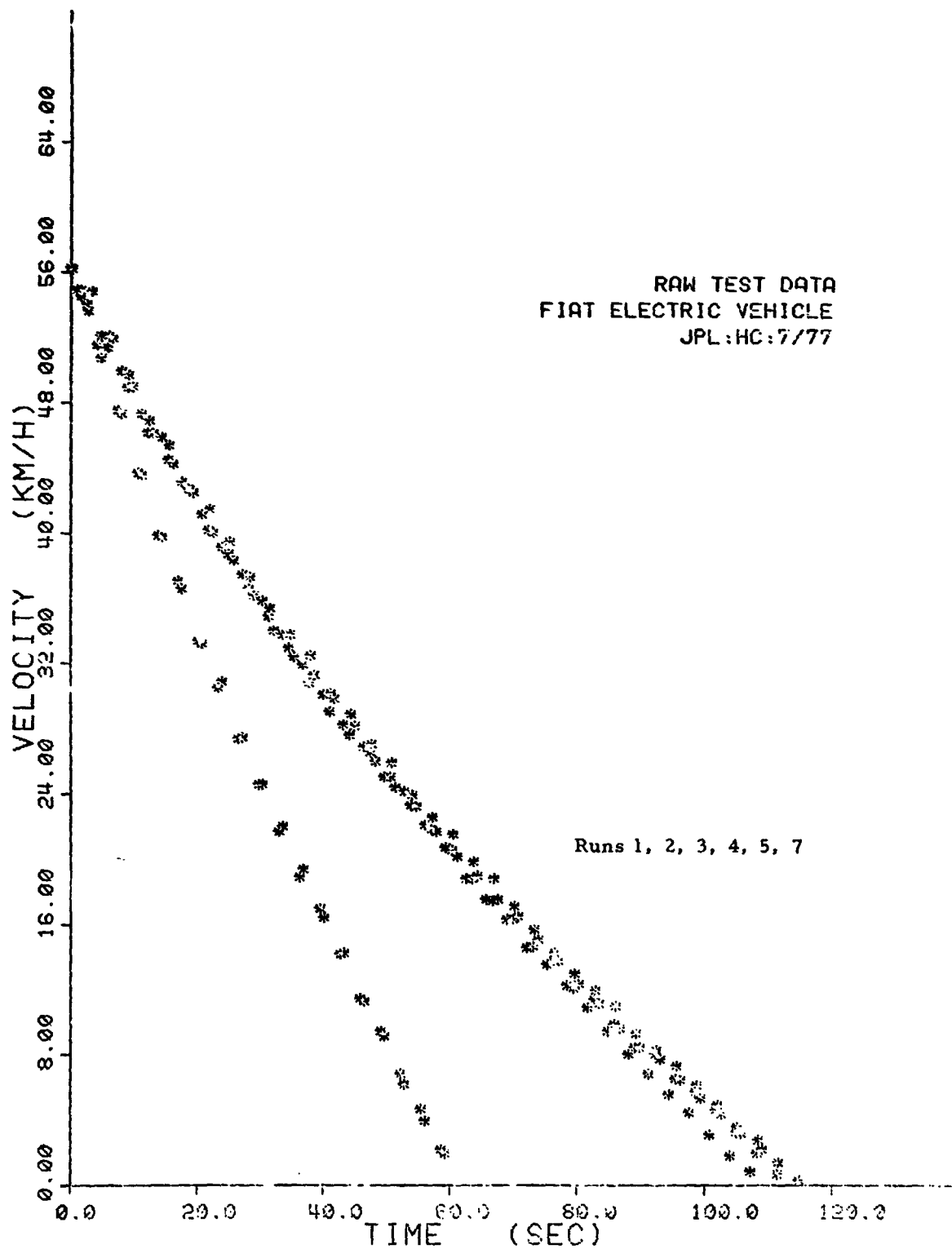


Figure 5.2.3. Velocity vs. Time (uncorrected)

The raw acceleration is calculated from the velocity data by taking the difference of two successive velocities and dividing this difference by the change in time.

$$Ar_i = \frac{v_i - v_{i-1}}{\Delta t}$$

$\Delta t = 3.2$ sec. sample time of data acquisition system

The coast down runs were normalized to begin at a velocity of 56 Kph (35 mph). The velocity v_1 is the first velocity less than 56 Kph which occurs after the van is released from the tow vehicle. The time associated with the first velocity, v_1 , which is the time it takes to coast down from 56 Kph to v_1 , is

$$t_1 = \frac{v_1 - 56}{Ar_1}$$

where

$$Ar_1 = \frac{v_1 - v_0}{\Delta t}$$

and

v_0 = velocity point preceding v_1 ($v_0 > 56$ Kph, $v_1 \leq 56$ Kph)

The slope-corrected velocity vs time curve is shown in Figure 5.2.4. The correction brings the various curves shown in Figure 5.2.3 together.

The coast down test consisted of eight runs made in opposite directions along the track with the odd numbered runs being made in the

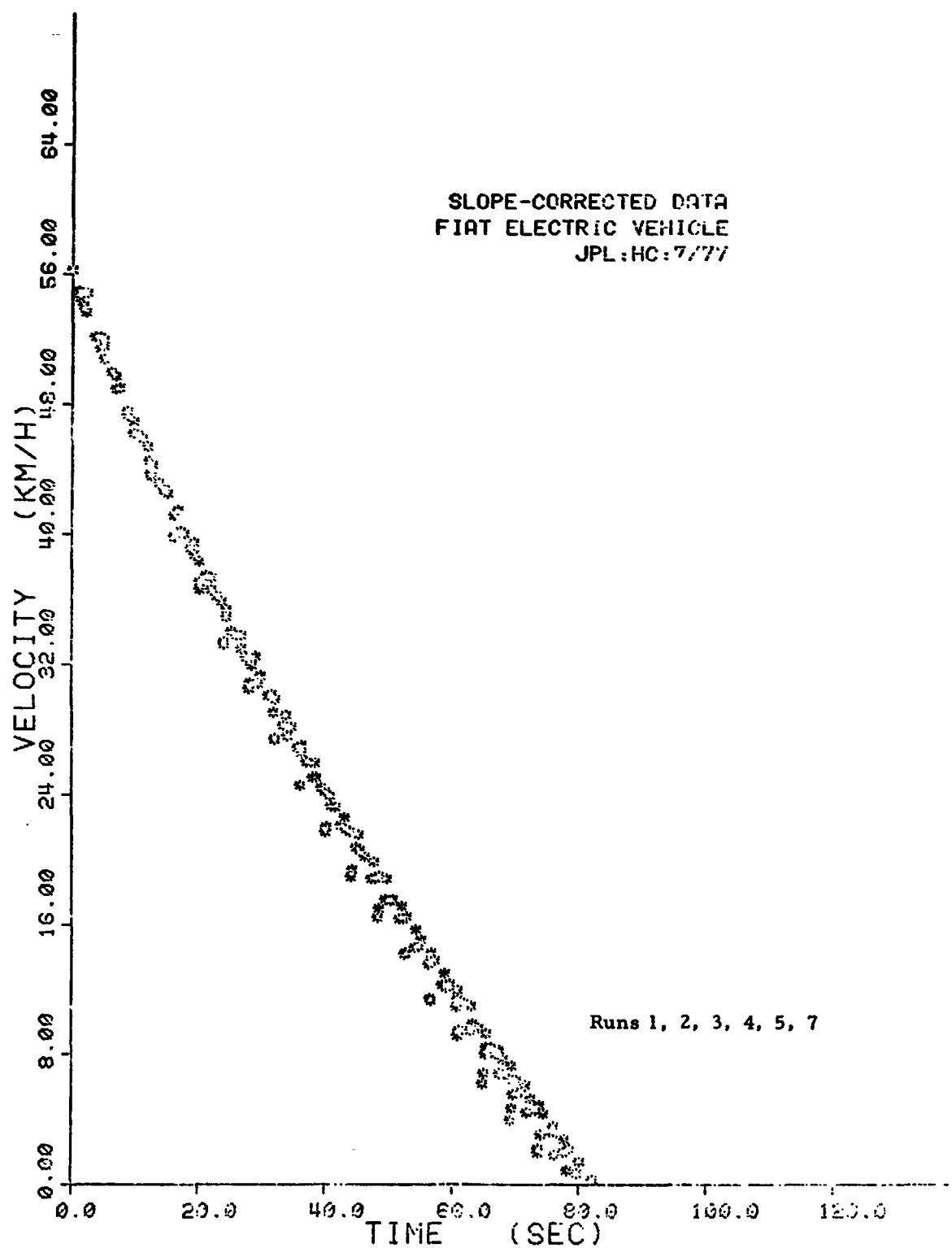


Figure 5.2.4. Velocity vs. Time (corrected)

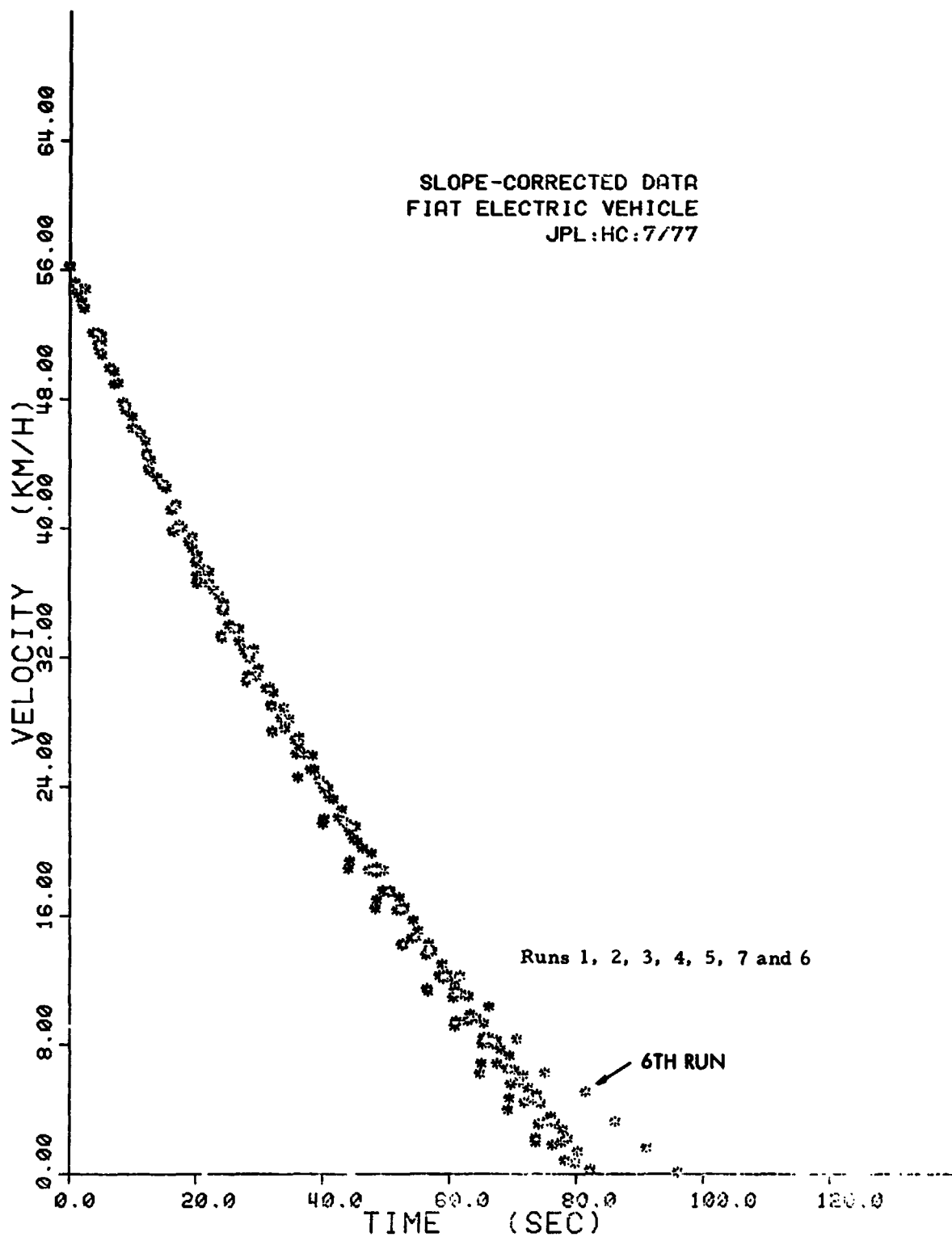


Figure 5.2.5. Velocity vs. Time (corrected)

SE direction. The sixth and eighth runs began with the vehicle going uphill on the $+0.500\%$ grade and ended with the vehicle going downhill on the -0.440% grade (Figure 5.2.1), and so these runs were not used. In Figure 5.2.5 the slope-corrected data is plotted for the good runs and also for the sixth run. The velocity vs time curve for the sixth run closely follows the other curves until it reaches the top of the hill and begins to coast down the other side.

The purpose of the test is to determine the power and energy consumed by the vehicle as a function of its velocity. The forces acting on the vehicle determine the amount of power and energy consumed. A free body diagram of the vehicle is shown in Figure 5.2.6.

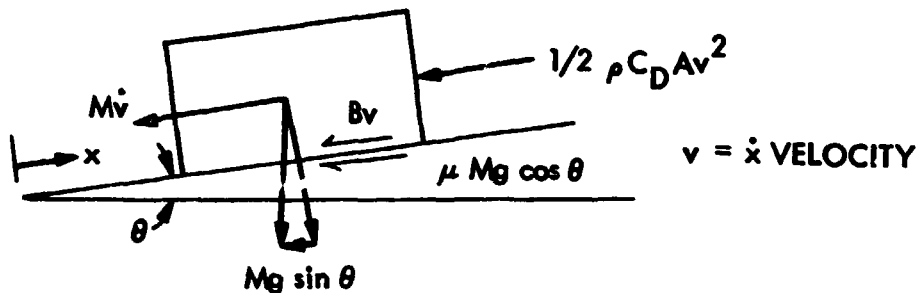


Figure 5.2.6. Force Diagram

The force equation is

$$\begin{array}{ccccccc}
 (M + J_w/r_w^2)\ddot{v} & + & Bv & + & 1/2 \rho C_D A v^2 & + & \mu Mg \cos \theta + Mg \sin \theta = 0 \\
 \text{Inertia} & & \text{Viscous} & & \text{Wind} & & \text{Rolling} & \text{Gravity} \\
 \text{Force} & & \text{Friction} & & \text{Drag} & & \text{Friction} & \text{Force}
 \end{array} \quad (5.2.1)$$

where

M = mass of vehicle (1986 Kg or 4370 lbm)

B = viscous coefficient

ρ = density of air

C_D = drag coefficient

A = frontal area of van (2.14 m^2 or 23 ft^2)

μ = rolling coefficient

J_w = moment of inertia of the wheels

r_w = radius of wheels

now

$$J_w/r_w^2 \approx 0.003 M \text{ and can be neglected.}$$

The external forces acting on the vehicle can be found from the acceleration data

$$M A_{r_i} + Mg \sin \theta = - (\mu Mg \cos \theta + Bv_{mi} + 1/2 \rho C_D A v_{mi}^2) \quad (5.2.2a)$$

or

$$M A_{r_i} = - (\mu Mg \cos \theta + Bv_{mi} + 1/2 \rho C_D A v_{mi}^2) \quad (5.2.2b)$$

$$\text{where } v_{mi} = \frac{v_i + v_{i-1}}{2}$$

The acceleration, Ar_i , is the average acceleration over an interval and must be associated with the average velocity over that same interval,

v_{mi} .

The power required by a vehicle to travel at a given velocity is obtained by multiplying eqn. (5.2.2) by the mean velocity,

v_{mi} .

$$Pc_i = + v_{mi} (A + B v_{mi} + C v_{mi}^2) \quad (5.2.3)$$

where

$$Pc_i = -M Ac_i v_{mi} = -M (Ar_i + g \sin \theta) v_{mi} \text{ slope-corrected power}$$

and

$$A = \mu Mg \cos \theta$$

$$C = 1/2 \rho C_D A$$

The graph of the slope-corrected road power vs velocity (i.e. Pc_i vs v_{mi}) is shown in Figure 5.2.7. The curve drawn on the graph is a least squares fit of the data to the equation

$$Pc = Av + Bv^2 + Cv^3$$

and the coefficients were found to be

$$A = .07507 \quad \text{Kw/(Kph)}$$

$$B = .8705 \times 10^{-3} \text{ Kw/(Kph)}^2$$

$$C = .9042 \times 10^{-5} \text{ Kw/(Kph)}^3$$

with

$$S.D. = \text{standard deviation} = .6631$$

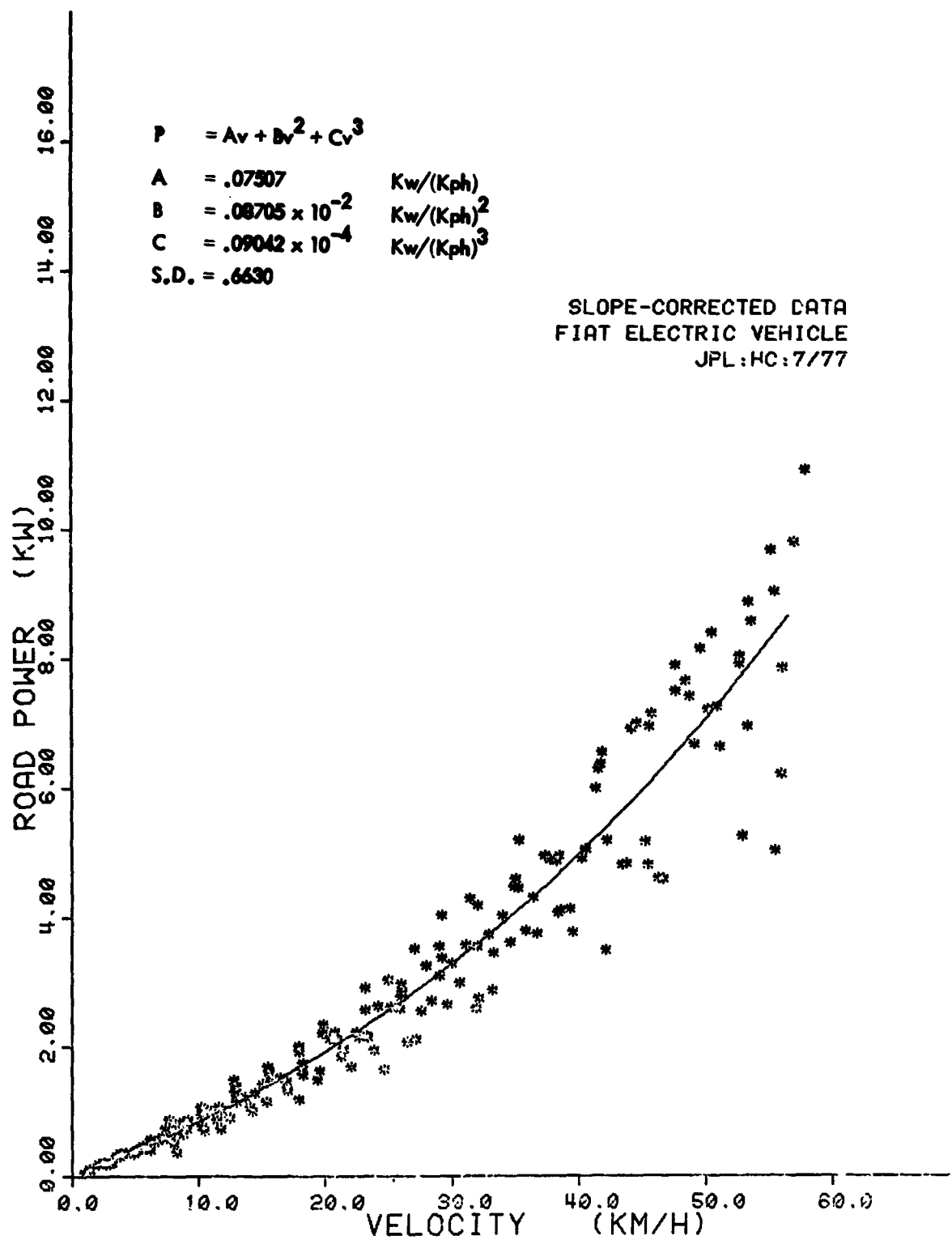


Figure 5.2.7. Road Power (corrected)

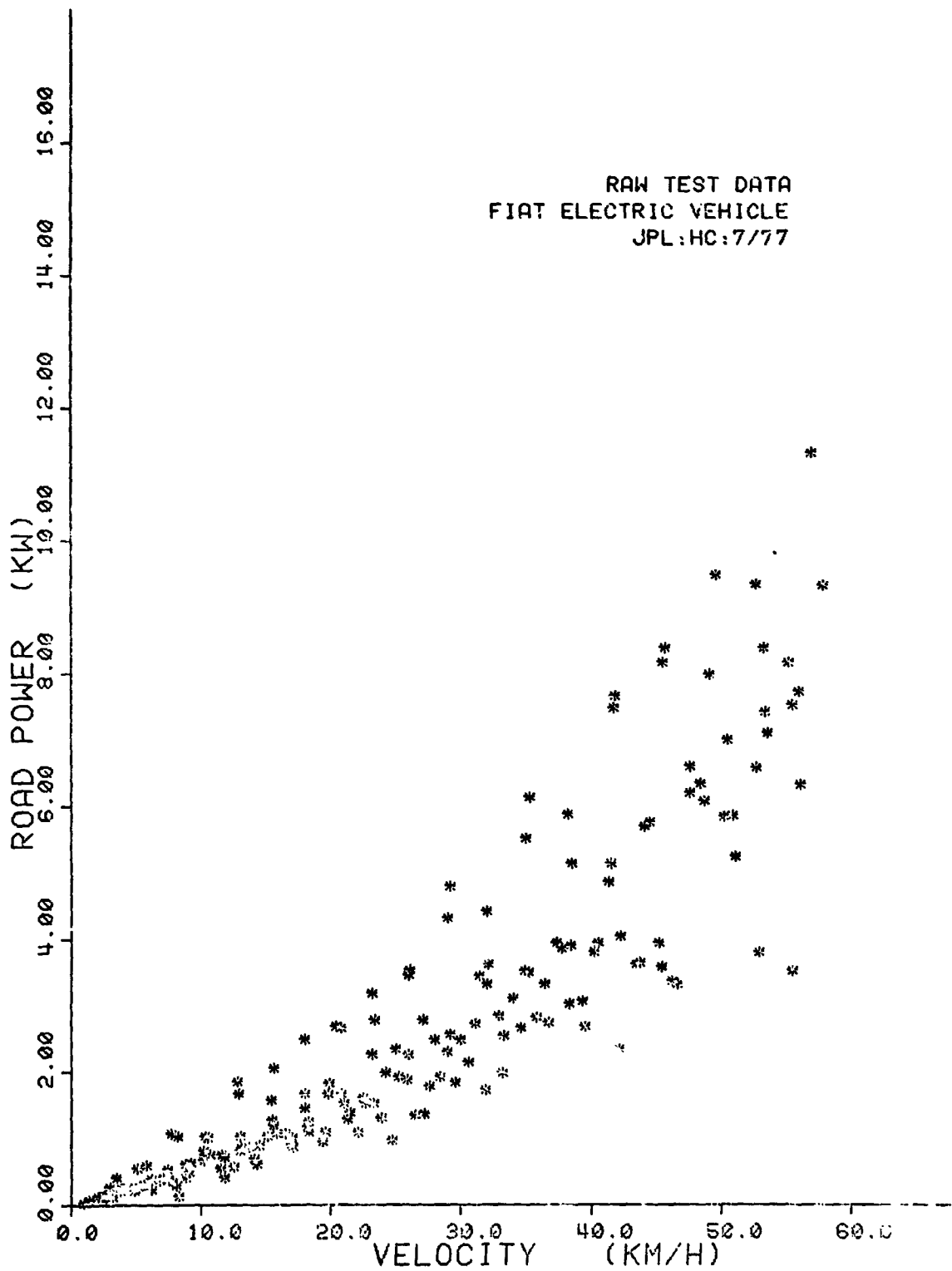


Figure 5.2.8. Road Power (uncorrected) vs. Velocity

The rolling and drag coefficients can be calculated from the above constants.

$$\mu = A/Mg \cos \theta = .014$$

$$C_D = C/(1/2 \rho A) = .33 \quad (5.2.4)$$

The accuracy of the rolling and drag coefficients are not known. The constants could be assigned a confidence level with further computer programming. A plot of the uncorrected road power vs velocity (i.e., Pa_i vs v_{mi}) data is given in Figure 5.2.8. The uncorrected road power can be written, from eqn. (5.2.2), in terms of the corrected road power as

$$Pa_i = Pc_i + (Ma \sin \theta) v_{mi} \quad (5.2.5)$$

where

$$Pa_i = -M Ar_i v_{mi}$$

The second term on the right hand side of eqn. (5.2.5) causes the increase in scatter of the data for the uncorrected road power plot.

The amount of energy consumed by the vehicle per unit distance is equal to the external forces acting on the vehicle, see eqn. (5.2.2),

$$Ea_i - (+ Mg \sin \theta) = A + B v_{mi} + C v_{mi}^2 \quad (5.2.6a)$$

or

$$Ec_i = A + B v_{mi} + C v_{mi}^2 \quad (5.2.6b)$$

where

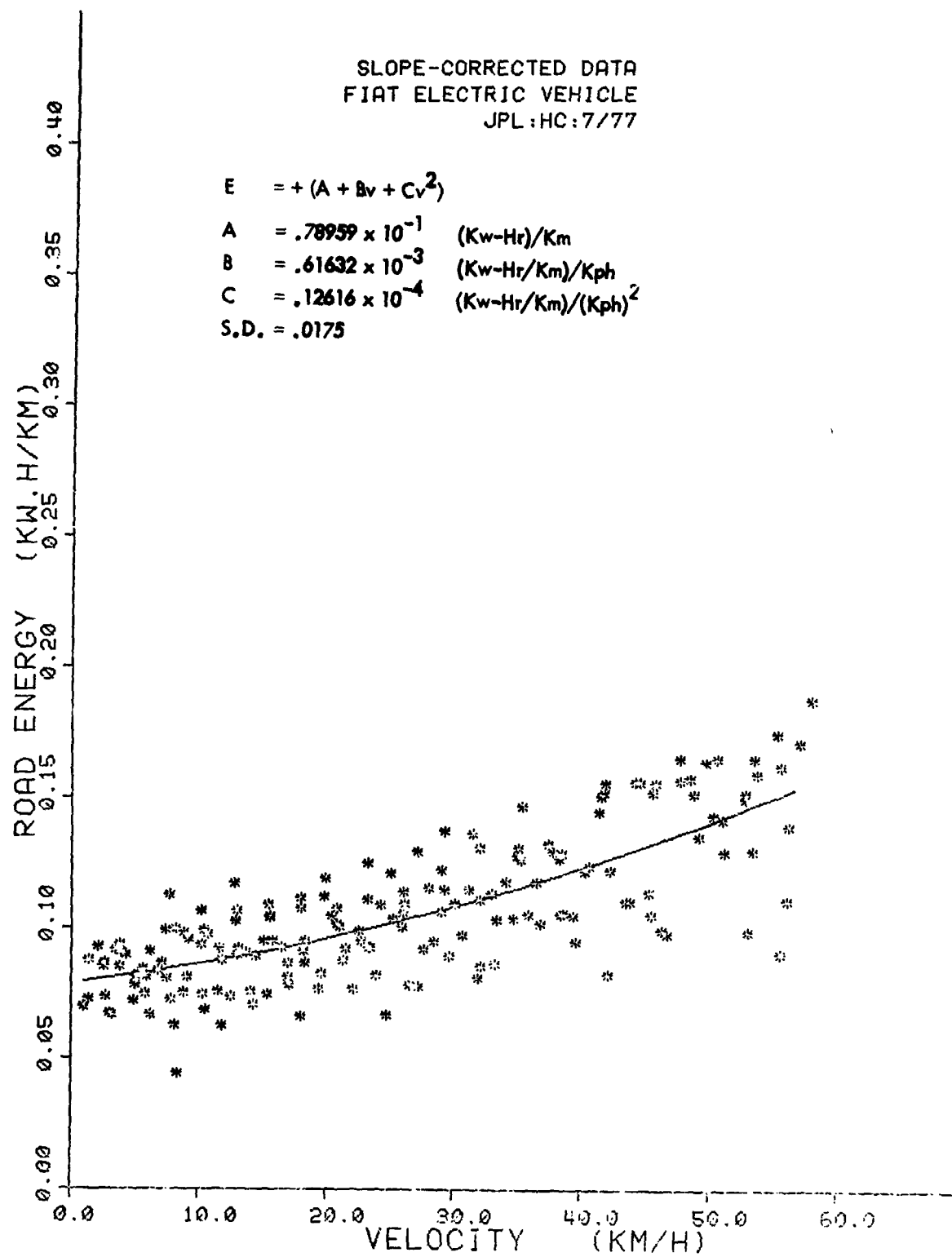


Figure 5.2.9. Road Energy (corrected)

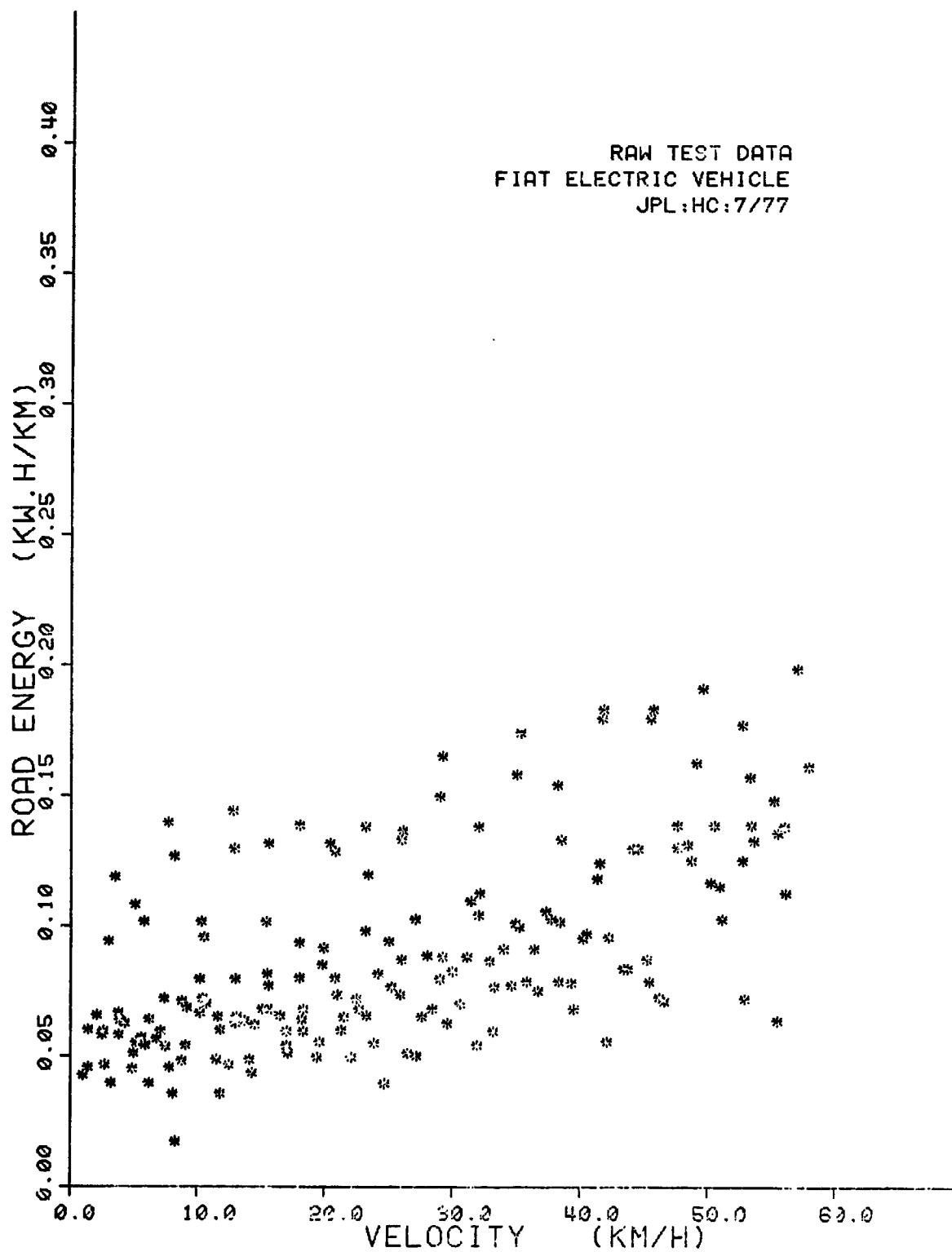


Figure 5.2.10. Road Energy (uncorrected) vs. Velocity

$$Ea_i = -M Ar_i \text{ uncorrected road energy}$$

and

$$Ec_i = -M (Ar_i \pm g \sin \theta) \text{ corrected road energy}$$

In Figure 5.2.9 the corrected road energy is plotted against the velocity. The curve shown on the figure is a least squares fit of the data to the equation

$$Ec = A + B v + C v^2$$

and the coefficients were found to be

$$A = .07896 \quad (\text{Kw-Hr})/\text{Km}$$

$$B = .61632 \times 10^{-3} \quad (\text{Kw-Hr/Km})/\text{Kph}$$

$$C = .12616 \times 10^{-4} \quad (\text{Kw-Hr/Km})/(\text{Kph})^2$$

$$\text{S.D.} = .0175$$

These constants do not agree with those obtained from the power data, eqn. (5.2.4). However, the two sets do indicate a range of values for the constants. The rolling and drag coefficients calculated from the above constants are

$$\mu = A / \text{kg} \cos \theta = .015$$

$$C_D = C / (1/2 \rho A) = .16$$

A graph of the uncorrected road energy vs velocity is shown in Figure 5.2.10. The uncorrected road energy data, like the road power data, is more scattered than the corrected data.

The force equation, eqn. (5.2.1), can be integrated to find velocity as a function of time. If the force equation is divided by the mass of the vehicle, M, then eqn. (5.2.1) can be written as

$$\frac{dv}{dt} = - (A' + B' v + C' v^2) \quad (5.2.7)$$

with

$$\begin{aligned} A' &= .5166 \quad (\text{Kph/sec}) \\ B' &= .4033 \times 10^{-2} \quad (\text{Kph/sec})/\text{Kph} \\ C' &= .8250 \times 10^{-4} \quad (\text{Kph/sec})/(\text{Kph})^2 \end{aligned}$$

The constants shown are the ones found from the least squares fit of the road energy data. The road energy constants have been divided by the mass and converted to the appropriate dimensions. The solution of the differential equation is

$$\begin{aligned} v(t) = \frac{1}{2C'} \sqrt{4A'C' - B'^2} \tan \left[\tan^{-1} \left(\frac{B' + 2C' v_0}{\sqrt{4A'C' - B'^2}} \right) \right. \\ \left. - \frac{t}{2} \sqrt{4A'C' - B'^2} \right] - \frac{B'}{2C'} \end{aligned} \quad (5.2.8)$$

Eqn. (5.2.8) is plotted in Figure 5.2.11, with the data points being those of the velocity vs corrected time (Figure 5.2.4). The agreement between the velocity equation and the data points is very good.

In Table 5.2.1 the direction of run, grade, wind direction, and wind magnitude is tabulated for each run. The coast down data used for the figures in this section is given in Appendix A.

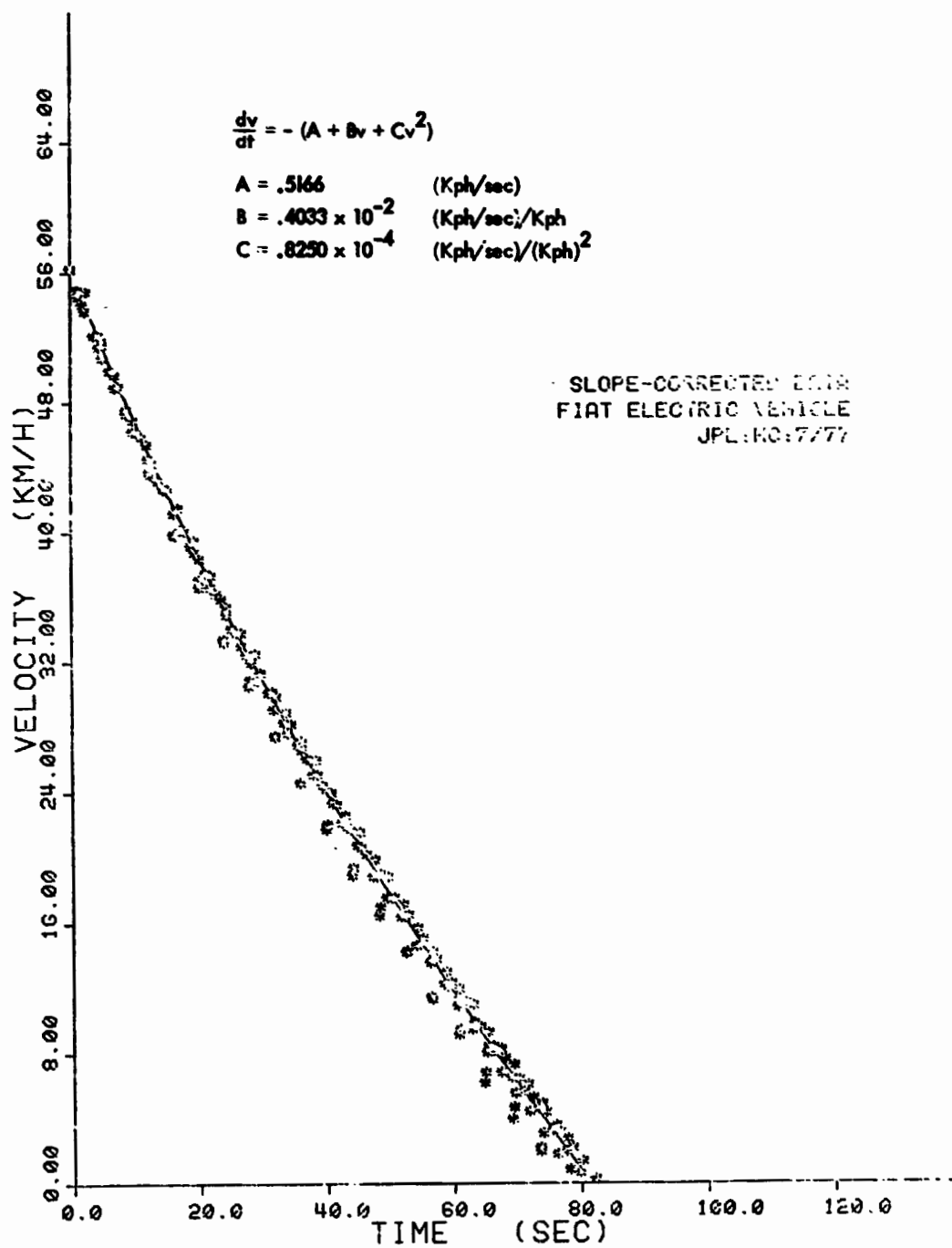


Figure 5.2.11. Formal Solution for $v(t)$

Table 5.2.1. Wind and Grade Information

Run No.	Direction of Run	Grade	Direction of Wind	Velocity of Wind
1	S.E.	downhill .500%	S to E	8.9 Kph (5.5 mph) with gusts to 17.7 Kph (11 mph)
2	N.W.	uphill .500%	N to E	6.4 Kph (4 mph) with gusts to 22.5 Kph (14 mph)
3	S.E.	downhill .500%		
4	N.W.	uphill .500%	N to E	6.4 Kph (4 mph) with gusts to 21 Kph (13 mph)
5	S.E.	downhill .500%	N to E	4.8 Kph (3 mph) with gusts to 17.7 Kph (11 mph)
6	N.W.	uphill .500% downhill .440%	N to E	4.8 Kph (3 mph) with gusts to 23 Kph (14.5 mph)
7	S.E.	downhill .500%	N to E	16 Kph (10 mph) with gusts to 19 Kph (12 mph)

5.3 ACCELERATION TEST

The acceleration test was conducted over the same portion of track as the coast down test (Fig. 5.2.1). The acceleration runs were done at battery charge levels of 100%, 80%, 40%, and 20%. The runs should have been made for battery discharge levels of 0%, 40%, and 80%. The reason for not conducting any runs at the 60% battery charge level is due to a misreading of the test specification. The information obtained from the tests conducted at the 40% and 80% battery charge levels will help compensate for not conducting the test at the 60% charge level.

The calculation by which the state of battery charge was determined is based on the amount of energy consumed and not on the charge used. Since the instrumentation did not include an amp-hr meter, the amount of charge used could not be determined, and the charge levels had to be calculated from the used energy. A 20% battery discharged state occurred when 20% of the energy consumed during the maximum cruise speed, 56 Kph (35 mph), range test had been used. A later comparison of the different charge levels of the battery as determined by both the energy and charge methods showed very little difference between the methods.

The results of the acceleration test are presented in Figures 5.3.1 through 5.3.17. The figures contain four plots each. The plots are arranged according to the battery state of charge with the first plot associated with the 100% charged state while the fourth plot is associated with the 20% charged state. Since all the plots in a figure are similar, a discussion of one plot is applicable to all.

In Figure 5.3.1 the velocity is plotted against the uncorrected time. The time associated with the first velocity datum, v_1 , is calculated from the first valid acceleration datum,

$$t_1 = v_1/a_1$$

where

$$a_1 = (v_2 - v_1)/\Delta t$$

and

$$\Delta t = 3.2 \text{ sec}$$

so that

$$(t_i, v_i) = (t_1 + (i-1) \Delta t, v_i)$$

A graph of the velocity vs corrected time is shown in Figure 5.3.2. The time is corrected in the same manner as the time for the coast down data,

$$\Delta t^* = \frac{v_i - v_{i-1}}{Ac_i}$$

and

$$t_i^* = t_{i-1}^* + \Delta t^* = \text{corrected time}$$

where

$$Ac_i = Ar_i \pm g \sin \theta$$

$$Ac_i = \text{corrected acceleration}$$

$$Ar_i = \text{uncorrected acceleration}$$

$$\theta = \tan^{-1} (\% \text{ grade}/100)$$

The spread in the data points for the velocity vs uncorrected time curve (Figure 5.3.1) is reduced when a correction is made for the slope.

The battery voltage is shown as a function of velocity in Figure 5.3.3. The battery voltage drops slightly at the beginning of a run and then stabilizes at about 140V. The motor or armature voltage (figure 5.3.6) increases linearly with respect to velocity until it becomes equal to the battery voltage at about 25 Kph (15.5 mph). The battery and motor (armature) currents are the opposite of their voltage counterpart. The battery current (Figure 5.3.4) increases linearly with respect to velocity whereas the motor current (Figure 5.3.7) is approximately constant, although the curve shown may not appear to be constant, over the 25 Kph velocity domain. The lines drawn on the graphs can sometimes be misleading. The lines are drawn by averaging three consecutive points, storing these points, and then averaging the stored points three at a time. When the above process is repeated a few times, six times for these graphs, a smooth curve results. It is interesting to note that the motor current is larger than the battery current. The excess voltage of the battery is transformed into motor current by the chopper armature control.

The graphs of the motor field voltage and current (Figure 5.3.9 and 5.3.10 respectively) plotted as a function of velocity have similar slopes. The two functions are linearly decreasing during the first 25 Kph (15.5 mph), and then they rapidly fall until a speed of approximately 35 Kph (22 mph) is reached, at this velocity the rate of decrease is slowed. At about 55 Kph (34 mph) the field voltage and current become zero. The accuracy of the field current measurement is questionable because of the current sensor used which is not accurate at low current levels¹. The battery and motor currents also undergo a rapid

¹A more complete discussion of the current sensor is given in Section 2.

fall at about 25 Kph (15.5 mph) in a manner similar to the field voltage and current. The battery and motor currents drop to a nominal value of 140 amps after the drop.

The battery current, motor or armature current, and the field current are plotted against normalized time in Figures 5.3.5, 5.3.8, and 5.3.11 respectively. The origin of the normalized time corresponds to the calculated origin of the velocity curve. In some cases the currents have nonzero values prior to the defined start, which is obtained by extrapolating the velocity data backwards. The reason for these nonzero values may be that the extrapolated origin is not very accurate or that the time delays between the acceleration pedal and wheels results in current surges before the vehicle moves. The points which occur for negative time are not plotted. Another problem the plots with normalized time have is that the time is not corrected for slope. The motor characteristics are a function of velocity, and the velocity a car reaches in a given time depends on the slope so that a slope correction, like the one done for the velocity vs time curve, is required. The correction is not done because of time limitations.

The differential equation, which is very similar to eqn. 5.2.1, for a vehicle powered by an electric motor is

$$(M + J/r_w^2) \dot{v} + M(A' + B'v + C'v^2) + Mg \sin \theta = \frac{1}{r_w} K_a \phi i_a - \frac{1}{r_w} T_{loss} \quad (5.3.1a)$$

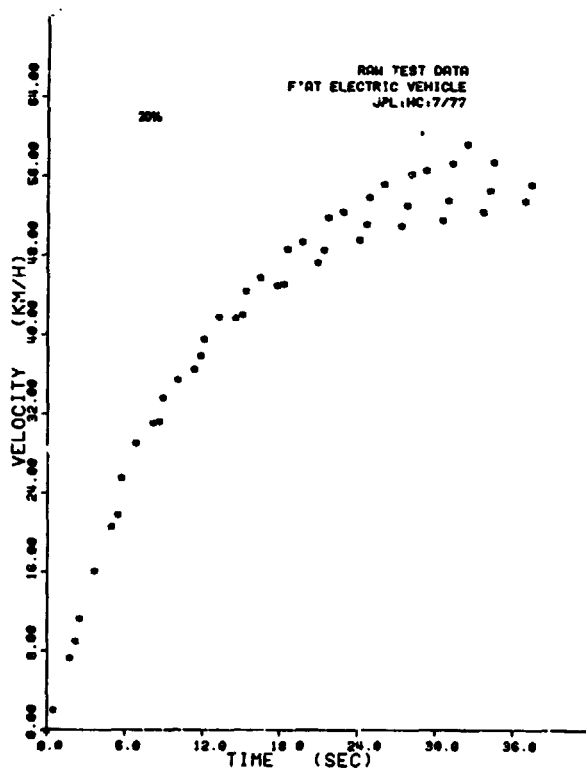
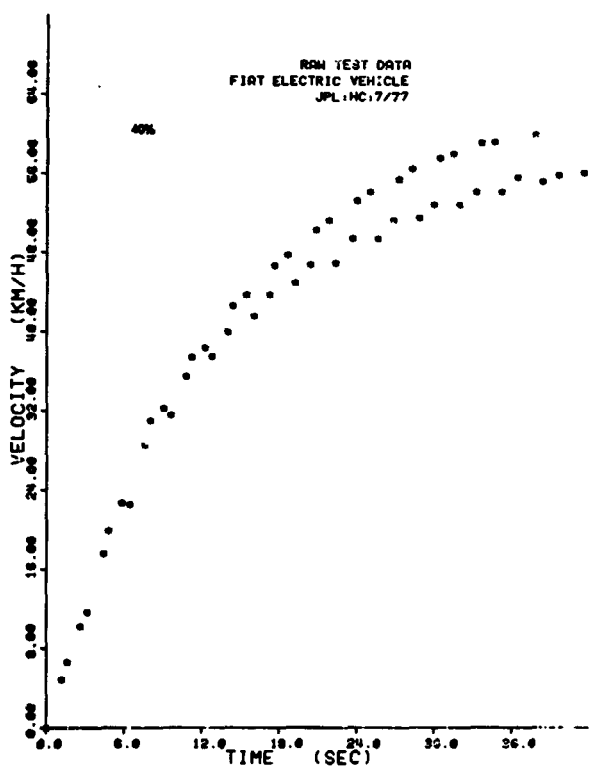
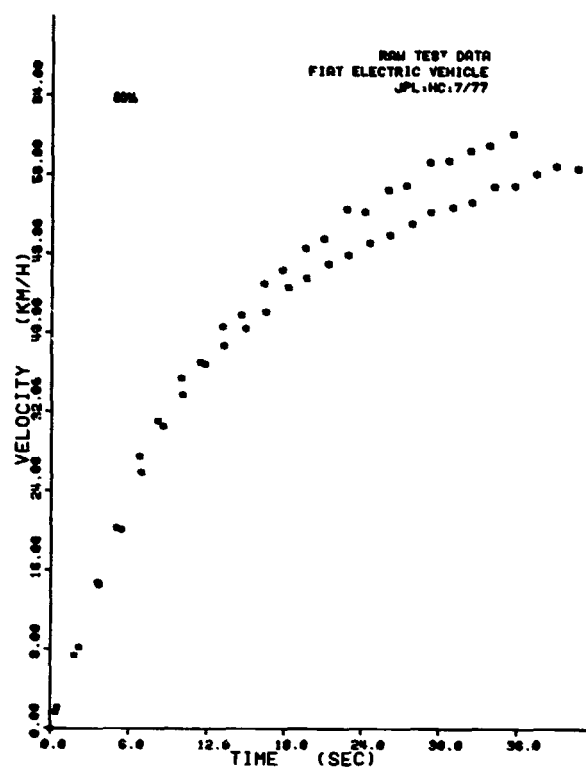
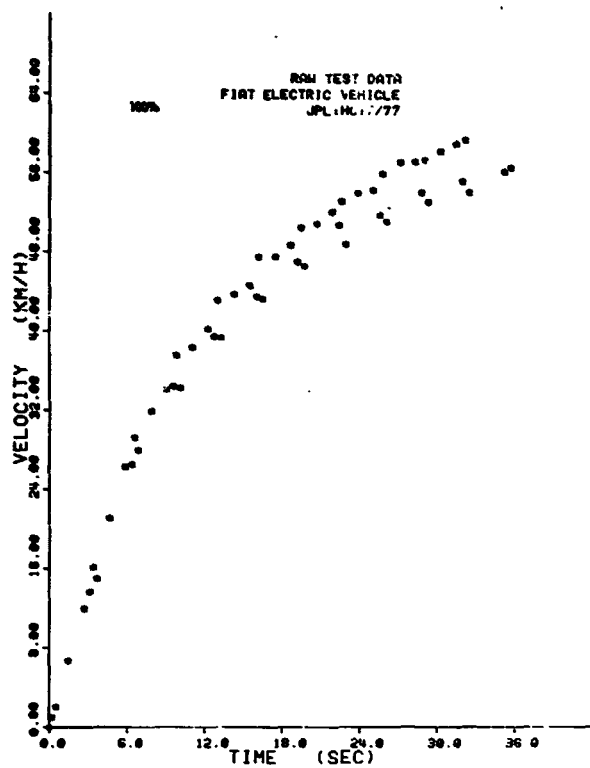


Figure 5.3.1. Velocity vs. Time (uncorrected)

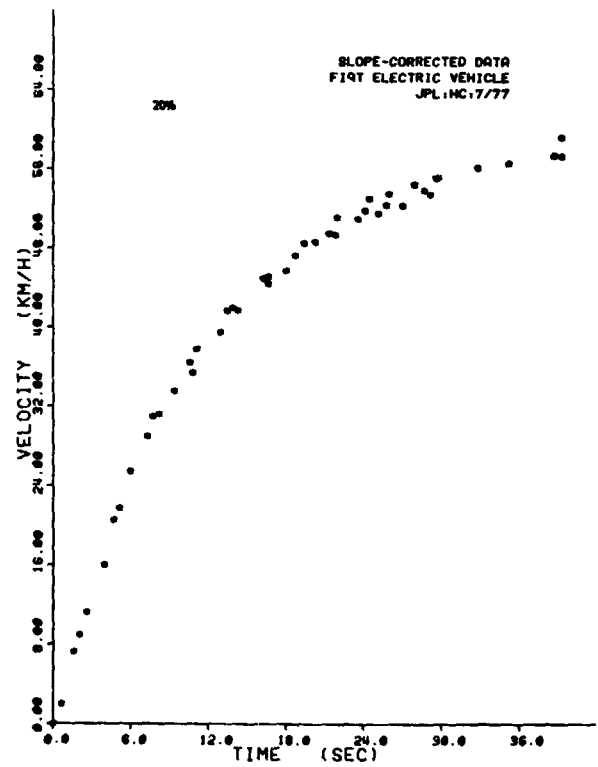
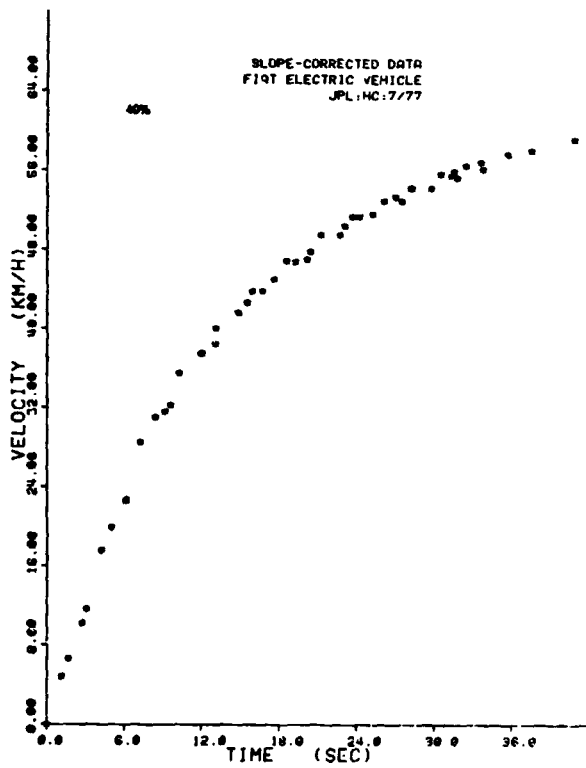
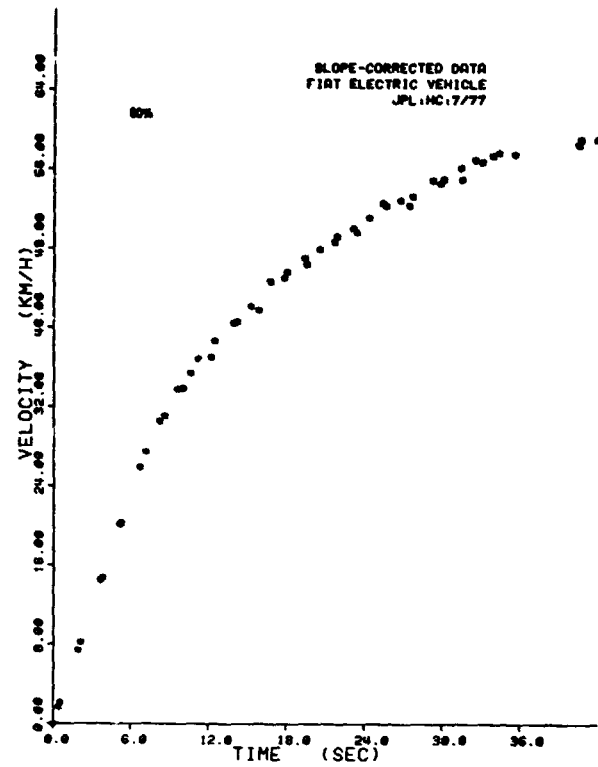
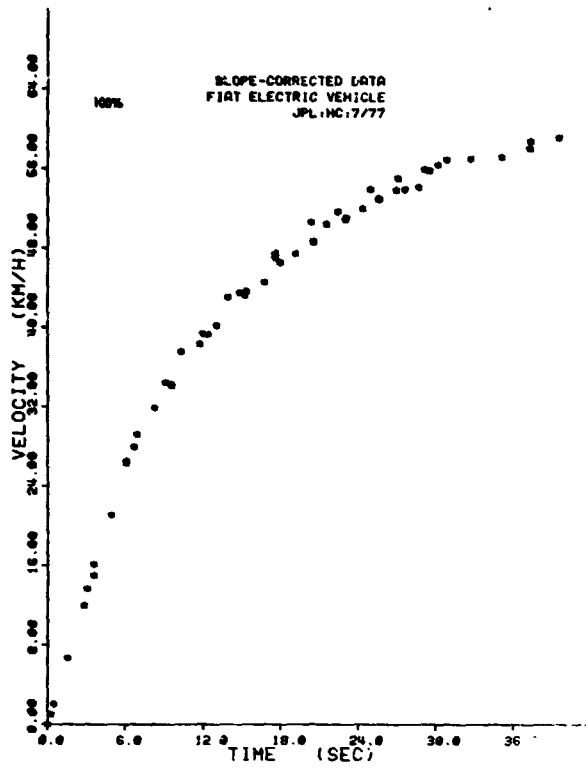


Figure 5.3.2. Velocity vs. Time (corrected)

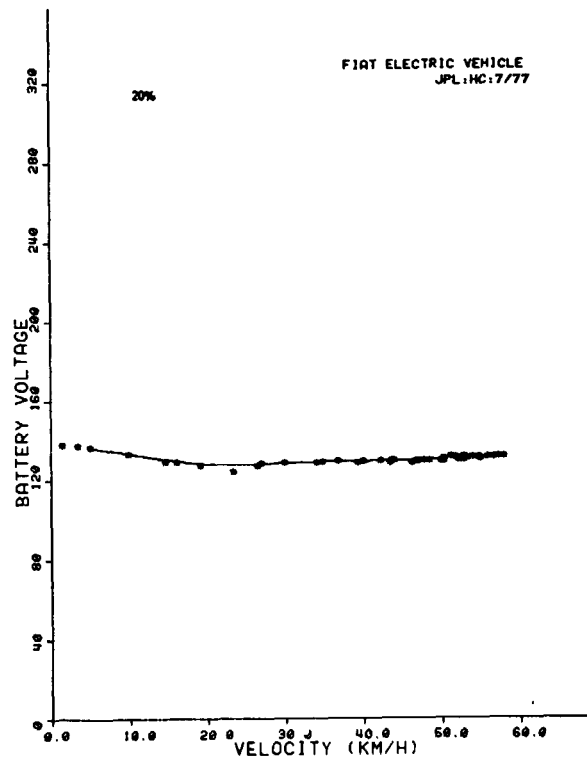
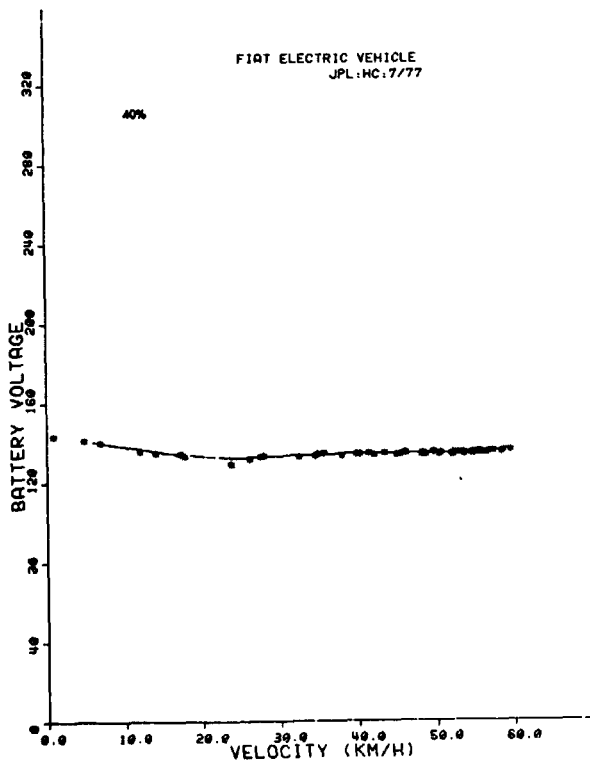
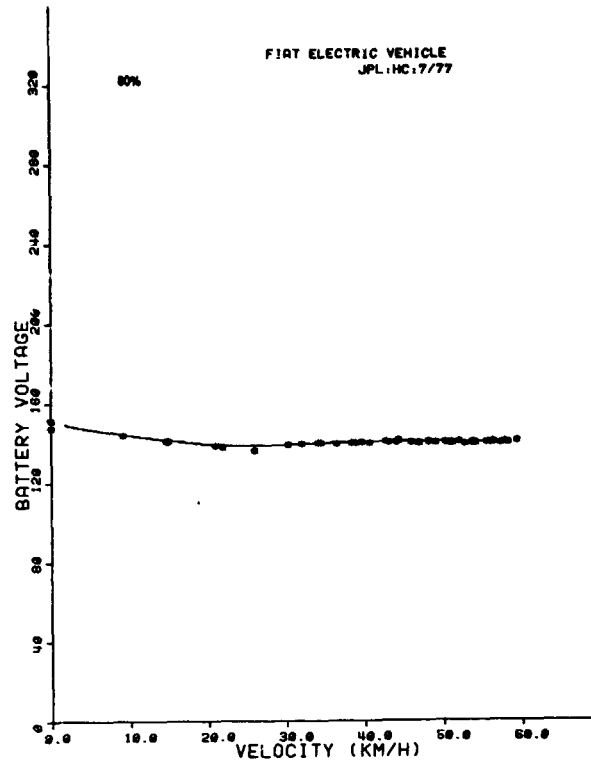
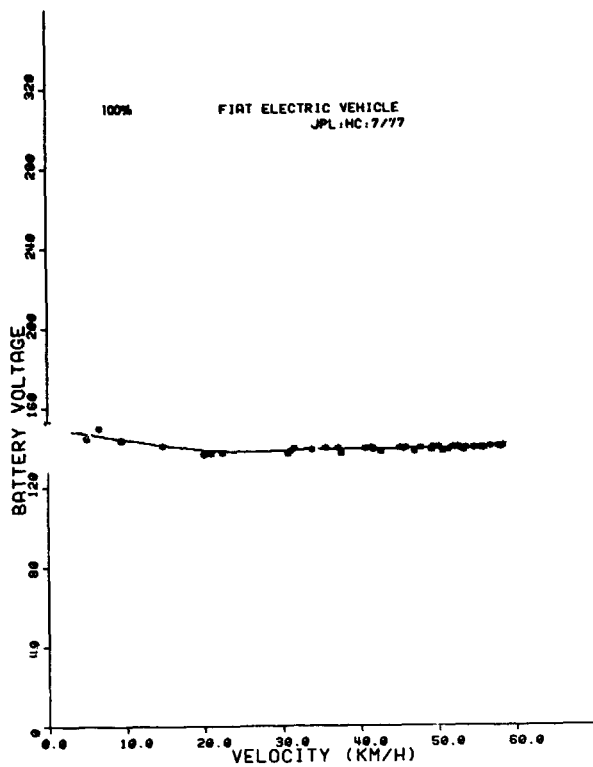


Figure 5.3.3. Battery Voltage vs. Velocity

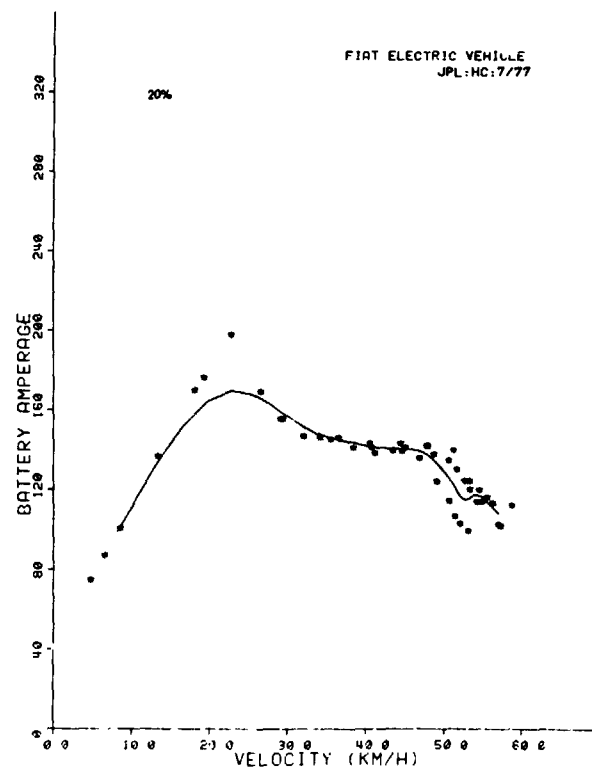
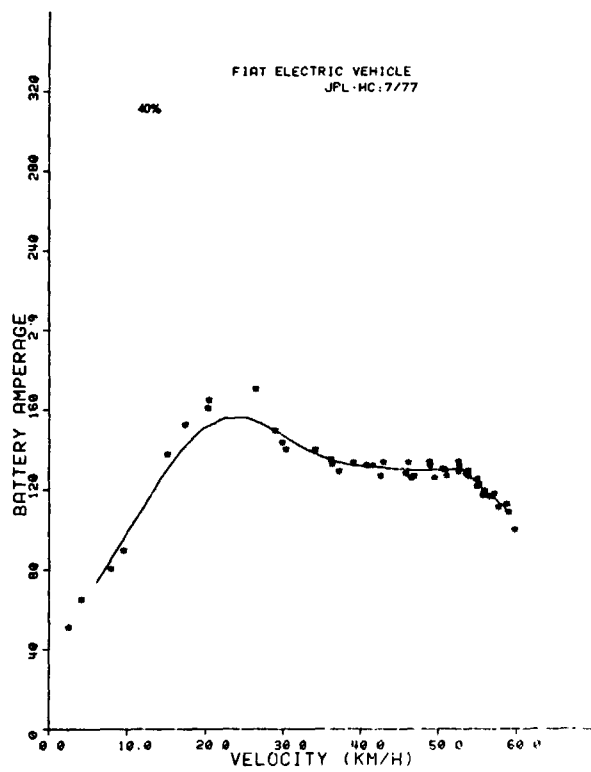
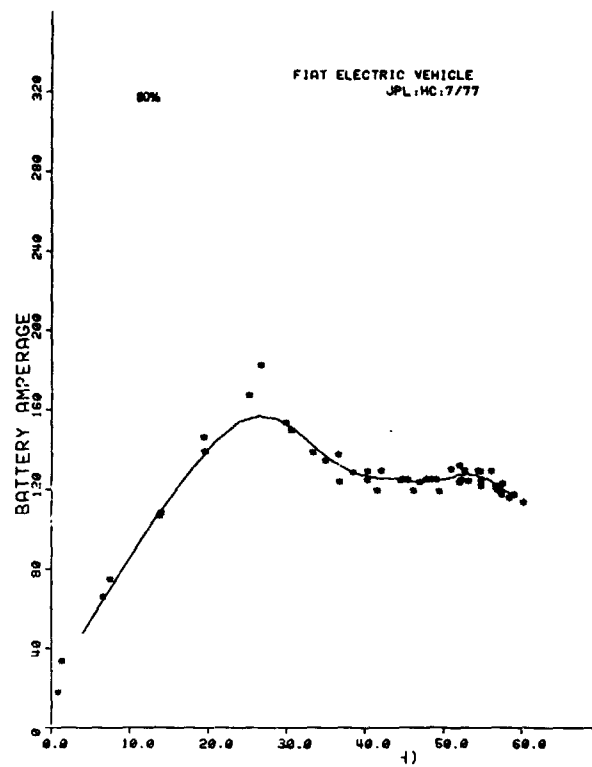
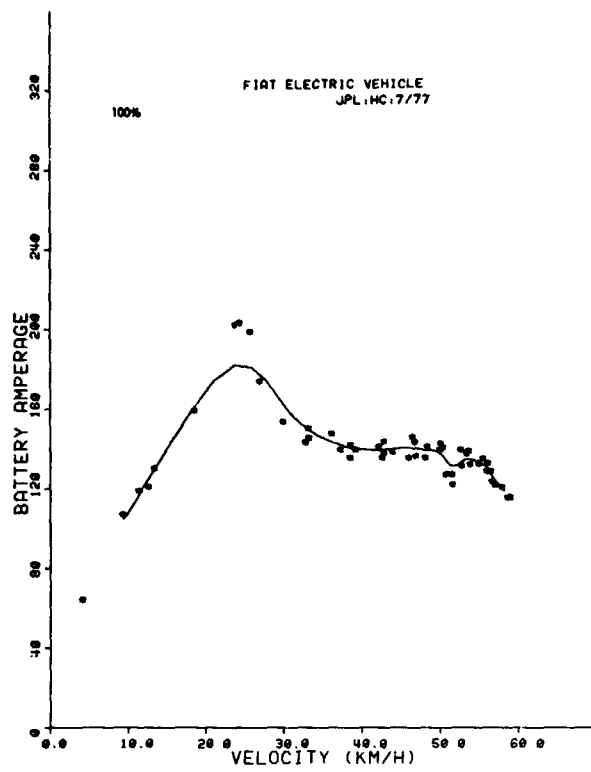


Figure 5.3.4. Battery Current vs. Velocity

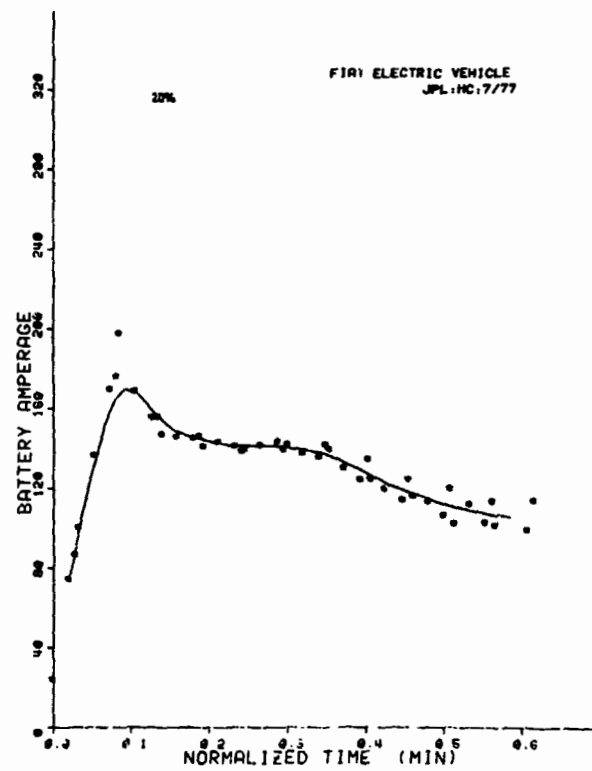
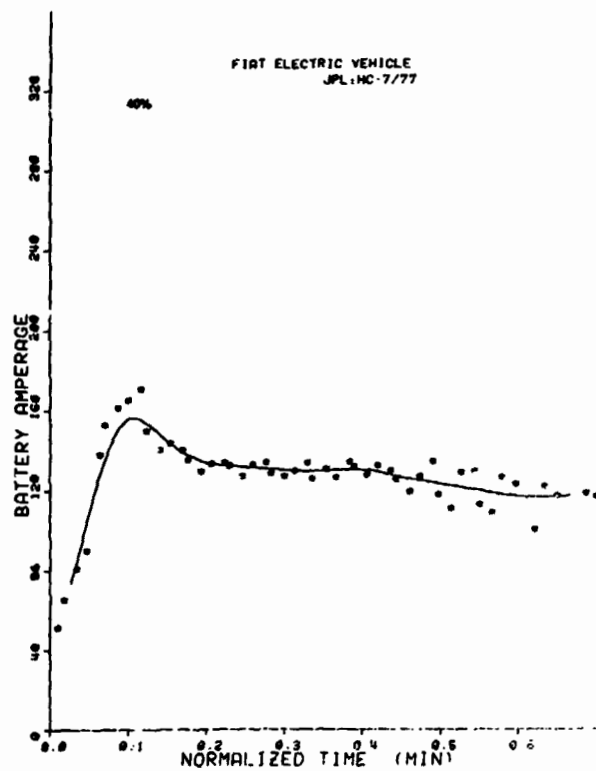
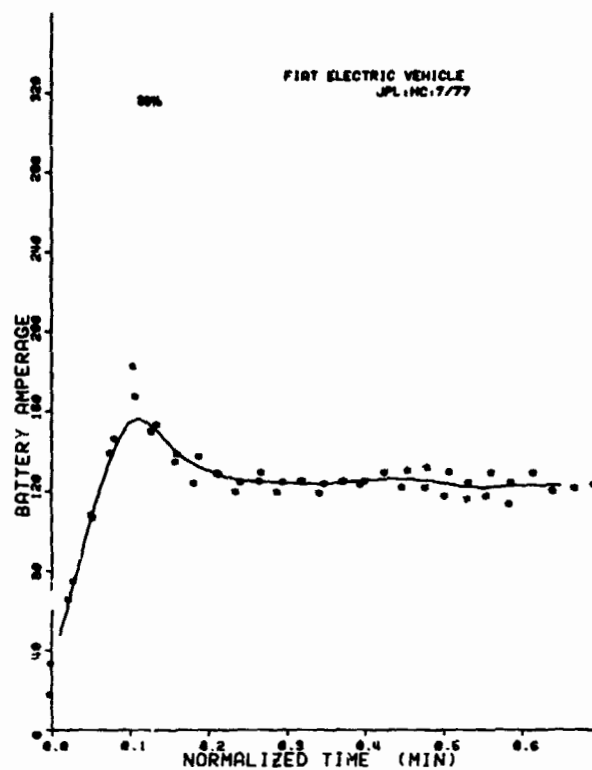
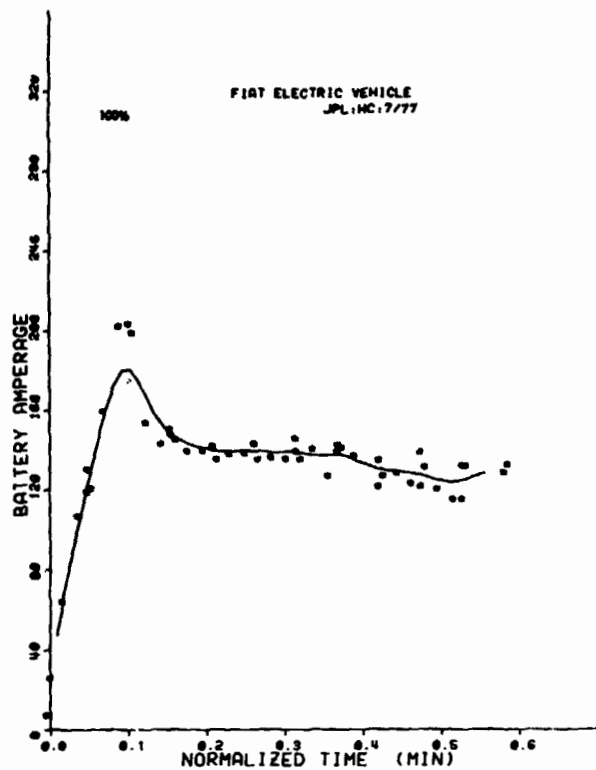


Figure 5.3.5. Battery Current vs. Time (normalized)

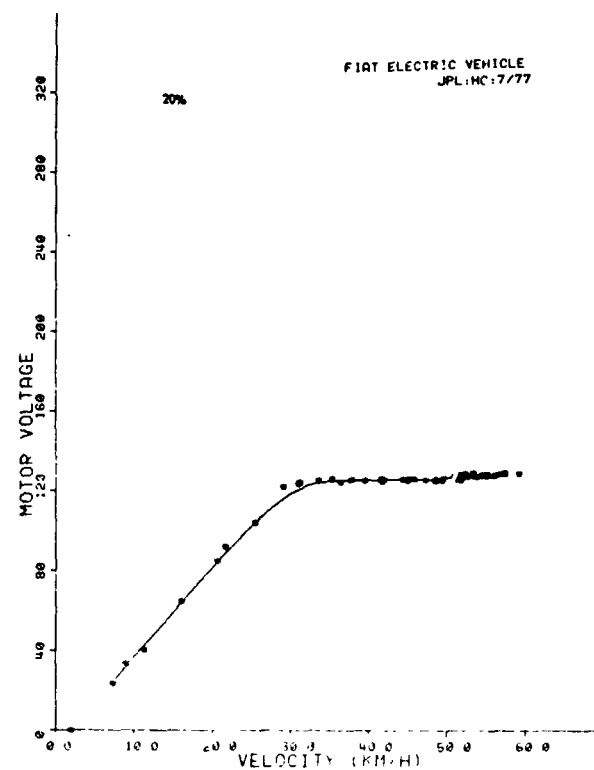
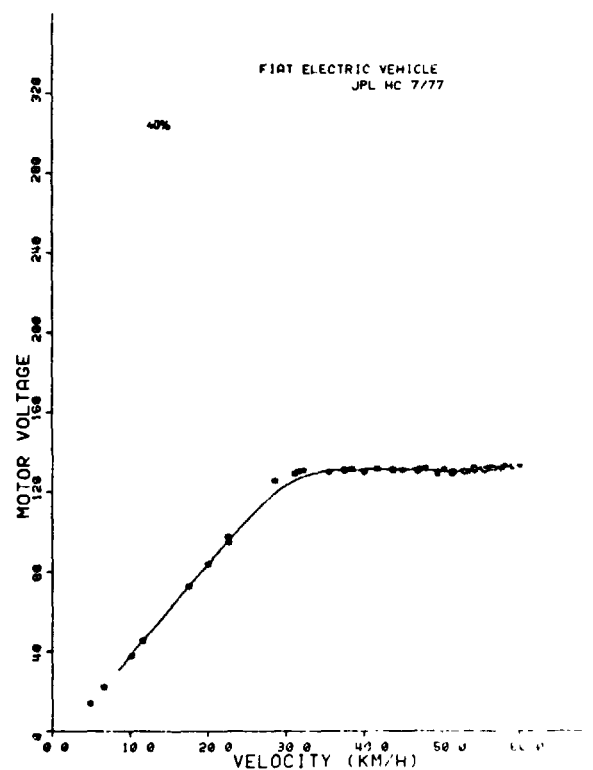
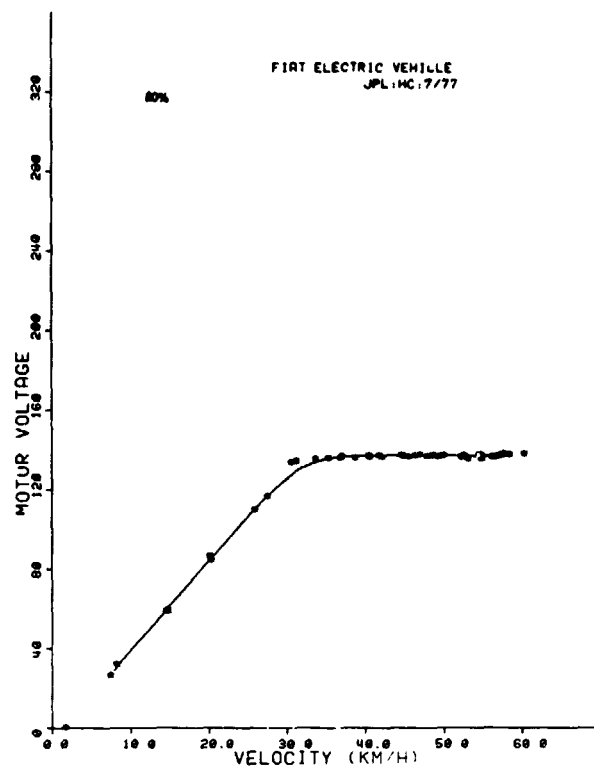
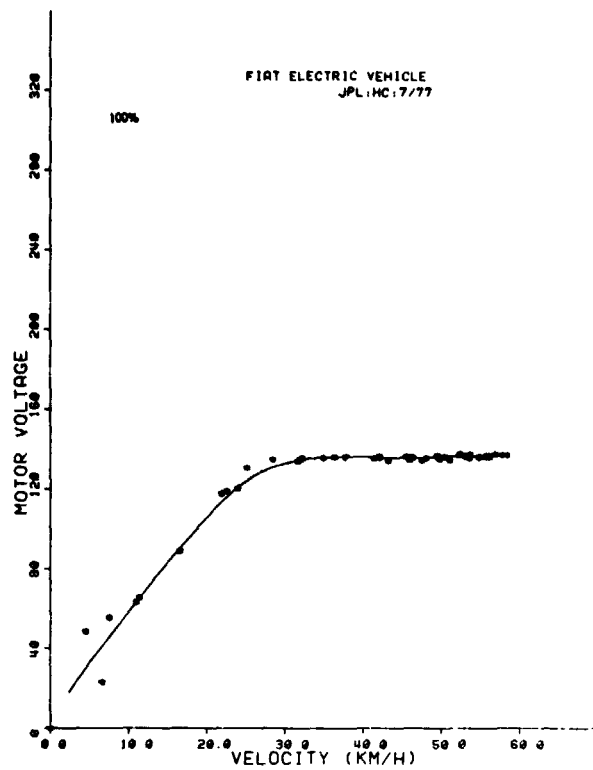


Figure 5.3.6. Motor Voltage vs. Velocity

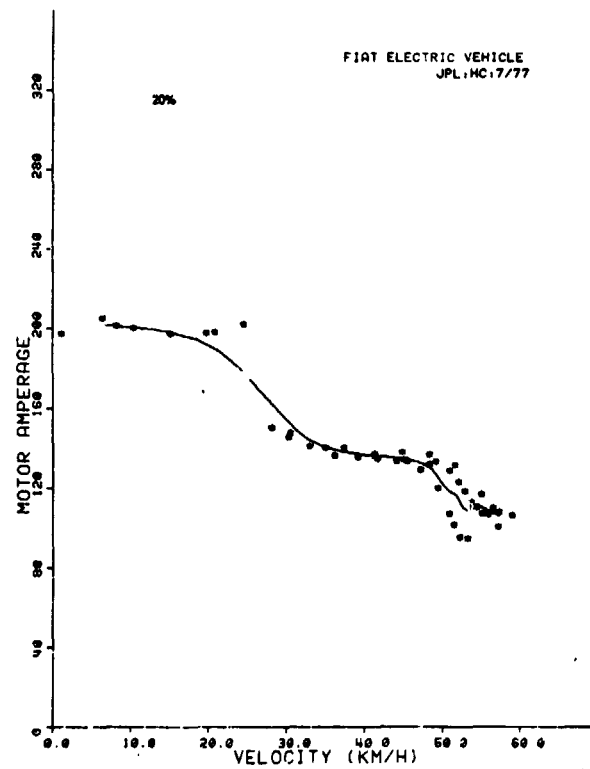
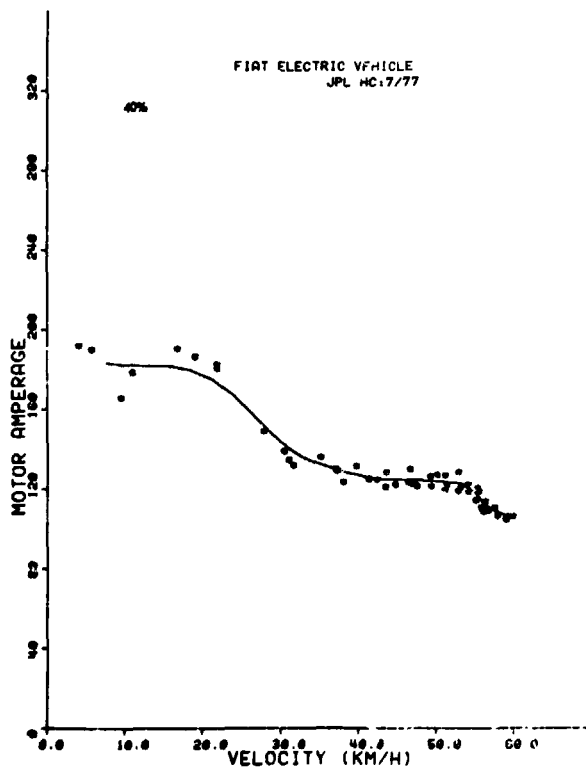
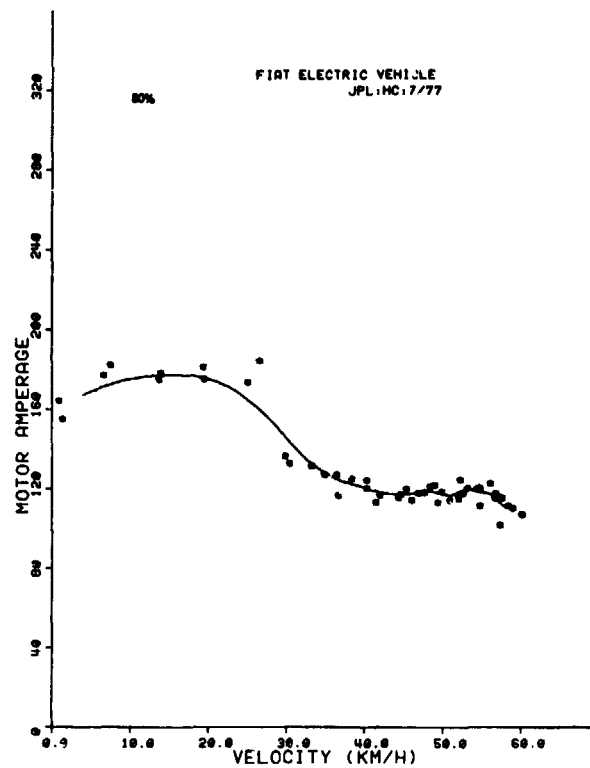
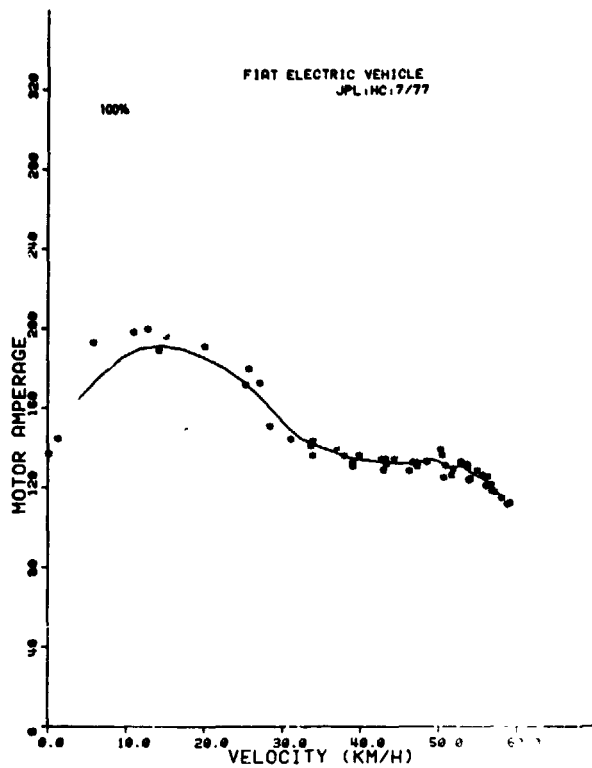


Figure 5.3.7. Motor Current vs. Velocity

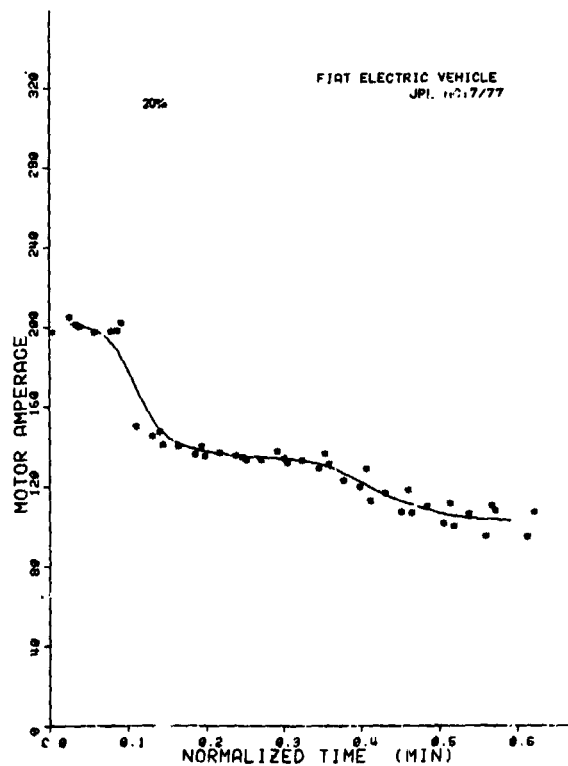
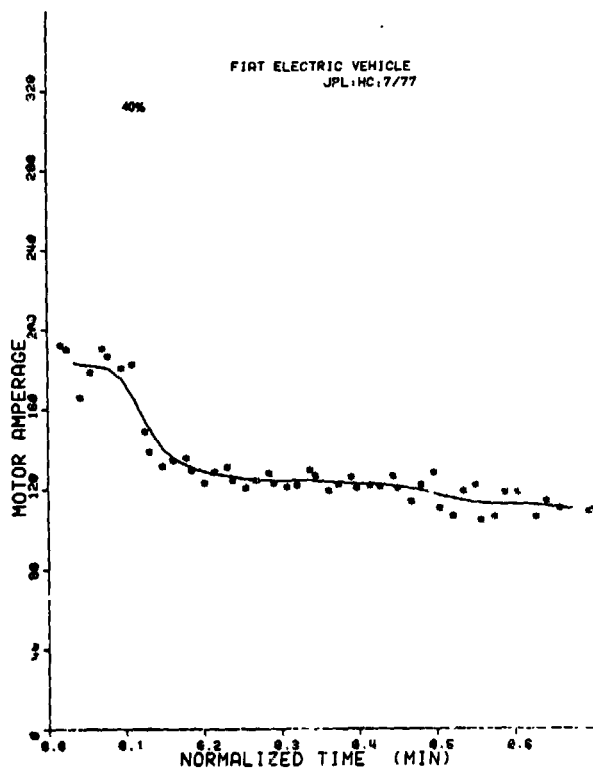
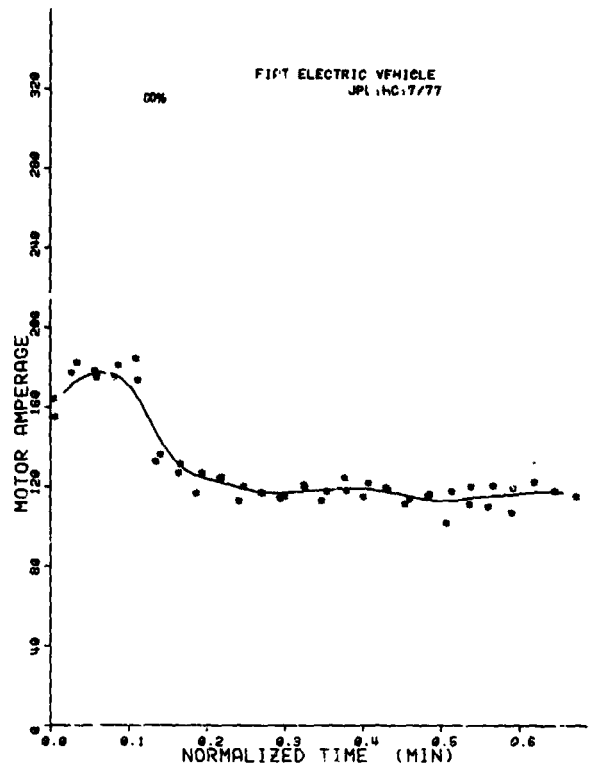
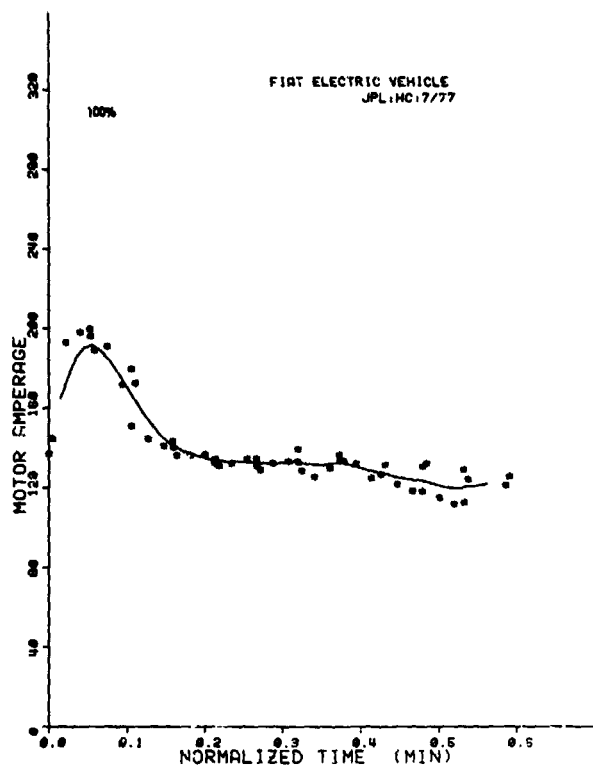


Figure 5.3.8. Motor Current vs. Time (normalized)

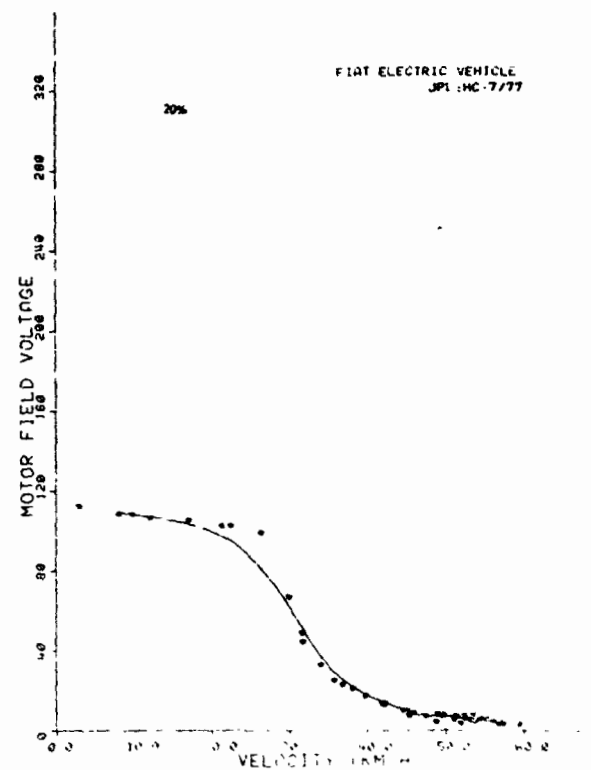
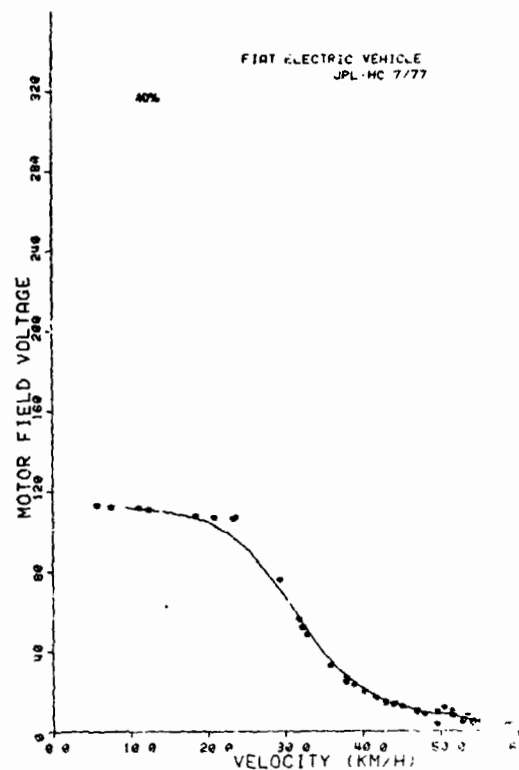
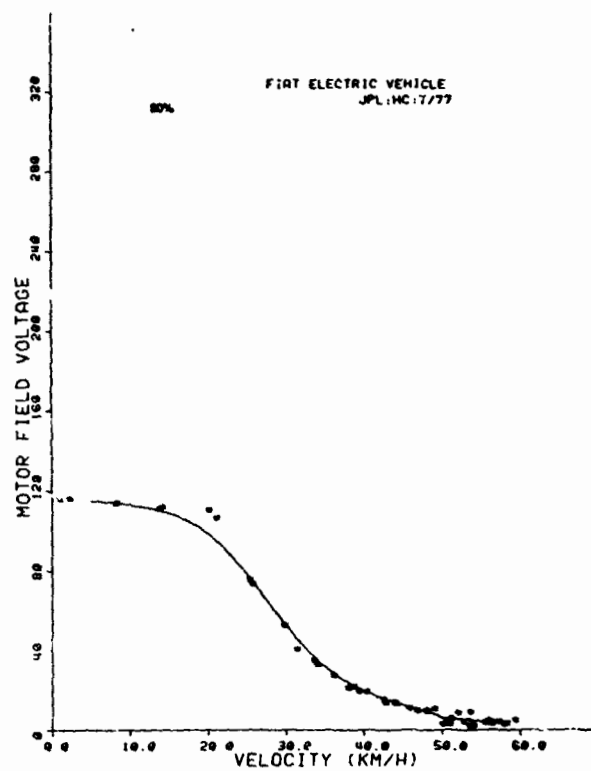
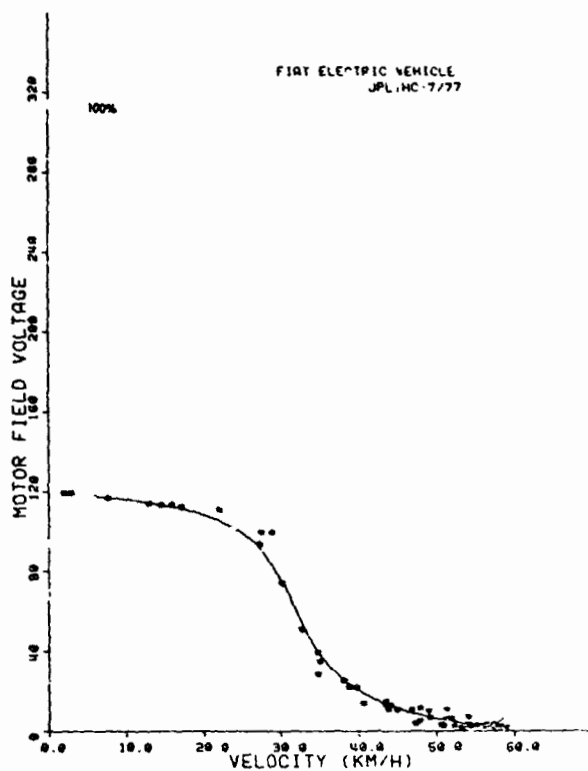


Figure 5.3.9. Motor Field Voltage vs. Velocity

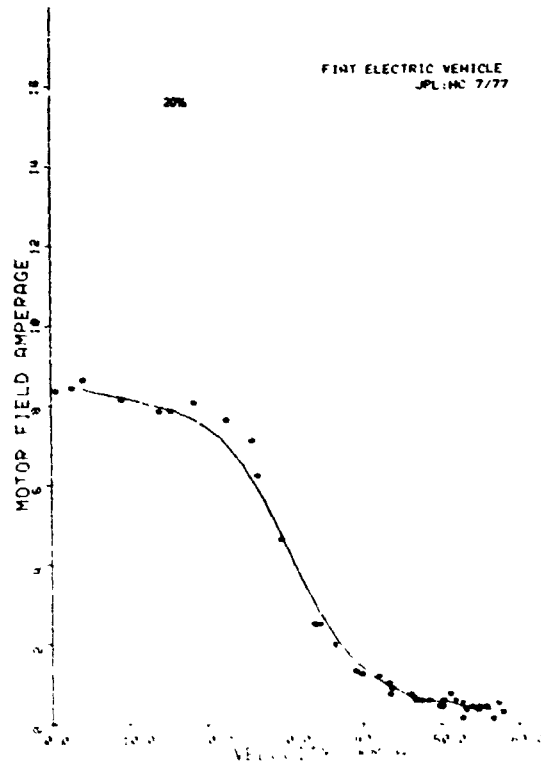
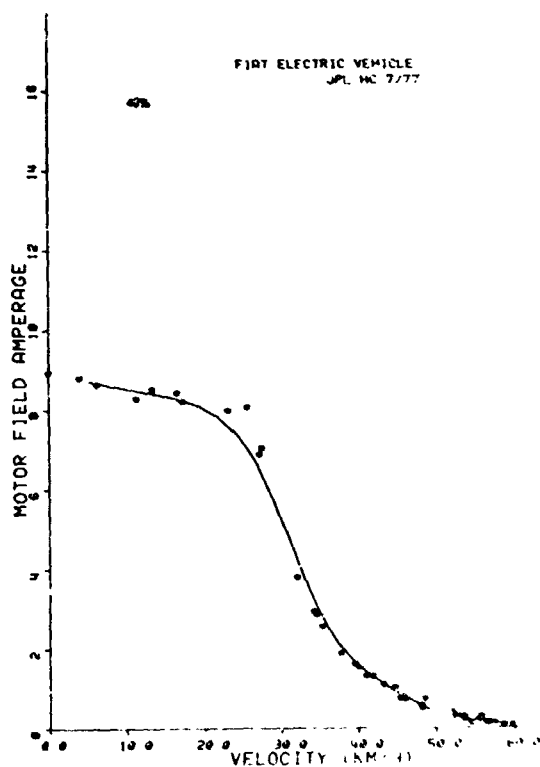
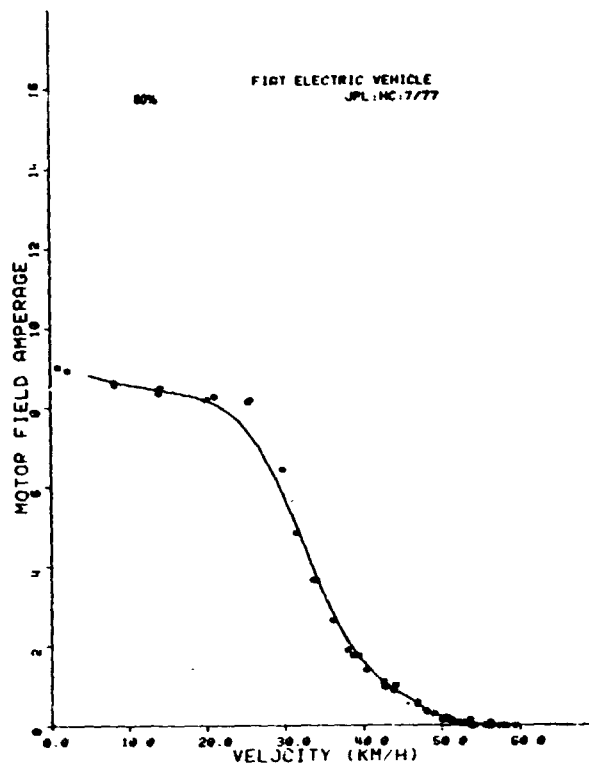
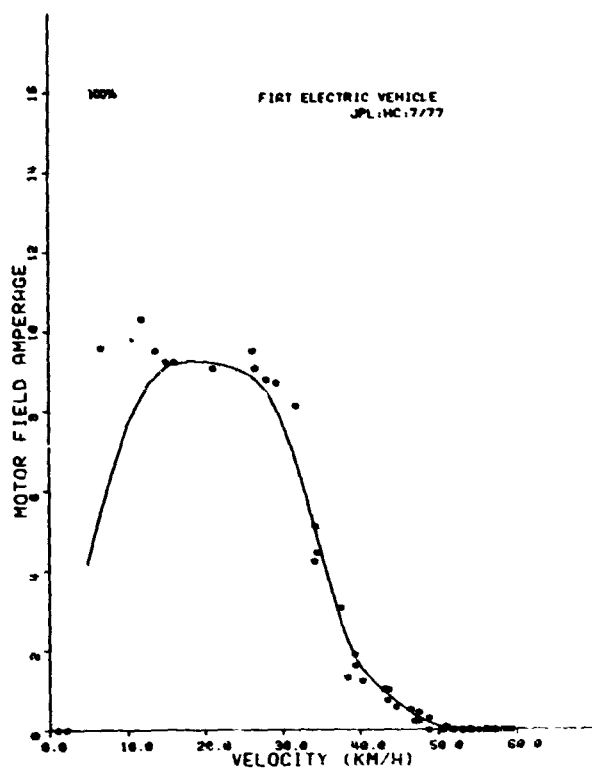


Figure 5.3.10. Motor Field Current vs. Velocity

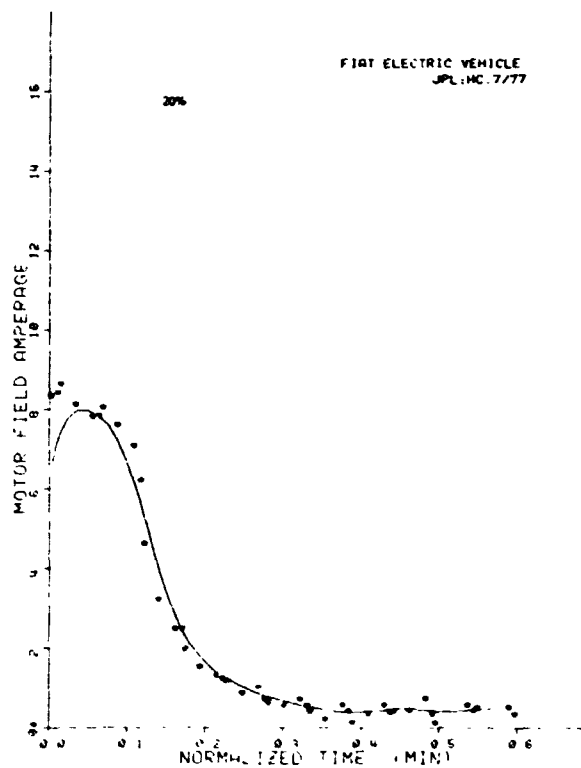
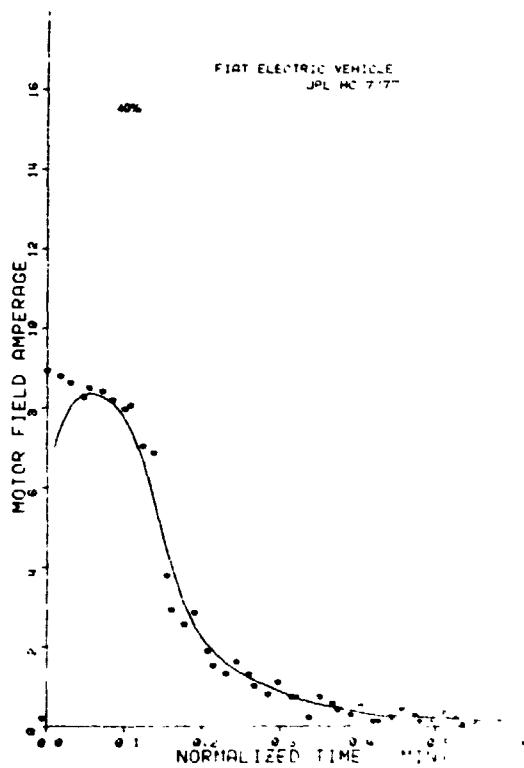
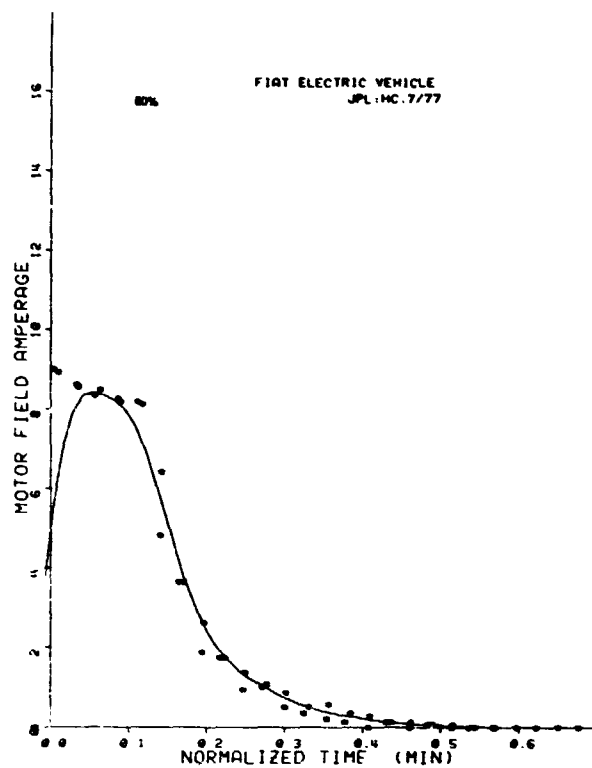
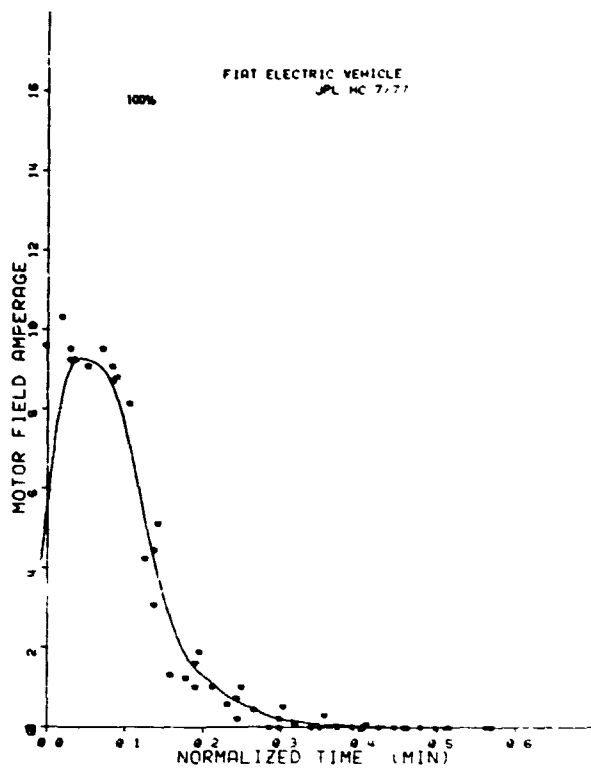


Figure 5.3.11. Motor Field Current vs. Time (normalized)

where

$A', B', C' = \text{constants from eqn. (5.2.7)}$

$K_a = \text{constant of proportionality}$

$\phi = \text{field flux}$

$i_a = \text{armature current}$

$J = \text{moment of inertia of drive train and wheels}$

$T_{\text{loss}} = \text{dissipative torques in drive train}$

Equation (5.3.1a) can be written in terms of the currents if the separately excited compound motor is operated in the magnetically linear region, then

$$K_a \phi = K_f \left(i_f + \frac{N_s}{N_f} i_a \right)$$

$i_f = \text{shunt field current}$

$N_s = \text{number of series field windings}$

$N_f = \text{number of shunt field windings}$

so

$$M(\dot{v} \pm g \sin \theta) = \frac{K_f}{r_w} \left(i_f + \frac{N_s}{N_f} i_a \right) - M(A' + B'v + C'v^2) \quad (5.3.1b)$$

The moment of inertia of the drive train and wheels, J , and the dissipative torques, T_{loss} , of the drive train are neglected in eqn. (5.3.1b).

The armature or motor current (Figure 5.3.7), and the field current (Figure 5.3.10), are used to control the motor. The type

of control used is discussed in a paper by G. Brusaglino.² Below a base velocity, which appears to be about 25 Kph (15.5 mph), both the armature and field current are controlled while above the base speed only the field current is controlled. The armature voltage is equal to the battery voltage for speeds above the base speed. For velocities less than the base speed, the field current (Figure 5.3.10) appears to be a linearly decreasing function of velocity while the armature current (Figure 5.3.7) is approximately constant, I_a . A constant armature current and a linearly decreasing field current produces an acceleration, eqn. (5.3.1b), which depends on velocity in the following way.

$$M A_c = \frac{K_f}{r_w} \left[\left(a_1 - b_1 v \right) + \frac{N_s}{N_f} I_a \right] I_a - \kappa (A' + B' v + C' v^2)$$

where

A_c = corrected acceleration

$i_f = a_1 - b_1 v$ linearly decreasing function of velocity

At low velocities the wind drag term is negligible, and the acceleration is a linear function of velocity

$$\frac{dv}{dt} = A + B v \quad \text{for} \quad v \leq 25 \text{ Kph (15.5 mph)} \quad (5.3.2a)$$

²"Fiat's Electric Vans for Enel," Fourth International Electric Vehicle Symposium, 1976.

The slope-corrected acceleration is plotted against velocity in Figure 5.3.12, and a least squares fit of the data to eqn. (5.3.2a) is done for velocities under 25 Kph (15.5 mph).

For velocities above the base speed, the armature voltage equals the battery voltage so that the armature current and field current are related

$$e_a = K_a \phi v + L_a \frac{di_a}{dt} + R i_a$$

where

e_a = armature voltage = E_b (battery voltage is constant)

L_a = armature inductance

R = armature resistance

assume

$$K_a \phi = K_f \left(i_f + \frac{N_s}{N_f} i_a \right)$$

If the inductance, L_a , is neglected, the armature current as a function of field current is

$$i_a = \frac{E_b - K_f i_f v}{K_f \frac{N_s}{N_f} v + R}$$

since $R \ll 1$

$$i_a \approx \frac{E_b N_f}{K_f N_s} / v - \frac{N_f}{N_s} i_f$$

$$\approx a_2/v - b_2 i_f$$

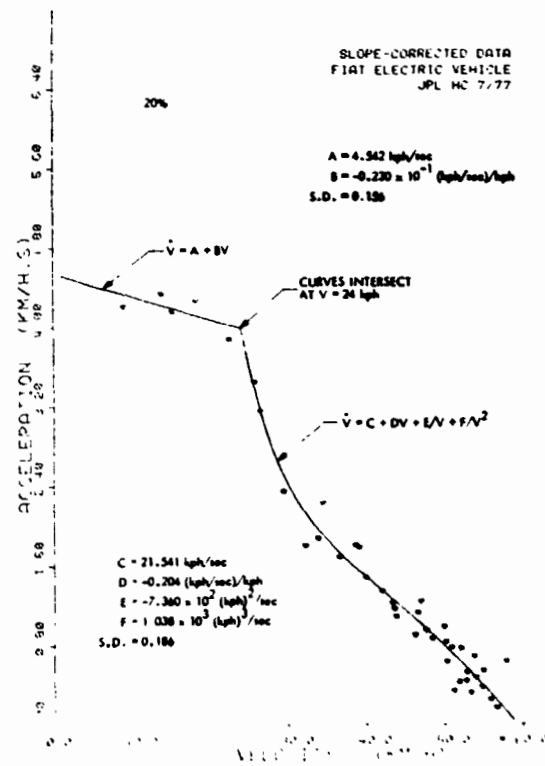
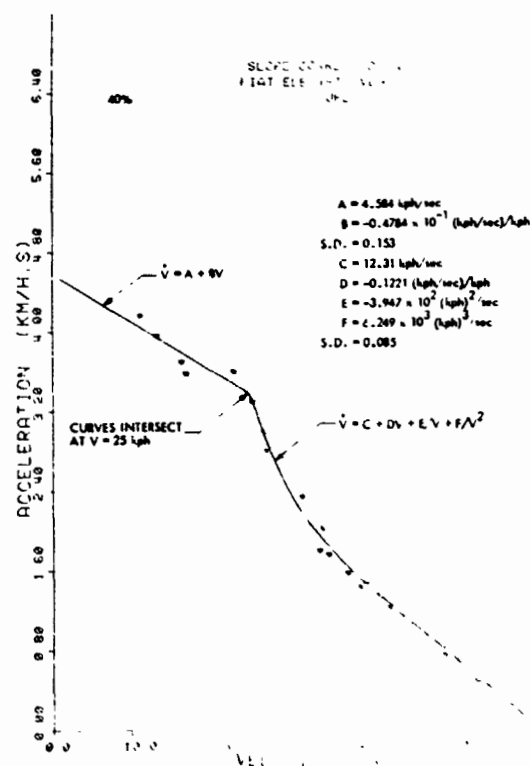
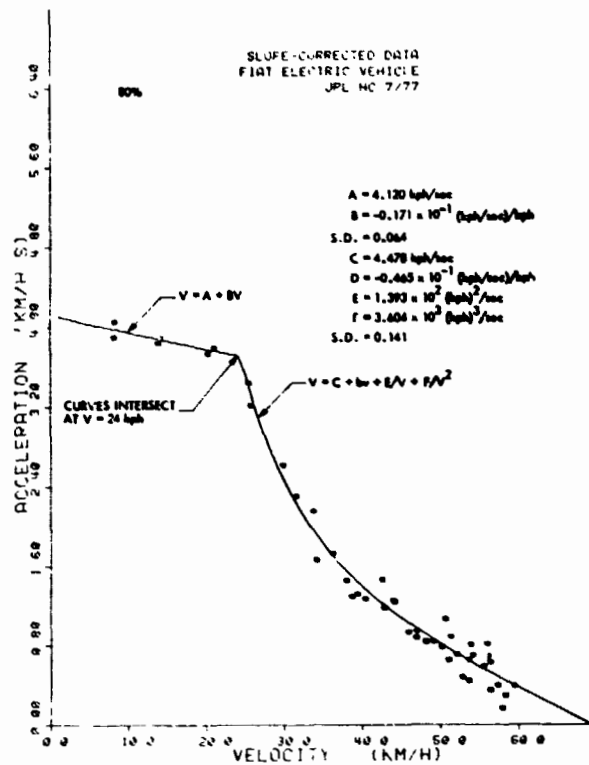
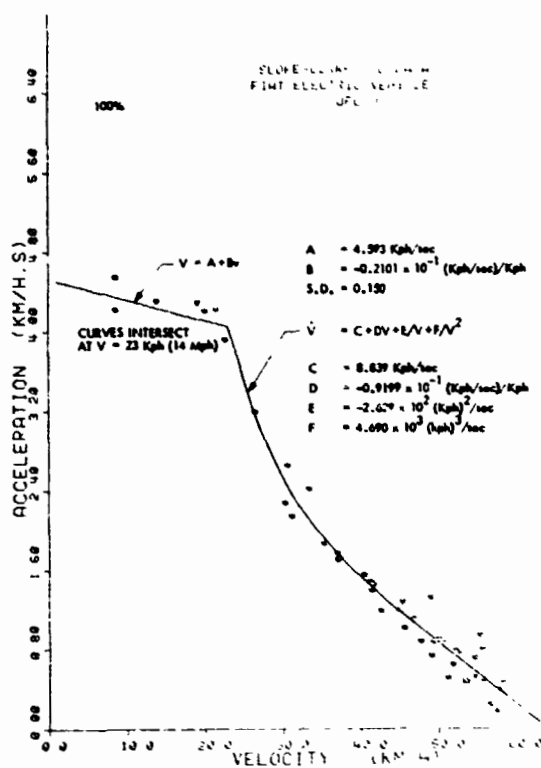


Figure 5.3.12. Acceleration (corrected) vs. Velocity

If the expression for the armature current is substituted into eqn. (5.3.1b), the form of the acceleration equation is

$$M A_c = \frac{K_f}{r_w} \left[i_f \left(\frac{e_2}{v} - b_2 i_f \right) + \frac{N_s}{N_f} \left(\frac{a_2}{v} - b_2 i_f \right)^2 \right] - M (A' + B' v + C' v^2)$$

A reasonable fit of the field current data can be made to the following equation

$$i_f \approx c_2 + d_2 v + e_2/v$$

When the expression for the field current is substituted into the acceleration equation, the functional form of the acceleration equation can be written as

$$\frac{dv}{dt} = C + D v + E/v + F/v^2 + G v^2 \quad (5.3.2b)$$

for $v \geq 25$ Kph (15.5 mph)

Our least squares curve fitting routine was unable to fit eqn. (5.3.2b) to the corrected acceleration data for velocities above the base speed. The routine was able to fit the above equation when the constant G was set equal to zero. The curve drawn on Figure 5.3.12 is a least squares fit of the data to the equation

$$\frac{dv}{dt} = \begin{cases} A + Bv & v \leq 25 \text{ Kph} \\ C + Dv + E/v + F/v^2 & v \geq 25 \text{ Kph} \end{cases} \quad (5.3.2)$$

The values for the constants are given on the graphs along with the standard deviation of the curve fit and the velocity where the curves intersect. The uncorrected acceleration is plotted against the velocity in Figure 5.3.13.

The acceleration equation, eqn. (5.3.2), was integrated by the computer with the following algorithm

$$\Delta v_i = \begin{cases} (A + Bv_{i-1}) \tau & v_{i-1} < 25 \text{ Kph} \\ C + Dv_{i-1} + E/v_{i-1} + F/v_{i-1}^2 & v_{i-1} \geq 25 \text{ Kph} \end{cases}$$

where

$$v_i = v_{i-1} + \Delta v_i$$

and

$$\tau = \text{time step}$$

The integrated velocity curve is drawn in Figure (5.3.14), with the velocity data plotted against the slope-corrected time. A comparison of the velocity curves for the different charge levels reveals very little difference between them. One possible explanation for this behavior is that the battery voltage does not deteriorate but remains approximately constant over the various charge levels. The battery voltage (Figure 5.3.3) does appear to be about the same for the different charge levels. Another reason for the lack of difference in the velocity curves is that some of the runs at the lower charge levels which began with the vehicle going uphill could have ended with the vehicle going downhill. The vehicle would reach a higher terminal velocity going downhill. The terminal velocity, which is the velocity at zero acceleration, also appears higher than 60 Kph (37.5 mph) which is the manufacturers listed maximum speed.

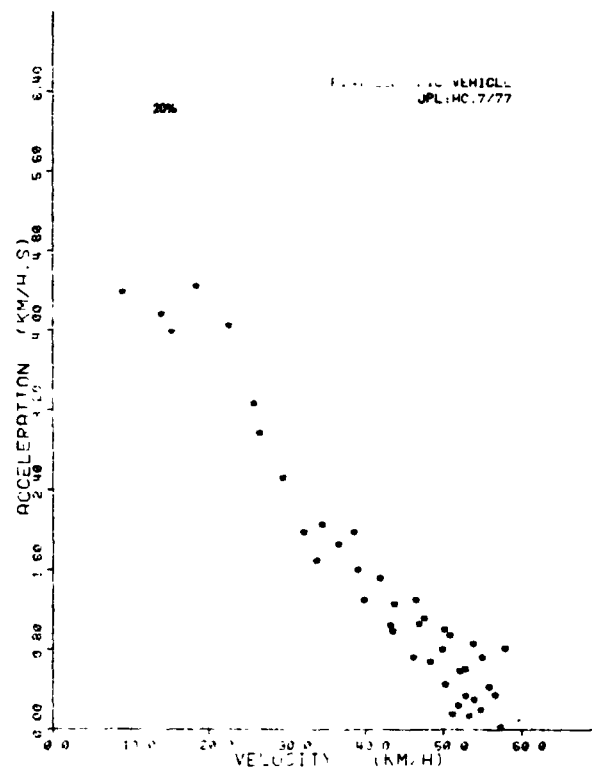
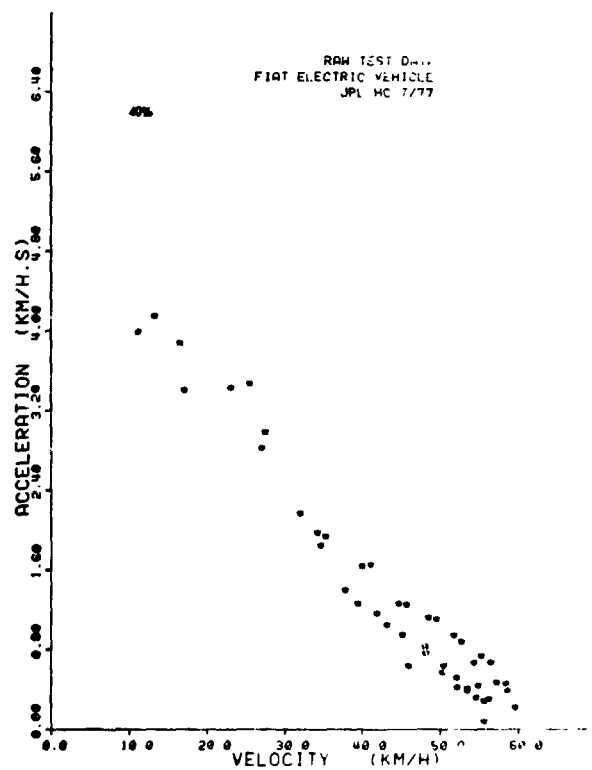
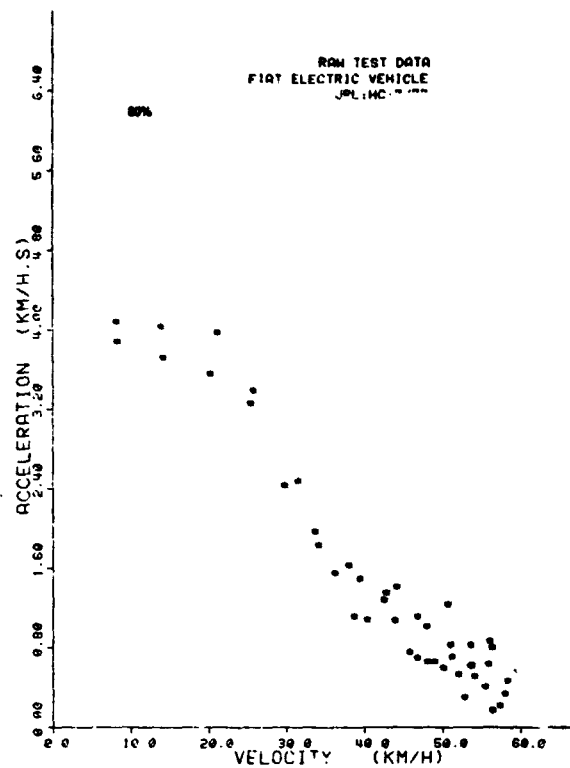
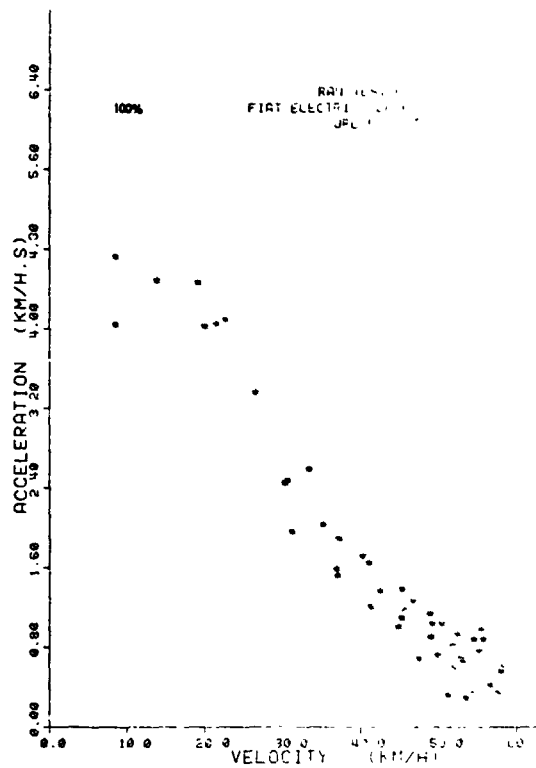


Figure 5.3.13. Acceleration (uncorrected) vs. Velocity

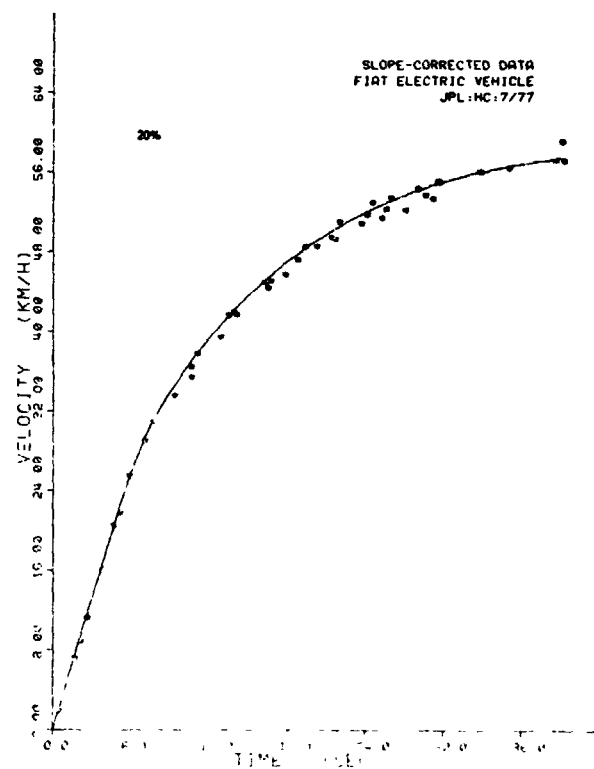
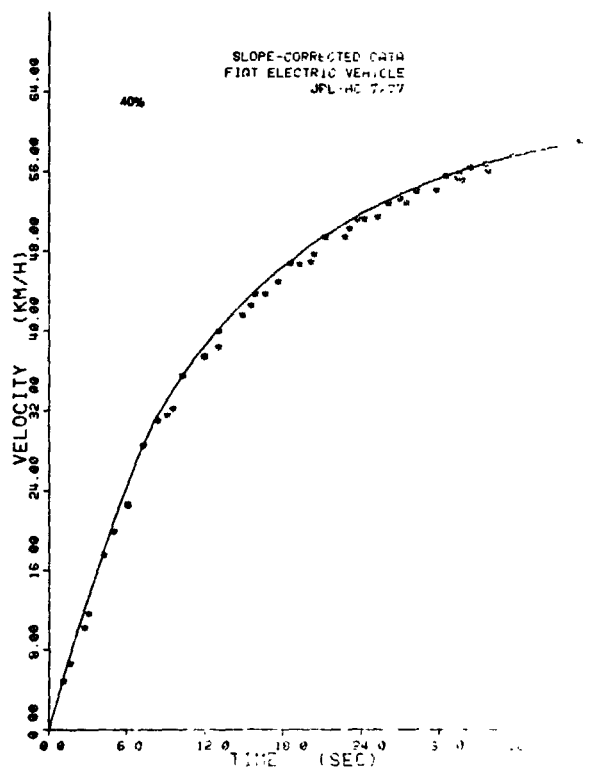
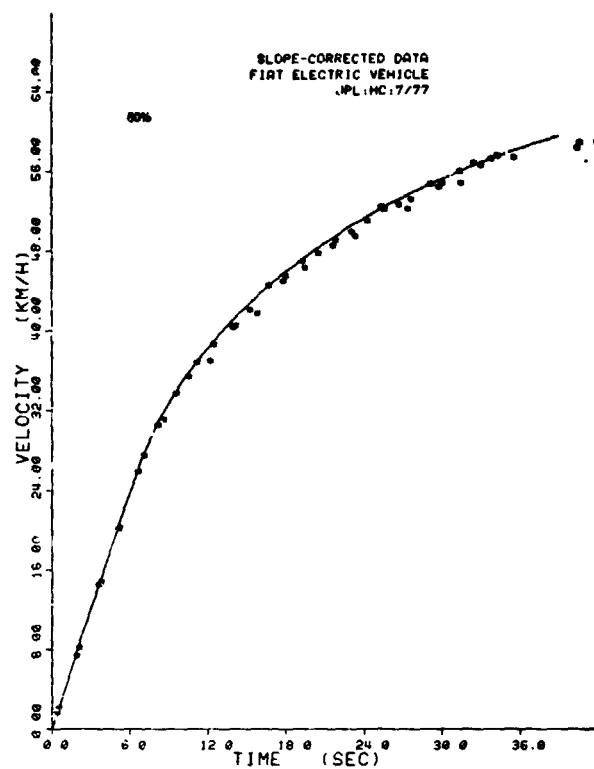
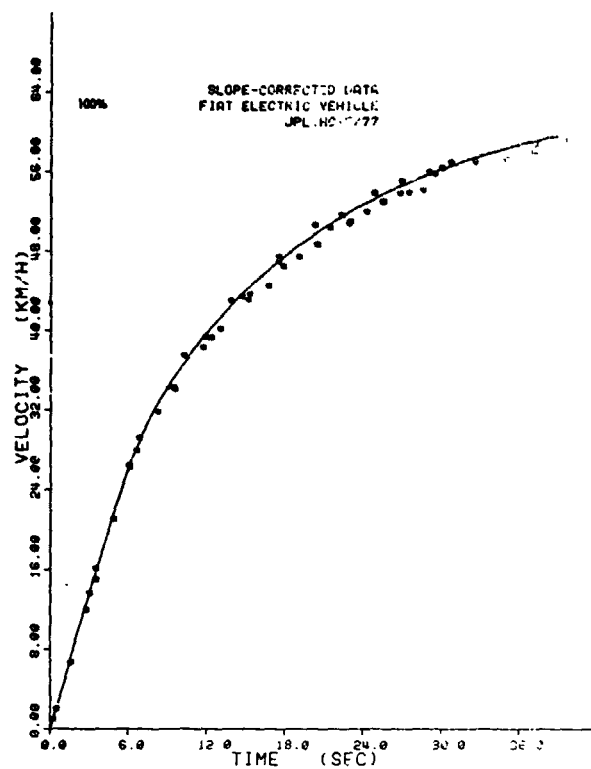


Figure 5.3.14. Integrated Acceleration vs. Time (corrected)

The percent gradeability is plotted against velocity in Figure 5.3.15. The velocity is interpreted as the maximum velocity for which the vehicle can climb the grade. The curve is very similar to the acceleration vs velocity curve, Figure 5.3.13, because

$$\% \text{ grade} = \frac{Ac}{\sqrt{g^2 - Ac^2}} \quad (5.3.3)$$

and when $Ac \ll g$

$$\% \text{ grad.} \approx Ac/g$$

For velocities below the base speed, the % gradeability is high, but for velocities above the base speed the % gradeability rapidly decreases.

The battery and motor power, which does not include the shunt field power, are plotted against % gradeability in Figures 5.3.16 and 5.3.17 respectively. The % gradeability is calculated from the acceleration, eqn. (5.3.3). The acceleration is obtained by substituting the velocity associated with a given power into eqn. (5.3.2). The power is proportional to the product of the acceleration, which is approximately the % gradeability, and the velocity. For a high % gradeability the climbing speed is small, and the power is small. At a high climbing velocity the % gradeability is low and the power is also low. The maximum power is attained at a velocity slightly less than the base speed where the % gradeability is high and the velocity is not small. The power consumed at 0% gradeability, no slope, and maximum speed is close to the continuous rated power of the motor. At a higher % gradeability the maximum continuous power is exceeded so that a prolonged climb could burn the motor out.

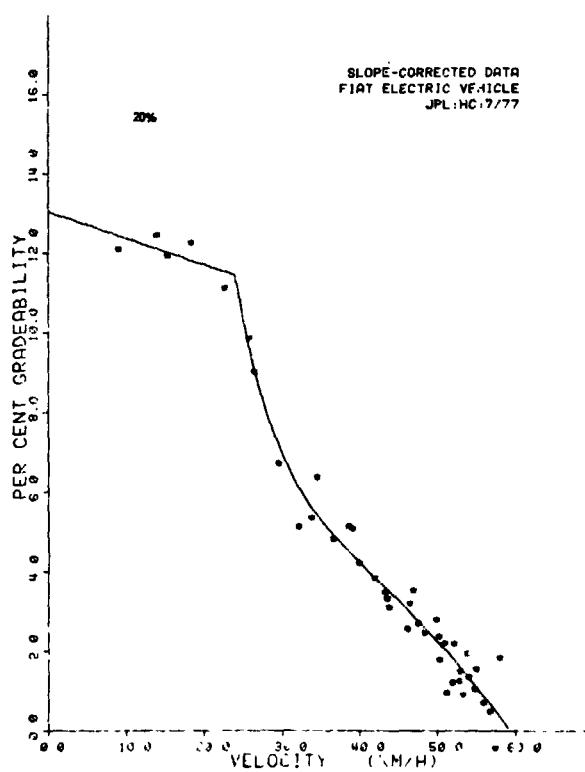
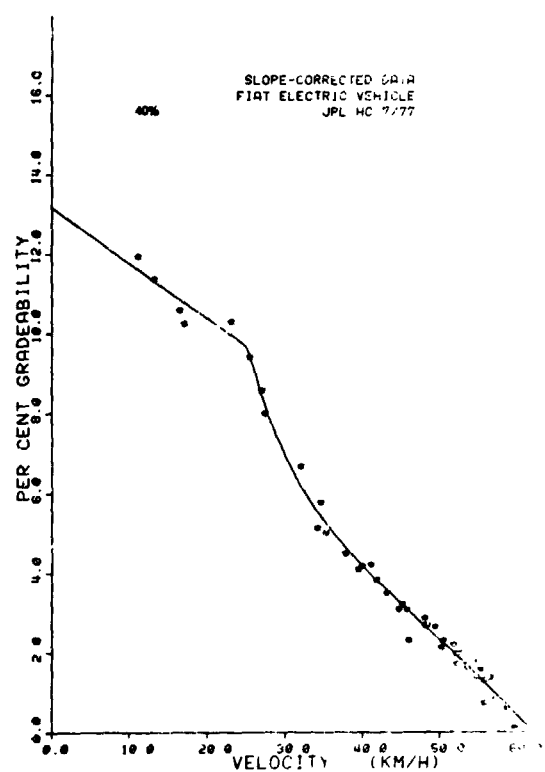
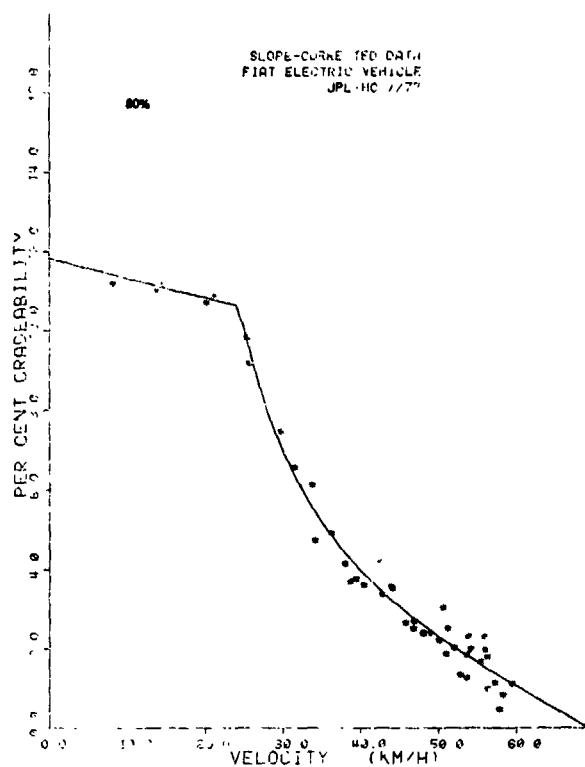
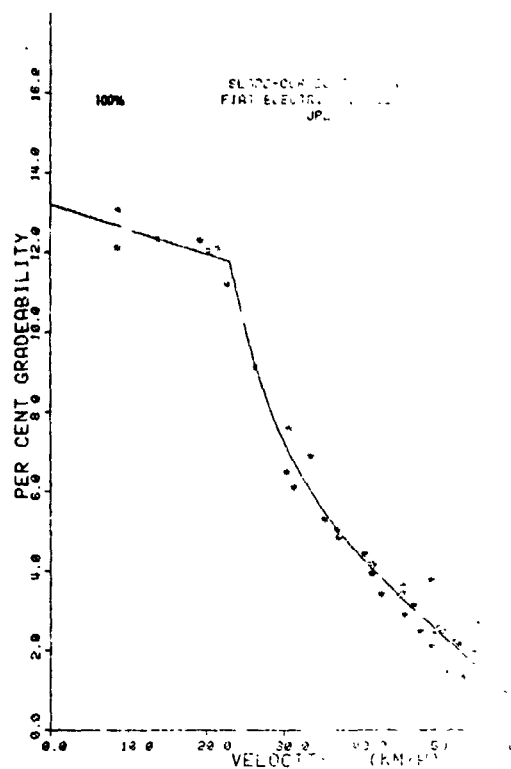


Figure 5.3.15. % Gradeability vs. Velocity

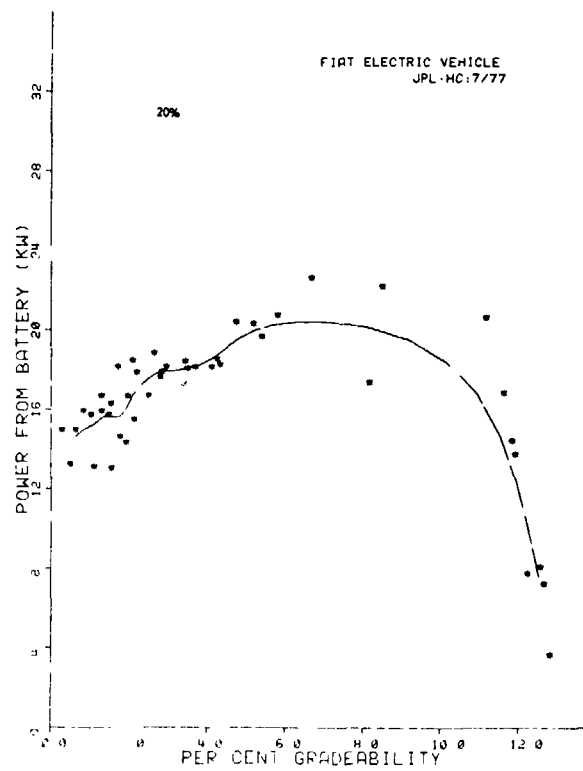
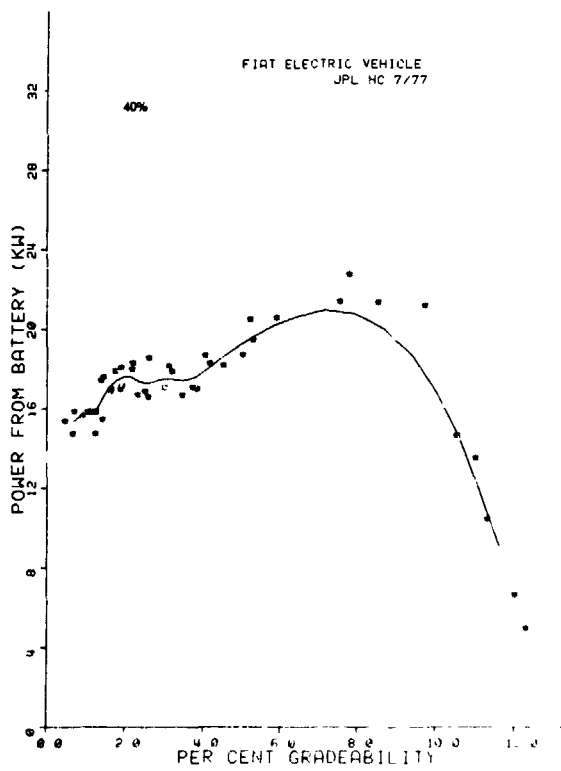
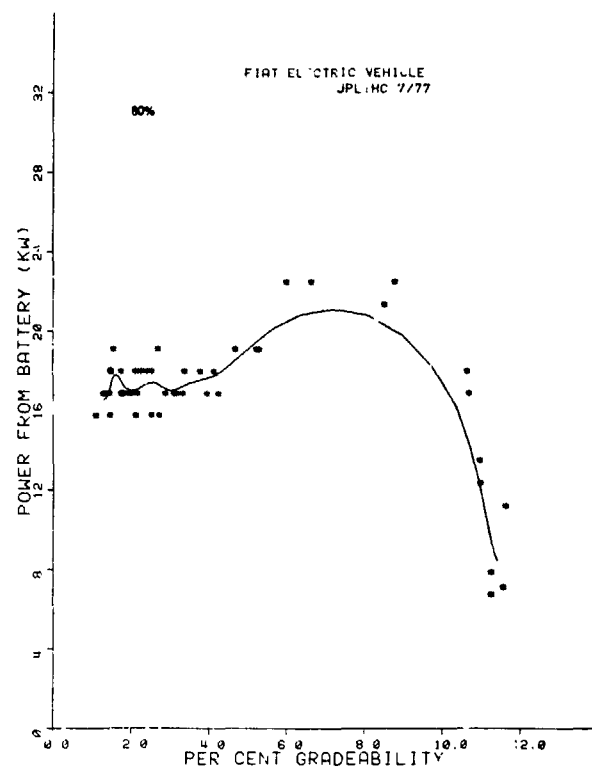
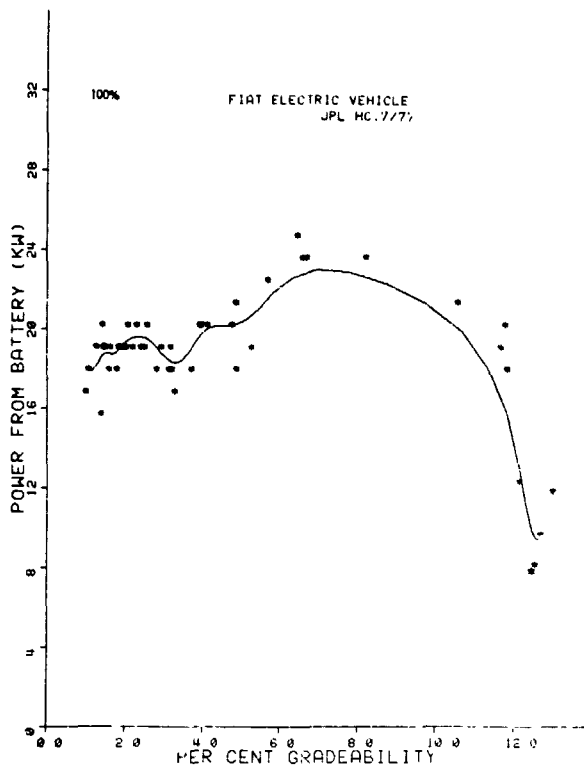


Figure 5.3.16. Battery Power vs. % Gradeability

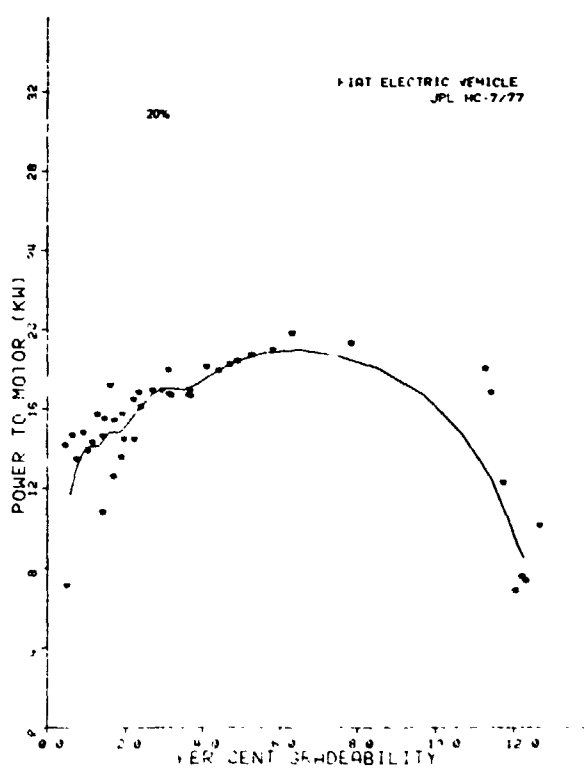
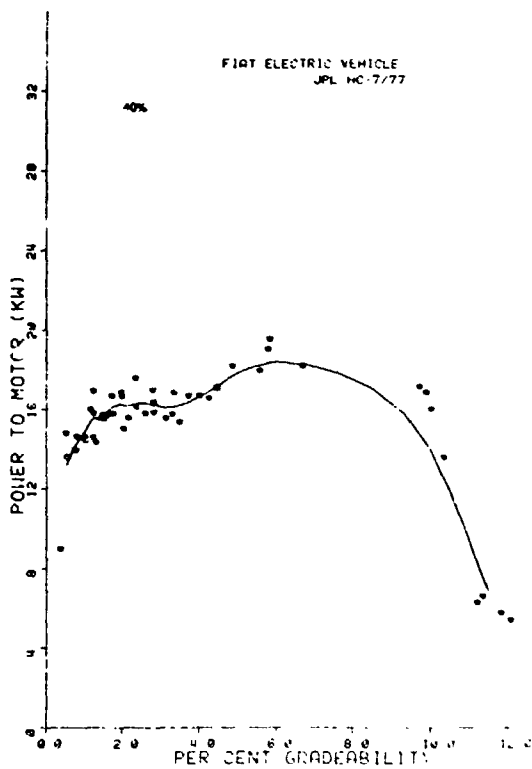
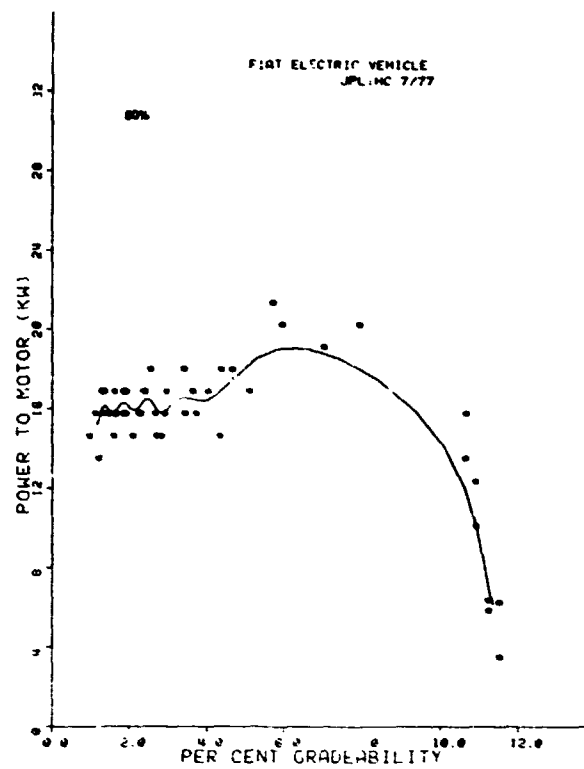
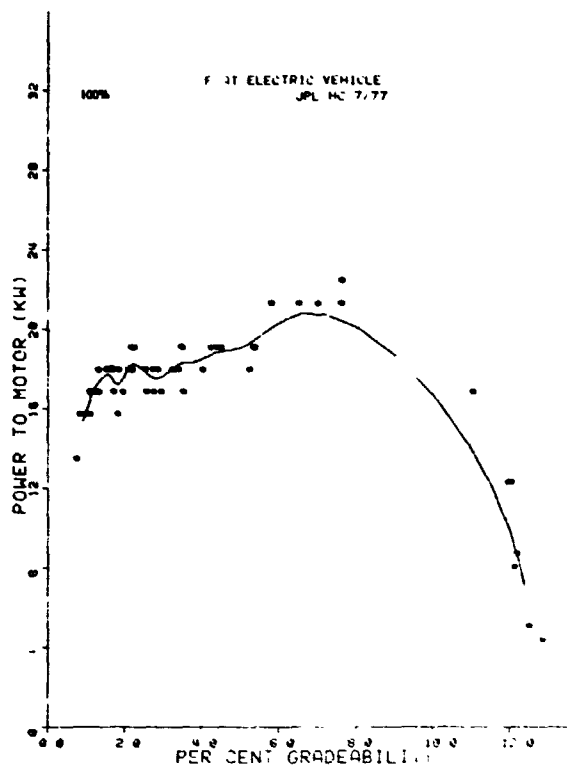


Figure 5.3.17. Motor Power vs. % Gradeability

In Table 5.3.1 the direction of run, grade, wind direction, and wind magnitude is tabulated for all the runs except those at the 30% charge level. The acceleration data used for the figures in this section is given in Appendix B.

Table 5.3.1. Wind and Grade Information

Run No.	Direction of Run	Grade	Direction of Wind	Velocity of Wind
100% 1	SE	downhill 0.500%	NE	4.8 Kph (3 mph)
2	NW	uphill 0.500%	NE	6.4 Kph (4 mph)
3	SE	downhill 0.500%	NE	5.6 Kph (3.5 mph)
4	SE	downhill 0.500%	NE	14.5 Kph (9 mph)
5	NW	uphill 0.500%	NE	11.3 Kph (7 mph)
80% 1	NW	uphill 0.500%	-	-
2	SE	downhill 0.500%	-	-
3	NW	uphill 0.500%	-	-
4	SE	downhill 0.500%	-	-
40% 1	SE	downhill 0.500%	N	3.2 Kph (2 mph)
2	NW	uphill 0.500%	NE-E	4.8 Kph (3 mph)
3	SE	downhill 0.500%	N-NE	2.4 Kph (1.5 mph)
4	NW	uphill 0.500%	N-NE	8.0 Kph (5 mph)
20% 1	SE	downhill 0.500%	W-SW	3.2 Kph (2 mph)
2	NW	uphill 0.500%	S-SW	0.8 Kph (0.5 mph)
3	SE	downhill 0.500%	W-SW	3.2 Kph (2 mph)
4	NW	uphill 0.500%	W-SW	2.4 Kph (1.5 mph)

The B-Cycle test was the only driving cycle the Fiat Van could perform. The C-Cycle test was just beyond the van's capabilities. In the velocity vs corrected time curves (Figure 5.3.2) for the acceleration test, the van appears to reach 30.6 Kph (19 mph) in about twenty seconds which would be sufficient acceleration for the C-Cycle. However, when the test was attempted on the large oval track, the vehicle failed to accelerate to the proper speed in the allotted time.

The inability of the van to accelerate normally could be attributed to an uphill grade, a rougher road surface condition, and/or a stronger than normal wind. The track where the C-Cycle test was attempted had an uphill grade of 0.228%. The road surface of the track for the C-Cycle was asphalt whereas the acceleration test was conducted on cement. The wind was also lower during the acceleration test than during the attempted C-Cycle test.

The range, number of driving cycles, and the energy to the various components of the van are summarized in Table 2.1 for the two B-Cycle tests. The range was determined when the vehicle could not accelerate to 30.6 Kph (19 mph) in twenty seconds. The average velocity for the first B-Cycle test (i.e., the test conducted on 5/31/77) was 29.2 Kph (18.1 mph). The second B-Cycle test had an average velocity of 25.4 Kph (15.8 mph). A calibration error resulted in the first B-Cycle test being run at a high velocity. The van was accelerated to a velocity of 39 Kph (24.5 mph) instead of 32 Kph (20 mph).

The results of the B-Cycle tests are summarized in Figures 5.4.1 through 5.4.14. Since the B-Cycle tests were conducted at different speeds, the beginning cycles and last cycle are shown for both

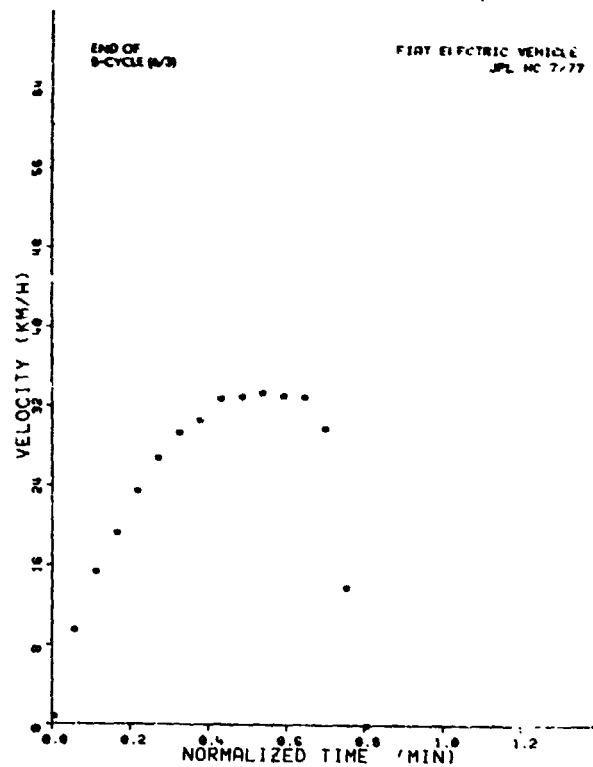
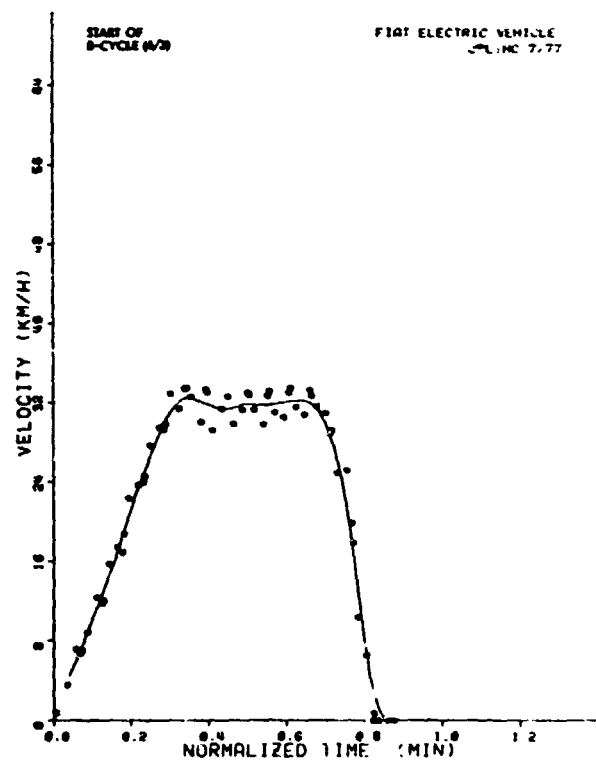
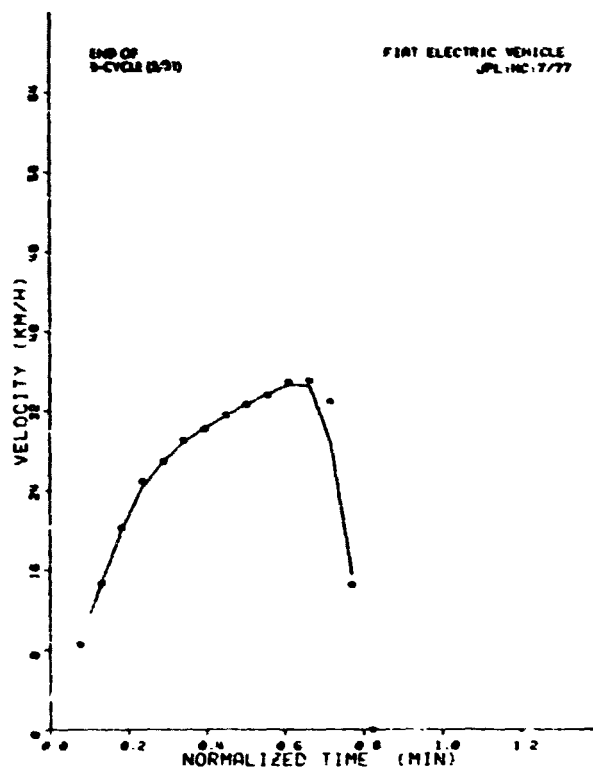
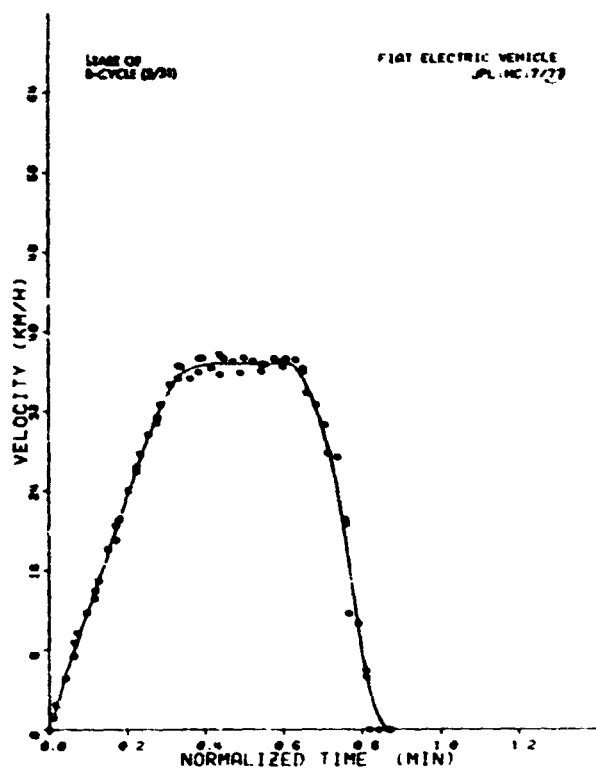


Figure 5.4.1. Velocity vs. Time (normalized)

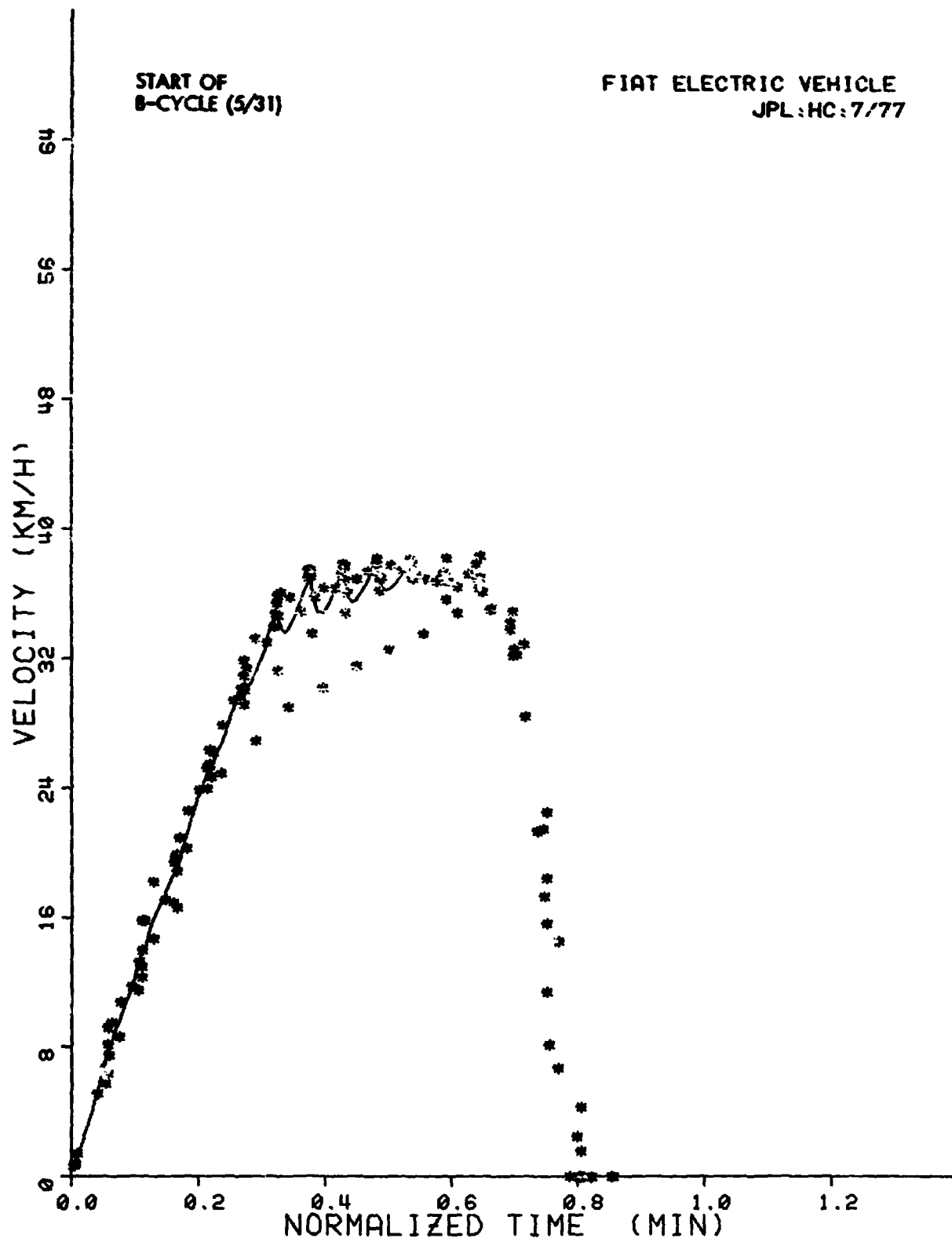


Figure 5.4.2. B-Cycle Battery Degradation

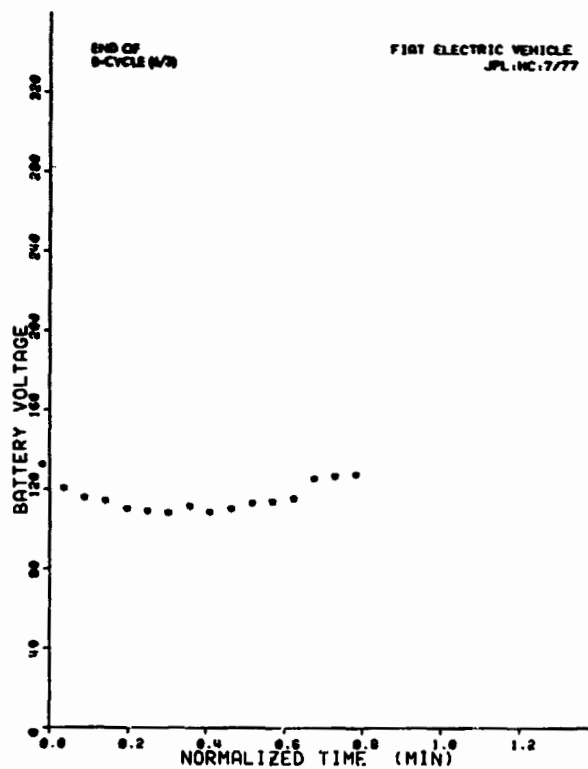
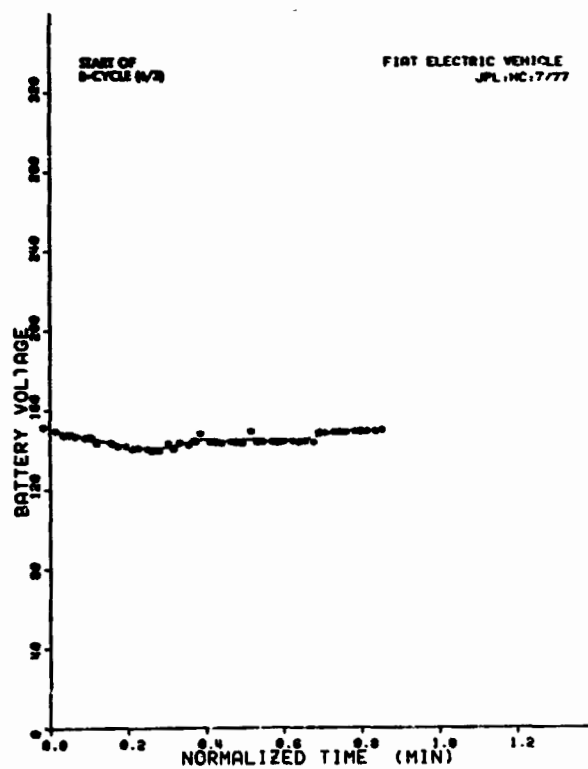
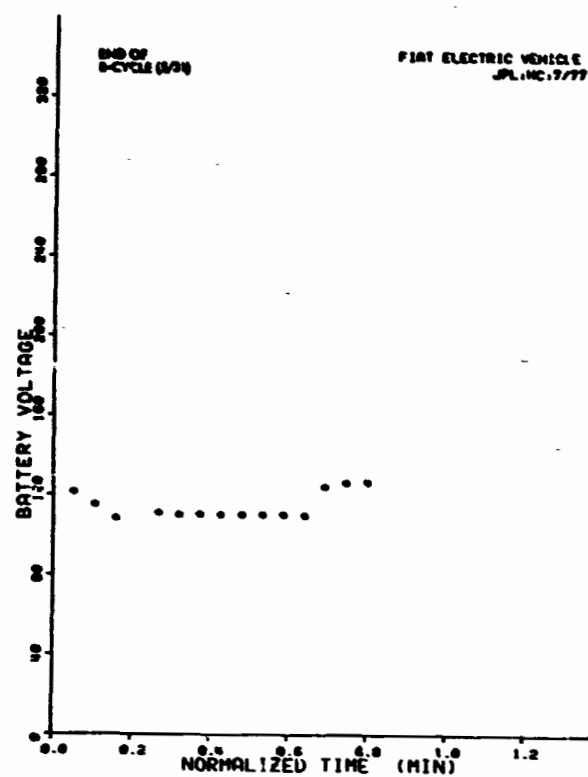
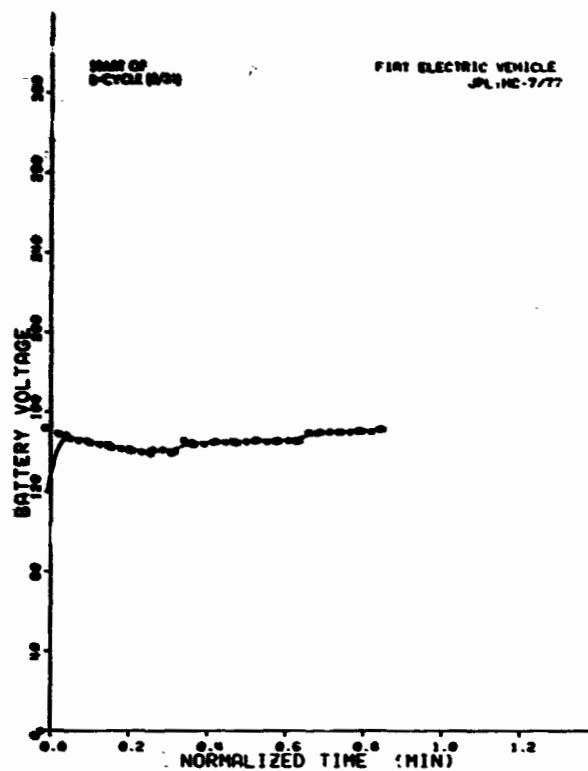


Figure 5.4.3. Battery Voltage vs. Time (normalized)

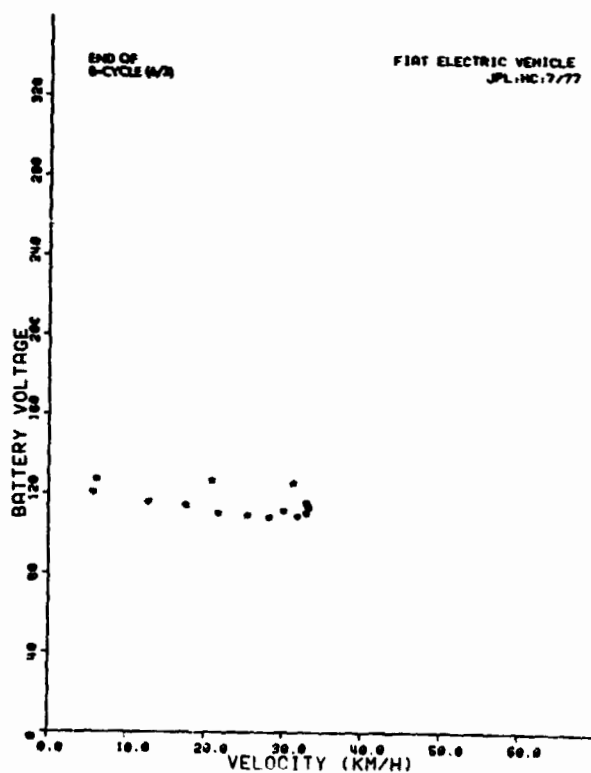
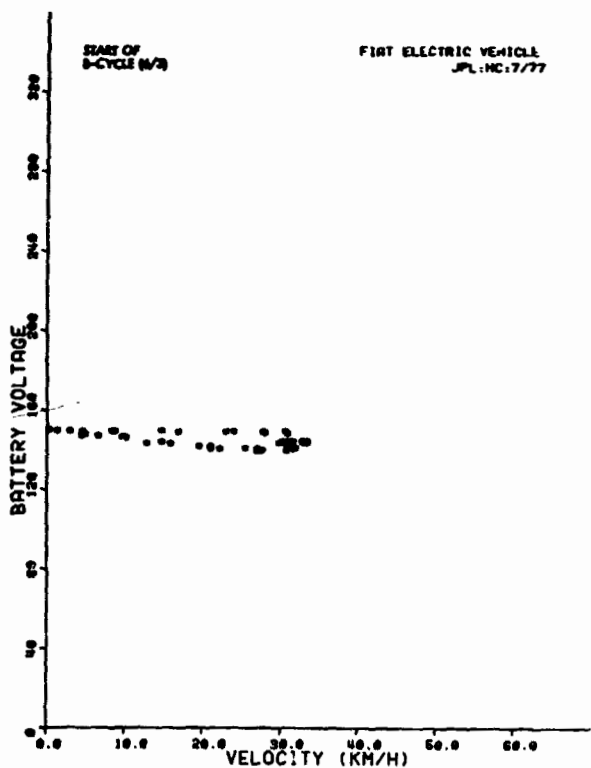
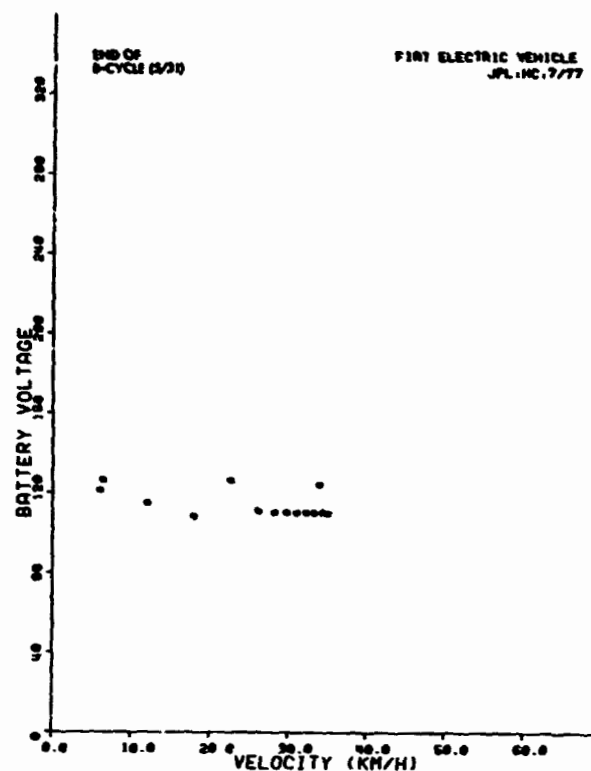
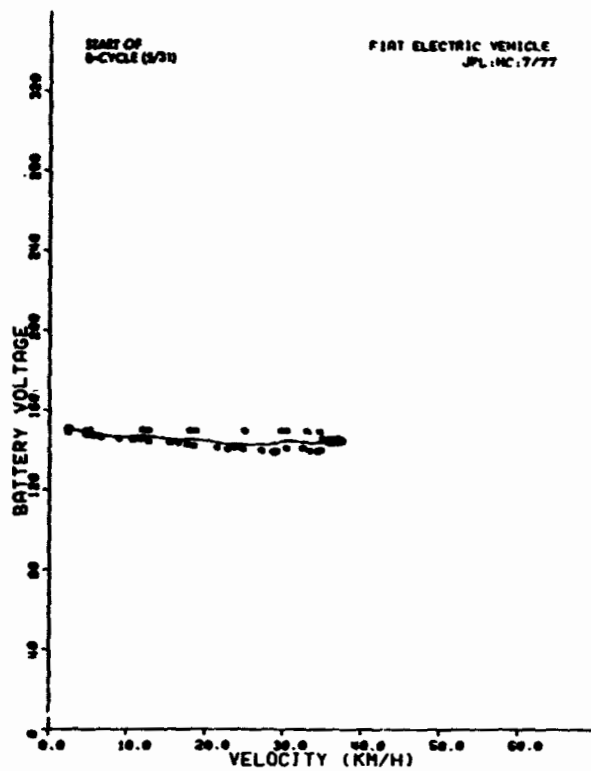


Figure 5.4.4. Battery Voltage vs. Velocity

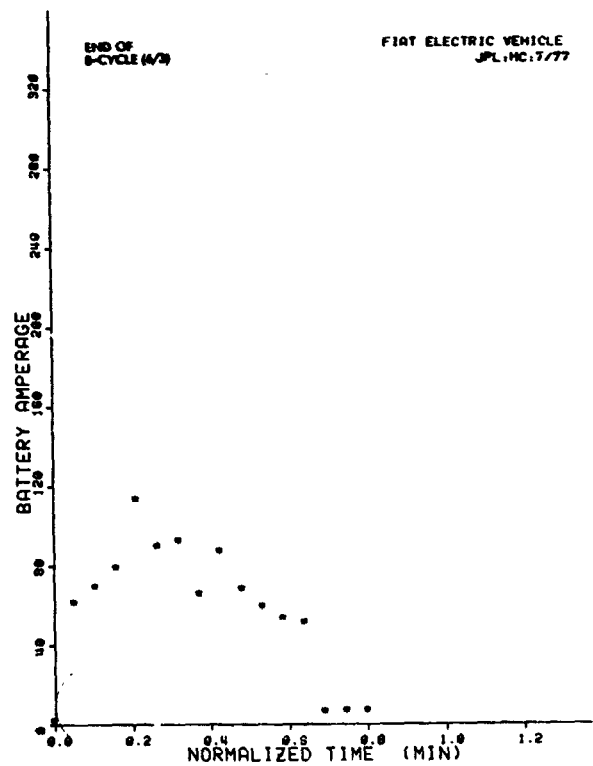
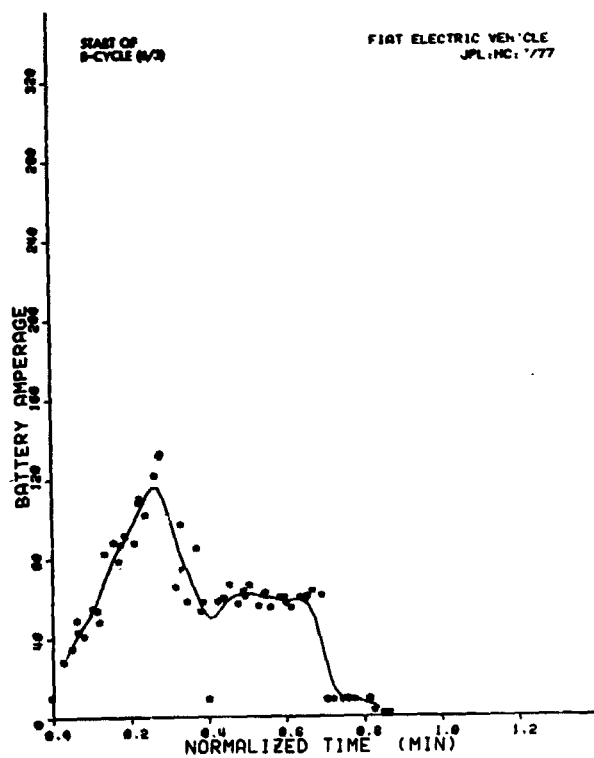
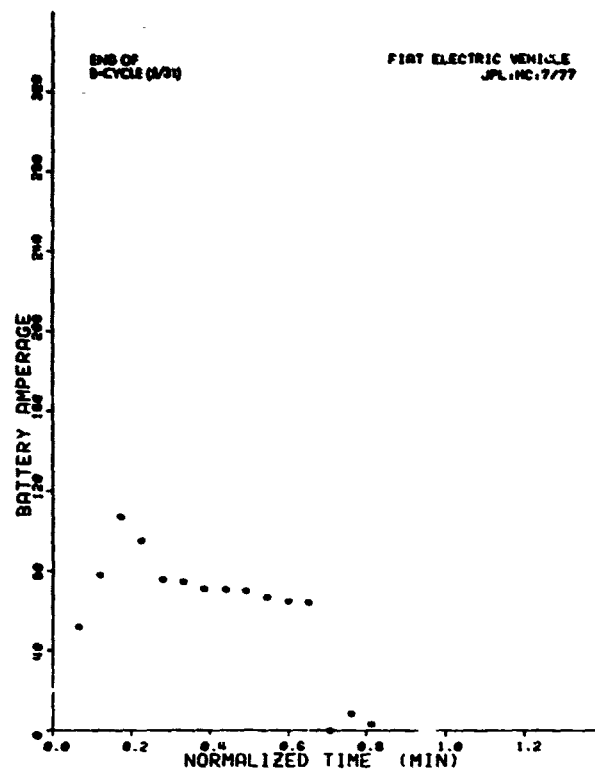
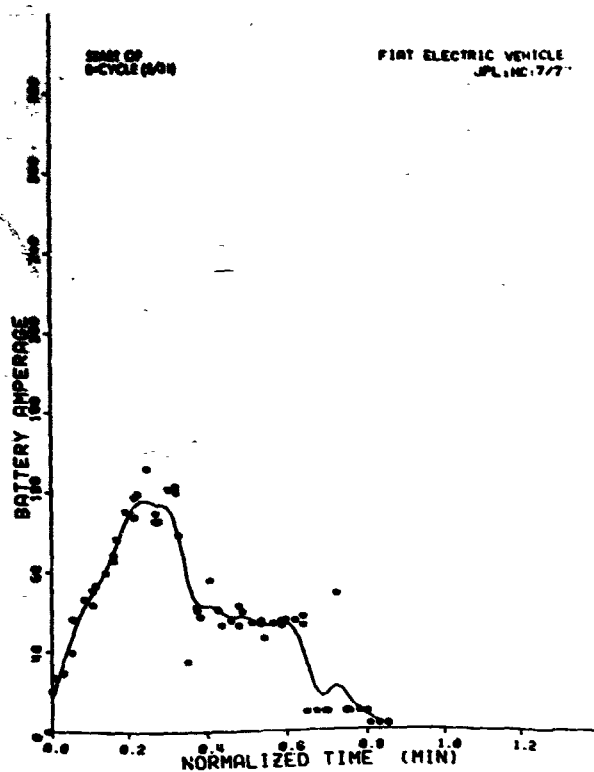


Figure 5.4.5. Battery Current vs. Time (normalized)

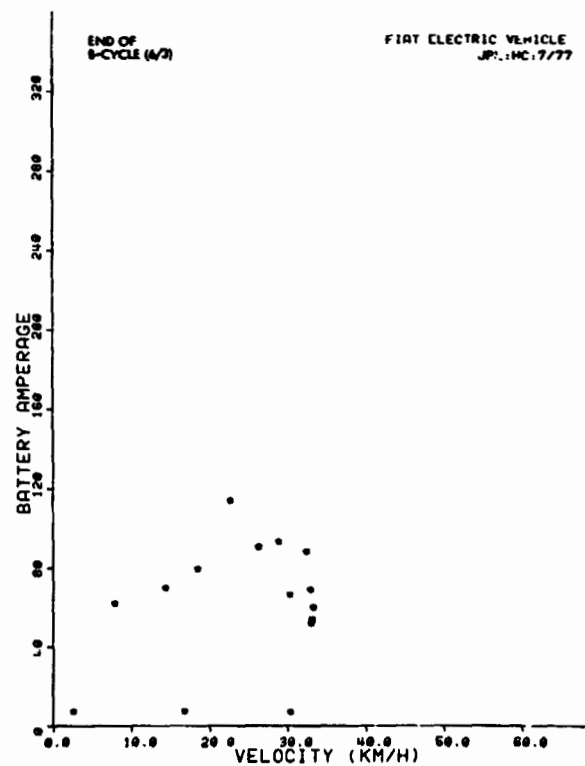
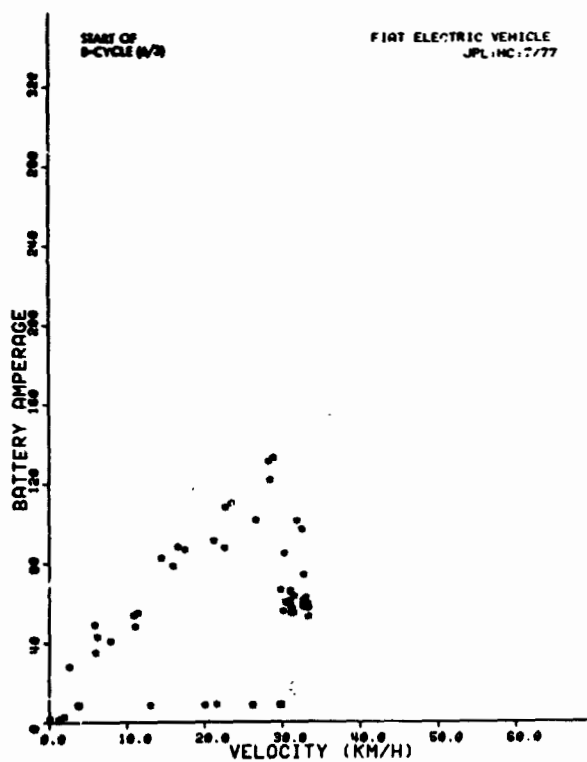
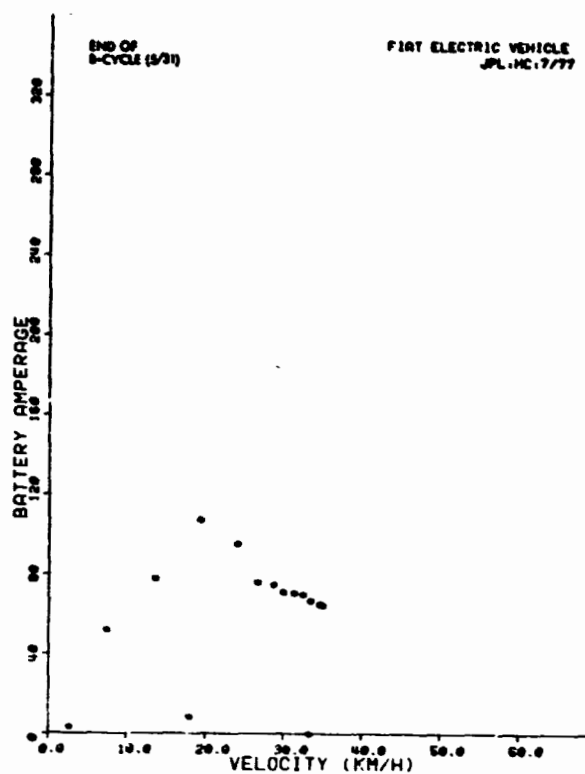
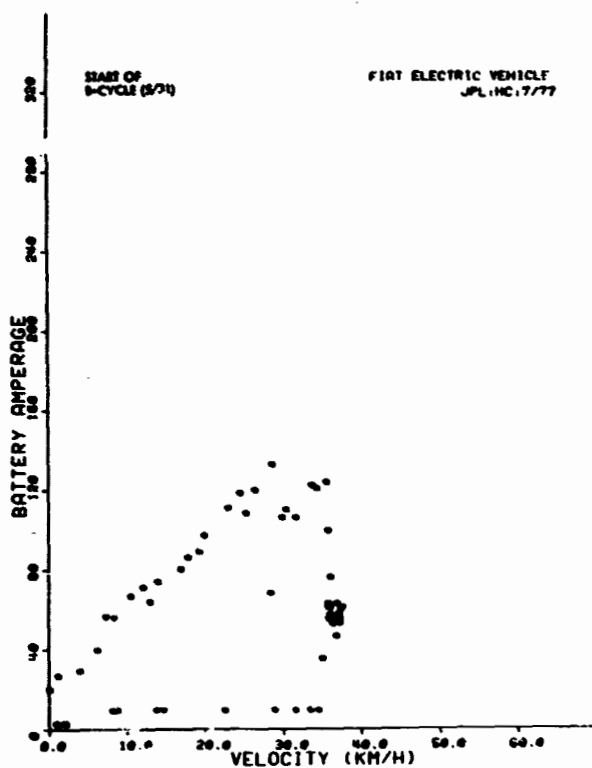


Figure 5.4.6. Battery Current v . Velocity

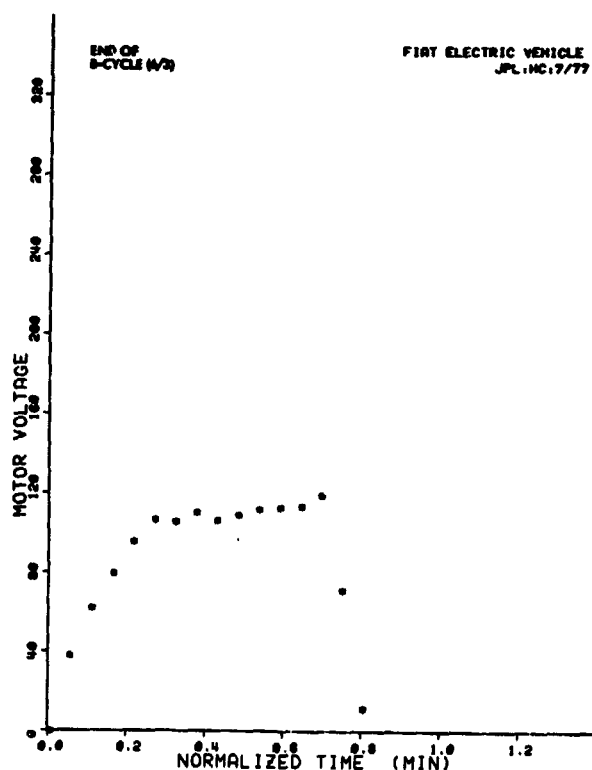
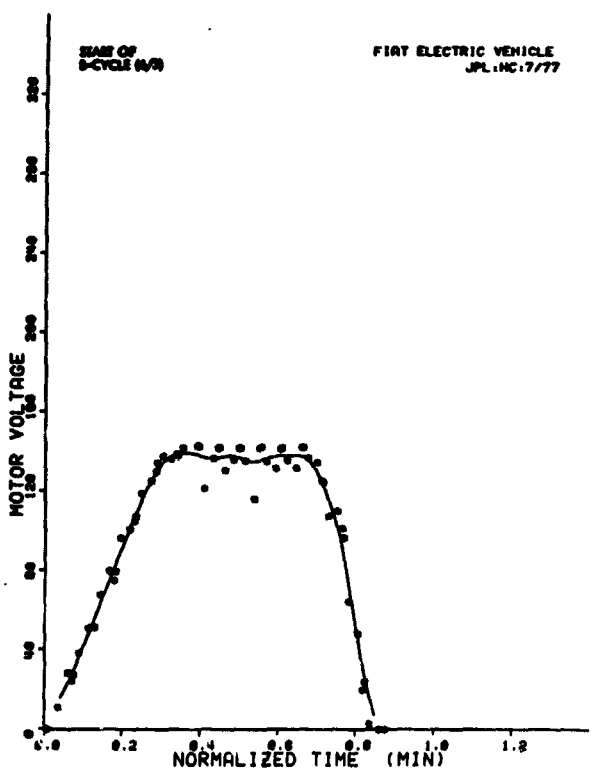
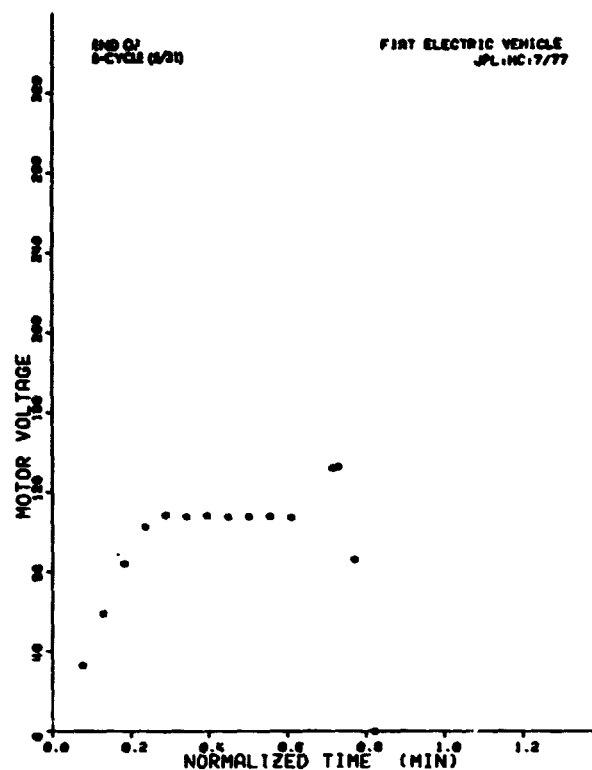
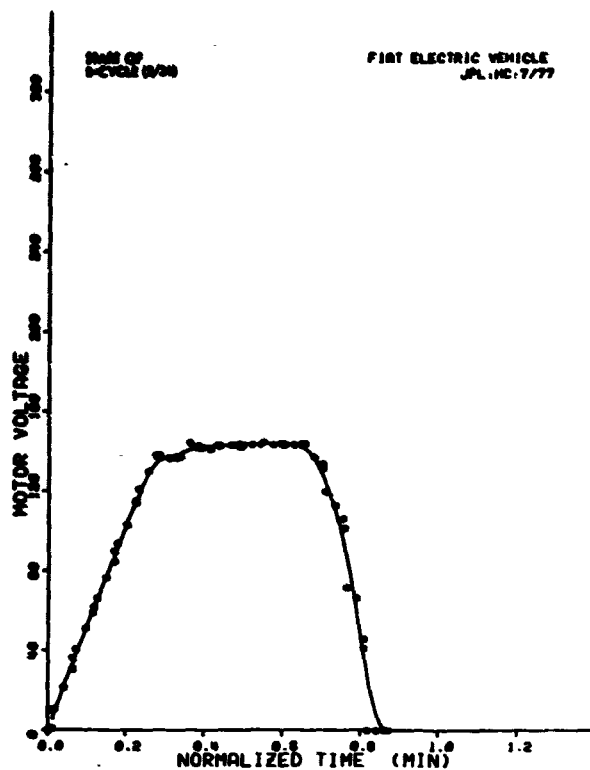


Figure 5.4.7. Motor Voltage vs. Time (normalized)

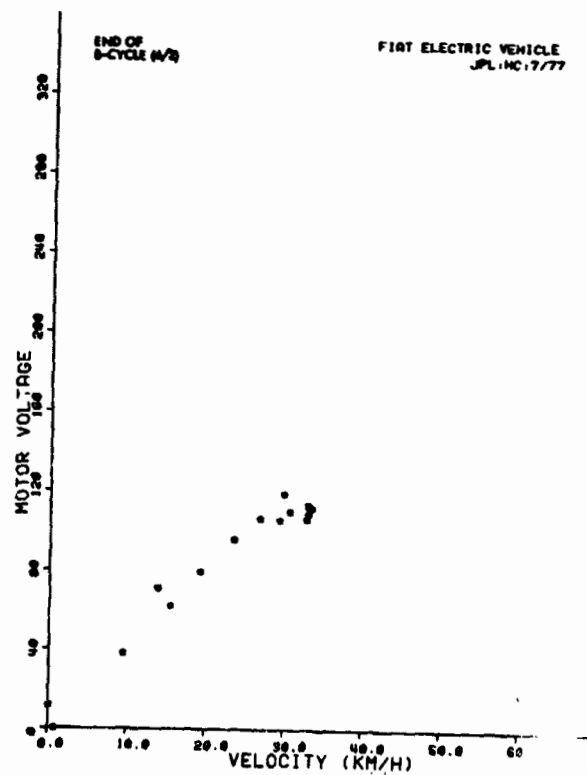
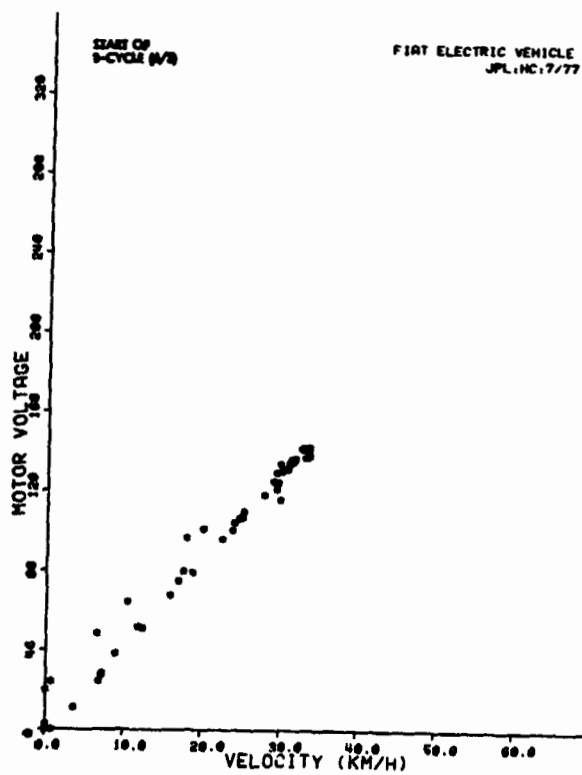
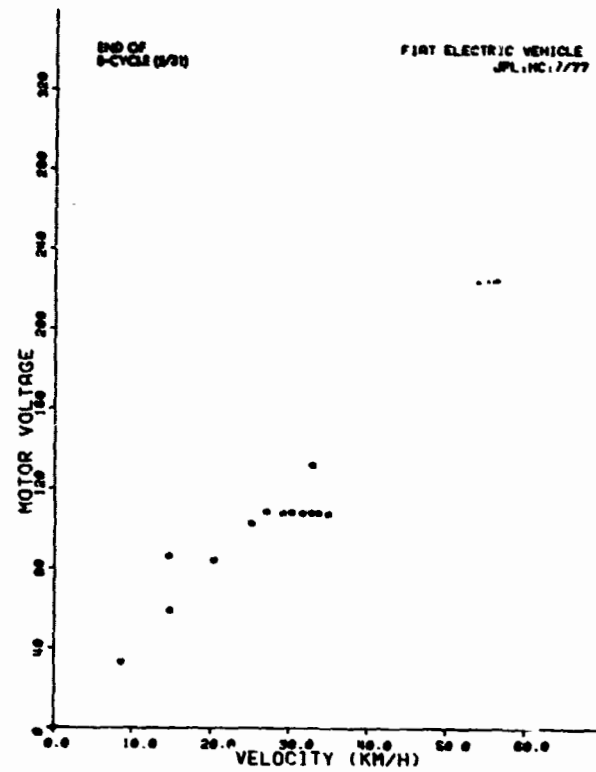
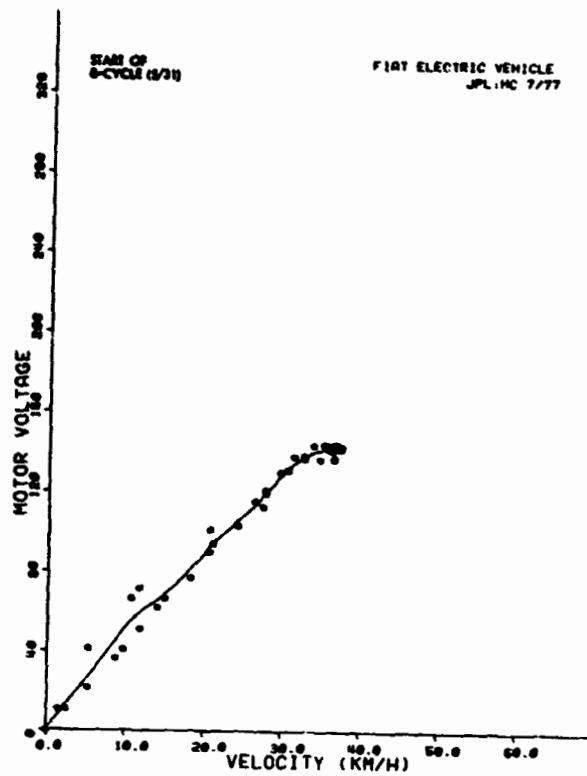


Figure 5.4.8. Motor Voltage vs. Velocity

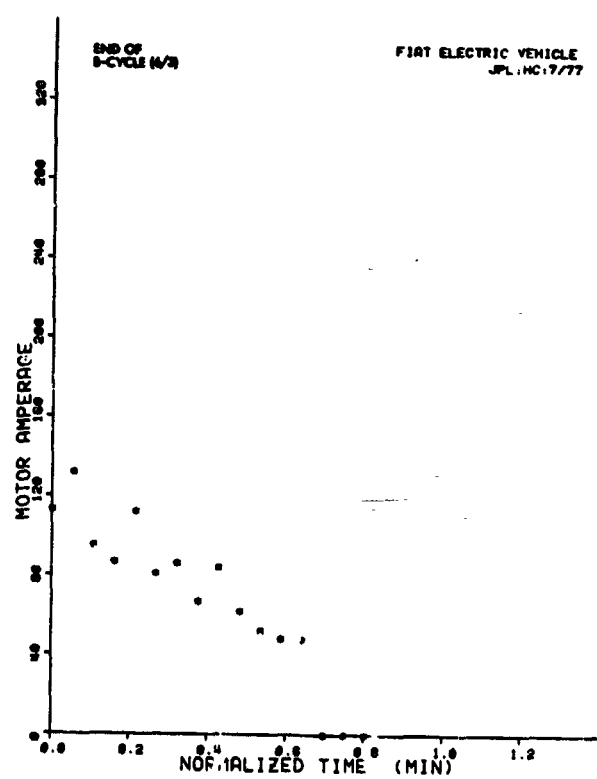
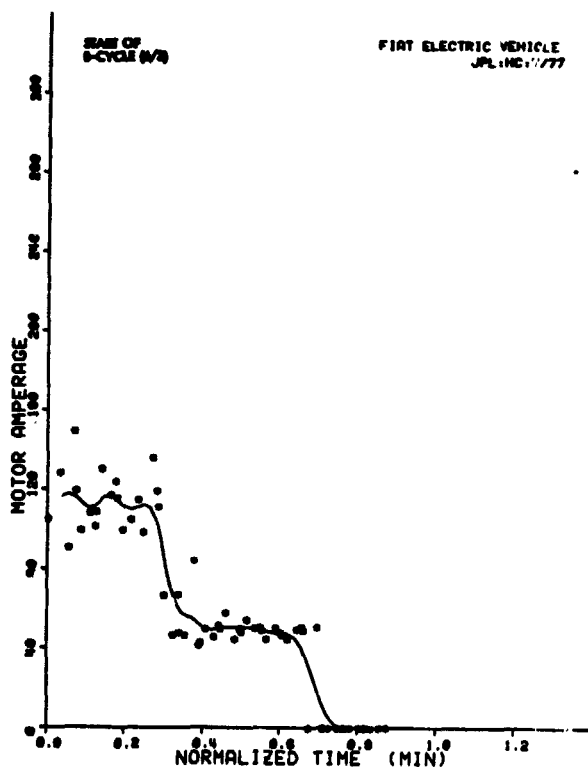
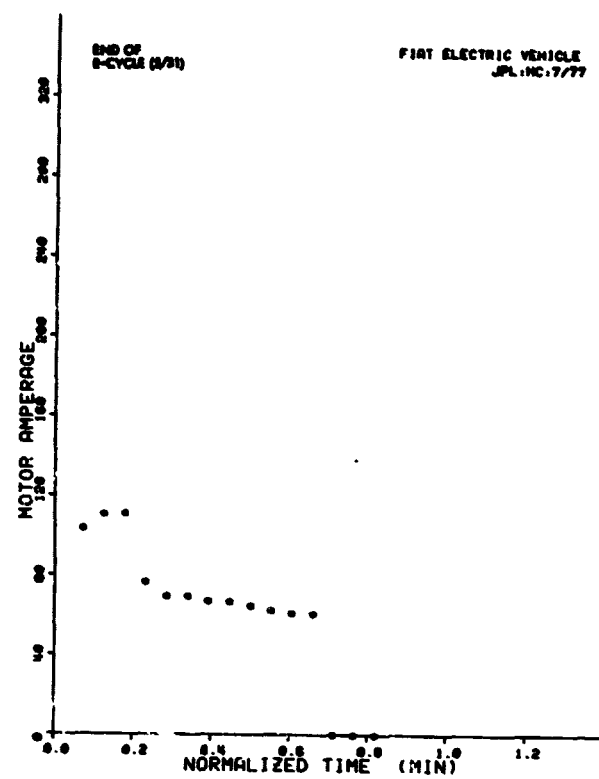
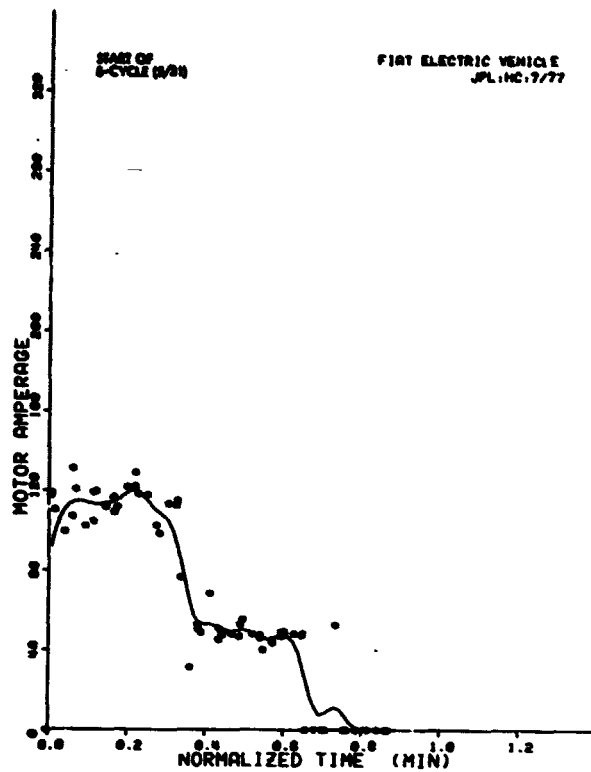


Figure 5.4.9. Motor Current vs. Time (normalized)

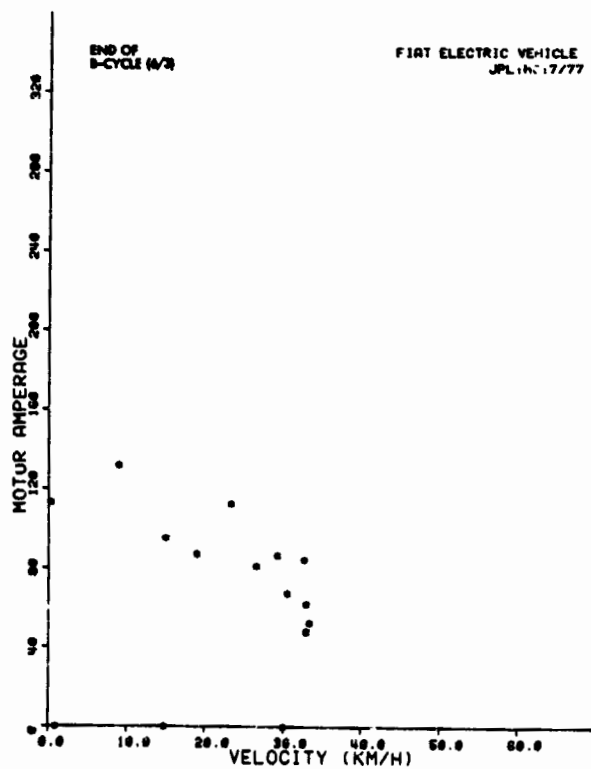
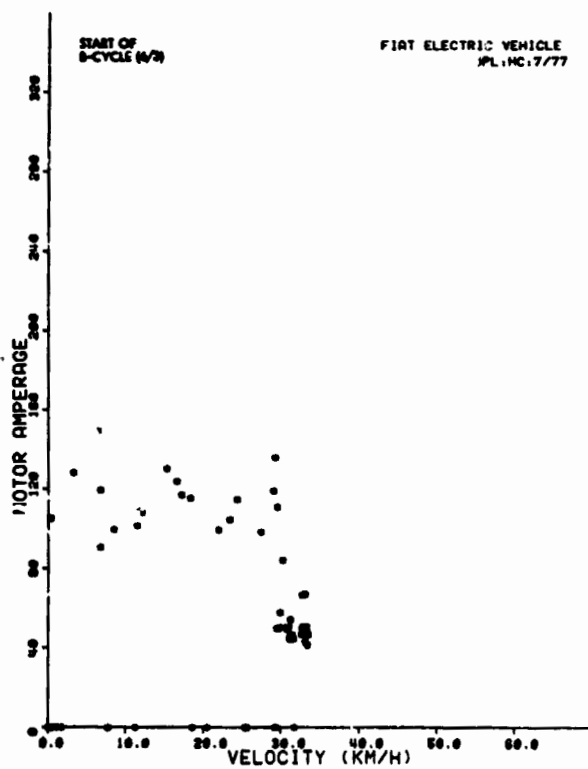
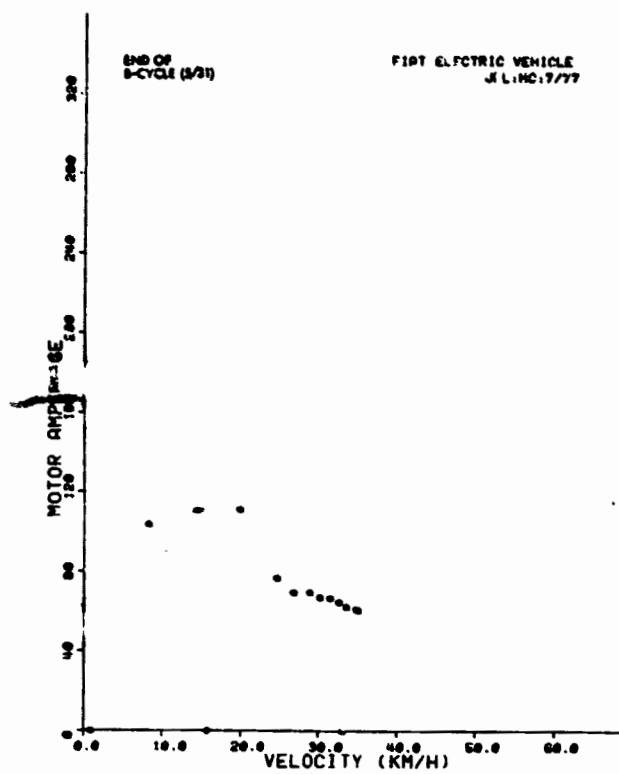
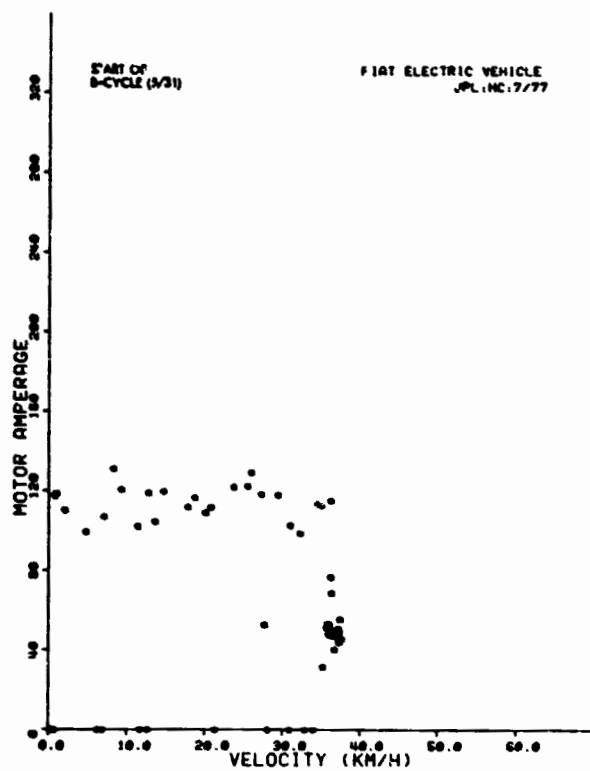


Figure 5.4.10. Motor Current vs. Velocity

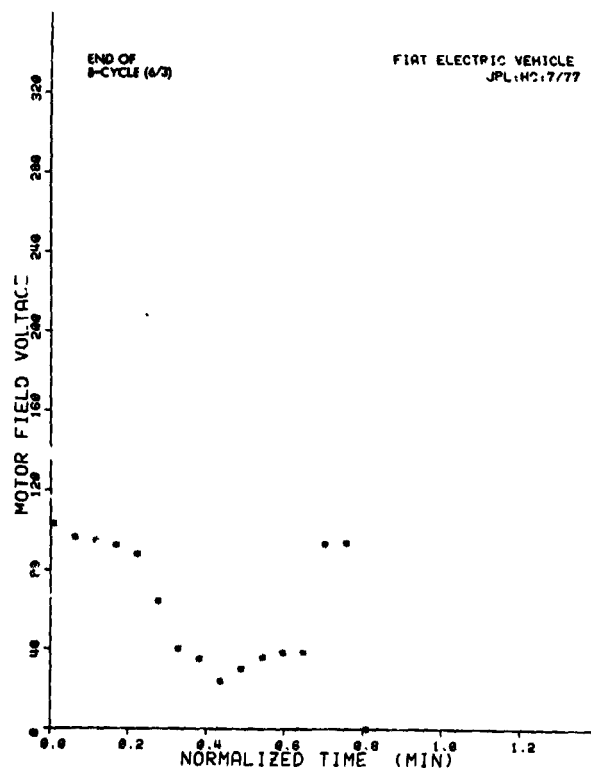
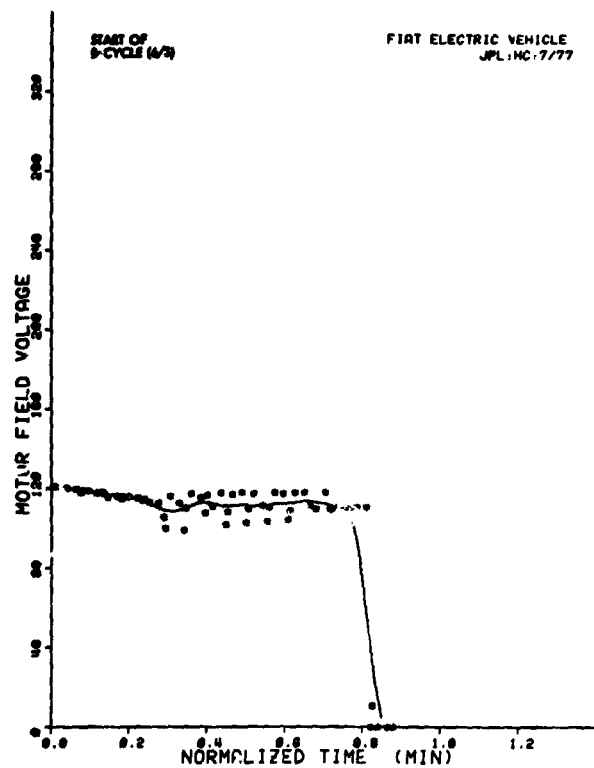
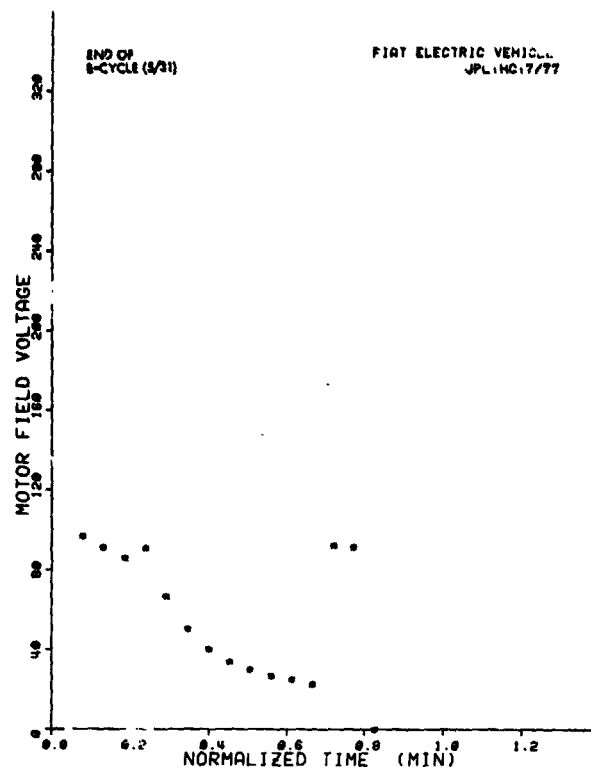
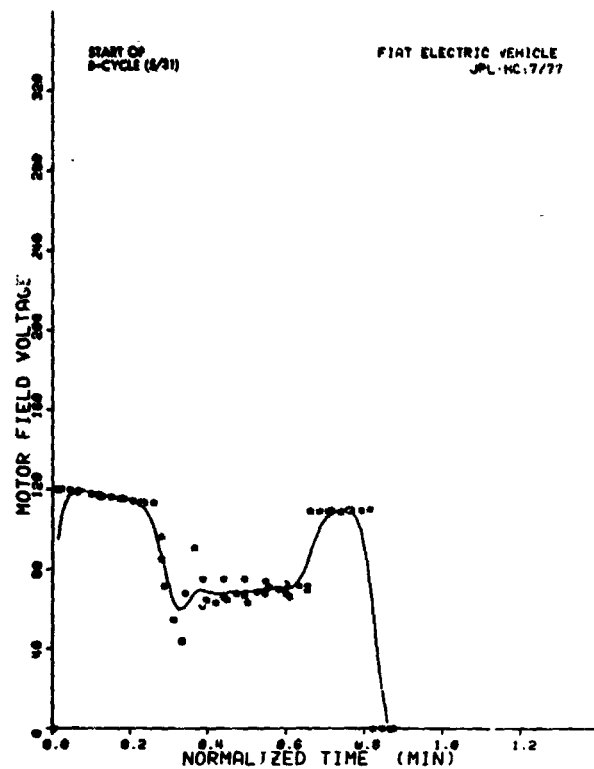


Figure 5.4.11. Motor Field Voltage vs. Time (normalized)

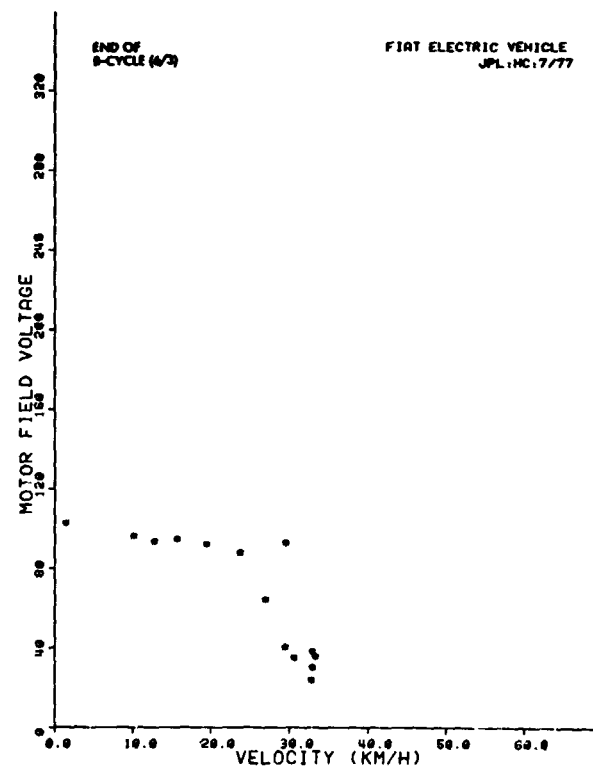
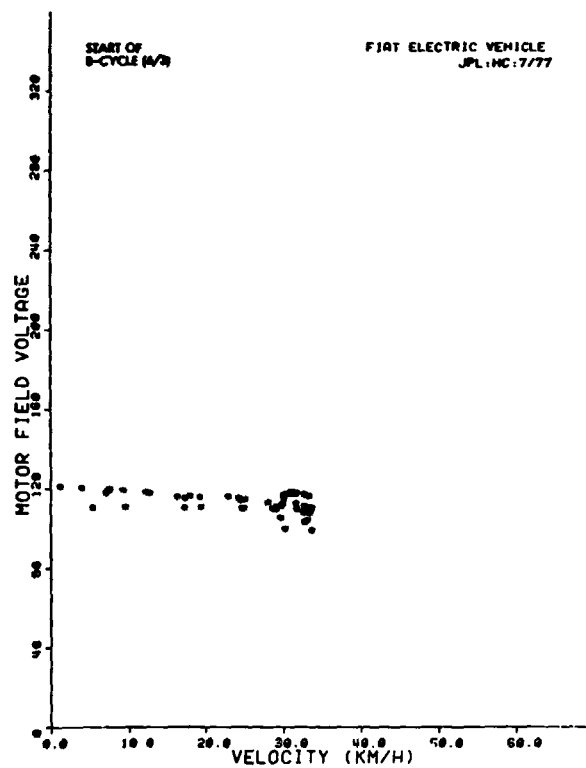
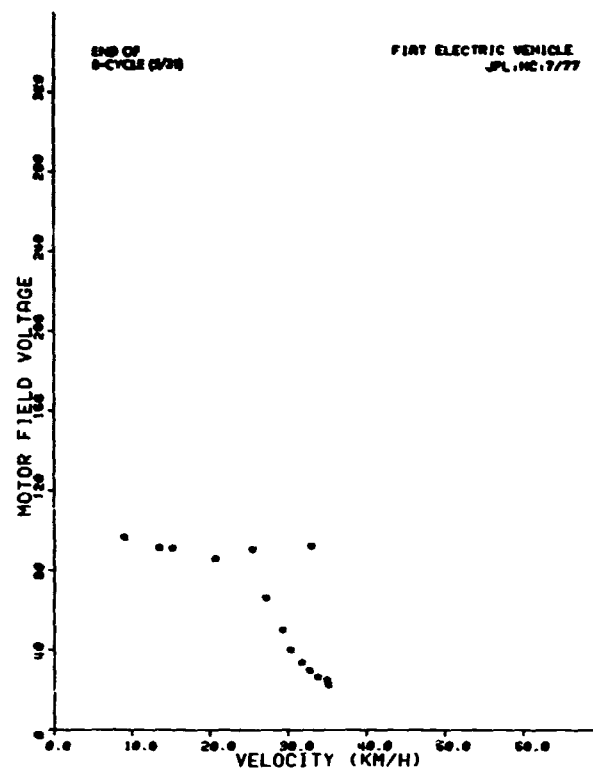
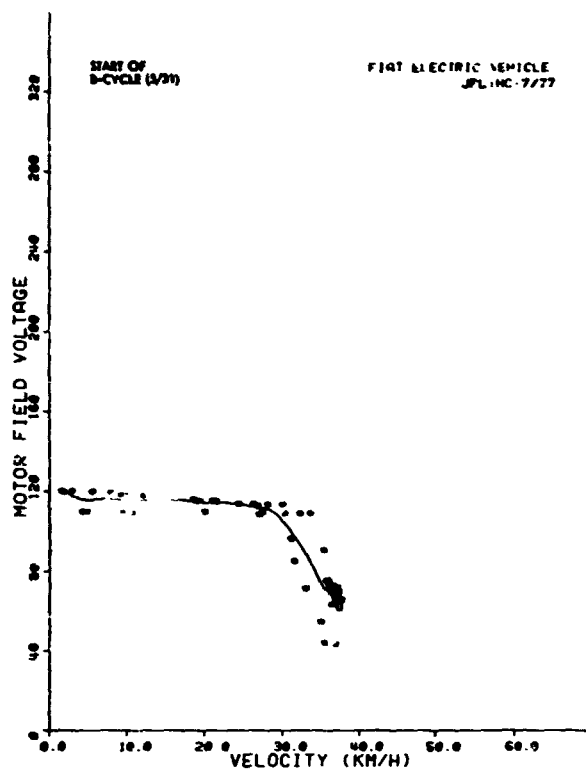


Figure 5.4.12. Motor Field Voltage vs. Velocity

C-2

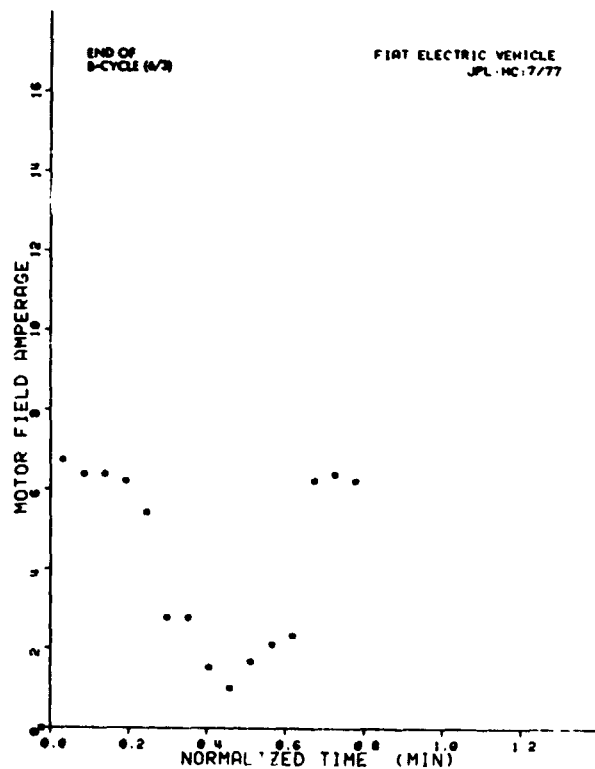
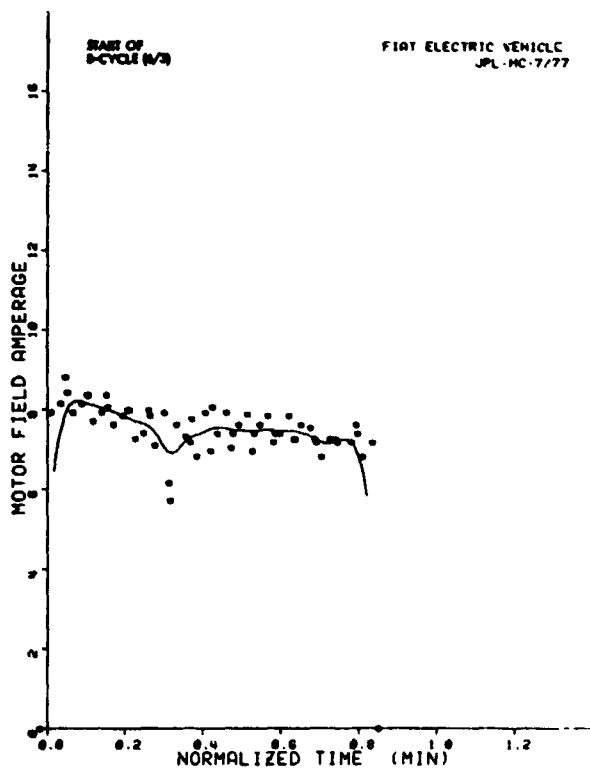
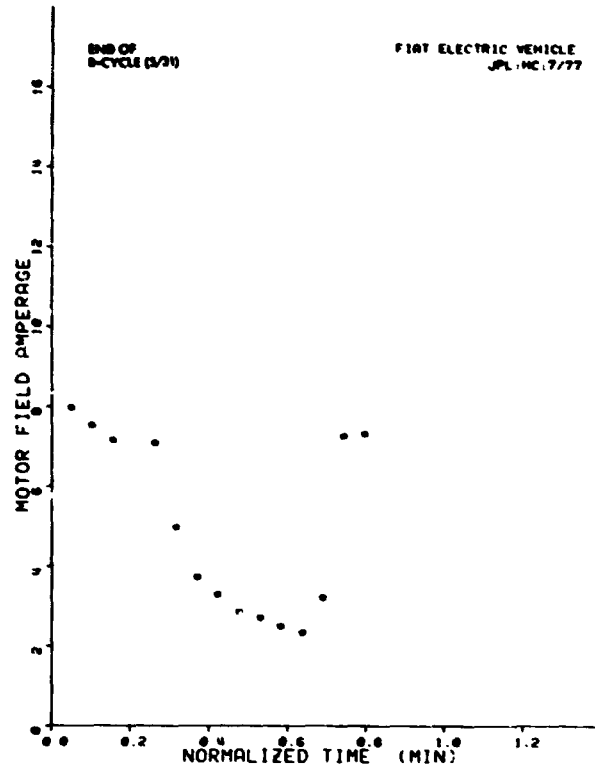
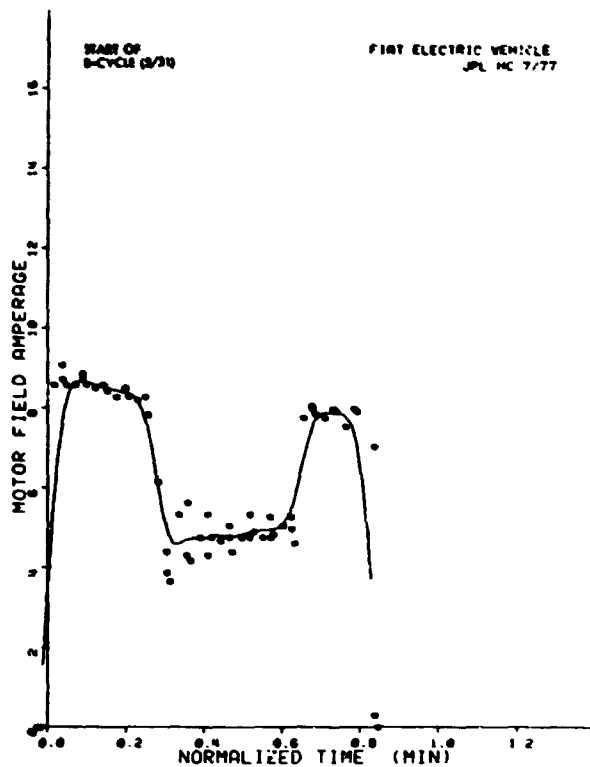


Figure 5.4.13. Motor Field Current vs. Time (normalized)

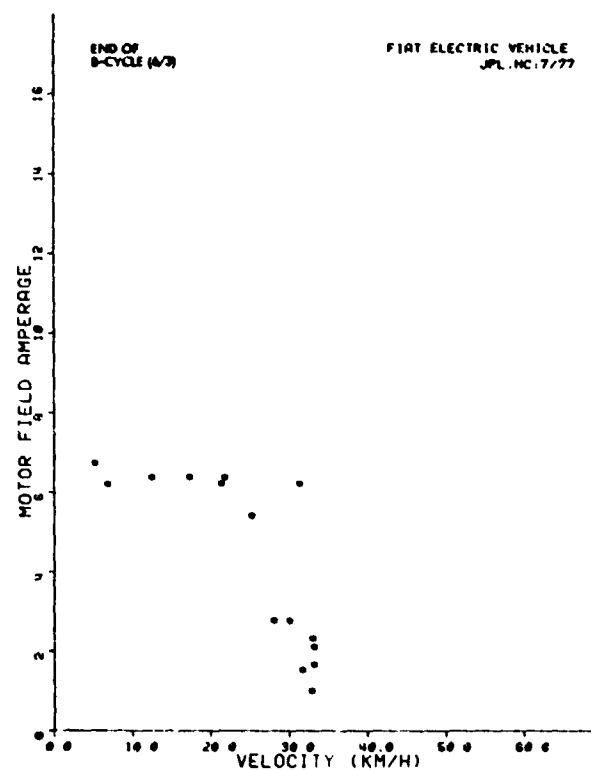
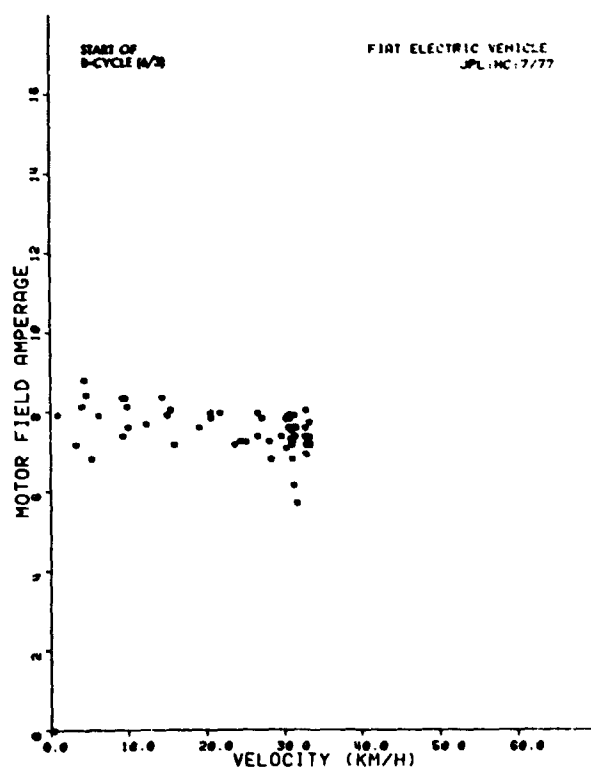
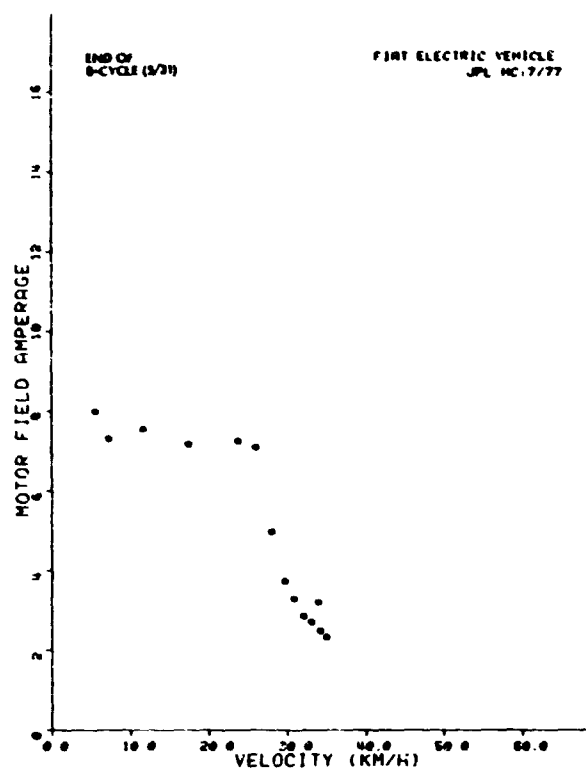
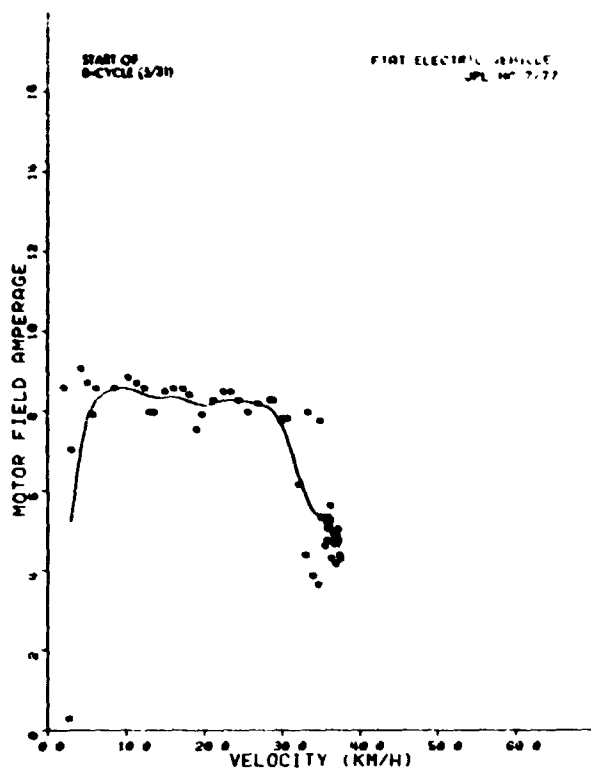


Figure 5.4.14. Motor Field Current vs. Velocity

tests in each figure. The first few cycles of both tests were erratic because the driver was inexperienced. The cycles chosen to best represent the average conditions for the beginning of the test were 5, 6, 7, and 9 for the first B-Cycle and 6, 7, 8, and 9 for the second B-Cycle. Only the last cycle was used to demonstrate conditions at the end of the test. In Figure 5.4.2 the last ten cycles of the first B-Cycle test are shown, and only the last two cycles deviate from the others. The last cycle is different enough from the second to the last cycle to prevent the use of even two cycles to characterize the end conditions.

Since the first B-Cycle was run at a velocity higher than specified, the question arises as to how many more cycles could have been completed had the test been conducted correctly. In Section 6 the total number of cycles for the first B-Cycle test, if that test was driven at the proper velocities, was estimated to be 120. The calculation was based on a motor efficiency which was assumed to be the same as the one found for the second B-Cycle test.

SECTION 6

ENERGY FLOW AND PERFORMANCE MODELS

An energy flow diagram of the electric vehicle is shown in Figure 6.1.1. All the blocks of the figure will be characterized by an efficiency except for the regenerative braking. The van produced very little regenerative power during the B-Cycle testing. The regenerative braking system employed by Fiat contains a relay, called the brake relay in Figure 3.5, which closes at about the base speed, 25 Kph (15.5 mph). When the relay closes it opens a path to ground through a resistor giving the braking effect of an internal combustion engine. The power generated by the motor is dissipated in the dynamic braking resistor (Figure 3.5) for velocities below the base speed. In the B-Cycle tests the braking occurs after the vehicle has coasted for four seconds from a velocity of 32 Kph (20 mph). The velocity at which braking begins is not much higher than the base speeds so that very little power is returned to the batteries.

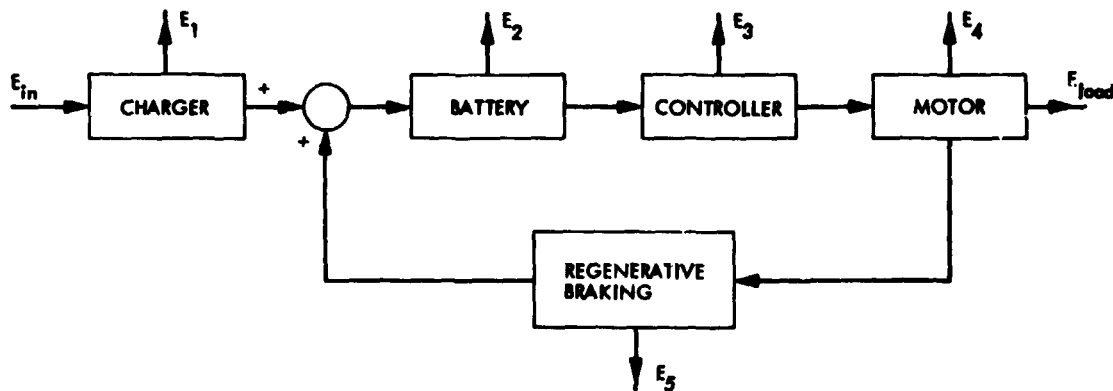


Figure 6.1.1. Energy Flow Diagram

6.1 CHARGER AND BATTERY

The charger efficiency and the battery efficiency are not independent since they are both a function of the charging cycle. The energy loss in the charger, E_1 (Figure 6.1.1), is due to resistive losses, IR^2 , and voltage losses, IV (i.e., V is a constant voltage drop). The energy loss in the battery, E_2 , is due to the battery's internal resistance; back potential losses resulting from the diffusion layer; and hydrolysis. The charger should be compatible with the battery so that a charging cycle which is efficient for the battery is also efficient for the charger.

The battery manufacturer, Magnetti-Marelli, supplied a charging curve, Figure 6.1.2, which could not be followed with the

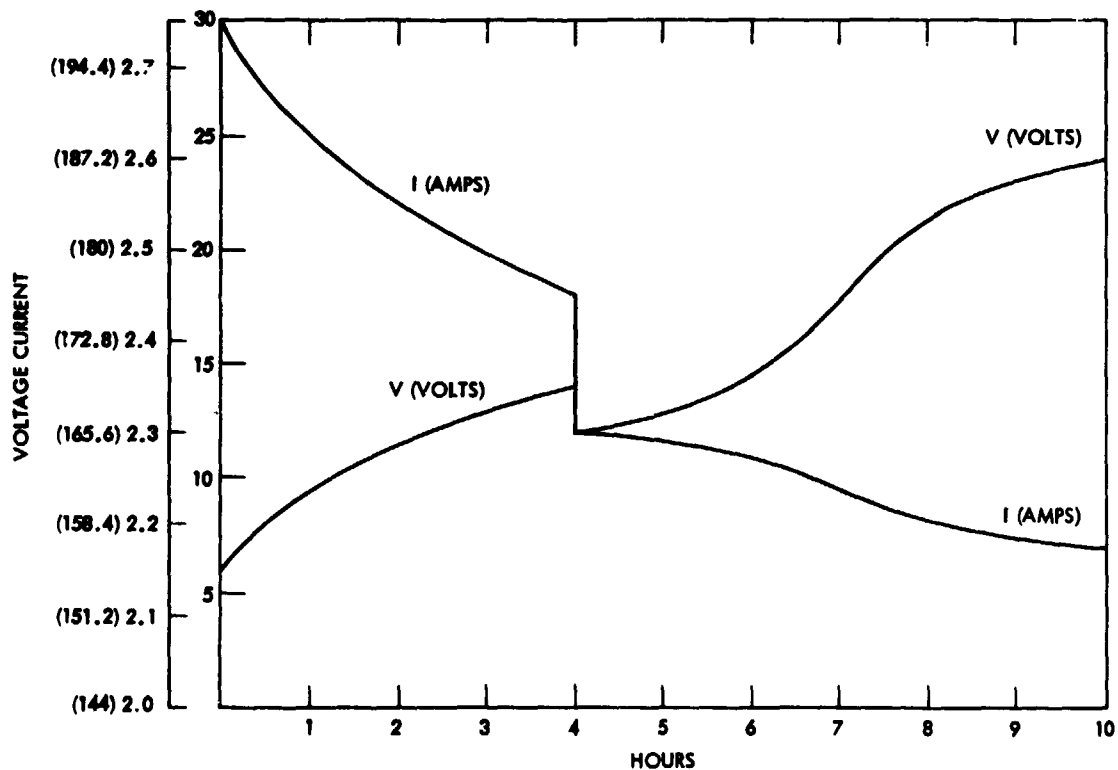


Figure 6.1.2. Magnetti-Marelli Charging Curve

charger furnished by Fiat. If the charging curve could have been followed, the total charge into the battery would have been 148 amp-hrs and the energy to the battery would have been 24.7 Kw-hrs.

The charger and battery data is listed in Table 6.2.1. The actual energies used in charging the batteries are given in columns one and two of the table. The energy into the battery fluctuated widely because of the initial necessity to overcharge the batteries to equalize the cells and also because of operator error. A charging curve which was different from the battery manufacturers recommended curve but which produced a charge of 150 amp-hrs was developed. Unfortunately, the battery charger had to be hand operated during the charging cycle and this introduced operator error.

Since 150 amp-hrs was the intended charge, the amount of energy used to produce this charge will be considered the energy to the battery, column five of Table 6.1.1, and the overcharge will be subtracted. The charger efficiency was calculated to be 89% so that the energy to the charger, column four, is obtained by dividing the energy to the battery by 0.89. The efficiency of the charger is based on a charge where a wattmeter measured the energy from the wall. The wattmeter was used because the resolution of the energy meter used for measuring the energy to the charger was ± 1 Kw-hr. However, the accuracy of the wattmeter might not be much better since the current sensor of the wattmeter was temperature sensitive and also had a resolution problem; it was rated at 150 amps full scale but the currents during charging were below 20 amps. The charger efficiency and thus the energy to the charger is not very accurate. The energy listed in column four of Table 6.1.1 will be used to calculate the vehicle energy economy.

Table 6.1.1.1. Energy Flow for Charger and Battery

Test	Date	Actual Charging			Charging to 150 amp-hr			Battery Output		
		1	2	3	4	5	6	7		
		Energy to Charger (Kw-hr)	Energy to Battery (Kw-hr)	Amp-hrs to Battery (Amp-hr)	Energy ¹ to Charger (Kw-hr)	Energy to Battery (Kw-hr)	Energy from Battery (Kw-hr)	Amp-hrs from Battery (Amp-hr)		
25 mph Range	5/19	-	-	-	-	-	12.0	86.7		
25 mph Range	5/21	40	33.6	188.5	29.4	26.2	12.9	91.7		
25 mph Range	5/26	30	29.4	168.0	29.2	26.0	12.6	90.6		
35 mph Range	5/23	36	29.9	170.0	29.2	26.0	11.1	80.8		
35 mph Range	5/25	29	26.9	153.0	29.6	26.3	11.6	83.7		
B-Cycle with regen braking	5/31	31	27.5	153.9	29.9	26.6	12.3	89.4		
B-Cycle with regen braking	6/3	28	27.1	155.8	29.2	26.0	11.9	90.4		

¹The energy to the charger is calculated from the battery energy by assuming a charger efficiency of 89%.

¹The energy to the charger is calculated from the battery energy by assuming a charger efficiency of 89%.

The charge into the battery, even assuming 150 amp-hrs, greatly exceeds the charge out of the battery. It is important to determine the best way to charge a battery. If the battery is overcharged, the efficiency is decreased while if the battery is undercharged, the performance suffers. The amp-hr efficiency of the battery is given in Table 2.2 along with the battery energy efficiency. The efficiency calculations are based on the 150 amp-hr charging cycle.

6.2 CONTROLLER

The efficiency of the controller for the various tests is shown in Table 2.2. For both the 40 Kph (25 mph) and 56 Kph (35 mph) range tests the controller efficiency was about 91% while for the B-Cycle tests it was slightly lower at 87%.

6.3 MOTOR

The efficiency of the motor is difficult to determine since the energy to the load is not recorded. The load energy must be computed from the data obtained during the coast down tests. Since the wheels were disconnected from the drive train during the coast down test, the energy losses in the drive train will add to the energy losses of the motor, E_h in Figure 6.1.1.

If regenerative braking is not used so that the kinetic energy of the vehicle is not recoverable, the energy consumed can be calculated by integrating the left hand side of eqn. (5.3.1a).

$$E_{load} = \int F dx = M \int (\dot{v} + A' + B'v + C'v^2) dx \quad (6.3.1)$$

The load energy can be broken up into the kinetic energy, the road energy consumed during acceleration, and the road energy consumed at constant speed.

$$E_{\text{load}} = M \frac{v_o^2}{2} + M \int_0^{t_f} (A' + B'v + C'v^2) v dt$$

$$+ M (A' + B'v_o + C'v_o^2) d$$

where

v_o = constant speed characterizing test

d = distance traveled at constant speed

t_f = time to accelerate to constant speed

and

A', B', C' given by eqn. (5.2.7)

when

$$v = \frac{v_o}{t_f} t$$

$$E_{\text{load}} = M \frac{v_o^2}{2} + M (A'/2 + B'v_o/3 + C'v_o^2/4) v_o t_f$$

$$+ M (A' + B'v_o + C'v_o^2) d \quad (6.3.2)$$

In the range at constant speed tests, the road energy consumed during acceleration is negligible (i.e., $v_o t_f \ll d$). For the B-Cycle the quantities $v_o t_f$ and d should be equal (i.e., $v_o t_f = d$). The first B-Cycle test was run at a high velocity, 39 Kph (24.5 mph) instead of 32 Kph (20 mph), because of a calibration error.

The calculated load energy for the various tests is give in Table 6.3.1. The energy efficiency of the motor, which is based on the calculated load energy, is listed in Table 2.2. If the first B-Cycle test had been run at the correct velocity, and if the efficiency of the second test is assumed for the first, then the energy to the load would have been 5.35 Kw-hr and 120 B-Cycles would have been completed.

Table 6.3.1. Motor Efficiency

Test	25 mph Range Tests			35 mph Range Tests		B-Cycles	
	5/19	5/21	5/26	5/23	5/25	5/31	6/3
Energy to Motor (Kw-hr)	10.94	11.86	11.43	10.10	10.60	10.70	10.30
Energy to Load (Kw-hr)	8.70	9.1	8.86	8.94	8.98	Total 6.75 1 cycle 0.062	Total 5.15 1 cycle 0.044
Energy Efficiency of Motor	80%	77%	78%	89%	85%	63%	50%

SECTION 7

OBSERVATIONS AND CONCLUSIONS

In this report the electric car components shown in Figure 6.1.1 were examined. The charger furnished by Fiat was not the charger usually used with the van, and it had to be hand operated over the charging cycle. The batteries were new, had not been deep cycled, and the cells were not initially equalized. The batteries were only forty to fifty percent efficient. The regenerative power flowing to the battery from the motor during the B-cycle tests was negligible. A C-Cycle, where a higher velocity is attained than during the B-Cycle, might have provided a better test for the Fiat regenerative braking system since the system does not return energy to the battery below 25 Kph (15.5 mph). The C-Cycle was, unfortunately, just beyond the capability of the van. The controller and motor, which incorporated both a shunt and series field, operated well and was efficient.

The load on the motor, which is needed to determine the motor efficiency, was calculated from the coefficients obtained in the coast down test. Since the motor was disconnected from the wheels after the drive train, the drive train losses are included with the motor losses in efficiency calculations. The accuracy of the coefficients is sensitive to the slope and road surface of the tract; the wind; and the time step of the data recording system. Since the motor can have a high efficiency, the coefficients should be known more accurately. The efficiency of this motor was high for the constant speed tests but fell during the B-cycle tests. A considerable amount of power was consumed by the shunt field at the lower velocities.

The overall energy efficiency of the van was low (Table 2.2). The low overall efficiency is attributed to the low battery efficiency. The charging curve supplied by Fiat produced a 150 amp-hr charge to the battery. The amount of charging actually needed by the batteries is questionable. The amp-hr efficiency of the batteries was low which means that a lot of hydrolysis was occurring either during charging or discharging. The charging of batteries, and for that matter, the overall maintenance of batteries, is a major problem area of electric vehicles and should be investigated more thoroughly.

APPENDIX A
COAST DOWN DATA

EGN. PTS.

ORIGINAL PAGE IS
OF POOR QUALITY

Table A.2. Velocity vs. Time (corrected)

E.G.N. PTS.

	RUN #1		RUN #2		RUN #3		RUN #4		RUN #5		RUN #6		RUN #7	
	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
1	0.0000	56.3255	36	0.0000	56.3255	112	0.0000	56.3255	149	0.0000	56.3255	173	0.0000	56.3255
2	0.9937	54.9576	37	1.1346	54.9576	93	1.1746	54.9576	112	2.1646	53.6541	150	0.7066	55.2473
3	3.6427	52.1735	38	4.9979	51.6263	94	4.9979	50.0256	114	4.4927	51.1596	175	4.4049	51.4171
4	6.1770	50.8178	39	8.7248	47.6192	95	8.7248	47.3339	115	7.6075	47.0274	176	7.8031	48.9718
5	8.8007	49.3539	40	12.4775	43.7738	96	12.5435	43.6281	116	9.7403	45.9735	153	12.2749	44.7225
6	11.1381	48.0972	41	16.2102	39.9267	97	16.3241	39.8324	117	12.0731	45.4466	154	16.0077	41.1981
7	13.2784	46.1775	42	20.2417	37.1265	98	20.1995	36.6277	118	14.7215	42.7269	155	19.9472	37.0029
8	15.2753	44.1559	43	24.8298	33.4734	99	24.8538	33.3125	119	16.9305	40.5083	156	23.9360	35.0184
9	18.7278	39.1784	44	28.8669	30.8767	100	28.2653	30.8468	120	19.3368	37.5083	157	27.9216	32.2026
10	21.1927	37.5128	45	31.3118	27.4386	101	32.8938	27.4958	121	21.9353	34.2129	158	31.8951	29.0648
11	23.5971	35.9377	46	33.9012	24.6384	102	36.6918	24.6223	122	24.3359	31.8175	159	35.7571	26.7546
12	26.0534	33.8111	47	39.9012	21.7416	103	40.2142	22.1118	123	26.7359	29.4229	160	40.1258	23.0020
13	28.4723	31.9929	48	43.9246	18.9736	104	44.2624	19.4082	124	28.9674	27.0222	161	44.2141	21.2749
14	30.9734	30.1422	49	48.4223	17.0183	105	48.2350	16.4953	125	31.3117	24.7099	162	48.3240	18.7162
15	33.3735	28.2915	50	52.4457	14.2423	106	52.5867	14.3558	126	33.7206	22.5913	163	52.5980	16.4631
16	35.6364	26.5226	51	56.4075	11.5226	107	56.5256	11.3295	127	36.2535	20.0845	164	56.7887	13.9044
17	36.8014	25.0090	52	60.9419	9.5110	108	60.8736	9.1891	128	38.7225	17.0863	165	61.6742	12.3111
18	39.9997	24.2522	53	65.0057	7.0556	109	64.8430	6.2682	129	40.6115	14.8268	166	66.1078	10.3639
19	42.4995	22.1922	54	69.3614	4.7122	110	69.1076	3.9311	130	43.0821	12.6429	167	70.6847	8.4005
20	44.7624	20.0243	55	73.5016	2.5295	111	73.5905	2.8116	131	45.1579	10.5978	168	75.0695	6.2924
21	47.2335	17.8732	76	46.2722	3.12269	132	47.5545	19.5978	169	81.4568	5.1498	193	47.0639	10.0771
22	49.4415	16.3827	77	49.3711	1.6511	133	49.6384	18.6610	170	85.9672	3.2508	194	50.1248	17.2233
23	51.6455	14.6567	78	50.6747	1.6511	134	52.0769	17.1711	171	90.9689	1.6737	195	52.2642	16.3827
24	54.0544	13.6308	79	52.7720	16.5036	135	54.4506	15.7022	172	96.6135	0.1287	196	54.6371	14.7573
25	56.1189	12.3111	80	54.6651	5.1117	136	56.5377	13.0192	173	58.6368	1.2058	197	56.6154	13.0400
26	58.3579	10.9432	81	57.5572	13.4370	137	58.6368	12.0376	174	60.6368	1.0076	198	59.0062	12.1663
27	60.6287	10.9432	82	59.5507	11.1035	138	60.6368	11.0076	175	62.6368	0.8076	199	60.6368	11.0076
28	62.8989	9.5431	83	61.7223	8.5122	139	62.6368	9.3339	176	64.6368	0.6076	200	61.7223	9.5431
29	65.2283	8.0465	84	64.1940	6.5122	140	64.6368	8.3339	177	66.6368	0.4076	201	63.8076	8.0465
30	67.3496	6.9280	85	66.2390	5.5122	141	66.6368	7.3339	178	68.6368	0.2076	202	64.8076	6.9280
31	69.6846	5.5682	86	68.6650	4.5122	142	68.6368	6.3339	179	70.6368	0.0076	203	65.8076	5.5682
32	71.7927	4.4049	87	70.2743	3.5122	143	70.6368	5.3339	180	72.6368	0.0076	204	66.8076	4.4049
33	73.9887	3.3059	88	72.4133	2.5122	144	72.6368	4.3339	181	74.6368	0.0076	205	67.8076	3.3059
34	76.1677	1.8668	89	74.4181	1.5122	145	74.6368	3.3339	182	76.6368	0.0076	206	68.8076	2.1663
35	78.1845	0.9012	90	76.6951	0.5122	146	76.6368	2.3339	183	78.6368	0.0076	207	69.8076	0.9012
			91	78.6342	2.2847	147	78.6368	1.3339	184	80.6368	0.0076	208	70.8076	0.1663
						148	82.1209	0.3208						

Table A.3. Road Power (corrected) vs. Velocity

IGN PTS.	RUN #1	RUN #2	RUN #3	RUN #4	RUN #5	RUN #6	RUN #7
	X	X	X	X	X	X	X
1	56.1404	57.0095	54	55.9715	55.9878	144	55.4645
2	53.5626	53.2759	55	52.6643	52.6977	145	52.7207
3	51.0933	49.6220	56	49.8937	49.9343	146	50.1341
4	48.6406	46.5861	57	46.5118	46.5514	147	47.6831
5	46.1965	44.0498	58	43.1297	43.1693	148	45.2321
6	43.7524	41.5135	59	40.7476	40.7872	149	42.7811
7	41.3083	39.0772	60	38.3655	38.4051	150	40.3301
8	38.8642	36.6410	61	35.9834	36.0230	151	37.8791
9	36.4201	34.2048	62	33.6013	33.6409	152	35.4281
10	33.9760	31.7686	63	31.2192	31.2588	153	32.9771
11	31.5319	29.3324	64	28.8371	28.8767	154	30.5261
12	29.0878	26.8962	65	26.4550	26.4946	155	28.0751
13	26.6437	24.4599	66	24.0729	24.1125	156	25.6241
14	24.1996	22.0238	67	21.6908	21.7304	157	23.1731
15	21.7555	19.5876	68	19.3087	19.3483	158	20.7221
16	19.3114	17.1515	69	16.9266	16.9662	159	18.2711
17	16.8673	14.7154	70	14.5445	14.5841	160	15.8201
18	14.4232	12.2793	71	12.1624	12.2020	161	13.3691
19	11.9791	9.8432	72	9.7803	9.8200	162	10.9181
20	9.5350	7.4071	73	7.3915	7.4311	163	8.4671
21	7.0909	4.9710	74	5.0029	5.0425	164	6.0161
22	4.6468	2.5349	75	2.6149	2.6545	165	3.5651
23	2.2027	1.0988	76	1.2268	1.2664	166	1.1141
24	0.7586	0.6627	77	0.7809	0.8205	167	0.6631
25	0.3145	0.2668	78	0.3332	0.3728	168	0.2121
26	0.2704	0.2227	79	0.2891	0.3287	169	0.1611
27	0.2263	0.1786	80	0.2450	0.2846	170	0.1101
28	0.1822	0.1345	81	0.2009	0.2405	171	0.0591
29	0.1381	0.0904	82	0.1568	0.1964	172	0.0081
30	0.0940	0.0463	83	0.1127	0.1523	173	0.0000
31	0.0499	0.0022	84	0.0686	0.1079	174	0.0000
32	0.0058	0.0000	85	0.0245	0.0682	175	0.0000
33	0.0000	0.0000	86	0.0000	0.0245	176	0.0000
34	0.0000	0.0000	87	0.0000	0.0000	177	0.0000
35	0.0000	0.0000	88	0.0000	0.0000	178	0.0000

Table A. 4. Road Power (uncorrected) vs. Velocity

EGN. PTS.

	RUN #1		RUN #2		RUN #3		RUN #4		RUN #5		RUN #6		RUN #7	
	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
1	56.1484	6.3438	57.0895	11.3487	54	57.9826	9.3418	89	55.9715	7.7435	108	55.2878	8.1894	144
2	53.5856	5.2824	53.2759	8.3843	55	55.5458	7.5434	90	52.6843	9.3584	109	52.6877	8.1810	145
3	51.0953	5.2624	48.6228	8.4863	56	53.4287	7.4317	91	50.9343	8.0885	110	50.9343	8.0885	146
4	48.7855	6.1019	45.6361	8.3541	57	50.5879	7.8655	92	48.5110	8.1853	111	48.5110	8.1853	147
5	46.6456	3.3342	41.8498	7.6876	58	47.5875	6.6213	93	41.7452	7.9880	112	46.2111	3.3742	148
6	44.5374	5.7851	38.5266	5.1524	59	45.4213	3.5623	94	38.2458	5.9884	113	44.8868	2.7656	149
7	42.1717	4.8516	35.3888	6.1589	60	43.4278	1.6882	95	34.9781	5.5369	114	42.1395	2.3644	150
8	40.1681	3.8283	32.8251	4.4386	61	41.3187	4.0897	96	32.1237	3.6391	115	40.5382	3.9562	151
9	38.3416	3.8353	29.8876	4.3476	62	39.2588	3.8772	97	29.2168	4.8288	116	38.4381	3.9293	152
10	36.7242	2.7662	26.8365	3.4823	63	37.3197	3.9594	98	26.8546	3.5645	117	36.4184	3.3382	153
11	34.8735	3.5381	23.1980	3.2883	64	35.1632	3.5134	99	23.3678	2.8817	118	34.6482	2.6891	154
12	32.9671	2.8767	20.3576	2.6913	65	33.3125	2.5584	100	20.7680	2.6886	119	33.1999	1.9984	155
13	31.0675	2.7460	17.9928	1.6871	66	31.9366	1.7428	101	17.9517	2.4974	120	31.4216	3.4535	156
14	29.2168	2.5824	15.6263	2.8658	67	30.6258	2.1655	102	15.4251	1.5768	121	29.6111	1.8662	157
15	27.6875	1.8836	12.8824	1.6733	68	29.8479	2.3219	103	12.8422	1.8557	122	28.8179	2.4988	158
16	26.0953	2.2787	10.5168	1.8184	69	27.1328	2.7945	104	10.2593	1.8487	123	26.5454	1.3678	159
17	24.6786	0.9868	8.1833	1.8378	70	25.2499	1.9487	105	7.7246	1.8886	124	25.8166	2.7658	160
18	23.2222	2.2846	5.7854	0.5914	71	23.8659	1.3287	106	5.1356	8.5535	125	23.3398	1.7424	161
19	21.5883	1.4852	3.4688	0.4132	72	22.5362	1.6278	107	3.8813	8.2837	126	22.1198	1.1851	162
20	19.8588	1.8316			73	21.8814	1.5496				127	20.7519	1.6747	163
21	18.2656	1.8958			74	19.6415	1.1828				128	12.3840	8.9684	164
22	17.0183	1.8198			75	18.3380	1.2544				129	18.8161	1.4548	165
23	15.5217	1.2765			76	17.8327	0.8797				130	16.4792	1.8893	166
24	14.1457	0.6958			77	15.8275	1.8827				131	15.8711	1.8389	167
25	12.9718	0.8175			78	14.4596	0.9882				132	13.6871	8.8732	168
26	11.6272	0.7596			79	13.1238	0.8574				133	12.5284	8.5874	169
27	10.2432	0.6849			80	11.8042	0.7167				134	11.5226	8.5668	170
28	8.7948	0.6287			81	10.4122	0.7523				135	10.1788	8.1330	171
29	7.4832	0.4826			82	9.0845	0.4957				136	8.8272	8.4274	172
30	6.2441	0.4831			83	8.1350	0.2339				137	7.8373	8.3614	173
31	5.8291	0.2598			84	7.1292	0.4374				138	6.7591	8.3844	174
32	3.7889	8.7334			85	5.9383	8.3236				139	5.5681	8.3285	175
33	2.4783	8.1448			86	4.8842	0.2315				140	4.2868	8.2788	176
34	1.3848	8.8638			87	3.7379	0.2219				141	3.2186	8.1286	177
					88	2.6556	0.1264				142	2.1882	8.1353	178
											143	0.9656	8.8416	

ORIGINAL PAGE IS
OF POOR QUALITY

Table A.5. Road Energy (corrected) vs. Velocity

EGN. PTS.	RUN #1		RUN #2		RUN #3		RUN #4		RUN #5		RUN #6		RUN #7	
	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
1	0.9556	0.8796	1	56.1404	0.1400	35	57.0095	0.1726	54	57.9836	0.1895	89	55.9715	0.1113
2	2.3096	0.8065	2	53.5956	0.1305	36	53.2759	0.1305	56	55.5459	0.0999	90	52.6643	0.1585
3	3.8124	0.8015	3	51.0953	0.1600	37	49.6228	0.1643	55	53.4287	0.1662	91	49.0997	0.1359
4	5.2359	0.8025	4	48.7855	0.1523	38	45.6961	0.1566	57	50.5079	0.1652	92	45.5110	0.1528
5	6.6593	0.8036	5	46.6456	0.0985	39	41.8498	0.1566	58	47.5951	0.1662	93	41.7452	0.1528
6	8.0827	0.8048	6	44.5374	0.1570	40	38.5266	0.1067	59	43.2213	0.1147	94	38.2450	0.1274
7	9.5061	0.8060	7	42.1717	0.1231	41	35.3000	0.1474	60	40.4278	0.1109	95	34.9781	0.1313
8	10.9296	0.8072	8	40.1681	0.1224	42	32.0251	0.1113	61	37.1107	0.1451	96	32.1297	0.0959
9	12.3530	0.8088	9	38.3416	0.1062	43	29.8075	0.1228	62	34.2508	0.1355	97	29.2168	0.1382
10	13.7764	0.8098	10	36.7242	0.1067	44	26.8385	0.1067	63	31.3127	0.1351	98	26.0546	0.1098
11	15.1998	0.8112	11	34.8735	0.1285	45	23.1908	0.1113	64	28.1632	0.1278	99	23.3678	0.0929
12	16.6233	0.8127	12	32.9621	0.1139	46	19.3576	0.1032	65	25.3125	0.1039	100	20.7600	0.1021
13	18.0467	0.8142	13	31.0675	0.1154	47	17.5928	0.0667	66	22.4658	0.0816	101	17.9517	0.1121
14	19.4701	0.8157	14	29.2168	0.1154	48	15.6263	0.1052	67	19.6258	0.0978	102	15.4251	0.0752
15	20.8935	0.8173	15	27.3675	0.0924	49	12.6824	0.1028	68	16.6479	0.1078	103	12.8422	0.1174
16	22.3170	0.8190	16	25.5183	0.1147	50	10.5168	0.0698	69	13.7138	0.1301	104	10.2593	0.0752
17	23.7404	0.8207	17	23.7406	0.0670	51	8.1833	0.0998	70	10.7439	0.1039	105	7.7246	0.1120
18	25.1638	0.8225	18	22.2222	0.1254	52	5.7854	0.0752	71	7.7465	0.0824	106	5.1256	0.0913
19	26.5872	0.8243	19	20.5083	0.0924	53	3.4530	0.0921	72	5.2392	0.0933	107	3.0013	0.0675
20	28.0107	0.8261	20	19.5088	0.1193				73	2.1014	0.1098			
21	29.4341	0.8279	21	18.2656	0.0670	74	19.6415	0.0932	74	19.3640	0.0932	108	19.3640	0.0932
22	30.8575	0.8297	22	17.0183	0.0878	75	18.3703	0.0932	75	18.0161	0.0932	109	18.0161	0.0932
23	32.2809	0.8315	23	15.5217	0.1893	76	17.0027	0.0932	76	16.4792	0.0932	110	16.4792	0.0932
24	33.7044	0.8333	24	14.1457	0.0717	77	15.8255	0.0932	77	15.8255	0.0932	111	15.8255	0.0932
25	35.1278	0.8351	25	12.9718	0.0981	78	14.4596	0.0932	78	14.4596	0.0932	112	14.4596	0.0932
26	36.5512	0.8369	26	11.8272	0.0932	79	13.1238	0.0932	79	13.1238	0.0932	113	13.1238	0.0932
27	37.9747	0.8387	27	10.2432	0.0932	80	11.8342	0.0932	80	11.8342	0.0932	114	11.8342	0.0932
28	39.3981	0.8405	28	8.7948	0.0985	81	10.4152	0.0932	81	10.4152	0.0932	115	10.4152	0.0932
29	40.8215	0.8423	29	7.4832	0.0985	82	9.0045	0.0932	82	9.0045	0.0932	116	9.0045	0.0932
30	42.2449	0.8441	30	6.2441	0.0916	83	7.1292	0.0932	83	7.1292	0.0932	117	7.1292	0.0932
31	43.6684	0.8459	31	5.0291	0.0786	84	5.9303	0.0932	84	5.9303	0.0932	118	5.9303	0.0932
32	45.0918	0.8477	32	3.7899	0.0939	85	4.8842	0.0724	85	4.8842	0.0724	119	4.8842	0.0932
33	46.5152	0.8495	33	2.4703	0.0855	86	3.7979	0.0932	86	3.7979	0.0932	120	3.7979	0.0932
34	47.9387	0.8513	34	1.3840	0.0732	87	2.6956	0.0732	87	2.6956	0.0732	121	2.6956	0.0732
35	49.3621	0.8531	35			88			88					
36	50.7855	0.8549	36											
37	52.2089	0.8567	37											
38	53.6324	0.8585	38											
39	55.0558	0.8603	39											
40	56.4792	0.8621	40											

Table A. 6. Road Energy (uncorrected) vs. Velocity

EGN. PTS.	RUN #1		RUN #2		RUN #3		RUN #4		RUN #5		RUN #7						
	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y					
1	56.1404	0.1130	35	57.0095	0.1991	54	57.9026	0.1614	89	55.3715	0.1384	100	55.2070	0.1403	144	55.4645	0.1360
2	53.5656	0.1020	36	53.2759	0.1576	55	55.5450	0.0638	90	52.6643	0.1276	109	52.8977	0.0723	145	52.7207	0.1253
3	51.8953	0.1330	37	49.6220	0.1914	56	53.4207	0.1391	91	49.0997	0.1630	118	50.9343	0.1153	146	50.1541	0.1160
4	48.7855	0.1253	38	45.6961	0.1837	57	50.5079	0.1391	92	45.5110	0.1799	111	48.3514	0.1314	147	47.6031	0.1307
5	46.6456	0.0715	39	41.8490	0.1337	58	47.5951	0.1391	93	41.7452	0.1799	112	46.2111	0.0720	148	45.4064	0.0792
6	44.5374	0.1299	40	38.5266	0.1337	59	45.2213	0.0876	94	36.2450	0.1545	113	44.0658	0.1299	149	43.7005	0.0630
7	42.1717	0.0961	41	35.3000	0.1745	60	43.4270	0.0838	95	34.9701	0.1303	114	42.1395	0.0561	150	41.5199	0.1245
8	40.1681	0.0953	42	32.0251	0.1384	61	41.3107	0.1184	96	32.1297	0.1130	115	40.5302	0.0576	151	39.5003	0.0604
9	38.3416	0.0792	43	29.8076	0.1499	62	37.3197	0.0784	97	29.2168	0.1653	116	38.4301	0.1022	152	37.7059	0.1030
10	36.7242	0.0753	44	26.8305	0.1337	63	37.3197	0.1051	98	26.8546	0.1653	117	36.4184	0.0915	153	35.7909	0.0792
11	34.8735	0.1815	45	23.1900	0.1384	64	35.1632	0.0999	99	23.3670	0.1199	118	34.6402	0.0776	154	34.0126	0.0915
12	32.9021	0.0869	46	20.3576	0.1322	65	33.3125	0.0759	100	20.7600	0.1291	119	33.1999	0.0600	155	31.9607	0.0630
13	31.0675	0.0884	47	17.9920	0.0938	66	31.9366	0.0546	101	17.9517	0.1391	120	31.4216	0.1099	156	29.9974	0.0630
14	29.2160	0.0884	48	15.6263	0.1322	67	30.6250	0.0707	102	15.4251	0.1022	121	29.6111	0.0630	157	28.4122	0.0604
15	27.6075	0.0653	49	12.8824	0.1299	68	29.0479	0.0799	103	12.8422	0.1445	122	28.0179	0.0892	158	27.1650	0.0507
16	26.0063	0.0875	50	10.5150	0.0961	69	27.1320	0.1030	104	10.2593	0.1022	123	26.5454	0.0515	159	25.0615	0.0730
17	24.6706	0.0400	51	8.1033	0.1260	70	25.2499	0.0759	105	7.7246	0.1399	124	25.0156	0.0945	160	24.2200	0.0022
18	23.2222	0.0984	52	5.7054	0.1022	71	23.0650	0.0553	106	5.1256	0.1064	125	23.3340	0.0661	161	22.6509	0.0604
19	21.5083	0.0653	53	3.4600	0.1191	72	22.5302	0.0723	107	3.0013	0.0945	126	22.1190	0.0500	162	21.2991	0.0607
20	19.0500	0.0522	73	21.0014	0.0730	74	19.6415	0.0730	127	20.7319	0.0807	163	19.7703	0.0807	163	19.7703	0.0807
21	18.2656	0.0600	75	18.3300	0.0561	76	17.0827	0.0604	128	19.3040	0.0500	164	18.2012	0.0646	164	18.2012	0.0646
22	17.0103	0.0600	76	17.0827	0.0515	77	16.0827	0.0515	129	18.0161	0.0607	165	16.3540	0.0546	165	16.3540	0.0546
23	15.5217	0.0822	77	15.0275	0.0634	78	15.0275	0.0634	130	16.4792	0.0661	166	15.5700	0.0776	166	15.5700	0.0776
24	14.1457	0.0492	78	14.4596	0.0623	79	14.4596	0.0623	131	15.0711	0.0630	167	14.2906	0.0430	167	14.2906	0.0430
25	12.9710	0.0630	79	13.1238	0.0653	80	13.1238	0.0653	132	13.6871	0.0630	168	13.0031	0.0799	168	13.0031	0.0799
26	11.6272	0.0659	80	11.8042	0.0607	81	11.8042	0.0607	133	12.5204	0.0492	169	11.7001	0.0361	169	11.7001	0.0361
27	10.2432	0.0659	81	10.4122	0.0623	82	10.4122	0.0623	134	11.5226	0.0492	170	10.6097	0.0707	170	10.6097	0.0707
28	7.9400	0.0530	82	9.0845	0.0546	83	9.0845	0.0546	135	10.1700	0.0799	171	9.2032	0.0630	171	9.2032	0.0630
29	7.4032	0.0530	83	8.1350	0.0361	84	8.1350	0.0361	136	8.6270	0.0404	172	8.2959	0.0177	172	8.2959	0.0177
30	6.2441	0.0646	84	7.1202	0.0600	85	7.1202	0.0600	137	7.8373	0.0461	173	7.3545	0.0723	173	7.3545	0.0723
31	5.0291	0.0515	85	5.9303	0.0546	86	5.9303	0.0546	138	6.7591	0.0569	174	6.1797	0.0400	174	6.1797	0.0400
32	3.7009	0.0569	86	4.8042	0.0453	87	4.8042	0.0453	139	5.5601	0.0576	175	5.1819	0.0533	175	5.1819	0.0533
33	2.4703	0.0504	87	3.7979	0.0504	88	3.7979	0.0504	140	4.2968	0.0630	176	3.9147	0.0630	176	3.9147	0.0630
34	1.3040	0.0461	88	2.6956	0.0459				141	3.2106	0.0400	177	2.6393	0.0400	177	2.6393	0.0400
									142	2.1062	0.0661	178	1.3760	0.0661	178	1.3760	0.0661
									143	0.9656	0.0430						

APPENDIX B
ACCELERATION DATA

Table B.1. Velocity vs. Time (uncorrected)

RUN #1			RUN #2			RUN #3			RUN #4			RUN #5		
X	Y		X	Y		X	Y		X	Y		X	Y	
1	0.0000	0.0000	12	0.0000	0.0000	24	0.0000	0.0000	36	0.0000	0.0000	47	0.0000	0.0000
2	2.6851	12.0215	13	3.2000	13.5951	25	0.2178	1.0300	37	1.5013	6.7430	48	0.5207	2.1082
3	5.8851	26.3442	14	6.0000	26.5856	26	3.4178	16.1574	38	4.7013	21.1140	49	3.7207	15.0630
4	9.0851	34.1976	15	9.0000	34.5195	28	6.6178	29.2732	39	7.9013	31.0963	50	6.9207	28.0179
5	12.2851	40.2647	16	12.0000	39.4118	28	9.8178	37.5611	40	11.013	38.4301	51	10.1207	34.3103
6	15.4851	44.5581	17	16.0000	43.5155	29	13.0178	43.0971	41	14.3013	43.7247	52	13.3207	39.3957
7	18.6851	48.7457	18	19.0000	47.8398	30	16.2178	47.5307	42	17.5013	47.5307	53	16.5207	43.2741
8	21.8851	52.1091	19	22.0000	50.7098	31	19.4178	50.4516	43	20.7013	50.8861	54	19.7207	46.5249
9	25.0851	54.2495	20	25.0000	51.7712	32	22.6178	53.0908	44	23.9013	53.8955	55	22.9207	50.7010
10	28.2851	57.0980	21	28.0000	53.9920	33	25.8178	55.9232	45	27.1013	57.6336	56	26.1207	54.8861
11	31.4851	59.9165	22	32.0000	55.1024	34	29.0178	57.2911	46	30.3013	58.1601	57	29.3207	59.1140
12	34.6851	62.7457	23	35.2000	56.1163	35	32.2178	59.3188	47	33.6013	60.1140	58	32.5207	61.1140
13	37.8851	65.5749												
14	40.6102	66.7278												
15	0.0000	0.0000	15	0.0000	0.0000	28	0.0000	0.0000	43	0.0000	0.0000	59	0.0000	0.0000
16	2.2102	8.2235	16	0.4177	1.7059	29	0.5473	2.1243	44	1.8418	7.4199	60	0.5207	2.1082
17	5.4102	20.1323	17	3.6177	14.7734	30	3.7473	14.5401	45	5.0410	20.3094	61	3.7207	15.0630
18	8.6102	30.5767	18	6.8177	27.4868	31	6.9473	25.9419	46	8.2410	31.1568	62	6.9207	28.0179
19	11.8102	36.9012	19	10.0177	35.4207	32	10.1473	33.7478	47	11.4418	37.0461	63	10.1207	34.3103
20	15.0102	40.4900	20	13.2177	40.6509	33	13.3473	38.7037	48	14.6418	41.8418	64	13.3207	39.3957
21	18.2102	44.6098	21	16.4177	45.0121	34	16.5473	42.1958	49	17.8418	46.3000	65	16.5207	43.2741
22	21.4102	47.8398	22	19.6177	48.6009	35	19.7473	45.6337	50	21.0418	50.8861	66	19.7207	46.5249
23	24.6102	49.1641	23	22.8177	52.5758	36	22.9473	47.8920	51	24.2410	54.9576	67	22.9207	50.7010
24	27.8102	51.0953	24	26.0177	54.5714	37	26.1473	50.0170	52	27.4418	57.5406	68	26.1207	54.8861
25	31.0102	52.8172	25	29.2177	57.3555	38	29.3473	52.0662	53	30.6418	59.1140	69	29.3207	59.1140
26	34.2102	54.6443	26	32.4177	58.4498	39	32.5473	53.2517	54	33.8418	60.1140	70	32.5207	61.1140
27	37.4102	56.1646	27	35.6177	60.2683	40	35.7473	54.9254	55	37.0418	63.0908	71	35.7207	63.0908
28	40.6102	56.7278	28	38.8177	63.0908	41	38.9473	56.9692	56	40.2410	66.0662	72	38.9207	66.0662
29	43.8102	57.2911	29	42.0177	65.9334	42	42.1473	57.6934	57	43.4418	69.0418	73	42.1207	69.0418
30	47.0102	58.7457	30	45.2177	68.8000	43	45.3473	60.6000	58	46.6418	72.0179	74	45.3207	72.0179
31	50.2102	60.2683	31	48.4177	71.6662	44	48.4473	63.5662	59	49.9418	75.0000	75	48.5207	75.0000
32	53.4102	62.7457	32	51.6177	74.5334	45	51.5473	66.5334	60	53.1418	78.0000	76	51.7207	78.0000
33	56.6102	65.1646	33	54.8177	77.4000	46	54.6473	69.5000	61	56.3418	81.0000	77	54.9207	81.0000
34	59.8102	67.5831	34	58.0177	80.2662	47	57.8473	72.4662	62	59.5418	84.0000	78	58.1207	84.0000
35	63.0102	70.0000	35	61.2177	83.1334	48	60.9473	75.4334	63	62.7418	87.0000	79	61.3207	87.0000
36	66.2102	72.4571	36	64.4177	86.0000	49	64.0473	78.4000	64	65.9418	90.0000	80	64.5207	90.0000
37	69.4102	74.8861	37	67.6177	88.8662	50	67.2473	81.3662	65	69.1418	93.0000	81	67.7207	93.0000
38	72.6102	77.3094	38	70.8177	91.7334	51	70.4473	84.3334	66	72.3418	96.0000	82	70.9207	96.0000
39	75.8102	79.7555	39	74.0177	94.6000	52	73.6473	87.3000	67	75.5418	99.0000	83	74.1207	99.0000
40	79.0102	82.1662	40	77.2177	97.4662	53	76.8473	90.2662	68	79.1418	102.0000	84	77.3207	102.0000
41	82.2102	84.5831	41	80.4177	100.3334	54	80.0473	93.2334	69	82.3418	105.0000	85	80.5207	105.0000
42	85.4102	86.9999	42	83.6177	103.2000	55	83.2473	96.2000	70	85.5418	108.0000	86	83.7207	108.0000
43	88.6102	89.4166	43	86.8177	106.0662	56	86.4473	99.1662	71	88.7418	111.0000	87	86.9207	111.0000
44	91.8102	91.8331	44	90.0177	108.9334	57	89.6473	102.1334	72	91.9418	114.0000	88	90.1207	114.0000
45	95.0102	94.2500	45	93.2177	111.8000	58	92.8473	105.1000	73	95.1418	117.0000	89	93.3207	117.0000
46	98.2102	96.6662	46	96.4177	114.6662	59	96.0473	108.0662	74	98.3418	120.0000	90	96.5207	120.0000
47	101.4102	99.0831	47	99.6177	117.5334	60	99.2473	111.0334	75	101.5418	123.0000	91	99.7207	123.0000
48	104.6102	101.4999	48	102.8177	120.4000	61	102.4473	114.0000	76	104.7418	126.0000	92	102.9207	126.0000
49	107.8102	103.9166	49	106.0177	123.2662	62	105.6473	116.9662	77	107.9418	129.0000	93	106.1207	129.0000
50	111.0102	106.3331	50	109.2177	126.1334	63	108.8473	119.9334	78	111.1418	132.0000	94	109.3207	132.0000
51	114.2102	108.7500	51	112.4177	129.0000	64	112.0473	122.9000	79	114.3418	135.0000	95	112.5207	135.0000
52	117.4102	111.1662	52	115.6177	131.8662	65	115.2473	125.8662	80	117.5418	138.0000	96	115.7207	138.0000
53	120.6102	113.5831	53	118.8177	134.7334	66	118.4473	128.8334	81	120.7418	141.0000	97	118.9207	141.0000
54	123.8102	116.0000	54	122.0177	137.6000	67	121.6473	131.8000	82	123.9418	144.0000	98	122.1207	144.0000
55	127.0102	118.4166	55	125.2177	140.4662	68	124.8473	134.7662	83	127.1418	147.0000	99	125.3207	147.0000
56	130.2102	120.8331	56	128.4177	143.3334	69	128.0473	137.7334	84	130.3418	150.0000	100	128.5207	150.0000
57	133.4102	123.2500	57	131.6177	146.2000	70	131.2473	140.7000	85	133.5418	153.0000	101	131.7207	153.0000
58	136.6102	125.6662	58	134.8177	149.0662	71	134.4473	143.6662	86	136.7418	156.0000	102	134.9207	156.0000
59	139.8102	128.0831	59	138.0177	151.9334	72	137.6473	146.6334	87	139.9418	159.0000	103	138.1207	159.0000
60	143.0102	130.5000	60	141.2177	154.8000	73	140.8473	149.6000	88	143.1418	162.0000	104	141.3207	162.0000
61	146.2102	132.9166	61	144.4177	157.6662	74	144.0473	152.5662	89	146.3418	165.0000	105	144.5207	165.0000
62	149.4102	135.3331	62	147.6177	160.5334	75	147.2473	155.5334	90	149.5418	168.0000	106	147.7207	168.0000
63	152.6102	137.7500	63	150.8177	163.4000	76	150.4473	158.5000	91	152.7418	171.0000	107	150.9207	171.0000
64	155.8102	140.1662	64	154.0177	166.2662	77	153.6473	161.4662	92	155.9418	174.0000	108	154.1207	174.0000
65	159.0102	142.5831	65	157.2177	169.1334	78	156.8473	164.4334	93	159.1418	177.0000	109	157.3207	177.0000
66	162.2102	145.0000	66	160.4177	172.0000	79	160.0473	167.4000	94	162.3418	180.0000	110	160.5207	180.0000
67	165.4102	147.4166	67	163.6177	174.8662	80	163.2473	170.3662	95	165.5418	183.0000	111	163.7207	183.0000
68	168.6102	149.8331	68	166.8177	177.7334	81	166.4473	173.3334	96	168.7418	186.0000	112	166.9207	186.0000
69	171.8102	152.2500	69	170.0177	180.6000	82	169.6473	176.3000	97	171.9418	189.0000	113	170.1207	189.0000
70	175.0102	154.6662	70	173.2177	183.4662	83	172.8473	179.2662	98	175.1418	192.0000	114	173.3207	192.0000
71	178.2102	157.0831	71	176.4177	186.3334	84	176.0473	182.2334	99	178.3418	195.0000	115	176.5207	195.0000
72	181.4102	159.5000	72	179.6177	189.2000	85	179.2473	185.2000	100	181.5418	198.0000	116	179.7207	198.0000
73	184.6102	161.9166	73	182.8177	192.0662	86	182.4473	188.1662	101	184.7418	201.0000	117	182.9207	201.0000
74	187.8102	164.3331	74	186.0177	194.9334	87	185.6473	191.1334	102	187.9418	204.0000	118	186.1207	204.0000
75	191.0102	166.7500												

Table B.2. Velocity vs. Time (corrected)

RUN #1			RUN #2			RUN #3			RUN #4			RUN #5		
X	Y		X	Y		X	Y		X	Y		X	Y	
1	0.0000	0.0000	12	0.0000	0.0000	24	0.0000	0.0000	36	0.0000	0.0000	47	0.0000	
2	2.7956	12.0215	13	3.0740	13.6951	25	0.2263	1.0300	37	1.5623	6.7430	43	0.4789	
3	6.1274	26.3442	14	6.1282	26.5836	26	3.5503	16.1574	38	4.8942	21.1149	49	3.5648	
4	9.5762	34.1976	15	9.1249	34.5155	27	6.8952	29.2732	39	0.2717	31.8963	51	6.6368	
5	13.1057	48.2647	16	11.9920	39.4118	28	10.3330	37.5511	40	11.7754	38.4301	56	9.5665	
6	16.7794	44.5581	17	14.6747	43.5155	29	13.0947	43.0971	41	15.3505	43.7247	52	12.4457	
7	20.4942	48.7457	18	17.5616	47.0398	30	17.1111	47.5157	42	19.1178	47.5387	53	15.2379	
8	24.3423	52.1891	19	20.3576	50.7096	31	21.1111	50.4316	43	22.9500	50.8861	54	17.9631	
9	28.6541	54.7495	20	22.4706	51.7712	32	25.1111	53.0908	44	26.9198	53.0955	55	20.5164	
10	33.6104	57.0060	21	24.9702	53.9970	33	29.1111	55.9232	45	30.8158	55.9236	56	23.0914	
11	37.7377	59.0165	22	27.3053	55.1024	34	33.1111	57.2011	46	37.2510	57.1601	57	25.3787	
			23	29.1111	56.1163	35	39.1111	59.0168				58	27.5745	
												59	30.1700	
1	0.0000	0.0000	15	0.0000	0.0000	28	0.0000	0.0000	43	0.0000	0.0000			
2	2.1098	8.2235	16	0.4316	1.7639	29	0.5734	2.1243	44	1.9205	7.4189			
3	5.1645	28.1223	17	3.7816	14.7734	30	3.1111	16.5101	45	5.2736	20.3054			
4	8.1599	36.5767	18	7.1989	27.4268	31	6.6423	29.9419	46	8.6493	31.1560			
5	11.1368	50.5612	19	10.5769	35.4707	32	9.6158	33.7470	47	12.1904	37.8461			
6	13.9806	48.4909	20	14.1636	40.6509	33	12.4911	35.7037	48	15.8190	41.8418			
7	16.7138	44.6898	21	17.8133	45.8121	34	15.2418	37.1959	49	19.4754	46.3900			
8	19.3888	47.8398	22	21.6431	48.6089	35	17.9091	40.6397	50	23.3507	49.6303			
9	21.8751	49.1641	23	25.3729	52.5748	36	20.5768	47.8929	51	27.4119	52.9422			
10	24.3044	51.0953	24	29.8434	54.5714	37	23.8732	50.6170	52	31.4797	54.9476			
11	26.7772	52.6172	25	33.8608	57.3555	38	26.6331	53.2802	53	35.5751	57.5496			
12	29.2185	54.0449	26	37.4943	58.4498	39	27.6499	55.2517	54	40.0007	59.0513			
13	31.6574	56.1646	27	41.1427	60.2683	40	30.0000	57.9254						
14	33.9728	57.7276				41	32.5462	56.9692						
						42	34.3417	57.6934						
1	0.0000	0.0000	14	0.0000	0.0000	28	0.0000	0.0000	48	0.0000	0.0000			
2	2.7715	10.2673	15	3.0516	11.6511	29	1.6822	6.6786	41	1.1674	4.0601			
3	6.1244	22.6911	16	6.0977	22.5674	30	5.0119	19.9559	42	4.2314	17.6218			
4	9.5263	32.2343	17	9.1951	31.6067	31	8.5966	31.0756	43	7.2741	28.5912			
5	13.0483	38.4301	18	12.0257	37.5209	32	11.9114	37.4601	44	10.2325	39.9911			
6	16.6317	43.7247	19	14.8321	41.5682	33	15.4987	42.6465	45	13.8728	43.9911			
7	20.3561	47.7479	20	17.5709	44.9317	34	19.2207	45.6858	46	15.8513	43.7247			
8	24.1623	51.3845	21	20.8764	48.9755	35	23.9173	50.2906	47	18.5489	45.7663			
9	28.1681	54.1268	22	22.6779	49.4377	36	26.9543	53.3161	48	21.1862	49.4216			
10	32.3047	56.4703	23	25.1835	51.4815	37	31.2946	55.4726	49	23.6313	51.2562			
11	37.5983	57.9831	24	27.4454	52.8494	38	35.6453	57.6129	50	26.0162	52.9138			
12	43.3321	59.2383	25	29.6934	54.1851	39	40.6294	59.0935	51	28.2212	54.1690			
13	59.3323	59.9474	26	31.7464	55.1990				52	30.5069	55.5852			
			27	33.7247	56.1163				53	31.5869	55.8427			
									54	33.5237	56.0883			
1	0.0000	0.0000	13	0.0000	0.0000	26	0.0000	0.0000	38	0.0000	0.0000			
2	0.6374	2.8116	14	2.1150	8.9638	27	2.6621	11.2490	39	1.6152	7.2579			
3	3.3717	16.0769	15	5.1790	21.7255	28	5.5946	25.4913	40	4.6849	20.5990			
4	7.3176	29.0648	16	8.1992	31.2365	29	9.4354	39.5566	41	7.7287	31.0756			
5	10.8316	35.4846	17	11.1456	37.8186	30	12.9700	39.5566	42	10.6189	36.5150			
6	14.3455	41.7452	18	13.9627	41.9966	31	16.5914	44.4328	43	13.5089	41.6487			
7	18.0675	45.7846	19	16.6776	45.1578	32	20.2947	48.6809	44	16.2378	44.9960			
8	21.8672	49.3733	20	19.4219	48.5687	33	24.1741	51.8356	45	18.0892	47.3134			
9	25.7996	52.4149	21	22.0449	51.1436	34	28.6578	53.8150	46	21.3551	49.5182			
10	29.9238	55.1829	22	24.5096	53.0425	35	32.8923	56.1324	47	23.6625	50.9826			
11	35.2403	56.5669	23	25.9551	53.5092	36	39.3291	57.2589	48	25.1863	51.4976			
12	39.3217	59.1981	24	27.3719	54.4748	37	38.6716	57.3555	49	27.0642	52.3822			
			25	29.6539	55.1024				58	29.1833	53.4127			

Table B.3. Battery Voltage vs. Velocity

RUN #1		RUN #2		RUN #3		RUN #4		RUN #5	
X	Y	X	Y	X	Y	X	Y	X	Y
1 1.6559	146.2271	11 4.9553	144.8107	21 0.0000	152.7717	31 6.5382	149.9389	40 0.0000	152.2833
2 20.0759	136.7033	12 20.9582	137.8452	22 9.5448	143.9316	32 14.8323	141.1477	41 9.3365	144.8781
3 30.7577	137.3871	13 31.0547	138.5592	23 33.9343	139.2918	33 35.9343	139.9267	42 22.3557	137.5336
4 37.6084	137.3871	14 41.7225	139.3895	24 40.6688	139.4872	34 41.4844	140.0733	43 31.5564	139.6825
5 42.7384	138.8220	15 45.4575	139.5368	25 45.5885	139.5849	35 45.8632	140.0733	44 37.1656	139.8291
6 46.9562	138.1197	16 49.1056	139.1941	26 49.1782	139.2430	36 49.4224	140.2198	45 41.5740	139.9267
7 50.6331	138.2662	17 51.3871	139.2918	27 51.9335	140.2686	37 52.5837	140.2198	46 45.0996	139.9756
8 53.3151	138.9499	18 54.8167	139.5849	28 54.6800	139.9756	38 55.6637	140.1709	47 47.7830	140.1709
9 55.8584	139.8291	19 54.6193	139.8779	29 56.6852	140.8547	39 57.6675	140.9035	48 50.0754	140.2686
10 58.1257	140.4640	20 55.6763	140.1221	30 58.4311	141.2454			49 52.1927	139.9756
								50 53.5758	139.9267
								51 55.3759	139.8291
1 14.9248	140.7082	13 0.1000	151.5018	25 0.0000	151.1600	39 0.0000	147.7900		
2 26.0102	135.9787	14 3.8563	143.8828	26 9.1165	143.8828	40 14.6726	140.9524		
3 34.1375	139.4872	15 21.9255	137.7778	27 20.9572	138.3150	41 34.4682	139.7882		
4 38.9214	139.7314	16 31.9515	139.0476	28 30.3289	138.7057	42 39.7369	139.9756		
5 42.8113	140.2686	17 38.3623	139.6825	29 36.5294	139.3895	43 44.3961	141.2454		
6 45.9781	140.1709	18 43.1070	139.5756	30 40.6640	139.5849	44 40.2168	140.2686		
7 48.2356	140.1709	19 47.0775	139.7882	31 44.1369	140.1709	45 51.1390	139.9756		
8 50.2520	139.8779	20 50.8391	139.7882	32 46.9085	139.5849	46 53.7944	139.8779		
9 52.0666	140.2198	21 53.6577	139.6825	33 49.0875	139.5849	47 56.4147	140.5617		
10 53.9569	140.1221	22 56.1345	139.9756	34 51.2931	139.5360	48 58.3975	139.8291		
11 55.5338	139.9756	23 57.9687	140.2686	35 52.8261	139.3895				
12 56.4778	139.9756	24 59.4789	140.751	36 54.1937	139.6825				
				37 56.0770	139.5849				
				38 57.3732	139.7882				
1 4.8188	141.5873	15 6.9579	140.1221	26 0.8513	143.5409	37 12.0177	135.8738		
2 17.2310	134.7497	16 17.7643	133.7729	27 14.1238	135.1893	38 23.7659	129.4759		
3 28.6383	133.7241	17 27.1263	133.1868	28 26.1858	132.8146	39 32.4593	133.1380		
4 35.5976	134.6540	18 34.9135	134.5141	29 34.6874	133.7241	40 36.8125	133.5287		
5 41.3811	134.0962	19 39.7281	134.5855	30 40.2205	134.3101	41 42.0677	133.9194		
6 45.9660	134.9939	20 43.4553	134.8962	31 44.8899	134.1536	42 45.4111	133.8217		
7 49.7242	135.0427	21 48.3242	134.7009	32 48.6859	134.1148	43 48.2333	133.8786		
8 52.8630	135.1896	22 50.8391	134.7009	33 51.5676	134.1148	44 50.4248	133.9682		
9 55.4231	135.2869	23 53.5777	134.7009	34 54.5825	134.2124	45 52.1624	133.7241		
10 57.2980	135.7753	24 54.7337	134.8962	35 56.6548	135.0916	46 57.5945	134.8171		
11 58.1114	136.0155	25 55.4737	134.8962	36 58.4286	135.2869	47 54.9383	134.3101		
12 59.6143	136.0684	26 55.4737	135.1484	37 58.4286	135.2869	48 55.7076	134.7009		
						49 56.3676	134.8474		
1 5.9818	133.3333	7 3.3635	137.6313	19 5.0034	136.8498	30 1.4041	130.8228		
2 23.3539	124.3956	8 16.1296	129.1331	20 19.2398	127.4725	31 14.7445	129.2308		
3 43.0930	136.1099	9 27.0490	126.2548	21 30.6211	128.8400	32 26.4703	127.3260		
4 47.7765	129.9657	10 34.9157	129.2308	22 36.9167	129.5726	33 34.1156	128.7424		
5 55.9346	131.7704	11 40.1452	129.6703	23 42.2751	129.5238	34 39.3871	128.8889		
6 58.0183	132.1123	12 43.7478	129.6169	24 46.7591	129.5726	35 43.5124	128.9866		
		13 47.0470	129.4750	25 50.3996	129.4261	36 46.2729	128.8400		
		14 49.9512	129.7192	26 52.9219	130.5495	37 43.5317	129.8168		
		15 52.1596	130.5983	27 55.0210	130.9890	38 50.3225	130.8425		
		16 53.2876	131.0379	28 56.6885	131.5751	39 51.2502	131.8193		
		17 54.0259	131.4774	29 57.2882	132.1612	40 51.9298	131.7704		
		18 54.8188	131.4286			41 52.9089	131.9658		

Table B.4. Battery Current vs. Velocity

RUN #1		RUN #2		RUN #3		RUN #4		RUN #5	
X	Y	X	Y	X	Y	X	Y	X	Y
1 9.3310 107.3993	10 11.2815 119.1209	21 13.3274 130.2564	31 4.0538 64.4689	41 12.6366 121.0256					
2 23.6575 202.4908	11 24.1731 203.5165	22 26.6215 174.5788	32 18.4252 159.4139	42 25.5954 199.0476					
3 32.7194 143.4432	12 33.0389 150.8425	23 36.0026 147.9854	33 29.6819 154.0659	43 33.1258 145.9341					
4 39.1274 140.8900	13 38.4982 142.4176	24 42.0532 141.6850	34 37.2049 140.1465	44 38.4388 135.8242					
5 43.8370 136.9011	14 42.7482 144.0293	25 46.6984 143.5897	35 42.7272 139.3150	45 42.5437 136.1172					
6 47.9763 136.1172	15 46.3775 146.5201	26 49.8989 140.0000	36 46.8151 136.7033	46 45.9123 136.1172					
7 51.4739 127.6190	16 50.0250 143.0769	27 52.5949 139.5353	37 50.2632 141.3187	47 48.3435 141.6117					
8 56.5783 123.8895	17 51.5706 122.3443	28 55.3862 135.6777	38 53.3348 138.0952	48 50.6584 127.6190					
9 58.5797 116.0440	18 53.5716 139.5604	29 57.0271 122.2711	39 56.4484 129.3733	49 52.6804 132.0145					
	19 54.8986 132.7473	30 58.9412 115.8974	40 57.9477 121.3919	50 53.8112 132.8203					
	20 55.9285 129.0842			51 55.0916 133.0403					
1 7.4842 74.8718	14 9.8870 17.9487	26 1.3536 23.5531	39 6.6153 66.0806						
2 19.3892 146.2271	15 13.9580 108.4249	27 13.7744 106.8132	40 19.5869 139.0476						
3 29.9281 153.7729	16 26.6926 182.9304	28 25.2283 167.7656	41 30.4858 149.9634						
4 36.5084 137.7269	17 34.9279 134.7253	29 33.2547 138.6061	42 36.6710 124.1026						
5 40.2666 124.9817	18 40.3213 129.2398	30 38.3875 128.9377	43 41.5362 119.7078						
6 44.3583 124.6154	19 44.7464 125.2015	31 41.9762 129.3238	44 46.1029 119.5684						
7 46.8862 123.8895	20 48.3827 125.2747	32 45.4317 125.3480	45 49.4351 119.2674						
8 49.0343 125.0549	21 52.3273 124.6886	33 47.7433 125.2747	46 52.1395 123.5897						
9 50.9750 130.5495	22 54.4460 129.6703	34 52.1423 131.8681	47 54.7865 122.1978						
10 52.7140 120.6703	23 57.1778 121.5780	35 53.1876 124.3223	48 57.3900 117.5892						
11 54.7136 129.3040	24 59.3807 115.8974	36 54.8243 124.3956	49 58.9600 117.6557						
12 56.0798 129.3773	25 60.1519 113.4799	37 56.8421 120.1465							
13 56.6830 121.6117		38 57.6422 123.2967							
1 7.5265 80.8059	13 9.8870 17.9487	26 1.3536 23.5531	39 6.6153 66.0806						
2 20.4303 161.0236	14 13.9580 108.4249	27 13.7744 106.8132	40 19.5869 139.0476						
3 30.4394 140.5128	15 26.6926 182.9304	28 25.2283 167.7656	41 30.4858 149.9634						
4 37.0279 129.6703	16 34.9279 134.7253	29 33.2547 138.6061	42 36.6710 124.1026						
5 42.7172 127.3593	17 40.3213 129.2398	30 38.3875 128.9377	43 41.5362 119.7078						
6 46.9883 127.3260	18 44.7464 125.2015	31 41.9762 129.3238	44 46.1029 119.5684						
7 50.6231 130.8425	19 48.3827 125.2747	32 45.4317 125.3480	45 49.4351 119.2674						
8 53.5826 127.9121	20 52.3273 124.6886	33 47.7433 125.2747	46 52.1395 123.5897						
9 56.0250 119.4139	21 54.4460 129.6703	34 52.1423 131.8681	47 54.7865 122.1978						
10 57.6909 117.2821	22 57.1778 121.5780	35 53.1876 124.3223	48 57.3900 117.5892						
11 58.1107 108.7119	23 59.3807 115.8974	36 54.8243 124.3956	49 58.9600 117.6557						
12 59.0370 140.0756	24 59.3807 115.8974	37 56.8421 120.1465							
		38 57.6422 123.2967							
1 13.4295 137.1420	11 6.5051 62.1135	24 4.7527 74.8718	23 8.5757 100.6593						
2 26.5125 169.2303	12 19.3732 176.1103	35 18.0929 170.1099	24 22.8123 197.8022						
3 34.2800 146.4469	13 29.4515 155.9707	36 29.1012 155.9707	25 32.0578 147.2527						
4 40.1404 143.5155	14 36.5112 145.2271	37 35.4909 145.7143	26 38.4210 141.3919						
5 45.0155 141.6117	15 41.2011 139.9811	38 40.6840 141.5385	27 43.5183 140.0733						
6 48.6866 137.9487	16 44.5315 139.6337	39 44.3689 143.7365	28 47.6150 142.4176						
7 51.7161 130.4762	17 47.0131 141.9700	40 46.8636 135.9707	29 51.2201 140.0733						
8 54.6211 120.0000	18 50.5923 144.9451	41 49.1080 124.4689	30 53.4285 124.9817						
9 56.2950 113.5531	19 52.6602 124.8352	42 50.7802 114.4322	31 55.5836 116.4835						
10 58.6974 112.2744	20 53.4106 120.4396	43 51.5924 106.8132	32 57.0157 102.8571						
	21 54.2932 114.1392	44 52.1449 103.2967	33 57.3240 102.0000						
	22 54.2911 114.5708	45 53.1868 99.7670							

Table B. 5. Battery Current vs. Time (normalized)

RUN #1			RUN #2			RUN #3			RUN #4			RUN #5		
	X	Y	X	Y	Y	X	X	Y	X	X	Y	X	X	Y
1	0.0347	107.3993	10	0.0457	119.1209	21	-0.0064	7.7700	32	0.0150	64.4689	42	-0.0013	26.1500
2	0.0881	202.4908	11	0.1000	203.5165	22	0.0470	130.2564	33	0.0684	159.4139	43	0.0528	121.0256
3	0.1414	143.4432	12	0.1533	150.9425	23	0.1003	174.5788	34	0.1217	154.0659	44	0.1053	199.0476
4	0.1947	140.0000	13	0.2067	142.4176	24	0.1536	147.9854	35	0.1750	140.1465	45	0.1587	145.9341
5	0.2481	138.9011	14	0.2600	144.0293	25	0.2070	141.6850	36	0.2284	138.3150	46	0.2120	135.8242
6	0.3014	136.1172	15	0.3133	146.5201	26	0.2603	143.5897	37	0.2817	136.7033	47	0.2653	135.1172
7	0.3547	127.6190	16	0.3667	143.0769	27	0.3136	149.0060	38	0.3350	141.3187	48	0.3187	136.1172
8	0.4080	123.8095	17	0.4200	122.3443	28	0.3670	139.8535	39	0.3884	138.0952	49	0.3720	141.6117
9	0.4614	116.0440	18	0.4733	139.5604	29	0.4203	135.6777	40	0.4417	129.3773	50	0.4253	127.6190
			19	0.5267	132.7473	30	0.4736	122.2711	41	0.4950	121.3919	51	0.4787	132.0146
			20	0.5800	129.0842	31	0.5270	115.8974				52	0.5328	132.8205
												53	0.5853	133.0403
1	0.0269	74.8718	14	-0.0030	17.9487	26	-0.0009	33.5531	39	0.0207	66.0806			
2	0.0802	146.2271	15	0.0503	108.4249	27	0.0525	106.8132	40	0.0740	139.0476			
3	0.1335	153.7729	16	0.1035	192.9304	28	0.1058	167.7656	41	0.1274	149.9634			
4	0.1869	137.7289	17	0.1570	134.7253	29	0.1591	138.6981	42	0.1607	124.1026			
5	0.2402	124.9817	18	0.2103	129.2306	30	0.2125	128.9377	43	0.2340	119.7070			
6	0.2935	124.6154	19	0.2636	125.2015	31	0.2659	129.5238	44	0.26.4	119.5684			
7	0.3469	123.8095	20	0.3170	125.2747	32	0.3191	125.3480	45	0.3407	119.2674			
8	0.4002	125.0549	21	0.3703	124.6886	33	0.3725	125.2747	46	0.3949	123.5897			
9	0.4535	130.5495	22	0.4236	129.6703	34	0.4791	131.8681	47	0.4474	122.1979			
10	0.5069	129.6703	23	0.4778	121.9780	35	0.5325	124.3223	48	0.5007	117.5892			
11	0.5602	129.3040	24	0.5303	115.8974	36	0.5858	124.7956	49	0.5.40	117.6557			
12	0.6135	129.3773	25	0.5836	113.4799	37	0.6391	120.1455						
13	0.6669	121.617				38	0.6925	123.2967						
1	0.0241	60.8059	13	0.0471	89.6971	26	0.0166	65.2015	37	0.0103	51.2821			
2	0.0874	161.0256	14	0.1004	165.1282	27	0.0702	152.9670	38	0.0637	138.1685			
3	0.1408	140.5128	15	0.1537	143.5897	28	0.135	149.8901	39	0.1170	170.6960			
4	0.1941	129.6703	16	0.2071	135.0403	29	0.1768	135.5711	40	0.1703	140.2198			
5	0.2474	127.3993	17	0.2604	132.8938	30	0.2302	132.4542	41	0.2237	133.9194			
6	0.3008	127.3268	18	0.3137	129.5000	31	0.2635	128.5214	42	0.2770	134.8659			
7	0.3541	130.8425	19	0.3671	126.2271	32	0.3368	126.8077	43	0.3303	134.8659			
8	0.4074	127.9121	20	0.4204	132.5010	33	0.3902	132.01	44	0.3837	134.3590			
9	0.4608	119.4139	21	0.4737	127.3260	34	0.4435	125.6410	45	0.4378	129.9634			
10	0.5141	111.2821	22	0.5271	129.3040	35	0.4963	117.0022	46	0.4903	134.3590			
11	0.5674	108.7179	23	0.5804	126.9597	36	0.5488	112.9933	47	0.5437	129.7238			
12	0.6208	100.0733	24	0.6337	122.0513				48	0.5970	123.2234			
			25	0.6871	118.5348				49	0.6503	117.362			
									50	0.7037	116.7766			
1	-0.0023	24.3556	12	0.0275	87.1795	24	0.0322	100.6593	35	0.0190	74.8718			
2	0.0510	137.1429	13	0.0808	176.4103	25	0.0855	197.8022	36	0.0724	170.1099			
3	0.1043	169.2309	14	0.1342	155.9707	26	0.1308	147.2527	37	0.1257	155.9707			
4	0.1577	146.4459	15	0.1875	146.2271	27	0.1922	141.3919	38	0.1790	145.7143			
5	0.2110	143.5165	16	0.2408	138.9011	28	0.2455	140.0733	39	0.2324	14.5385			
6	0.2643	141.6117	17	0.2942	139.6337	29	0.2988	142.4176	40	0.2857	143.7363			
7	0.3177	137.9487	18	0.3475	141.9780	30	0.3522	140.0733	41	0.3398	135.9707			
8	0.3710	130.4762	19	0.4008	134.9451	31	0.4055	124.9817	42	0.3924	124.4639			
9	0.4243	120.0000	20	0.4542	124.9352	32	0.4588	116.4835	43	0.4457	114.4322			
10	0.4777	113.5531	21	0.5075	120.4396	33	0.5122	102.8571	44	0.4990	106.8132			
11	0.5310	112.2344	22	0.5608	114.1392	34	0.5655	102.8000	45	0.5524	103.2967			
			23	0.6142	114.5780				46	0.6057	99.7070			

Table B.6. Motor Voltage vs. Velocity

RUN #1			RUN #2			RUN #3			RUN #4			RUN #5		
X	Y		X	Y		X	Y		X	Y		X	Y	
1 4.6163 48.7424			10 7.4545 55.5311			20 0.0000 0.0000			30 5126 23.0525			40 0.0000 0.0000		
2 21.8667 117.9487			11 22.5617 119.0720			21 11.4357 65.8852			31 10.6288 89.0843			41 11.0167 63.7851		
3 31.7385 134.2613			12 32.0468 135.2869			22 25.1820 131.1844			32 20.5339 135.0916			42 23.9756 120.7326		
4 43.2877 134.9451			13 37.8373 136.2149			23 34.9684 136.8684			33 36.3893 136.2637			43 32.3411 136.0684		
5 47.4663 134.9939			14 42.2354 136.2637			24 41.3610 135.9219			34 42.0658 136.0987			44 37.8018 136.5568		
6 51.0535 134.9939			15 45.9375 135.1893			25 46.1435 136.2637			35 46.3397 136.5079			45 42.0588 136.0010		
7 53.5842 135.9707			16 49.5654 136.7833			26 49.5345 137.3871			36 49.8428 135.6777			46 45.5059 136.6544		
8 56.2144 136.8498			17 53.2941 136.2149			27 52.2642 137.7778			37 52.9592 137.3382			47 48.0632 135.9219		
9 58.3527 137.4359			18 54.7584 136.4591			28 55.0331 136.9963			38 56.0560 137.3871			48 50.3669 136.9475		
			19 55.8824 137.1917			29 56.8561 137.9243			39 57.8876 137.7778			49 52.4366 138.0220		
												50 53.6935 137.8266		
												51 55.6933 136.7521		
100%														
1 8.2282 32.7810			13 1.7039 0.2930			25 14.5507 59.2918			38 7.4211 26.9597					
2 20.1777 86.9353			14 14.7749 97.4972			26 25.9401 109.8413			39 20.3127 84.7863					
3 30.5811 137.1148			15 27.4871 116.9231			27 33.7423 135.6777			40 31.1640 134.2124					
4 36.9936 137.9707			16 35.4239 136.0684			28 38.6972 136.0684			41 37.0301 136.7521					
5 46.4983 137.2894			17 40.6478 136.4591			29 42.1947 136.4591			42 41.8360 137.1429					
6 44.6161 137.1429			18 45.0197 136.5544			30 45.6474 136.5568			43 46.3873 137.0940					
7 47.0375 137.4359			19 48.6069 137.8452			31 47.8095 136.6056			44 49.6382 136.9475					
8 49.1674 136.5568			20 52.5753 137.2405			32 50.0194 137.2405			45 52.3862 136.9475					
9 52.8219 136.8498			21 54.5707 137.5326			33 52.2838 136.4591			46 54.9518 135.6288					
10 54.8397 136.1561			22 57.5308 137.1429			34 53.2479 135.4335			47 57.5526 138.0220					
11 56.1625 136.5568			23 58.4494 137.4359			35 54.9294 137.2405								
12 56.7230 136.8010			24 60.2654 137.8266			36 56.9696 136.8987								
						37 57.6871 137.5336								
1 10.2680 37.9487			13 11.6581 45.4212			26 6.6808 22.4664			36 4.6640 14.0171					
2 22.6888 94.6032			14 22.5543 97.4359			27 19.9535 84.1026			37 17.6218 72.8205					
3 32.2399 130.6900			15 31.6121 130.2076			28 31.0740 129.3284			38 20.5954 125.5189					
4 38.4280 131.6239			16 37.5312 131.0379			29 37.3906 130.8425			39 35.5133 129.8657					
5 43.7192 131.7216			17 41.5689 131.6778			30 46.5706 131.3797			40 39.9974 129.9634					
6 47.7548 131.9170			18 44.5299 131.3197			31 50.2383 131.6728			41 43.7192 130.6960					
7 51.2972 130.9983			19 46.3702 131.6230			32 53.5151 130.2076			42 46.7684 130.3541					
8 54.1222 132.5889			20 49.4364 130.9983			33 55.4674 131.2021			43 49.4140 129.3284					
9 56.4763 132.4054			21 51.4766 130.4029			34 57.6197 132.1612			44 51.2524 129.7680					
10 57.9785 133.1868			22 52.8443 130.9890			35 59.0935 132.0807			45 52.9115 129.8168					
11 59.2340 133.2357			23 54.1835 131.5751						46 54.1671 130.9890					
12 59.9515 133.3333			24 55.1984 131.8681						47 55.5795 131.1844					
			25 56.1176 132.1612						48 55.8486 131.9658					
									49 56.8127 131.8193					
40%														
1 2.0174 0.5861			13 6.9677 33.5043			24 11.2545 40.2442			35 7.2637 23.4432					
2 16.0748 64.8596			14 21.7247 92.0635			25 25.4913 104.2735			36 20.6037 84.8840					
3 29.0561 122.5885			15 31.2310 124.7375			26 33.5892 125.4212			37 31.8740 123.8584					
4 35.3998 126.3004			16 37.8226 126.0073			27 39.5490 125.6800			38 36.5223 124.6886					
5 41.7451 126.8376			17 41.9923 125.8120			28 44.4366 125.9896			39 41.6555 125.1282					
6 45.7818 126.5934			18 45.1541 126.3980			29 48.6068 126.2827			40 44.9972 125.5678					
7 49.3691 125.9585			19 48.5620 125.7631			30 51.8353 126.1050			41 47.3865 125.8120					
8 52.2699 127.6679			20 51.0730 126.5446			31 53.8883 127.4725			42 49.5261 126.7399					
9 55.1759 128.3028			21 53.0460 127.4725			32 56.0055 128.0586			43 50.9834 127.8144					
10 56.5668 128.0400			22 53.5169 127.8633			33 57.2611 129.4261			44 51.4991 129.9866					
11 59.1892 129.1331			23 54.4810 128.5470			34 57.3508 129.2308			45 52.3062 129.0354					
									46 53.4048 129.4261					

Table B.7. Motor Current vs. Velocity

ORIGINAL PAGE IS
OF POOR QUALITY

RUN #1			RUN #2			RUN #3			RUN #4			RUN #5		
X	Y		X	Y		X	Y		X	Y		X	Y	
1	11.1218	198.3150	11	12.8930	199.8535	22	0.0855	137.3626	33	5.8503	193.3333	43	1.2976	144.8352
2	25.4483	171.9414	12	25.7846	179.8577	23	15.2191	196.4875	34	20.2216	191.2088	44	14.2564	189.1575
3	33.7883	141.2454	13	34.8318	143.6677	24	27.0367	151.1355	35	31.2299	144.6154	45	27.2153	172.6807
4	39.1869	136.5231	14	39.1892	132.6507	25	37.8367	140.5128	36	38.8284	136.2637	46	33.9185	136.2637
5	44.3863	134.8718	15	43.2611	134.6528	26	42.7454	134.7253	37	43.3886	132.4542	47	39.8741	131.1355
6	48.4864	133.5331	16	46.8175	133.3333	27	47.2533	139.7878	38	47.2925	132.6807	48	43.8285	129.9377
7	51.8943	130.8366	17	50.4846	136.9963	28	50.2632	139.7878	39	50.6836	125.4212	49	46.3187	128.9377
8	54.1223	125.3488	18	51.7823	126.9537	29	52.9255	133.7729	40	53.7183	132.2344	50	48.6237	131.6264
9	56.9262	118.6813	19	53.8490	130.6968	30	55.7393	126.6667	41	56.8487	122.8513	51	50.9498	131.7216
10	58.8867	112.0146	20	55.8387	129.6842	31	57.1988	118.2418	42	58.8878	115.8916	52	52.9742	132.3877
11			21	56.8546	121.5385	32	59.1962	112.8938	43			53	53.9289	124.5421
12												54	56.2998	125.9341
13														
1	7.4842	182.5641	14	0.8878	164.5471	26	1.3536	155.3114	40	6.6153	177.3626			
2	19.3892	181.0256	15	13.9588	170.5348	27	13.7744	175.3946	41	19.5858	175.8916			
3	29.9281	136.4835	16	26.6926	164.2491	28	25.2283	173.4799	42	26.4858	133.6887			
4	36.5084	127.3268	17	34.9278	127.1062	29	33.2547	131.5751	43	36.8718	116.8388			
5	40.2666	120.5128	18	40.3213	124.7956	30	38.3875	125.2747	44	41.5362	113.2681			
6	44.3583	115.4579	19	44.7464	117.3626	31	41.5762	116.7766	45	46.1829	114.2125			
7	46.8852	117.9487	20	48.3827	121.1722	32	45.4317	120.1485	46	49.4351	113.2681			
8	48.8343	121.9848	21	52.3273	124.9884	33	47.7493	118.5348	47	52.1395	115.3114			
9	49.9750	114.5788	22	54.4468	120.8888	34	49.8963	118.9911	48	54.7865	111.5818			
10	50.7148	117.8755	23	57.1778	115.9787	35	52.1423	116.4835	49	57.3980	102.1578			
11	54.7136	120.8859	24	58.3887	111.6484	36	53.1876	128.5881	50	58.9688	118.4762			
12	56.8798	122.6374	25	60.1519	107.3993	37	54.8243	119.7878						
13	56.6888	115.6777				38	56.8421	117.8755						
						39	57.6422	115.4579						
1	5.4588	155.1570	12	10.3741	174.7545	26	5.8494	150.2564	37	4.8545	172.3542			
2	21.5285	166.5293	13	15.7185	154.7185	27	19.1211	186.6667	38	16.8216	190.6227			
3	31.6393	134.6146	14	31.4747	134.6320	28	30.3768	132.1941	39	27.6972	149.8118			
4	38.9351	127.3137	15	37.1561	129.0110	29	35.9992	129.1941	40	35.8772	136.1172			
5	42.6632	124.3114	16	41.3114	124.6545	30	42.3113	124.6545	41	39.7148	131.6463			
6	47.4994	121.4652	17	44.7165	122.4388	31	46.4232	123.7112	42	43.4834	128.3517			
7	51.8726	117.7878	18	46.5394	122.6374	32	50.4555	121.9438	43	46.2454	129.9634			
8	53.9424	12.9848	19	49.4798	121.7567	33	53.1266	120.9124	44	49.2454	126.5934			
9	56.3259	113.9327	20	51.3458	122.2443	34	55.3276	120.9124	45	51.1347	126.7399			
10	57.8817	106.8864	21	52.7553	113.1263	35	57.4538	110.7632	46	52.8846	128.4982			
11	59.1521	106.2271	22	54.1821	119.1688	36	59.4538	110.7632	47	54.8853	122.3443			
12	59.9937	106.2390	23	55.1328	114.4322	37	59.4538	110.7632	48	55.4888	118.9744			
			24	55.1328	114.4322				49	55.8285	118.9137			
			25	56.8569	100.8645				50	56.7491	109.7436			
1	1.1368	197.6557	12	8.1674	201.7582	24	18.3619	209.2930	35	6.4270	205.2747			
2	15.1933	197.6557	13	20.9245	198.3083	25	24.5965	202.4176	36	19.7670	198.0220			
3	28.2419	150.4762	14	30.6338	147.6923	26	33.8762	141.3187	37	38.4166	145.7876			
4	35.0882	140.2958	15	37.4875	148.3563	27	39.1731	135.5311	38	36.1786	136.5568			
5	41.3484	137.6596	16	41.7298	134.9451	28	44.1288	133.4799	39	41.3324	135.9787			
6	45.5264	133.7729	17	44.9533	134.4322	29	48.3429	132.9146	40	44.7851	137.8759			
7	49.1417	133.3333	18	48.3457	136.6380	30	51.6393	131.5018	41	47.1589	129.3773			
8	52.8854	123.8837	19	50.9129	128.8645	31	53.6917	112.8938	42	49.3841	129.8920			
9	54.9911	116.7766	20	52.9195	118.2418	32	55.8649	106.8864	43	50.8980	107.1862			
10	56.4759	109.8981	21	53.4842	111.7949	33	57.1793	108.4396	44	51.4635	101.3385			
11	59.0219	106.2271	22	54.4174	110.3297	34	57.3418	108.8888	45	52.2525	95.3846			
			23	55.8662	107.2527				46	53.3328	94.8718			

ORIGINAL PAGE IS
OF POOR QUALITY

Table B.8. Motor Current vs. Time (normalized)

	RUN #1		RUN #2		RUN #3		RUN #4		RUN #5						
	X	Y	X	Y	X	Y	X	Y	X	Y					
100%	1	0.0414	190.3150	11	0.0533	199.0535	22	0.0083	137.3626	33	0.0217	193.3333	43	0.0053	144.0352
	2	0.0947	171.9414	12	0.1067	179.8535	23	0.0536	196.4835	34	0.0750	191.2088	44	0.0587	189.1575
	3	0.1481	141.2454	13	0.1600	143.6630	24	0.1070	151.1355	35	0.1204	144.6154	45	0.1120	172.6007
	4	0.2014	136.9231	14	0.2133	132.6007	25	0.1603	140.5128	36	0.1817	136.2637	46	0.1653	136.2637
	5	0.2547	134.8718	15	0.2667	134.6520	26	0.2136	134.7253	37	0.2350	132.4542	47	0.2187	131.1355
	6	0.3081	133.5531	16	0.3200	133.3333	27	0.2670	131.1355	38	0.2884	132.6007	48	0.2720	129.2308
	7	0.3614	130.0366	17	0.3733	136.9963	28	0.3203	139.7070	39	0.3417	125.4212	49	0.3253	120.9377
	8	0.4147	125.3480	18	0.4267	126.9597	29	0.3736	137.7729	40	0.3950	132.2311	50	0.3787	133.6264
	9	0.4681	118.6013	19	0.4800	130.6960	30	0.4270	126.6667	41	0.4484	122.0513	51	0.4320	131.7216
	10	0.5214	112.0146	20	0.5333	129.0842	31	0.4833	118.2418	42	0.5017	115.0916	52	0.4853	132.3077
				21	0.5867	121.5385	32	0.5336	112.0938				53	0.5207	124.5421
													54	0.5920	125.9341
80%	1	0.0335	102.5641	14	0.0036	164.5421	26	0.0050	155.3114	40	0.0274	177.3626			
	2	0.0863	101.0256	15	0.0570	178.5348	27	0.0591	175.3846	41	0.0807	175.0916			
	3	0.1402	136.4835	16	0.1103	184.2491	28	0.1125	173.4799	42	0.1340	172.0007			
	4	0.1935	127.3268	17	0.1636	127.1062	29	0.1658	131.5751	43	0.1874	116.0300			
	5	0.2469	120.5128	18	0.2170	124.3956	30	0.2191	125.2747	44	0.2407	113.2681			
	6	0.3002	115.4579	19	0.2703	117.3626	31	0.2725	116.7766	45	0.2940	114.2125			
	7	0.3535	117.9407	20	0.3236	121.1722	32	0.3258	120.1465	46	0.3474	113.2681			
	8	0.4069	121.9048	21	0.3770	124.9084	33	0.3791	118.5348	47	0.4007	115.3114			
	9	0.4602	114.5700	22	0.4303	120.8000	34	0.4325	118.9811	48	0.4540	111.5018			
	10	0.5135	117.8755	23	0.4838	115.5707	35	0.4858	116.4835	49	0.5074	102.1970			
	11	0.5609	120.8059	24	0.5370	111.6484	36	0.5391	120.5861	50	0.5607	110.4762			
	12	0.6202	122.6374	25	0.5903	107.3993	37	0.5925	119.7070						
	13	0.6735	115.6777				38	0.6450	117.8755						
							39	0.6991	115.4579						
40%	1	0.0400	166.1538	13	0.0557	170.7546	25	0.0235	190.2564	37	0.0170	192.4542			
	2	0.0941	190.6593	14	0.1071	162.7106	26	0.0768	186.6667	38	0.0703	190.6227			
	3	0.1474	132.0146	15	0.1600	130.6520	27	0.1302	139.1941	39	0.1237	149.8110			
	4	0.2008	123.7363	16	0.2137	129.0110	28	0.1835	130.1832	40	0.1770	136.1172			
	5	0.2541	121.3187	17	0.2671	123.8549	29	0.2302	124.0806	41	0.2303	131.6483			
	6	0.3074	121.4652	18	0.3204	122.4900	30	0.3435	127.0330	42	0.3337	120.3517			
	7	0.3603	119.7070	19	0.3737	122.6374	31	0.3950	120.9524	43	0.3903	126.5934			
	8	0.4141	121.9048	20	0.4271	121.7502	32	0.4502	120.9524	44	0.4437	126.7399			
	9	0.4674	113.9527	21	0.4804	122.3443	33	0.5033	110.7692	45	0.4970	128.4902			
	10	0.5208	106.8064	22	0.5337	119.1209	34	0.5568	104.9084	46	0.5503	122.3443			
	11	0.5741	106.2271	23	0.5871	110.6081	35			47	0.6037	110.9744			
	12	0.6274	106.2300	24	0.6404	114.4322	36			48	0.6570	110.9157			
				25	0.6937	108.8645				49	0.7103	109.7436			
20%	1	0.0043	197.6557	12	0.0342	201.7502	24	0.0380	200.2930	35	0.0257	205.2747			
	2	0.0577	197.6557	13	0.0875	198.5803	25	0.0922	202.4176	36	0.0790	198.0220			
	3	0.1110	150.4762	14	0.1400	147.6923	26	0.1455	141.3187	37	0.1324	145.7076			
	4	0.1643	149.2930	15	0.1942	140.3663	27	0.1980	135.5311	38	0.1857	136.5568			
	5	0.2177	137.0696	16	0.2475	134.9451	28	0.2522	133.4799	39	0.2390	135.9707			
	6	0.2710	133.7729	17	0.3008	134.4322	29	0.3055	132.0146	40	0.2924	137.0759			
	7	0.3243	133.3333	18	0.3542	136.6300	30	0.3588	131.5018	41	0.3457	129.3773			
	8	0.3777	123.0037	19	0.4075	128.8645	31	0.4122	112.0938	42	0.3990	120.0000			
	9	0.4310	116.7766	20	0.4600	110.2418	32	0.4655	106.8964	43	0.4524	107.1062			
	10	0.4843	109.8901	21	0.5142	111.7949	33	0.5186	100.4396	44	0.5057	101.5305			
	11	0.5377	106.2271	22	0.5675	110.3297	34	0.5722	100.0000	45	0.5590	95.3946			
				23	0.6208	107.2527				46	0.6124	94.8718			

Table B.9. Motor Field Voltage vs. Velocity

RUN #1		RUN #2		RUN #3		RUN #4		RUN #5	
X	Y	X	Y	X	Y	X	Y	X	Y
1 12.9126	114.2857	11 14.5044	113.7973	21 1.9772	119.7070	32 7.6457	117.0208	42 2.9174	119.5634
2 27.2391	94.1148	12 27.3960	99.9756	22 17.1108	112.9142	33 22.0180	111.2008	43 15.8763	113.7973
3 34.6812	28.6691	13 35.8231	35.3602	23 30.1005	74.2857	34 22.5779	51.2352	44 28.8351	99.9267
4 40.1646	13.8217	14 43.7740	11.1844	24 38.8708	25.7875	35 30.8359	22.3687	45 34.6952	39.6981
5 44.9356	10.6960	15 47.2575	4.1514	25 43.4377	13.7729	36 44.0500	13.5222	46 39.7103	22.1734
6 48.9965	7.1306	16 50.9442	2.7350	26 47.8002	5.1770	37 47.1690	11.4286	47 43.5133	15.2381
7 52.3146	2.8327	17 51.9240	6.3288	27 50.6275	3.4676	38 51.1040	6.3283	48 46.7250	10.7937
8 54.3913	2.7839	18 54.1265	3.0281	28 53.2563	1.4652	39 54.0858	3.6142	49 48.9040	10.3541
9 57.2821	2.1978	19 55.1788	3.0769	29 56.0924	2.8327	40 57.2331	3.1258	50 51.2413	10.6471
10 59.0337	2.1450	20 56.1807	3.2723	30 57.3696	3.0201	41 58.2280	2.2456	51 53.1680	1.6117
								52 54.0466	7.2283
								53 56.6061	3.2234
100%									
1 2.2759	116.4347	14 6.2394	112.9927	25 8.3403	114.2857	38 0.9750	116.4347		
2 14.1808	111.9414	15 21.1310	106.6662	26 20.2454	110.3785	39 13.8669	111.7949		
3 25.3572	75.4890	16 31.4555	48.6838	27 29.0412	52.8449	40 25.7383	73.4554		
4 33.7423	35.2625	17 38.6359	21.1966	28 36.2198	27.6923	41 34.1811	33.2112		
5 39.6972	21.9292	18 42.8337	13.9683	29 40.4468	19.4872	42 39.4371	19.7802		
6 42.5535	15.5311	19 46.9133	9.8657	30 43.9211	13.9693	43 44.1117	13.7729		
7 45.8268	11.1355	20 50.5911	3.4108	31 46.7683	10.2876	44 48.8128	9.8657		
8 48.1075	9.6215	21 53.5730	2.3932	32 48.9544	10.6960	45 50.9722	3.2234		
9 50.1315	3.2234	22 55.9607	4.4444	33 51.1516	5.9505	46 53.6290	9.3773		
10 51.9587	8.9866	23 57.9001	3.0769	34 52.7659	4.2002	47 56.2522	3.6142		
11 53.0389	3.9972	24 59.3574	5.6794	35 54.0866	2.4420	48 58.3036	3.7607		
12 55.5011	4.0845			36 55.9495	4.7863				
13 56.4438	3.806			37 57.3284	4.2979				
40%									
1 11.0491	112.2379	13 12.5420	111.3365	26 7.5141	112.2344	37 5.5658	113.2112		
2 23.4561	107.1062	14 23.2590	106.3736	27 20.7868	107.1551	38 18.4329	107.8308		
3 32.8465	48.3517	15 37.1319	51.8681	28 31.7727	55.8730	39 25.2743	76.8928		
4 38.8192	23.2479	16 37.9840	26.5132	29 37.7933	24.6154	40 35.9499	32.8205		
5 44.8543	13.9683	17 41.6225	15.8607	30 41.1134	14.5543	41 40.2812	19.7314		
6 48.0105	8.8480	18 45.1435	12.4054	31 46.8143	9.8637	42 43.9553	13.6752		
7 51.5221	9.8657	19 47.1011	13.2772	32 50.5174	11.6728	43 46.9824	10.8611		
8 54.3022	4.0049	20 49.1004	3.7697	33 53.5177	8.1074	44 49.5827	9.9145		
9 56.6269	3.5653	21 51.6975	7.6190	34 55.6053	3.6142	45 51.3787	8.3028		
10 58.0750	3.4109	22 52.9331	4.9817	35 57.7577	4.2979	46 53.0186	5.6166		
11 59.1159	3.0281	23 54.2765	4.8352	36 59.1454	3.5165	47 54.2489	4.7863		
12 59.5407	3.0300	24 55.2642	5.2747			48 55.6712	3.1258		
		25 56.1785	4.5421			49 55.8688	4.2979		
						50 56.8763	4.3956		
20%									
1 2.8997	112.2344	12 9.7607	109.5226	24 12.1480	106.6134	35 8.1013	108.3272		
2 16.5572	105.1526	13 22.5256	102.2711	25 26.3849	98.6569	36 21.4412	102.2711		
3 29.3712	66.7155	14 31.6285	43.5421	26 34.8946	32.8285	37 31.7321	48.6447		
4 35.7998	25.1036	15 38.2391	21.3919	27 39.5252	17.1429	38 36.8663	23.1582		
5 42.1463	13.7241	16 42.2569	13.6752	28 44.7456	9.8657	39 41.9089	14.0659		
6 46.8175	9.8042	17 45.3551	7.5214	29 48.8709	8.2851	40 45.2094	9.9634		
7 49.5967	8.1074	18 48.7784	4.5421	30 52.0485	3.9872	41 47.4542	7.5214		
8 52.4546	5.8400	19 51.2334	5.5189	31 53.2350	4.5398	42 49.6682	7.5214		
9 55.3610	3.5653	20 53.1727	5.3724	32 56.1462	4.7863	43 51.0779	7.2283		
10 56.6563	3.2234	21 53.5497	4.8352	33 57.1429	3.8095	44 51.5177	7.5214		
11 59.5407	3.2234	22 54.5446	5.3585	34 57.3597	3.8100	45 52.5689	7.8114		
		23 55.1513	5.8120			46 53.4768	7.8144		

Table B. 10. Motor Field Current vs. Velocity

RUN #1			RUN #2			RUN #3			RUN #4			RUN #5		
X	Y		X	Y		X	Y		X	Y		X	Y	
1 12.0172	0.3297		11 13.6987	0.5238		22 1.0313	0.0000		33 6.7485	0.5971		43 2.1075	0.0000	
2 26.3437	0.5238		12 26.5903	0.0042		23 16.1649	9.2308		34 21.1198	5.0042		44 15.0663	9.2308	
3 34.1987	0.2454		13 34.5271	0.4589		24 29.2807	0.7179		35 31.9039	0.1319		45 28.0252	0.7912	
4 40.2666	1.2454		14 39.4146	1.6117		25 37.5538	3.0769		36 38.4282	1.3187		46 34.3028	5.1262	
5 44.6610	0.5861		15 43.5175	0.7256		26 43.0916	1.0256		37 42.7193	1.0056		47 39.3922	1.9048	
6 48.7414	0.0000		16 47.0275	0.2198		27 47.5307	0.2198		38 47.5307	0.2198		48 43.2709	1.0256	
7 52.1045	0.0000		17 50.7144	0.0000		28 50.4454	0.0000		39 50.4454	0.0000		49 46.5218	0.5128	
8 54.2568	0.0000		18 51.7692	0.0000		29 53.0509	0.0000		40 53.0509	0.0000		50 48.7639	0.2930	
9 57.1042	0.0000		19 53.9078	0.0000		30 55.9157	0.0000		41 57.0369	0.0000		51 51.0956	0.0733	
10 58.9202	0.0000		20 55.1088	0.0000		31 57.2035	0.0000		42 50.1579	0.0000		52 53.0461	0.0000	
			21 56.1177	0.0000		32 59.3237	0.0000		43 50.1579	0.0000		53 53.9378	0.0000	
												54 56.4540	0.0000	
100%														
1 2.2759	0.9377		14 8.2394	0.6447		25 8.3403	0.5714		38 0.9750	9.0110				
2 14.1608	0.4982		15 21.1310	0.2784		26 20.2454	0.2051		39 13.8669	0.3516				
3 25.3572	0.1319		16 31.4555	0.0552		27 29.8412	0.4469		40 25.7383	0.2051				
4 33.7423	3.6630		17 38.0358	1.9048		28 36.2198	2.6374		41 34.1811	0.7582				
5 38.6972	1.7582		18 42.8337	0.9524		29 40.4450	1.3919		42 39.4371	0.7582				
6 42.5535	1.0989		19 46.8133	0.5128		30 43.5211	0.8791		43 44.1117	0.0256				
7 45.8268	0.5128		20 50.5911	0.2198		31 46.7695	0.5861		44 48.0128	0.3663				
8 48.1025	0.3663		21 53.5730	0.0000		32 48.9544	0.2930		45 50.9722	0.1465				
9 50.1315	0.1465		22 55.9607	0.0000		33 51.1516	0.1465		46 53.6290	0.1465				
10 51.9587	0.0733		23 57.9801	0.0000		34 52.7659	0.0733		47 56.2522	0.0733				
11 53.8308	0.0000		24 59.3574	0.0000		35 54.0886	0.0000		48 58.3035	0.0000				
12 55.5811	0.0000					36 55.9495	0.0000							
13 56.4428	0.0000					37 57.3284	0.0000							
80%														
1 4.0312	0.2912		13 15.0755	0.6447		26 0.0184	0.3377		37 11.2120	0.2704				
2 10.5222	0.4249		14 17.0759	0.2784		27 13.2909	0.4982		38 23.6775	0.3553				
3 27.4300	0.0330		15 20.0057	0.0552		28 25.4875	0.0586		39 32.0330	0.0000				
4 35.0075	2.5641		16 27.0057	2.0000		29 24.2000	2.9304		40 37.7209	1.9048				
5 41.0471	1.3187		17 30.0000	1.0117		30 29.0000	1.5309		41 41.2318	1.3187				
6 45.7185	0.8059		18 33.0000	0.6447		31 30.0000	1.0000		42 45.7272	0.7326				
7 49.4995	0.2198		19 36.0000	0.2784		32 31.0000	0.7256		43 48.0646	0.5861				
8 52.6831	0.2930		20 39.0000	0.0733		33 32.0000	0.4396		44 50.3065	0.1465				
9 55.2727	0.2198		21 42.0000	0.0000		34 33.0000	0.1465		45 52.5554	0.2930				
10 57.2000	0.1465		22 45.0000	0.3663		35 34.0000	0.1465		46 54.5127	0.2198				
11 58.0000	0.0733		23 48.0000	0.2930		36 35.0000	0.1465		47 56.5170	0.1465				
12 59.0000	0.0733		24 50.0000	0.1465		37 36.0000	0.0733		48 58.6874	0.2930				
			25 51.0000	0.2198					49 56.3040	0.1465				
20%														
1 9.0199	0.1319		7 2.5629	0.4249		18 4.1184	0.6447		29 0.5610	0.3516				
2 22.5392	0.0733		8 15.3199	0.2784		19 13.2437	0.0586		30 13.9075	0.0000				
3 43.7375	0.0733		9 26.4515	0.2784		20 29.5110	0.0586		31 25.0126	0.1062				
4 47.5489	0.5861		10 34.5004	2.4580		21 36.5405	1.9708		32 33.7717	2.4908				
5 55.0444	0.4396		11 39.0000	1.2454		22 41.0000	1.1722		33 39.0629	1.3187				
6 57.8510	0.2930		12 42.0000	0.7326		23 46.0000	0.6593		34 43.3003	1.0256				
			13 45.0000	0.5861		24 50.0000	0.4396		35 46.1252	0.7326				
			14 48.0000	0.4396		25 52.7952	0.1465		36 48.0000	0.5861				
			15 53.2548	0.3663		26 54.8803	0.4396		37 50.2261	0.5861				
			16 53.5723	0.4396		27 56.6967	0.1465		38 51.2146	0.7326				
			17 54.7662	0.3663		28 57.2793	0.5128		39 51.0760	0.5861				
									40 52.8289	0.5128				

Table B.11. Motor Field Current vs. Time (normalized)

RUN #1			RUN #2			RUN #3			RUN #4			RUN #5		
	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
1	0.0181	0.3297	0.0580	0.5238	-0.0230	0.0000	0.0000	0.0000	-0.0016	0.5971	-0.0180	0.0000	0.0180	0.0000
2	0.0714	0.5238	0.0833	0.8842	0.0833	0.2308	0.2308	0.2308	0.0517	0.9042	0.0353	0.2308	0.0353	0.2308
3	0.1247	0.7179	0.1367	0.4682	0.0836	0.7179	0.7179	0.7179	0.1850	0.1313	0.0887	0.7179	0.0887	0.7179
4	0.1781	1.2454	0.1988	1.6117	0.1370	0.8769	0.8769	0.8769	0.1584	1.3187	0.1420	1.3187	0.1420	1.3187
5	0.2314	0.5861	0.2433	0.7326	0.1983	1.0256	1.0256	1.0256	0.2117	0.8256	0.1953	1.0256	0.1953	1.0256
6	0.2847	0.0000	0.2957	0.2198	0.2436	0.2198	0.2198	0.2198	0.2650	0.4356	0.2487	0.4356	0.2487	0.4356
7	0.3381	0.0000	0.3500	0.0000	0.2970	0.0000	0.0000	0.0000	0.3184	0.0723	0.3020	0.0723	0.3020	0.0723
8	0.3914	0.0000	0.4033	0.0000	0.3583	0.0000	0.0000	0.0000	0.3717	0.0000	0.3553	0.0000	0.3553	0.0000
9	0.4447	0.0000	0.4567	0.0000	0.4036	0.0000	0.0000	0.0000	0.4259	0.0000	0.4087	0.0000	0.4087	0.0000
10	0.4981	0.0000	0.5100	0.0000	0.4570	0.0000	0.0000	0.0000	0.4784	0.0000	0.4620	0.0000	0.4620	0.0000
			0.5633	0.0000	0.5103	0.0000	0.0000	0.0000			0.5153	0.0000	0.5153	0.0000
											0.5687	0.0000	0.5687	0.0000
1	0.0102	0.9377	-0.0197	0.0000	-0.0175	0.0000	0.0000	0.0000	0.0040	0.0110	0.0040	0.0110	0.0040	0.0110
2	0.0635	0.4982	0.0336	0.6447	0.0358	0.5714	0.5714	0.5714	0.0574	0.3516	0.0574	0.3516	0.0574	0.3516
3	0.1169	0.1319	0.0870	0.2784	0.0891	0.2051	0.2051	0.2051	0.1107	0.2051	0.1107	0.2051	0.1107	0.2051
4	0.1702	0.6630	0.1403	0.8352	0.1425	0.4469	0.4469	0.4469	0.1640	0.6630	0.1640	0.6630	0.1640	0.6630
5	0.2235	1.7582	0.1936	1.3048	0.1958	2.6174	2.6174	2.6174	0.2174	1.7582	0.2174	1.7582	0.2174	1.7582
6	0.2769	1.0983	0.2470	0.9524	0.2491	1.7919	1.7919	1.7919	0.2707	1.0256	0.2707	1.0256	0.2707	1.0256
7	0.3302	0.5128	0.3003	0.2198	0.3025	0.0791	0.0791	0.0791	0.3240	0.3663	0.3240	0.3663	0.3240	0.3663
8	0.3835	0.3663	0.3536	0.2198	0.3558	0.5861	0.5861	0.5861	0.3774	0.1465	0.3774	0.1465	0.3774	0.1465
9	0.4369	0.1465	0.4070	0.0000	0.4091	0.2930	0.2930	0.2930	0.4387	0.1465	0.4387	0.1465	0.4387	0.1465
10	0.4902	0.0733	0.4603	0.0000	0.4625	0.1465	0.1465	0.1465	0.4840	0.0733	0.4840	0.0733	0.4840	0.0733
11	0.5435	0.0000	0.5136	0.0000	0.5158	0.0733	0.0733	0.0733	0.5374	0.0000	0.5374	0.0000	0.5374	0.0000
12	0.5969	0.0000	0.5670	0.0000	0.5691	0.0000	0.0000	0.0000						
13	0.6502	0.0000			0.6225	0.0000	0.0000	0.0000						
					0.6758	0.0000	0.0000	0.0000						
1	0.0174	0.7912	0.0304	0.6447	0.0062	0.9377	0.9377	0.9377	0.03470	0.2704	0.03470	0.2704	0.03470	0.2704
2	0.0708	0.4249	0.0337	0.2651	0.0535	0.4582	0.4582	0.4582	0.1063	0.9853	0.1063	0.9853	0.1063	0.9853
3	0.1241	0.8330	0.1371	0.6951	0.1068	0.8586	0.8586	0.8586	0.1537	1.9848	0.1537	1.9848	0.1537	1.9848
4	0.1774	2.5641	0.1904	2.8341	0.1602	2.9304	2.9304	2.9304	0.2003	1.9848	0.2003	1.9848	0.2003	1.9848
5	0.2307	1.3187	0.2437	1.6117	0.2135	1.5033	1.5033	1.5033	0.2603	1.3187	0.2603	1.3187	0.2603	1.3187
6	0.2841	0.8859	0.2971	1.0969	0.2666	1.0256	1.0256	1.0256	0.3137	0.7326	0.3137	0.7326	0.3137	0.7326
7	0.3374	0.2198	0.3504	0.7326	0.3202	0.7326	0.7326	0.7326	0.3670	0.5861	0.3670	0.5861	0.3670	0.5861
8	0.3908	0.2930	0.4037	0.5128	0.3735	0.4396	0.4396	0.4396	0.4203	0.1465	0.4203	0.1465	0.4203	0.1465
9	0.4441	0.2198	0.4571	0.4396	0.4260	0.1465	0.1465	0.1465	0.4737	0.2930	0.4737	0.2930	0.4737	0.2930
10	0.4974	0.1465	0.5104	0.3663	0.4902	0.1465	0.1465	0.1465	0.5270	0.2198	0.5270	0.2198	0.5270	0.2198
11	0.5508	0.0733	0.5637	0.2930	0.5535	0.0733	0.0733	0.0733	0.5803	0.1465	0.5803	0.1465	0.5803	0.1465
12	0.6041	0.0733	0.6171	0.1465	-0.0053	0.2192	0.2192	0.2192	0.6337	0.2930	0.6337	0.2930	0.6337	0.2930
			0.6784	0.2198					0.6870	0.1465	0.6870	0.1465	0.6870	0.1465
1	-0.0190	0.0733	0.0190	0.4117	0.0155	0.6447	0.6447	0.6447	0.0024	0.3516	0.0024	0.3516	0.0024	0.3516
2	0.0343	0.1319	0.0640	0.7830	0.0688	0.8586	0.8586	0.8586	0.0557	0.7388	0.0557	0.7388	0.0557	0.7388
3	0.0877	0.6190	0.1175	0.6127	0.1222	4.6154	4.6154	4.6154	0.1090	2.1062	0.1090	2.1062	0.1090	2.1062
4	0.1410	3.2234	0.1708	2.4908	0.1755	1.9780	1.9780	1.9780	0.1624	2.4908	0.1624	2.4908	0.1624	2.4908
5	0.1943	1.5335	0.2242	1.2454	0.2288	1.1722	1.1722	1.1722	0.2157	1.3187	0.2157	1.3187	0.2157	1.3187
6	0.2477	0.8791	0.2775	0.7326	0.2822	0.6593	0.6593	0.6593	0.2690	1.0256	0.2690	1.0256	0.2690	1.0256
7	0.3010	0.5861	0.3308	0.5861	0.3355	0.4356	0.4356	0.4356	0.3224	0.7326	0.3224	0.7326	0.3224	0.7326
8	0.3543	0.2198	0.3842	0.4396	0.3888	0.1465	0.1465	0.1465	0.3757	0.5861	0.3757	0.5861	0.3757	0.5861
9	0.4077	0.2198	0.4375	0.4000	0.4422	0.4396	0.4396	0.4396	0.4290	0.5861	0.4290	0.5861	0.4290	0.5861
10	0.4610	0.4396	0.4908	0.3663	0.4955	0.1465	0.1465	0.1465	0.4824	0.7326	0.4824	0.7326	0.4824	0.7326
11	0.5143	0.2198	0.5442	0.4396	0.5488	0.5128	0.5128	0.5128	0.5357	0.5861	0.5357	0.5861	0.5357	0.5861
									0.5890	0.5128	0.5890	0.5128	0.5890	0.5128

Table B.12. Acceleration (corrected) vs. Velocity

RUN #1			RUN #2			RUN #3			RUN #4			RUN #5		
X	Y		X	Y		X	Y		X	Y		X	Y	
1 19.1829	4.2988		10 20.1484	4.2053		20 8.5937	4.5503		30 13.9285	4.3139		39 8.5056	4.2254	
2 27.2709	2.2772		11 30.5526	2.6564		21 22.7153	3.9217		31 26.5052	3.1924		40 21.5405	4.2254	
3 37.2312	1.7189		12 36.9656	1.7059		22 33.4171	2.4129		32 35.1632	1.8648		41 31.1641	2.1434	
4 42.4614	1.1959		13 41.4536	1.4594		23 40.3291	1.5530		33 41.0774	1.4775		42 36.0530	1.7662	
5 46.7019	1.1004		14 45.2777	1.2784		24 45.6319	1.2110		34 45.6317	1.0149		43 41.3349	1.3890	
6 50.4274	0.8741		15 48.8744	1.3236		25 48.9951	0.7332		35 49.2124	0.8990		44 44.8995	1.1929	
7 53.1793	0.4918		16 51.2401	0.5089		26 51.7712	0.6477		36 52.3908	0.7634		45 47.6433	0.8761	
8 55.6737	0.7131		17 52.8316	0.8710		27 54.5070	0.7081		37 55.4645	0.8036		46 49.9285	0.9062	
9 59.0072	0.3913		18 54.5472	0.5240		28 56.6071	0.2504		38 57.5968	0.1750		47 52.0689	0.7855	
			19 55.6094	0.4939		29 58.3049	0.4566					48 53.5173	0.4737	
												49 55.2231	0.9465	
1 14.1779	2.8959		13 0.1413	5.8402		24 3.5322	4.8522		37 13.8641	3.8513				
2 25.3545	2.4469		14 21.1117	3.7769		25 20.2440	3.7376		38 25.7327	3.2126				
3 33.7350	2.1534		15 31.0730	2.3023		26 29.8445	2.5161		39 34.1011	1.6636				
4 38.6355	1.2005		16 30.0773	1.4574		27 36.2253	1.7200		40 39.4439	1.3216				
5 42.5499	1.4645		17 32.0715	1.1959		28 40.4790	1.2683		41 44.1109	1.2412				
6 45.8248	0.9364		18 46.5665	0.9445		29 43.9179	1.2572		42 48.0054	0.0308				
7 48.1029	0.8409		19 50.3103	1.4652		30 46.7663	0.8311		43 50.9665	0.6578				
8 50.1297	0.7805		20 53.5735	0.4406		31 48.9713	0.8409		44 53.6299	0.6528				
9 51.9567	0.7151		21 55.5617	1.6300		32 51.1117	0.9061		45 56.2531	0.6327				
10 53.1114	0.6311		22 57.5220	0.1650		33 52.7411	0.4100		46 58.3049	0.2957				
11 55.0073	0.5154		23 59.3510	0.5793		34 54.0006	0.7000							
12 56.0073	0.3720					35 55.5073	0.8157							
						36 57.3313	0.4033							
1 16.4792	3.7054		12 17.1069	3.5367		24 13.3170	3.9720		34 11.2410	4.1651				
2 27.4627	2.8052		13 27.0845	3.0034		25 25.5155	3.2981		35 23.1015	3.6018				
3 35.3322	1.7592		14 34.5678	2.0272		26 34.2379	1.7994		36 32.0492	2.3445				
4 41.0774	1.4775		15 39.5483	1.4393		27 40.0233	1.4625		37 37.7542	1.5751				
5 45.7363	1.0802		16 43.2499	1.2281		28 44.6661	1.0853		38 41.8579	1.3430				
6 49.5262	0.9344		17 45.9536	0.8157		29 48.4882	0.9495		39 45.2453	1.1275				
7 52.7126	0.7031		18 48.2066	0.9465		30 51.8034	0.7684		40 48.0379	1.0068				
8 55.2956	0.5572		19 50.4596	0.8157		31 54.3943	0.4969		41 50.3389	0.7503				
9 57.2267	0.2957		20 52.1655	0.6045		32 56.5428	0.4918		42 52.0050	0.6950				
10 58.6107	0.2152		21 53.5173	0.5944		33 58.3532	0.2857		43 53.5414	0.5693				
11 59.5924	0.0443		22 54.6921	0.4939					44 54.0771	0.6196				
			23 55.6576	0.4657					45 55.7140	0.2575				
									46 56.3255	0.4708				
1 9.0443	4.2184		11 15.3447	4.1651		22 18.3702	4.2727		32 13.9285	4.3461				
2 15.5704	3.8014		12 26.4310	3.1492		23 23.5387	2.3526		33 25.8373	3.4509				
3 23.43	1.8044		13 34.5275	2.2339		24 36.5713	1.6003		34 33.7953	1.8760				
4 30.5749	1.8044		14 39.9026	1.4796		25 41.9947	1.3468		35 35.0019	1.7013				
5 43.7649	1.0853		15 42.5718	1.1677		26 46.5168	1.1255		36 43.3224	1.2231				
6 47.5790	0.9445		16 46.6628	1.2432		27 50.2182	0.8338		37 46.1547	0.9012				
7 50.8341	0.7735		17 49.8561	0.9817		28 52.8253	0.4416		38 48.4158	0.8660				
8 53.7989	0.6080		18 52.0930	0.7705		29 54.9737	0.5472		39 50.2504	0.6347				
9 55.8749	0.2555		19 53.2759	0.3229		30 56.6956	0.1750		40 51.2401	0.3380				
10 57.8707	0.0637		20 53.9920	0.4708		31 57.3072	-0.1468		41 51.8959	0.4285				
			21 54.7966	0.3732					42 52.8575	0.5240				

Table B. 13. Acceleration (uncorrected) vs. Velocity

RUN #1		RUN #2		RUN #3		RUN #4		RUN #5	
X	Y	X	Y	X	Y	X	Y	X	Y
1 12.1829	4.4759	10 20.1464	4.1385	20 8.5717	4.7273	30 13.5570	4.4910	39 8.5856	4.0484
2 30.2769	2.4542	11 38.4550	2.4753	21 22.7157	4.0967	31 26.5142	3.7595	40 21.5485	4.6794
3 37.2312	1.8960	12 36.9056	1.5239	22 33.4721	2.5520	32 35.1142	2.9419	41 31.1641	1.9364
4 42.4514	1.3729	13 41.4155	1.2824	23 40.3731	1.7360	33 41.6724	1.6545	42 36.8530	1.5292
5 46.7819	1.2774	14 43.2417	1.1011	24 45.3179	1.3330	34 45.0517	1.3115	43 41.3349	1.2129
6 50.4274	1.0511	15 48.6714	1.1456	25 48.9951	0.9183	35 48.4124	1.0608	44 44.8995	1.0159
7 53.1793	0.6689	16 51.2144	0.3319	26 51.7712	0.8248	36 52.7090	0.5004	45 47.6433	0.6990
8 55.6737	0.8981	17 52.5116	0.0940	27 54.5071	0.1831	37 55.4640	0.0987	46 49.9285	0.7292
9 58.8972	0.5583	18 54.5072	0.3478	28 56.6071	0.4275	38 57.5970	0.3520	47 52.8689	0.6885
		19 55.5104	0.3168	29 58.7040	0.1637			48 53.5173	0.2964
								49 55.2221	0.7694
1 15.1770	5.7215	13 0.2100	4.0036	24 8.3312	3.8024	37 13.8641	4.8283		
2 25.3545	3.2639	14 21.1301	3.7780	25 26.2458	3.5686	38 25.7327	3.3896		
3 30.2769	1.9764	15 31.4039	2.4793	26 29.8445	2.4391	39 34.1811	1.8486		
4 39.6253	1.1215	16 38.0555	1.6344	27 36.2253	1.5490	40 39.4439	1.4987		
5 42.5499	1.2874	17 42.6715	1.3623	28 40.4458	1.0913	41 44.1189	1.4192		
6 45.8248	0.7594	18 46.8665	1.1215	29 43.9170	0.7662	42 48.0654	1.0159		
7 48.1020	0.6638	19 50.5793	1.2422	30 45.7653	0.7041	43 50.9665	0.8348		
8 50.1297	0.6835	20 53.5736	0.6236	31 48.9043	0.6658	44 53.6299	0.8298		
9 51.9562	0.5781	21 55.9634	0.3420	32 51.3816	0.7091	45 56.2531	0.8897		
10 53.8314	0.5787	22 57.9960	0.3420	33 52.7609	0.3017	46 58.3849	0.4727		
11 55.5339	0.4124	23 59.1146	0.1653	34 54.0886	0.5238				
12 56.2400	0.1769			35 55.9473	0.6387				
				36 57.3313	0.2263				
1 16.4792	3.8824	12 17.1069	3.4097	24 13.3170	4.1498	34 11.2410	3.9888		
2 27.4627	2.9822	13 27.8845	2.8263	25 25.5155	3.4751	35 23.1815	3.4248		
3 35.3322	1.9322	14 34.5678	1.8587	26 34.2379	3.4751	36 32.8492	2.1675		
4 41.0774	1.6546	15 39.5485	1.2623	27 40.8233	1.6395	37 37.7542	1.3981		
5 45.7363	1.2573	16 43.2499	1.0511	28 44.6661	1.2623	38 41.8579	1.1667		
6 49.5262	1.1114	17 45.9536	0.8387	29 48.4882	1.1265	39 45.2453	0.9589		
7 52.7126	0.8881	18 48.2066	0.7694	30 51.8834	0.9455	40 48.8939	0.8258		
8 55.2956	0.7342	19 58.4596	0.6387	31 54.3943	0.6739	41 50.3389	0.5733		
9 57.2267	0.4727	20 52.1655	0.4275	32 56.5428	0.6689	42 52.8850	0.5180		
10 58.6107	0.3923	21 53.5173	0.4174	33 58.3532	0.4827	43 53.5414	0.3923		
11 59.5924	0.2213	22 54.6921	0.3168			44 54.8771	0.4426		
		23 55.6576	0.2867			45 55.7148	0.8885		
						46 56.3255	0.3817		
1 9.0443	4.3954	11 15.3447	3.9888	22 18.3702	4.4587	32 13.9265	4.1691		
2 22.5784	4.0585	12 26.4816	2.9722	23 29.5387	2.5296	33 25.8373	3.2739		
3 32.2343	1.9815	13 34.5275	2.0569	24 36.5713	1.8658	34 33.7953	1.6998		
4 38.5749	1.9815	14 39.9026	1.3825	25 41.9947	1.5238	35 39.8819	1.6843		
5 43.7649	1.2623	15 43.5719	0.9987	26 46.5168	1.3028	36 43.3224	1.0460		
6 47.5798	1.1215	16 46.8328	1.0662	27 50.2182	1.0188	37 46.1547	0.7242		
7 50.8941	0.9505	17 49.8561	0.8047	28 52.8253	0.6186	38 48.4158	0.6898		
8 53.7989	0.8658	18 52.0938	0.5934	29 54.9737	0.7242	39 50.2584	0.4576		
9 55.8749	0.4325	19 53.2759	0.1458	30 56.6956	0.3528	40 51.2481	0.1689		
10 57.8785	0.8197	20 53.9920	0.3017	31 57.3872	0.8382	41 51.8999	0.2515		
		21 54.7886	0.1961			42 52.8575	0.3478		

Table B.14. Gradeability vs. Velocity

RUN #1			RUN #2			RUN #3			RUN #4			RUN #5		
X	Y		X	Y		X	Y		X	Y		X	Y	
1 19.1039	2.3447		10 17.1069	0.2281		20 20.2450	11.0643		30 20.2450	11.0643		39 20.2450	11.0643	
2 20.2450	2.5035		11 17.1069	0.2281		21 20.2450	11.0643		31 20.2450	11.0643		40 20.2450	11.0643	
3 21.3861	2.6623		12 17.1069	0.2281		22 20.2450	11.0643		32 20.2450	11.0643		41 20.2450	11.0643	
4 22.5272	2.8211		13 17.1069	0.2281		23 20.2450	11.0643		33 20.2450	11.0643		42 20.2450	11.0643	
5 23.6683	2.9799		14 17.1069	0.2281		24 20.2450	11.0643		34 20.2450	11.0643		43 20.2450	11.0643	
6 24.8094	3.1387		15 17.1069	0.2281		25 20.2450	11.0643		35 20.2450	11.0643		44 20.2450	11.0643	
7 25.9505	3.2975		16 17.1069	0.2281		26 20.2450	11.0643		36 20.2450	11.0643		45 20.2450	11.0643	
8 27.0916	3.4563		17 17.1069	0.2281		27 20.2450	11.0643		37 20.2450	11.0643		46 20.2450	11.0643	
9 28.2327	3.6151		18 17.1069	0.2281		28 20.2450	11.0643		38 20.2450	11.0643		47 20.2450	11.0643	
10 29.3738	3.7739		19 17.1069	0.2281		29 20.2450	11.0643		39 20.2450	11.0643		48 20.2450	11.0643	
11 30.5149	3.9327		20 17.1069	0.2281		30 20.2450	11.0643		40 20.2450	11.0643		49 20.2450	11.0643	
12 31.6560	4.0915		21 17.1069	0.2281		31 20.2450	11.0643		41 20.2450	11.0643		50 20.2450	11.0643	
13 32.7971	4.2503		22 17.1069	0.2281		32 20.2450	11.0643		42 20.2450	11.0643		51 20.2450	11.0643	
14 33.9382	4.4091		23 17.1069	0.2281		33 20.2450	11.0643		43 20.2450	11.0643		52 20.2450	11.0643	
15 35.0793	4.5679		24 17.1069	0.2281		34 20.2450	11.0643		44 20.2450	11.0643		53 20.2450	11.0643	
16 36.2204	4.7267		25 17.1069	0.2281		35 20.2450	11.0643		45 20.2450	11.0643		54 20.2450	11.0643	
17 37.3615	4.8855		26 17.1069	0.2281		36 20.2450	11.0643		46 20.2450	11.0643		55 20.2450	11.0643	
18 38.5026	5.0443		27 17.1069	0.2281		37 20.2450	11.0643		47 20.2450	11.0643		56 20.2450	11.0643	
19 39.6437	5.2031		28 17.1069	0.2281		38 20.2450	11.0643		48 20.2450	11.0643		57 20.2450	11.0643	
20 40.7848	5.3619		29 17.1069	0.2281		39 20.2450	11.0643		49 20.2450	11.0643		58 20.2450	11.0643	
21 41.9259	5.5207		30 17.1069	0.2281		40 20.2450	11.0643		50 20.2450	11.0643		59 20.2450	11.0643	
22 43.0670	5.6795		31 17.1069	0.2281		41 20.2450	11.0643		51 20.2450	11.0643		60 20.2450	11.0643	
23 44.2081	5.8383		32 17.1069	0.2281		42 20.2450	11.0643		52 20.2450	11.0643		61 20.2450	11.0643	
24 45.3492	5.9971		33 17.1069	0.2281		43 20.2450	11.0643		53 20.2450	11.0643		62 20.2450	11.0643	
25 46.4903	6.1559		34 17.1069	0.2281		44 20.2450	11.0643		54 20.2450	11.0643		63 20.2450	11.0643	
26 47.6314	6.3147		35 17.1069	0.2281		45 20.2450	11.0643		55 20.2450	11.0643		64 20.2450	11.0643	
27 48.7725	6.4735		36 17.1069	0.2281		46 20.2450	11.0643		56 20.2450	11.0643		65 20.2450	11.0643	
28 49.9136	6.6323		37 17.1069	0.2281		47 20.2450	11.0643		57 20.2450	11.0643		66 20.2450	11.0643	
29 51.0547	6.7911		38 17.1069	0.2281		48 20.2450	11.0643		58 20.2450	11.0643		67 20.2450	11.0643	
30 52.1958	6.9499		39 17.1069	0.2281		49 20.2450	11.0643		59 20.2450	11.0643		68 20.2450	11.0643	
31 53.3369	7.1087		40 17.1069	0.2281		50 20.2450	11.0643		60 20.2450	11.0643		69 20.2450	11.0643	
32 54.4780	7.2675		41 17.1069	0.2281		51 20.2450	11.0643		61 20.2450	11.0643		70 20.2450	11.0643	
33 55.6191	7.4263		42 17.1069	0.2281		52 20.2450	11.0643		62 20.2450	11.0643		71 20.2450	11.0643	
34 56.7602	7.5851		43 17.1069	0.2281		53 20.2450	11.0643		63 20.2450	11.0643		72 20.2450	11.0643	
35 57.9013	7.7439		44 17.1069	0.2281		54 20.2450	11.0643		64 20.2450	11.0643		73 20.2450	11.0643	
36 59.0424	7.9027		45 17.1069	0.2281		55 20.2450	11.0643		65 20.2450	11.0643		74 20.2450	11.0643	
37 60.1835	8.0615		46 17.1069	0.2281		56 20.2450	11.0643		66 20.2450	11.0643		75 20.2450	11.0643	
38 61.3246	8.2203		47 17.1069	0.2281		57 20.2450	11.0643		67 20.2450	11.0643		76 20.2450	11.0643	
39 62.4657	8.3791		48 17.1069	0.2281		58 20.2450	11.0643		68 20.2450	11.0643		77 20.2450	11.0643	
40 63.6068	8.5379		49 17.1069	0.2281		59 20.2450	11.0643		69 20.2450	11.0643		78 20.2450	11.0643	
41 64.7479	8.6967		50 17.1069	0.2281		60 20.2450	11.0643		70 20.2450	11.0643		79 20.2450	11.0643	
42 65.8890	8.8555		51 17.1069	0.2281		61 20.2450	11.0643		71 20.2450	11.0643		80 20.2450	11.0643	
43 67.0301	9.0143		52 17.1069	0.2281		62 20.2450	11.0643		72 20.2450	11.0643		81 20.2450	11.0643	
44 68.1712	9.1731		53 17.1069	0.2281		63 20.2450	11.0643		73 20.2450	11.0643		82 20.2450	11.0643	
45 69.3123	9.3319		54 17.1069	0.2281		64 20.2450	11.0643		74 20.2450	11.0643		83 20.2450	11.0643	
46 70.4534	9.4907		55 17.1069	0.2281		65 20.2450	11.0643		75 20.2450	11.0643		84 20.2450	11.0643	
47 71.5945	9.6495		56 17.1069	0.2281		66 20.2450	11.0643		76 20.2450	11.0643		85 20.2450	11.0643	
48 72.7356	9.8083		57 17.1069	0.2281		67 20.2450	11.0643		77 20.2450	11.0643		86 20.2450	11.0643	
49 73.8767	9.9671		58 17.1069	0.2281		68 20.2450	11.0643		78 20.2450	11.0643		87 20.2450	11.0643	
50 75.0178	10.1259		59 17.1069	0.2281		69 20.2450	11.0643		79 20.2450	11.0643		88 20.2450	11.0643	
51 76.1589	10.2847		60 17.1069	0.2281		70 20.2450	11.0643		80 20.2450	11.0643		89 20.2450	11.0643	
52 77.2999	10.4435		61 17.1069	0.2281		71 20.2450	11.0643		81 20.2450	11.0643		90 20.2450	11.0643	
53 78.4410	10.6023		62 17.1069	0.2281		72 20.2450	11.0643		82 20.2450	11.0643		91 20.2450	11.0643	
54 79.5821	10.7611		63 17.1069	0.2281		73 20.2450	11.0643		83 20.2450	11.0643		92 20.2450	11.0643	
55 80.7232	10.9199		64 17.1069	0.2281		74 20.2450	11.0643		84 20.2450	11.0643		93 20.2450	11.0643	
56 81.8643	11.0787		65 17.1069	0.2281		75 20.2450	11.0643		85 20.2450	11.0643		94 20.2450	11.0643	
57 83.0054	11.2375		66 17.1069	0.2281		76 20.2450	11.0643		86 20.2450	11.0643		95 20.2450	11.0643	
58 84.1465	11.3963		67 17.1069	0.2281		77 20.2450	11.0643		87 20.2450	11.0643		96 20.2450	11.0643	
59 85.2876	11.5551		68 17.1069	0.2281		78 20.2450	11.0643		88 20.2450	11.0643		97 20.2450	11.0643	
60 86.4287	11.7139		69 17.1069	0.2281		79 20.2450	11.0643		89 20.2450	11.0643		98 20.2450	11.0643	
61 87.5698	11.8727		70 17.1069	0.2281		80 20.2450	11.0643		90 20.2450	11.0643		99 20.2450	11.0643	
62 88.7109	12.0315		71 17.1069	0.2281		81 20.2450	11.0643		91 20.2450	11.0643		100 20.2450	11.0643	
63 89.8520	12.1903		72 17.1069	0.2281		82 20.2450	11.0643		92 20.2450	11.0643		101 20.2450	11.0643	
64 90.9931	12.3491		73 17.1069	0.2281		83 20.2450	11.0643		93 20.2450	11.0643		102 20.2450	11.0643	
65 92.1342	12.5079		74 17.1069	0.2281		84 20.2450	11.0643		94 20.2450	11.0643		103 20.2450	11.0643	
66 93.2753	12.6667		75 17.1069	0.2281		85 20.2450	11.0643		95 20.2450	11.0643		104 20.2450	11.0643	
67 94.4164	12.8255		76 17.1069	0.2281		86 20.2450	11.0643		96 20.2450	11.0643		105 20.2450	11.0643	
68 95.5575	12.9843		77 17.1069	0.2281		87 20.2450	11.0643		97 20.2450	11.0643		106 20.2450	11.0643	
69 96.6986	13.1431		78 17.1069	0.2281		88 20.2450	11.0643		98 20.2450	11.0643		107 20.2450	11.0643	
70 97.8397	13.3019		79 17.1069	0.2281		89 20.2450	11.0643		99 20.2450	11.0643		108 20.2450	11.0643	
71 98.9808	13.4607		80 17.1069	0.2281		90 20.2450	11.0643		100 20.2450	11.0643		109 20.2450	11.0643	
72 100.1219	13.6195		81 17.1069	0.2281		91 20.2450	11.0643		101 20.2450	11.0643		110 20.2450	11.0643	
73 101.2630	13.7783		82 17.1069	0.2281		92 20.2450	11.0643		102 20.2450	11.0643		111 20.2450	11.0643	
74 102.4041	13.9371		83 17.1069	0.2281		93 20.2450	11.0643		103 20.2450	11.0643		112 20.2450	11.0643	
75 103.5452	14.0959		84 17.1069	0.2281		94 20.2450	11.0643		104 20.2450	11.0643		113 20.2450	11.0643	
76 104.6863	14.2547		85 17.1069	0.2281		95 20.2450	11							

Table B.15. Power from Battery vs. Gradeability

	RUN #1		RUN #2		RUN #3		RUN #4		RUN #5						
	X	Y	X	Y	X	Y	X	Y	X	Y					
100%	1	12.6911	9.7023	11	12.5582	8.1905	22	12.4500	7.8753	31	13.0075	11.8949	41	12.4778	7.8750
	2	11.8333	18.0000	12	11.7863	20.2500	23	10.5665	21.3750	32	12.1471	12.3750	42	11.6781	19.1250
	3	6.7078	23.6250	13	6.5971	23.6250	24	5.6705	22.5000	33	8.2116	23.6250	43	6.4562	24.7500
	4	4.7690	20.2500	14	4.6636	21.3750	25	4.1146	20.2500	34	5.2559	19.1250	44	4.8868	18.0000
	5	3.7184	18.0000	15	3.9207	20.2500	26	3.1833	19.1250	35	3.9692	20.2500	45	3.9538	20.2500
	6	2.9393	19.1250	16	3.2105	18.0000	27	2.5575	20.2500	36	3.1403	18.0000	46	3.2069	16.8750
	7	2.2948	20.2500	17	2.5605	20.2500	28	2.0746	20.2500	37	2.5800	19.1250	47	2.8116	18.0000
	8	1.8382	19.1250	18	2.2018	19.1250	29	1.5920	18.0000	38	1.9568	19.1250	48	2.4042	19.1250
	9	1.3852	15.7500	19	1.8637	19.1250	30	1.5563	19.1250	39	1.4162	20.2500	49	2.0368	19.1250
	10	0.9976	16.8750	20	1.6214	19.1250				40	1.2061	18.0000	50	1.8058	18.0000
			21	1.4373	19.1250							51	1.4742	19.1250	
80%	1	11.5576	7.1164	14	11.2601	6.7500	25	11.2591	7.8750	38	11.6150	11.2146			
	2	10.9778	13.5000	15	10.6344	18.0000	26	10.6856	16.8750	39	10.9871	12.3750			
	3	8.7890	22.5000	16	5.9841	22.5000	27	6.6128	22.5000	40	8.5123	21.3750			
	4	5.3033	19.1250	17	4.2366	16.8750	28	4.6730	19.1250	41	5.2146	19.1250			
	5	4.1366	18.0000	18	3.3204	16.8750	29	3.7795	18.0000	42	3.9491	16.8750			
	6	3.3747	18.0000	19	2.6978	19.1250	30	3.1555	16.8750	43	3.1013	16.8750			
	7	2.8702	16.8750	20	2.1589	16.8750	31	2.7297	15.7500	44	2.5280	15.7500			
	8	2.5352	18.0000	21	1.7994	16.8750	32	2.4137	18.0000	45	2.1275	15.7500			
	9	2.2538	18.0000	22	1.4894	18.0000	33	2.1133	18.0000	46	1.7819	16.8750			
	10	2.0123	16.8750	23	1.2801	16.8750	34	1.9195	16.8750	47	1.4565	15.7500			
	11	1.7663	18.0000	24	1.0964	15.7500	35	1.7390	16.8750						
	12	1.5683	19.1250				36	1.5021	18.0000						
	13	1.4544	16.8750				37	1.3545	16.8750						
40%	1	12.2972	4.9814	13	12.0208	6.6796	26	11.0203	13.5736	36	11.3118	10.4791			
	2	10.6038	14.6250	14	10.5442	14.6989	27	8.5182	21.3802	37	9.7254	21.2396			
	3	7.5470	21.4506	15	7.7710	22.7868	28	5.2991	19.4813	38	5.8956	20.6066			
	4	5.0298	18.7077	16	5.2255	20.5312	29	4.0411	18.6863	39	4.5258	18.2154			
	5	3.8349	17.0190	17	4.1650	19.2857	30	3.1941	17.8637	40	3.7225	17.0901			
	6	2.9976	17.8901	18	3.4700	16.6681	31	2.5075	16.8791	41	3.1100	18.1451			
	7	2.3188	16.7385	19	3.0042	17.8901	32	1.9116	17.1684	42	2.6810	18.5670			
	8	1.7472	17.9341	20	2.5847	16.5978	33	1.4466	17.5824	43	2.2899	18.3150			
	9	1.2688	15.8242	21	2.1827	18.0044	34	1.0341	15.8945	44	1.8913	18.8747			
	10	0.9171	15.6835	22	1.8835	17.0198	35	0.6956	15.8945	45	1.6285	16.8791			
	11	0.6524	14.7692	23	1.6306	17.0198				46	1.3726	17.4418			
	12	0.4597	15.4022	24	1.4163	15.4725				47	1.2393	14.7692			
				25	1.2345	15.8945				49	1.1040	15.8945			
20%	1	12.2348	7.8065	11	12.6691	7.2906	23	12.5554	8.1287	34	12.7952	3.7344			
	2	11.1813	20.6769	12	11.8321	14.4879	24	11.6214	16.8791	35	11.9280	13.7846			
	3	5.8108	20.7473	13	8.1507	17.4037	25	6.6811	22.6462	36	8.4940	22.2242			
	4	4.3399	18.2857	14	5.1933	20.3253	26	4.7500	20.3962	37	5.4114	19.6923			
	5	3.3908	17.3811	15	4.1240	18.1451	27	3.7089	18.1451	38	4.2594	18.5670			
	6	2.6465	18.4804	16	3.4484	18.4264	28	2.8459	17.9341	39	3.4913	18.8747			
	7	1.9732	16.6681	17	2.7973	17.6527	29	2.0958	13.4967	40	2.9664	18.1451			
	8	1.3078	16.7385	18	2.2029	17.8637	30	1.5459	16.3165	41	2.5078	16.7385			
	9	0.8303	15.9648	19	1.7210	18.1451	31	1.0431	15.7538	42	2.1367	15.5363			
	10	0.2705	14.9802	20	1.4827	15.7538	32	0.6430	14.9802	43	1.9459	14.3473			
				21	1.2991	15.9648	33	0.5087	13.2923	44	1.7896	14.6286			
				22	1.1181	13.1516				45	1.5634	13.8813			

Table B. 16. Power to Motor vs. Gradeability

	RUN #1		RUN #2		RUN #3		RUN #4		RUN #5					
	X	Y	X	Y	X	Y	X	Y	X	Y				
1	12.2086	8.7693	11	12.1249	8.0393	22	12.8373	4.4006	33	12.5235	5.1364	43	12.0413	12.3750
2	7.6288	21.3750	12	7.6392	22.5000	23	11.9511	12.3750	34	11.8557	16.8750	44	7.8134	21.3750
3	5.3399	19.1250	13	5.2482	18.0000	24	6.5295	21.3750	35	5.2229	21.3750	45	5.3879	19.1250
4	4.8353	18.0000	14	4.2558	19.1250	25	4.5181	19.1250	36	4.3997	19.1250	46	4.2526	19.1250
5	3.2533	18.0000	15	3.4750	19.1250	26	3.5055	19.1250	37	3.3955	18.0000	47	3.5384	16.8750
6	2.5382	18.0000	16	2.8520	18.0000	27	2.7331	18.0000	38	2.7540	16.8750	48	2.9536	16.8750
7	1.9632	16.8750	17	2.1524	18.0000	28	2.2687	19.1250	39	2.1752	19.0000	49	2.5373	16.8750
8	1.6263	18.0000	18	2.0979	18.0000	29	1.8142	15.7500	40	1.6612	18.0000	50	2.1738	19.1250
9	1.1037	15.7500	19	1.6712	16.8900	30	1.5134	16.0000	41	1.1053	16.3750	51	1.8448	18.8888
10	0.9169	15.7500	20	1.5110	18.0000	31	1.1209	16.8750	42	0.9749	15.7500			
			21	1.3378	16.8750	32	0.7379	13.5000						
1	11.2315	6.4017	14	11.5396	3.5393	26	11.5238	6.2678	40	11.2618	5.8968			
2	10.6517	15.7500	15	10.9920	12.3750	27	10.9189	10.1250	41	10.6339	13.5000			
3	5.9512	20.2500	16	7.0265	19.1250	28	7.9335	20.2500	42	5.7249	21.3750			
4	4.3724	18.0000	17	4.6348	18.0000	29	5.1083	16.8750	43	4.3687	14.6250			
5	3.7252	15.7500	18	3.6368	16.8750	30	4.0343	15.8750	44	3.4337	15.7500			
6	2.9866	16.8750	19	2.9125	15.7500	31	2.4123	10.0000	45	2.7009	14.6250			
7	2.6636	15.7500	20	2.4034	16.8750	32	2.8446	14.6250	46	2.2789	15.7500			
8	2.3651	16.8750	21	1.8637	15.7500	33	2.5437	18.0000	47	1.9299	15.7500			
9	2.1873	14.6250	22	1.6779	15.7500	34	2.2475	15.7500	48	1.5953	14.6250			
10	1.8960	16.8750	23	1.2599	16.8750	35	1.9425	16.8750	49	1.2797	16.8750			
11	1.6239	16.8750	24	1.2863	13.5000	36	1.8497	15.7500	50	1.1256	15.7500			
12	1.4769	15.7500	25	0.3766	14.6250	37	1.6205	15.7500						
13	1.1750	15.7500				38	1.3625	16.8750						
						39	1.3060	15.7500						
1	11.3447	6.6556	12	0.3869	9.6322	26	11.8120	5.8823	37	12.8727	5.4397			
2	9.8722	16.8750	13	11.1541	6.3282	27	10.8024	16.0352	38	10.3335	13.6440			
3	5.5677	18.0044	14	9.7386	17.1604	28	8.8212	19.5516	39	6.6813	18.2138			
4	4.2593	16.5978	15	5.7758	17.9593	29	4.4689	17.0941	40	4.8611	18.2138			
5	3.2774	15.8175	16	4.4564	17.1604	30	3.4179	15.4322	41	4.8891	16.7385			
6	2.5847	15.8287	17	3.7225	16.7385	31	2.7894	17.0193	42	3.3315	16.8791			
7	1.9521	16.8791	18	3.1218	15.6132	32	2.1360	15.6132	43	2.7977	16.3868			
8	1.4482	15.6132	19	2.7954	15.8952	33	1.5935	15.7538	44	2.3296	17.5824			
9	1.0138	14.4879	20	2.3316	16.1758	34	1.2157	16.9494	45	2.0195	15.8585			
10	0.7516	13.9556	21	1.9711	16.6681	35	0.7981	14.6989	46	1.7173	16.7385			
11	0.5122	14.3396	22	1.7401	15.8242	36	0.5306	13.6440	47	1.4954	15.5429			
			23	1.4380	15.7538				48	1.2208	15.8242			
			24	1.3882	14.4176				49	1.2183	14.6286			
			25	1.1351	16.0352				50	0.9991	14.6286			
1	12.6383	18.1948	11	12.1963	7.5820	23	12.0300	6.9011	34	12.3029	7.3981			
2	11.1760	12.3780	12	11.2659	18.8747	24	7.8494	19.3487	35	11.4277	16.8791			
3	6.3207	19.8330	13	5.8232	18.9890	25	5.2538	18.7425	36	5.8131	18.9890			
4	4.9072	18.4264	14	4.3918	10.8044	26	4.8782	18.1451	37	4.7018	18.2957			
5	3.6456	16.7385	15	3.6763	16.9494	27	3.1887	16.7385	38	3.7859	16.6681			
6	2.9469	16.9494	16	3.1835	18.0044	28	2.1617	16.8791	39	3.1277	16.8888			
7	2.2222	16.5275	17	2.4014	16.1758	29	1.5903	15.4725	40	2.7047	16.9494			
8	1.6847	17.2388	18	1.6928	15.7538	30	1.2851	15.7538	41	2.2436	14.5125			
9	9.9187	14.8396	19	1.4650	15.5429	31	0.7371	13.5833	42	1.9567	14.5125			
10	0.6338	14.7362	20	1.4206	14.9889	32	0.4626	14.2066	43	1.8812	13.5900			
			21	1.1692	14.3473	33	0.4957	7.1736	44	1.6865	12.6593			
			22	1.8322	13.9253				45	1.4193	10.8308			

APPENDIX C
B-CYCLE DATA

Table C.1. Velocity vs. Time (normalized)

B-CYCLE (5/31)		BEGINNING CYCLES				LAST CYCLE	
		CYCLE #5		CYCLE #6		CYCLE #9	
		X	Y	X	Y	X	Y
1	0.0099	1.1658	0.0106	1.4573	0.9166	0.0001	0.0000
2	0.0632	7.4859	0.0640	8.7653	0.6719	0.0426	5.2239
3	0.1165	13.2055	0.1173	13.9678	0.1253	0.0959	11.7766
4	0.1699	19.0347	0.1706	20.5593	0.1786	0.1492	18.1828
5	0.2232	25.9177	0.2240	26.3885	0.2319	0.2826	24.8793
6	0.2765	30.8277	0.2773	31.3210	0.2853	0.2559	29.7067
7	0.3299	35.2869	0.3306	36.5449	0.3386	0.3092	34.7288
8	0.3832	37.3072	0.3840	38.9171	0.3919	0.3626	35.2445
9	0.4365	37.6435	0.4373	38.7153	0.4453	0.4159	36.3431
10	0.5432	35.7500	0.5440	35.8050	0.4986	0.4692	36.9708
11	0.5965	36.9260	0.5973	36.9619	0.5519	0.5226	37.0603
12	0.6499	36.2982	0.6506	36.4552	0.6053	0.5759	37.2847
13	0.7565	21.1250	0.7573	20.8292	0.6586	0.6292	37.1502
14	0.8099	5.9413	0.8106	30.6035	0.7119	0.6826	32.6213
15	0.8632	0.0000	0.8640	28.6498	0.7653	0.7359	27.3750
				5.3136	0.8186	0.7892	18.6496
				0.0000	0.8719	0.8426	0.0000

B-CYCLE (6/3)		BEGINNING CYCLES				LAST CYCLE	
		CYCLE #6		CYCLE #7		CYCLE #9	
		X	Y	X	Y	X	Y
1	0.0727	6.3157	0.0735	7.1872	0.0065	0.0263	3.6096
2	0.1260	11.8154	0.1268	12.0629	0.0539	0.0899	8.8784
3	0.1794	16.9272	0.1832	18.7657	0.1132	0.1432	15.7614
4	0.2327	23.5096	0.2365	24.6173	0.1665	0.1965	22.4202
5	0.2860	29.2867	0.2898	29.8412	0.2199	0.2499	27.7113
6	0.3394	33.4060	0.3432	33.4957	0.2732	0.3032	32.9801
7	0.3927	33.3836	0.3965	33.0249	0.3265	0.3565	32.6213
8	0.4994	33.0249	0.4498	32.6562	0.3793	0.4099	29.3032
9	0.5527	32.7559	0.5032	32.8231	0.4332	0.4632	29.9533
10	0.6060	33.0697	0.5565	33.1818	0.4865	0.5165	31.3210
11	0.6594	33.3164	0.6098	33.4957	0.5399	0.5699	31.0968
12	0.7127	28.9220	0.6632	32.7110	0.5932	0.6232	31.6124
13	0.7660	19.5339	0.7165	29.3032	0.6465	0.6765	31.6573
14	0.8194	0.0000	0.7698	17.9361	0.6999	0.7299	24.9761
				0.7174	0.7532	0.7832	18.3805
				0.8080	0.8065	0.8365	0.0000

Table C.2. Battery Voltage vs. Time (normalized)

B-CYCLE (5/31)				BEGINNING CYCLES				LAST CYCLE			
CYCLE #5		CYCLE #6		CYCLE #7		CYCLE #9		CYCLE #9		CYCLE	
X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
1	0.0135	151.8437	18	-0.0127	151.9414	35	0.0486	146.9109	51	-0.0232	0.0000
2	0.0399	148.2784	19	0.0496	147.6435	36	0.1019	144.5107	52	0.0192	149.1575
3	0.0932	143.4945	20	0.0946	145.7876	37	0.1553	142.5641	53	0.0726	145.9929
4	0.1465	143.9805	21	0.1473	143.2479	38	0.2086	140.8059	54	0.1259	144.8293
5	0.1999	140.6593	22	0.2006	141.5385	39	0.2619	141.1477	55	0.1792	141.6850
6	0.2532	135.2918	23	0.2540	139.9267	40	0.3153	140.2198	56	0.2326	139.8779
7	0.3065	140.1221	24	0.3073	139.7802	41	0.3686	144.0293	57	0.2859	141.0389
8	0.3599	144.0293	25	0.3606	144.9573	42	0.4219	145.2015	58	0.3392	145.9829
9	0.4132	144.8107	26	0.4148	144.8107	43	0.4753	144.7131	59	0.3926	144.0293
10	0.4665	145.5922	27	0.4673	144.7619	44	0.5286	146.1783	60	0.4459	144.7619
11	0.5199	145.5922	28	0.5206	145.4457	45	0.5819	145.4457	61	0.4992	145.2015
12	0.5732	145.3968	29	0.5740	145.4457	46	0.6353	145.5922	62	0.5526	145.2015
13	0.6265	145.5922	30	0.6273	145.2991	47	0.6886	149.8901	63	0.6059	145.4945
14	0.6799	149.6947	31	0.6806	149.6947	48	0.7419	150.1343	64	0.6592	149.4505
15	0.7332	150.8855	32	0.7340	150.8855	49	0.7953	150.2808	65	0.7126	149.8901
16	0.7865	150.3297	33	0.7873	150.2808	50	0.8486	151.0623	66	0.7659	150.0365
17	0.8399	151.0623	34	0.8406	151.0623				67	0.8192	150.1343

B-CYCLE (6/3)				BEGINNING CYCLES				LAST CYCLE			
CYCLE #6		CYCLE #7		CYCLE #8		CYCLE #9		CYCLE #9		CYCLE	
X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
1	0.0294	147.9365	16	0.0532	143.0330	32	-0.0163	151.4041	48	0.0132	149.8413
2	0.1027	146.8620	17	0.1065	146.3736	33	0.0565	147.5458	49	0.0665	147.3016
3	0.1560	141.1758	18	0.1598	143.1990	34	0.0999	146.4325	50	0.1199	143.6386
4	0.2094	140.9035	19	0.2132	143.0859	35	0.1965	141.8803	51	0.1772	142.0757
5	0.2627	139.4872	20	0.2655	140.3241	36	0.2499	140.9637	52	0.2265	141.3431
6	0.3160	140.9524	21	0.3198	141.9581	37	0.3172	143.5407	53	0.2799	140.1321
7	0.3694	144.6642	22	0.3732	144.3712	38	0.3565	142.9060	54	0.3332	144.0293
8	0.4227	144.2735	23	0.4265	143.3712	39	0.4099	144.1758	55	0.3865	140.5714
9	0.4760	144.1758	24	0.4798	144.3712	40	0.4532	144.4689	56	0.4399	143.6874
10	0.5294	144.2247	25	0.5332	144.1758	41	0.5165	149.5482	57	0.4932	143.3386
11	0.5827	144.1758	26	0.5865	144.1270	42	0.5699	144.3223	58	0.5465	144.3712
12	0.6360	144.3223	27	0.6398	144.2735	43	0.6232	144.2247	59	0.5999	144.4200
13	0.6894	143.6203	28	0.6932	148.7179	44	0.6765	143.9316	60	0.6532	144.5177
14	0.7427	149.5049	29	0.7465	149.3040	45	0.7299	149.0110	61	0.7065	148.9621
15	0.7960	149.5971	30	0.7998	149.6459	46	0.7832	149.4817	62	0.7599	149.2063
			31	0.8532	150.4762	47	0.8365	149.4994	63	0.8132	149.2482

B-CYCLE (5/31)

B-CYCLE (6/3)

ORIGINAL PAGE IS
POOR QUALITY

Table C. 4. Battery Current vs. Time (normalized)

B-CYCLE (5/31)				BEGINNING CYCLES				LAST CYCLE			
CYCLE #5		CYCLE #6		CYCLE #7		CYCLE #9		CYCLE #9		CYCLE #9	
X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
1	-0.0001	20.2930	18	0.0006	27.1755	51	-0.0093	0.0000	1	0.0357	52.0147
2	0.0532	39.9267	19	0.0544	56.5588	52	0.0326	29.6703	2	0.1190	78.0220
3	0.1065	71.2088	20	0.1073	73.9927	53	0.0359	66.8132	3	0.1724	107.1062
4	0.1599	86.2271	21	0.1606	89.2308	54	0.1392	80.5128	4	0.2257	95.3114
5	0.2132	118.4615	22	0.2140	120.1455	55	0.1926	111.0623	5	0.2790	76.0440
6	0.2665	106.4469	23	0.2673	108.2271	56	0.2459	132.6007	6	0.3324	74.8718
7	0.3199	128.0059	24	0.3206	124.0293	57	0.2992	122.3443	7	0.3957	71.3953
8	0.3732	63.2967	25	0.3740	61.3919	58	0.3526	35.5311	8	0.4390	70.7692
9	0.4265	61.2454	26	0.4273	61.4652	59	0.4059	76.4835	9	0.4924	69.8169
10	0.4799	53.8403	27	0.4806	63.0769	60	0.4592	56.1172	10	0.5457	66.6667
11	0.5332	53.9927	28	0.5340	55.6044	61	0.5126	54.6520	11	0.5954	64.6154
12	0.5865	55.6777	29	0.5873	53.1136	62	0.5659	54.2857	12	0.6324	64.3223
13	0.6399	53.1136	30	0.6406	57.5092	63	0.6192	55.6044	13	0.7057	3.9808
14	0.6932	9.4505	31	0.6940	9.4505	64	0.6726	9.4505	14	0.7596	3.4249
15	0.7465	9.6703	32	0.7473	9.6703	65	0.7259	68.5714	15	0.8124	3.8769
16	0.7999	9.7436	33	0.8006	9.6703	66	0.7792	9.4505			
17	0.8532	2.7106	34	0.8540	3.0037	67	0.8326	3.2234			

B-CYCLE (6/31)				BEGINNING CYCLES				LAST CYCLE			
CYCLE #6		CYCLE #7		CYCLE #8		CYCLE #9		CYCLE #9		CYCLE #9	
X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
1	0.0627	49.0110	16	0.0665	43.0769	32	-0.0033	10.5297	48	0.0265	28.4982
2	0.1160	53.9194	17	0.1198	40.6203	33	0.0499	35.1648	49	0.0799	41.0989
3	0.1694	78.9011	18	0.1732	97.2537	34	0.1032	55.3114	50	0.1332	82.7839
4	0.2227	106.5714	19	0.2265	118.5495	35	0.1565	88.4982	51	0.1865	91.4206
5	0.2760	131.6483	20	0.2792	133.0403	36	0.2099	87.9121	52	0.2399	102.1245
6	0.3294	57.2161	21	0.3332	77.3590	37	0.2632	123.3513	53	0.2932	101.5303
7	0.3827	53.1136	22	0.3865	50.1685	38	0.3165	65.7143	54	0.3465	58.5348
8	0.4360	59.5604	23	0.4398	59.7802	39	0.3599	85.2615	55	0.3999	9.3773
9	0.4894	63.4432	24	0.4932	60.8791	40	0.4232	59.5348	56	0.4532	66.9597
10	0.5427	61.7582	25	0.5465	62.7106	41	0.4765	57.0696	57	0.5065	66.5201
11	0.5961	69.2550	26	0.5998	57.5824	42	0.5299	55.0448	58	0.5599	55.7381
12	0.6494	59.6337	27	0.6532	61.3187	43	0.5832	50.3663	59	0.6132	53.1648
13	0.7027	9.5377	28	0.7065	8.8645	44	0.6365	60.3663	60	0.6665	67.6630
14	0.7560	9.0110	29	0.7598	9.9645	45	0.6899	61.2454	61	0.7193	8.7179
15	0.8094	9.0110	30	0.8132	8.9377	46	0.7432	8.7912	62	0.7732	9.7512
			31	0.8665	2.1245	47	0.7959	3.0769	63	0.8265	3.0769

Table C.5. Battery Current vs. Velocity

<u>BEGINNING CYCLES</u>						<u>CYCLE #7</u>		<u>CYCLE #9</u>		<u>LAST CYCLE</u>				
<u>CYCLE #6</u>			<u>CYCLE #7</u>			<u>CYCLE #9</u>			<u>LAST CYCLE</u>					
X	Y		X	Y		X	Y		X	Y				
1	6.2947	39.9267	13	0.0869	20.2930	30	1.1714	27.1795	46	3.9964	29.6703	1	7.5107	52.0147
2	12.1293	71.2088	14	7.3959	56.9963	31	8.4356	56.5568	47	10.5431	66.8132	2	13.6898	78.0220
3	17.9417	86.2271	15	12.9925	63.9560	32	14.0238	73.9927	48	16.9805	88.5128	3	19.2519	107.1062
4	24.6271	118.4615	16	19.3234	89.2308	33	19.3234	97.3626	49	22.9737	111.0623	4	24.8975	95.3114
5	29.9971	186.4469	17	25.2955	108.4249	34	26.4796	120.1465	50	28.6516	132.6087	5	26.5973	76.8448
6	34.4346	120.8959	18	30.3961	110.5495	35	31.7189	186.2271	51	33.7872	122.3443	6	28.6838	74.8718
7	36.9246	63.2967	19	35.5654	124.8293	36	35.7588	99.4139	52	35.1478	75.3311	7	30.8262	71.3333
8	37.5884	61.2454	20	36.0338	61.3919	37	37.1698	57.8755	53	36.1371	76.4835	8	31.3568	70.7652
9	36.8924	55.6777	21	35.7532	61.4652	38	37.3114	53.7729	54	36.8531	56.1172	9	32.4686	69.8168
10	36.4159	53.1136	22	35.7882	63.0769	39	37.3880	60.2930	55	37.8437	54.6520	10	33.4313	66.6667
11	8.8167	9.7436	23	35.9325	55.6044	40	36.8321	46.6667	56	37.2427	54.2857	11	34.6279	64.6154
12	1.1140	2.7106	24	36.3627	53.1136	41	37.1572	56.1172	57	37.1754	55.6044	12	35.8273	64.3223
			25	36.1091	57.5892	42	34.4752	9.5238	58	37.4705	9.4505	13	33.3346	8.0000
			26	31.6208	9.4505	43	28.8954	9.4505	59	28.3587	68.5714	14	18.0342	8.42
			27	22.5154	9.6703	44	14.6950	9.5971	60	13.7856	9.4505	15	2.7367	3.
			28	0.1090	9.6703	45	2.1902	3.2567	61	1.9968	3.2234			
			29	0.9963	3.0037									

B-CYCLE (6/3)			BEGINNING CYCLES				LAST CYCLE				
CYCLE #6			CYCLE #7		CYCLE #8		CYCLE #9		CYCLE #10		
X	Y		X	Y	X	Y	X	Y	X	Y	
1	5.8783	49.0110	14	6.1782	45.0769	30	5.9947	35.1640	45	2.6218	28.4982
2	10.8780	53.9194	15	11.1330	48.4249	31	11.4231	55.3114	46	7.8905	41.0989
3	15.9688	78.9011	16	17.5087	87.2527	32	16.5891	88.4982	47	14.4708	82.7839
4	22.5654	108.5714	17	23.5202	119.5495	33	22.5827	87.5121	48	21.1716	91.4286
5	28.2886	131.5483	18	28.8618	133.0403	34	28.4610	122.0513	49	26.7192	102.1245
6	32.6325	97.2161	19	32.8105	74.7598	35	31.1164	55.7143	50	31.9922	101.5385
7	33.3878	53.1136	20	33.1132	58.1685	36	30.3485	85.2015	51	32.6886	58.5348
8	32.8063	61.7582	21	32.7334	59.7892	37	31.0898	58.5348	52	29.9253	9.3773
9	33.8169	60.2330	22	32.7937	60.8791	38	31.2845	57.0696	53	29.8314	66.9597
10	33.2701	59.6337	23	33.1146	62.7106	39	30.6921	56.0440	54	31.0645	66.5201
11	29.7460	8.9377	24	33.4369	57.5824	40	30.4200	60.3663	55	31.1388	55.2301
12	21.7355	9.8110	25	32.8582	61.3187	41	30.7591	50.3663	56	31.5157	53.1648
13	3.7414	9.8110	26	29.9421	8.8645	42	30.5510	61.2454	57	31.6489	63.6630
			27	20.0674	8.8645	43	26.3031	8.7912	58	26.2288	8.7179
			28	3.9459	8.9377	44	1.2359	2.1245	59	13.1172	8.7912
			29	0.1345	2.1245				60	1.9464	3.0769

Table C.7. Motor Voltage vs. Velocity

<u>B-CYCLE (5/31)</u>		<u>BEGINNING CYCLES</u>				<u>LAST CYCLE</u>	
<u>CYCLE #5</u>		<u>CYCLE #6</u>		<u>CYCLE #7</u>		<u>CYCLE #9</u>	
X	Y	X	Y	X	Y	X	Y
1		1.4571	10.3853	18	2.5333	5.2237	21.4408
2		8.7661	36.2882	19	9.7974	11.7704	51.0378
3		13.9676	62.1734	20	14.9983	18.1926	76.0254
4		20.5591	99.1099	21	21.1420	24.0791	103.2479
5		26.3883	115.0672	22	27.7111	29.7065	129.9634
6		31.3208	137.8266	23	32.6436	34.7207	136.8498
7		36.5447	136.9953	24	36.4775	35.2445	144.2247
8		35.9171	142.8571	25	37.3295	36.3438	141.2943
9		35.7153	142.8571	26	37.3968	36.9788	143.3456
10		35.8850	142.5641	27	36.7018	37.0685	143.0037
11		35.5612	143.0525	28	37.2623	37.2847	143.3456
12		36.4552	143.2479	29	33.8321	37.1502	143.2479
13		36.0292	143.5403	30	27.7564	32.6215	136.8018
14		30.6837	131.3309	31	11.6814	27.3752	112.7717
15		20.6493	101.0012	32	0.0004	10.6501	66.2753
16		5.3141	41.2698			0.0000	0.0000
17		0.0002	0.0000			0.0003	0.0008

<u>B-CYCLE (6/3)</u>		<u>BEGINNING CYCLES</u>				<u>LAST CYCLE</u>	
<u>CYCLE #6</u>		<u>CYCLE #7</u>		<u>CYCLE #8</u>		<u>CYCLE #9</u>	
X	Y	X	Y	X	Y	X	Y
1	6.8156	1.1070	27.5458	31	0.7845	3.6905	11.3797
2	11.8153	12.0519	51.5263	32	7.1967	8.8762	38.2418
3	16.9271	18.7555	79.7070	33	12.3962	15.7612	60.0830
4	23.9894	24.0172	107.3393	34	17.5549	22.4203	96.5079
5	29.2886	29.8411	134.5543	35	23.428	27.7112	118.6325
6	33.4059	33.4356	130.5592	36	29.5496	32.9799	137.5824
7	33.3036	33.0249	142.5641	37	31.4778	32.6213	142.0757
8	83.1250	32.5662	142.3199	38	31.3209	29.3033	121.6606
9	32.7559	32.0271	141.9392	39	31.2761	29.9533	130.6960
10	33.0697	33.1018	142.4176	40	30.8189	31.3209	135.7265
11	33.0054	33.4957	142.4664	41	30.5507	31.0968	135.9916
12	28.6271	32.7110	142.2222	42	30.8953	31.6124	135.3219
13	19.9642	29.3033	124.8352	43	30.9847	31.6573	137.1429
14	0.0005	17.9365	96.9475	44	25.2279	24.9765	107.6923
		0.0000	24.1278	45	6.5921	10.3810	64.5665
			0.0000	46	0.0002	0.0003	2.0327

Table C.8. Motor Current vs. Time (normalized)

B-CYCLE (5/31)		BEGINNING CYCLES				CYCLE #9				LAST CYCLE	
		CYCLE #5		CYCLE #6		CYCLE #7		CYCLE #8		CYCLE #9	
X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
1	0.0065	117.7289	17	0.0073	118.7546	34	0.0153	110.3297	51	-0.0032	0.0000
2	0.0599	107.3993	18	0.0606	131.3553	35	0.0506	120.7526	52	0.0392	99.5604
3	0.1132	119.1289	19	0.1140	104.6886	36	0.1219	119.0535	53	0.0926	102.4176
4	0.1665	116.0498	20	0.1673	109.0843	37	0.1753	111.5414	54	0.1459	111.0681
5	0.2199	122.5641	21	0.2206	129.3040	38	0.2280	118.3983	55	0.1992	122.1970
6	0.2655	112.8205	22	0.2743	102.7106	39	0.2810	93.6278	56	0.2526	118.1685
7	0.3799	50.7692	23	0.3273	115.3114	40	0.3553	76.7033	57	0.3059	113.5531
8	0.4332	45.4945	24	0.3806	52.0205	41	0.3886	49.3040	58	0.3592	31.7216
9	0.4865	47.2527	25	0.4340	51.3553	42	0.4319	48.1319	59	0.4126	60.8645
10	0.5399	46.3004	26	0.4873	53.1136	43	0.4553	55.7509	60	0.4659	48.3517
11	0.5932	47.3993	27	0.5406	47.9121	44	0.5436	40.2199	61	0.5192	48.3517
12	0.6465	47.5459	28	0.5940	49.6703	45	0.6019	49.6703	62	0.5726	43.8828
13	0.6999	0.0000	29	0.6473	48.4249	46	0.6553	0.0000	63	0.6259	48.5714
14	0.7532	0.0000	30	0.7005	0.0000	47	0.7086	0.0000	64	0.6792	0.0000
15	0.8065	0.0000	31	0.7540	0.0000	48	0.7519	0.0000	65	0.7326	52.0205
16	0.8599	0.0000	32	0.8073	0.0000	49	0.8153	0.0000	66	0.7859	0.0000
			33	0.8606	0.0000	50	0.8686	0.0000	67	0.8332	0.0000

B-CYCLE (6/3)		BEGINNING CYCLES				CYCLE #8				LAST CYCLE	
		CYCLE #6		CYCLE #7		CYCLE #8		CYCLE #9		CYCLE #9	
X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
1	0.0694	149.5971	15	0.0732	119.6337	31	0.0732	105.2717	48	0.0432	129.4982
2	0.1227	101.4652	16	0.1265	108.9377	32	0.0555	90.9830	49	0.0065	99.4139
3	0.1760	123.9560	17	0.1798	115.6944	33	0.1090	109.4302	50	0.1395	130.3297
4	0.2297	119.0476	18	0.2332	114.7935	34	0.1672	117.9696	51	0.1932	99.4872
5	0.2830	67.1795	19	0.2865	111.0623	35	0.2165	104.7619	52	0.2465	98.2418
6	0.3894	41.6850	20	0.3398	47.6288	36	0.2699	136.0440	53	0.2999	66.8864
7	0.4427	51.7216	21	0.3932	43.5967	37	0.3232	46.6567	54	0.3532	46.6667
8	0.4960	49.9634	22	0.4465	49.8901	38	0.3735	84.4689	55	0.4065	50.1832
9	0.5494	50.8425	23	0.4998	43.4249	39	0.4239	46.0806	56	0.4599	57.0022
10	0.6027	48.1319	24	0.5532	49.0110	40	0.4832	44.6886	57	0.5132	54.4322
11	0.6560	50.7692	25	0.6065	45.6667	41	0.5365	50.4762	58	0.5665	44.6154
12	0.7094	0.0000	26	0.6598	49.1575	42	0.5898	50.2297	59	0.6199	44.8352
13	0.7627	0.0000	27	0.7132	0.0000	43	0.6432	49.5971	60	0.6732	0.0000
14	0.8160	0.0000	28	0.7665	0.0000	44	0.6965	50.7692	61	0.7265	0.0000
			29	0.8198	0.0000	45	0.7498	0.0000	62	0.7799	0.0000
			30	0.8732	0.0000	46	0.8032	0.0000	63	0.8332	0.0000

Table C.9. Motor Current vs. Velocity

B-CYCLE (5/31)

CYCLE #5

CYCLE #6

CYCLE #7

CYCLE #8

CYCLE #9

LAST CYCLE

1

2

3

4

5

6

7

8

9

10

11

12

0.7721

7.0722

12.8468

18.6704

25.4675

34.9895

37.1796

37.6224

36.9148

36.3375

6.0958

0.3715

117.7289

107.3993

119.1209

116.8498

122.5641

112.8205

58.7692

45.4945

47.3993

47.5458

0.0000

0.0000

13

14

15

16

17

18

19

20

21

22

23

24

25

26

27

28

29

1.0005

8.0095

13.6427

20.1473

26.0242

31.0127

36.2104

35.9563

35.7279

35.7994

35.9521

36.4244

36.0558

30.9426

21.2711

6.2720

0.3321

119.7546

131.3553

104.6885

109.0843

129.3040

102.7106

115.3114

52.8285

51.3553

53.1136

47.9121

49.6703

48.4249

0.0000

0.0000

0.0000

30

31

32

33

34

35

36

37

38

39

40

41

42

43

44

45

2.0795

9.3436

14.6740

20.7583

27.3008

32.3355

36.2330

37.2763

37.3086

37.3912

36.7452

37.2273

34.0454

28.1359

12.6856

0.7301

110.5297

120.7326

119.8335

111.9414

113.3083

98.0278

76.7033

49.3040

48.1319

55.7509

40.2158

49.6703

0.0000

0.0000

0.0000

0.0000

46

47

48

49

50

51

52

53

54

55

56

57

58

59

60

61

4.8147

11.3614

17.7820

23.7107

29.3550

34.4149

35.2123

36.2744

36.9316

37.0549

37.2707

37.1586

32.9044

27.7829

11.6949

0.6656

99.5604

102.4176

111.8681

122.1978

118.1685

113.5531

31.7216

68.0645

40.3517

48.3517

43.0828

48.5714

0.0000

52.8205

0.0000

0.0000

B-CYCLE (6/3)

CYCLE #6

CYCLE #7

CYCLE #8

CYCLE #9

LAST CYCLE

1

2

3

4

5

6

7

8

9

10

11

12

6.5032

11.5929

16.6077

23.9500

33.1432

33.3050

32.7727

33.0501

33.3009

29.1967

20.5144

1.2471

149.5971

101.4652

123.9568

119.0476

67.1795

41.6850

50.8425

48.1319

58.7692

0.0000

0.0000

0.0000

13

14

15

16

17

18

19

20

21

22

23

24

25

26

27

28

6.7951

11.7524

18.3467

24.2516

29.5147

33.2673

33.0543

32.6866

32.6133

33.1594

33.4761

32.7601

29.5161

18.6466

1.7936

0.0448

105.2747

98.5830

108.4982

117.0696

104.7619

136.0440

46.5667

84.4589

46.0006

44.6886

50.4762

49.3297

49.5371

50.7692

0.0000

0.0000

46

47

48

49

50

51

52

53

54

55

56

57

58

59

60

61

3.2803

6.5491

15.3512

22.0040

27.3806

32.6500

32.6438

29.5105

29.5127

31.2355

31.1188

31.5802

31.6545

25.3336

11.2928

0.6488

128.4982

99.4139

130.3297

99.4872

98.2418

66.0064

46.6667

50.1932

57.0022

44.6154

44.8352

0.0000

0.0000

0.0000

0.0000

0.0000

Table C.10. Motor Field Voltage vs. Time (normalized)

[illegible]

<u>B-CYCLE (6/3)</u>			<u>BEGINNING CYCLES</u>			<u>CYCLE #8</u>			<u>CYCLE #9</u>			<u>LAST CYCLE</u>		
<u>CYCLE #6</u>			<u>CYCLE #7</u>			<u>CYCLE #8</u>			<u>CYCLE #9</u>			<u>LAST CYCLE</u>		
X	Y		X	Y		X	Y		X	Y		X	Y	
1	0.0760	118.1441	15	0.6798	119.1697	31	0.2099	121.3675	46	0.0399	120.2442	1	0.0084	103.3944
2	0.1294	118.2418	16	0.1332	117.9407	32	0.0632	120.0488	49	0.0932	119.3162	2	0.0618	96.3614
3	0.1827	115.3682	17	0.1663	116.0440	33	0.1165	118.1929	50	0.1465	116.1905	3	0.1151	94.6832
4	0.2360	114.3346	18	0.2398	114.6764	34	0.1699	116.3058	51	0.1999	115.8974	4	0.1684	92.4542
5	0.2694	105.7875	19	0.2332	99.8291	35	0.2332	115.5556	52	0.2532	113.3577	5	0.2218	87.9121
6	0.3427	99.1941	20	0.3455	110.3297	36	0.2765	112.9670	53	0.3065	116.4347	6	0.2751	64.4689
7	0.3960	107.9365	21	0.3998	116.9231	37	0.3299	112.7228	54	0.3599	117.4683	7	0.3284	40.3419
8	0.4494	101.8315	22	0.4532	108.3272	38	0.3832	115.4090	55	0.4132	111.3965	8	0.3818	35.2137
9	0.5027	102.9860	23	0.5065	110.1343	39	0.4365	117.9487	56	0.4665	117.0696	9	0.4351	24.1278
10	0.5550	103.5409	24	0.5598	113.8181	40	0.4899	118.0952	57	0.5199	117.7045	10	0.4884	36.3339
11	0.6094	104.5177	25	0.6132	108.7668	41	0.5432	111.4842	58	0.5732	118.1441	11	0.5418	38.1905
12	0.7160	110.0356	26	0.6665	111.5507	42	0.5965	117.7045	59	0.6265	118.1929	12	0.5951	38.3394
13	0.7694	110.7204	27	0.7198	110.0366	43	0.6499	117.8510	60	0.6799	109.9878	13	0.6484	38.5346
14	0.8227	0.0000	28	0.7732	110.5739	44	0.7032	117.9976	61	0.7332	110.5250	14	0.7018	92.7961
			29	0.8265	10.7937	45	0.7565	110.4762	62	0.7865	110.8669	15	0.7551	93.4799
			30	0.8798	0.1954	46	0.8099	110.7652	63	0.8399	0.0000	16	0.8084	0.0000
						47	0.8632	0.0000						

Table C.11. Motor Field Voltage vs. Velocity

B-CYCLE (5/31)				BEGINNING CYCLES				LAST CYCLE			
CYCLE #5		CYCLE #6		CYCLE #7		CYCLE #9		CYCLE #9		CYCLE #9	
X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
1	1.5596	120.5861	13	1.5141	120.1954	29	2.9875	120.3987	44	5.6331	119.9512
2	7.8597	119.4139	14	9.2231	118.6325	30	10.2516	118.6325	45	12.1798	118.0464
3	13.5642	117.6068	15	14.2929	116.7766	31	15.3242	116.7766	46	18.5835	116.4835
4	19.3998	115.7021	16	20.9713	115.7021	32	21.5262	115.5067	47	24.4478	114.5788
5	26.3479	113.9438	17	28.7529	113.1624	33	28.1219	113.6020	48	30.0584	113.5531
6	31.1346	96.4591	18	31.6232	85.1770	34	32.9528	71.5507	49	35.0427	54.6520
7	35.5444	44.2802	19	36.8714	43.6142	35	36.7172	68.1807	50	35.2767	90.6471
8	37.4347	61.7330	20	35.8779	75.3114	36	37.3828	64.8107	51	36.4117	63.2479
9	37.6645	65.0852	21	35.7027	75.1648	37	37.3858	64.8596	52	37.0101	67.0877
10	36.9372	68.1807	22	35.8106	75.1648	38	37.4824	63.1502	53	37.0661	68.8645
11	36.2558	63.7436	23	35.9717	74.0904	39	36.6584	71.3065	54	37.2987	70.1832
12	4.9829	109.0901	24	36.4868	72.9678	40	37.2973	66.4713	55	37.1418	71.9902
			25	36.0026	71.5018	41	37.6176	109.1087	56	32.3383	109.1087
			26	30.2644	109.3529	42	27.3764	109.4505	57	27.0471	108.9622
			27	20.0268	109.8901	43	10.5762	109.7435	58	9.6042	109.7924
			28	4.3551	110.0366						

B-CYCLE (6/3)				BEGINNING CYCLES				LAST CYCLE			
CYCLE #6		CYCLE #7		CYCLE #8		CYCLE #9		CYCLE #9		CYCLE #9	
X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
1	7.1282	118.1441	12	7.4169	119.1697	26	1.1855	121.3675	42	3.9389	120.2442
2	12.1279	118.2418	13	12.3717	117.9487	27	7.5976	120.0488	43	9.2077	119.3162
3	17.2467	115.3602	14	19.1847	116.0440	28	12.7234	118.1929	44	16.1916	116.1905
4	24.4310	114.3346	15	24.5831	114.6764	29	17.8773	116.7858	45	22.0363	115.8974
5	29.6114	105.7875	16	30.1677	99.8291	30	24.1297	115.5556	46	28.0428	113.3577
6	33.339	99.1941	17	33.7241	110.397	31	29.9127	112.9670	47	33.3094	116.4347
7	33.3822	107.9365	18	32.9955	116.9231	32	31.5984	112.7228	48	32.5989	117.4603
8	32.7390	103.5409	19	32.6438	100.3272	33	30.0810	115.4890	49	29.9949	117.0696
9	33.0894	104.5177	20	32.8329	110.1343	34	31.3980	117.9487	50	29.9949	117.0696
10	28.5474	118.0366	21	33.2843	118.8181	35	31.2733	118.0952	51	31.4064	117.7045
11	19.3934	110.7204	22	33.5153	108.7668	36	29.7277	111.4042	52	31.0828	118.1441
			23	32.6620	111.5507	37	30.6049	117.7045	53	31.6447	118.1929
			24	29.0902	118.0366	38	30.8207	117.8510	54	31.6601	109.9878
			25	17.2257	118.5739	39	30.9959	117.9976	55	24.5585	110.5250
						40	24.8626	110.4762	56	9.4633	110.8669
						41	5.4271	110.7692			

Table C.12. Motor Field Current vs. Time (normalized)

B-CYCLE (5/31)				BEGINNING CYCLES				LAST CYCLE			
CYCLE #5		CYCLE #6		CYCLE #7		CYCLE #9		CYCLE #9		CYCLE #9	
X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
1	-0.0168	0.0000	0.0000	18	-0.0168	0.0000	0.0000	51	-0.0266	0.0000	0.0000
2	0.0365	0.0842	0.0842	19	0.0373	0.0842	0.0842	52	0.0159	0.0000	0.0000
3	0.0899	0.0845	0.0845	20	0.0906	0.0845	0.0845	53	0.0692	0.0000	0.0000
4	0.1432	0.0845	0.0845	21	0.1440	0.0845	0.0845	54	0.1226	0.0000	0.0000
5	0.1965	0.0845	0.0845	22	0.1973	0.0845	0.0845	55	0.1759	0.0000	0.0000
6	0.2499	0.0845	0.0845	23	0.2506	0.0845	0.0845	56	0.2292	0.0000	0.0000
7	0.3032	0.0845	0.0845	24	0.3040	0.0845	0.0845	57	0.2826	0.0000	0.0000
8	0.3565	0.0845	0.0845	25	0.3573	0.0845	0.0845	58	0.3359	0.0000	0.0000
9	0.4099	0.0845	0.0845	26	0.4106	0.0845	0.0845	59	0.3892	0.0000	0.0000
10	0.4632	0.0845	0.0845	27	0.4640	0.0845	0.0845	60	0.4426	0.0000	0.0000
11	0.5165	0.0845	0.0845	28	0.5173	0.0845	0.0845	61	0.4959	0.0000	0.0000
12	0.5699	0.0845	0.0845	29	0.5706	0.0845	0.0845	62	0.5492	0.0000	0.0000
13	0.6232	0.0845	0.0845	30	0.6240	0.0845	0.0845	63	0.6026	0.0000	0.0000
14	0.6765	0.0845	0.0845	31	0.6773	0.0845	0.0845	64	0.6559	0.0000	0.0000
15	0.7299	0.0845	0.0845	32	0.7306	0.0845	0.0845	65	0.7092	0.0000	0.0000
16	0.7832	0.0845	0.0845	33	0.7840	0.0845	0.0845	66	0.7626	0.0000	0.0000
17	0.8365	0.0845	0.0845	34	0.8373	0.0845	0.0845				

B-CYCLE (6/3)				BEGINNING CYCLES				LAST CYCLE			
CYCLE #6		CYCLE #7		CYCLE #8		CYCLE #9		CYCLE #9		CYCLE #9	
X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
1	0.0460	0.7912	0.7912	16	0.0498	0.0000	0.0000	49	0.0099	0.0000	0.0000
2	0.0994	0.3516	0.3516	17	0.1032	0.0000	0.0000	50	0.0632	0.0000	0.0000
3	0.1527	0.3516	0.3516	18	0.1565	0.0000	0.0000	51	0.1165	0.0000	0.0000
4	0.2060	0.3516	0.3516	19	0.2098	0.0000	0.0000	52	0.1699	0.0000	0.0000
5	0.2594	0.3516	0.3516	20	0.2632	0.0000	0.0000	53	0.2232	0.0000	0.0000
6	0.3127	0.3516	0.3516	21	0.3165	0.0000	0.0000	54	0.2765	0.0000	0.0000
7	0.3660	0.3516	0.3516	22	0.3698	0.0000	0.0000	55	0.3299	0.0000	0.0000
8	0.4194	0.3516	0.3516	23	0.4232	0.0000	0.0000	56	0.3832	0.0000	0.0000
9	0.4727	0.3516	0.3516	24	0.4765	0.0000	0.0000	57	0.4365	0.0000	0.0000
10	0.5260	0.3516	0.3516	25	0.5298	0.0000	0.0000	58	0.4899	0.0000	0.0000
11	0.5794	0.3516	0.3516	26	0.5832	0.0000	0.0000	59	0.5432	0.0000	0.0000
12	0.6327	0.3516	0.3516	27	0.6365	0.0000	0.0000	60	0.5965	0.0000	0.0000
13	0.6860	0.3516	0.3516	28	0.6898	0.0000	0.0000	61	0.6499	0.0000	0.0000
14	0.7394	0.3516	0.3516	29	0.7432	0.0000	0.0000	62	0.7032	0.0000	0.0000
15	0.7927	0.3516	0.3516	30	0.7965	0.0000	0.0000	63	0.7565	0.0000	0.0000

Table C. 13. Motor Field Current vs. Velocity

B-CYCLE (5/31)			BEGINNING CYCLES			LAST CYCLE							
CYCLE #5			CYCLE #6			CYCLE #7			CYCLE #9				
X	Y		X	Y		X	Y		X	Y			
1	4.3159	9.0842	13	5.1118	28	2.6568	0.2530	44	1.9506	8.5714	1	5.6049	7.9853
2	10.3357	8.0845	14	11.3670	29	6.1655	0.5714	45	8.4972	8.5714	2	11.7033	7.5458
3	16.1201	8.5714	15	17.2635	30	12.3963	0.5714	46	14.9767	8.4982	3	17.5214	7.1795
4	22.4762	8.4982	16	23.4739	31	18.6707	8.4582	47	21.1310	8.2784	4	25.9738	7.1862
5	28.3727	8.2784	17	28.8547	32	24.4268	8.2784	48	26.6930	8.2051	5	28.0252	4.9817
6	33.0473	4.9956	18	33.9329	33	30.1775	7.8388	49	32.2178	6.1538	6	29.6619	3.7363
7	36.2870	4.3223	19	36.2310	34	34.5607	3.6530	50	34.9867	5.3480	7	30.9286	3.2967
8	37.4753	4.3223	20	35.8162	35	36.5936	4.1758	51	35.7938	4.7619	8	32.1393	2.8571
9	36.8363	4.7619	21	35.7602	36	37.3184	4.7619	52	36.6570	4.6886	9	33.1378	2.7106
10	36.6121	4.9817	22	35.8835	37	37.3520	4.3956	53	37.0157	4.7619	10	34.2356	2.4908
11	13.6090	7.9853	23	36.2036	38	0493	4.9884	54	37.1726	4.7619	11	34.9642	2.3443
12	2.9747	7.0330	24	36.2422	39	9821	4.8352	55	37.2175	5.0549	12	34.0002	3.2234
			25	33.3164	40	5472	4.6154	56	34.8858	7.7656	13	23.7654	7.2527
			26	25.6262	41	4.7941	7.8388	57	29.9982	7.7656	14	7.2978	7.3260
			27	12.9813	42	19.7185	7.9121	58	19.0123	7.5458			
					43	5.8405	7.9121						

B-CYCLE (6/3)				BEGINNING CYCLES													
CYCLE #6				CYCLE #7				CYCLE #8				CYCLE #9				LAST CYCLE	
	X	Y		X	Y		X	Y		X	Y		X	Y		X	Y
1	4.3159	8.7912	14	4.6258	8.4249	30	3.9988	8.1319	46	0.9753	7.9121	1	5.1791	6.7395			
2	9.3156	8.3516	15	9.5846	8.3516	31	9.7976	8.1319	47	6.2440	7.9121	2	12.4544	6.3736			
3	14.3713	8.3516	16	15.4139	8.8586	32	14.9767	7.9121	48	12.3199	7.6923	3	17.3388	6.3736			
4	20.4584	7.9853	17	21.6915	7.9853	33	20.6499	7.8338	49	19.0988	7.6198	4	21.4113	6.2271			
5	26.6352	7.9853	18	27.2293	7.8388	34	26.6464	7.3993	50	25.0657	7.2527	5	25.1554	5.4212			
6	31.3434	6.1538	19	31.6685	5.7143	35	30.5138	7.9121	51	30.3457	7.1062	6	28.0476	2.7839			
7	33.3948	6.1538	20	33.2603	7.7656	36	30.7829	7.3260	52	32.8087	7.6198	7	29.9533	2.7839			
8	32.8984	6.9597	21	32.8455	8.0586	37	30.7044	7.9121	53	30.9622	6.8132	8	31.6909	1.5385			
9	32.9128	7.1795	22	32.7446	7.3993	38	31.2985	7.9121	54	29.6282	7.3993	9	32.8984	1.0256			
10	33.1931	7.2527	23	33.9025	7.3993	39	30.5475	7.8700	55	30.6372	7.6198	10	33.1818	1.6850			
11	31.1192	7.2527	24	33.3538	7.3993	40	30.1887	7.8388	56	31.2889	7.6198	11	33.2043	2.1245			
12	24.4380	7.2527	25	33.1834	7.2527	41	30.6828	7.8388	57	31.3546	7.3993	12	32.9913	2.3443			
13	9.9770	7.6198	26	31.0871	7.1795	42	30.8959	7.5458	58	31.6348	7.6198	13	31.3658	6.2271			
			27	23.6196	7.1795	43	28.1037	7.2527	59	28.3167	6.8132	14	21.8036	6.3736			
			28	9.3268	7.3993	44	15.9871	7.1795	60	5.1903	6.8132	15	6.9166	6.2271			
			29	0.3587	0.0008	45	3.2958	7.1795									

APPENDIX D

DATA FLOW PATH OVERVIEW

Electrical measurements made on the electric vehicles are recorded, computer processed, and eventually presented in tabular and/or graphical format. The flow from one end to the other is very complex. In this section, an overview description is given of the data collection system and the data analysis software.

A. DATA RECORDING PHASE

Performance tests of the electric vehicles were made during their operation around a race track. Electrical parameters such as voltage, current, and power were measured continuously during the test. A custom-made portable data logger transcribed the electrical measurements from their respective transducers onto a magnetic tape cassette via a Datel recorder (Fig. D.1). Sixteen different parameters were measured, scanned, and recorded serially on a digital cassette. All data entries onto the tape were followed by a hexadecimal channel or parameter identification number. A more comprehensive description of the recording system is given in Section 4.

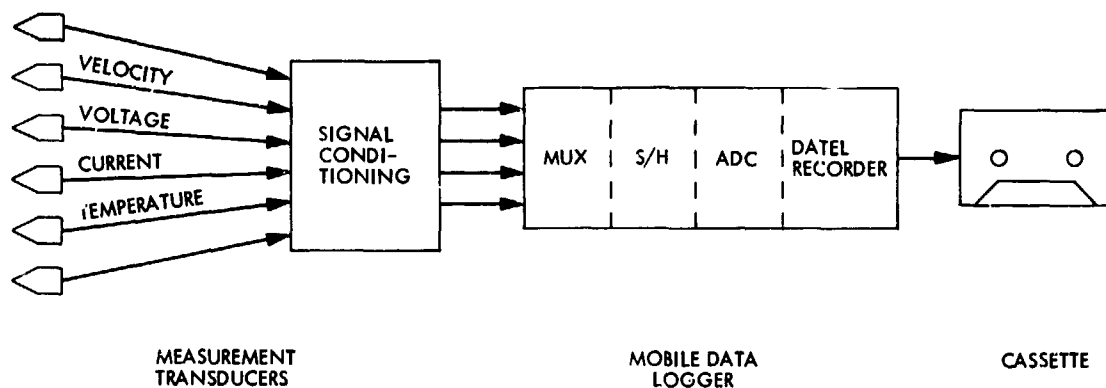


Figure D.1. Functional diagram of the Data Acquisition System used on board the electric vehicles

B. DATA ANALYSIS PHASE

The electrical measurements recorded on cassette during a test were read or transcribed into the memory of the Automated Control and Test System (ACTS) mini-computer for subsequent storage and analysis. A Datel LPR-16 reader was used to convert the magnetic images on the cassette's tape into a serial stream of hexadecimal ASCII (American Standard Code for Information Interchange) characters. Each character is coded by a sequence of seven binary data bits followed by a parity and a stop bit. Each bit is represented electrically as a "0" or LO by a 0 volt level or as a "1" or HI by an applied voltage level.

The serial stream of bits which represent a character, which in turn code a data measurement entry are made available at an RS232 connector of the Datel reader. The signal is received by a DL11 interface input/output card of the ACTS mini-computer. The mini-computer is a PDP-11/10 supported by 28K memory, dual disk-cartridge drives, operator terminals, and an electrostatic printer/plotter (Figure D.2).

Extensive software programs were written to accept the data and handle it appropriately. A description of these is given below. The operational sequence for data analysis was to

- 1) turn-on the ACTS and supporting equipment,
- 2) load and rewind the cassette and the Datel reader,
- 3) type-in commands at the operator terminal to run or execute the software data acquisition programs,
- 4) perform operations according to instructions given at the terminal by the program, and
- 5) once the data is loaded into the computer, run other special analysis software.

C. GENERAL SOFTWARE DESCRIPTION

The one entity which gives "power" to a computer, which greatly facilitates reduction of massive data, and which opens the avenues to varied forms of data analysis is the software. For the electric vehicle project, two basic types of programs were written:

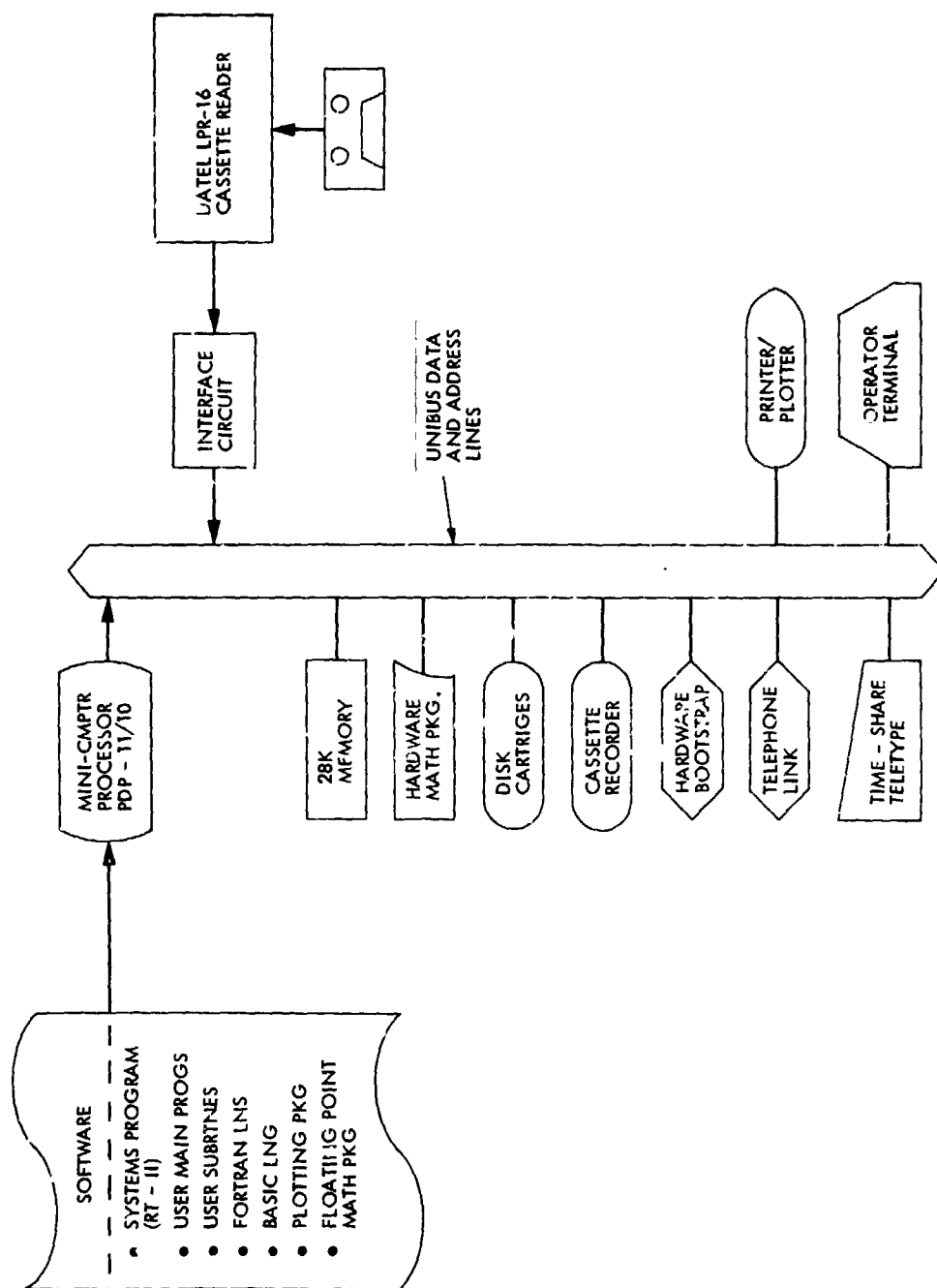


Figure D.2. Configuration of the Automated Control and Test System (ACTS) used in conjunction with the Datel cassette reader for data recovery and analysis

- 1) data acquisition and storing
- 2) data analysis and presentation.

Most programs were written in DEC RT-11 FORTRAN language which is analogous to FORTRAN IV. This language was chosen since it is popular among programmers and different people can write their own special analysis or user software.

The user programs (those which the operator calls at the terminal) conform to certain conventions. A single program consists basically of four parts (Figure D.3):

- 1) non-executable statements such as dimensioning of arrays, data entries of constants and alphanumeric labels, and input/output (I/O) format specifications;
- 2) a central executive loop which coordinates execution of the program;
- 3) the main program consisting of a sequential list of computer instructions and categorized in sections, each of which accomplishes one operator task; and
- 4) subroutines which are shared by different sections of the program and which accomplish one detailed mathematical or I/O operation. Subroutines may be internal to the user program, or be called-in from a library, such as the least-square-fit routine and the plotting package. The latter routines are also called sub-programs since they are compiled separately from the user program.

The executive loop allows the program to:

- 1) be interactive with the operator
- 2) incorporate several tasks such as acquire, store, and print data in one user program.

The program will type questions at the terminal and wait for the operator to respond. Typically, information is requested such as the file name to store data into, whether the cassette is ready to be read, or simply what operation it shall perform next. The latter is referred to the

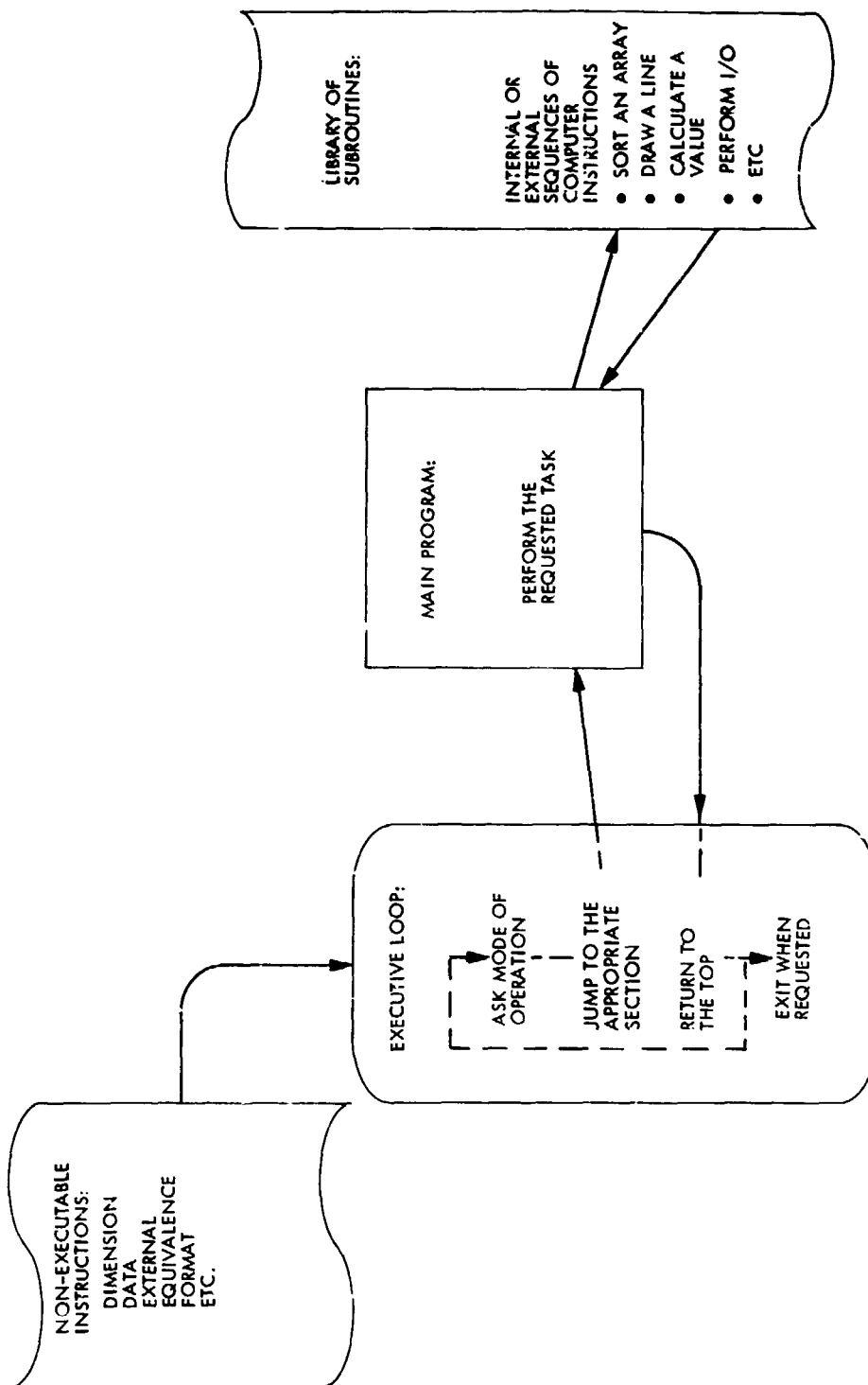


Figure D.3. Typical structure of the user software programs developed for data analysis of the electric vehicles

program's mode of operation; that is, one mode of operation will perform a given operator task which is defined by one section of the main part of the user program.

Systems programs are also available to the operator. These enable one to create a user program, run it, duplicate it, and transfer it (or a data file) from one peripheral to another. One system program, for example, called PIP allows the operator to create storage space on disk by deleting old un-used data files.

Report #2

RIPP Electric Passenger Car

Section II

900-850

TEST TRACK EVALUATION
OF THE RIPP-ELECTRIC

October 1977

Prepared by:

Wally E. Rippel
Electrochemical Power Group
Electric Propulsion and
Power Section

Approved by:

Aiji Uchigama

CONTENTS

1	INTRODUCTION -----	1-1
2	SUMMARY OF RESULTS -----	2-1
2.1	CONSTANT SPEED TESTS -----	2-1
2.1.1	Range (miles) -----	2-1
2.1.2	Miles per Line KWH -----	2-1
2.2	DRIVING CYCLE TESTS -----	2-1
2.2.1	Range (miles) -----	2-1
2.2.2	Miles per Line KWH -----	2-1
2.3	ACCELERATION TESTS (BATTERY 20% DISCHARGED) -----	2-1
2.3.1	EV-106 Batteries, 2N6251 Transistors -----	2-1
2.3.2	LEV-115 Batteries, SDT-12302 Transistors -----	2-2
3	VEHICLE DESCRIPTION -----	3-1
3.1	GENERAL DESCRIPTION -----	3-1
3.2	BATTERY -----	3-9
3.3	TRACTION MOTOR -----	3-15
3.4	DATA ON BAKER-OTIS 1265 MOTOR -----	3-15
3.5	CONTROL SYSTEM -----	3-19
3.6	DATA ON MOTOR-CONTROL SYSTEM COMBINATION -----	3-19
3.7	CHARGER -----	3-20
3.8	INSTRUMENT PANEL -----	3-20
3.9	ADDITIONAL SPECIFICATIONS -----	3-21
3.9.1	Vehicle -----	3-21
3.9.2	Transmission -----	3-21
3.9.3	Rear axle -----	3-21
3.9.4	Wheels -----	3-21
3.9.5	Previous service -----	3-22
4	INSTRUMENTATION -----	4-1
4.1	GENERAL DESCRIPTION -----	4-1
4.1.1	Vehicle Instrumentation Equipment -----	4-1
4.1.2	Data Reading and Processing Equipment -----	4-1
4.1.3	Calibration Instrumentation -----	4-1
4.2	VEHICLE INSTRUMENTATION -----	4-3
4.2.1	Fifth Wheel and Associated Components -----	4-3
4.2.2	Charge/Discharge Current Integrator -----	4-4
4.2.3	AC Watt-Hours Meter -----	4-5
4.2.4	Voltage, Current, Energy, and Temperature Data Acquisition -----	4-5
4.3	DATA READING AND PROCESSING -----	4-11
4.3.1	Data Acquisition Software -----	4-11
4.3.2	Data Analysis Software -----	4-14
4.4	SCALE FACTORS -----	4-27
4.4.1	Sensors -----	4-27
4.4.2	Interfaces -----	4-28
4.4.3	Measuring and Recording Instruments -----	4-28
4.5	MANUFACTURERS' SPECIFICATIONS -----	4-29
4.5.1	Sensors -----	4-29
4.5.2	Interfaces -----	4-29
4.5.3	Measuring and Recording Instruments -----	4-30

4.6	LAB AND FIELD CALIBRATIONS -----	4-32
4.6.1	AAC Current Sensors -----	4-32
4.6.2	Current Integrator Field Cal. April 14, 1977, Dynamic Science -----	4-32
4.6.3	Energy Counter Field Measurements -----	4-33
4.6.4	Fifth Wheel Lab and Field Measurements -----	4-33
4.6.5	AC KWH Meter -----	4-33
4.7	LIST OF INSTRUMENTS, MODEL AND SERIAL NUMBERS -----	4-36
5.1	TEST PROCEDURES -----	5-1
5.2	PROCEDURES FOR CONSTANT SPEED TESTS -----	5-1
5.2.1	Charge State -----	5-1
5.2.2	Battery Temperature -----	5-1
5.2.3	Charging -----	5-1
5.2.4	Wind Velocity -----	5-1
5.2.5	Instrumentation -----	5-2
5.2.6	Vehicle Test Weight -----	5-2
5.2.7	Tire Pressures -----	5-2
5.2.8	Test Start -----	5-2
5.2.9	Test Termination -----	5-3
5.2.10	Tests to be Performed -----	5-3
5.3	PROCEDURES FOR DRIVING CYCLE TESTS -----	5-3
5.3.1	Charge-State -----	5-3
5.3.2	Battery Temperature -----	5-3
5.3.3	Charging -----	5-3
5.3.4	Wind Velocity -----	5-3
5.3.5	Instrumentation -----	5-4
5.3.6	Vehicle Test Weight -----	5-4
5.3.7	Tire Pressures -----	5-4
5.3.8	Test Start -----	5-4
5.3.9	Driving Cycle Tests Details -----	5-4
5.3.10	Test Termination -----	5-5
5.4	PROCEDURES FOR ACCELERATION TESTS -----	5-6
5.4.1	Track Conditions -----	5-6
5.4.2	Wind Velocity -----	5-6
5.4.3	Instrumentation -----	5-6
5.4.4	Driving Technique -----	5-6
5.4.5	Charge State -----	5-6
5.5	PROCEDURES FOR COAT-DOWN TESTS -----	5-8
5.5.1	Warm-UP -----	5-8
5.5.2	Track Survey -----	5-8
5.5.3	Wind Velocity -----	5-8
5.5.4	Instrumentation -----	5-8
5.5.5	Other Procedures -----	5-8
5.6	PROCEDURES FOR WEIGHT SENSITIVITY TESTS -----	5-9
5.6.1	Definitions -----	5-9
5.6.2	Procedures for Constant Speed Tests -----	5-9
5.6.3	Procedures for Driving Cycle Tests -----	5-10
5.6.4	Parameters to be Measured -----	5-10
6.1	MEASURED DATA-CONSTANT SPEED TESTS -----	6-1
6.2	MEASURED DATA-DRIVING CYCLE TESTS -----	6-18
6.3	MEASURED DATA - ACCELERATION TESTS -----	6-44
6.3.1	Test Weight -----	6-44
6.3.2	Measured Wind Speeds -----	6-44
6.3.3	Ambient Temperatures -----	6-44

6.4	MEASURED DATA - COAST-DOWN TESTS -----	6-49
6.5	MEASURED DATA - WEIGHT SENSITIVITY TESTS -----	6-57
6.5.1	Constant Speed Tests -----	6-57
6.5.2	Driving Cycle Tests -----	6-57
7.1	REDUCED DATA - CONSTANT SPEED TESTS -----	7-1
7.1.1	Average Speed Achieved (1) -----	7-1
7.1.2	Distance Traveled (2) -----	7-1
7.1.3	End of Test Battery Voltage (3) -----	7-1
7.1.4	Discharge Amp-Hours -----	7-1
7.1.5	Discharge KWH (4) -----	7-1
7.1.6	Discharge KWH, corrected (5) -----	7-2
7.1.7	KWH to Motor (6) -----	7-2
7.1.8	KWH to Motor, corrected (7) -----	7-2
7.1.9	Recharge Amp-Hours (8) -----	7-2
7.1.10	Recharge Amp-Hours, corrected (9) -----	7-2
7.1.11	Recharge KWH (10) -----	7-2
7.1.12	Recharge KWH, corrected (11) -----	7-2
7.1.13	Charger Input -----	7-3
7.1.14	Weather Conditions -----	7-3
7.1.15	Miles per Line KWH (12) -----	7-3
7.1.16	Miles per Amp-Hour Discharged (13) -----	7-3
7.1.17	Charger Efficiency (14) -----	7-3
7.1.18	Coulombic Efficiency (15) -----	7-3
7.1.19	Voltaic Efficiency (16) -----	7-3
7.1.20	Cycle Efficiency (17) -----	7-4
7.1.21	Controller Efficiency (18) -----	7-4
7.1.22	Average Motor Amps (19) -----	7-4
7.1.23	Average Motor Volts (20) -----	7-4
7.1.24	Average Motor Torque (21) -----	7-4
7.1.25	Average Motor RPM (22) -----	7-4
7.1.26	Average Motor-Controller Efficiency (23) -----	7-4
7.1.27	Average Motor Efficiency (24) -----	7-4
7.1.28	DC Motor Efficiency (25) -----	7-5
7.1.29	Chopper Induced Losses (25) -----	7-5
7.1.30	Road Load KWH (27) -----	7-5
7.1.31	Average Gear Train Efficiency -----	7-5
7.2	REDUCED DATA - DRIVING CYCLE TESTS -----	7-7
7.2.1	Corrected Distance (2) -----	7-7
7.2.2	End-of-Test Battery Voltage (3) -----	7-7
7.2.3	Discharge KWH (4) -----	7-7
7.2.4	Discharge KWH, corrected (5) -----	7-7
7.2.5	KWH to Motor (6) -----	7-7
7.2.6	KWH to Motor, corrected (7) -----	7-7
7.2.7	Recharge Amp-Hours (8) -----	7-7
7.2.8	Recharge Amp-Hours, corrected (9) -----	7-7
7.2.9	Recharge KWH (10) -----	7-7
7.2.10	Recharge KWH, corrected (11) -----	7-7
7.2.11	Charger Input -----	7-7
7.2.12	Weather Conditions -----	7-7
7.2.13	Miles per Line KWH (12) -----	7-7
7.2.14	Miles per Net Amp-Hour Discharged (13) -----	7-7
7.2.15	Charger Efficiency (14) -----	7-8
7.2.16	Coulombic Efficiency (15) -----	7-8
7.2.17	Voltaic Efficiency (16) -----	7-8

7.2.18	Cycle Efficiency (17) -----	7-8
7.2.19	Forward Controller Efficiency (18a) -----	7-8
7.2.20	Reverse Controller Efficiency (18b) -----	7-8
7.2.21	Regenerative Braking Recharge Amp-Hours (19) -----	7-8
7.2.22	Regenerative Braking Recharge KWH (20) -----	7-8
7.2.23	Regenerative Braking Recharge KWH, corrected (21) ---	7-8
7.2.24	Kinetic Energy prior to braking (KWH) (22) -----	7-8
7.2.25	Tire KWH (23) -----	7-9
7.2.26	Aerodynamic KWH (24) -----	7-9
7.2.27	Road Load KW (25) -----	7-9
7.2.28	Forward Propulsion Efficiency (26) -----	7-9
7.2.29	Reverse Propulsion Efficiency (27) -----	7-9
7.2.30	Net Propulsion Efficiency (28) -----	7-10
7.3	REDUCED DATA - ACCELERATION TESTS -----	7-12
7.3.1	Fifth Wheel Errors, Corrected Speeds -----	7-12
7.3.2	Time Corrections -----	7-12
7.3.3	Data Plots -----	7-14
7.3.4	Acceleration Times -----	7-14
7.4	REDUCED DATA - COAST-DOWN TESTS -----	7-20
7.4.1	Fifth Wheel Errors -----	7-20
7.4.2	Generalized Road Load -----	7-21
7.4.3	Road Load Resolved into Rolling Resistance and Aerodynamic Components -----	7-23
7.5	REDUCED DATA - WEIGHT SENSITIVITY TESTS -----	7-34
7.5.1	Instrument Errors -----	7-34
7.5.3	Driving Cycle Tests -----	7-37
8	ENERGY FLOW MODELING -----	8-1
8.1	CONSTANT SPEED ANALYSES -----	8-1
8.1.1	Charger Input -----	8-1
8.1.2	Charger Efficiency, Battery Input -----	8-1
8.1.3	Control System Efficiency, Motor Input -----	8-2
8.1.4	Motor Efficiency, Motor Output -----	8-2
8.1.5	Road-Load Energy, Gear Train Efficiency -----	8-2
8.1.6	Summary of Constant Speed Energy Flow Analyses -----	8-2
8.2	DRIVING CYCLE ANALYSES (NO REGENERATIVE BRAKING) -----	8-2
8.2.1	Charger Input -----	8-2
8.2.2	Charger Efficiency, Battery Input -----	8-2
8.2.3	Control System Efficiency, Motor Input -----	8-2
8.2.4	Motor Efficiency, Motor Output -----	8-3
8.2.5	Road-Load Energy -----	8-3
8.2.6	Kinetic Energy -----	8-3
8.2.7	Gear Train Efficiency -----	8-3
8.2.8	Energy Dissipated on Brakes -----	8-3
8.2.9	Summary of Driving Cycle Energy Flow Analyses -----	8-3
8.3	DRIVING CYCLE ANALYSES (REGENERATIVE BRAKING) -----	8-3
8.3.1	Charger Input -----	8-4
8.3.2	Charger Efficiency, Battery Input -----	8-4
8.3.3	Control System Efficiency, Motor Input (forward flow) -----	8-4
8.3.4	Control System Efficiency, Motor Return (reverse flow) -----	8-4
8.3.5	Road-Load Energy -----	8-4
8.3.6	Kinetic Energy -----	8-4

8.3.7	Energy Returned to Wheels -----	8-4
8.3.8	Energy Dissipated on Brakes -----	8-4
8.3.9	Summary of Driving Cycle Energy Flow Analyses -----	8-4
9	OBSERVATIONS AND CONCLUSIONS -----	9-1
9.1.1	Chassis Dynamometer Testing -----	9-2
9.1.2	Application of Battery Models -----	9-2
9.1.3	Bench Tests for Sub-Components -----	9-2
9.2	INSTRUMENTATION -----	9-3
9.2	OBSERVATIONS ON THE RIPP-ELECTRIC -----	9-4
9.2.1	Chopper Induced Losses -----	9-4
9.2.2	Regenerative Braking -----	9-4
9.2.3	Transformerless Charger -----	9-4

Figures

3.1.1	Ripp-Electric Vehicle -----	3-2
3.1.2	Drive Line View -----	3-3
3.1.3	Baker-Otis Motor, Model 1265 -----	3-4
3.1.4	Rear Battery Pack View -----	3-5
3.1.5	Power Control Unit -----	3-6
3.1.6	Propulsion System Block Diagram -----	3-7
3.1.7	Instrument Panel View -----	3-8
3.2.1	Battery Discharge Curve, 75 Amp -----	3-10
3.2.2	Battery Discharge Curve, 300 Amp -----	3-11
3.2.3	Battery Discharge Curve, 500 Amp -----	3-12
3.2.4	Battery Discharge Time vs Current -----	3-13
3.2.5	Energy Density, Power Density vs Time -----	3-14
3.4.1	Motor Torque vs Current -----	3-17
3.4.2	Motor Efficiency vs Current -----	3-17
3.4.3	Motor RPM vs Torque -----	3-18
4.1.1	Vehicle Instrumentation Block Diagram -----	4-2
4.2.1	Current Integrator Block Diagram -----	4-8
4.2.2	Energy Counter Block Diagram -----	4-9
4.2.3	Digital Integrator Block Diagram -----	4-10
4.3.1	Sample of Preliminary Data Analysis -----	4-19
4.3.2	Sample Output from Operator's Terminal -----	4-20
4.3.3	Sample Printout of Rough Data -----	4-21
4.3.4	Sample Printout of Data in Engineering Units -----	4-22
4.3.5	Computer Plot of Battery Current -----	4-23
4.3.6	Computer Plot of Schedule C Data -----	4-24
4.3.7	Sample Printout of Core Memory Data -----	4-25
4.3.8	Computer Plot of Integrated Energy (Sample from Fiac Data) -----	4-26
4.6.1	Fifth Wheel Calibration Plot -----	4-35
6.1.1	Plot of Range vs Speed -----	6-2
6.1.2	Plot of Energy Consumption vs Speed -----	6-2
6.1.3	Motor Case Temp. - Test No. 2. -----	6-3
6.1.4	Motor Case Temp. - Test No. 3. -----	6-3
6.1.5	Motor Case Temp. - Test No. 4. -----	6-4
6.1.6	Motor Case Temp. - Test No. 5. -----	6-4
6.2.1	SAE J227a Driving Schedules B and C -----	6-20
6.2.2	Range and Miles per KWH -----	6-20

6.2.3	Strip Chart Speed Samples - Test No. 12 -----	6-21
6.2.4	Strip Chart Speed Samples - Test No. 13 -----	6-22
6.2.5	Strip Chart Speed Samples - Test No. 17 -----	6-23
6.2.6	Strip Chart Speed Samples - Test No. 24 -----	6-24
6.2.7	Strip Chart Speed Samples - Test No. 25 -----	6-25
6.2.8	Motor Case Temp. - Test No. 17. -----	6-26
6.2.9	Motor Case Temp. - Test No. 18. -----	6-26
6.2.10	Motor Case Temp. - Test No. 20. -----	6-27
6.2.11	Motor Case Temp. - Test No. 21. -----	6-27
6.2.12	Computer Plot of Speed vs Time - Test 22 -----	6-28
6.2.13	Computer Plot of Batt. Volts vs Time-Test 22 -----	6-29
6.2.14	Computer Plot of Batt. Amps vs Time-Test 22 -----	6-30
6.2.15	Computer Plot of Mot. Volts vs Time-Test 22 -----	6-31
7.3.1	Plot of Speed vs Time - Test No. 24 -----	7-15
7.3.2	Plot of Speed vs Time - Test No. 31 -----	7-15
7.3.3	Plot of Acceleration vs Speed - Test No. 24 -----	7-16
7.3.4	Plot of Acceleration vs Speed - Test No. 31 -----	7-16
7.3.5	Plot of Batt. Volts and Amps vs Time - Test 24 -----	7-17
7.3.6	Plot of Batt. Volts and Amps vs Time - Test 31 -----	7-17
7.3.7	Plot of Mot. Volts and Amps vs Time - Test 24 -----	7-18
7.3.8	Plot of Mot. Volts and Amps vs Time - Test 31 -----	7-18
7.3.9	Plot of Batt. Energy vs Time - Test 24 -----	7-19
7.3.10	Plot of Batt. Energy vs Time - Test 31 -----	7-19
7.4.1	Plot of Road Load vs Speed -----	7-31
7.4.2	Plot of P/V vs V_2^2 - Run No. 1 -----	7-31
7.4.3	Plot of P/V vs V_2^2 - Run No. 2 -----	7-32
7.4.4	Plot of P/V vs V_2^2 - Run No. 4 -----	7-32
7.4.5	Plot of P/V vs V_2^2 - Run No. 6 -----	7-33
7.4.6	Plot of P/V vs V_2^2 - Run No. 9 -----	7-33
8.1.1	Energy Flow Model for 25 mph -----	8-5
8.1.2	Energy Flow Model for 35 mph -----	8-6
8.1.3	Energy Flow Model for 45 mph -----	8-7
8.1.4	Energy Flow Model for Top Speed -----	8-8
8.2.1	Energy Flow Model for Sched. C -----	8-9
8.2.2	Energy Flow Model for SCHED. B -----	8-10
8.2.3	Energy Flow Model for Sched. C W. Regen. -----	8-11
8.2.4	Energy Flow Model for Sched. B. W. Regen. -----	8-12

Tables

3.4.1	Data on Baker-Otis 1265 Motor -----	3-16
4.6.1	AAC Current Sensor Cal. Test -----	4-34
4.6.2	Energy Counter Cal. Test -----	4-34
5.6.1	Constant Speed Weight Sensitivity Parameters -----	5-11
5.6.2	Driving Cycle Weight Sensitivity Parameters -----	5-11
6.1.1	Constant Speed, Uncorrected Data -----	6-5
6.1.1A	Test No. 28 Uncorrected Data -----	6-6
6.1.2	Printout Samples - Test No. 2 (25 mph) -----	6-7
6.1.3	Printout Samples - Test No. 3 (35 mph) -----	6-8
6.1.4	Printout Samples - Test No. 4 (45 mph) -----	6-9
6.1.5	Printout Samples - Test No. 5 (Max Speed) -----	6-10
6.1.6	Printout Samples - Test No. 6 (35 mph) -----	6-11

6.1.7	Printout Samples - Test No. 7 (Max Speed) -----	6-12
6.1.8	Printout Samples - Test No. 9 (25 mph) -----	6-13
6.1.9	Printout Samples - Test No. 10 (35 mph) -----	6-14
6.1.10	Printout Samples - Test No. 11 (45 mph) -----	6-15
6.1.11	Printout Samples - Test No. 22 (25, 35 mph) -----	6-16
6.1.12	Printout Samples - Test No. 22 (45, Max) -----	6-17
6.2.1	Driving Cycle, Uncorrected Data -----	6-32
6.2.1A	Driving Cycle, Uncorrected Data -----	6-33
6.2.2	Printout Samples - Test No. 12 (Sch. C) -----	6-34
6.2.3	Printout Samples - Test No. 13 (Sch. B, W. Regen.)---	6-35
6.2.4	Printout Samples - Test No. 15 (Sch. B) -----	6-36
6.2.5	Printout Samples - Test No. 16 (Sch. B, W. Regen.) --	6-37
6.2.6	Printout Samples - Test No. 17 (Sch. B, W. Regen.) --	6-38
6.2.7	Printout Samples - Test No. 18 (Sch. C) -----	6-39
6.2.8	Printout Samples - Test No. 19 (Sch. C, W. Regen.) --	6-40
6.2.9	Printout Samples - Test No. 20 (Sch. B) -----	6-41
6.2.10	Printout Samples - Test No. 21 (Sch. C, W. Regen.) --	6-42
6.2.11	Printout Samples - Test No. 22 (Schs. B, C) -----	6-43
6.3.1	Uncorrected Acceleration Data-Test No. 24 -----	6-45
6.3.2	Uncorrected Acceleration Data-Test No. 31 -----	6-47
6.4.1	Uncorrected Coast-Down Data -----	6-50
6.4.2	Strip-Chart Coast-Down Data -----	6-53
6.4.3	Track Survey Data -----	6-55
6.5.1	Const. Speed Weight Sensitivity Data -----	6-58
6.5.2	Driving Cycle Weight Sensitivity Data -----	6-59
7.1.1	Constant Speed Uncorrected, Corrected, and Computed Data -----	7-6
7.2.1	Driving Cycle Uncorrected, Corrected, and Computed -----	7-11
7.3.1	Corrected Speeds - Acceleration Data -----	7-13
7.4.1	Intermediate Coast-Down Calculations -----	7-25
7.4.2	Coast-Down Calculations -----	7-28
7.5.1	Constant Speed Weight Sensitivity Data (Runs 1 through 12) -----	7-36
7.5.2	Constant Speed Weight Sensitivity Data (Runs 13 through 29) -----	7-36
7.5.3	Driving Cycle Weight Sensitivity Data (Runs 1 through 4) -----	7-37
7.5.4	Driving Cycle Weight Sensitivity Data (Runs 5 through 8) -----	7-37

SECTION 1

INTRODUCTION

As a part of ERDA's Electric and Hybrid Vehicle "State-of-Art Assessment" Program, the Ripp-Electric was field-tested at the facility of Dynamic Science, Inc, of Phoenix, Arizona, during March and April 1977. This report is a description, compilation, and analysis of the field tests.

Prior to the above tests, with support from NASA and ERDA, a series of performance tests was conducted on the Ripp-Electric, using JPL's chassis dynamometer facility. These results are reported in JPL document 900-759, October 1976.

The State-of-Art Assessment reported the results of the above tests. However, because of the expanded capability of the data acquisition system described in this report and the desire of JPL to present the data in a vehicle system energy-flow format, the report was expanded to include energy-flow analysis (Section 8).

This report also contains much data on the Ripp-Electric generated by the designer of the vehicle prior to the tests conducted for the ERDA program. These tests are so noted in the text.

Section 2

SUMMARY OF RESULTS

The following is a summary of performance tests conducted on the Ripp-Electric at Dynamic Science, Inc., of Phoenix, Arizona, during March and April, 1977.

2.1 CONSTANT SPEED TESTS

2.1.1 Range (miles)

25 mph (av. 2 tests)		101.30
35 mph (av. best 2 tests)		87.81
45 mph (av. 2 tests)		71.00
Max Speed (av. 2 tests)		54.26

2.1.2 Miles per Line KWH

25 mph (one test only)		4.09
35 mph (av. best 2 tests)		3.50
45 mph (av. 2 tests)		2.92
Max Speed (one test only)		2.40

2.2 DRIVING CYCLE TESTS

2.2.1 Range (miles)

Sched. B, no regen. br. (one test only)	. . .	65.39
Sched. B, with regen. br. (one test only)	. .	73.01
Sched. C no regen. br. (av. 2 tests)		58.23
Sched. C with regen. br. (av. best 2 tests)		76.55

2.2.2 Miles per Line KWH

Sched. B, no regen. br. (one test only)	. . .	2.46
Sched. B, with regen. br. (one test only)	. .	2.76
Sched. C, no regen. br. (av. 2 tests)		2.29
Sched. C, with regen. br. (av. best 2 tests)		2.78

2.3 ACCELERATION TESTS (BATTERY 20% DISCHARGED)

2.3.1 EV-106 batteries, 2N6251 Transistors

0-10 mph		3.4 sec
0-20 mph		8.2 sec
0-30 mph		14.5 sec
0-40 mph		22.6 sec
0-45 mph		28.3 sec

2.3.2 LEV-115 Batteries*, SDT-12302 Transistors

0-10 mph	3.3 sec
0-20 mph	8.4 sec
0-30 mph	15.2 sec
0-40 mph	24.8 sec
0-45 mph	31.4 sec

* New batteries loaned by ESB, Inc.

Section 3

VEHICLE DESCRIPTION

3.1 GENERAL DESCRIPTION

The Ripp-Electric is a converted 1971 Datsun 1200 Sedan (Figure 3.1.1). The drive line, consisting of the standard hydraulic clutch, four-speed transmission, and rear axle, has been retained. The internal combustion engine and associated components were replaced with an advanced electric drive system.

In addition to the above modifications, the conversion includes modification to both the front and rear suspension. In the case of the front suspension, the original coil springs were replaced with stiffer, slightly shorter units, and the McPherson shocks were replaced with Koni inserts. In the case of the rear suspension, additional leaves were added to the original semi-elliptical units, and the original shocks were replaced with heavy-duty counterparts.

Other modifications include:

- Body modifications so that the spare tire is accessed from under the car (Figure 3.1.2).
- Body modifications to provide space for six batteries in the motor compartment (Figure 3.1.3).
- Construction of an aluminum "cross-member" to replace original unit and provide adequate space for motor.
- Modification of steering "cross-rod" to allow adequate space for motor.

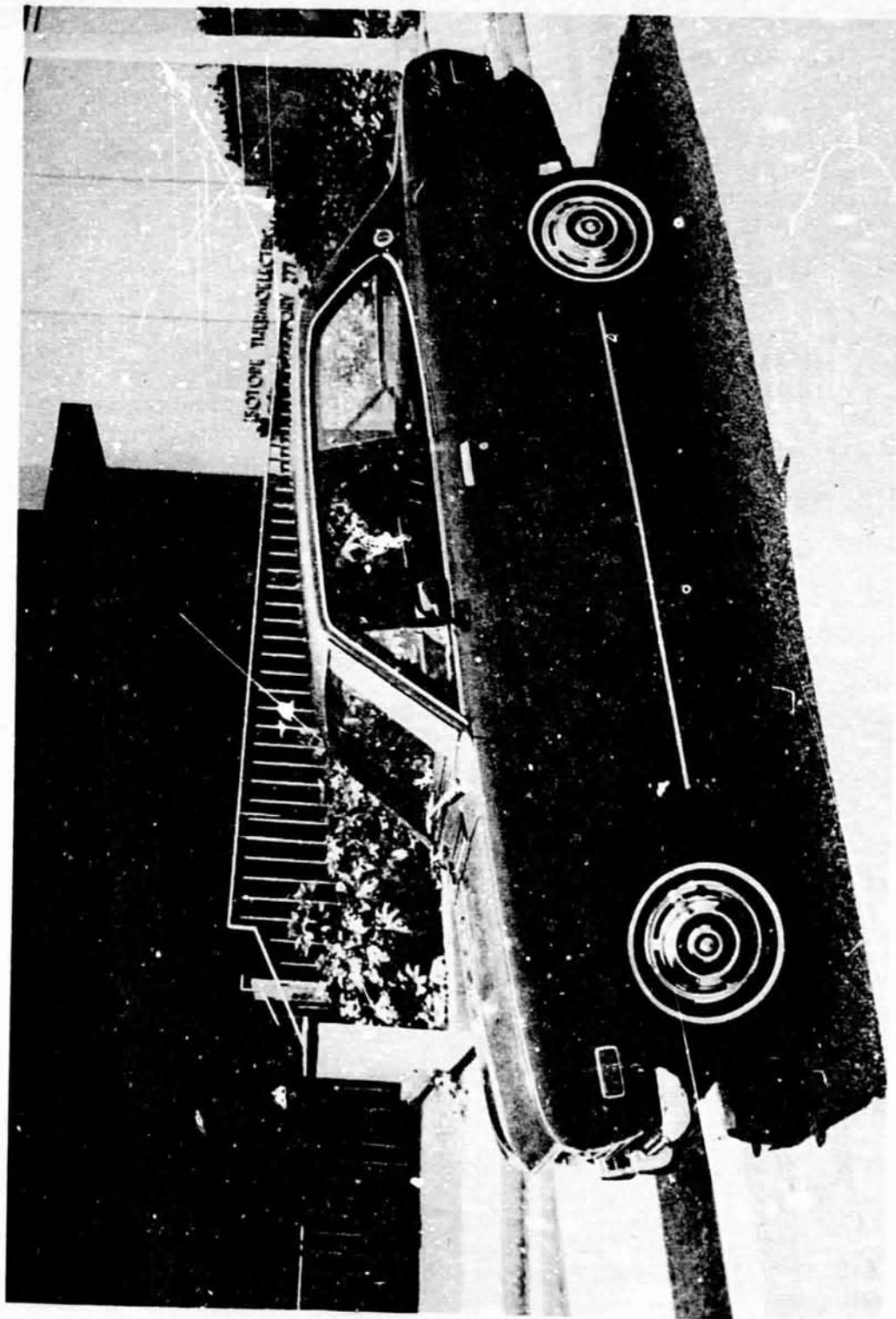


Figure 3.1.1. Ripp-Electric Vehicle

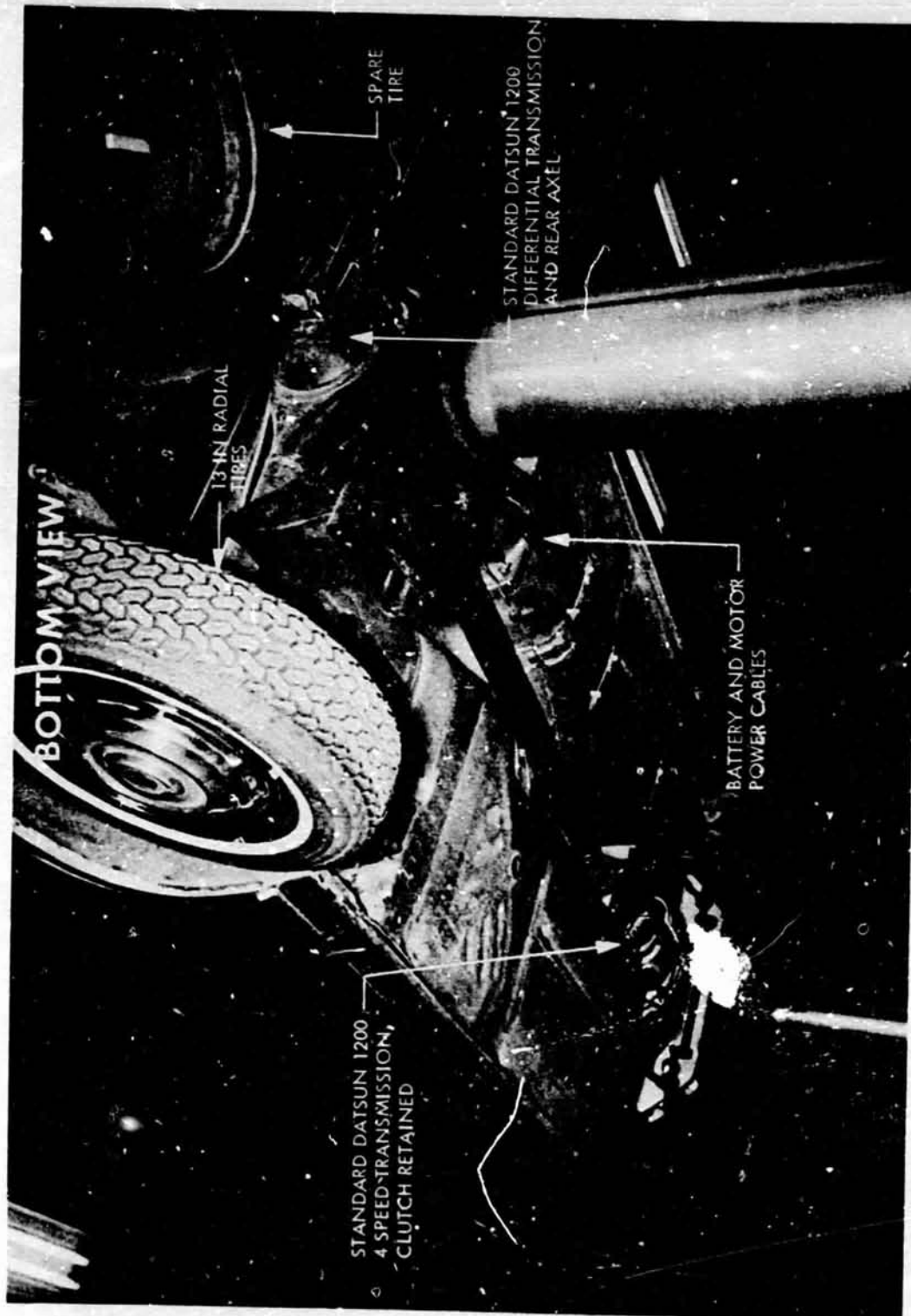


Figure 3.1.2. Drive Line View Showing Standard Transmission and Rear Axle

ORIGINAL PAGE IS
OF POOR QUALITY

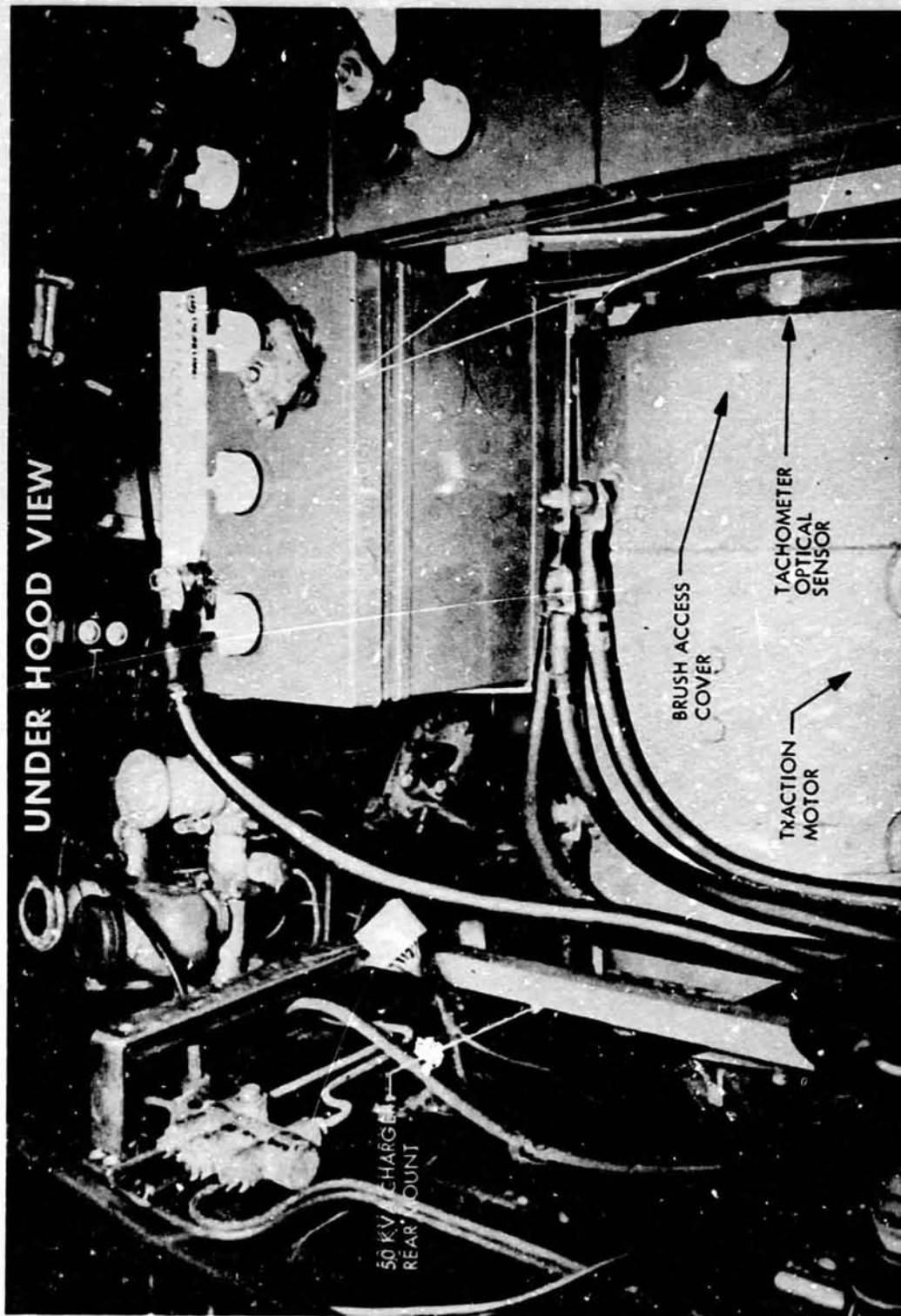


Figure 3.1.3. Baker Otis Motor, Model 1265

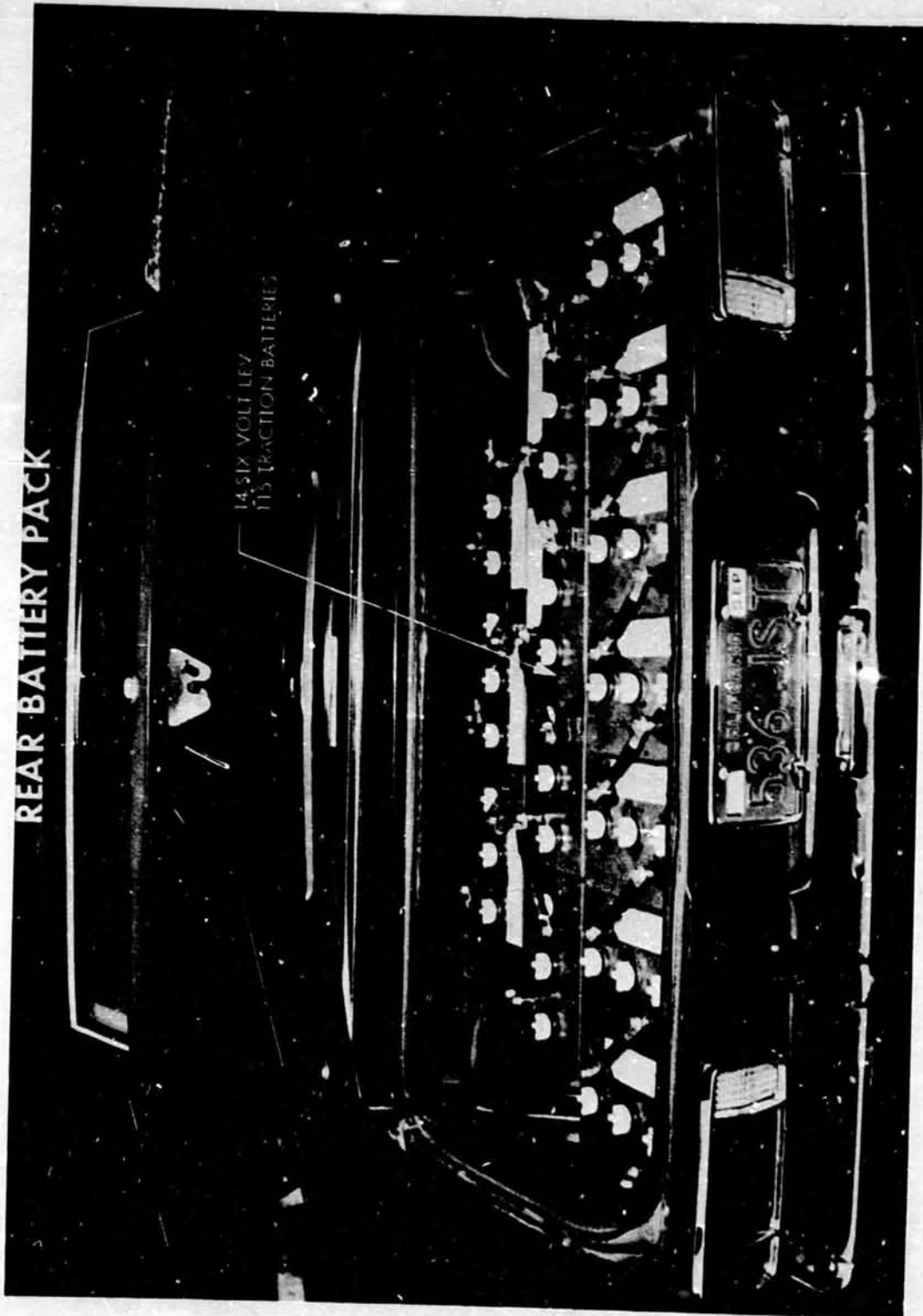


Figure 3.1.4. Rear Battery Pack, 14 Exide LEV-115, 6-Volt Units

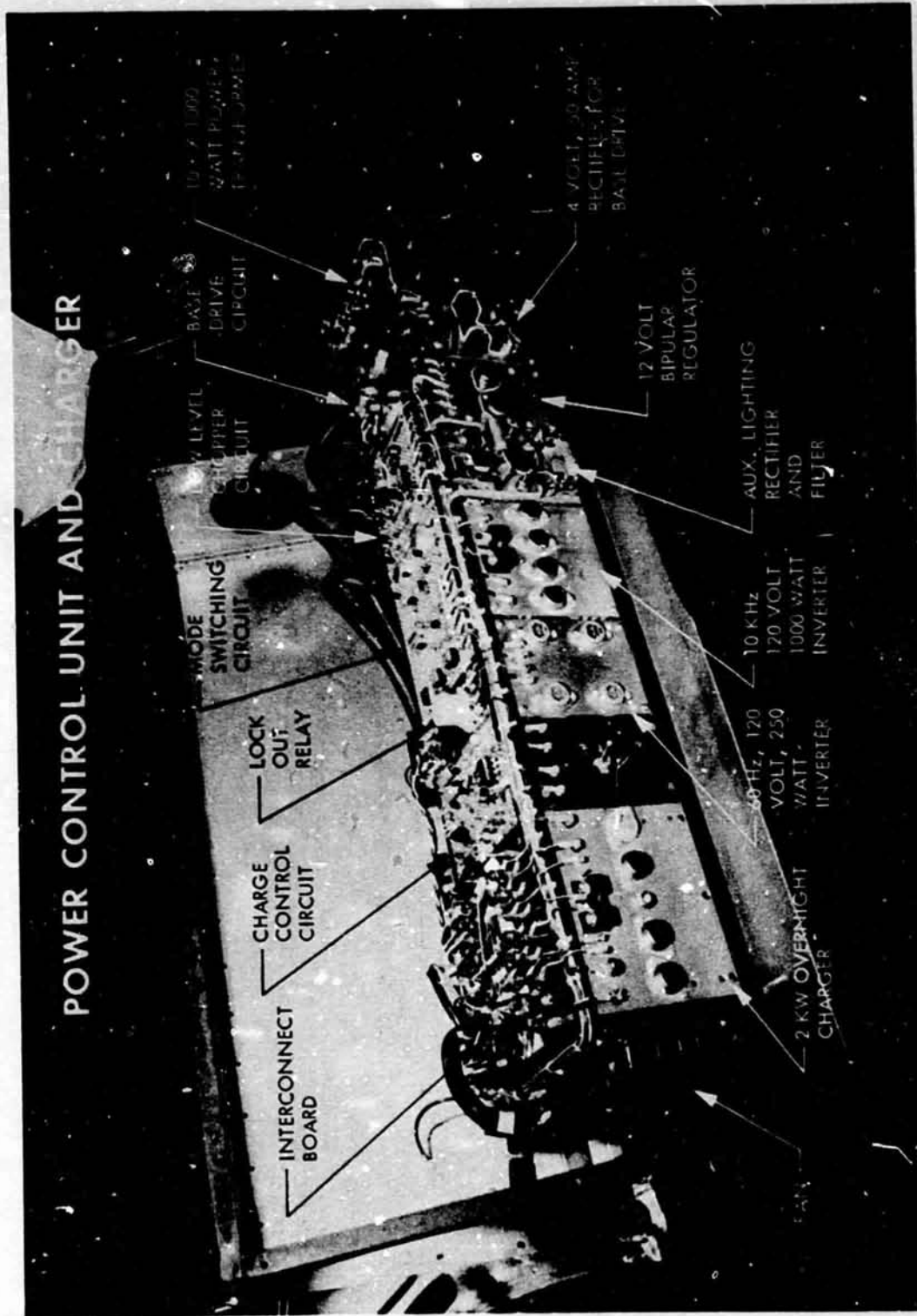


Figure 3.1.5. Power Control Unit and 2-KW Charger

ORIGINAL PAGE IS
OF POOR QUALITY

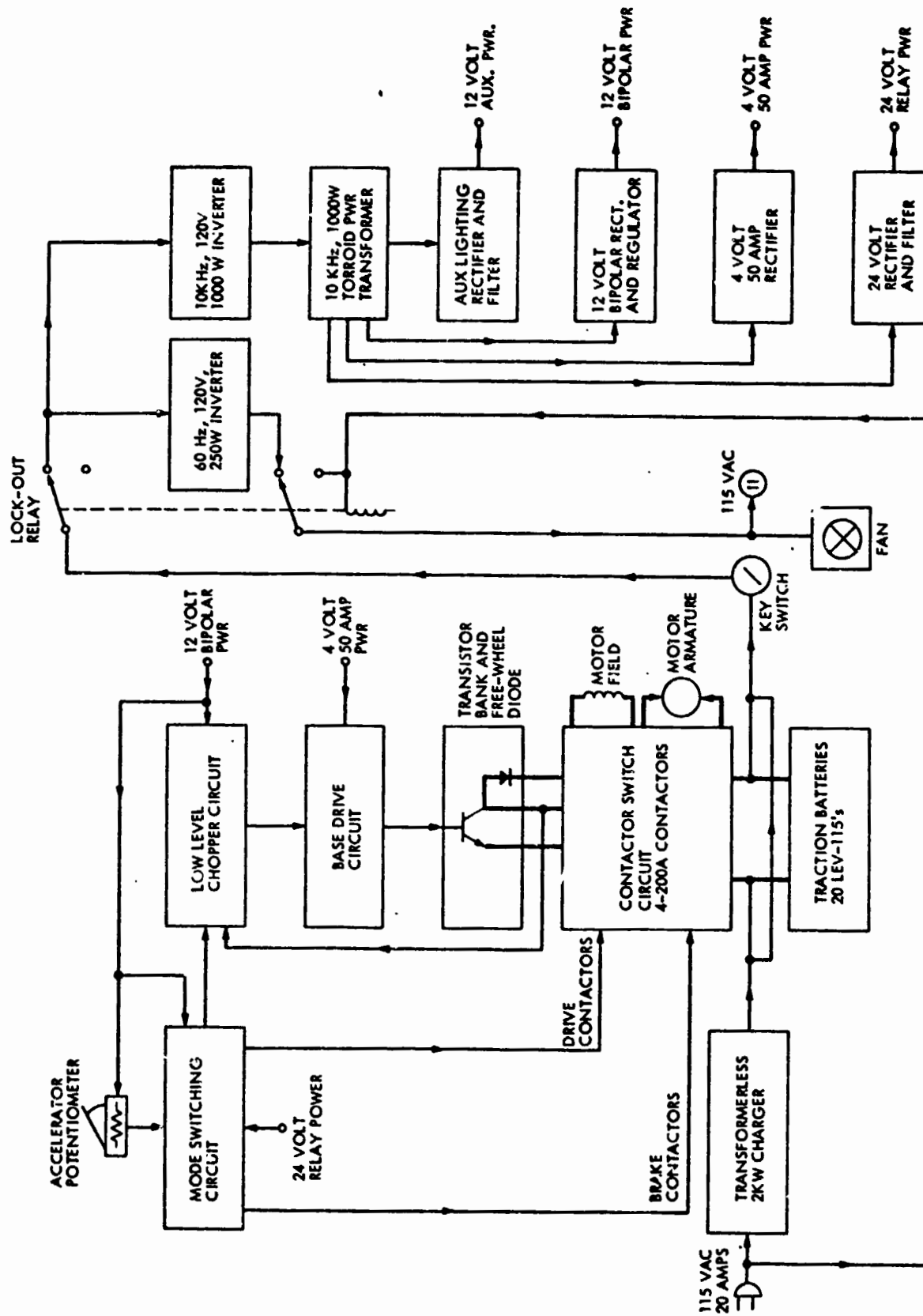


Figure 3.1.6. Propulsion System Block Diagram

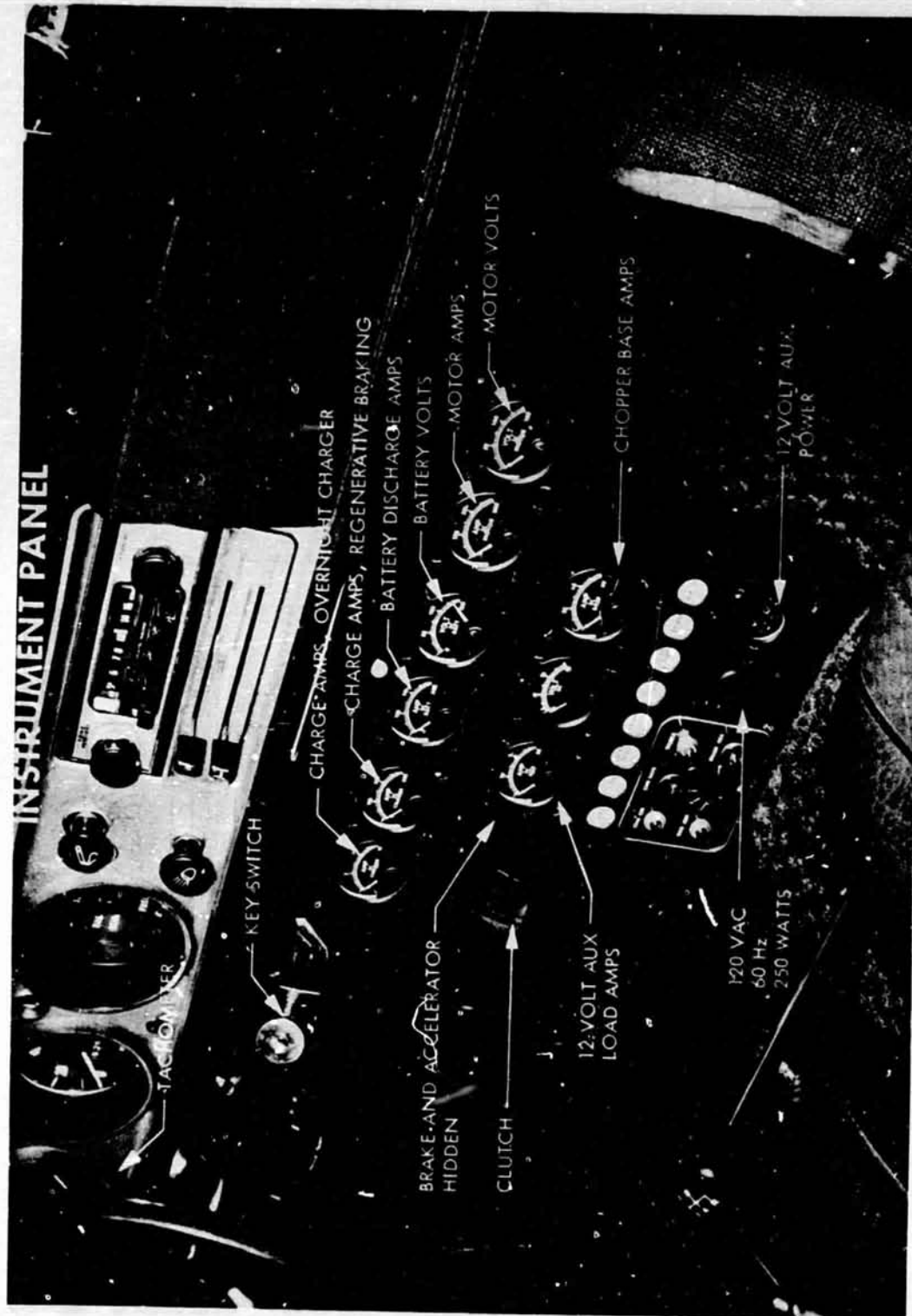


Figure 3.1.7. Instrument Panel

3.2 BATTERY

A set of new ESB EV-106 batteries was used for tests 1 through 27 at Dynamic Science. Tests 28 through 31 used a new set (on loan from ESB) of LEV-115s.

Specifics on the EV-106 batteries are as follows:

- Nominal Capacity 75 amps for 106 minutes (ESB spec)
- Nominal Voltage 120 volts (20 six volt units in series)
- Weight 1300 lb (20 batteries, each 65 lb)
- Energy Storage 15.23 KWH at 75 amps and 27°C, based on ESB spec where average discharge voltage = 5.75 volts over 106 minutes)

Figures 3.2.1 through 3.2.5 are ESB data on discharge voltages vs time.

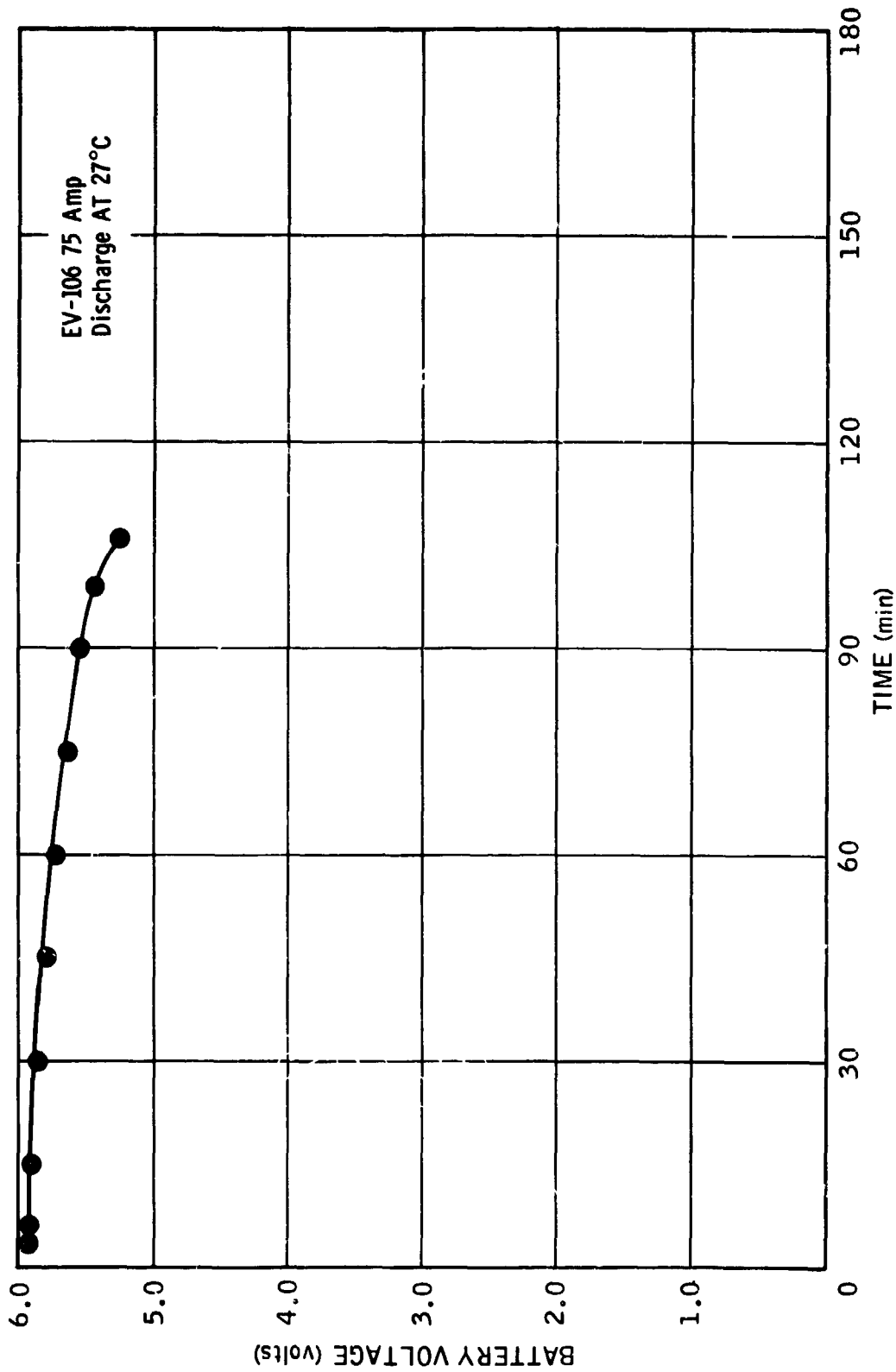


Figure 3.2.1. ESB Data, Discharge Voltage vs Time for ESB's EV-106 Battery-75 Amp
Constant Current Discharge

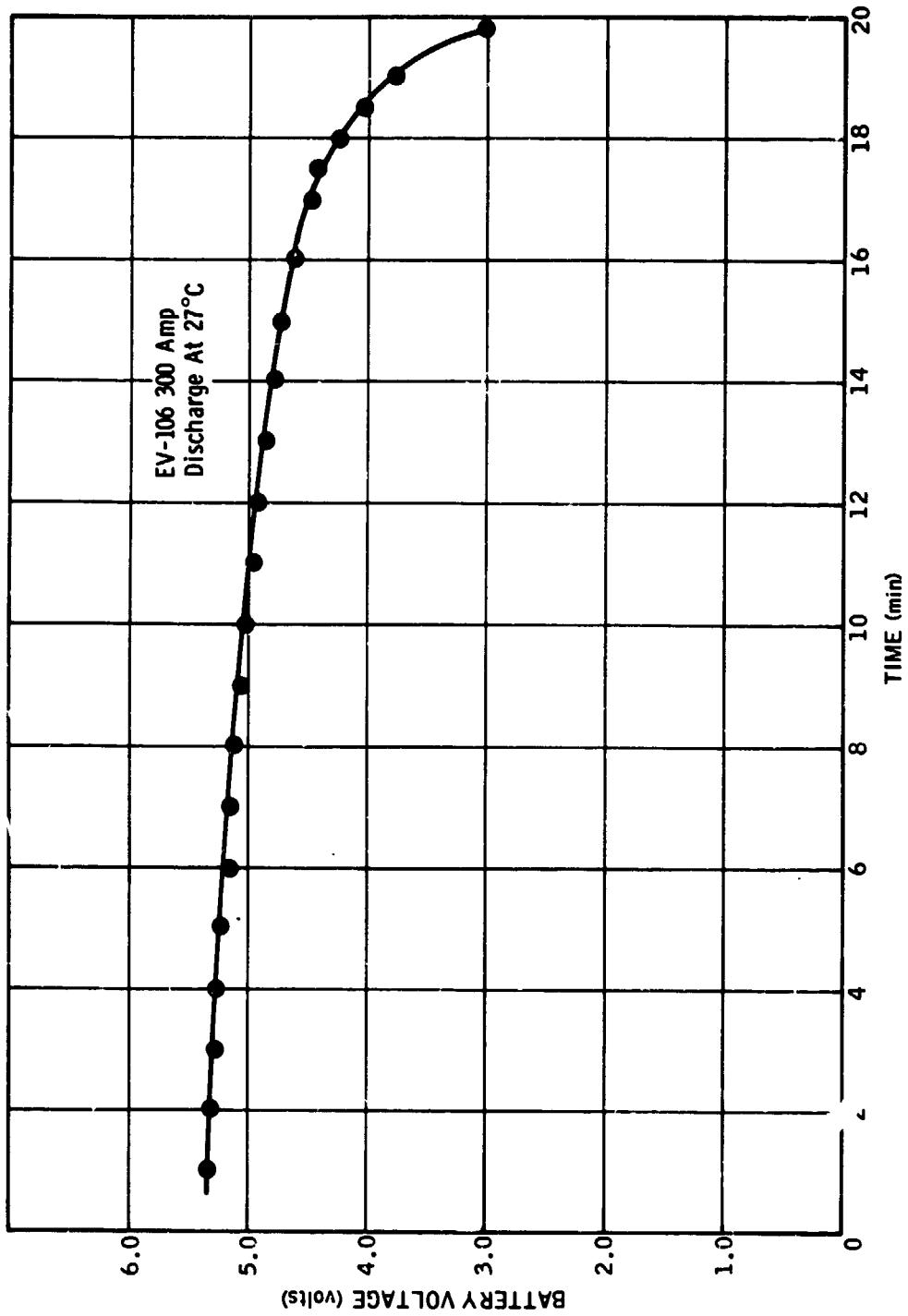


Figure 3.2.2. ESB Data, Discharge Voltage vs Time for ESB's EV-106 Battery-300 Amp Constant Current Discharge

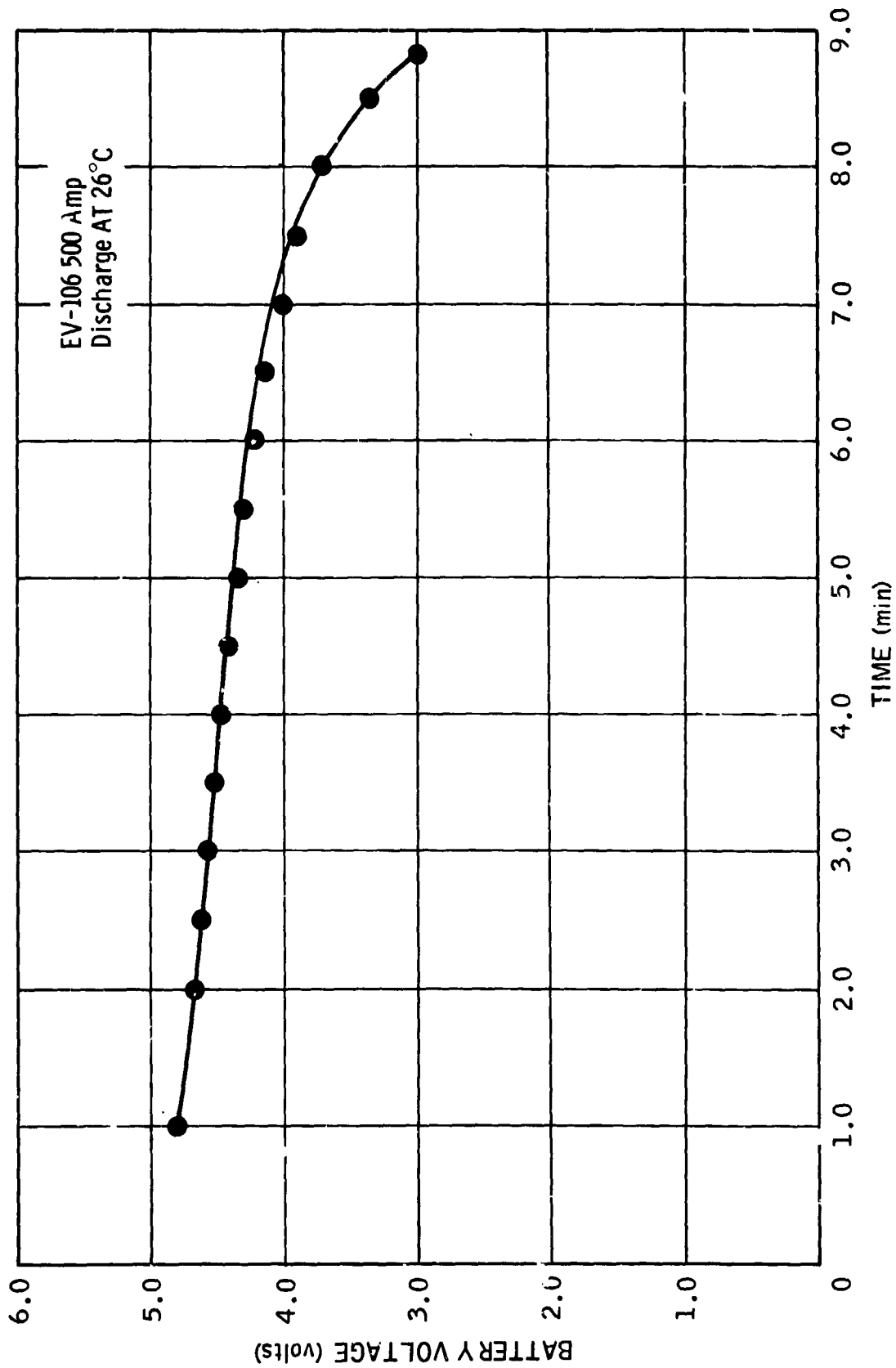


Figure 3.2.3. ESB Data, Discharge Voltage vs Time for ESB's EV-106 Battery-500 Amp Constant Current Discharge

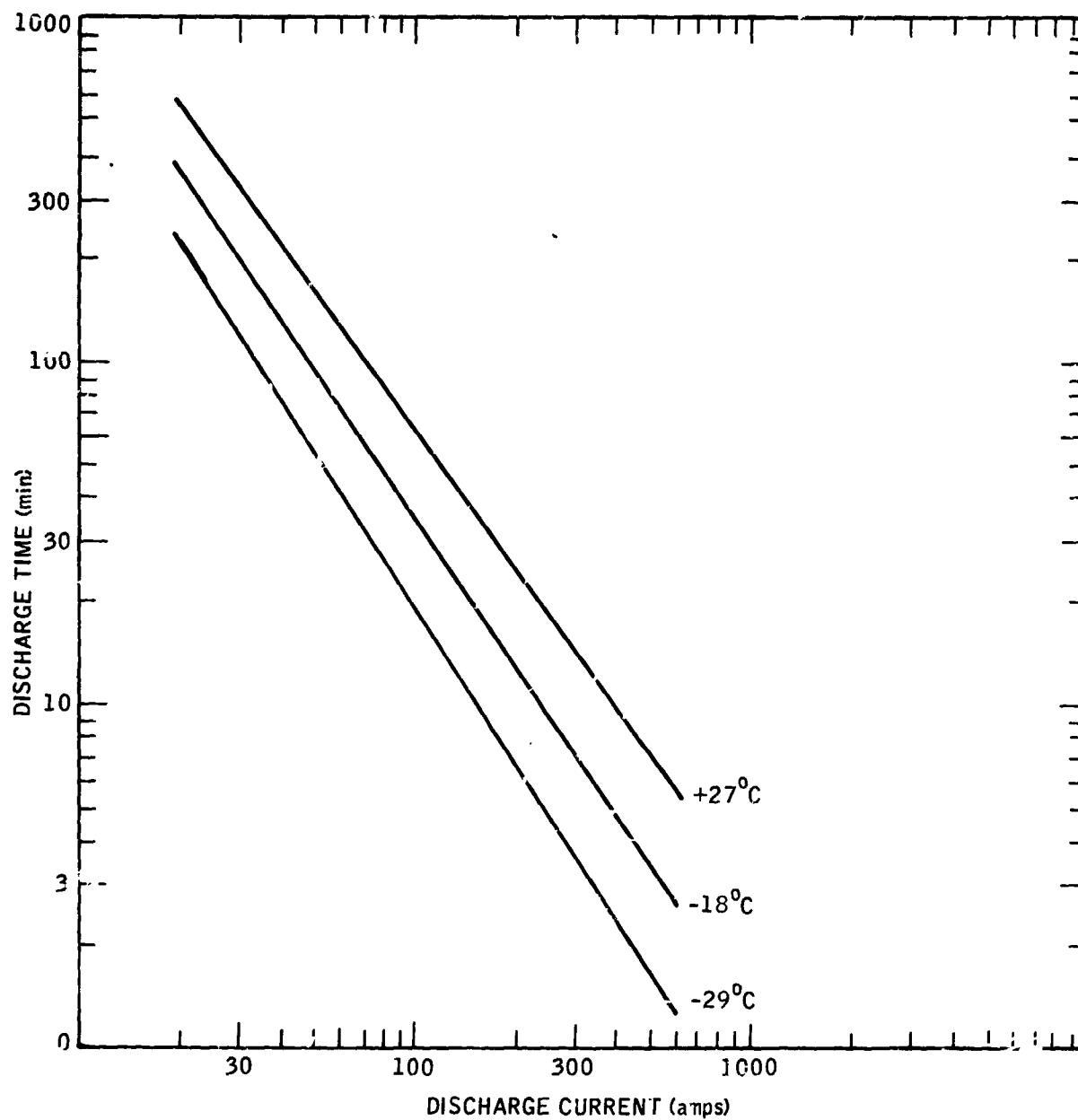


Figure 3.2.4. ESB Data, EV-106 Discharge Time vs Discharge Rate for various temperatures (Measured Data). For currents less than 90 amps, termination is at 1.75 volts per cell; for currents greater than 90 amps, termination is at 1.00 volt per cell.

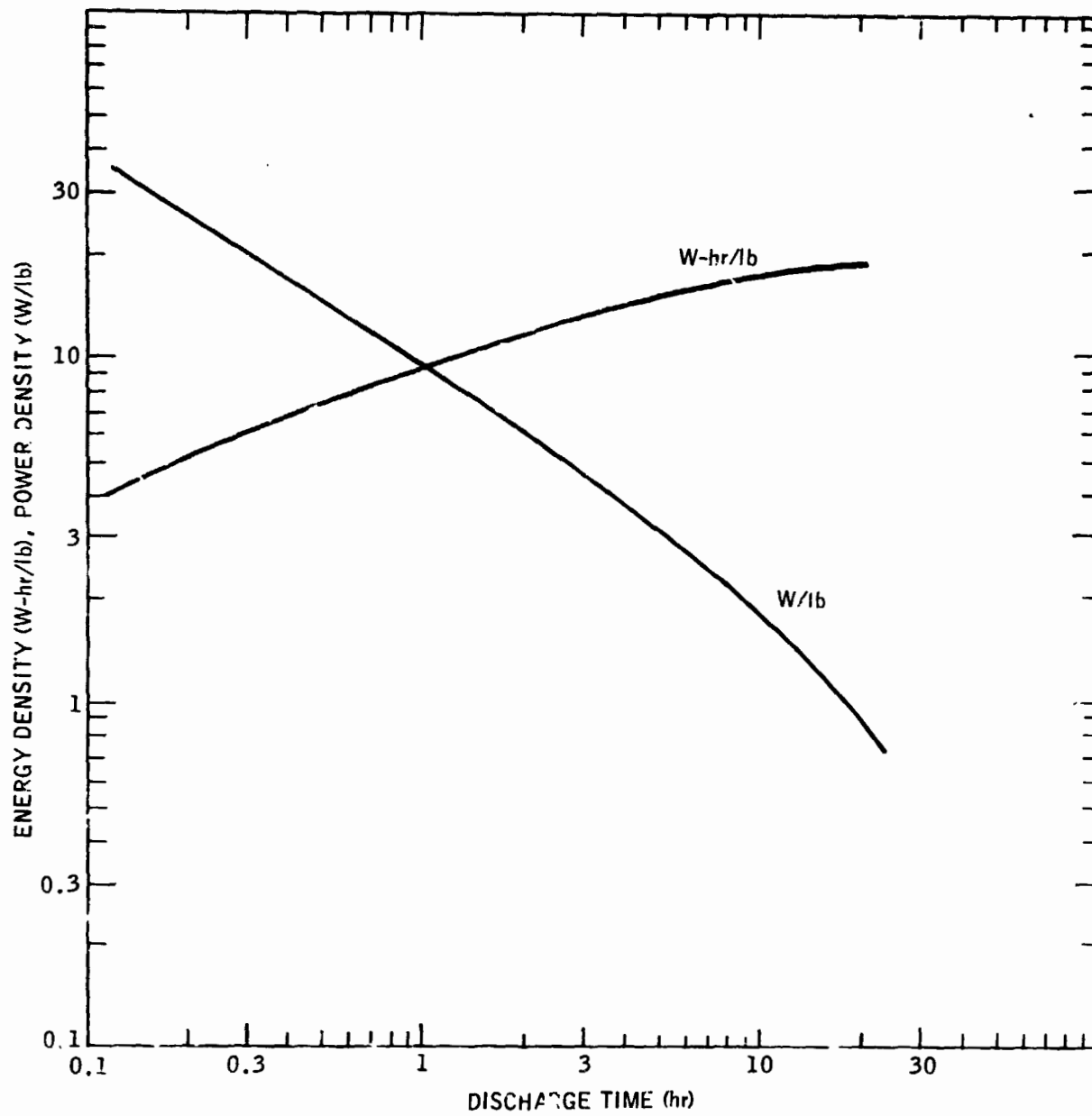


Figure 3.2.5. ESB Data, EV-106 Energy and Power Density vs Time of Discharge

3.3 TRACTION MOTOR

The electric motor is located under the hood (Figure 3.1.3). The unit was manufactured by Baker-Otis Company and is designated as model 1265. A specially fabricated shaft adapter couples the motor shaft to a modified Datsun flywheel.

The motor is a totally enclosed four-pole, 120 volt machine with no interpoles, a nonlaminated frame and a non-skewed armature. Maximum efficiency at its best operating point is 86%. Maximum continuous power rating is 15 to 20 hp, and maximum speed is 4000 RPM. Motor weight is 205 lb.

3.4 DATA ON BAKER-OTIS 1265 MOTOR

Prior to conduct of the tests described in this report, data was acquired on the 1265 motor by the author and is included here for reader information. Torques and RPM data were obtained with special instrumentation; voltages and currents were measured with a Fluke 8100A DVM. Sources of measurement error, in addition to the instruments themselves, include operating-point drift. Errors are estimated at $\pm 0.2A \pm 0.5$ percent of reading for all currents, $\pm 0.1V \pm 0.2$ percent of reading for all voltages, ± 1 percent of reading for RPMs and ± 2 ft-lb ± 1 percent of reading for torques. Data is listed in Table 3.4.1 and plotted in Figures 3.4.1 through 3.4.3.

Table 3.4.1. Data On Baker-Otis 1265 Motor

Motor Voltage (Volts)	Motor Current (Amps)	Torque (ft-lb)	RPM	H.P.	Eff.
103.1	189	55.4	2086	22.03	84.3
104.5	161	46.4	2238	19.78	84.7
107.1	129	33.4	2506	15.94	86.0
109.1	103	24.2	2841	13.09	86.9
110.3	87.8	18.8	3150	11.28	86.8
81.7	181	53.2	1658	16.80	84.7
83.5	148	40.0	1841	14.02	84.6
85.2	120	30.0	2050	11.71	85.4
87.1	96.6	21.2	2371	9.57	84.8
88.6	73.8	14.0	2800	7.46	85.1
61.4	164	46.3	1279	11.27	83.5
62.9	132	34.0	1446	9.36	84.1
64.5	103	22.9	1684	7.35	82.5
65.9	83.4	15.8	2038	6.13	83.2
66.8	66.0	10.5	2408	4.81	81.4
67.7	51.6	6.7	2862	3.65	77.9
40.6	157	43.7	820	6.92	79.8
41.8	126	31.4	953	5.70	80.7
42.8	103	23.2	1106	4.89	82.7
43.9	74.4	13.0	1422	3.52	80.4
44.9	51.0	6.0	1943	2.22	72.3
19.0	170	49.0	275	2.56	59.2
19.9	130	33.6	368	2.35	68.0
20.7	93.0	21.0	513	2.05	79.5
21.7	55.8	8.0	844	1.29	79.2
22.1	43.8	4.2	1070	.85	65.9

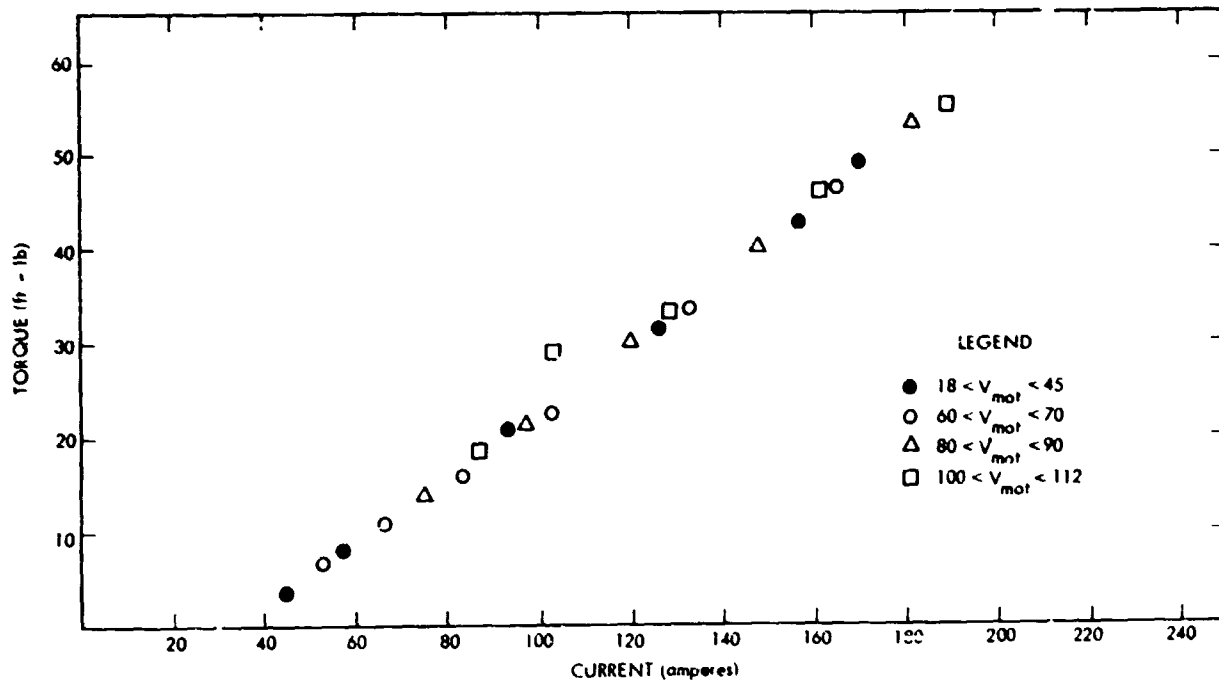


Figure 3.4.1. Plot of Torque vs Current for Baker-Otis 1265 Motor Using Table 3.4.1 Data. Note that Torque is Virtually Independent of Voltage and RPM.

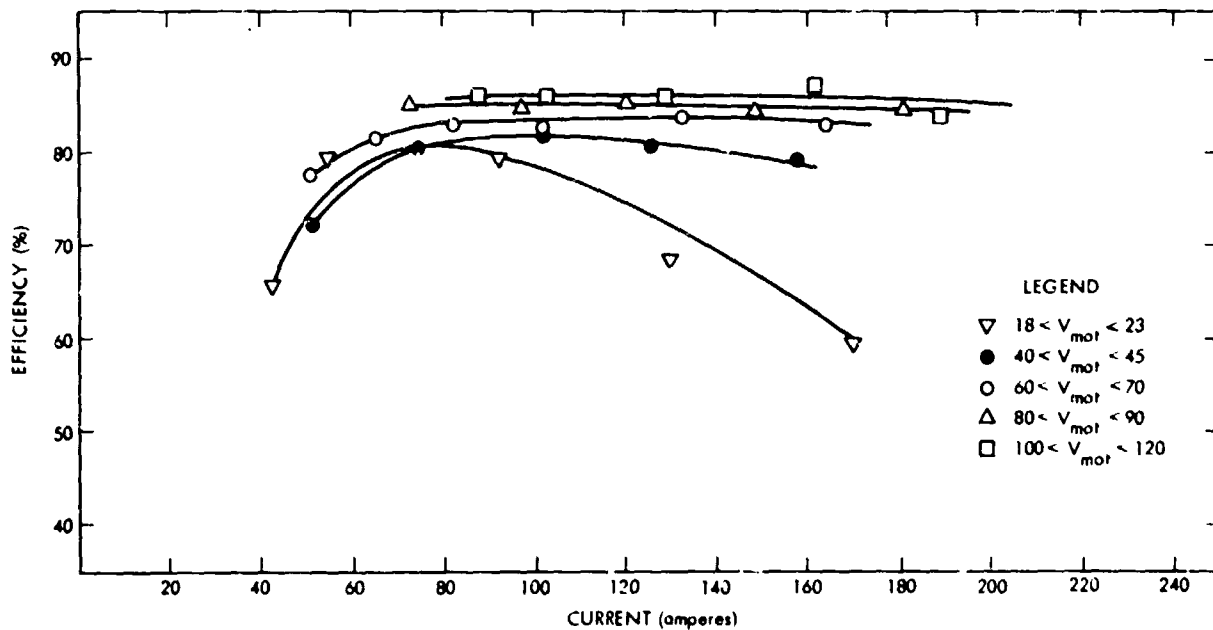


Figure 3.4.2. Plot of Efficiency vs Current for Baker-Otis 1265 Motor Using Table 3.4.1 Data.

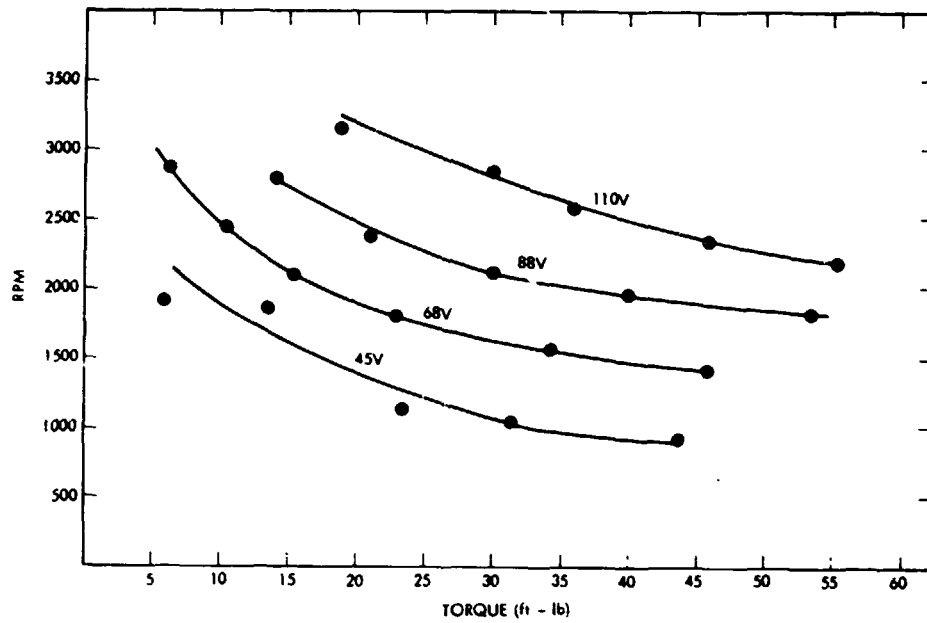


Figure 3.4.3. Plot of RPM vs Torque for Baker-Otis 1265 Motor, using Table 3.4.1 Data. Data Points were Extrapolated to 45, 68, 88, and 110 Volts on the Basis that RPM is Proportional to Motor Voltage; this Assumption is Confirmed by Noting that Efficiency is only a Weak Function of Voltage.

3.5 CONTROL SYSTEM

The control system, a 2-KW transformerless charger and a DC to DC converter for 12 volt auxiliary power, is integrally packaged and hinge-mounted within a metal encasement (Figure 3.1.5). Total weight of the system is 39 lb. A block diagram of the system is shown in Figure 3.1.6.

Power control in both the drive and regenerative brake modes is achieved via a transistor chopper which operates in the pulse-width modulation mode. In the drive mode, the chopper operates conventionally as a buck system. In the brake mode, contactors switch the transistor circuit into a boost configuration. In both modes of operation the transistor chopper operates at all times in a current limiting fashion, with the actual current limit being proportional to an input control signal. This control signal is derived from an accelerator potentiometer and is modified by the mode switching circuit.

Specifics on the transistor chopper are as follows:

- Transistors -----32 paralleled 10A, 250V To-3 units
- Chopping Frequency -----400 Hz
- Current Limit (motor DC)-270A
- Current limit (peak) ----300A
- Current Limit Technique--Threshold turn-off, based on transistor de-saturation

Internal power requirements for the control system, such as base drive power, bipolar power for the low-level electronics, and contactor coil power are provided by a 1000 watt, DC to DC converter system. This converter system also provides up to 350 watts of 12 volt DC power for auxiliary uses, such as headlights, wipers, and radio.

All electronic components are forced air, cooled by a 100 CFM pancake fan. In the recharge mode, this fan is relay-switched across the line input and when the vehicle is operating, the fan is across the output of a 250 watt inverter (inverter provides up to 200 watts of 120 volt 60 Hz square-wave power for external use).

3.6 DATA ON MOTOR-CONTROL SYSTEM COMBINATION

Data was obtained prior to the vehicle tests on the combination of the 1265 motor and the controller. Data was measured using the technique outlined in paragraph 3.4.

In addition to the errors noted in paragraph 3.4, an error involving unmeasured AC energy is expected here. In particular, pulse currents drawn by the chopper "induce" a ripple voltage across the

battery. As a result of this ripple voltage, power measurement errors result when average voltage is multiplied by average current. From analysis of scope-measured ripple voltages, the worst case error is less than 4 percent and, in all cases, is such that the true battery power is lower than the apparent battery power. It should be noted that energy measurements conducted at Dynamic Science used instrumentation which inherently measured true power - thus eliminating this type of error. Data is listed in Tables 3.6.1 and 3.6.2 and plotted in Figures 3.6.1 through 3.6.5. These tables and figures can be found in Appendix I.

3.7 CHARGER

The charger is a transformerless 2-KW unit. Standard 115 VAC power is first full-wave rectified, boosted by a transistor boost chopper, and then applied to the battery. The chopper duty cycle is servo-controlled to provide a line current limit and a temperature-corrected final voltage limit. Over each half-cycle of line voltage, the chopper duty cycle is "modulated" so that the instantaneous line current is proportionate to the instantaneous line voltage, thus effecting a "synthetic power factor" which is near unity. Measurements made by the manufacturer indicate that the charger energy efficiency, averaged over an entire recharge cycle, is about 95 percent, while the power factor - at the full power point, is also about 95 percent. The charger is packed with the motor controller and weighs approximately 6 pounds.

3.8 INSTRUMENT PANEL

The instrument panel contains meters for monitoring battery and motor voltages and currents, charger current, regenerative braking currents, chopper base currents, and auxiliary load currents (Figure 3.1.7).

The instrument panel also contains indicator lights (which signal nominal or faulty operation of the control system), a 12-volt auxiliary power outlet, and controls for a 50-KVA SCR battery charger which can be mounted above the traction motor.

A tachometer is dash-mounted in the standard location. The signal input for the tachometer is generated by an LED-photo transistor system which is integrated with the back end of the motor shaft.

Mounted directly below the tachometer, and hidden from the view of Figure 3.1.7, is a digital current integrator which reads Amp-Hours charged and Amp-Hours discharged on separate electro-mechanical counters. The current integrator will be discussed more fully in paragraph 4.2.2.

3.9 ADDITIONAL CHARACTERISTICS

3.9.1 Vehicle

3.9.1.1	Overall length	150.8 in (383 cm)
3.9.1.2	Overall width	58.9 in (150 cm)
3.9.1.3	Overall height	54.7 in (140 cm)
3.9.1.4	Capacity	4 passengers
3.9.1.5	Road clearance	6.7 in (17 cm)
3.9.1.6	Curb weight	2950 lbs (1348 kg) for EV-106 battery set 3030 lbs (1385 kg) for LEV-115 battery set
3.9.1.7	Gross vehicle weight	3550 lbs (1622 kg) for EV-106 battery set 3630 lbs (1659 kg) for LEV-115 battery set

3.9.2 Transmission

3.9.2.1 Type Datsun F14W56, Warner-type
synchromesh

3.9.2.2 Ratios

First	3.757
Second	2.169
Third	1.404
Fourth	1.000
Reverse	3.640

3.9.3 Rear axle

3.9.3.1 Type Semi-floating hyploid

3.9.3.2 Ratio 3.90 (39/10)

3.9.4 Wheels

3.9.4.1 Hubs Datsun 510 hubs used in place of
1200 hubs

3.9.4.2	Tires	165SR13 Goodyear radials
3.9.4.3	Tire pressures	30 psi front, 40 psi rear
3.9.4.4	Wheel base	90.6 in (230 cm)
3.9.4.5	Track, front	48.8 in (124 cm)
3.9.4.6	Track, rear	49.0 in (124.5 cm)
3.9.4.7	Rolling distance per revolution	5.99 ft (1.823 m)
3.9.5	Previous service	

At the time of these tests, the vehicle had been in operation for approximately two and one half years and had accumulated about 26,000 miles.

Section 4

INSTRUMENTATION

4.1 GENERAL DESCRIPTION

The instrumentation used for the tests performed on the Ripp-Electric at the Dynamic Science Test Track in Phoenix, Arizona, consisted of three major blocks.

4.1.1 Vehicle Instrumentation Equipment (Figure 4.1.1)

This equipment consisted of sensors, interfaces, displays, and recording apparatus for handling the following classes of data:

- Speed and distance
- Instantaneous voltages and currents
- Battery amp-hours, charged and discharged
- Energy measurements

4.1.2 Data Reading and Processing Equipment

This equipment consisted of a Datel Cassette Tape Reader and a PDP-1108 Computer. Together, these systems provided the capability of generalized processing; outputs in the form of tabular and graphical displays were generated by the computer.

4.1.3 Calibration Instrumentation.

The calibration instrumentation used in the course of the tests consisted of a "Fifth Wheel Spinner," a 4-1/2 digit DVM, and a wrist watch.

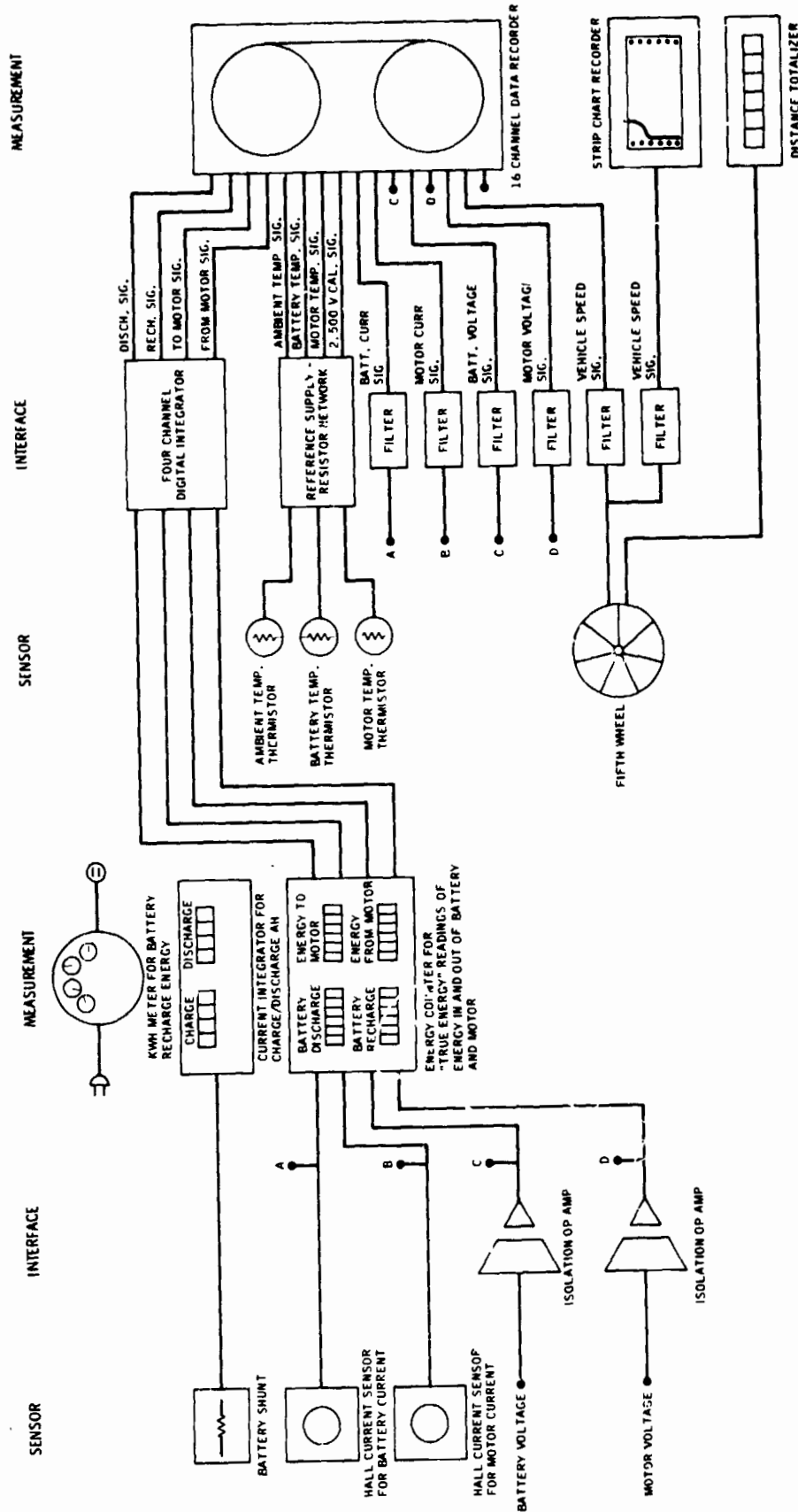


Figure 4.1.1. Block Diagram of Electric Vehicle Instrument System

4.2 VEHICLE INSTRUMENTATION (Figure 4.1.1)

The vehicle instrumentation may be viewed as four separate blocks.

4.2.1 Fifth Wheel and Associated Components

All speed and distance information was derived from a Nucleus Corporation, NC-5 Fifth Wheel equipped with a distance totalizer.

Speed signals were generated by an electromechanical tach-generator, directly coupled to the Fifth Wheel shaft. This signal was applied simultaneously to three points of use:

- Weston Model 901 Meter calibrated in mph
- Hewlett Packard 7100 B Strip-Chart Recorder (15701 A amplifiers)
- Channel 9 input of the Datel LPS-16 Data Logger

The Weston Meter, which connected directly across the tach-generator, served as a precision speedometer. Its use was limited to constant speed driving; it was also used as a backup for the Strip-Chart Recorder.

The Hewlett Packard Strip-Chart Recorder was connected across the tach-generator, but was a low-pass filter in series (100 μ F electrolytic capacitor and 2700 ohm resistor). The filter was required to attenuate "hash" produced by the tach-generator. The Strip-Chart system was used to record all speed-time information - this included constant speed tests, driving cycle tests, acceleration tests, and coast-down tests. In the case of the driving cycle tests, Strip-Charts were used which contained pre-recorded, computer-generated speed-time profiles of the appropriate schedules. In this way the Strip-Chart apparatus served the dual purpose of indicating to the driver the desired speed, while recording the actual speed - at each instant (see paragraph 4.2.1.1 for details of pre-recording of Strip-Charts).

Finally, the Fifth Wheel speed signal was applied to channel 9 of the Datel LPS-16 Data Logger via a two-section low-pass filter (1 μ F capacitors, 10 K resistors). Here too, the filter was required to eliminate commutator "hash". The Data Logger sampled this speed signal once every 3.2 seconds to 12-bit accuracy (corresponding speed error is ± 0.02 mph).

Distance information was derived from an optical encoder which is directly coupled to the Fifth Wheel shaft. This signal was applied to an electronic unit which displayed distance traveled in feet.

The electronic display included a gate circuit which enabled distance counting to start and stop upon the closure and opening of an external circuit. By taking advantage of this feature, it was possible to obtain corresponding measures for Amp-Hours, Watt-Hours, and distance associated with a given test. This technique proved essential in the weight sensitivity tests (see paragraph 5.3.2.2).

4.2.1.1 Strip-Chart Pre-recorded Driving Cycles

A complete program operating in a real-time operating system environment on JPL's Automatic Charge/Discharge Controller and Data Processing System (ACDCDPS) generates a voltage-time function such that an HP 7100 Strip Chart Recorder measuring this voltage produces a chart recorded with the selected driving cycle of SAE Test Procedure J227a. Driving cycle charts recorded by the above method were used at the test track.

The program controls the output resistance of a HP 69501A card located in a HP 6904B Multiprogrammer (Digital I/O Subsystem) within the ACDCDPS. The strip chart recorder measures the voltage drop across this output resulting from a constant current at approximately 0.8×10^{-7} amps. Values may be entered during program run time to control the shape of the curve generated or existing programs may be selected which automatically "construct" profiles for Schedules B, C, or D.

4.2.2 Charge/Discharge Current Integrator

Battery charge and discharge Amp-Hours were recorded by a specially built instrument. Two four-digit electromechanical counters provide separate displays of Amp-Hours charged and Amp-Hours discharged. Resolution of 0.01 Amp-Hour and typical accuracies are about 1%.

The Charge/Discharge Current Integrator basically consists of two voltage-to-frequency converters, driver circuits for electro-mechanical counters, and a housekeeping power supply (Figure 4.2.1). Design is such that one converter generates a frequency proportionate to positive input voltages while the other converter responds to negative input voltages. Scale factors were chosen so that counters increment one digit when 0.01 Amp-Hour flows through a 50-MV, 300A input shunt.

Voltage-to-frequency conversion is achieved via elements U1, U2, U3, C, R, and Q. U1, in conjunction with R and C, generates a voltage ramp, the slope of which is proportionate to the input voltage. When the output of U1 reaches the value of the reference voltage applied to comparator U2, the output of U2 swings positive, thus causing one-shot U3 to generate a short pulse. This pulse, in turn, places Q in conduction, thus resetting C. The U3 pulse is widened by U4 so that an adequate signal for driving the corresponding counter is provided.

Precision components are used for U₁, R, C, and the reference voltages. Calibration adjustments include scale factor and zero offset.

In operation, the Charge/Discharge Current Integrator remains connected with a calibrated 50-mV, 300A shunt which is in series with the vehicle battery. The Current Integrator operates both during recharge and driving. During driving, input AC power is derived from a 60-Hz inverter which is part of the vehicle's control system.

4.2.3 AC Watt-Hours Meter

AC recharge energy was recorded by a standard single-phase 115-VAC, 60-Hz, 2-KW watt-hour meter. It should be noted that while this class of watt-hour meter inherently reads true energy, and not apparent energy, the accuracy of such measurements is degraded by non sinusoidal currents. In the case of the Ripp-Electric Charger, the full-load power factor exceeds 90%, and current total harmonic distortion is less than 20%. Accordingly, accuracy degradations due to wave-shape and power factor should be of little concern.

All readings were interpolated to the nearest tenth KWH.

4.2.4 Voltage, Current, Energy, and Temperature Data Acquisition

Motor and battery voltages, currents, and true energies in addition to temperatures were sensed and recorded by specially designed equipment (Figure 4.1.1). This portion of the total system may be divided into three sections:

- (1) Sensors - These include Hall Effect Current Sensors which sensed motor and battery currents, and thermistors which sensed ambient, motor, and battery temperatures.
- (2) Interfaces - These include isolation amplifiers which electrically isolated the instrumentation from the vehicle electrical environment, a digital integrator connected between the "Energy Counter" and the Data Recorder which provided an analog signal proportionate to "elapsed energy", a reference supply which provided both power for the thermistors and a calibration voltage for the Data Recorder, and low-pass filters which filter out the AC components of chopped waveforms.
- (3) Measuring Instruments - These included a four-channel digital energy recorder ("Energy Counter") which "kept account" of battery recharge and discharge energy, energy to the motor, and energy from the motor, and a 16-channel tape recorder which recorded analog data from the interfaces.

Additional circuitry, not shown in Figure 4.1.1 includes the following:

- (1) Battery - a rechargeable lead-acid battery was used to power the circuitry of Figure 4.1.1 (except for the Current Integrator). This same battery also provided power for the Strip-Chart recorder via an inverter.
- (2) DC-to-DC Converter - A Stevens Arnold DC-to-DC converter was used to convert battery power into regulated bipolar power for the current sensors, the isolation amplifiers and the data recorder.
- (3) Crystal Clock - A precision 5.000-Hz signal was generated by a crystal oscillator and count-down circuits; this signal regulated the sample rate of the data recorder and served as an incremental time base.

4.2.4.1 Energy Counter. The function of the Energy Counter was to measure energy flow to and from the battery, and to and from the motor. Originally it was felt that this task could be accomplished at the software level simply by multiplying recorded voltage, current, and time values. Upon quantitatively considering the errors inherent in this method, it was decided to use a "mathematically correct" approach. The result was JPL's development of the Energy Counter system and its effective use for capturing energy data during the Dynamic Science Tests.

Its concept of operation is straightforward. Input signals which are proportionate to voltage and current are multiplied by a four-quadrant multiplier. The resulting "true power" signal is then used to drive a voltage-to-frequency converter. At this point, frequency is proportionate to the true power, and phase or cycle number is proportionate to true energy. A counter connected to the converter output (with necessary interfaces) will therefore generate a count increment proportionate to the increment of true energy.

A block diagram of the system is shown in Figure 4.2.2. Added complexity results from the requirement that separate account be made of "forward flow" and "reverse flow" energy. To achieve this, an absolute valve circuit connects between the multiplier and the "V-to-F" converter, and a gate circuit is used to steer the converter output to the appropriate counter circuit.

A standard DC-to-DC converter is used to supply the internal power requirements (regulated 15 volts bipolar).

4.2.4.2 Digital Integrator. The function of the four channel "Digital Integrator" was to generate analog signals which correspond to each of the four Energy Counter readings.

The scheme depicted in Figure 4.2.3 was arrived at as the most easily effected, yet most accurate means of achieving this requirement. Each integrator input receives a pulse for each increment of the corresponding energy Counter Channel. Action of the Ripple Counter, the resistor network, and associated components is such that the integrator output increments 19.53 μ V for each pulse; after 4.980 volts is reached, the output resets to zero with the next input pulse. Each of the four integrator outputs connected to a recording channel. Energy increments associated with each channel were determined at the data process level by noting the difference in channel values and the number of cycles associated with given intervals of measurement.

4.2.4.3 Data Recorder. A Datel LPS-16 Data Logger System was used to record signals corresponding to voltage, current, energy, temperature, and vehicle speed. The system includes an input multiplexer, a 12-bit A-to-D converter, a formatter, and an incremental write-only digital tape transport.

The system offers moderate flexibility - in that the sample rate is externally controlled, single quadrant, or bipolar input signals may be used, sequential or random sampling of the inputs is possible, and file gaps of various lengths are also possible. As presently configured, the system constants include:

- (1) Sample rate of five channels per second. The channel advance signal is generated by a precision crystal clock and is accurate to within 0.1% (Five channels per second is the upper limit of the LPS-16).
- (2) Sequential sample order. A scheme was devised to enable random sampling whereby desired channels could be skipped and differing sample rates assigned to various channels. This capability was not utilized during the Dynamic Science Tests, due to technical uncertainties.
- (3) A-to-D converter configured to accept only Single Quadrant voltages - in the range of 0.000 to 5.000 volts. (In the case of regenerative braking currents, negative signals are recorded by using op-amp inverters and extra channels.)
- (4) Formatter configured so that a File Gap occurs after every 64 words.

One circuit board modification on the LPS-16 multiplexer circuit was required. Originally, the input impedances were about 20K ohms, except during the sample interval, when the impedances momentarily rose to about 100 megohms. The nominally low input impedances proved unacceptable in terms of interface problems. Accordingly, a modification was implemented which enabled high input impedances - for all channels at all times. The fix consisted of disconnecting an internal "pulse mode" power supply which provided bipolar power to the multiplexer and other analog circuitry - and in its place, connecting to an external DC-to-DC converter which powered the current sensors and other peripheral circuits.

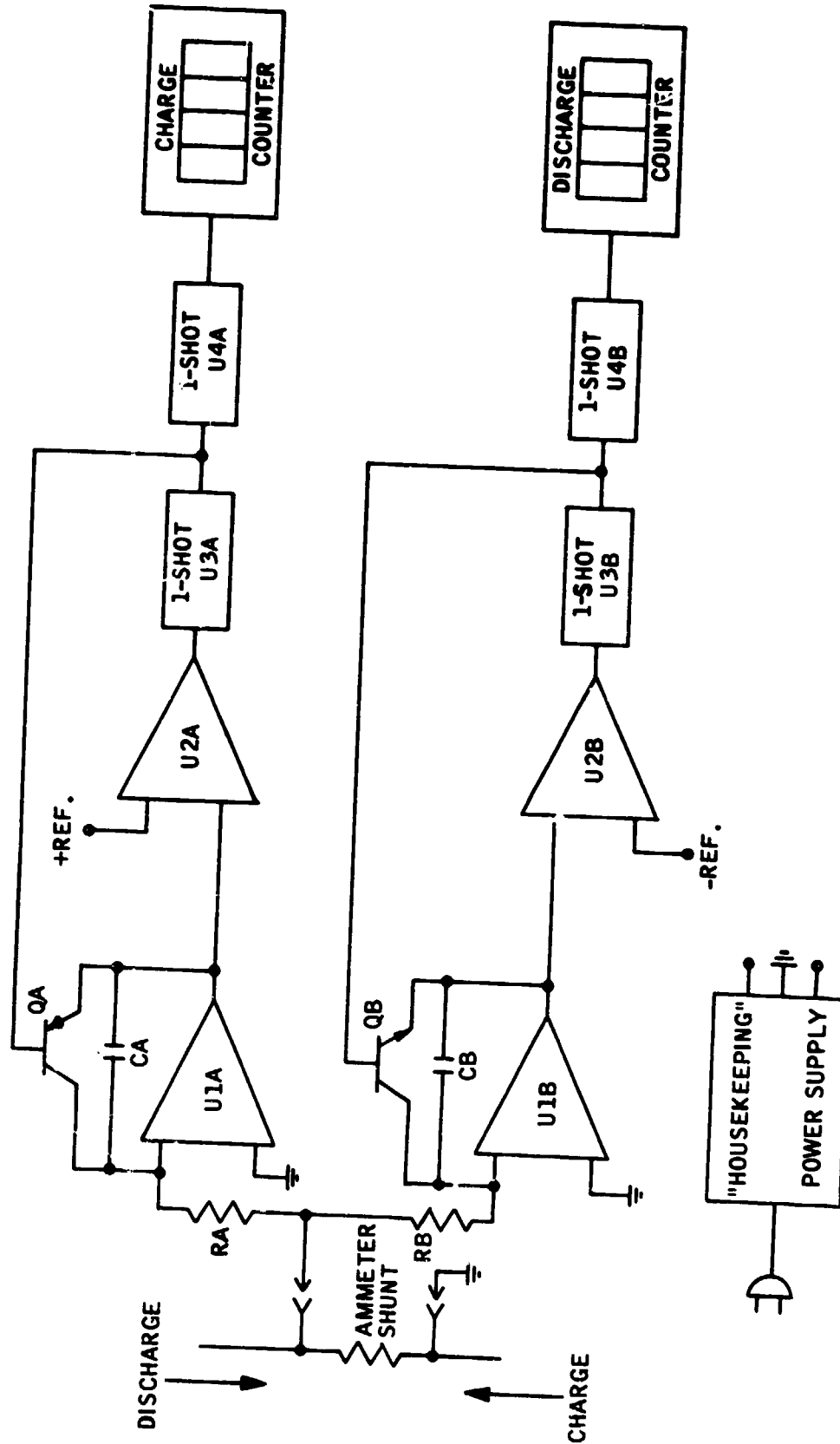


Figure 4.2.1.1. Block Diagram of Charge/Discharge Current Integration

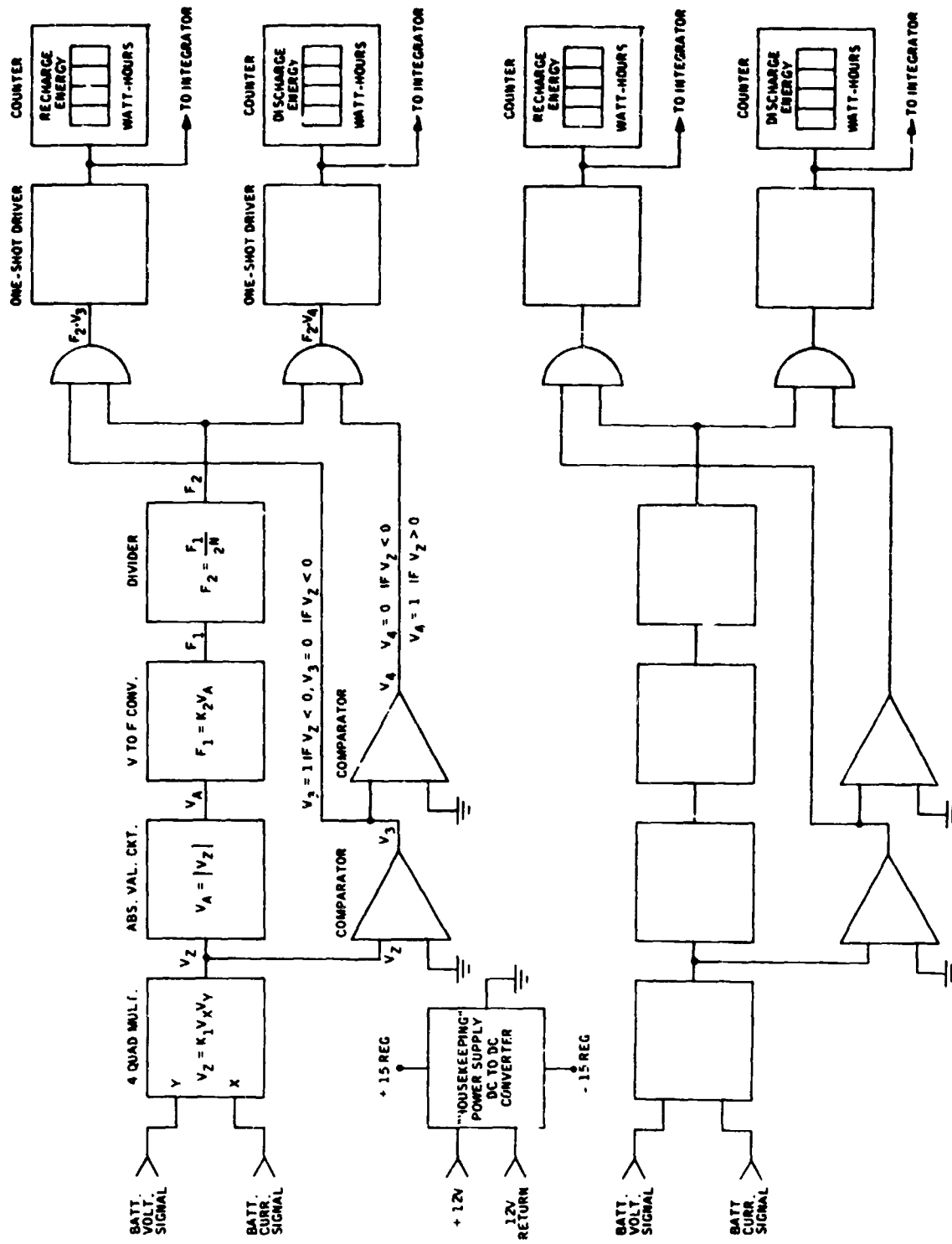


Figure 4.2.2. Block Diagram for Energy Counter which Reads True Energy

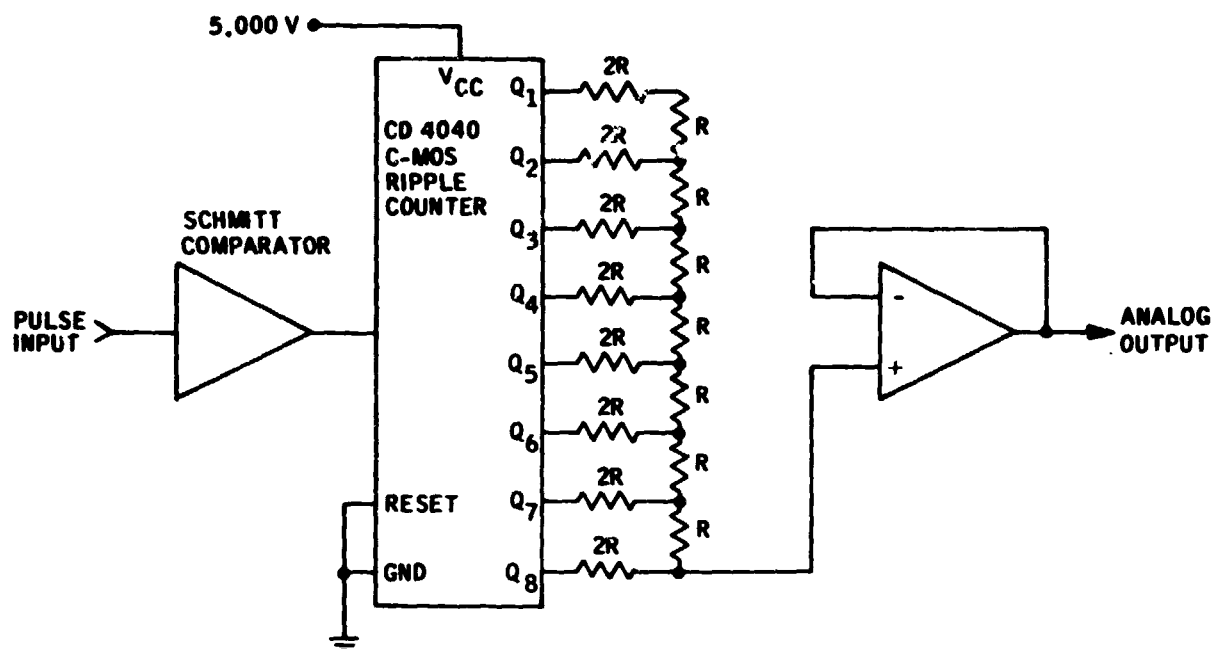


Figure 4.2.3. Digital Integrator (one of four channels). Output increments 19.53 MV for each input pulse. After 257th increment above zero, output reaches 4.980V; with next increment, output resets to zero.

4.3 DATA READING AND PROCESSING

4.3.1 Data Acquisition Software

The purpose of the data acquisition program (called EVHTF or EF) is to accept the data from the cassettes and store them on disk for ready reference by the computer. The main program is written in FORTRAN language. A special MACRO assembly language module or sub-program (called EVHTM or EM) was written which enables the FORTRAN program to communicate with the Datal reader. The capabilities of both programs are given below.

4.3.1.1 Macro Assembly Module

Communication between the Datal reader and the computer is done hardware-wise through the interface card. However, the hexadecimal ASCII data from the reader must be converted into an octal binary digital format acceptable by the FORTRAN program. In addition, the incoming data must be screened from noise and faulty data. The assembly language EM program accomplishes these tasks.

Once control is transferred to the EM program from the main EF driver, the following sequence of operation is taken.

- (1) the return address is saved for later transfer of data to EF.
- (2) various registers (memory locations) are cleared or preset.
- (3) the first six ASCII characters are received and temporarily stored in a buffer.
- (4) a discrimination routine will validate the characters in the buffer to conform to a data code followed by a channel identification code. If the format is correct, advance to the next step. If not, then accept an additional character and re-evaluate until valid data is obtained.
- (5) convert the ASCII code to a binary number.
- (6) convert the hexadecimal number to an octal number.
- (7) increment the software counter for the number of data points or entries recorded.
- (8) evaluate and count the number of data points rejected or missing.
- (9) increment the software counter for recording the elapsed time.

- (10) transfer the channel, data, and time results to EF.
- (11) return control to the EF program.

The above sequence occurs typically in less than 1 msec. Plenty of time is available to the EF program to record the data point and return for more data without any loss. At the high communication speed of 9600 baud, a fully recorded cassette (about 4 hours of data) was played back in about 15 minutes.

One additional feature of the EM module is a time-out counter. If no data is being received, the operator is warned by a ringing bell. If no action is taken within 15 secs, it is assumed that no more data is to be read and the program terminates automatically. The latter is also useful when the operator is temporarily out of the room.

4.3.1.2 Fortran Main Driver

Operator control during the data acquisition phase is afforded by the FORTRAN main driver program (EF). The EF program consists roughly of 600 lines of code and accomplishes several tasks. These modes of operation are:

- (1) accept or read data from the Datel reader via the EM module,
- (2) tabulate the unprocessed octal data on the printer,
- (3) convert the data to engineering units and print them,
- (4) save all of the received data in mass disk storage, and
- (5) save only selected portions of the data in a FORTRAN callable data file.

Several special features have been incorporated in the program. During the reading phase (mode "R") the data in several channels are accumulated. Integrated results such as the total number of data points recorded, mean vehicle velocity, hours in motion, total KWH energy expended, etc., are displayed at the conclusion of the reading cycle (Fig. 4.3.1). The reading mode allows one to accumulate only a specific number of data points, or all the data points including those from different cassettes. Some of the performance tests are lengthy such that more than one cassette is used to record the data.

A third feature of the program is the interactive communication with the operator. Figure 4.3.2 shows a typical listing of a reading cycle with EFW. EFW is a modified version of the general EF program. Several questions are asked throughout the program execution. If no answer is given (i.e., if only the carriage return key is typed), then default answers are assumed. For example, in Fig. 4.3.2 no entry

was made after the first MODE? message. The program automatically prints the possible codes that may be entered, and asks once more what mode of operation it should enter. Another default answer is assumed after the NO. PTS? question which will read all of the data from the cassette. The actual reading will not begin until the operator confirms that the cassette is ready for processing. Finally, status messages are printed such as the indication that data was stored into a second file. The latter occurs only when the original file is filled to capacity and data is still flowing in.

Sample output of the printout mode of operation are shown in Figs. 4.3.3 and 4.3.4. The former (mode 'I') lists sequentially across the page the original data and channel numbers in the integer format after octal to digital conversion. The latter printout (mode 'D') performs several operations prior to printing, such as:

- (1) convert the data to engineering units,
- (2) calculate the recorder time for each data point,
- (3) sort the data into columns corresponding to channels,
- (4) print a mnemonic label to identify the channel
- (5) print the data with the time. Since the cassette recording is organized in blocks, file gaps are produced. The printout displays asterisks for the data that was missed during a file gap.

The mass storage mode is used to save all the rough data on disk cartridges (mode 'M'). The operator assigns a file name which identifies the data. The inherent advantage of mass storage is that the data may be retrieved by EF much faster from a FORTRAN callable disk file than from the cassette reader.

Finally, the EF program allows one to selectively save only that data which is necessary (mode 'S'). A special routine was written which is similar to an EDITOR program. Initially, instructions are given to specify the file name into which data shall be stored, and which channels shall be considered.

Then, simple commands are used to scan through the rough data in increments of a line equivalent to the "D" mode printout. Another command is used to store the data from the predefined channels for a given number of lines of data. The commands available at the time of this report are:

- B = Jump to the beginning of the data
- nA = Advance n lines of data (n may be negative to backspace lines)

- L = List on the terminal the current line of data
- nS = Store the next n lines of data
- N = Advance to the next set of storage
- T = Terminate this mode of selective storage.

The information saved with the above mode is stored as floating point numbers, in engineering units, in a direct access formatted FORTRAN file. That is, the data is stored in the form of fixed arrays which are accessible to any other FORTRAN-written program. Up to 13 parameters or channels may be recorded simultaneously in sets of up to 40 entries each. A set, for example, may contain all the data points pertaining to one driving cycle. Any number (up to 32767) of sets may be recorded in one file. Each set is directly accessible by an index or record number. That is, one needs not sequentially step through the file until the desired set is found. By convention, parameter No. 1 is used to automatically store the recorder time, parameters No. 2-10 are filled with desired data, and parameters No. 11-13 are reserved for computed data. The use of this array-type storage is shown later with the description of the ED data analysis program.

4.3.2 Data Analysis Software

Once the data has been selected and stored in a general accessible file, a number of analysis programs are written. Different vehicle tests, for example, require different types of analysis and, therefore, different programs. For the current project, four basic tests were evaluated:

- (1) vehicle performance at constant speeds of 25, 35, 45, and maximum MPH
- (2) performance during acceleration
- (3) coastdown; and
- (4) performance during schedule B and C of the federal driving cycle of idle, acceleration, cruising, coast-down, and braking. Three analysis programs are briefly outlined below: acceleration test performance, curve fitting with least squares approximation, and a general purpose analysis program.

4.3.2.1 Polynomial Curve Fitting

One goal in analyzing performance data is to be able to relate the behavior or shape of the data to physical parameters. The coefficients of a polynomial equation, for example, are related to such phenomena as vehicle drag, wheel slippage, etc. The PEF program was written to call a least squares fit subprogram and to evaluate the best polynomial that would fit a given set of data.

Inherent capabilities programmed into the PEF package include:

- (1) mathematically accurate determination of the least squares value,
- (2) ability to specify the degree of the polynomial to be used,
- (3) ability to choose the degree that will give the best fit,
- (4) ability to fit only a specified portion of the data,
- (5) calculate and print the resulting coefficients and standard deviation,
- (6) if more than one function is used, determine their common point of intersection, and
- (7) plot the calculated fit superimposed on the rough data.

4.3.2.2 General Purpose Program

Compatible with the data file generated by the EF program, a general purpose data analysis program called ED was developed. The main concept of ED is to recall from disk storage several sets of data (up to 10) into core memory. The selected data can then be readily modified or otherwise operated on. Thirteen different modes of operation have been programmed at the time of this report. A description of these is given below.

Subroutines to sort the data in increasing order. to select appropriate points to plot, etc. are used extensively throughout the program. One particular subroutine proved to be particularly helpful in visualizing the pattern of rough data. A two-dimensional three-point averaging algorithm was developed to filter the high frequency noise. Given three sequential points A, B, and C, an average value was calculated which replaced the center point (B):

$$B' = \frac{A + 2B + C}{4} \quad (4.3.1)$$

All data points are eventually replaced with a new value by applying the above equation.

Averaging is done for both the abscissa and ordinate elements of a point. This filtering algorithm can be iterated several times thus yielding a smooth line which truly represents the data. Figures 4.3.5 and 4.3.6 are typical samples with seven iterations of the above algorithm. The latter also shows the driver's driving pattern during a schedule-C cycle test.

1. Data Fetch

The first mode of operation of the ED program allows one to retrieve certain sets of data from a named file on disk. The latter file was generated by mode "S" of the EF program. The ED program will set-up a pointer reference table so that the operator need not renumber his parameters and sets. Also, the program associates a certain default type of data to each parameter. For example, the EDD version of the program assumes parameter No. 1 to be recorder time, parameter No. 2 to be vehicle velocity at the time coordinates of No. 1, parameter No. 3 to include battery voltage data, etc. The fetch mode is entered automatically when the program is first called.

2. Data Save

The information which was fetched into core memory by mode 1 may be modified by subsequent modes. Mode 2 allows one to save these modifications into the same storage data file as above.

3. Data Modification

Mode 3 allows the user to change the numerical value of any entry present in core. For example, missing data may be interpolated or individual noise glitches may be removed.

4. Custom Analysis

Different analysts often require different mathematical operations. Mode 4 allows the user to execute a particular pre-programmed formula tailored to his needs such as calculating grade ability. Several such functions can be incorporated in a single version of the ED program.

5. Two-parameter Plot

Probably the most widely-used mode of operation is that of plotting any two parameters. To minimize operator input such as parameter description, upper and lower limits of data, number of filtering iterations to be performed, etc., certain default conditions are assumed. These may be changed with mode 6.

6. Default Operations Table

A number of details are assumed by the program. Some of these may be changed at the operator's terminal during program execution. The default conditions which may be intercepted include the

- a) use of automatic or fixed scaling to draw a plot (if fixed some upper and lower limits must be entered);

- b) method of plotting the data such as with individual asterisks, with a line through the points, or with superposition of the filtered data; and
- c) specification of the number of iterations for the filtering algorithm.

7. Print Data

The contents of the data arrays currently used in core memory may be printed with mode 7. This ability is particularly useful in interpreting or troubleshooting resulting plots. A sample of the printout is shown in Fig. 4.3.7. The array printed on the top left corner is the pointer reference table mentioned earlier. Column numeration refer to the parameter number.

8. Normalized Time

The recorder time stored as parameter No. 1 is never reset during a performance test, however one test may contain several runs or cycles. Mode 8 allows one to normalize the time for each set of data entered. A given set would include all the data entries for a particular run or cycle. Since the first measurement sampled by the portable data logger may not be at time zero of the run, a linear interpolation is done on the time/velocity data. All data sets are normalized to the true time zero, and saved a parameter No. 13.

The advantages of time-normalized data include:

- 1) correction for time lag between sampling by the data logger,
- 2) superposition of different runs of data for averaging and/or plotting.

9. Program Termination

Computer generated files must be properly opened and closed. Mode 9 will exit the program correctly according to system specifications. Program termination also occurs at the conclusion of drawing a plot.

10. Curve Fitting

Similar to the PEF program described earlier, mode 10 enables the user to perform a least squares fit of the data up to a sixth degree polynomials. Both the coefficients and the fitted data are printed and plotted.

11. Data Intergration

Any given parameter may be integrated within a set. Parameter No. 7, for example, was used to record the watt-hours (W-H) from the vehicle's battery. Integration thereof yields an increasing function which can be readily plotted and easily interpreted. Figure 4.3.8 shows such a graph plotted versus velocity.

12. Data Interpolation

It is sometimes desirable to plot a parameter not against time, but versus some other parameter such as velocity (Fig. 4.3.8). Measurements, however, were sampled sequentially in time. A current measurement, for example, does not coincide in time with a velocity measurement. Time offsets are in increments of 0.2 secs/channel. Mode 12 will generate a new set of velocity values which are time-corrected to the parameter of interest. Conventional storage of the new values are done as parameter No. 12. The time correction is accomplished by linear interpolation of the velocity/normalized time data.

13. Metric Conversion

A special routine has been incorporated in the ED program to convert data to its metric equivalent units. Velocity, for example, is expressed in Km/hr while acceleration is calculated in Km/hr sec.

Finally, one additional command is available to the operator to abort the program in the middle of a run. Two control-C characters must be typed in sequence at the keyboard. Computer control is then given to the MONITOR which allows one to restart a user or system program.

E V H T DATA STATISTICS FOR TEST RUN: #FS 25MPH

ANALYSIS DATE: 16-JUN-77
 31111 PTS RECD, 368 PTS REJECTD
 TOTAL ELAPSED TIME: 1.75 HRS

CALCULATIONS:

CAR-IN-MOTION HRS =	1.65
MEAN VELOCITY (MPH) =	25.71
APPROX. MILAGE =	42.39
MEAN MOT. VOLTS =	103.05
MOT. AMP-HRS =	83.23
MEAN BATT VOLT =	105.51
BATT AMP-HRS =	92.32
REGEN BATT AMP-HRS =	0.07
FROM MOT. K-W-H =	3.08
TO MOT. K-W-H =	11.74
FROM BATT K-W-H =	15.71
TO BATT K-W-H =	3.96
REGEN BATT K-W-H =	0.01

Figure 4.3.1. Sample of Preliminary Data Analysis at the Conclusion of Accepting Data into the Computer from the Cassettes. Results of a 25-MPH Constant Speed Range Test are Shown.

RT-11SJ V02E-05

.DAT 31-JUL-77

.R EFW

EVHTF 31-JUL-77

OPERATE ON DATA FROM DATEL OR MASS STORAGE? D/Y

D

ID CODE (36 LETT):

V22 CALIBRATION TEST RUN 17-APR-77

MODE?

—

R = READ DATA FROM DATEL

D = DUMP DATA (ENG'N G UNITS)

S = STORE DATA FOR ANALYSIS

I = INTEGER DATA DUMP

E = EXIT PROGRAM

MODE?

R

NO. PTS?

—

PAUSE -- CST RDY? <CR>

ADDITIONAL DATA READ INTO FTN2. DAT

MORE DATA ? (Y/N)

N

118687 PTS RECD. 1619 PTS REJCTD

MODE?

E

STOP --

Figure 4.3.2. Sample Output from an Operator's Terminal during Execution of the EF Data Acquisition Software Program. Underline Messages are the User's Input.

Figure 4.3.3.3. Sample Printout of the Rough Data in the Unprocessed Integer Format

E V H T F RESULTS :			16-JUN-77			PAGE NO. 2			075 25MPH							
ELAPSED TIME	FIELD RPM	BATT VOLT	U-H FROM BATT	POT VOLT	BATT AMP	BATT UNFIL	U-H TO BATT	M.T. R/P FIL	M.P.H. FIFTH WHEEL	FIELD VOLT	DEC.C MOTOR	U-H TO MOTOR	U-H FROM MOTOR	RECCH AMP FIL	RECCH AMP UNFIL	FIXED COLL-BRATN
MIN SEC	1	2	3	4	5	6	7	1	9	10	11	12	13	14	15	16
2 115.2	0.5	2.3	0.	0.0	0.0	0.0	0.	0.3	0.00	0.00	30.07	0.	0.	0.00	-0.07	2.437
2 118.4	0.7	2.4	0.	0.0	0.0	0.0	0.	0.3	0.00	0.00	30.16	0.	0.	0.00	-0.15	2.437
2 121.4	0.5	2.3	0.	0.0	0.0	0.0	0.	0.3	0.00	0.00	30.14	0.	0.	0.00	-0.07	2.430
2 124.6	0.7	2.3	0.	0.0	0.0	0.0	0.	0.3	0.00	0.05	30.21	0.	0.	0.00	-0.07	2.437
2 127.8	0.5	2.4	0.	0.0	0.0	0.0	0.	0.3	0.00	0.05	30.30	0.	0.	0.00	-0.07	2.430
2 131.0	0.7	2.4	0.	0.0	0.0	0.0	0.	0.3	0.00	0.00	30.35	1.	0.	0.00	-0.15	2.437
2 134.0	0.7	2.4	0.	0.0	0.0	0.0	0.	0.3	0.00	0.00	30.33	0.	0.	0.00	-0.07	2.437
2 137.0	0.5	2.4	0.	0.0	0.0	0.0	0.	0.3	0.00	0.05	30.37	0.	0.	0.00	-0.22	2.430
2 140.2	0.5	2.4	0.	0.0	0.0	0.0	0.	0.3	0.00	0.00	30.42	0.	0.	0.00	-0.07	2.437
2 143.4	0.7	2.4	0.	0.0	0.0	0.0	0.	0.3	0.00	0.05	30.49	0.	0.	0.00	-0.15	2.437
2 146.4	0.5	2.4	0.	0.0	0.0	0.0	0.	0.3	0.00	0.00	30.54	0.	0.	0.00	-0.07	2.437
2 152.8	0.7	2.4	0.	0.0	0.0	0.0	0.	0.3	0.00	0.05	30.54	0.	0.	0.00	-0.07	2.437
2 156.0	0.7	2.4	0.	0.0	0.0	0.0	0.	0.3	0.00	0.00	30.56	0.	0.	0.00	-0.07	2.437
2 159.0	0.8	2.4	0.	0.0	0.0	0.0	0.	0.3	0.00	0.05	30.61	0.	0.	0.00	-0.07	2.437
3 12.0	0.7	2.4	0.	0.0	0.0	0.0	0.	0.3	0.00	0.05	30.61	0.	0.	0.00	-0.07	2.435
3 15.2	0.7	153.0	0.	0.0	0.0	0.0	0.	0.3	0.00	0.00	30.61	0.	0.	0.00	-0.07	2.437
3 18.4	0.5	153.1	0.	0.0	0.0	0.0	0.	0.3	0.00	0.05	30.63	0.	0.	0.00	-0.22	2.435
3 111.4	0.8	152.0	0.	0.0	4.7	3.3	0.	0.3	0.00	0.05	30.63	0.	0.	0.00	0.00	2.437
3 114.4	0.8	152.0	0.	0.1	2.7	2.9	0.	0.3	0.00	0.10	30.65	0.	0.	0.00	0.00	2.437
3 117.6	0.5	151.8	0.	0.0	2.7	3.0	0.	0.3	0.00	0.05	30.65	0.	0.	0.00	0.00	2.437
3 120.8	0.8	151.9	0.	0.0	2.6	3.2	0.	0.3	0.00	0.05	30.63	0.	0.	0.00	0.00	2.437
3 123.8	0.7	151.8	0.	0.0	1.5	3.0	0.	0.3	0.00	0.05	30.63	0.	0.	0.00	0.00	2.437
3 127.0	0.7	151.6	0.	0.1	2.9	2.9	0.	0.3	0.00	0.05	30.75	0.	0.	0.00	0.00	2.437
3 130.2	0.7	151.6	0.	0.0	4.2	9.7	0.	0.3	0.00	119.46	30.66	0.	0.	0.00	0.00	2.437
3 133.4	11.6	147.9	0.	20.2	13.0	46.7	0.	0.3	0.00	117.02	30.73	4.	0.	0.00	0.00	2.437
3 136.4	11.3	143.2	0.	66.2	14.8	84.0	0.	0.3	0.00	114.02	30.60	7.	0.	0.00	0.00	2.437
3 139.6	10.9	140.8	0.	95.1	129.6	97.0	0.	0.3	0.00	111.50	30.73	10.	0.	0.00	0.00	2.437
3 142.8	10.6	136.0	0.	129.5	142.8	140.6	0.	0.3	0.00	109.21	30.60	14.	0.	0.00	0.00	2.437
3 146.0	8.3	130.5	0.	136.0	103.4	30.5	0.	0.3	0.00	63.54	30.75	12.	0.	0.00	0.00	2.437
3 149.0	5.2	130.7	0.	136.0	100.1	102.1	0.	0.3	0.00	39.02	30.02	11.	0.	0.00	0.00	2.437
3 152.0	3.8	130.9	0.	135.0	91.0	98.2	0.	0.3	0.00	34.04	30.02	11.	0.	0.00	0.00	2.437
3 155.2	4.5	142.5	0.	130.2	00.5	93.4	0.	0.3	0.00	28.00	30.02	9.	0.	0.00	0.00	2.437
3 150.4	3.3	140.7	0.	138.3	00.5	93.4	0.	0.3	0.00	25.05	30.91	9.	0.	0.00	0.00	2.437
4 1.6	0.0000	140.2	0.	138.0	93.0	91.4	0.	0.3	0.00	23.15	30.59	10.	0.	0.00	0.00	2.437
4 1.4	2.0	141.0	0.	138.7	76.0	70.5	0.	0.3	0.00	19.70	30.94	9.	0.	0.00	0.00	2.437
4 1.7	2.0	141.7	0.	139.7	92.0	75.5	0.	0.3	0.00	21.00	30.91	10.	0.	0.00	0.00	2.437
4 118.0	2.0	141.1	0.	139.7	75.1	74.6	0.	0.3	0.00	20.17	30.94	8.	0.	0.00	0.00	2.437
4 114.0	2.5	0.0000	0.	139.0	72.7	69.3	0.	0.3	0.00	19.10	30.94	9.	0.	0.00	0.00	2.437
4 117.0	0.0000	142.1	0.	139.0	72.7	69.3	0.	0.3	0.00	19.54	30.70	8.	0.	0.00	0.00	2.437
4 120.0	2.7	143.0	0.	140.0	76.0	69.9	0.	0.3	0.00	24.42	31.10	7.	0.	0.00	0.00	2.437
4 121.2	3.1	143.6	0.	141.7	54.3	52.2	0.	0.3	0.00	25.04	30.99	6.	0.	0.00	0.00	2.437
4 126.4	3.1	144.3	0.	142.5	51.6	54.0	0.	0.3	0.00	26.27	31.03	5.	0.	0.00	0.00	2.437
4 129.4	3.6	0.0000	0.	142.5	40.1	45.1	0.	0.3	0.00	32.72	31.08	6.	0.	0.00	0.00	2.437

Figure 4.3.4. Sample Computer Printout of the Same Data of Figure. 3-3 Tabulated, and in Engineering Units

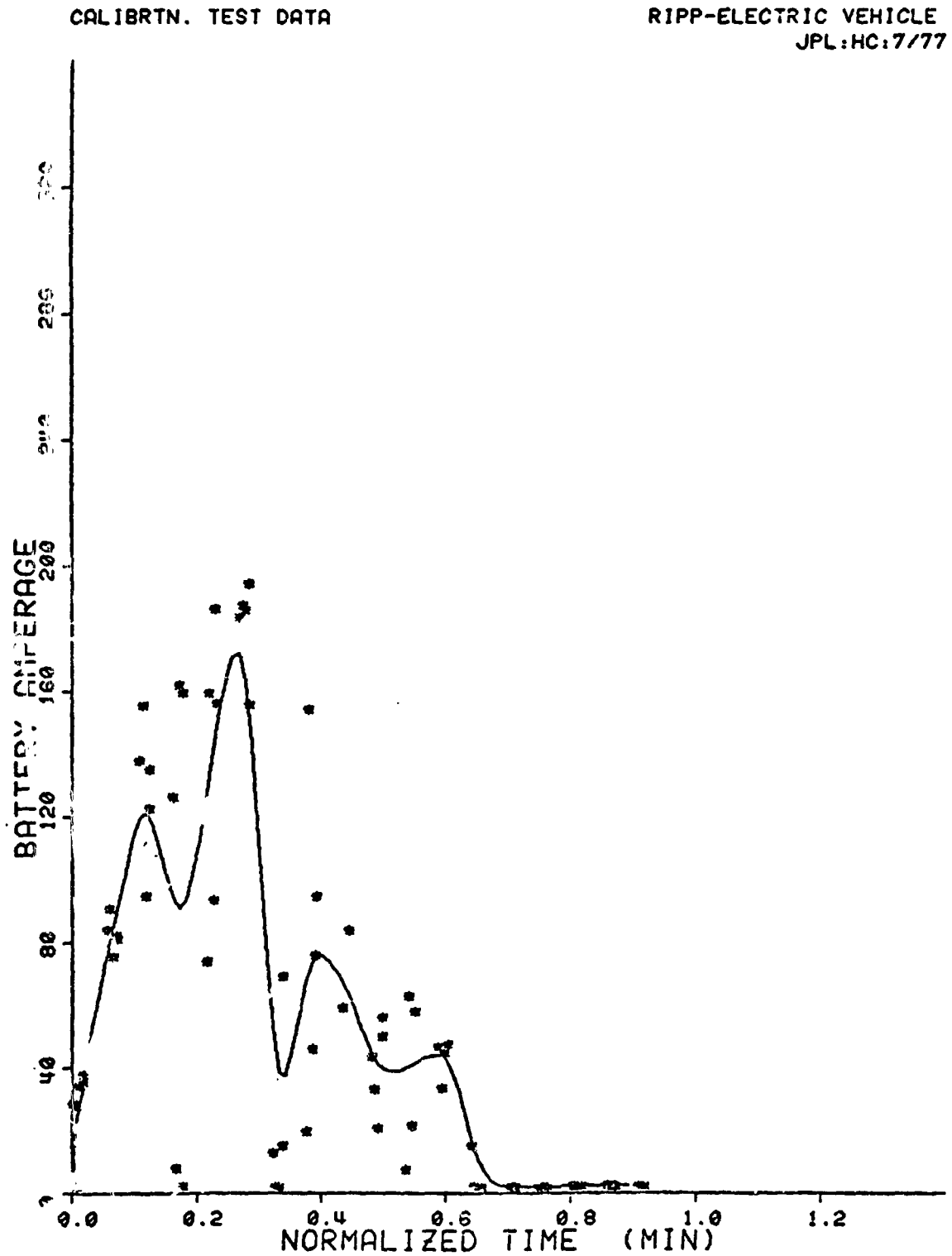


Figure 4.0.5. Effect of the Filtering Algorithm on Vehicle Performance Data. Dips in the Current Correspond to Gear Shifting

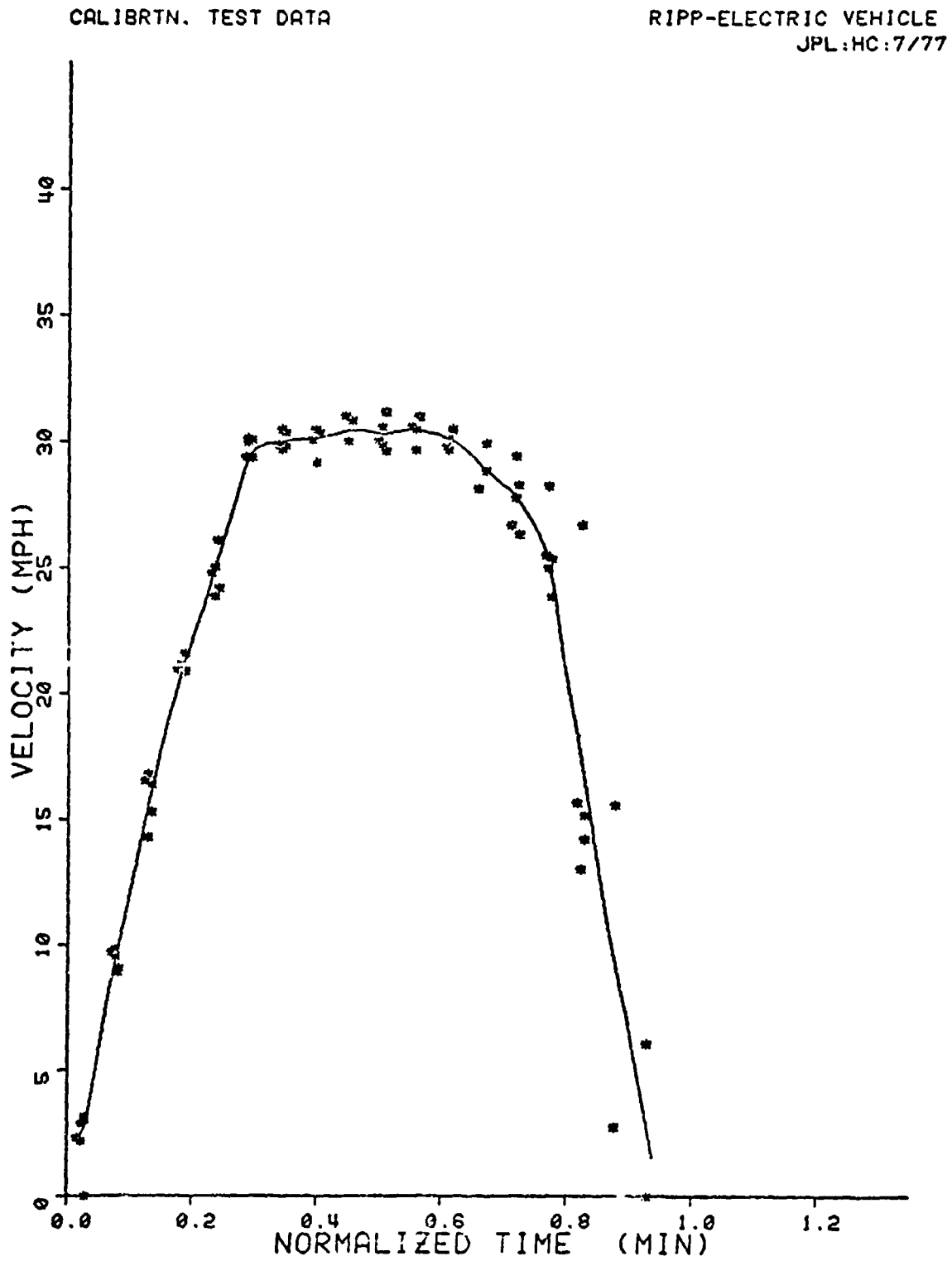


Figure 4.3.6. Schedule "C" Driving Cycle Plot for the Data of Figure 4-4

INDEX	ISET	IPAR	IPT	1	2	3	4	5	6	7	8	9	10	11	12	13
1	1	13	10													
2	3	13	11													
3	0	0	0													
4	0	0	0													
5	0	0	0													
6	0	0	0													
7	0	0	0													
8	0	0	0													
9	0	0	0													
10	0	0	0													
PT	1	2	3													
SET NO. 1																
1	1.63	12.02	145.23	107.40	198.32	48.74	0.00	0.00	0.00	0.00	0.00	114.29	10.33	0.00	6.64	0.045
2	1.76	26.34	135.70	202.49	171.94	117.95	16.00	19.00	19.00	19.00	19.00	94.11	9.52	0.00	20.97	0.098
3	1.76	34.19	137.39	143.44	141.25	134.26	37.00	36.00	36.00	36.00	36.00	28.67	4.25	0.00	31.25	0.151
4	1.81	40.27	137.39	140.00	136.92	*****	55.00	52.00	52.00	52.00	52.00	13.82	1.25	0.00	37.99	0.205
5	1.87	44.66	130.02	130.90	134.87	134.95	71.00	68.00	68.00	68.00	68.00	10.70	0.59	0.00	43.01	0.258
6	1.92	48.74	130.12	136.12	133.55	134.99	80.00	84.00	84.00	84.00	84.00	7.13	0.00	0.00	47.21	0.311
7	1.97	52.10	138.27	127.62	130.84	134.99	105.00	99.00	99.00	99.00	99.00	2.83	0.00	0.00	50.84	0.365
8	2.03	54.26	138.55	*****	125.35	135.97	123.00	115.00	115.00	115.00	115.00	2.78	0.00	0.00	53.45	0.418
9	2.08	57.10	139.03	123.81	118.68	136.85	137.00	129.00	129.00	129.00	129.00	2.20	0.00	0.00	56.04	0.471
10	2.13	58.92	140.46	116.84	112.01	137.44	152.00	142.00	142.00	142.00	142.00	2.15	0.00	0.00	50.24	0.525
SET NO. 3																
1	5.92	1.03	152.77	0.00	137.36	0.00	0.00	1.00	1.00	1.00	1.00	119.71	0.00	0.00	0.00	0.004
2	5.97	16.16	143.93	130.26	196.48	65.89	7.00	12.00	12.00	12.00	12.00	112.92	9.23	0.00	10.49	0.057
3	6.03	29.28	*****	174.58	151.14	131.10	26.00	31.00	31.00	31.00	31.00	74.29	8.72	0.00	24.36	0.110
4	6.00	37.55	139.29	147.99	140.51	136.07	46.00	48.00	48.00	48.00	48.00	25.79	3.08	0.00	34.45	0.164
5	6.13	43.09	139.49	141.68	134.73	135.92	64.00	65.00	65.00	65.00	65.00	13.77	1.03	0.00	41.01	0.217
6	6.19	47.53	139.58	143.59	131.14	136.26	81.00	81.00	81.00	81.00	81.00	5.10	0.22	0.00	45.87	0.270
7	6.24	50.45	139.24	140.00	139.71	137.39	81.00	90.00	90.00	90.00	90.00	3.47	0.00	0.00	49.35	0.324
8	6.29	53.09	140.27	139.85	133.77	137.78	117.00	112.00	112.00	112.00	112.00	1.47	0.00	0.00	52.10	0.377
9	6.35	55.92	139.93	135.68	126.67	137.00	133.00	128.00	128.00	128.00	128.00	2.83	0.00	0.00	54.86	0.430
10	6.40	57.28	140.85	122.27	118.24	137.92	150.00	143.00	143.00	143.00	143.00	3.03	0.00	0.00	56.77	0.484
11	6.45	59.32	141.25	115.90	112.89	*****	150.00	155.00	155.00	155.00	155.00	26.03	0.00	0.00	50.56	0.537

Figure 4.3.7. Sample Printout of the Data Array Present in Core Memory Available for Manipulation with the Data Analysis Software Program

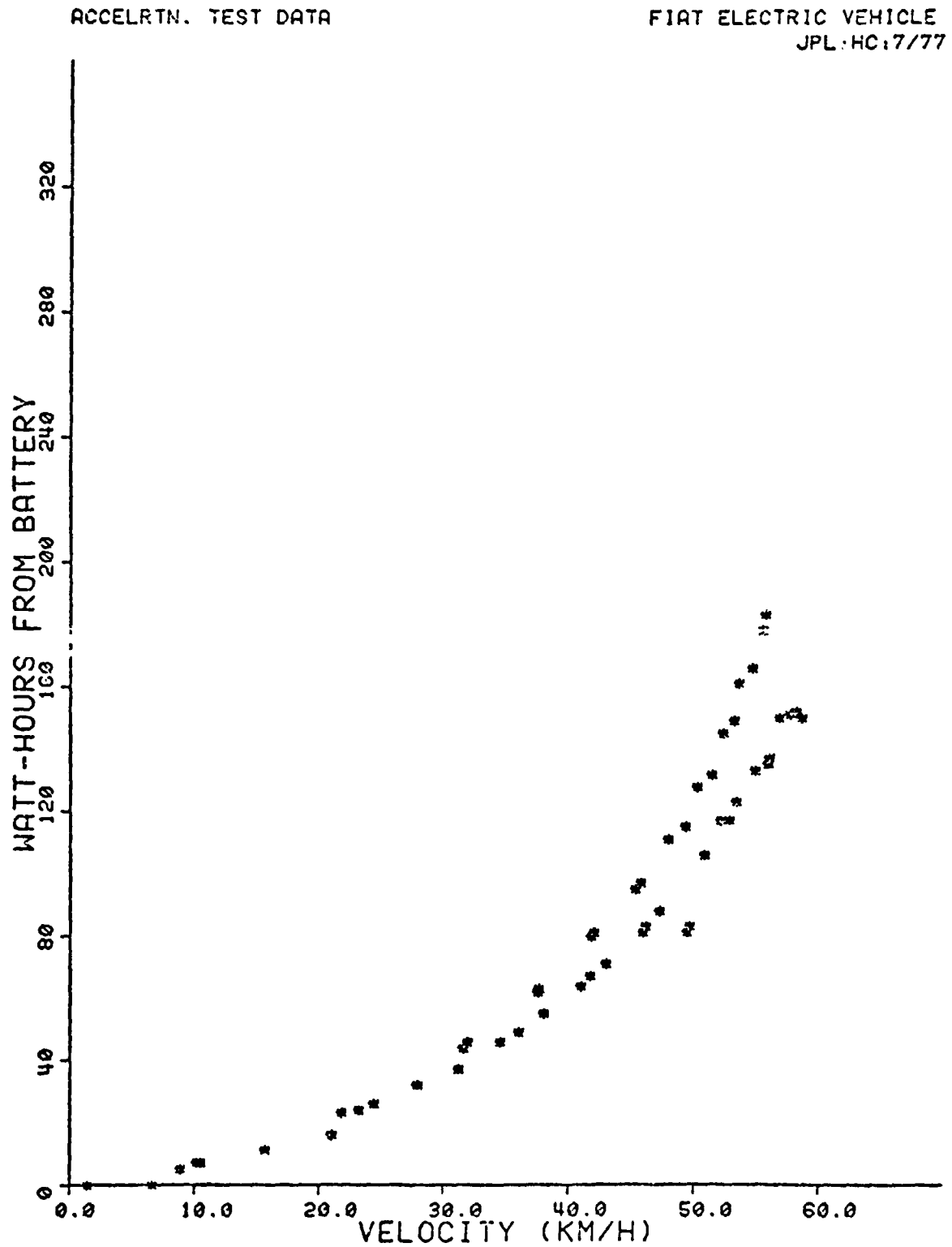


Figure 4.3.8. Sample Display of an Integrated Parameter
Energy Consumption

4.4 SCALE FACTORS

The following scale factors were used for sensors, interfaces, and measuring instruments.

4.4.1 Sensors

4.4.1.1 Current Sensors (Battery and Motor Current).

Manufacturer ----- American Aerospace Controls, Inc.

Model Number ----- 924A-300

Scale Factor ----- 0.01667 V/A for $-300A < I < 300A$

4.4.1.2 Battery Shunt (for Current Integrator).

Manufacturer ----- Janco, Inc.

Scale Factor ----- 0.0001667 V/A for $-300A < I < 300A$

4.4.1.3 Thermistors (Ambient, Battery, Motor Temp).

Manufacturer ----- Fenwall

Part Type ----- C516

Part Number ----- F1263

Temperature Equation $T = \frac{3887}{\ln R + 5.436}$ for T in °K
and R in ohms

4.4.1.4 Fifth Wheel (Tachometer Output)

Manufacturer ----- Nucleus Corporation

Model Number ----- NC-5

Scale Factor

(Measured at JPL) ---- 0.0826 V/mph (0.0563 V/kmph)

(Measured at DSI) ---- 0.0813 V/mph (0.0543 V/kmph)

(Used in Computer

Program ----- 0.0850 V/mph (0.0580 V/kmph)

4.4.2 Interfaces

4.4.2.1 Isolation Amplifiers (Battery and Motor Voltage).

Manufacturer ----- Burr-Brown

Model Number ----- 3452

Scale Factor ----- 0.03125 V/V (scale factor achieved
by use of external components).

4.4.2.2 Thermistor Circuit. Consists of precision 5 volt source connected across precision 2K resistor in series with thermistor. Output to tape recorder taken across thermistor. Voltage to temperature relation is:

$$T + \frac{3887}{\ln \left(\frac{V}{5 - V} \right) + 13.04} - 273$$

where

T is in °C and V in volts.

4.4.2.3 Filters. Each of the six filters shown in Figure 4.1.1 consists of two 10 K resistors and two 1 μF capacitors connected as a two section low pass filter.

4.4.3 Measuring and Recording Instruments.

4.4.3.1 AC Watt-Hour Meter

Manufacturer ----- General Electric

Model Number ----- 120V-2W-FMIS-TA15

Scale Factor ----- Unity

4.4.3.2 Charge/Discharge Current Integrator

Manufacturer ----- Ripp-Electric

Scale Factor ----- 1 Amp-Hour = 1.667×10^{-4} Volt-Hour4.4.3.3 Energy Counter

Manufacturer ----- JPL

Scale Factor (present

Calibration ----- 1 Increment = 1.333 Watt-Hour
= 2.500 Volt²-Sec

Scale Factor (nominal
calibration) ----- 1 Increment = 1.000 Watt-Hour
= 1.875 Volt²-Sec

4.4.3.4 Data Recorder.

Manufacturer ----- Datel Systems, Inc.

Model Number ----- LPS-16-12BA3-64

Scale Factor ----- Least Significant Bit = 1.22 MV

4.5 MANUFACTURERS' SPECIFICATIONS (see Section 4.4 for Manufacturers and Model Numbers)

4.5.1 Sensors

4.5.1.1 Current Sensors.

Accuracy ----- $\pm 1\%$ F.S.

Response ----- 100 μ sec

Operating Temp ----- 0 to +70°C

Temp. Coeff. ----- $\pm 0.08\%$ FS/°C

Off-Set T.C. ----- ± 0.24 A/°C (implied)

4.5.1.2 Battery Shunt (see Section 4.6.1.2).

4.5.1.3 Thermistors

25°C Resistance ----- 2000 ohms

Accuracy ----- $\pm 5\%$

4.5.1.4 Fifth Wheel. No meaningful specs available.

4.5.2 Interfaces

4.5.2.1 Isolation Amplifiers.

Nonlinearity ----- 0.005% FS

Frequency Response ----- 2.5 kHz (3 dB point)

Setting Time ----- 1 msec (to 0.1%)

Isolation Mode

Rejection ----- 120 dB (60 Hz)

4.5.2.2 Thermistor Circuit.

Accuracy of
Resistors ----- 1%

Accuracy of
voltage ----- 0.3% or better

4.5.3 Measuring and Recording Instruments

4.5.3.1 AC Watt-Hour Meter.4.5.3.2 Charge/Discharge Current Integrator (Ripp-Electric Measurements)

Offset counting
rate (measured 3 weeks
after calibration -
with temp varied
between 16°C and
27°C ----- Less than 0.05 amp-hour per hour
for both counters.

Counting rate accuracy
(measured at 100 amps
or 16.66 MV - 3 weeks
after calibration with
temperature between
60°F and 80°F) ----- Ranged between 99.24 and 100.36
amp-hours per hour for both
counters

Linearity (measured at
50, 100, 200,
300 amps ----- Error less than 0.1% of full scale
counting rate - for both counters.

4.5.3.3 Energy Counter.

4.5.3.4 Data Recorder.

Recording Medium ----- Cassette Tape
Number of Inputs ----- 16 Analog Channels
Input Configuration ----- Single Ended
Input Voltage Range ----- 0 to +5 V F.S. (as used)
Input Channel
Impedances ----- 100 Megohms (after mod.)
System Accuracy ----- ± 1.9 MV
Resolution ----- 12 binary bits (LSB = 1.22 MV)
System Temp. Coeff. ----- $\pm 0.004\%/^{\circ}\text{C}$
Max Scan Rate ----- 5 channels per sec

4.6 LAB AND FIELD CALIBRATIONS

4.6.1 AAC Current Sensors

4.6.1.1 Lab Cal. - Dec 1976. JPL. The following tests and calibrations were applied to the battery current sensor (No. 1) and the motor current sensor (No. 2): Bipolar excitation power was derived from two lab supplies, each adjusted to 15 ± 0.1 volts. Sensed currents were effected by 40 turns of No. 22 wire connected to lab supply through 1Ω , 1%, 10 watt precision resistor. All subsequent voltage readings were with a Fluke 8900A DVM.

With sensed current = 0, output voltage of each sensor was first observed; initial offsets were about 0.1 volts. Next step was to adjust null control for output zero. Subsequent drift rates were about 1 MV in 15 minutes.

Next, the sensed current was set at 1000 amps as indicated by a 1.000 volt drop across the resistor. For each sensor, forward and reverse currents gave same readings. Battery Sensor gave readings of ± 0.668 V and Motor Sensor gave ± 0.669 V. Correct reading for 40.0 ampere turns is ± 0.667 V.

4.6.1.2 Field Cal. No. 1 March 30, 1977, Dynamic Science. With both sensors energized but sensed current = 0, output offsets were checked. For Motor Sensor, offset was only ± 0.014 V. For Battery Sensor, offset was ± 0.041 V. At this time it was noted that a 0.010 V signal ground voltage difference was present between sensor grounds and Energy Counter signal ground. On March 31, Battery Sensor was zeroed for null voltage at Energy Counter. On April 15, a No. 14 ground connection between sensors and Energy Counter was added; both sensors were slightly adjusted for zero offset as seen at Energy Counter inputs.

4.6.1.3 Field Cal No. 2 March 30, 1977, Dynamic Science. In these tests several points of static operation were tested for each sensor. Test setup consisted of a 20A Nobatron Power Supply in series with 10A, 100 MV shunt and 14 turns of No. 14 through sensor under test. Fluke 8100A DVM was used to measure both the shunt signal and the sensor output. Results are summarized in Table 4.6.1.

4.6.2 Current Integrator Field Cal. April 14, 1977, Dynamic Science

Data recorded during tests indicated that the "charge" portion of the current integrator may have developed larger than nominal offset errors. A 5.00 amp current was simulated by a 0.83 MV signal (as read on Fluke 8100A DVM). The integrator was allowed to warm up for one half hour ($T_A = 29.5^\circ\text{C}$) before the counting rate was checked. Measurement produced 92 counts (0.92Ah) in 12 minutes. Since correct reading was 100 counts, error at the 5 amp point was 8%. Both charge and discharge counters were zeroed at this time.

4.6.3 Energy Counter Field Measurements

4.6.3.1 Offset Count Rate - Measured March 9, 1977, Dynamic Science. With all input signals at zero, counting rates, based on counts over 10 minutes interval, were:

Batt. Discharge ----- 336 counts/hr = 448 watts

Batt. Recharge ----- 0 counts/hr; offset not known

Energy to Motor ----- 60 counts/hr - 80 watts

Energy from Motor ----- 0 counts/hr; offset not known

4.6.3.2 Cal. Tests - March 18, 1977, Dynamic Science. Various input voltages were applied to the Energy Counter to determine accuracy at different points of operation for each of the counters. All voltages were measured with Fluke 8100A DVM; time was measured with wrist watch. Scale factors for voltage were 5 volts input (voltage signal) corresponds to 160 volts (battery or motor) and 5 volts input (current signal) corresponds to 300 amps (battery and motor). Computed K factor is the number of watt-hours per LSD. Results are summarized in Table 4.6.2.

4.6.4 Fifth Wheel Lab and Field Measurements

Fifth Wheel tachometer output vs speed was measured at JPL for various speeds. Results of these measurements were plotted in Figure 4.6.1. Voltage to speed proportionality, determined from Figure 4.6.1, is 0.826 V/mph.

Using Dynamic Science's 1800 RPM "Fifth Wheel Spinner", Fluke 8100A reading of tachometer was 4.305 V (test performed on March 14, 1977). The rating given the Fifth Wheel Calibrator by Dynamic Science is 52.95 mph. The corresponding voltage to speed proportionality is 0.0813 V/mph.

For all tests, the vehicle speed was driver controlled, using the HP Strip Chart recorder as a speed indicator. The Strip-Chart Recorder was periodically calibrated by running the Fifth Wheel on the Calibrator.

4.6.5 AC KWH Meter

No measurements or calibrations were performed.

Table 4.6.1. AAC Current Sensor Cal. Test

Sensor	Shunt Voltage (MV)	Ampere-Turns	Expected Sensor Reading (Volts)	Actual Sensor Reading (Volts)	% Error
Battery	0.00	0.00	0.000	-0.013	-
Battery	+24.97	+34.96	+0.583	+0.575	+1.37
Battery	+49.80	+69.72	+1.162	+1.153	+0.77
Battery	+100.0	+140.00	+2.333	+2.330	+0.13
Battery	-100.0	-140.00	-2.333	-2.371	-1.63
Battery	-50.3	-70.42	-1.174	-1.210	-3.06
Battery	-25.07	-35.10	-0.585	-0.610	-4.27
Motor	0.00	0.00	0.000	-0.002	-
Motor	+50.20	+70.28	+1.171	+1.177	-0.51
Motor	+100.1	+140.14	+2.336	+2.344	+0.34
Motor	+25.10	+35.14	+0.585	+0.593	-1.36
Motor	-25.05	-35.07	-0.584	-0.609	-4.28
Motor	-50.10	-70.14	-1.169	-1.138	-2.48
Motor	-100.0	-140.00	-2.333	-2.366	-1.44

Table 4.6.2. Energy Counter Cal. Test

Circuit Test	Voltage Simulated (Volts)	Voltage Signal (Volts)	Current Simulated (Amps)	Current Signal (Volts)	Counting Time (Sec)	Observed Counts	Predicted Watt-Hours	(Watt-Hrs per Count)
Batt. Disch	120.0	3.750	100.0	1.667	150	380	500.0	1.316
Batt. Disch	105.0	3.281	200.0	3.333	150	665	875.0	1.316
Batt. Rech	130	4.063	-40.0	-0.667	150	164	216.7	1.321
Batt. Rech	150.0	4.688	-5.0	-0.083	150	28	31.3	1.116
Batt. Rech	150.0	4.688	-12.0	-0.200	150	61	75.0	1.230
Batt. Rech	150.0	4.688	-2.0	-0.033	150	14	12.5	0.893
To Motor	60.0	1.875	150.0	2.500	150	289	375.0	1.298
To Motor	75.0	2.344	75.0	1.250	150	180	234.4	1.302
To Motor	110.0	3.438	250.0	4.167	150	870	1145.8	1.317

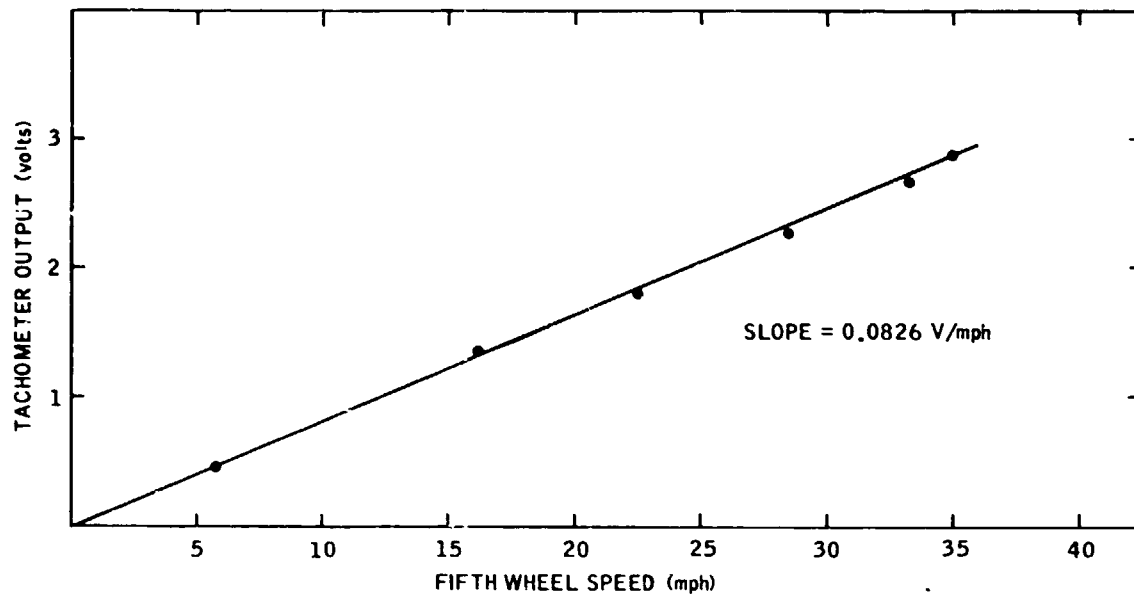


Figure 4.6.1. Calibration Test Run on NC-5 Fifth Wheel, December 16, 1977

4.7 LIST OF INSTRUMENTS, MODEL AND SERIAL NUMBERS

Tire Pressure

Gauge ----- Milton, no PN

Data Recorder ----- Datel, PN LPS-16-12B3A-64

AC KWH Meter ----- GE, PN: 120V-2W-FMIS-TA15

DVM ----- Fluke, PN 8100A

Strip Chart Recorder ---- HP, PN 7100B, 15701A amplifiers

Fifth Wheel ----- Nucleus, PN NC-5

Fifth Wheel Speed

Meter ----- Weston, PN 901

5.1 TEST PROCEDURES

In paragraphs 5.2 through 5.6, which follow, test procedures for constant speed, driving cycle, acceleration, coast-down, and weight sensitivity measurements are respectively discussed. With the exception of the weight sensitivity tests, all procedures derive from ERDA Document EHV-TEP.

The procedures in paragraphs 5.2 through 5.5 discuss those cases where deviations from the recommended ERDA procedures were used. These sections also test various "standards" which were adopted when corresponding ERDA procedures were nonexistent.

Procedures for the weight sensitivity tests were formulated by W. Rippel. The underlying purpose of these added tests was to provide, for design engineers, an estimate of range and energy improvements which could be achieved through weight reductions.

5.2 PROCEDURES FOR CONSTANT SPEED TESTS

Tests were conducted in accordance with Section 2.8.1 of ERDA Document EHV-TEP, but with the following additions and modifications.

5.2.1 Charge State

All tests were started with a fully charged battery. A specific gravity increase of $.005 \text{ g/cm}^3$ or less, during a one-hour interval of charging, served as an indication of "full charge" for both the EV-106 and LEV-115 batteries. Prior to each test, the specific gravity and temperature of each cell was recorded. If any cell yielded a temperature-corrected gravity of less than 1.275 g/cm^3 , additional charging was performed.

5.2.2 Battery Temperature

Tests were conducted only if the ambient temperature was between 40°F and 90°F (5°C and 32°C). Battery charging was permitted only if worst-case cell temperatures are between 40°F and 120°F (5°C and 49°C). Track tests was initiated only when worst-case cell temperatures were between 40°F and 110°F (5°C and 43°C).

5.2.3 Charging

All charging was done with the on-board vehicle charger. Any adjustments made on the charger during the course of the tests were noted.

5.2.4 Wind Velocity

Tests were not run when the rms wind velocity exceeded 10 mph (16 Km/h).

5.2.5 Instrumentation

At the end of each test, amp-hour, battery discharge KWH, motor KWH, fifth wheel distance, and elapsed time values were recorded - in addition to the specific gravities and temperatures of each of the battery cells.

During each test, the following parameters were recorded on the cassette data recorder:

- Speed (Strip Chart record included)
- Battery voltage
- Battery current
- Battery discharge energy
- Motor voltage
- Motor current
- Energy to motor
- Ambient temperature
- Motor temperature

During recharge, AC line, battery recharge energy, recharge amp-hours, and recharge time were recorded.

5.2.6 Vehicle Test Weight

No payload, in addition to the instrumentation and the driver, was added. The reasons for this decision are as follows:

- (1) ERDA procedures enable the manufacturer to specify payload
- (2) Weight sensitivity tests (paragraph 7.5) enable performance predictions with various payloads
- (3) With minimum payload, vehicle "wear and tear" was minimized

5.2.7 Tire Pressures

At start of tests, front tire pressures were set at 28 ± 1 PSI and rear pressures at 37 ± 1 PSI.

5.2.8 Test Start

Vehicle was driven to track starting point, which required no more than 0.3 amp-hour. That corresponding range error, for EV-106, was less than .25 percent.

5.2.9 Test Termination

The following conditions were used to terminate a test:

- (1) Inability to maintain 95 percent of desired speed

- (2) Drop of battery voltage below 1.55 volts per cell for more than 4 seconds (in the case of the Ripp-Electric, where the battery is a 120 volt unit, this cutoff voltage is 92 volts)

After the above cutoff condition was reached, the vehicle was decelerated over a distance which did not exceed 1000 feet (note that 1000 ft corresponds to a range error of between .2 percent and .4 percent. Accordingly, the coast distance may be used to offset errors due to "pre-test" driving as mentioned in paragraph 5.2.8).

5.2.10 Tests Performed

In accordance with paragraph 2.8.1.2.2 of ERDA Document EHV-TEP, constant speed tests will be run at 25, 35, 45 mph, and at "top speed."

The highest constant speed maintainable over both the battery cycle and during up-grade portions of the track was approximately 47 mph, whereas the average speed possible over a battery charge was about 53 mph.

In all cases, at least two of each test were performed; when range values differed by more than 10 percent, a third test was run.

5.3 PROCEDURES FOR DRIVING CYCLE TESTS

Tests were performed in accordance with paragraph 2.8.2 of ERDA Document EHV-TEP, but with the following additions and modifications.

5.3.1 Charge-State

See paragraph 5.2.1.

5.3.2 Battery Temperature

See paragraph 5.2.2.

5.3.3 Charging

See paragraph 5.2.3.

5.3.4 Wind Velocity

See paragraph 5.2.4.

5.3.5 Instrumentation

Procedures identical to paragraph 5.2.5, but with the following additions:

- 5.3.5.1 Strip-Chart recorder was used in conjunction with pre-recorded Strip Charts to display desired speed as well as to record actual speed (see paragraph 5.3.9 for details).
- 5.3.5.2 After each driving cycle, discharge and recharge amp-hours, plus cycle number, were recorded.
- 5.3.6 Vehicle Test Weight
See paragraph 5.2.6.
- 5.3.7 Tire Pressures
See paragraph 5.2.7.
- 5.3.8 Test Start
See paragraph 5.2.8.
- 5.3.9 Driving Cycle Tests Details

J227a, Schedule B and C tests were run with and without regenerative braking until a termination point was reached (paragraph 5.3.10). A pre-recorded Strip Chart was used to display the desired vehicle speed at each instant of time. The driver maintained the vehicle speed as close as possible to the desired speed at each instant in time - but with the following exceptions:

1. Hydraulic brakes were not used to assist regenerative braking in cases where regenerative decelerations fell below profile
2. In cases where the vehicle could not linearly accelerate to the cruise speed within the allotted time, initial over-accelerations were used
3. Small speed errors were purposefully introduced to compensate for driver-caused errors occurring previously in the same cycle

Schedules B and C are displayed and defined in Figure 5.3.1. Data for the "coast" portions was obtained from previously run coast-down tests (Ontario tests, December 1976).

5.3.10 Test Termination

Any of the following three conditions were used to terminate a test:

- (1) Inability to maintain 95 percent of the cruise speed
- (2) Inability to reach cruise speed within 2 seconds of the allotted acceleration time
- (3) Drop of battery voltage below 1.55 volts per cell for more than 4 seconds (in this case, where the battery is a 120 volt unit, the cutoff voltage is 92 volts).

If the cutoff first occurred during the nth cycle acceleration, and 95 percent of nth cycle cruise speed is maintained, the test was terminated upon completion of nth cycle, and range (and cycle number) included the nth cycle. However, if 95 percent of the nth cycle cruise speed could not be maintained, then the range was defined by the conclusion of the (n-1)th cycle.

5.4 PROCEDURES FOR ACCELERATION TESTS

Tests were conducted in accordance with paragraph 2.8.3 of ERDA Document EHV-TEP, but with the following additions and modifications:

5.4.1 Track Conditions

All tests were performed on a straight portion of the track. Tests were run in opposite directions, starting at designated locations. Average grade over any 100-foot segment did not exceed 1 percent.

5.4.2 Wind Velocity

Tests were not run when rms wind velocity exceeded 10 mph (16 km/h).

5.4.3 Instrumentation

The following parameters were recorded as functions of elapsed time:

Speed	(strip chart and magnetic tape)
Battery voltage	(magnetic tape)
Battery current	(magnetic tape)
Battery energy	(magnetic tape)
Battery amp-hours	(amp-hour integrator)
Motor voltage	(magnetic tape)
Motor current	(magnetic tape)
Motor energy	(magnetic tape)

5.4.4 Driving Technique

The Ripp-Electric is a manually shifted vehicle, and normal shifting procedures were used. Accordingly, the accelerator was released to the zero power point prior to clutch depression, and power was only reapplied after the clutch was re-engaged.

5.4.5 Charge State

Tests were run at "full charge," "40 percent discharged," and "80 percent discharged." For each of the three charge states, at least two accelerations were performed in a given direction, and at least two accelerations were performed in the reverse direction.

Battery discharges to the 40 percent and 80 percent point were achieved by constant speed driving at a speed chosen, which may be maintained at the 80 percent discharge point. Using this procedure, 100 percent discharge was defined as the number of amp-hours, where the above constant speed operation is terminated as a result of lowered battery voltage or inability to maintain speed. The 40 percent test will be started when 40 percent of the above amp-hours have been discharged; likewise for the 80 percent test.

900-850

In the case of the Ripp-Electric with EV-106 batteries, battery discharges were performed at 45 mph. Since 45 mph range tests established a charge availability of 141 amp-hours, the 40 percent test was started after a total of 56.6 amp-hours had been discharged via the full charge acceleration tests and the subsequent 45 mph operation. Similarly, the 80 percent test was started after a total discharge of 113.2 amp-hours.

5.5 PROCEDURES FOR COAST-DOWN TESTS

Coast-down tests were run as per paragraph 2.8.6 of ERDA Document EHV-TEP (May 1977), but with the following additions:

5.5.1 Warm-Up

The vehicle was run for 6 miles (3 laps) at maximum speed, prior to the tests, to achieve stable tire and lubricant temperatures.

5.5.2 Track Survey

The coast-down tests were performed only on a straight, surveyed portion of track. The starting point ($t=0$ location) was noted for each test, so that the track survey could be "synchronized" with the data.

5.5.3 Wind Velocity

The test was not run when the rms wind velocity exceeded 3 mph (5 km/h).

5.5.4 Instrumentation

A Nucleus NC-5 speed sensor was used. Speed signals were recorded on both digital magnetic tape and on a strip chart. Appropriate filtering was used to eliminate "hash" from the tachometer generator.

5.5.5 Other Procedures

At least two tests in each of two directions was started ($t=0$) with vehicle at maximum attainable speed (without constraints of safety and track particulars). When coast-down distances exceeded the straight, surveyed section of track, repeat tests were performed with reduced initial speed, such that the vehicle came to rest before reaching the end of the surveyed straight.

Prior to the tests, brake drag was determined for each of the four wheels. This was determined by jacking the car and using a spring scale (at a measured radius) to apply torque. If after applying and releasing brakes, any wheel torque exceeded 1 ft-lb (1.4 Nm), the corresponding brake was adjusted until the torque was within the above limit.

5.6 PROCEDURES FOR WEIGHT SENSITIVITY TESTS

In order to quantitatively assess the impact of added or reduced weight on a given vehicle, "weight sensitivity" tests were devised.

5.6.1 Definitions

Weight sensitivity is defined as:

$$S_x = \frac{\Delta x / x_o}{\Delta W / W_o} , \quad (5.5.1)$$

where

W_o is the nominal gross vehicle weight

ΔW is weight increment

x_o is the value of a particular parameter (x) associated with nominal weight conditions

Δx is the increment in x associated with Δ .

S_x is the weight sensitivity associated with parameter x

As an example, the weight sensitivity associated with battery discharge energy is

$$S_{BE} = \frac{\Delta BE / BE_o}{\Delta W / W_o} ,$$

where BE_o is the energy used (for a particular test) with weight W_o , and $BE_o + \Delta BE$ is the energy used (same test) with weight $W_o + \Delta W$.

5.6.2 Procedures for Constant Speed Tests

5.6.2.1 Warm-Up

The vehicle was run for 6 miles (3 laps) at maximum speed to achieve stable tire and lubricant temperature.

5.6.2.2 Test Conditions

Tests were run at 25, 35, 45 mph and top speed. Each test was initiated after the desired speed was achieved. The test terminated after exactly one or an integral number of laps had been run. When the test was initiated, a switch was thrown which simultaneously activated the energy, charge, and distance recording instruments. At test termination, this switch was turned off. With this approach, a simultaneous measure of energy, charge, and distance was achieved.

Tests were alternately run with and without a known added weight (ΔW). Each test was performed at least twice.

5.6.3 Procedures for Driving Cycle Tests

5.6.3.1 Warm-Up

If driving cycle tests were run within 30 minutes after completion of constant speed tests, no warm-up was required - otherwise a 6 mile warm-up was required.

5.6.3.2 Test Conditions

Schedule B and C tests, with and without regenerative braking, and with and without added weight, were run (8 separate tests).

Each Schedule B test consisted of 10 (or a multiple of 10) consecutive cycles (10 cycles = approximately one lap). Each Schedule C test consisted of 6 (or a multiple of 6) consecutive cycles (6 cycles = approximately one lap).

Energy, charge, and distance recording instruments were enabled just prior to start of the first cycle, and disabled just after end of the last cycle of each test.

Each test was performed once in order to conserve battery energy.

5.6.4 Parameters to be Measured

5.6.4.1 Constant Speed

See Table 5.6.1.

Table 5.6.1. Constant Speed Weight Sensitivity Parameters Measured

	25 mph	35 mph	45 mph	Top Speed
Battery Energy	$S_{BE\ 25}$	$S_{BE\ 35}$	$S_{BE\ 45}$	$S_{BE\ top}$
Motor Energy	$S_{ME\ 25}$	$S_{ME\ 35}$	$S_{ME\ 45}$	$S_{ME\ top}$
AH Disch.	$S_{AH\ 25}$	$S_{AS\ 35}$	$S_{AH\ 45}$	$S_{AH\ top}$

5.6.4.2 Driving Cycles (See Table 5.6.2)

Table 5.6.2. Driving Cycle Weight Sensitivity Parameters Measured

	Sch B No Regen.	Sch B W. Regen.	Sch C No Regen.	Sch C W. Regen.
Batt. Disch. Energy	$S_{BE\ bnr}$	$S_{BE\ br}$	$S_{BE\ cnr}$	$S_{BE\ cr}$
Batt. Rech. Energy	-	$S_{RBE\ br}$	-	$S_{RBE\ cr}$
Energy to Motor	$S_{ME\ bnr}$	$S_{ME\ br}$	$S_{ME\ cnr}$	$S_{ME\ cr}$
Energy from Motor	-	$S_{RME\ br}$	-	$S_{RHE\ cr}$
AH Disch.	$S_{AH\ bnr}$	$S_{AH\ br}$	$S_{AH\ cnr}$	$S_{AH\ cr}$
AH Rech.	-	$S_{RAH\ br}$	-	$S_{RAG\ cr}$

6.1 MEASURED DATA-CONSTANT SPEED TESTS

In accordance with paragraph 5.2, tests were run at 25, 35, 45 mph and top speed. Nine tests were initially run - two at 25 mph, three at 35 mph, two at 45 mph, and two at top speed.

In the course of these tests, an instrumentation error went unnoticed, whereby the motor armature voltage was sensed rather than the total motor voltage. For this reason, a group of short repeat tests (22A through 22E) was performed with the instrumentation properly connected.

The results of all 14 constant speed tests are displayed in Table 6.1.1. Figures 6.1.1. and 6.1.2 display range vs speed and energy consumption vs speed, respectively.

Samples of the constant speed computer printouts are included in Tables 6.1.2 through 6.1.14.

Plots of motor temperature vs time are included in Figures 6.1.3 through 6.1.6.

Records of specific gravities and cell temperatures are included in Appendix I.

In addition to the above tests, all of which were run with EV-106 batteries and 2N6251 control system transistors, one 45-mph test (No. 28) was performed using LEV-115 batteries and Silitron SDT-12302 transistors. Results of this test are displayed in Table 6.1.1A (instrumentation was connected to sense full motor voltage in this test). Test 28 data was not used for Section 7.1 computations.

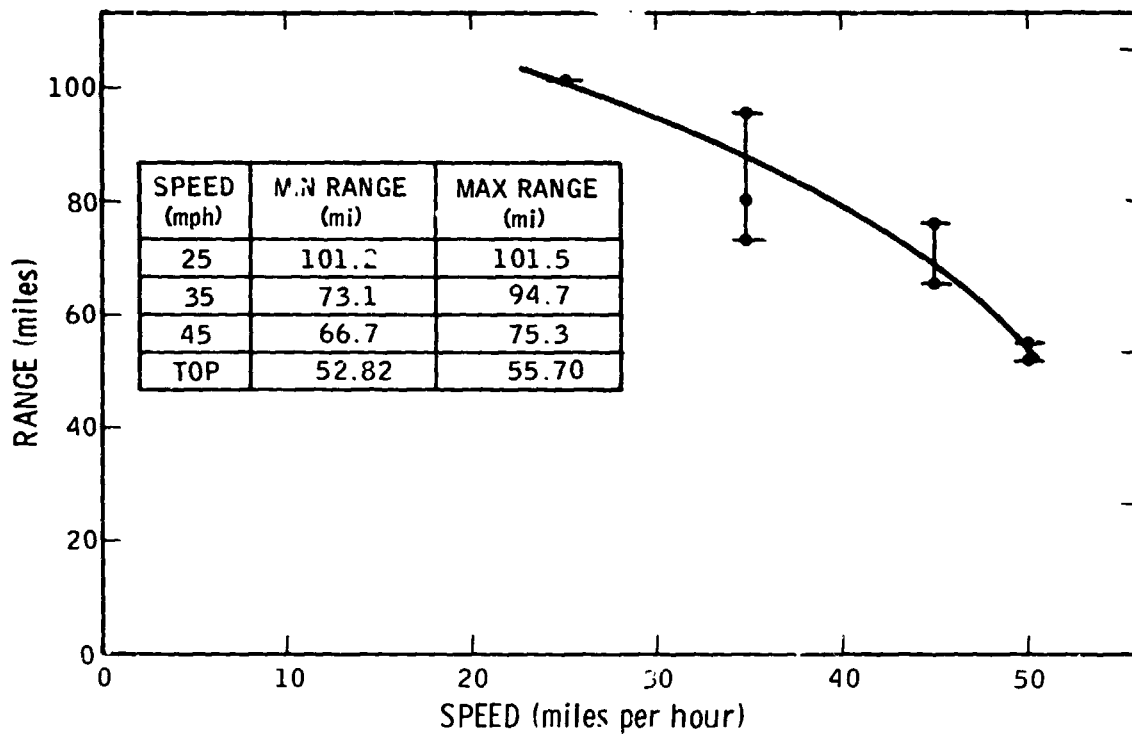


Figure 6.1.1. Plot of Range vs Speed

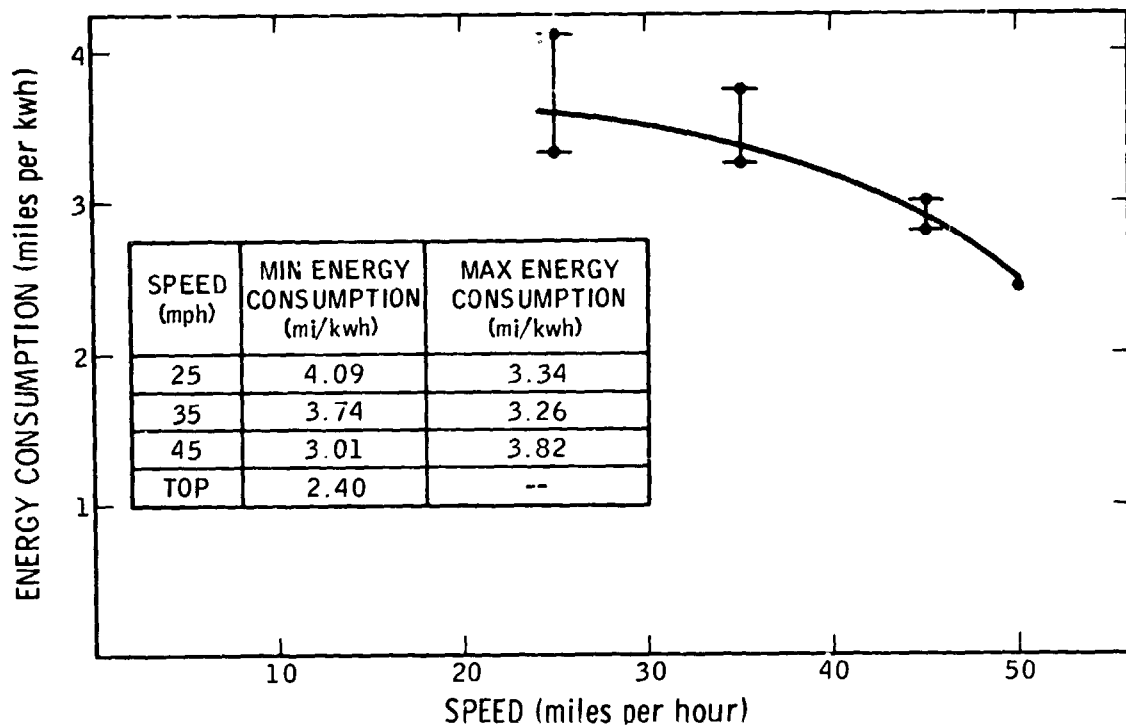


Figure 6.1.2. Plot of Energy Consumption vs Speed

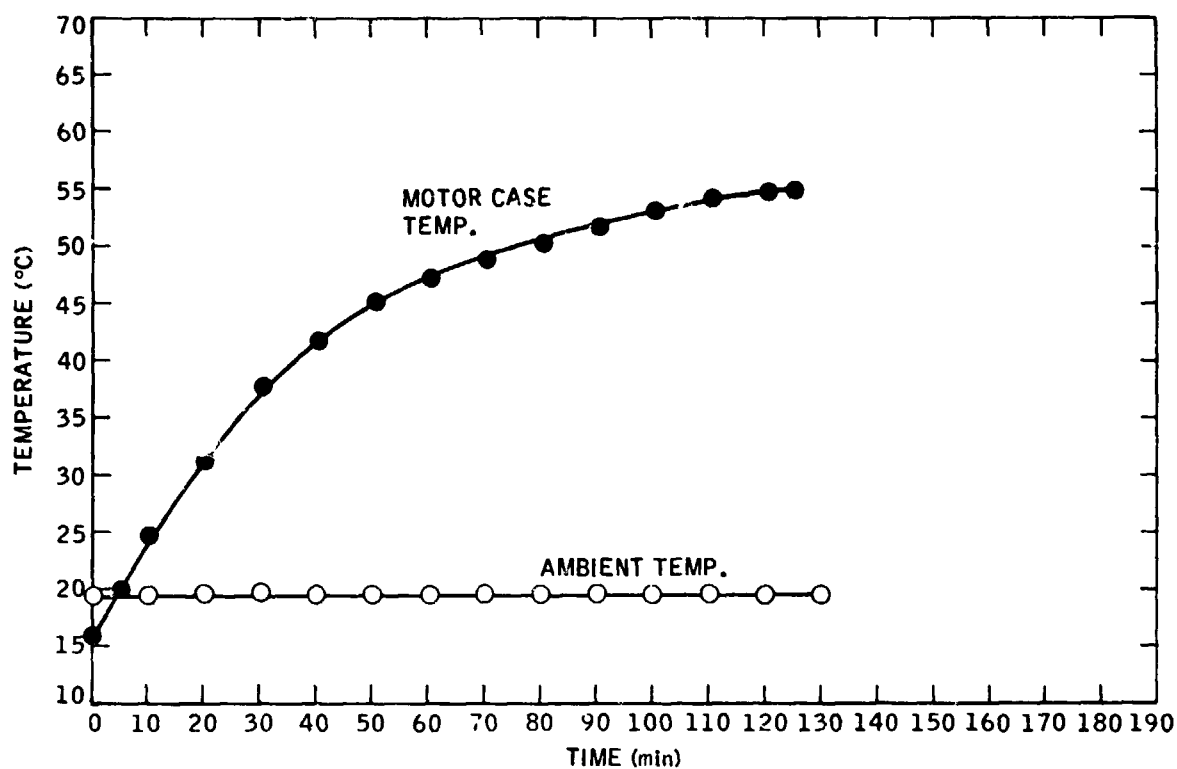


Figure 6.1.3. Motor Case and Ambient Temp. vs Time for Test No. 2
(Const 25 mph). (Data Terminated at 2.1 hr)

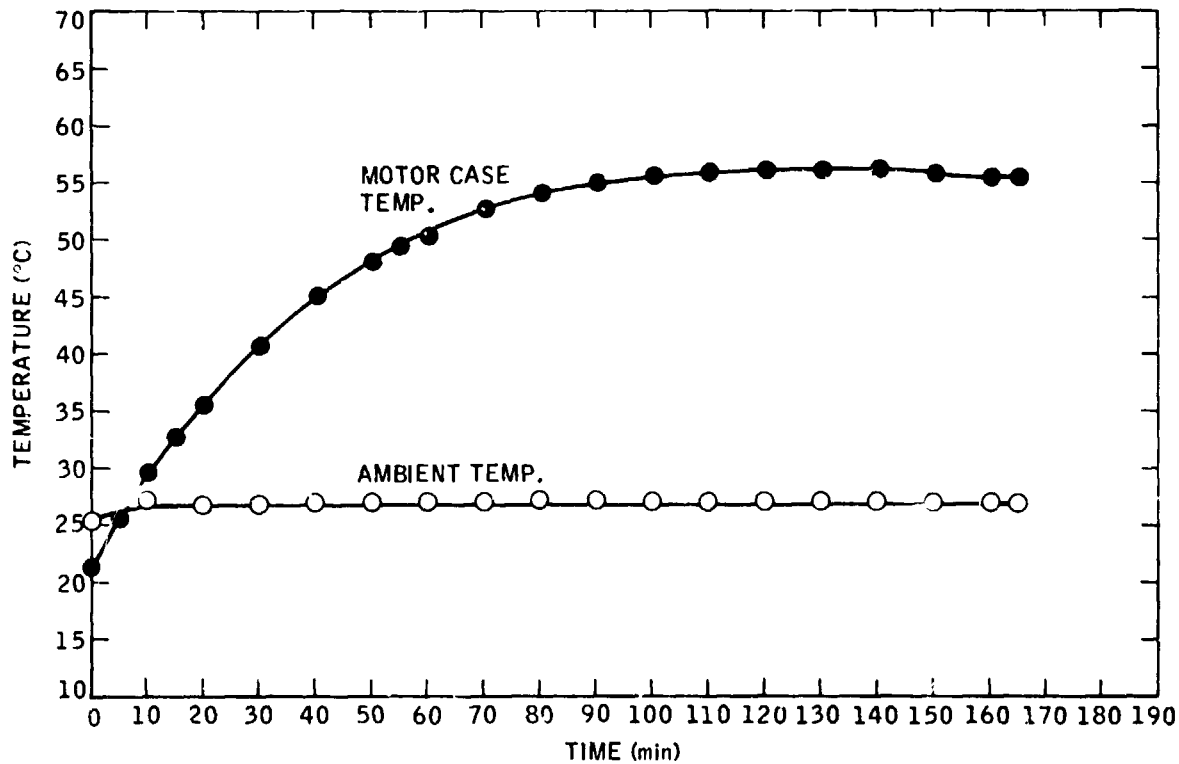


Figure 6.1.4. Motor Case and Ambient Temp. vs Time for Test No. 3
(Const 35 mph).

900-850

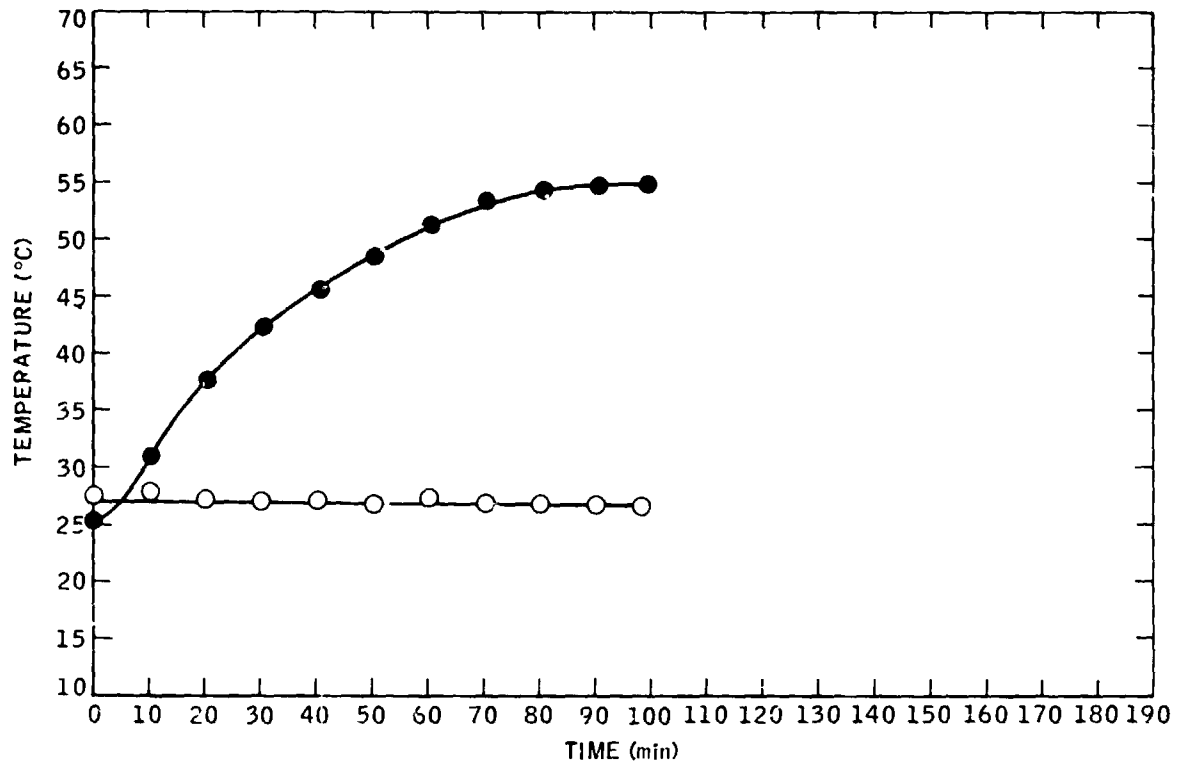


Figure 6.1.5. Motor case and Ambient Temp. vs Time for Test No. 4 (Const 45 mph).

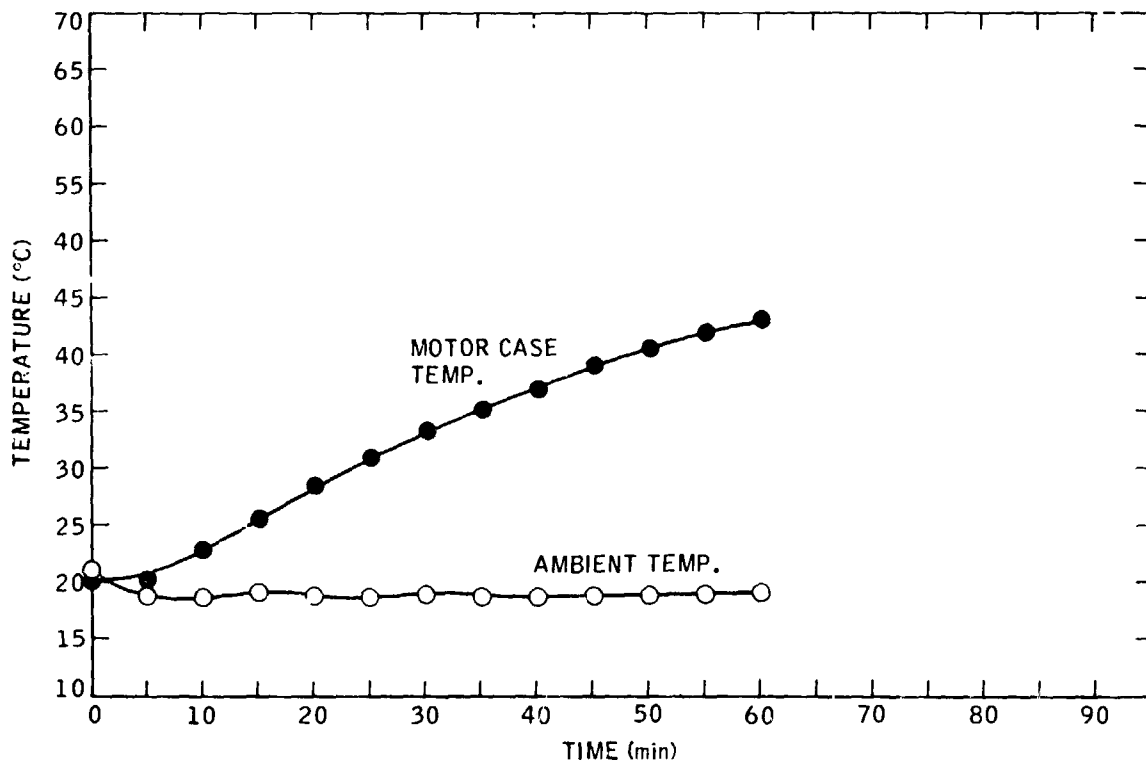


Figure 6.1.6. Motor Case and Ambient Temp. vs Time for Test No. 5 (Top Speed).

Table 6.1.1.1. Constant Speed, Uncorrected Raw Data

Test No.	2	3	4	5	6	7	9	10	11	22A	22B	22C	22D	22E
Date of Test	3/4	3/7	3/8	3/10	3/11	3/14	3/15	3/16	3/17	4/17	4/17	4/17	4/17	4/17
Test Description	25 mph	35 mph	45 mph	"Top"	35 mph	"Top"	25 mph	35 mph	45 mph	25 mph	35 mph	45 mph	"Top"	"Top"
Distance Traveled (mi) ²	101.2	94.75	75.31	52.82	73.05	55.70	101.5	80.87	66.69	4.045	4.049	4.059	4.052	4.050
End of Test Batt. Voltage ³	92	90.3	88.3	91.7	92	91.5	91.0	90.8	91.5	-	-	-	-	-
Gear	2	3	4	4	3	4	2	3	4	2	3	4	4	4
<u>BATTERY DISCHARGE</u>														
Discharge Amp-Hours	159.23	154.49	145.85	126.13	140.94	127.95	162.35	155.36	137.18	5.77	6.19	7.33	8.95	9.07
Discharge KWH ⁴	18.10	18.50	16.90	14.22	16.51	14.53	17.68	18.20	15.94	0.715	0.749	0.865	1.011	1.027
<u>ENERGY TO MOTOR</u>														
KWH to Motor ⁶	15.54	15.98	15.29	13.46	14.90	13.72	16.03	15.73	14.78	0.680	0.727	0.845	1.012	0.991
<u>BATTERY RECHARGE</u>														
Recharge Amp-Hours ⁸	211.43	170.23	167.80	149.28	153.12	147.35	178.48	-	162.91	-	-	-	-	-
Recharge KWH ¹⁰	30.3	19.24	18.22	16.55	-	19.86	20.10	-	-	-	-	-	-	-
<u>CHARGER INPUT</u>														
Line KWH	30.3	25.3	25.0	22.0	22.4	-	24.8	14.6	23.6	-	-	-	-	-
Recharge Time (hr.)	25.5	18.8	19.0	18.8	-	15.1	18.3	18.0	18.7	-	-	-	-	-
<u>WEATHER CONDITIONS</u>														
Ambient Temp (°C)	18-20	25-27	26-28	18-19	12-15	18-20	12-22	17-18	16-19	31-32	31-32	31-32	31-32	29-30
Wind Speed (mph)	5-10	3-7	5-10	10-20	10-20	10-15	0-5	10-20	4-6	5-10	5-10	5-10	5-10	5-10

Table 6.1.1A. Uncorrected Data from Test No. 28
 (45 mph Constant Speed with LEV-115 Batteries
 and SDT-12302 Control Transistors)

Date of Test	4/20/77
Distance Traveled (mi)	68.87
End of Test Voltage	90.1
Gear	4

BATTERY DISCHARGE

Discharge Amp-Hours	141.81
Discharge KWH	15.25

ENERGY TO MOTOR

To motor	15.06

BATTERY RECHARGE

Recharge Amp-Hours	191.23
Recharge KWH	24.51

CHARGER INPUT

Line KWH	28.5 (overcharged)
Recharge Time (hr)	32

WEATHER CONDITIONS

Ambient Temp (°C)	27-30
Wind Speed (mph)	8-12

Table 6.1.2. Samples of Data Printout for Test No. 2 (25 mph)

PAGE NO. 1

42 NR12 25MPH --1

ELAPSED TIME		BATT VOLT UNFIL	BATT VOLT FIL	POT VOLT UNFIL	POT VOLT FIL	BATT APP UNFIL	BATT APP FIL	POT APP UNFIL	POT APP FIL	FIFTH UNFIL	DEG.C	DEG.C	DEG.C	DEG.C	INVTB APP UNFIL	INVTB APP FIL	FIXED CAL-1 BATH
MIN	SEC	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0	5.4	126.9	126.9	0.5	0.5	0.4	0.5	0.0	0.0	0.22	19.35	16.45	-91.03	-91.03	-1.54	-1.50	5.000
0	6.2	126.9	126.9	0.5	0.5	0.5	0.5	0.0	0.0	0.20	19.40	16.50	-91.03	-91.03	-1.47	-1.03	5.000
0	11.4	126.9	126.9	0.5	0.5	0.5	0.5	0.0	0.0	0.20	19.42	16.52	-91.03	-91.03	-1.54	-1.03	5.000
0	11.4	126.9	126.9	0.5	0.5	0.5	0.5	0.0	0.0	0.20	19.44	16.54	-91.03	-91.03	-1.54	-1.03	5.000
0	11.7	126.9	126.9	0.6	0.6	0.0	0.0	0.0	0.0	0.20	19.46	16.54	-91.03	-91.03	-1.54	-1.03	5.000
0	12.0	126.9	126.9	0.5	0.5	0.4	0.5	0.0	0.0	0.22	19.46	16.56	-91.03	-91.03	-1.47	-1.75	5.000
0	123.2	126.9	126.9	0.5	0.5	1.6	2.0	0.0	0.0	0.22	19.43	16.53	-91.03	-91.03	0.00	0.00	5.000
0	125.4	125.9	125.5	0.0	0.0	3.4	3.9	0.1	0.0	0.10	19.51	16.61	-91.03	-91.03	0.00	0.00	5.000
0	129.6	126.0	125.6	0.0	0.0	3.2	3.7	0.0	0.1	0.00	19.53	16.63	-91.03	-91.03	0.00	0.00	5.000
0	132.1	126.3	125.5	0.4	0.0	3.5	3.7	0.0	0.1	0.22	19.53	16.63	-91.03	-91.03	0.00	0.00	5.000
0	135.4	126.2	125.5	0.0	0.0	3.7	3.7	0.1	0.1	0.22	19.53	16.63	-91.03	-91.03	0.00	0.00	5.000
0	139.6	125.7	125.6	0.0	0.0	3.2	3.7	0.0	0.1	0.10	19.53	16.63	-91.03	-91.03	0.00	0.00	5.000
0	141.0	125.4	125.6	0.0	0.0	3.0	3.9	0.0	0.0	0.22	19.57	16.65	-91.03	-91.03	0.00	0.00	5.000
0	144.6	124.7	125.6	0.9	0.0	3.4	3.7	0.0	0.0	0.20	19.57	16.65	-91.03	-91.03	0.00	0.00	5.000
0	147.0	126.3	125.7	0.2	0.3	1.5	2.0	0.0	110.3	0.62	19.59	16.65	-91.03	-91.03	0.00	0.00	5.000
0	151.0	114.1	117.6	31.5	65.9	105.1	142.1	213.3	105.1	10.20	19.62	16.65	-91.03	-91.03	0.00	0.00	5.000
0	154.2	115.0	120.4	55.9	34.9	105.1	142.1	213.3	105.1	13.62	19.62	16.72	-91.03	-91.03	0.00	0.00	5.000
0	157.0	100.9	109.9	103.9	107.1	170.5	172.2	161.0	150.5	20.46	19.59	16.65	-91.03	-91.03	0.00	0.00	5.000
1	0.2	114.1	114.2	111.6	111.9	120.2	120.7	92.0	110.3	23.41	19.59	16.67	-91.03	-91.03	0.00	0.00	5.000
1	3.4	116.4	115.5	112.1	113.1	110.3	110.6	105.3	105.4	25.91	19.57	16.67	-91.03	-91.03	0.00	0.00	5.000
1	6.6	121.6	120.0	80.3	74.0	63.5	60.1	40.1	60.1	25.73	19.53	16.74	-91.03	-91.03	0.00	0.00	5.000
1	9.4	120.0	120.5	80.7	69.2	57.4	59.3	40.1	60.1	25.37	19.46	16.82	-91.03	-91.03	0.00	0.00	5.000
1	12.6	120.3	120.2	40.1	75.9	40.4	63.0	79.4	52.9	24.00	19.44	16.70	-91.03	-91.03	0.00	0.00	5.000
1	15.0	120.1	110.5	101.4	54.1	73.0	70.3	60.6	80.3	25.51	19.42	16.74	-91.03	-91.03	0.00	0.00	5.000
1	18.0	119.5	120.4	89.7	75.7	24.2	46.6	60.0	61.5	25.01	19.35	16.70	-91.03	-91.03	0.00	0.00	5.000
1	22.0	110.9	100.0	94.2	84.5	53.6	65.1	69.0	70.3	23.33	19.25	16.70	-91.03	-91.03	0.00	0.00	5.000
1	25.0	117.0	119.0	90.0	92.1	60.1	70.2	81.3	81.3	25.75	19.22	16.00	-91.03	-91.03	0.00	0.00	5.000
1	27.0	117.2	119.0	95.9	93.1	66.6	70.2	90.3	77.2	25.90	19.29	16.67	-91.03	-91.03	0.00	0.00	5.000
1	31.4	120.1	119.4	105.3	90.3	60.7	64.9	89.0	80.0	25.90	19.25	16.91	-91.03	-91.03	0.00	0.00	5.000
1	34.4	119.9	119.4	97.9	90.0	65.7	64.9	91.3	75.3	25.37	19.16	16.91	-91.03	-91.03	0.00	0.00	5.000
1	37.4	119.5	119.5	90.1	91.0	65.6	64.9	91.3	75.3	25.37	19.16	16.91	-91.03	-91.03	0.00	0.00	5.000
1	40.0	119.6	119.6	101.3	90.0	63.2	59.9	40.4	70.3	25.96	19.09	16.90	-91.03	-91.03	0.00	0.00	5.000
1	43.0	120.0	120.1	96.1	86.3	62.4	57.4	73.9	69.1	25.00	19.07	16.90	-91.03	-91.03	0.00	0.00	5.000
1	46.0	119.0	120.1	114.0	85.9	70.5	60.0	64.3	64.3	25.30	19.05	17.02	-91.03	-91.03	0.00	0.00	5.000
1	49.0	118.3	120.7	117.5	90.0	76.0	58.4	57.4	64.3	25.10	19.03	17.04	-91.03	-91.03	0.00	0.00	5.000
1	53.0	119.3	120.7	89.9	75.5	26.2	50.3	84.9	64.3	25.34	19.05	17.05	-91.03	-91.03	0.00	0.00	5.000
1	56.2	121.3	120.0	91.7	75.0	30.0	50.3	94.0	65.3	24.74	19.00	17.05	-91.03	-91.03	0.00	0.00	5.000

E V M T		RESULTS 1										18-MM-777										PAGE NO. 22										42 NR12 25MPH --2																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																
ELAPSED TIME		BATT VOLT UNFIL		BATT VOLT FIL		POT VOLT UNFIL		POT VOLT FIL		BATT APP UNFIL		BATT APP FIL		POT APP UNFIL		POT APP FIL		FIFTH UNFIL		FIFTH APP		DEG.C		DEG.C		DEG.C		DEG.C		INVTB APP UNFIL		INVTB APP FIL		FIXED CAL-1 BATH																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																														
MIN	SEC	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																											
44	33.0	120.1	119.9	32.7	56.0	34.5	25.0	20.5	39.5	25.66	19.27	51.70	-91.03	0.00	0.00	5.000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 6.1.3. Samples of Data Printout for Test No. 3 (35 mph)

RESULTS										PAGE NO. 1		03 SEP88 3:47		1		
ELAPSED TIME	BATT VOLT UNFIL	BATT VOLT FIL	U-H VOLT DISCH	U-H VOLT FIL	BATT APP UNFIL	BATT APP FIL	U-H APP RECHG	H ⁺ APP	FIFTH INEEL FWH	NEG.C APP	NEG.C MOTOR	U-H TO MOTOR	U-H FROM MOTOR	REGEN APP FIL	REGEN APP UNFIL	FIXED CALI-16
MIN SEC	1	2	3	4	5	6	7	3	9	10	11	12	13	14	15	16
0 0.2	126.0	126.0														5.00E
0 0.0	126.0	126.0	0.9	0.3	3.4	3.2	0.0	0.0	0.14	25.58	21.32	341.3	341.3	0.00	0.00	5.00E
0 0.0	126.0	126.0	0.9	0.3	3.4	3.2	0.0	0.0	0.16	25.70	21.32	341.3	341.3	0.00	0.00	5.00E
0 7.2	126.0	126.0	0.0	0.4	3.4	3.2	0.0	0.0	0.16	25.70	21.61	341.3	341.3	0.00	0.00	5.00E
3 10.2	127.0	126.0	0.0	0.4	3.2	3.2	0.0	0.0	0.16	25.73	21.63	341.3	341.3	0.00	0.00	5.00E
0 13.0	126.0	126.0	0.7	0.4	3.4	3.2	0.0	0.0	0.17	25.75	21.61	341.3	341.3	0.00	0.00	5.00E
0 11.0	127.0	127.0	0.0	0.4	3.1	3.2	0.0	0.0	0.16	25.76	21.63	341.3	341.3	0.00	0.00	5.00E
0 21.2	126.9	127.0	0.9	0.4	3.4	3.3	0.0	0.0	0.17	25.82	21.69	341.3	341.3	0.00	0.00	5.00E
0 24.4	126.9	127.0	1.0	0.4	3.2	3.2	0.0	0.0	0.16	25.75	21.63	341.3	341.3	0.00	0.00	5.00E
0 27.0	127.0	127.0	0.9	0.4	3.4	3.3	0.0	0.0	0.17	25.82	21.69	341.3	341.3	0.00	0.00	5.00E
0 30.0	127.1	127.1	0.9	0.4	3.4	3.3	0.0	0.0	0.11	25.90	21.74	341.3	341.3	0.00	0.00	5.00E
0 33.0	127.1	127.0	0.8	0.4	3.4	3.3	0.0	0.0	0.16	25.66	21.74	341.3	341.3	0.00	0.00	5.00E
0 36.2	127.0	127.0	1.2	0.5	3.3	3.3	0.0	0.0	0.17	25.91	21.76	341.3	341.3	0.00	0.00	5.00E
0 39.0	126.9	127.0	0.9	0.4	3.4	3.3	0.0	0.0	0.17	25.91	21.76	341.3	341.3	0.00	0.00	5.00E
0 42.4	127.0	127.0	0.9	0.4	3.4	3.3	0.0	0.0	0.17	25.93	21.76	341.3	341.3	0.00	0.00	5.00E
0 45.4	127.1	127.0	0.0	0.4	3.5	3.3	0.0	0.0	0.20	25.97	21.91	341.3	341.3	0.00	0.00	5.00E
0 48.6	126.3	119.4	43.9	60.3	133.2	140.4	97.9	106.1	5.82	25.93	21.79	341.3	341.3	0.00	0.00	5.00E
0 51.6	115.9	115.9	109.3	173.1	173.3	180.9	133.3	135.3	13.98	25.90	21.83	341.3	341.3	0.00	0.00	5.00E
0 54.0	110.4	110.4	223.5	187.2	192.0	189.0	161.0	159.1	29.14	26.07	21.98	341.3	341.3	0.00	0.00	5.00E
0 57.0	114.8	114.1	238.9	111.6	135.2	138.9	74.5	32.1	22.86	26.60	21.83	341.3	341.3	0.00	0.00	5.00E
0 1.0	115.4	115.4	249.4	112.9	116.3	114.9	122.5	132.0	24.92	26.00	21.83	341.3	341.3	0.00	0.00	5.00E
0 4.0	109.3	109.3	212.5	104.4	105.4	108.4	21.4	19.1	30.50	26.04	21.91	341.3	341.3	0.00	0.00	5.00E
1 7.0	112.1	112.2	232.1	185.0	163.4	162.9	155.0	153.3	30.50	26.04	21.91	341.3	341.3	0.00	0.00	5.00E
1 10.0	113.7	113.8	237.9	110.9	144.8	143.7	156.3	137.1	32.72	26.02	21.98	341.3	341.3	0.00	0.00	5.00E
1 13.2	114.9	114.8	243.2	112.8	134.1	134.1	145.3	127.0	33.83	26.06	22.00	341.3	341.3	0.00	0.00	5.00E
1 16.4	117.9	117.9	250.4	115.1	137.9	137.9	149.8	129.4	35.03	26.10	22.06	341.3	341.3	0.00	0.00	5.00E
1 19.6	119.5	119.2	258.4	97.1	63.7	92.8	54.5	34.4	34.22	26.18	22.16	341.3	341.3	0.00	0.00	5.00E
1 22.0	110.4	110.1	221.6	97.0	92.5	92.9	126.0	101.1	33.99	26.11	22.13	341.3	341.3	0.00	0.00	5.00E
1 25.0	119.1	118.2	231.9	96.2	98.6	93.3	125.4	101.1	34.55	26.11	22.20	341.3	341.3	0.00	0.00	5.00E
1 28.0	110.8	110.6	224.4	96.2	101.3	95.9	61.6	95.6	35.32	26.18	22.20	341.3	341.3	0.00	0.00	5.00E
1 31.2	122.1	120.3	200.5	03.1	70.2	64.3	105.3	70.3	35.03	26.20	22.27	341.3	341.3	0.00	0.00	5.00E
1 34.2	122.0	123.6	215.0	02.1	62.2	64.2	08.3	79.0	34.27	26.19	22.33	341.3	341.3	0.00	0.00	5.00E
1 37.4	116.0	115.5	230.3	112.4	140.6	139.5	05.1	126.0	33.64	26.15	22.35	341.3	341.3	0.00	0.00	5.00E
1 40.6	112.7	112.4	246.5	113.7	108.5	109.8	04.4	91.4	34.95	26.19	22.35	341.3	341.3	0.00	0.00	5.00E
1 43.6	111.0	110.3	241.8	92.1	101.5	101.4	02.4	91.2	34.29	26.20	22.44	311.3	341.3	0.00	0.00	5.00E
1 46.6	112.0	111.4	215.5	91.9	71.3	93.1	127.1	97.7	33.57	26.15	22.49	341.3	341.3	0.00	0.00	5.00E
1 49.6	117.0	116.5	227.3	98.4	69.0	93.0	133.4	107.4	33.43	26.22	22.49	341.3	341.3	0.00	0.00	5.00E
1 52.6	119.0	118.7	246.5	113.7	135.1	135.1	101.1	97.4	34.27	26.20	22.50	341.3	341.3	0.00	0.00	5.00E
1 55.0	116.9	116.8	220.4	09.1	97.0	103.1	142.1	110.9	35.20	26.20	22.50	341.3	341.3	0.00	0.00	5.00E
1 58.0	121.3	119.6	168.6	06.5	93.5	91.8	123.9	92.7	34.71	26.26	22.62	341.3	341.3	0.00	0.00	5.00E
2 0.0	116.5	116.3	230.5	113.3	121.3	130.3	143.3	124.3	35.50	26.18	22.62	341.3	341.3	0.00	0.00	5.00E
2 3.0	116.4	116.4	246.5	113.7	135.1	135.1	124.4	124.4	35.50	26.18	22.62	341.3	341.3	0.00	0.00	5.00E
2 6.0	116.7	116.7	245.2	124.1	121.3	129.8	139.2	124.1	37.85	26.10	22.80	341.3	341.3	0.00	0.00	5.00E

E V M T F RESULTS 1				67-002-77				PAGE NO. 22				63 SEP 14 3/7				2	
ELAPSED TIME		BATT VOLT UNFIL	BATT VOLT FIL	U-M H-1000 SCN	BATT VOLT UNFIL	BATT VOLT FIL	U-M H-1000 RECON	FIFTH FIFTH MPH	DEC.C	DEC.C	U-M H-1000 MOTOR	U-M H-1000 MOTOR	RECON RECON FIL	RECON RECON UNFIL	FIFTH FIFTH GARTH		
MIN	SEC	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
40	115.8	187.7	188.3	184.9	67.7	54.8	45.5	39.1	31.3	34.56	24.99	54.47	341.3	341.3	0.00	0.00	
40	117.2	188.3	188.3	184.2	67.7	31.9	45.5	78.6	57.4	34.56	25.06	54.44	341.3	341.3	0.00	0.00	
40	121.2	188.0	188.3	173.8	67.5	61.0	45.5	53.7	54.9	33.64	24.99	54.44	341.3	341.3	0.00	0.00	
40	125.2	188.0	188.3	173.8	67.5	38.2	54.9	57.4	57.4	34.56	25.06	54.44	341.3	341.3	0.00	0.00	
40	127.6	188.2	187.5	201.5	72.4	49.7	52.0	67.4	61.5	34.00	25.03	54.44	341.3	341.3	0.00	0.00	
40	130.8	187.4	187.4	175.3	72.4	61.7	49.9	35.8	51.7	34.26	24.99	54.51	341.3	341.3	0.00	0.00	
40	133.0	188.7	188.5	187.0	66.8	40.1	43.4	36.5	34.3	34.30	24.95	54.51	341.3	341.3	0.00	0.00	
40	137.2	188.0	188.3	187.5	67.5	57.7	45.5	57.4	57.4	34.56	24.99	54.51	341.3	341.3	0.00	0.00	
40	140.2	189.6	188.5	181.5	65.7	51.7	43.3	64.2	56.3	33.77	24.99	54.47	341.3	341.3	0.00	0.00	
40	143.4	188.0	188.0	189.9	69.9	36.6	58.7	77.6	61.4	33.93	24.99	54.44	341.3	341.3	0.00	0.00	
40	146.2	187.9	188.9	183.5	74.7	43.2	57.5	59.9	64.2	33.86	25.01	54.47	341.3	341.3	0.00	0.00	
40	148.6	186.4	188.0	187.5	75.8	57.5	57.5	57.5	57.5	34.56	25.06	54.44	341.3	341.3	0.00	0.00	
40	152.6	186.2	185.5	183.5	81.6	59.3	62.9	185.4	77.9	34.14	25.06	54.47	341.3	341.3	0.00	0.00	
40	155.0	188.9	188.0	209.9	98.8	105.1	185.5	114.1	91.5	34.49	24.99	54.55	341.3	341.3	0.00	0.00	
40	158.0	188.6	188.6	209.9	96.1	101.1	188.4	108.0	96.9	35.47	24.97	54.55	341.3	341.3	0.00	0.00	
40	161.0	188.0	188.3	201.5	97.9	97.9	188.0	108.0	97.9	35.47	24.99	54.51	341.3	341.3	0.00	0.00	
40	165.2	188.4	188.6	197.1	65.7	79.9	71.8	92.4	70.2	35.51	24.97	54.78	341.3	341.3	0.00	0.00	
40	168.4	181.2	181.7	201.2	91.7	87.4	82.5	91.0	86.7	35.41	24.97	54.74	341.3	341.3	0.00	0.00	
40	171.4	184.8	184.1	172.5	71.3	44.9	48.4	71.8	61.3	35.48	24.94	54.81	341.3	341.3	0.00	0.00	
40	174.6	184.8	184.1	197.8	81.5	78.1	68.6	71.8	71.8	35.48	24.99	54.81	341.3	341.3	0.00	0.00	
40	177.2	183.3	182.0	200.0	85.2	69.5	77.5	90.4	70.7	35.79	24.94	54.96	341.3	341.3	0.00	0.00	
40	181.0	181.1	181.2	194.6	90.4	83.2	81.0	90.4	84.2	35.29	24.97	55.00	341.3	341.3	0.00	0.00	
40	184.8	188.3	188.0	203.6	96.9	75.8	71.8	89.2	70.5	35.37	24.97	55.15	341.3	341.3	0.00	0.00	
40	187.2	181.1	181.6	196.6	61.7	61.7	61.7	61.7	61.7	35.82	24.94	55.19	341.3	341.3	0.00	0.00	
40	190.4	181.2	181.9	211.9	83.3	68.4	69.1	95.5	75.4	35.25	24.95	55.11	341.3	341.3	0.00	0.00	
40	193.6	186.5	186.6	206.9	86.3	82.2	76.2	82.3	81.8	35.42	24.94	55.23	341.3	341.3	0.00	0.00	
40	196.4	186.3	186.6	193.5	85.9	81.6	82.8	81.6	81.6	35.42	24.94	55.23	341.3	341.3	0.00	0.00	
40	199.2	186.3	186.6	193.5	81.2	81.2	81.2	81.2	81.2	34.89	24.92	55.38	341.3	341.3	0.00	0.00	
40	202.0	186.3	186.6	193.5	81.2	81.2	81.2	81.2	81.2	34.89	24.92	55.38	341.3	341.3	0.00	0.00	
40	204.8	186.3	186.6	193.5	81.2	81.2	81.2	81.2	81.2	34.89	24.92	55.38	341.3	341.3	0.00	0.00	
40	207.6	186.3	186.6	193.5	81.2	81.2	81.2	81.2	81.2	34.89	24.92	55.38	341.3	341.3	0.00	0.00	
40	210.4	186.3	186.6	193.5	81.2	81.2	81.2	81.2	81.2	34.89	24.92	55.38	341.3	341.3	0.00	0.00	
40	213.2	186.3	186.6	193.5	81.2	81.2	81.2	81.2	81.2	34.89	24.92	55.38	341.3	341.3	0.00	0.00	
40	216.0	186.3	186.6	193.5	81.2	81.2	81.2	81.2	81.2	34.89	24.92	55.38	341.3	341.3	0.00	0.00	
40	218.8	186.3	186.6	193.5	81.2	81.2	81.2	81.2	81.2	34.89	24.92	55.38	341.3	341.3	0.00	0.00	
40	221.6	186.3	186.6	193.5	81.2	81.2	81.2	81.2	81.2	34.89	24.92	55.38	341.3	341.3	0.00	0.00	
40	224.4	186.3	186.6	193.5	81.2	81.2	81.2	81.2	81.2	34.89	24.92	55.38	341.3	341.3	0.00	0.00	
40	227.2	186.3	186.6	193.5	81.2	81.2	81.2	81.2	81.2	34.89	24.92	55.38	341.3	341.3	0.00	0.00	
40	230.0	186.3	186.6	193.5	81.2	81.2	81.2	81.2	81.2	34.89	24.92	55.38	341.3	341.3	0.00	0.00	
40	232.8	186.3	186.6	193.5	81.2	81.2	81.2	81.2	81.2	34.89	24.92	55.38	341.3	341.3	0.00	0.00	
40	235.6	186.3	186.6	193.5	81.2	81.2	81.2	81.2	81.2	34.89	24.92	55.38	341.3	341.3	0.00	0.00	
40	238.4	186.3	186.6	193.5	81.2	81.2	81.2	81.2	81.2	34.89	24.92	55.38	341.3	341.3	0.00	0.00	
40	241.2	186.3	186.6	193.5	81.2	81.2	81.2	81.2	81.2	34.89	24.92	55.38	341.3	341.3	0.00	0.00	
40	244.0	186.3	186.6	193.5	81.2	81.2	81.2	81.2	81.2	34.89	24.92	55.38	341.3	341.3	0.00	0.00	
40	246.8	186.3	186.6	193.5	81.2	81.2	81.2	81.2	81.2	34.89	24.92	55.38	341.3	341.3	0.00	0.00	
40	249.6	186.3	186.6	193.5	81.2	81.2	81.2	81.2	81.2	34.89	24.92	55.38	341.3	341.3	0.00	0.00	
40	252.4	186.3	186.6	193.5	81.2	81.2	81.2	81.2	81.2	34.89	24.92	55.38	341.3	341.3	0.00	0.00	
40	255.2	186.3	186.6	193.5	81.2	81.2	81.2	81.2	81.2	34.89	24.92	55.38	341.3	341.3	0.00	0.00	
40	258.0	186.3	186.6	193.5	81.2	81.2	81.2	81.2	81.2	34.89	24.92	55.38	341.3	341.3	0.00	0.00	
40	260.8	186.3	186.6	193.5	81.2	81.2	81.2	81.2	81.2	34.89	24.92	55.38	341.3	341.3	0.00	0.00	
40	263.6	186.3	186.6	193.5	81.2	81.2	81.2	81.2	81.2	34.89	24.92	55.38	341.3	341.3	0.00	0.00	
40	266.4	186.3	186.6	193.5	81.2	81.2	81.2	81.2	81.2	34.89	24.92	55.38	341.3	341.3	0.00	0.00	
40	269.2	186.3	186.6	193.5	81.2	81.2	81.2	81.2	81.2	34.89	24.92	55.38	341.3	341.3	0.00	0.00	
40	272.0	186.3	186.6	193.5	81.2	81.2	81.2	81.2	81.2	34.89	24.92	55.38	341.3	341.3	0.00	0.00	
40	274.8	186.3	186.6	193.5	81.2	81.2	81.2	81.2	81.2	34.89	24.92	55.38	341.3	341.3	0.00	0.00	
40	277.6	186.3	186.6	193.5	81.2	81.2	81.2	81.2	81.2	34.89	24.92	55.38	341.3	341.3	0.00	0.00	
40	280.4	186.3	186.6	193.5	81.2	81.2	81.2	81.2	81.2	34.89	24.92	55.38	341.3	341.3	0.00	0.00	
40	283.2	186.3	186.6	193.5	81.2	81.2	81.2	81.2	81.2	34.89	24.92	55.38	341.3	341.3	0.00	0.00	
40	286.0	186.3	186.6	193.5	81.2	81.2	81.2	81.2	81.2	34.89	24.92	55.38	341.3	341.3	0.00	0.00	
40	288.8	186.3	186.6	193.5	81.2	81.2	81.2	81.2	81.2	34.89	24.92	55.38	341.3	341.3	0.00	0.00	
40	291.6	186.3	186.6	193.5	81.2	81.2	81.2	81.2	81.2	34.89	24.92	55.38	341.3	341.3	0.00	0.00	
40	294.4	186.3	186.6	193.5	81.2	81.2	81.2	81.2	81.2	34.89	24.92	55.38	341.3	341.3	0.00	0.00	
40	297.2	186.3	186.6	193.5	81.2	81.2	81.2	81.2	81.2	34.89	24.92	55.38	341.3	341.3	0.00	0.00	
40	300.0	186.3	186.6	193.5	81.2	81.2	81.2	81.2	81.2	34.89	24.92	55.38	341.3	341.3	0.00	0.00	
40	302.8	186.3	186.6	193.5	81.2	81.2	81.2	81.2	81.2	34.89	24.92	55.38	341.3	341.3	0.00	0.00	
40	305.6	186.3	186.6	193.5	81.2	81.2	81.2	81.2	81.2	34.89	24.92	55.38	341.3	341.3	0.00	0.00	
40	308.4	186.3	186.6	193.5	81.2	81.2	81.2	81.2	81.2	34.89	24.92	55.38	341.3	341.3	0.00	0.00	
40	311.2	186.3	186.6	193.5	81.2	81.2	81.2	81.2	81.2	34.89	24.92	55.38	341.3	341.3	0.00	0.00	
40	314.0	186.3	186.6	193.5	81.2	81.2	81.2	81.2	81.2	34.89	24.92	55.38	341.3	341.3	0.00	0.00	
40	316.8	186.3	186.6	193.5	81.2	81.2	81.2	81.2	81.2	34.89	24.92	55.38	341.3	341.3	0.00	0.00	
40	319.6	186.3	186.6	193.5	81.2	81.2	81.2	81.2	81.2	34.89	24.92	55.38	341.3	341.3	0.00	0.00	
40	322.4	186.3	186.6	193.5	81.2	81.2	81.2	81.2	81.2	34.89	24.92	55.38	341.3	341.3	0.00	0.00	
40	325.2	186.3	186.6	193.5	81.2	81.2	81.2	81.2	81.2	34.89	24.92	55.38	341.3	341.3	0.00	0.00	
40	328.0	186.3	186.6	1													

Table 6.1.4. Samples of Data Printout for Test No. 4 (45 mph)

E V H T RESULTS 1 15-100-77 PAGE NO. 2 04 AR12 45MPH																
ELAPSED TIME	BATT VOLT UNFIL	BATT VOLT FIL	POT VOLT UNFIL	POT VOLT FIL	BATT AMP UNFIL	BATT AMP FIL	POT AMP UNFIL	POT AMP FIL	FIFTH LABEL RPM	REG.C AMP/T	REG.C MOTOR	REG.C FRONT BATT	REG.C REAR BATT	INVTD APP FIL	INVTD APP UNFIL	FIXED CALI-NORTH
MIN SEC	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
2 111.0	117.9	118.9	102.0	98.3	99.6	107.9	106.4	117.4	43.96	27.19	25.69	-91.03	-91.03	0.00	0.00	5.000
2 114.0	115.9	115.4	111.3	111.9	105.5	103.2	159.2	157.9	44.14	27.19	25.73	-91.03	-91.03	0.00	0.00	5.000
2 117.0	115.6	115.7	111.2	112.2	100.0	107.9	140.7	145.3	45.07	27.24	25.73	-91.03	-91.03	0.00	0.00	5.000
2 120.0	115.6	115.6	111.2	112.2	99.3	102.4	102.9	101.4	44.93	27.19	25.73	-91.03	-91.03	0.00	0.00	5.000
2 122.0	121.7	120.9	104.9	97.4	78.1	81.0	63.9	96.6	45.00	27.20	25.91	-91.03	-91.03	0.00	0.00	5.000
2 126.0	120.4	120.0	104.9	95.2	120.9	121.6	145.1	146.6	45.40	27.15	25.82	-91.03	-91.03	0.00	0.00	5.000
2 129.0	116.6	116.4	111.3	108.3	104.2	96.7	97.3	96.7	46.76	27.17	25.77	-91.03	-91.03	0.00	0.00	5.000
2 132.0	124.4	124.3	111.3	112.7	93.4	94.0	94.0	94.0	46.34	27.17	25.75	-91.03	-91.03	0.00	0.00	5.000
2 135.0	126.1	124.3	104.9	97.4	15.3	30.0	25.1	45.9	44.30	27.22	25.84	-91.03	-91.03	0.00	0.00	5.000
2 138.0	125.6	123.9	112.7	102.4	20.9	43.0	62.7	62.0	44.07	27.19	25.82	-91.03	-91.03	0.00	0.00	5.000
2 141.0	123.4	122.5	104.4	96.2	32.9	64.0	93.3	84.6	43.20	27.15	25.80	-91.03	-91.03	0.00	0.00	5.000
2 144.0	118.0	118.0	100.1	100.3	96.3	117.3	131.0	131.0	43.20	27.19	25.91	-91.03	-91.03	0.00	0.00	5.000
2 147.0	119.1	118.4	103.1	103.1	104.9	122.0	134.5	126.1	43.21	27.19	25.93	-91.03	-91.03	0.00	0.00	5.000
2 150.0	119.2	118.1	110.7	103.6	119.0	124.0	131.4	116.3	47.04	27.15	25.97	-91.03	-91.03	0.00	0.00	5.000
2 153.0	122.2	122.6	107.1	106.0	42.4	29.0	23.9	46.3	45.03	27.15	26.00	-91.03	-91.03	0.00	0.00	5.000
2 156.0	122.4	124.6	107.1	106.0	14.9	25.3	40.6	46.0	44.90	27.31	26.00	-91.03	-91.03	0.00	0.00	5.000
2 159.0	125.1	124.1	106.9	106.2	19.3	39.6	41.2	35.0	44.33	27.15	26.00	-91.03	-91.03	0.00	0.00	5.000
2 162.0	122.6	123.3	111.0	102.5	104.1	97.6	127.3	106.6	43.60	27.17	26.00	-91.03	-91.03	0.00	0.00	5.000
2 165.0	119.3	120.2	102.0	93.2	96.6	94.1	108.6	105.3	45.23	27.22	26.11	-91.03	-91.03	0.00	0.00	5.000
2 168.0	122.2	122.2	102.0	93.2	96.6	94.1	108.6	105.3	45.23	27.22	26.11	-91.03	-91.03	0.00	0.00	5.000
2 171.0	122.2	122.2	102.0	93.2	96.6	94.1	108.6	105.3	45.23	27.22	26.11	-91.03	-91.03	0.00	0.00	5.000
2 174.0	122.2	122.2	102.0	93.2	96.6	94.1	108.6	105.3	45.23	27.22	26.11	-91.03	-91.03	0.00	0.00	5.000
2 177.0	122.2	122.2	102.0	93.2	96.6	94.1	108.6	105.3	45.23	27.22	26.11	-91.03	-91.03	0.00	0.00	5.000
2 180.0	122.2	122.2	102.0	93.2	96.6	94.1	108.6	105.3	45.23	27.22	26.11	-91.03	-91.03	0.00	0.00	5.000
2 183.0	122.2	122.2	102.0	93.2	96.6	94.1	108.6	105.3	45.23	27.22	26.11	-91.03	-91.03	0.00	0.00	5.000
2 186.0	122.2	122.2	102.0	93.2	96.6	94.1	108.6	105.3	45.23	27.22	26.11	-91.03	-91.03	0.00	0.00	5.000
2 189.0	122.2	122.2	102.0	93.2	96.6	94.1	108.6	105.3	45.23	27.22	26.11	-91.03	-91.03	0.00	0.00	5.000
2 192.0	122.2	122.2	102.0	93.2	96.6	94.1	108.6	105.3	45.23	27.22	26.11	-91.03	-91.03	0.00	0.00	5.000
2 195.0	122.2	122.2	102.0	93.2	96.6	94.1	108.6	105.3	45.23	27.22	26.11	-91.03	-91.03	0.00	0.00	5.000
2 198.0	122.2	122.2	102.0	93.2	96.6	94.1	108.6	105.3	45.23	27.22	26.11	-91.03	-91.03	0.00	0.00	5.000
2 201.0	122.2	122.2	102.0	93.2	96.6	94.1	108.6	105.3	45.23	27.22	26.11	-91.03	-91.03	0.00	0.00	5.000
2 204.0	122.2	122.2	102.0	93.2	96.6	94.1	108.6	105.3	45.23	27.22	26.11	-91.03	-91.03	0.00	0.00	5.000
2 207.0	122.2	122.2	102.0	93.2	96.6	94.1	108.6	105.3	45.23	27.22	26.11	-91.03	-91.03	0.00	0.00	5.000
2 210.0	122.2	122.2	102.0	93.2	96.6	94.1	108.6	105.3	45.23	27.22	26.11	-91.03	-91.03	0.00	0.00	5.000
2 213.0	122.2	122.2	102.0	93.2	96.6	94.1	108.6	105.3	45.23	27.22	26.11	-91.03	-91.03	0.00	0.00	5.000
2 216.0	122.2	122.2	102.0	93.2	96.6	94.1	108.6	105.3	45.23	27.22	26.11	-91.03	-91.03	0.00	0.00	5.000
2 219.0	122.2	122.2	102.0	93.2	96.6	94.1	108.6	105.3	45.23	27.22	26.11	-91.03	-91.03	0.00	0.00	5.000
2 222.0	122.2	122.2	102.0	93.2	96.6	94.1	108.6	105.3	45.23	27.22	26.11	-91.03	-91.03	0.00	0.00	5.000
2 225.0	122.2	122.2	102.0	93.2	96.6	94.1	108.6	105.3	45.23	27.22	26.11	-91.03	-91.03	0.00	0.00	5.000
2 228.0	122.2	122.2	102.0	93.2	96.6	94.1	108.6	105.3	45.23	27.22	26.11	-91.03	-91.03	0.00	0.00	5.000
2 231.0	122.2	122.2	102.0	93.2	96.6	94.1	108.6	105.3	45.23	27.22	26.11	-91.03	-91.03	0.00	0.00	5.000
2 234.0	122.2	122.2	102.0	93.2	96.6	94.1	108.6	105.3	45.23	27.22	26.11	-91.03	-91.03	0.00	0.00	5.000
2 237.0	122.2	122.2	102.0	93.2	96.6	94.1	108.6	105.3	45.23	27.22	26.11	-91.03	-91.03	0.00	0.00	5.000
2 240.0	122.2	122.2	102.0	93.2	96.6	94.1	108.6	105.3	45.23	27.22	26.11	-91.03	-91.03	0.00	0.00	5.000
2 243.0	122.2	122.2	102.0	93.2	96.6	94.1	108.6	105.3	45.23	27.22	26.11	-91.03	-91.03	0.00	0.00	5.000
2 246.0	122.2	122.2	102.0	93.2	96.6	94.1	108.6	105.3	45.23	27.22	26.11	-91.03	-91.03	0.00	0.00	5.000
2 249.0	122.2	122.2	102.0	93.2	96.6	94.1	108.6	105.3	45.23	27.22	26.11	-91.03	-91.03	0.00	0.00	5.000
2 252.0	122.2	122.2	102.0	93.2	96.6	94.1	108.6	105.3	45.23	27.22	26.11	-91.03	-91.03	0.00	0.00	5.000
2 255.0	122.2	122.2	102.0	93.2	96.6	94.1	108.6	105.3	45.23	27.22	26.11	-91.03	-91.03	0.00	0.00	5.000
2 258.0	122.2	122.2	102.0	93.2	96.6	94.1	108.6	105.3	45.23	27.22	26.11	-91.03	-91.03	0.00	0.00	5.000
2 261.0	122.2	122.2	102.0	93.2	96.6	94.1	108.6	105.3	45.23	27.22	26.11	-91.03	-91.03	0.00	0.00	5.000
2 264.0	122.2	122.2	102.0	93.2	96.6	94.1	108.6	105.3	45.23	27.22	26.11	-91.03	-91.03	0.00	0.00	5.000
2 267.0	122.2	122.2	102.0	93.2	96.6	94.1	108.6	105.3	45.23	27.22	26.11	-91.03	-91.03	0.00	0.00	5.000
2 270.0	122.2	122.2	102.0	93.2	96.6	94.1	108.6	105.3	45.23	27.22	26.11	-91.03	-91.03	0.00	0.00	5.000
2 273.0	122.2	122.2	102.0	93.2	96.6	94.1	108.6	105.3	45.23	27.22	26.11	-91.03	-91.03	0.00	0.00	5.000
2 276.0	122.2	122.2	102.0	93.2	96.6	94.1	108.6	105.3	45.23	27.22	26.11	-91.03	-91.03	0.00	0.00	5.000
2 279.0	122.2	122.2	102.0	93.2	96.6	94.1	108.6	105.3	45.23	27.22	26.11	-91.03	-91.03	0.00	0.00	5.000
2 282.0	122.2	122.2	102.0	93.2	96.6	94.1	108.6	105.3	45.23	27.22	26.11	-91.03	-91.03	0.00	0.00	5.000
2 285.0	122.2	122.2	102.0	93.2	96.6	94.1	108.6	105.3	45.23	27.22	26.11	-91.03	-91.03	0.00	0.00	5.000
2 288.0	122.2	122.2	102.0	93.2	96.6	94.1	108.6	105.3	45.23	27.22	26.11	-91.03	-91.03	0.00	0.00	5.000
2 291.0	122.2	122.2	102.0	93.2	96.6	94.1	108.6	105.3	45.23	27.22	26.11	-91.03	-91.03	0.00	0.00	5.000
2 294.0	122.2	122.2	102.0	93.2	96.6	94.1	108.6	105.3	45.23	27.22	26.11	-91.03	-91.03	0.00	0.00	5.000
2 297.0	122.2	122.2	102.0	93.2	96.6	94.1	108.6	105.3	45.23	27.22	26.11	-91.03	-91.03	0.00	0.00	5.000
2 300.0	122.2	122.2	102.0	93.2	96.6	94.1	108.6	105.3	45.23	27.22	26.11	-91.03	-91.03	0.00	0.00	5.000

E V H T RESULTS 1 15-100-77 PAGE NO. 43 04 AR12 45MPH																	
ELAPSED TIME		BATT VOLT UNFIL	BATT VOLT FIL	POT VOLT UNFIL	POT VOLT FIL	BATT AMP UNFIL	BATT AMP FIL	POT AMP UNFIL	POT AMP FIL	FIFTH LABEL RPM	REG.C AMP/T	REG.C MOTOR	REG.C FRONT BATT	REG.C REAR BATT	INVTD APP FIL	INVTD APP UNFIL	FIXED CALI-NORTH
MIN	SEC	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
56	130.2	98.0	98.6	88.3	87.8	110.9	110.6	104.8	105.2	41.46	26.42	26.43	-91.03	-91.03	0.00	0.00	5.000
56	141.4	89.9	89.9	88.0	87.1	111.1	110.6	106.3	105.7	40.62	26.40	26.39	-91.03	-91.03	0.00	0.00	5.000
56	144.6	89.9	89.9	87.1	87.1	107.7	107.7	102.1	102.1	41.36	26.54	26.62	-91.03	-91.03	0.00	0.00	5.000
56	147.6	89.9	89.9	88.0	87.1	108.0	108.0	99.9	99.9	42.33	26.39	26.40	-91.03	-91.03	0.00	0.00	5.000
56	150.8	89.9	89.9	87.6	87.6	102.9	102.6	97.9	97.5	42.33	26.39	26.64	-91.03	-91.03	0.00	0.00	5.000
56	154.0	89.4	89.5	86.5	86.9	101.5	101.5	95.9	95.8	42.32	26.43	26.64	-91.03	-91.03	0.00	0.00	5.000
56	157.2	89.9	89.4	86.2	86.9	100.0	99.9	94.1	94.4	43.15	26.42	26.65	-91.03	-91.03	0.00	0.00	5.000
56	157.6	89.9	89.4	86.5	86.9	99.9	99.9	92.4	92.7	43.49	26.42	26.65	-91.03	-91.03	0.00	0.00	5.000
56	17.4	96.0	95.6	73.5	72.4	52.6	51.2	54.6	72.2	43.00	26.54	26.60	-91.03	-91.03	0.00	0.00	5.000
56	17.6	91.6	91.7	85.6	84.0	89.3	88.4	32.9	61.8	44.52	26.40	25.56	-91.03	-91.03	0.00	0.00	5.000
56	17.8	97.8	98.0	74.5	68.1	61.6	58.2	75.8	61.8	43.27	26.27	25.37	-91.03	-91.03	0.00	0.00	5.000
56	113.6	96.0	95.6	73.5	72.4	76.9	75.9	88.4	86.6	44.52	26.40	25.56	-91.03	-91.03	0.00	0.00	5.000
56	113.0	92.6	92.4	87.1	83.5	87.8	85.2	88.0	82.9	44.90	26.40	25.23	-91.03	-91.03	0.00	0.00	5.000
56	113.0	92.6	92.4	87.1	83.5	87.8	85.2	88.0	82.9	44.90	26.40	25.23	-91.03	-91.03	0.00	0.00	5.000
56	113.0	91.1	91.2	86.5	84.0	91.7	90.0	32.5	85.9	42.50	26.5	25.11	-91.03	-91.03	0.00	0.00	5.000
56	122.4	89.9	89.4	86.5	86.9	94.2	94.0	92.5	91.6	43.95	26.43	26.34	-91.03	-91.03	0.00	0.00	5.000
56	125.4	89.9	89.4	87.3	86.9	94.2	94.0	92.5	91.6	44.40	26.42	26.61	-91.03	-91.03	0.00	0.00	5.000
56	128.4	88.0	88.0	86.2	86.3	95.5	95.7	91.1	90.7	45.31	26.33	26.54	-91.03	-91.03	0.00	0.00	5.000
56	131.6	89.5	89.9	87.1	82.4	83.0	81.9	86.4	82.3	45.08	26.47	26.60	-91.03	-91.03	0.00	0.00	5.000
56	134.0	89.9	89.9	85.0	85.6	28.7	14.9	32.3	27.6	44.84	26.45	26.60	-91.03	-91.03	0.00	0.00	5.000
56	134.0	89.9	89.9	85.0	85.6	28.7	14.9	32.3	27.6	45.30	26.45	26.60	-91.03	-91.03	0.00	0.00	5.000
56	141.6	88.0	88.0	86.2	86.3	97.4	97.1	92.8	92.1	43.83	26.53	26.38	-91.03	-91.03	0.00	0.00	5.000
56	144.2	88.4	89.3	85.6	85.9	62.5	54.3	44.5	57.2	44.59	26.40	25.84	-91.03	-91.03	0.00	0.00	5.000
56	147.4	88.4	89.3	85.6	85.9	35.5	36.0	74.4	75.1	43.40	26.47	25.84	-91.03	-91.03	0.00	0.00	5.000
56	150.6	91.4	90.6	89.5	84.5	92.2	96.8	93.8	89.5	43.11	26.40	25.84	-91.03	-91.03	0.00	0.00	5.000
56	153.6	88.1	88.1	85.1	85.5	90.0	73.5	14.4	6.5	43.00	26.40	25.84	-91.03	-91.03	0.00	0.00	5.000
56	156.0	102.2	107.3	1.0	1.7	4.2	4.2	0.2	0.2	41.64	26.47	25.84	-91.03	-91.03	0.00	0.00	5.000
56	156.0	102.2	107.3	1.0	1.7	4.2	4.2	0.2	0.2	41.64	26.47	25.84	-91.03	-91.03	0.00	0.00	5.000
56	156.0	102.2	107.3	1.0	1.7	4.2	4.2	0.2	0.2	41.64	26.47	25.84	-91.03	-91.03	0.00	0.00	5.000
56	156.0	102.2	107.3	1.0	1.7	4.2	4.2	0.2	0.2	41.64	26.47	25.84	-91.03	-91.03	0.00	0.00	5.000
56	156.0	102.2	107.3	1.0	1.7	4.2	4.2	0.2	0.2	41.64	26.47	25.84	-91.03	-91.03	0.00	0.00	5.000
56	156.0	102.2	107.3	1.0	1.7	4.2	4.2	0.2	0.2	41.64	26.47	25.84	-91.03	-91.03	0.00	0.00	5.000
56	156.0	102.2	107.3	1.0	1.7	4.2	4.2	0.2	0.2	41.64	26.47	25.84	-91.03	-91.03	0.00	0.00	5.000
56	156.0	102.2	107.3	1.0	1.7	4.2	4.2	0.2	0.2	41.64	26.47	25.84	-91.03	-91.03	0.00	0.00	5.000
56	156.0	102.2	107.3	1.0	1.7	4.2	4.2	0.2	0.2	41.64	26.47	25.84	-91.03	-91.03	0.00	0.00	5.000
56	156.0	102.2	107.3	1.0	1.7	4.2	4.2	0.2	0.2	41.64	26.47	25.84	-91.03	-91.03	0.00	0.00	5.000
56	156.0	102.2	107.3	1.0	1.7	4.2	4.2	0.2	0.2	41.64	26.47	25.84	-91.03	-91.03	0.00	0.00	5.000
56	156.0	102.2	107.3	1.0	1.7	4.2	4.2	0.2	0.2	41.64	26.47	25.84	-91.03	-91.03	0.00	0.00	5.000
56	156.0	102.2	107.3	1.0	1.7	4.2	4.2	0.2	0.2	41.64	26.47	25.84	-91.03	-91.03	0.00	0.00	5.000
56	156.0	102.2	107.3	1.0	1.7	4.2	4.2	0.2	0.2	41.64	26.47	25.84	-91.03	-91.03	0.00	0.00	5.000
56	156.0	102.2	107.3	1.0	1.7	4.2	4.2	0.2	0.2	41.64	26.47	25.84	-91.03	-91.03	0.00	0.00	5.000
56	156.0	102.2	107.3	1.0	1.7	4.2	4.2	0.2	0.2	41.64	26.47	25.84	-91.03	-91.03	0.00	0.00	5.000
56	156.0	102.2	107.3	1.0	1.7	4.2	4.2	0.2	0.2	41.64	26.47	25.84	-91.03	-91.03	0.00	0.00	5.000
56	156.0	102.2	107.3	1.0	1.7	4.2	4.2	0.2	0.2	41.64	26.47	25.84	-91.03	-91.03	0.00	0.00	5.000
56	156.0	102.2	107.3	1.0	1.7	4.2	4.2	0.2	0.2	41.64	26.47	25.84	-91.03	-91.03	0.00	0.00	5.000
56	156.0	102.2	107.3	1.0	1.7	4.2	4.2	0.2	0.2	41.64	26.47	25.84	-91.03	-91.03	0.00	0.00	5.000
56	156.0	102.2	107.3	1.0	1.7	4.2	4.2	0.2	0.2	41.64	26.47	25.84	-91.03	-91.03	0.00	0.00	5.000
56	156.0	102.2	107.3	1.0	1.7	4.2	4.2	0.2	0.2	41.64	26.47	25.84	-91.03	-91.03	0.00	0.00	5.000
56	156.0	102.2	107.3	1.0	1.7	4.2	4.2	0.2	0.2	41.64	26.47	25.84	-91.03	-91.03	0.00	0.00	5.000
56	156.0	102.2	107.3	1.0	1.7	4.2	4.2	0.2	0.2	41.64	26.47	25.84	-91.03	-91.03	0.00	0.00	5.000
56	156.0	102.2	107.3	1.0	1.7	4.2	4.2	0.2	0.2	41.64	26.47	25.84	-91.03	-91.03	0.00	0.00	5.000
56	156.0	102.2	107.3	1.0	1.7	4.2	4.2	0.2	0.2	41.64	26.47	25.84	-91.03	-91.03	0.00	0.00	5.000
56	156.0	102.2	107.3	1.0	1.7	4.2	4.2	0.2	0.2	41.64	26.47	25.84	-91.03	-91.03	0.00	0.00	5.000
56	156.0	102.2	107.3	1.0	1.7	4.2	4.2	0.2	0.2	41.64	26.47	25.84	-91.03	-91.03	0.00	0.00	5.000
56	156.0	102.2	107.3	1.0	1.7	4.2	4.2	0.2	0.2	41.64	26.47	25.84	-91.03	-91.03	0.00	0.00	5.000
56																	

Table 6.1.5. Samples of Data Printout for Test No. 5 (Max Speed)

EVT RESULTS 1 15-PMR-77 PAGE NO. 7										45 ARIZ MAX SPEED						
ELAPSED TIME	BATT VOLT UNFIL	BATT VOLT FIL	NOT VOLT UNFIL	NOT VOLT FIL	BATT APP UNFIL	BATT APP FIL	NOT APP UNFIL	NOT APP FIL	FIFTH WHEEL RPM	DEG.C APB'T	DEG.C MOTOR	DEG.C FRONT BATT	DEG.C REAR BATT	INVTD APP FIL	INVTD APP UNFIL	FIXED CALI- BRATH
MIN SEC	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
13 159.6	116.4	116.3	113.0	113.7	115.4	115.7	111.4	111.1	51.19	25.39	-91.03	-91.03	0.00	0.00	5.000	
14 1 2.4	116.4	116.3	113.1	113.6	116.3	115.0	112.2	111.7	52.19	25.44	-91.03	-91.03	0.00	0.00	5.000	
14 1 5.6	116.0	116.3	113.5	113.6	115.3	115.0	110.5	111.7	51.96	25.44	-91.03	-91.03	0.00	0.00	5.000	
14 1 8.0	116.0	116.3	114.2	113.6	115.3	115.0	110.5	111.7	51.17	25.45	-91.03	-91.03	0.00	0.00	5.000	
14 1 11.0	116.3	116.3	113.7	113.5	116.3	116.6	111.6	112.1	51.50	25.50	-91.03	-91.03	0.00	0.00	5.000	
14 1 14.6	116.2	116.3	113.3	113.5	116.3	117.0	112.0	112.7	51.31	25.40	-91.03	-91.03	0.00	0.00	5.000	
14 1 17.0	116.3	116.2	113.7	113.5	115.0	116.1	112.1	112.7	51.05	25.50	-91.03	-91.03	0.00	0.00	5.000	
14 1 21.0	116.2	116.4	113.3	113.7	115.4	115.3	110.5	110.5	51.61	25.55	-91.03	-91.03	0.00	0.00	5.000	
14 1 24.0	116.3	116.2	113.2	113.5	116.6	115.5	113.2	111.4	51.60	25.67	-91.03	-91.03	0.00	0.00	5.000	
14 1 26.6	116.4	116.4	113.1	113.6	115.0	116.1	111.5	112.1	52.60	25.70	-91.03	-91.03	0.00	0.00	5.000	
14 1 29.6	116.4	116.2	113.1	113.5	117.4	117.0	112.0	112.7	50.81	25.77	-91.03	-91.03	0.00	0.00	5.000	
14 1 32.0	116.3	116.2	113.3	113.4	117.1	117.5	113.5	113.4	50.95	25.77	-91.03	-91.03	0.00	0.00	5.000	
14 1 33.0	115.7	116.1	113.0	113.3	117.6	117.7	113.0	113.3	50.92	25.70	-91.03	-91.03	0.00	0.00	5.000	
14 1 39.0	115.9	116.0	113.0	113.3	118.5	118.5	114.0	114.7	50.75	25.73	-91.03	-91.03	0.00	0.00	5.000	
14 1 42.0	115.9	116.0	113.0	113.2	120.7	119.4	114.3	115.1	50.95	25.86	-91.03	-91.03	0.00	0.00	5.000	
14 1 45.2	116.2	115.9	114.5	113.2	116.2	120.5	114.6	116.4	50.70	25.74	-91.03	-91.03	0.00	0.00	5.000	
14 1 48.2	116.1	115.9	113.1	113.0	120.5	121.1	117.4	117.4	50.20	25.82	-91.03	-91.03	0.00	0.00	5.000	
14 1 51.4	115.7	115.0	113.5	113.0	122.1	122.1	118.0	117.7	49.90	25.75	-91.03	-91.03	0.00	0.00	5.000	
14 1 54.4	115.6	115.2	113.4	113.1	123.6	122.7	118.0	118.0	50.22	25.81	-91.03	-91.03	0.00	0.00	5.000	
14 1 57.6	115.0	115.7	112.6	112.0	123.6	124.3	119.6	120.2	50.03	25.86	-91.03	-91.03	0.00	0.00	5.000	
15 0 0.6	115.0	115.6	111.4	112.7	124.6	124.0	120.5	120.7	50.42	25.77	-91.03	-91.03	0.00	0.00	5.000	
15 0 3.0	116.2	115.5	112.2	112.6	124.9	124.0	121.3	121.3	49.90	25.77	-91.03	-91.03	0.00	0.00	5.000	
15 0 6.4	115.0	115.5	112.0	112.5	127.0	126.4	121.0	121.0	49.20	25.75	-91.03	-91.03	0.00	0.00	5.000	
15 0 9.0	115.4	115.4	112.0	112.5	127.0	126.0	121.0	121.0	49.47	25.77	-91.03	-91.03	0.00	0.00	5.000	
15 0 12.0	115.5	115.3	112.4	112.3	129.7	129.4	125.0	125.1	47.06	25.70	-91.03	-91.03	0.00	0.00	5.000	
15 0 16.0	115.1	115.2	112.5	112.4	129.1	129.2	125.1	124.7	46.90	25.75	-91.03	-91.03	0.00	0.00	5.000	
15 0 19.0	114.9	115.2	112.4	112.1	130.5	131.2	126.4	127.3	47.35	25.75	-91.03	-91.03	0.00	0.00	5.000	
15 0 22.1	114.0	115.0	110.4	111.9	132.5	133.4	129.3	129.0	47.40	25.82	-91.03	-91.03	0.00	0.00	5.000	
15 0 25.2	114.0	114.6	113.2	111.4	139.1	139.3	134.9	135.3	45.95	25.77	-91.03	-91.03	0.00	0.00	5.000	
15 0 28.4	114.6	114.4	111.0	111.3	139.6	139.6	135.0	134.1	46.24	25.82	-91.03	-91.03	0.00	0.00	5.000	
15 0 31.2	114.0	114.0	111.0	111.0	139.6	139.6	135.0	134.1	46.24	25.82	-91.03	-91.03	0.00	0.00	5.000	
15 0 34.4	114.0	114.0	111.0	111.0	139.6	139.6	135.0	134.1	46.24	25.82	-91.03	-91.03	0.00	0.00	5.000	
15 0 37.4	114.9	114.9	111.0	111.0	139.6	139.6	135.0	134.1	46.24	25.82	-91.03	-91.03	0.00	0.00	5.000	
15 0 40.6	114.9	115.1	112.0	112.1	139.6	139.6	135.0	134.1	46.24	25.82	-91.03	-91.03	0.00	0.00	5.000	
15 0 43.2	115.0	115.5	112.1	112.4	139.6	139.6	135.0	134.1	46.24	25.82	-91.03	-91.03	0.00	0.00	5.000	
15 0 46.2	115.5	115.5	112.7	112.6	139.6	139.6	135.0	134.1	46.24	25.82	-91.03	-91.03	0.00	0.00	5.000	
15 0 49.2	115.7	115.7	112.1	112.0	139.6	139.6	135.0	134.1	46.24	25.82	-91.03	-91.03	0.00	0.00	5.000	
15 0 52.4	115.0	115.6	113.3	112.9	139.6	139.6	135.0	134.1	46.24	25.82	-91.03	-91.03	0.00	0.00	5.000	
15 0 55.6	115.5	115.5	113.0	113.0	139.6	139.6	135.0	134.1	46.24	25.82	-91.03	-91.03	0.00	0.00	5.000	
15 0 58.4	115.7	115.0	113.0	113.0	139.6	139.6	135.0	134.1	46.24	25.82	-91.03	-91.03	0.00	0.00	5.000	
16 0 1.4	115.9	115.0	112.5	113.1	116.0	117.4	113.0	113.7	52.02	26.29	-91.03	-91.03	0.00	0.00	5.000	
16 0 4.6	116.2	116.0	113.1	113.3	115.9	116.0	112.4	112.1	51.66	26.30	-91.03	-91.03	0.00	0.00	5.000	
16 0 7.8	115.9	116.1	113.3	113.4	115.9	116.0	112.4	112.1	51.66	26.30	-91.03	-91.03	0.00	0.00	5.000	
16 0 10.2	116.3	116.2	113.3	113.5	113.0	113.1	110.4	109.0	52.27	26.45	-91.03	-91.03	0.00	0.00	5.000	

E V M T		RESULTS 1		15-PMR-77		PAGE NO. 23		45 ARIZ MAX SPEED									
ELAPSED TIME		BATT VOLT UNFIL	BATT VOLT FIL	NOT VOLT UNFIL	NOT VOLT FIL	BATT APP UNFIL	BATT APP FIL	NOT APP UNFIL	NOT APP FIL	FIFTH WHEEL RPM	DEG.C APB'T	DEG.C MOTOR	DEG.C FRONT BATT	DEG.C REAR BATT	INVTD APP FIL	INVTD APP UNFIL	FIXED CALI-BRATH
MIN	SEC	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
51	143.4	109.2	109.1	103.6	106.4	111.2	111.4	100.9	100.0	48.70	19.01	40.40	-91.03	-91.03	0.00	0.00	5.000
51	146.6	109.3	109.2	107.2	106.1	111.5	112.1	107.8	107.4	48.77	19.01	40.40	-91.03	-91.03	0.00	0.00	5.000
51	149.8	109.1	109.0	107.2	106.4	112.5	111.4	106.3	105.5	47.99	19.01	40.40	-91.03	-91.03	0.00	0.00	5.000
51	152.0	109.1	109.2	106.1	106.4	110.0	111.2	100.5	100.0	49.41	19.03	40.40	-91.03	-91.03	0.00	0.00	5.000
51	156.0	109.3	109.1	106.4	106.5	111.2	110.5	106.5	106.6	49.24	19.03	40.51	-91.03	-91.03	0.00	0.00	5.000
51	159.2	109.2	109.1	106.0	106.4	110.4	110.5	106.0	106.3	48.81	19.05	40.56	-91.03	-91.03	0.00	0.00	5.000
52	0 2.4	109.0	109.1	106.4	106.4	111.5	111.1	107.5	107.2	48.34	19.20	40.67	-91.03	-91.03	0.00	0.00	5.000
52	0 5.4	109.0	109.0	106.7	106.2	111.5	112.2	107.0	106.0	48.94	19.05	40.62	-91.03	-91.03	0.00	0.00	5.000
52	0 8.6	109.0	109.0	106.7	106.1	113.4	113.6	109.7	109.6	48.63	19.07	40.62	-91.03	-91.03	0.00	0.00	5.000
52	0 11.0	109.2	109.7	106.7	106.0	114.9	115.0	110.6	110.6	47.63	19.03	40.64	-91.03	-91.03	0.00	0.00	5.000
52	0 15.0	109.7	109.6	105.5	105.0	115.0	115.5	111.4	111.4	47.22	19.07	40.62	-91.03	-91.03	0.00	0.00	5.000
52	0 18.0	109.7	109.6	104.6	105.0	116.0	116.7	112.5	112.0	46.04	19.03	40.55	-91.03	-91.03	0.00	0.00	5.000
52	0 21.2	109.7	109.4	105.5	105.1	117.9	119.6	114.9	115.9	45.59	19.03	40.53	-91.03	-91.03	0.00	0.00	5.000
52	0 24.4	109.1	109.0	103.3	104.9	124.4	125.1	119.5	120.0	45.62	19.03	40.42	-91.03	-91.03	0.00	0.00	5.000
52	0 27.6	109.0	107.6	105.4	105.0	120.7	124.3	115.4	115.4	45.93	19.01	40.40	-91.03	-91.03	0.00	0.00	5.000
52	0 30.4	107.0	107.7	104.7	104.6	125.9	126.3	122.0	121.9	44.73	19.01	40.34	-91.03	-91.03	0.00	0.00	5.000
52	0 33.6	107.9	107.0	105.0	104.7	124.2	124.4	120.0	120.2	44.69	19.06	40.32	-91.03	-91.03	0.00	0.00	5.000
52	0 36.0	107.9	106.0	105.3	104.9	122.1	122.9	110.6	111.2	45.40	19.22	40.45	-91.03	-91.03	0.00	0.00	5.000
52	0 40.0	107.9	107.0	105.0	104.9	123.0	123.0	110.5	110.5	45.40	19.05	40.29	-91.03	-91.03	0.00	0.00	5.000
52	0 43.0	109.0	107.9	106.0	104.9	121.2	121.9	117.9	117.2	45.04	19.03	40.32	-91.03	-91.03	0.00	0.00	5.000
52	0 46.2	106.1	106.0	104.0	105.1	120.9	119.9	116.0	115.2	46.61	19.03	40.37	-91.03	-91.03	0.00	0.00	5.000
52	0 49.4	109.1	109.1	105.2	105.3	110.0	110.7	113.6	114.4	46.53	19.00	40.40	-91.03	-91.03	0.00	0.00	5.000
52	0 52.6	109.2	109.2	104.0	105.0	110.2	110.7	113.2	113.2	46.40	19.04	40.42	-91.03	-91.03	0.00	0.00	5.000
52	0 55.6	109.3	109.3	105.3	105.3	113.6	116.4	112.9	112.9	46.26	19.05	40.52	-91.03	-91.03	0.00	0.00	5.000
52	0 58.8	109.2	109.3	105.4	105.5	113.6	114.9	111.2	111.0	47.68	19.02	40.51	-91.03	-91.03	0.00	0.00	5.000
53	0 2.0	109.3	109.4	104.4	105.6	113.6	114.9	111.0	110.7	47.45	19.04	40.62	-91.03	-91.03	0.00	0.00	5.000
53	0 5.2	103.3	103.3	105.7	105.5	113.9	114.0	110.3	109.7	46.44	19.07	40.62	-91.03	-91.03	0.00	0.00	5.000
53	0 8.4	108.2	108.2	105.0	105.0	113.9	114.0	110.3	110.7	47.17	19.07	40.67	-91.03	-91.03	0.00	0.00	5.000
53	0 11.4	108.2	109.3	106.1	105.3	115.6	115.4	111.1	111.0	46.19	19.03	40.04	-91.03	-91.03	0.00	0.00	5.000
53	0 14.6	108.2	108.2	103.5	105.3	116.7	116.3	112.7	112.0	47.59	19.04	40.67	-91.03	-91.03	0.00	0.00	5.000
53	0 17.7	109.1	109.2	107.0	106.3	116.0	115.5	111.0	110.5	47.03	19.04	40.51	-91.03	-91.03	0.00	0.00	5.000
53	0 20.9	109.0	109.0	106.2	106.3	116.0	116.6	110.6	111.4	47.13	19.00	40.62	-91.03	-91.03	0.00	0.00	5.000
53	0 23.0	109.0	109.0	106.3	105.1	117.0	117.7	113.6	113.5	47.17	19.01	40.64	-91.03	-91.03	0.00	0.00	5.000
53	0 27.0	109.1	109.0	105.5	106.0	117.3	117.9	113.0	113.0	46.66	19.06	40.33	-91.03	-91.03	0.00	0.00	5.000
53	0 30.2	109.1	109.1	105.7	106.0	117.1	117.1	113.0	113.3	47.83	19.03	40.52	-91.03	-91.03	0.00	0.00	5.000
53	0 33.2	109.0	109.7	105.9	105.9	110.2	110.0	114.7	115.9	46.37	19.02	40.40	-91.03	-91.03	0.00	0.00	5.000
53	0 36.4	109.1	107.0	105.7	105.0	110.0	110.1	114.6	113.7	45.62	19.02	40.51	-91.03	-91.03	0.00	0.00	5.000
53	0 39.6	109.0	107.9	105.5	105.9	117.1	117.1	112.0	111.0	46.13	19.00	40.56	-91.03	-91.03	0.00	0.00	5.000
53	0 42.8	109.0	109.0	105.6	105.6	116.9	116.9	111.0	110.7	46.49	19.03	40.51	-91.03	-91.03	0.00	0.00	5.000
53	0 45.8	109.0	109.1	104.7	105.9	114.9	114.6	111.1	111.1	45.49	19.03	41.00	-91.03	-91.03	0.00	0.00	5.000
53	0 49.0	109.0	108.0	105.2	105.3	113.0	112.6	107.4	107.0	47.16	19.07	41.00	-91.03	-91.03	0.00	0.00	5.000
53	0 52.2	109.1	109.2	104.2	105.3	111.2	112.1	107.0	107.1	47.06	19.06	41.14	-91.03	-91.03	0.00	0.00	5.000
53	0 55.4	109.1	109.1	105.3	105.3	111.2	111.2	107.7	107.7	46.85	19.03	41.00	-91.03	-91.03	0.00	0.00	5.000
53	0 58.6	109.2	109.2	105.6	105.3	111.1	111.4	109.2	109.5	47.91	19.00	41.29	-91.03	-91.03	0.00	0.00	5.000

Table 6.1.6. Samples of Data Printout for Test No. 6 (35 mph)

E V H T		RESULTS		17-PMR-77		PAGE NO. 1		06 APR 82 20PM 3/11										
TIME		BATT VOLT	BATT VOLT UNFIL	POT VOLT FIL	POT VOLT UNFIL	BATT VOLT UNFIL	BATT VOLT FIL	POT VOLT FIL	P3 VOLT FIL	FIFTH VOLT FIL	RES.C RND-T	RES.C FOTOR	RES.C DRIFT BATT	RES.C DRIFT BATT	INVT VOLT FIL	INVT VOLT UNFIL	FINED VOLT BATT	
MIN	SEC	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
0	0.2	124.7	113.3	109.3	2.2													
0	0.4	124.7	116.7	113.3	114.2	1.4-2	134.1	127.0	127.4	22.90	17.24	10.25	-91.03	-91.03	0.00	0.00	0.000	
0	3.4	121.9	124.2	119.4	24.2	4.2	131	126.8	127.8	23.50	17.09	10.25	-91.03	-91.03	0.00	0.00	0.000	
0	6.6	121.9	124.2	119.4	24.2	4.2	131	126.8	127.8	23.50	17.09	10.25	-91.03	-91.03	0.00	0.00	0.000	
0	9.6	113.7	113.6	109.3	110.3		169.6	169.0	163.0	161.6	31.21	16.74	10.26	-91.03	-91.03	0.00	0.00	0.000
0	12.0	114.0										16.61	10.13	-91.07	-91.03	0.00	0.00	0.000
0	14.4	115.0	115.0	112.3	112.9		140.0	141.5	136.2	136.0	34.26	16.41	10.11	-91.03	-91.03	0.00	0.00	0.000
0	16.8	116.4				4.000	140.0	141.5	136.0	136.2	34.26	16.41	10.11	-91.03	-91.03	0.00	0.00	0.000
0	20.0	123.1	120.0	105.1	87.0		101.7	72.7	112.6	87.1	33.95	15.91	17.92	-91.03	-91.03	0.00	0.00	0.000
0	23.0	115.0	117.0	113.2	107.4		110.5	122.6	120.7	125.1	33.76	15.71		-91.03	-91.03	0.00	0.00	0.000
0	26.0	117.6	117.0	112.2	109.5		127.4	123.7	129.0	121.1	34.45	15.49	10.02	-91.03	-91.03	0.00	0.00	0.000
0	29.0	119.4				11.2	127.4	123.7	129.0	121.1	34.45	15.49	10.02	-91.03	-91.03	0.00	0.00	0.000
0	33.0	110.5	110.0	115.0	93.7	99.0	71.1	93.3	109.3	103.0	34.25	15.21	17.97	-91.03	-91.03	0.00	0.00	0.000
0	36.0	110.2	108.0	121.9	97.7		81.5	91.9	117.5	102.0	33.84	14.01	17.63	-91.03	-91.03	0.00	0.00	0.000
0	39.0	132.0	120.0	100.5	84.5	70.0	101.5	102.2	104.7	97.9	33.73	14.64	17.63	-91.03	-91.03	0.00	0.00	0.000
0	42.0	120.3			96.0		92.5	97.0	109.0	97.0	34.25	16.97	17.91	-91.03	-91.03	0.00	0.00	0.000
0	45.2	117.1	117.3	115.0	114.0	119.4	139.4	138.0	122.9	133.7	34.82	14.49	17.50	-91.03	-91.03	0.00	0.00	0.000
0	48.4	121.6	122.9	101.5	76.0	98.0	93.4	99.4	70.0	79.6	33.63	14.28	17.47	-91.03	-91.03	0.00	0.00	0.000
0	51.4	120.3	121.6	111.0	84.0	92.3	93.4	99.4	70.0	79.6	33.63	14.28	17.47	-91.03	-91.03	0.00	0.00	0.000
0	54.6	119.2	118.0	118.0	116.4	131.4	131.4	131.4	131.4	131.4	34.25	16.97	17.91	-91.03	-91.03	0.00	0.00	0.000
0	57.5	110.9	110.7	109.0	109.7	120.2	110.5	120.7	120.1	120.1	33.30	13.91	17.37	-91.03	-91.03	0.00	0.00	0.000
0	1	0.0	110.7	110.6	112.1	107.2	107.0	116.0	117.7	120.1	34.43	13.62	17.35	-91.03	-91.03	0.00	0.00	0.000
1	4.0	110.2	110.6	110.6	114.3	110.2	110.6	110.6	116.4	116.4	34.49	13.62	17.35	-91.03	-91.03	0.00	0.00	0.000
1	6.6	119.7	120.0	109.7	94.0	100.4	92.0	116.4	94.0		33.62	13.77	17.37	-91.03	-91.03	0.00	0.00	0.000
1	9.6	121.4	120.9	102.1	94.0	89.0	82.6	114.6	95.2	73.9	33.45	13.45	17.22	-91.03	-91.03	0.00	0.00	0.000
1	12.0	121.0	120.1	105.3	96.0	93.3	92.2	121.4	104.5	84.3	34.13	13.45	17.24	-91.03	-91.03	0.00	0.00	0.000
1	16.0	119.1	120.1	100.3	90.0	90.0	90.0	100.2	107.1	89.0	33.85	13.35	17.24	-91.03	-91.03	0.00	0.00	0.000
1	19.0	119.2	120.0	99.3	90.0	86.6	86.6	114.4	110.0	83.0	33.85	13.35	17.15	-91.03	-91.03	0.00	0.00	0.000
1	22.0	117.0	116.9	114.9	113.0	146.0	145.3	141.3	141.0	133.0	33.18	13.18	17.17	-91.03	-91.03	0.00	0.00	0.000
1	25.2	116.9	117.1	112.6	114.1	141.1	140.4	139.9	139.1	14.39	33.09	17.15	-91.03	-91.03	0.00	0.00	0.000	
1	28.4	121.6	120.1	107.5	95.7	90.0	90.0	92.4	100.0	84.0	34.73	13.25	17.25	-91.03	-91.03	0.00	0.00	0.000
1	31.6	120.1			93.0	100.7	90.0	90.4	83.4	34.48	13.00		-91.03	-91.03	0.00	0.00	0.000	
1	34.4	121.3	121.0	123.0	100.7	97.9	79.7	90.6	84.0	74.9	34.78	13.52	17.09	-91.03	-91.03	0.00	0.00	0.000
1	37.6	120.3	121.9	99.4	80.9	49.9	49.9	70.6	112.0	84.4	35.14	12.85	17.06	-91.03	-91.03	0.00	0.00	0.000
1	40.8	122.6	121.9	43.6	84.0	93.4	93.4	93.4	93.4	93.4	34.53	12.63	17.28	-91.03	-91.03	0.00	0.00	0.000
1	44.0	124.4			94.0	83.7	79.0	66.1	84.3		34.53	12.63	17.28	-91.03	-91.03	0.00	0.00	0.000
1	46.6	122.3	121.0	116.4	80.4	74.3	70.0	112.9	84.4	24.01	32.45	12.45	17.11	-91.03	-91.03	0.00	0.00	0.000
1	49.8	122.3	122.1	39.0	87.0	93.0	67.4	90.6	66.7	35.54	32.45	12.45	17.06	-91.03	-91.03	0.00	0.00	0.000
1	53.0	123.3	122.2	114.5	85.0	96.5	96.5	96.5	96.5	35.11	32.45	12.45	17.06	-91.03	-91.03	0.00	0.00	0.000
1	55.0	123.3	122.2	114.5	85.0	96.5	96.5	96.5	96.5	35.11	32.45	12.45	17.06	-91.03	-91.03	0.00	0.00	0.000
1	58.0	123.3	122.4	26.6	74.1	76.0	48.6	81.4	64.4	35.51	32.38	12.38	17.25	-91.03	-91.03	0.00	0.00	0.000
2	2.0	121.0	123.6	86.1	72.0	65.6	46.3	90.3	64.0	33.87	32.43	12.24	17.04	-91.03	-91.03	0.00	0.00	0.000
2	5.0	122.3	122.2	114.5	85.0	96.5	96.5	96.5	96.5	35.11	32.45	12.45	17.06	-91.03	-91.03	0.00	0.00	0.000
2	8.2	122.3	121.9	84.6	70.0	79.5	67.6	82.1	64.0	33.87	32.43	12.24	17.04	-91.03	-91.03	0.00	0.00	0.000

[illegible]

ORIGINAL PAGE IS
OF POOR QUALITY

Table 6.1.7. Samples of Data Printout for Test No. 7 (Max Speed)

E V N T F RESULTS 1 22-PM-77 PAGE NO. 2 97 MAX SPEED 3/14															
ELAPSED TIME	BATT VOLT	BATT VOLT	POT VOLT	POT VOLT	BATT VOLT	BATT VOLT	POT VOLT	POT VOLT	FIFTH WHEEL	DEG. C	DEG. C	DEG. C	DEG. C	INVTD	INVTD
MIN SEC	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
MIN SEC	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2:19.4	117.6	117.8	114.0	113.2	120.8	120.9	116.2	116.1	51.67	19.66	19.33	-91.03	-91.03	0.00	0.00
2:12.6	117.6	117.7	114.6	114.9	122.4	123.1	117.9	119.5	51.67	19.66	19.33	-91.03	-91.03	0.00	0.00
2:15.0	117.3	117.5	113.2	114.7	125.2	125.9	121.1	121.6	50.46	19.64	19.30	-91.03	-91.03	0.00	0.00
2:15.0	117.3	117.3	114.0	114.4	120.1	127.0	123.0	121.1	50.46	19.64	19.30	-91.03	-91.03	0.00	0.00
2:21.2	117.6	117.2	114.2	114.4	125.5	128.0	124.2	123.0	49.33	19.62	19.29	-91.03	-91.03	0.00	0.00
2:24.4	117.3	117.1	113.9	114.3	130.1	130.8	123.4	124.0	49.31	19.60	19.30	-91.03	-91.03	0.00	0.00
2:27.6	117.2	117.1	113.1	114.2	129.6	130.3	124.5	125.1	50.33	19.64	19.35	-91.03	-91.03	0.00	0.00
2:30.0	117.1	117.1	116.6	114.2	130.5	130.3	124.6	125.4	49.67	19.62	19.35	-91.03	-91.03	0.00	0.00
2:33.4	117.2	117.2	113.3	114.0	129.3	130.1	125.1	125.1	49.64	19.59	19.30	-91.03	-91.03	0.00	0.00
2:36.4	117.3	117.1	114.2	114.2	129.0	129.0	124.1	124.1	49.95	19.57	19.44	-91.03	-91.03	0.00	0.00
2:39.6	117.0	117.2	115.1	114.2	129.9	129.0	124.3	124.8	49.52	19.57	19.42	-91.03	-91.03	0.00	0.00
2:42.0	117.4	117.1	114.9	114.3	129.2	129.3	125.0	125.1	49.99	19.62	19.44	-91.03	-91.03	0.00	0.00
2:46.4	117.4	117.4	113.0	114.2	132.2	129.7	124.0	125.1	50.59	19.53	19.44	-91.03	-91.03	0.00	0.00
2:46.4	117.2	117.2	112.0	114.2	129.7	130.2	125.3	125.3	49.63	19.64	19.59	-91.03	-91.03	0.00	0.00
2:52.0	116.6	117.1	113.7	114.2	129.5	129.4	125.3	125.0	49.50	19.51	19.46	-91.03	-91.03	0.00	0.00
2:55.2	117.1	117.1	113.0	114.2	131.0	130.0	125.3	125.1	49.50	19.49	19.49	-91.03	-91.03	0.00	0.00
2:58.4	117.1	117.1	113.0	114.2	130.5	129.7	124.7	124.0	49.76	19.49	19.49	-91.03	-91.03	0.00	0.00
3:01.4	117.2	117.2	113.7	114.2	129.5	130.0	124.5	124.1	50.12	19.46	19.49	-91.03	-91.03	0.00	0.00
3:04.6	117.0	117.0	114.9	114.2	130.0	129.6	125.1	125.1	49.83	19.38	19.51	-91.03	-91.03	0.00	0.00
3:07.8	116.9	117.0	112.2	114.0	130.3	130.5	125.4	125.4	49.30	19.33	19.57	-91.03	-91.03	0.00	0.00
3:11.0	117.1	117.0	113.7	113.7	130.0	130.5	126.4	126.2	49.30	19.35	19.49	-91.03	-91.03	0.00	0.00
3:14.0	117.2	117.0	112.0	114.0	130.5	131.4	127.3	126.5	49.00	19.42	19.55	-91.03	-91.03	0.00	0.00
3:17.2	117.0	117.0	114.1	114.1	130.2	130.0	125.1	125.1	49.81	19.42	19.57	-91.03	-91.03	0.00	0.00
3:20.4	116.9	116.9	114.0	114.0	131.1	131.1	126.6	127.1	49.78	19.33	19.57	-91.03	-91.03	0.00	0.00
3:23.6	116.6	116.9	113.5	113.9	132.5	132.5	127.9	127.4	50.26	19.35	19.42	-91.03	-91.03	0.00	0.00
3:26.6	116.6	116.6	113.1	113.7	134.4	135.2	130.3	130.3	47.80	19.35	19.66	-91.03	-91.03	0.00	0.00
3:29.8	116.0	116.9	115.0	115.9	132.9	132.2	127.0	126.9	48.94	19.35	19.59	-91.03	-91.03	0.00	0.00
3:33.0	116.9	117.0	114.0	114.0	131.8	130.0	126.7	126.1	49.39	19.33	19.64	-91.03	-91.03	0.00	0.00
3:36.2	117.1	117.1	113.5	114.4	130.0	130.0	121.0	122.0	49.26	19.33	19.60	-91.03	-91.03	0.00	0.00
3:39.0	117.1	117.2	116.0	114.4	125.2	126.0	121.0	121.1	50.64	19.46	19.79	-91.03	-91.03	0.00	0.00
3:42.2	116.5	116.9	115.0	114.6	125.4	125.2	119.6	119.6	50.46	19.35	19.78	-91.03	-91.03	0.00	0.00
3:45.4	122.6	122.6	122.6	122.6	122.6	122.6	122.6	122.6	50.46	19.35	19.78	-91.03	-91.03	0.00	0.00
3:48.6	121.9	120.1	113.5	114.3	127.6	127.4	122.6	122.1	50.29	19.35	19.73	-91.03	-91.03	0.00	0.00
3:51.6	117.1	117.2	113.0	114.4	125.6	125.4	120.3	121.1	50.70	19.31	19.75	-91.03	-91.03	0.00	0.00
3:54.8	121.6	119.4	111.9	111.5	121.1	125.2	121.2	121.1	49.14	19.33	19.73	-91.03	-91.03	0.00	0.00
3:58.0	117.2	117.0	116.2	114.5	124.5	124.0	119.7	119.1	51.30	19.42	19.83	-91.03	-91.03	0.00	0.00
4:01.2	116.9	117.3	113.3	114.5	124.1	123.9	119.3	119.3	51.30	19.31	19.78	-91.03	-91.03	0.00	0.00
4:04.2	117.0	117.4	115.9	114.6	122.6	122.5	119.0	117.1	51.27	19.44	19.81	-91.03	-91.03	0.00	0.00
4:07.4	117.2	117.5	113.3	114.0	122.1	121.0	115.0	116.1	51.76	19.42	19.83	-91.03	-91.03	0.00	0.00
4:10.6	117.6	117.5	115.4	114.0	119.7	119.6	115.0	115.1	52.16	19.38	19.81	-91.03	-91.03	0.00	0.00
4:13.0	117.7	117.6	115.3	115.0	119.5	119.2	113.0	113.4	50.90	19.49	19.80	-91.03	-91.03	0.00	0.00
4:16.2	117.7	117.6	116.4	115.0	110.0	110.0	112.4	113.1	51.96	19.44	19.90	-91.03	-91.03	0.00	0.00
4:19.0	117.7	117.7	115.0	115.1	117.1	117.4	113.4	113.1	53.62	19.42	19.94	-91.03	-91.03	0.00	0.00
4:22.2	118.0	117.7	116.0	115.1	115.6	116.2	111.6	111.1	52.59	19.46	19.94	-91.03	-91.03	0.00	0.00

E V N T F RESULTS 1 22-PM-77 PAGE NO. 27 97 MAX SPEED 3/14																
ELAPSED TIME	BATT VOLT UNFIL	BATT VOLT 1	POT VOLT 2	POT VOLT 3	BATT VOLT 4	BATT VOLT 5	POT VOLT 6	POT VOLT 7	FIFTH WHEEL 8	DEG. C 9	DEG. C 10	DEG. C 11	DEG. C 12	INVTD 13	INVTD 14	FIXED 15
MIN SEC	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
59:56.2	105.0	105.0	102.4	103.3	101.1	101.0	97.3	97.2	50.52	17.92	40.06	-91.03	-91.03	0.00	0.00	0.00
59:59.0	105.0	105.0	102.3	103.3	100.0	100.0	96.6	97.1	50.03	17.96	40.09	-91.03	-91.03	0.00	0.00	0.00
60:02.2	105.7	105.0	102.1	103.3	100.9	100.5	96.6	97.6	50.46	17.94	40.01	-91.03	-91.03	0.00	0.00	0.00
60:05.4	105.0	105.0	104.6	103.3	100.4	100.2	96.0	96.7	50.49	18.00	40.04	-91.03	-91.03	0.00	0.00	0.00
60:08.6	105.6	105.0	103.1	103.3	100.0	100.3	96.2	96.2	49.77	17.96	40.08	-91.03	-91.03	0.00	0.00	0.00
60:11.0	105.7	105.0	103.0	103.2	101.0	101.3	96.3	97.9	49.03	17.96	40.05	-91.03	-91.03	0.00	0.00	0.00
60:14.0	105.7	105.6	103.3	103.3	103.3	103.3	96.3	96.3	49.73	18.05	40.05	-91.03	-91.03	0.00	0.00	0.00
60:16.0	105.3	105.4	103.6	102.0	104.5	104.5	101.2	101.7	47.09	17.96	40.01	-91.03	-91.03	0.00	0.00	0.00
60:19.2	105.1	105.2	102.5	102.6	105.7	105.7	102.9	101.9	46.70	18.02	40.04	-91.03	-91.03	0.00	0.00	0.00
60:22.4	104.9	104.9	101.4	102.3	107.5	108.0	105.1	104.1	46.16	18.05	40.04	-91.03	-91.03	0.00	0.00	0.00
60:25.4	103.7	104.7	102.4	101.9	109.1	109.7	105.0	104.9	47.63	18.02	40.09	-91.03	-91.03	0.00	0.00	0.00
60:28.6	104.6	104.6	104.5	102.0	101.0	110.9	110.0	105.0	47.00	18.05	40.02	-91.03	-91.03	0.00	0.00	0.00
60:31.0	104.4	104.4	101.3	101.6	111.0	111.4	107.5	106.1	46.34	18.02	40.05	-91.03	-91.03	0.00	0.00	0.00
60:34.0	104.3	104.3	101.4	101.6	112.5	112.9	107.7	107.8	47.03	17.96	40.02	-91.03	-91.03	0.00	0.00	0.00
60:37.0	104.3	104.3	101.4	101.6	112.4	112.5	108.4	108.9	46.66	18.02	41.06	-91.03	-91.03	0.00	0.00	0.00
60:40.0	103.9	103.9	101.3	101.3	112.0	112.5	109.0	109.3	46.23	18.00	41.11	-91.03	-91.03	0.00	0.00	0.00
60:43.2	103.9	103.9	101.3	101.1	112.0	112.5	109.0	109.3	46.23	18.00	41.11	-91.03	-91.03	0.00	0.00	0.00
60:46.4	104.0	103.9	101.3	101.1	113.3	114.0	110.2	110.0	45.94	17.96	41.14	-91.03	-91.03	0.00	0.00	0.00
60:49.6	103.7	103.7	101.3	101.1	113.7	114.3	111.1	110.6	46.41	17.96	41.22	-91.03	-91.03	0.00	0.00	0.00
60:52.4	103.4	103.4	101.3	101.1	115.0	114.9	112.0	111.1	47.45	17.92	41.20	-91.03	-91.03	0.00	0.00	0.00
60:55.6	103.3	103.4	101.2	100.5	115.1	115.4	112.0	111.3	48.13	17.92	41.20	-91.03	-91.03	0.00	0.00	0.00
60:58.6	103.1	103.2	101.1	100.3	115.0	115.7	112.7	111.0	45.00	17.89	41.20	-91.03	-91.03	0.00	0.00	0.00
61:01.2	103.0	103.0	100.6	100.1	115.0	115.4	111.6	111.0	44.40	17.87	41.31	-91.03	-91.03	0.00	0.00	0.00
61:04.0	102.8	102.9	99.8	100.0	116.3	116.0	111.5	111.2	44.9	17.87	41.31	-91.03	-91.03	0.00	0.00	0.00
61:07.0	102.8	102.9	99.8	99.8	116.3	116.0	111.5	111.2	44.9	17.87	41.31	-91.03	-91.03	0.00	0.00	0.00
61:10.0	102.8	102.9	99.8	99.8	116.3	116.0	111.5	111.2	44.9	17.87	41.31	-91.03	-91.03	0.00	0.00	0.00
61:13.0	102.8	102.9	99.8	99.8	116.3	116.0	111.5	111.2	44.9	17.87	41.31	-91.03	-91.03	0.00	0.00	0.00
61:16.0	102.8	102.9	99.8	99.8	116.3	116.0	111.5	111.2	44.9	17.87	41.31	-91.03	-91.03	0.00	0.00	0.00
61:19.0	102.8	102.9	99.8	99.8	116.3	116.0	111.5	111.2	44.9	17.87	41.31	-91.03	-91.03	0.00	0.00	0.00
61:22.0	102.8	102.9	99.8	99.8	116.3	116.0	111.5	111.2	44.9	17.87	41.31	-91.03	-91.03	0.00	0.00	0.00
61:25.0	102.8	102.9	99.8	99.8	116.3	116.0	111.5	111.2	44.9	17.87	41.31	-91.03	-91.03	0.00	0.00	0.00
61:28.0	102.8	102.9	99.8	99.8	116.3	116.0	111.5	111.2	44.9	17.87	41.31	-91.03	-91.03	0.00	0.00	0.00
61:31.0	102.8	102.9	99.8	99.8	116.3	116.0	111.5	111.2	44.9	17.87	41.31	-91.03	-91.03	0.00	0.00	0.00
61:34.0	102.8	102.9	99.8	99.8	116.3	116.0	111.5	111.2	44.9	17.87	41.31	-91.03	-91.03	0.00	0.00	0.00
61:37.0	102.8	102.9	99.8	99.8	116.3	116.0	111.5	111.2	44.9	17.87	41.31	-91.03	-91.03	0.00	0.00	0.00
61:40.0	102.8	102.9	99.8	99.8	116.3	116.0	111.5	111.2	44.9	17.87	41.31	-91.03	-91.03	0.00	0.00	0.00
61:43.0	102.8	102.9	99.8	99.8	116.3	116.0	111.5	111.2	44.9	17.87	41.31	-91.03	-91.03	0.00	0.00	0.00
61:46.0	102.8	102.9	99.8	99.8	116.3	116.0	111.5	111.2	44.9	17.87	41.31	-91.03	-91.03	0.00	0.00	0.00
61:49.0	102.8	102.9	99.8	99.8	116.3	116.0	111.5	111.2	44.9	17.87	41.31	-91.03	-91.03	0.00	0.00	0.00
61:52.0	102.8	102.9	99.8	99.8	116.3	116.0	111.5	111.2	44.9	17.87	41.31	-91.03	-91.03	0.00	0.00	0.00
61:55.0	102.8	102.9	99.8	99.8	116.3	116.0	111.5	111.2	44.9	17.87	41.31	-91.03	-91.03	0.00	0.00	0.00
61:58.0	102.8	102.9	99.8	99.8	116.3	116.0	111.5	111.2	44.9	17.87	41.31	-91.03	-91.03	0.00	0.00	0.00
62:01.0	102.8	102.9	99.8	99.8	116.3	116.0	111.5	111.2	44.9	17.87	41.31	-91.03	-91.03	0.00	0.00	0.00
62:04.0	102.8	102.9	99.8	99.8	116.3	116.0	111.5	111.2	44.9	17.87	41.31	-91.03	-91.03	0.00	0.00	0.00
62:07.0	102.8	102.9	99.8	99.8	116.3	116.0	111.5	111.2	44.9	17.87	41.31	-91.03	-91.03	0.00	0.00	0.00
62:10.0	102.8	102.9	99.8	99.8	116.3	116.0	111.5	111.2	44.9	17.87	41.31	-91.03	-91.03	0.00	0.00	0.00
62:13.0	102.8	102.9	99.8	99.8	116.3	116.0	111.5	111.2	44.9	17.87	41.31	-91.03	-91.03	0.00	0.00	0.00

Table 6.1.8. Samples of Data Printout for Test No. 9 (25 mph)

E V H T F RESULTS : 22-PMR-77 PAGE NO. 2 09A 25MPH 3/15 --1															
ELAPSED	BATT	BATT	NOT	NOT	BATT	BATT	NOT	NOT	FIFTH	DEG.C	DEG.C	DEG.C	DEG.C	INVTD	INVTD
TIME	VOLT	VOLT	VOLT	VOLT	VOLT	VOLT	VOLT	VOLT	UNFIL	UNFIL	UNFIL	UNFIL	UNFIL	UNFIL	UNFIL
MIN SEC	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2 112.4	122.1	123.0	79.9	80.8	71.4	54.4	84.1	68.8	24.81	23.24	25.75	-01.03	-01.03	0.00	0.00
2 115.6	124.7	122.5	49.1	86.2	57.1	64.0	52.0	71.4	24.86	23.86	25.64	-01.03	-01.03	0.00	0.00
2 113.8	123.5	122.3	93.1	87.1	48.7	64.2	60.2	76.3	24.10	23.55	25.55	-01.03	-01.03	0.00	0.00
2 121.8	128.7	127.2	93.3	87.8	77.8	64.2	41.4	76.0	24.91	22.90	25.60	-01.03	-01.03	0.00	0.00
2 124.0	123.4	122.7	123.3	88.5	54.1	64.4	93.7	75.7	25.21	22.97	25.70	-01.03	-01.03	0.00	0.00
2 128.0	122.2	127.5	119.6	14.1	49.5	57.2	94.1	62.0	25.25	22.68	25.75	-01.03	-01.03	0.00	0.00
2 131.2	123.4	122.9	94.4	12.5	45.4	56.3	77.8	60.6	25.37	22.25	25.79	-01.03	-01.03	0.00	0.00
2 134.2	122.2	122.0	43.3	83.5	47.0	55.0	60.4	67.1	25.61	22.54	25.79	-01.03	-01.03	0.00	0.00
2 137.2	123.6	123.0	34.5	82.6	38.4	54.9	66.0	67.0	25.10	22.86	25.64	-01.03	-01.03	0.00	0.00
2 140.4	121.9	123.2	114.2	79.0	79.9	52.0	66.3	64.0	24.65	22.86	25.86	-01.03	-01.03	0.00	0.00
2 143.6	122.3	123.2	114.0	79.9	79.0	52.0	78.0	65.3	24.55	22.86	25.51	-01.03	-01.03	0.00	0.00
2 146.4	124.5	123.2	98.2	78.4	51.9	54.6	54.7	72.5	24.89	23.86	25.09	-01.03	-01.03	0.00	0.00
2 149.4	121.7	120.7	48.0	100.5	102.4	88.2	103.4	95.0	24.59	22.97	25.80	-01.03	-01.03	0.00	0.00
2 152.6	119.4	121.4	58.3	90.0	82.3	64.2	89.5	74.9	24.81	22.88	26.82	-01.03	-01.03	0.00	0.00
2 155.8	124.6	122.7	44.9	79.6	52.9	58.0	51.1	59.8	24.81	22.90	26.84	-01.03	-01.03	0.00	0.00
2 158.0	124.0	124.0	16.6	57.9	51.0	38.2	67.1	44.2	24.76	22.84	26.84	-01.03	-01.03	0.00	0.00
3 1.0	123.9	123.0	15.2	77.4	51.2	38.3	52.5	44.0	24.76	22.79	26.70	-01.03	-01.03	0.00	0.00
3 1.0	125.9	124.0	35.0	57.2	16.0	36.5	23.0	45.2	24.29	22.84	26.84	-01.03	-01.03	0.00	0.00
3 1.2	124.3	123.1	29.6	57.7	23.1	31.4	23.7	47.0	24.28	22.82	25.53	-01.03	-01.03	0.00	0.00
3 1.11.4	125.4	124.0	37.4	61.0	17.0	34.1	63.5	49.2	24.83	22.82	25.86	-01.03	-01.03	0.00	0.00
3 1.11.4	124.9	124.3	14.3	61.2	33.9	34.1	25.0	49.4	24.12	22.75	26.89	-01.03	-01.03	0.00	0.00
3 1.17.4	123.9	124.9	26.0	61.4	10.6	34.2	50.0	50.4	24.82	22.77	26.89	-01.03	-01.03	0.00	0.00
3 1.20.0	126.4	124.9	95.4	62.2	13.3	34.1	26.6	40.6	24.78	22.77	26.87	-01.03	-01.03	0.00	0.00
3 1.23.0	125.7	124.9	97.4	61.6	56.9	34.3	25.1	48.2	24.78	22.75	26.11	-01.03	-01.03	0.00	0.00
3 1.26.0	125.1	124.9	19.4	61.9	17.0	34.6	71.7	48.9	25.28	22.77	26.20	-01.03	-01.03	0.00	0.00
3 1.29.0	126.4	124.9	84.7	62.0	20.6	34.1	74.7	48.7	25.80	22.77	26.20	-01.03	-01.03	0.00	0.00
3 1.33.0	126.9	124.9	95.4	62.2	19.3	34.1	78.6	40.6	24.78	22.77	26.27	-01.03	-01.03	0.00	0.00
3 1.36.0	125.6	124.9	27.0	62.3	56.9	34.3	25.1	48.2	24.78	22.75	26.11	-01.03	-01.03	0.00	0.00
3 1.39.0	122.6	125.0	60.3	60.3	40.3	32.0	51.1	46.2	24.55	22.75	26.31	-01.03	-01.03	0.00	0.00
3 1.42.0	125.7	125.1	33.3	59.7	37.0	31.9	23.4	46.4	24.28	22.73	26.24	-01.03	-01.03	0.00	0.00
3 1.45.2	125.3	125.1	34.9	59.6	56.1	32.0	47.1	46.6	24.60	22.80	26.51	-01.03	-01.03	0.00	0.00
3 1.48.4	125.3	125.1	82.9	59.4	16.3	32.0	29.1	48.9	24.85	22.86	26.42	-01.03	-01.03	0.00	0.00
3 1.51.4	123.3	125.1	97.0	60.0	10.1	32.1	45.6	46.9	24.32	22.88	26.47	-01.03	-01.03	0.00	0.00
3 1.54.4	123.3	125.1	89.5	60.7	17.0	33.3	34.4	48.1	23.79	22.93	26.56	-01.03	-01.03	0.00	0.00
3 1.57.6	125.7	124.9	18.0	61.7	52.7	34.4	62.0	45.4	24.60	22.80	26.51	-01.03	-01.03	0.00	0.00
4 1.0	127.7	124.9	85.5	62.0	25.7	35.1	44.7	49.3	24.89	22.86	26.51	-01.03	-01.03	0.00	0.00
4 1.3	124.6	124.0	17.5	63.0	35.0	35.0	77.2	40.6	24.69	22.58	26.8	-01.03	-01.03	0.00	0.00
4 1.6	125.5	124.0	112.2	63.2	17.9	35.2	25.1	41.6	24.79	22.46	26.72	-01.03	-01.03	0.00	0.00
4 1.9	126.2	124.5	100.0	63.3	17.9	35.2	28.1	41.6	24.79	22.50	26.85	-01.03	-01.03	0.00	0.00
4 1.13	124.7	121.0	69.0	63.5	36.4	34.0	71.9	40.2	25.25	23.81	26.90	-01.03	-01.03	0.00	0.00
4 1.16	125.5	124.9	34.7	61.1	18.2	34.0	22.6	40.3	25.25	22.82	26.81	-01.03	-01.03	0.00	0.00
4 1.19	125.0	125.3	29.3	57.1	19.7	37.6	20.0	41.6	25.78	22.80	26.97	-01.03	-01.03	0.00	0.00
4 1.22	126.0	125.0	53.1	51.2	12.5	24.5	19.2	31.7	25.87	22.87	27.86	-01.03	-01.03	0.00	0.00
4 1.25.6	126.0	125.9	101.9	50.4	14.1	24.3	70.5	31.9	25.24	22.82	27.86	-01.03	-01.03	0.00	0.00

E V H T F RESULTS : 22-PMR-77 PAGE NO. 43 09A 25MPH 3/15 --1																
ELAPSED	BATT	BATT	NOT	NOT	BATT	BATT	NOT	NOT	FIFTH	DEG.C	DEG.C	DEG.C	DEG.C	INVTD	INVTD	FIXED
TIME	VOLT	VOLT	VOLT	VOLT	VOLT	VOLT	VOLT	VOLT	UNFIL	UNFIL	UNFIL	UNFIL	UNFIL	APP	APP	CEL-
MIN SEC	1	2	3	4	5	6	7	8	9	0	1	2	3	14	15	16
56 136.4	120.2	119.6	104.2	87.2	41.8	68.8	63.3	70.1	25.87	20.1	53.33	-01.03	-01.03	0.00	0.00	5.000
56 133.6	120.9	119.6	113.0	87.1	45.8	68.8	63.3	69.7	25.38	20.1	53.26	-01.03	-01.03	0.00	0.00	5.000
56 136.0	118.4	119.6	95.0	87.2	70.5	57.4	82.3	64.3	25.01	19.94	53.26	-01.03	-01.03	0.00	0.00	5.000
56 140.0	120.1	120.3	98.4	81.6	37.1	71.7	62.0	62.0	25.00	20.27	53.27	-01.03	-01.03	0.00	0.00	5.000
56 142.8	121.4	120.3	119.5	81.2	38.6	51.6	43.4	62.1	24.92	20.23	53.19	-01.03	-01.03	0.00	0.00	5.000
56 146.2	122.1	120.3	45.9	80.5	43.8	58.5	35.2	61.7	25.54	20.21	53.15	-01.03	-01.03	0.00	0.00	5.000
56 149.4	121.0	120.4	44.9	81.0	63.3	50.5	61.4	61.4	24.89	20.23	53.11	-01.03	-01.03	0.00	0.00	5.000
56 152.0	119.9	121.0	53.0	71.3	67.4	48.4	79.9	52.9	24.89	20.23	53.11	-01.03	-01.03	0.00	0.00	5.000
56 155.6	121.4	120.7	110.2	77.2	28.9	49.3	31.9	62.1	23.98	20.23	53.00	-01.03	-01.03	0.00	0.00	5.000
56 158.0	119.2	119.9	54.9	84.6	82.3	57.9	54.2	68.1	24.79	20.25	52.98	-01.03	-01.03	0.00	0.00	5.000
57 1.0	118.0	119.0	92.7	83.5	82.1	57.9	97.4	70.1	23.54	20.25	52.97	-01.03	-01.03	0.00	0.00	5.000
57 1.3	117.6	119.0	90.7	83.2	83.7	58.0	54.9	70.1	23.26	20.29	52.93	-01.03	-01.03	0.00	0.00	5.000
57 1.11.2	119.4	119.0	32.0	85.5	71.0	57.9	53.0	65.1	24.31	20.27	52.92	-01.03	-01.03	0.00	0.00	5.000
57 1.14.4	123.1	122.2	30.0	53.3	13.0	25.2	19.3	37.3	24.56	20.29	52.61	-01.03	-01.03	0.00	0.00	5.000
57 1.17.6	123.7	122.4	1.2	52.7	13.1	26.4	20.5	46.7	24.76	20.32	52.51	-01.03	-01.03	0.00	0.00	5.000
57 1.20.0	122.7	122.3	59.2	55.8	14.0	29.4	40.7	46.2	24.35	20.29	52.47	-01.03	-01.03	0.00	0.00	5.000
57 1.23.0	120.7	121.2	87.4	71.4	54.7	42.1	83.7	55.1	23.42	20.29	52.36	-01.03	-01.03	0.00	0.00	5.000
57 1.26.0	121.1	121.0	41.0	71.0	23.1	39.1	23.9	56.1	24.80	20.32	52.26	-01.03	-01.03	0.00	0.00	5.000
57 1.30.2	120.4	121.4	85.0	67.6	60.9	37.1	50.9	49.5	25.76	20.29	52.19	-01.03	-01.03	0.00	0.00	5.000
57 1.33.2	123.3	123.4	19.5	34.3	7.1	13.3	12.7	22.3	24.99	20.29	52.05	-01.03	-01.03	0.00	0.00	5.000
57 1.36.4	121.7	122.6	82.9	54.0	13.0	28.1	21.6	42.1	24.98	20.29	51.90	-01.03	-01.03	0.00	0.00	5.000
57 1.39.6	121.6	122.1	84.3	58.0	28.5	38.3	63.1	44.1	24.29	20.29	51.91	-01.03	-01.03	0.00	0.00	5.000
57 1.42.0	121.4	122.1	21.5	59.0	34.5	38.2	27.2	43.7	24.33	20.29	51.88	-01.03	-01.03	0.00	0.00	5.000
57 1.45.2	121.9	122.0	63.5	59.4	37.4	38.3	73.3	43.4	24.91	20.29	51.73	-01.03	-01.03	0.00	0.00	5.000
57 1.48.0	122.0	123.3	29.9	44.1	9.1	14.8	12.3	21.7	25.48	20.29	51.63	-01.03	-01.03	0.00	0.00	5.000
57 1.52.2	123.3	123.5	68.6	34.7	12.8	13.6	49.2	27.9	24.75	20.32	51.51	-01.03	-01.03	0.00	0.00	5.000
57 1.55.6	123.6	123.8	69.9	35.9	12.9	13.7	49.2	27.9	24.75	20.32	51.51	-01.03	-01.03	0.00	0.00	5.000
57 1.58.2	123.9	122.6	32.1	50.9	13.2	24.0	19.9	38.9	23.82	20.36	51.45	-01.03	-01.03	0.00	0.00	5.000
58 1.4	123.4	122.6	20.0	51.1	37.3	24.1	32.1	39.3	24.82	20.36	51.38	-01.03	-01.03	0.00	0.00	5.000
58 1.6	122.1	122.1	19.5	49.1	35.5	25.0	25.0	35.0	24.82	20.36	51.31	-01.03	-01.03	0.00	0.00	5.000
58 1.8	121.7	122.0	12.0	56.1	38.0	38.5	45.1	45.1	23.97	20.36	51.31	-01.03	-01.03	0.00	0.00	5.000
58 1.10.0	122.0	122.0	30.4	39.4	33.6	31.6	31.0	41.1	24.38	20.36	51.20	-01.03	-01.03	0.00	0.00	5.000
58 1.14.0	121.8	121.9	35.8	60.7	31.1	32.4	24.4	46.4	24.43	20.36	51.31	-01.03	-01.03	0.00	0.00	5.000
58 1.17.2	122.4	121.8	35.8	60.7	31.1	32.4	24.4	46.4	24.43	20.36	51.31	-01.03	-01.03	0.00	0.00	5.000
58 1.20.0	121.8	121.8	65.5	62.1	22.4	43.1	43.2	47.7	24.92	20.42	51.31	-01.03	-01.03	0.00	0.00	5.000
58 1.23.6	121.0	121.0	19.6	67.3	45.3	27.8	68.6	46.4	25.20	20.36	51.31	-01.03	-01.03	0.00	0.00	5.000
58 1.26.6	121.9	121.0	33.3	62.2	47.5	27.7	73.3	46.4	24.68	20.36	51.35	-01.03	-01.03	0.00	0.00	5.000
58 1.29.7	122.6	121.9	22.0	62.2	47.5	27.7	73.3	46.4	24.68	20.36	51.35	-01.03	-01.03	0.00	0.00	5.000
58 1.33.0	122.6	121.9	22.0	62.2	47.5	27.7	73.3	46.4	24.68	20.36	51.35	-01.03	-01.03	0.00	0.00	5.000
58 1.36.2	122.1	121.0	77.4	44.7	9.9	19.2	17.1	3.0	25.17	20.34	51.35	-01.03	-01.03	0.00	0.00	5.000
58 1.39.7	123.5	123.0	26.5	44.3	15.6	19.1	37.5	3.4	25.18	20.36	51.35	-01.03	-01.03	0.00	0.00	5.000
58 1.42.9	123.3	123.3	26.5	44.3	15.6	19.1	37.5	3.4	25.18	20.36	51.35	-01.03	-01.03	0.00	0.00	5.000
58 1.45.6	122.9	123.0	26.1	44.9	15.6	19.1	37.5	3.4	25.18	20.36	51.35	-01.03	-01.03	0.00	0.00	5.000

Table 6.1.9. Samples of Data Printout for Test No. 10 (35 mph)

E V N T F RESULTS : 20-PR-77 PAGE NO. 2 010 33PM BPT 3/16

ELAPSED TIME	BATT VOLT UNFIL	BATT VOLT FIL	POT VOLT UNFIL	POT VOLT FIL	BATT AMP UNFIL	BATT AMP FIL	POT AMP UNFIL	POT AMP FIL	FIFTH WHEEL RPH	DEG.C FRONT	DEG.C REAR	DEG.C BATT	DEG.C BATT	INVTB RPH UNFIL	INVTB RPH FIL	FIXED CAL-BIRTH
MIN SEC	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
2:11.0	120.0	121.0	100.0	94.7	70.3	62.2	100.2	91.2	35.04	10.39	21.76	-91.03	-91.03	0.00	0.00	5.000
2:11.4	122.6	121.0	100.0	94.7	69.6	62.6	60.9	91.1	35.15	10.37	22.00	-91.03	-91.03	0.00	0.00	5.000
2:11.8	121.0	120.9	111.0	94.5	100.2	62.2	101.4	91.0	35.62	10.39	21.97	-91.03	-91.03	0.00	0.00	5.000
2:12.2	122.5	120.9	105.6	94.7	101.4	62.2	99.8	91.1	34.60	10.42	21.97	-91.03	-91.03	0.00	0.00	5.000
2:12.6	120.4	120.9	107.6	94.7	63.7	62.5	91.2	91.7	35.55	10.42	21.94	-91.03	-91.03	0.00	0.00	5.000
2:12.7	121.5	121.4	99.2	91.1	65.6	73.0	91.7	91.7	34.05	10.39	21.96	-91.03	-91.03	0.00	0.00	5.000
2:13.0	120.1	121.4	99.7	91.0	52.7	75.0	63.3	93.9	36.06	10.37	22.00	-91.03	-91.03	0.00	0.00	5.000
2:13.4	121.0	121.4	104.0	90.7	53.0	75.0	63.4	90.0	35.15	10.39	22.05	-91.03	-91.03	0.00	0.00	5.000
2:13.6	120.1	121.4	90.3	90.3	55.0	75.5	85.1	85.2	35.16	10.37	22.07	-91.03	-91.03	0.00	0.00	5.000
2:13.9	122.0	121.4	47.5	90.0	79.5	75.5	71.0	83.1	34.60	10.39	22.11	-91.03	-91.03	0.00	0.00	5.000
2:14.2	121.3	121.2	42.2	89.2	100.0	76.0	104.5	87.7	34.32	10.42	22.22	-91.03	-91.03	0.00	0.00	5.000
2:14.6	119.6	121.2	95.1	90.1	107.0	77.7	115.0	82.9	35.00	10.42	22.22	-91.03	-91.03	0.00	0.00	5.000
2:14.9	121.5	121.4	50.6	89.0	70.2	61.5	91.7	91.7	33.61	10.35	22.27	-91.03	-91.03	0.00	0.00	5.000
2:15.1	120.5	119.6	109.6	102.0	104.5	109.0	119.0	113.3	34.63	10.37	22.29	-91.03	-91.03	0.00	0.00	5.000
2:15.4	120.3	119.6	107.6	96.5	90.5	82.1	104.9	90.2	34.73	10.39	22.33	-91.03	-91.03	0.00	0.00	5.000
2:15.8	120.6	120.0	103.3	94.9	100.4	82.3	96.7	91.0	35.24	10.35	22.38	-91.03	-91.03	0.00	0.00	5.000
3:0.6	121.7	120.9	100.0	94.4	103.2	82.2	99.0	92.1	34.01	10.31	22.40	-91.03	-91.03	0.00	0.00	5.000
3:1.3	120.1	120.3	105.5	101.4	112.7	100.7	100.3	100.6	35.27	10.46	22.51	-91.03	-91.03	0.00	0.00	5.000
3:1.6	118.5	121.0	117.4	75.4	102.9	106.7	119.7	100.4	35.37	10.35	22.42	-91.03	-91.03	0.00	0.00	5.000
3:10.0	119.4	119.2	100.0	100.6	96.3	107.7	116.0	109.3	35.27	10.35	22.44	-91.03	-91.03	0.00	0.00	5.000
3:13.2	122.1	122.1	25.6	71.5	22.5	43.2	73.7	73.7	36.01	10.35	22.44	-91.03	-91.03	0.00	0.00	5.000
3:16.0	124.0	123.6	67.7	67.6	35.5	42.5	29.3	56.1	35.50	10.46	22.46	-91.03	-91.03	0.00	0.00	5.000
3:19.2	122.0	123.7	39.6	67.1	42.7	42.7	81.9	51.5	35.20	10.31	22.46	-91.03	-91.03	0.00	0.00	5.000
3:22.4	123.0	123.7	30.1	66.5	21.5	42.5	73.0	73.0	34.05	10.31	22.46	-91.03	-91.03	0.00	0.00	5.000
3:25.6	124.7	123.0	90.0	90.0	46.7	57.4	57.4	57.4	35.00	10.31	22.42	-91.03	-91.03	0.00	0.00	5.000
3:27.0	124.4	123.0	100.1	78.2	71.0	53.7	51.6	69.1	33.77	10.39	22.49	-91.03	-91.03	0.00	0.00	5.000
3:11.1	121.5	123.0	42.1	75.4	35.5	54.7	101.9	69.1	33.06	10.37	22.42	-91.03	-91.03	0.00	0.00	5.000
3:13.4	122.4	123.0	27.0	75.6	20.0	54.0	60.7	60.9	34.17	10.33	22.46	-91.03	-91.03	0.00	0.00	5.000
3:13.7	122.0	123.0	38.1	75.0	33.3	54.5	54.5	54.5	34.69	10.35	22.51	-91.03	-91.03	0.00	0.00	5.000
3:14.0	124.3	122.9	93.7	75.0	73.6	55.0	68.1	69.3	34.76	10.31	22.49	-91.03	-91.03	0.00	0.00	5.000
3:14.3	121.2	122.6	116.6	77.0	70.5	54.0	41.0	71.1	34.26	10.37	22.55	-91.03	-91.03	0.00	0.00	5.000
3:14.6	121.6	122.7	105.4	76.9	62.9	56.0	74.7	71.2	33.06	10.37	22.55	-91.03	-91.03	0.00	0.00	5.000
3:14.9	124.0	122.7	92.2	76.9	41.5	56.9	93.5	71.1	34.06	10.35	22.55	-91.03	-91.03	0.00	0.00	5.000
3:15.2	123.7	122.6	38.6	76.9	55.1	56.0	40.1	71.4	34.60	10.39	22.75	-91.03	-91.03	0.00	0.00	5.000
3:15.5	123.0	122.7	92.5	76.9	29.0	56.9	95.2	71.2	34.93	10.44	22.62	-91.03	-91.03	0.00	0.00	5.000
3:15.8	123.9	122.7	90.4	77.0	29.5	57.1	62.7	71.0	34.36	10.35	22.60	-91.03	-91.03	0.00	0.00	5.000
4:1.3	124.7	122.7	23.0	77.4	53.0	57.2	56.3	71.4	33.90	10.39	22.64	-91.03	-91.03	0.00	0.00	5.000
4:1.5	121.0	122.6	43.3	77.3	82.1	57.5	70.7	71.4	34.76	10.37	22.71	-91.03	-91.03	0.00	0.00	5.000
4:1.8	121.0	122.6	116.6	77.0	71.0	57.4	95.7	71.4	34.06	10.37	22.75	-91.03	-91.03	0.00	0.00	5.000
4:11.4	121.0	122.5	94.4	77.0	38.5	57.7	105.5	71.6	34.05	10.40	22.79	-91.03	-91.03	0.00	0.00	5.000
4:11.6	123.0	122.6	91.0	78.0	37.0	57.0	40.3	71.6	35.20	10.31	22.77	-91.03	-91.03	0.00	0.00	5.000
4:17.6	122.4	122.6	46.2	78.2	89.5	57.7	57.0	71.4	34.32	10.37	22.84	-91.03	-91.03	0.00	0.00	5.000
4:18.0	123.1	122.6	89.6	78.3	38.4	57.7	52.5	71.5	34.92	10.37	22.86	-91.03	-91.03	0.00	0.00	5.000
4:24.9	121.7	122.6	110.0	78.3	51.6	50.1	104.7	71.7	35.04	10.37	22.84	-91.03	-91.03	0.00	0.00	5.000

E V N T F RESULTS : 20-PR-77 PAGE NO. 10										010 CONT'D 3/16							
ELAPSED TIME		BATT VOLT UNFIL	BATT VOLT FIL	POT VOLT UNFIL	POT VOLT FIL	BATT AMP UNFIL	BATT AMP FIL	POT AMP UNFIL	POT AMP FIL	FIFTH WHEEL RPH	DEG.C FRONT	DEG.C REAR	DEG.C BATT	DEG.C REAR	INVTB RPH UNFIL	INVTB RPH FIL	FIXED CP-1 BIRTH
MIN	SEC	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
20:123.0	57.0	97.0	97.0	87.5	87.2	75.2	79.7	71.4	81.1	34.12	16.74	47.42	-91.03	-91.03	0.00	0.00	5.000
20:127.0	90.3	91.6	91.6	72.1	87.2	75.3	80.0	85.6	81.2	34.00	16.89	47.71	-91.03	-91.03	0.00	0.00	5.000
20:129.0	96.9	97.3	97.3	89.7	86.6	76.6	79.7	75.7	81.2	34.02	16.74	47.67	-91.03	-91.03	0.00	0.00	5.000
20:133.0	97.6	96.9	96.9	89.9	86.0	70.9	79.9	90.1	81.4	34.25	16.74	47.74	-91.03	-91.03	0.00	0.00	5.000
20:136.2	97.1	96.6	96.6	92.5	85.9	84.0	79.9	87.5	81.4	33.97	16.76	47.00	-91.03	-91.03	0.00	0.00	5.000
20:139.4	96.4	96.3	96.3	94.2	85.6	86.6	80.0	87.5	81.4	33.15	16.72	47.90	-91.03	-91.03	0.00	0.00	5.000
20:141.0	96.0	95.9	95.9	92.5	85.4	86.6	80.0	87.5	81.4	33.96	16.67	47.90	-91.03	-91.03	0.00	0.00	5.000
20:143.0	96.0	95.9	95.9	92.5	85.4	86.6	80.0	87.5	81.4	33.96	16.67	47.90	-91.03	-91.03	0.00	0.00	5.000
20:144.4	95.1	95.3	95.3	86.3	85.0	83.1	79.9	85.7	81.1	33.50	16.67	40.09	-91.03	-91.03	0.00	0.00	5.000
20:151.6	94.9	95.0	95.0	87.5	84.6	83.2	79.7	86.3	81.0	32.82	16.74	40.18	-91.03	-91.03	0.00	0.00	5.000
20:154.4	94.4	94.7	94.7	86.4	84.1	82.0	79.7	80.1	81.3	32.46	16.72	40.25	-91.03	-91.03	0.00	0.00	5.000
20:157.6	94.0	94.4	94.4	89.6	83.3	82.1	79.9	87.0	81.3	32.10	16.72	40.20	-91.03	-91.03	0.00	0.00	5.000
21:0.0	93.0	94.1	94.1	85.0	82.0	75.5	80.1	91.0	82.3	30.30	16.82	40.35	-91.03	-91.03	0.00	0.00	5.000
21:4.0	94.5	93.0	93.0	87.0	82.3	70.7	80.1	85.7	82.3	30.47	16.72	40.38	-91.03	-91.03	0.00	0.00	5.000
21:7.0	93.0	94.1	94.1	81.7	81.7	85.5	80.7	76.4	82.7	29.72	16.72	40.41	-91.03	-91.03	0.00	0.00	5.000
21:10.0	93.3	93.0	93.0	84.9	82.2	84.4	80.9	91.4	82.6	31.03	16.72	40.47	-91.03	-91.03	0.00	0.00	5.000
21:13.2	91.9	92.7	92.7	89.0	82.5	76.6	81.1	85.7	82.5	31.47	16.72	40.51	-91.03	-91.03	0.00	0.00	5.000
21:16.4	92.3	92.3	92.3	84.0	81.9	87.7	81.0	73.2	82.8	32.13	16.62	40.44	-91.03	-91.03	0.00	0.00	5.000
21:19.4	91.9	92.0	92.0	82.9	82.0	76.9	81.0	85.0	82.2	31.8	16.72	40.54	-91.03	-91.03	0.00	0.00	5.000
21:22.4	91.9	91.5	91.5	82.6	81.3	77.4	82.6	89.2	84.2	31.36	16.65	40.54	-91.03	-91.03	0.00	0.00	5.000
21:25.6	91.2	91.1	91.1	69.3	80.7	82.0	83.1	93.9	85.2	30.42	15.74	40.60	-91.03	-91.03	0.00	0.00	5.000
21:28.0	91.4	90.6	90.6	82.0	80.0	79.5	83.0	80.2	84.0	31.56	16.72	40.57	-91.03	-91.03	0.00	0.00	5.000
21:31.6	90.5	90.0	90.0	80.0	83.0	81.6	84.6	87.5	83.6	32.09	16.69	40.51	-91.03	-91.03	0.00	0.00	5.000
21:34.6	89.0	89.6	89.6	87.1	84.2	80.4	85.9	83.2	83.0	32.26	16.87	40.47	-91.03	-91.03	0.00	0.00	5.000
21:37.0	88.5	89.0	89.0	87.0	83.2	84.5	86.4	83.7	82.7	32.00	16.72	40.31	-91.03	-91.03	0.00	0.00	5.000
21:41.0	89.9	88.5	88.5	85.9	86.3	86.4	86.4	81.3	81.5	33.44	16.72	40.12	-91.03	-91.03	0.00	0.00	5.000
21:44.0	89.9	89.9	89.9	85.9	86.3	86.4	86.4	81.3	81.5	33.44	16.72	40.12	-91.03	-91.03	0.00	0.00	5.000
21:46.4	89.9	89.7	89.7	89.0	82.3	73.2	75.7	47.0	56.2	34.79	16.74	47.71	-91.03	-91.03	0.00	0.00	5.000
21:49.6	93.5	75.0	75.0	89.6	67.0	44.3	40.4	70.1	56.0	33.79	16.74	47.39	-91.03	-91.03	0.00	0.00	5.000
21:52.0	94.6	95.3	95.3	93.0	87.0	47.0	40.7	70.4	57.3	32.00	16.74	47.23	-91.03	-91.03	0.00	0.00	5.000
21:55.0	95.9	95.9	95.9	93.0	87.0	47.0	40.7	70.4	57.3	32.00	16.74	47.23	-91.03	-91.03	0.00	0.00	5.000
21:59.0	96.0	95.6	95.6	96.4	86.9	53.3	49.1	74.3	56.2	32.75	16.74	46.73	-91.03	-91.03	0.00	0.00	5.000
22:2.2	97.0	95.7	95.7	95.0	86.6	49.9	49.2	55.0	56.0	32.65	16.72	46.51	-91.03	-91.03	0.00	0.00	5.000
22:5.4	97.6	95.0	95.0	79.6	66.0	46.3	49.5	61.0	54.9	32.52	16.69	46.38	-91.03	-91.03	0.00	0.00	5.000
22:8.6	96.0	95.3	95.3	75.0	62.0	46.3	49.5	61.0	54.9	32.52	16.69	46.38	-91.03	-91.03	0.00	0.00	5.000
22:11.6	94.5	95.0	95.0	67.0	65.5	53.7	49.5	57.0	59.0	32.19	16.69	45.90	-91.03	-91.03	0.00	0.00	5.000
22:14.0	95.9	95.0	95.0	70.1	65.6	47.1	49.0	65.0	59.9	32.12	16.72	45.07	-91.03	-91.03	0.00	0.00	5.000
22:17.0	96.6	95.0	95.0	81.7	63.2	51.0	49.5	65.0	59.9	32.12	16.72	45.07	-91.03	-91.03	0.00	0.00	5.000
22:20.0	97.1	95.3	95.3	81.7	63.2	51.0	49.5	65.0	59.9	32.12	16.72	45.07	-91.03	-91.03	0.00	0.00	5.000
22:24.0	99.4	80.0	80.0	85.5	85.7	92.6	92.2	86.3	87.0	31.56	16.65	45.37	-91.03	-91.03	0.00	0.00	5.000
22:27.2	97.6	97.6	97.6	85.6	85.1	80.0	88.4	81.3	82.1	33.13	16.69	45.54	-91.03	-91.03	0.00	0.00	5.000
22:30.4	97.3	97.3	97.3	86.5	85.3	86.6	85.9	80.5	81.0	33.02	16.72	45.51	-91.03	-91.03	0.00	0.00	5.000
22:33.2	97.3	97.3	97.3	88.0	88.2	84.2	84.0	89.2	82.0	34.16	16.69	45.41	-91.03	-91.03	0.00	0.00	5.000
22:36.0	99.3	99.9	99.9	78.6	74.9	84.1	81.6	50.0	65.9	33.35	16.69	45.35	-91.03	-91.03	0.00	0.00	5.000

Table 6.1.10. Samples of Data Printout for Test No. 11 (45 mph)

RESULTS 1 20-PM-77 PAGE NO. 2 #11 45MPH RPT 3-17															
ELAPSED	BATT	BATT	FOT	FOT	BATT	BATT	FOT	FOT	FIFTH	DEC. C	DEC. C	DEC. C	DEC. C	INVT	INVT
TIME	VOLT	VOLT	VOLT	VOLT	VOLT	VOLT	VOLT	VOLT	WHEEL	WHEEL	WHEEL	WHEEL	WHEEL	WHEEL	WHEEL
MIN SEC	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2 112.2	119.8	110.2	101.5	101.5	144.1	127.1	116.8	125.5	43.39	10.66	20.40	-91.03	-91.03	0.00	0.00
2 115.2	117.0	117.0	112.0	103.1	140.4	120.9	117.5	125.4	43.79	10.70	20.40	-91.03	-91.03	0.00	0.00
2 118.4	119.6	117.9	109.4	104.3	130.7	130.3	136.0	135.9	43.24	10.63	20.45	-91.03	-91.03	0.00	0.00
2 121.6	118.0	119.5	115.0	93.9	112.6	88.1	84.9	101.2	43.91	10.66	20.53	-91.03	-91.03	0.00	0.00
2 124.8	119.5	120.5	99.0	100.0	103.7	93.0	70.4	106.2	47.35	10.61	20.56	-91.03	-91.03	0.00	0.00
2 127.0	116.4	116.0	110.0	109.5	153.4	150.9	140.9	149.0	44.09	10.66	20.50	-91.03	-91.03	0.00	0.00
2 131.0	122.5	121.1	90.7	93.4	89.6	107.0	116.4	121.9	43.44	10.61	20.62	-91.03	-91.03	0.00	0.00
2 134.2	120.9	119.0	104.6	99.9	106.7	113.1	104.7	122.9	44.20	10.61	20.67	-91.03	-91.03	0.00	0.00
2 137.4	117.0	119.0	100.9	100.5	100.0	114.1	101.2	123.3	43.73	10.63	20.67	-91.03	-91.03	0.00	0.00
2 140.6	120.7	118.9	104.9	100.3	124.6	113.7	120.4	123.3	44.03	10.55	20.69	-91.03	-91.03	0.00	0.00
2 143.8	117.0	110.9	106.5	100.5	105.7	114.1	110.2	123.3	43.50	10.53	20.67	-91.03	-91.03	0.00	0.00
2 146.0	118.0	110.9	107.3	100.0	111.7	114.5	121.0	123.5	44.52	10.57	20.82	-91.03	-91.03	0.00	0.00
2 150.0	119.1	110.9	101.2	101.2	105.0	115.5	100.0	125.0	44.54	10.46	20.73	-91.03	-91.03	0.00	0.00
2 152.1	117.6	110.0	104.2	101.4	135.5	116.0	139.0	124.2	44.26	10.42	20.73	-91.03	-91.03	0.00	0.00
2 156.0	116.6	110.0	104.9	101.1	136.6	116.0	117.1	124.6	43.91	10.44	20.80	-91.03	-91.03	0.00	0.00
2 159.2	119.9	110.0	111.2	101.0	101.9	115.5	127.0	124.3	44.03	10.46	20.77	-91.03	-91.03	0.00	0.00
3 0 0	120.7	110.0	100.0	100.0	105.0	115.5	127.0	125.0	43.67	10.44	20.77	-91.03	-91.03	0.00	0.00
3 0 0	110.0	110.0	100.0	100.0	105.0	115.5	127.0	125.0	44.52	10.37	20.84	-91.03	-91.03	0.00	0.00
3 0 0	110.0	110.0	100.0	100.0	105.0	115.5	127.0	125.0	44.13	10.33	20.86	-91.03	-91.03	0.00	0.00
3 0 0	110.0	110.0	100.0	100.0	105.0	115.5	127.0	125.0	43.03	10.35	20.80	-91.03	-91.03	0.00	0.00
3 0 0	110.0	110.0	100.0	100.0	105.0	115.5	127.0	125.0	43.06	10.35	20.91	-91.03	-91.03	0.00	0.00
3 0 0	110.0	110.0	100.0	100.0	105.0	115.5	127.0	125.0	44.00	10.33	20.95	-91.03	-91.03	0.00	0.00
3 0 0	110.0	110.0	100.0	100.0	105.0	115.5	127.0	125.0	42.51	10.31	20.95	-91.03	-91.03	0.00	0.00
3 0 0	110.0	110.0	100.0	100.0	105.0	115.5	127.0	125.0	42.00	10.33	20.97	-91.03	-91.03	0.00	0.00
3 0 0	110.0	110.0	100.0	100.0	105.0	115.5	127.0	125.0	43.00	10.35	20.96	-91.03	-91.03	0.00	0.00
3 0 0	110.0	110.0	100.0	100.0	105.0	115.5	127.0	125.0	44.29	10.35	21.02	-91.03	-91.03	0.00	0.00
3 0 0	110.0	110.0	100.0	100.0	105.0	115.5	127.0	125.0	44.29	10.37	21.04	-91.03	-91.03	0.00	0.00
3 0 0	110.0	110.0	100.0	100.0	105.0	115.5	127.0	125.0	43.53	10.35	21.00	-91.03	-91.03	0.00	0.00
3 0 0	110.0	110.0	100.0	100.0	105.0	115.5	127.0	125.0	43.64	10.35	21.00	-91.03	-91.03	0.00	0.00
3 0 0	110.0	110.0	100.0	100.0	105.0	115.5	127.0	125.0	44.13	10.31	21.04	-91.03	-91.03	0.00	0.00
3 0 0	110.0	110.0	100.0	100.0	105.0	115.5	127.0	125.0	42.54	10.37	21.12	-91.03	-91.03	0.00	0.00
3 0 0	110.0	110.0	100.0	100.0	105.0	115.5	127.0	125.0	43.14	10.39	21.15	-91.03	-91.03	0.00	0.00
3 0 0	110.0	110.0	100.0	100.0	105.0	115.5	127.0	125.0	43.64	10.44	21.30	-91.03	-91.03	0.00	0.00
3 0 0	110.0	110.0	100.0	100.0	105.0	115.5	127.0	125.0	44.11	10.42	21.26	-91.03	-91.03	0.00	0.00
3 0 0	110.0	110.0	100.0	100.0	105.0	115.5	127.0	125.0	43.40	10.39	21.19	-91.03	-91.03	0.00	0.00
3 0 0	110.0	110.0	100.0	100.0	105.0	115.5	127.0	125.0	44.34	10.42	21.23	-91.03	-91.03	0.00	0.00
3 0 0	110.0	110.0	100.0	100.0	105.0	115.5	127.0	125.0	44.29	10.44	21.30	-91.03	-91.03	0.00	0.00
3 0 0	110.0	110.0	100.0	100.0	105.0	115.5	127.0	125.0	43.07	10.42	21.32	-91.03	-91.03	0.00	0.00
3 0 0	110.0	110.0	100.0	100.0	105.0	115.5	127.0	125.0	43.65	10.59	21.43	-91.03	-91.03	0.00	0.00
3 0 0	110.0	110.0	100.0	100.0	105.0	115.5	127.0	125.0	44.20	10.26	21.37	-91.03	-91.03	0.00	0.00
3 0 0	110.0	110.0	100.0	100.0	105.0	115.5	127.0	125.0	44.06	10.40	21.40	-91.03	-91.03	0.00	0.00
3 0 0	110.0	110.0	100.0	100.0	105.0	115.5	127.0	125.0	43.75	10.50	21.45	-91.03	-91.03	0.00	0.00
3 0 0	110.0	110.0	100.0	100.0	105.0	115.5	127.0	125.0	44.26	10.40	21.54	-91.03	-91.03	0.00	0.00
3 0 0	110.0	110.0	100.0	100.0	105.0	115.5	127.0	125.0	43.74	10.35	21.54	-91.03	-91.03	0.00	0.00

RESULTS 1 20-PM-77 PAGE NO. 37 #11 45MPH RPT 3-17																
E V M Y F	BATT	BATT	FOT	FOT	BATT	BATT	FOT	FOT	FIFTH	DEC. C	DEC. C	DEC. C	DEC. C	INVT	INVT	FINED
TIME	VOLT	VOLT	VOLT	VOLT	VOLT	VOLT	VOLT	VOLT	WHEEL	WHEEL	WHEEL	WHEEL	WHEEL	WHEEL	WHEEL	WHEEL
MIN SEC	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
02 159.2	104.9	104.9	94.3	90.3	83.3	94.7	104.1	97.4	43.34	10.06	43.06	-91.03	-91.03	0.00	0.00	5.00%
03 1 2.2	104.5	104.1	95.2	90.4	83.3	94.6	102.3	100.0	43.21	10.03	43.00	-91.03	-91.03	0.00	0.00	5.00%
03 1 5.4	104.2	103.8	94.5	90.6	79.0	100.2	110.9	107.2	42.92	10.13	42.14	-91.03	-91.03	0.00	0.00	5.00%
03 1 8.6	102.8	102.7	97.5	93.2	104.6	106.1	105.1	111.9	42.74	10.17	43.23	-91.03	-91.03	0.00	0.00	5.00%
03 1 11.0	100.0	100.0	97.5	93.2	121.2	120.0	116.3	117.5	42.41	10.17	43.20	-91.03	-91.03	0.00	0.00	5.00%
03 1 14.6	99.9	100.2	97.7	96.9	119.0	119.6	114.0	111.5	43.00	10.23	43.26	-91.03	-91.03	0.00	0.00	5.00%
03 1 17.0	99.8	99.7	97.3	97.7	110.9	110.1	113.2	112.4	47.06	10.21	43.20	-91.03	-91.03	0.00	0.00	5.00%
03 1 21.0	99.6	99.3	94.7	96.3	117.0	117.9	112.2	112.9	42.42	10.30	43.20	-91.03	-91.03	0.00	0.00	5.00%
03 1 24.2	99.8	98.9	94.7	94.2	117.1	117.0	111.1	111.9	42.51	10.26	43.14	-91.03	-91.03	0.00	0.00	5.00%
03 1 27.2	99.2	99.5	99.9	95.6	117.2	116.3	111.1	111.1	41.96	10.23	43.09	-91.03	-91.03	0.00	0.00	5.00%
03 1 30.4	99.1	99.0	93.0	93.2	116.6	116.6	110.6	111.1	42.40	10.32	43.23	-91.03	-91.03	0.00	0.00	5.00%
03 1 33.6	97.9	97.6	94.2	94.6	116.0	116.1	110.1	110.3	42.36	10.23	43.00	-91.03	-91.03	0.00	0.00	5.00%
03 1 36.0	97.3	97.2	92.9	94.2	115.0	115.9	111.0	111.0	41.72	10.19	42.97	-91.03	-91.03	0.00	0.00	5.00%
03 1 39.0	96.1	96.6	93.5	93.7	115.5	115.2	110.0	111.4	41.97	10.15	42.97	-91.03	-91.03	0.00	0.00	5.00%
03 1 43.0	96.5	96.2	91.9	93.3	114.6	115.1	110.0	107.0	42.65	10.13	42.91	-91.03	-91.03	0.00	0.00	5.00%
03 1 46.2	96.1	96.0	93.0	93.0	115.2	114.9	110.2	107.0	41.72	10.04	42.89	-91.03	-91.03	0.00	0.00	5.00%
03 1 49.4	95.1	95.3	93.0	92.6	114.1	114.0	110.2	107.0	41.31	10.04	42.97	-91.03	-91.03	0.00	0.00	5.00%
03 1 52.4	94.7	95.0	92.4	92.0	115.0	114.1	109.0	107.0	41.54	10.01	42.89	-91.03	-91.03	0.00	0.00	5.00%
03 1 55.6	94.7	94.6	91.5	91.0	114.1	113.6	100.2	100.9	41.40	10.04	42.91	-91.03	-91.03	0.00	0.00	5.00%
03 1 58.0	94.4	94.2	92.3	91.4	113.1	113.7	107.5	106.7	41.76	10.05	42.91	-91.03	-91.03	0.00	0.00	5.00%
04 0 0.0	94.1	93.7	90.5	90.9	114.4	114.5	111.1	107.1	40.51	10.04	42.91	-91.03	-91.03	0.00	0.00	5.00%
04 0 3.0	93.1	93.3	91.4	91.4	114.7	114.5	111.1	107.1	40.51	10.04	42.91	-91.03	-91.03	0.00	0.00	5.00%
04 0 6.0	92.7	92.6	90.5	90.7	114.7	114.4	109.7	110.0	39.69	10.04	42.86	-91.03	-91.03	0.00	0.00	5.00%
04 0 9.0	92.5	92.2	88.4	89.2	114.0	114.9	109.7	107.7	39.97	10.04	42.83	-91.03	-91.03	0.00	0.00	5.00%
04 0 12.0	92.2	91.9	88.0	88.9	112.9	113.3	109.0	107.0	39.32	10.04	42.86	-91.03	-91.03	0.00	0.00	5.00%
04 0 15.0	91.6	91.2	90.0	89.9	114.4	114.9	110.1	110.5	37.75	10.05	42.83	-91.03	-91.03	0.00	0.00	5.00%
04 0 18.0	90.2	90.2	88.0	87.9	114.0	114.4	109.7	107.0	37.96	10.04	42.83	-91.03	-91.03	0.00	0.00	5.00%
04 0 21.0	89.6	89.3	87.9	87.5	116.4	116.6	111.4	111.4	37.00	10.05	42.97	-91.03	-91.03	0.00	0.00	5.00%
04 0 24.0	89.3	89.3	86.5	86.5	116.5	115.5	110.2	111.0	36.00	10.00	43.03	-91.03	-91.03	0.00	0.00	5.00%
04 0 27.0	89.2	89.4	87.9	86.7	111.9	111.0	106.7	107.0	35.23	10.02	43.20	-91.03	-91.03	0.00	0.00	5.00%
04 0 30.0	89.9	89.9	87.9	86.7	116.4	116.4	109.7	107.0	35.03	10.03	43.03	-91.03	-91.03	0.00	0.00	5.00%
04 0 33.0	89.4	89.4	87.4	87.4	109.5	109.9	109.7	107.1	34.00	10.06	43.26	-91.03	-91.03	0.00	0.00	5.00%
04 0 36.0	86.4	86.4	80.0	80.0	75.2	82.2	83.6	7.0	41.27	0.00	43.23	-91.03	-91.03	0.00	0.00	5.00%
04 0 39.0	86.2	86.2	80.0	80.0	74.9	80.4	80.4	6.5	41.41	10.01	43.23	-91.03	-91.03	0.00	0.00	5.00%
04 0 42.0	85.8	85.8	80.0	80.0	77.1	82.2	82.2	7.1	41.27	0.00	43.23	-91.03	-91.03	0.00	0.00	5.00%
04 0 45.0	85.4	85.4	80.0	80.0	76.0	81.2	81.2	6.5	41.31	10.09	43.23	-91.03	-91.03	0.00	0.00	5.00%
04 0 48.0	85.2	85.2	80.0	80.0	76.0	81.2	81.2	6.5	41.31	10.09	43.23	-91.03	-91.03	0.00	0.00	5.00%
04 0 51.0	85.2	85.2	80.0	80.0	76.0	81.2	81.2	6.5	41.31	10.09	43.23	-91.03	-91.03	0.00	0.00	5.00%
04 0 54.0	85.2	85.2	80.0	80.0	76.0	81.2	81.2	6.5	41.31	10.09	43.23	-91.03	-91.03	0.00	0.00	5.00%
04 0 57.0	85.2	85.2	80.0	80.0	76.0	81.2	81.2	6.5	41.31	10.09	43.23	-91.03	-91.03	0.00	0.00	5.00%
04 0 60.0	85.2	85.2	80.0	80.0	76.0	81.2	81.2	6.5	41.31	10.09	43.23	-91.03	-91.03	0.00	0.00	5.00%
04 0 63.0	85.2	85.2	80.0	80.0	76.0	81.2	81.2	6.5	41.31	10.09	43.23	-91.03	-91.03	0.00	0.00	5.00%
04 0 66.0	85.2	85.2	80.0	80.0	76.0	81.2	81.2	6.5	41.31	10.09	43.23	-91.03	-91.03	0.00	0.00	5.00%
04 0 69.0	85.2	85.2	80.0	80.0	76.0	81.2	81.2	6.5	41.31	10.09	43.23	-91.03	-91.03	0.00	0.00	5.00%
04 0 72.0	85.2	85.2	80.0	80.0	76.0	81.2	81.2	6.5	41.31	10.09	43.23	-91.03	-91.03	0.00	0.00	5.00%
04 0 75.0	85.2	85.2	80.0	80.0	76.0	81.2	81.2	6.5	41.31	10.09	43.23	-91.03	-91.03	0.00	0.00	5.00%
04 0 78.0	85.2	85.2	80.0	80.0	76.0	81.2	81.2	6.5	41.31	10.09	43.23	-91.03	-91.03	0.00	0.00	5.00%
04 0 81.0	85.2	85.2	80.0	80.0	76.0	81.2	81.2	6.5	41.31	10.09	43.23	-91.03	-91.03	0.00	0.00	5.00%
04 0 84.0	85.2	85.2	80.0	80.0	76.0	81.2	81.2	6.5	41.31	10.09	43.23	-91.03	-91.03	0.00	0.00	5.00%
04 0 87.0	85.2	85.2	80.0	80.0	76.0	81.2	81.2	6.5	41.31	10.09	43.23	-91.03	-91.03	0.00	0.00	5.00%
04 0 90.0	85.2	85.2	80.0	80.0	76.0	81.2	81.2	6.5	41.31	10.09	43.23	-91.03	-91.03	0.00	0.00	5.00%
04 0 93.0	85.2	85.2	80.0	80.0	76.0	81.2	81.2	6.5	41.31	10.09	43.23	-91.03	-91.03	0.00	0.00	5.00%
04 0 96.0	85.2	85.2	80.0	80.0	76.0	81.2	81.2	6.5	41.31	10.09	43.23	-91.03	-91.03	0.00	0.00	5.00%
04 0 99.0	85.2	85.2	80.0	80.0	76.0	81.2	81.2	6.5	41.31	10.09	43.23	-91.03	-91.03	0.00	0.00	5.00%
04 1 02.0	85.2	85.2	80.0	80.0	76.0	81.2	81.2	6.5	41.31	10.09	43.23	-91.03	-91.03	0.00	0.00	5.00%
04 1 05.0	85.2	85.2	80.0	80.0	76.0	81.2	81.2	6.5	41.31	10.09	43.23	-91.03	-91.03	0.00	0.00	5.00%
04 1 08.0	85.2	85.2	80.0	80.0	76.0	81.2	81.2	6.5	41.31	10.09	43.23	-91.03	-91.03	0.00	0.00	5.00%
04 1 11.0	85.2	85.2	80.0	80.0	76.0	81.2	81.2	6.5	41.31	10.09	43.23	-91.03	-91.03	0.00	0.00	5.00%
04 1 14.0	85.2	85.2	80.0	80.0	76.0	81.2	81.2	6.5	41.31	10.09	43.23	-91.03	-91.03	0.00	0.00	5.00%
04 1 17.0	85.2	85.2	80.0	80.0	76.0	81.2	81.2	6.5	41.31	10.09	43.23	-91.03	-91.03	0.00	0.00	5.00%
04 1 20.0	85.2	85.2	80.0	80.0	76.0	81.2	81.2	6.5	41.31	10.09	43.23	-91.03	-91.03	0.00	0.00	5.00%
04 1 23.0	85.2	85.2	80.0	80.0	76.0	81.2	81.2	6.5	41.31	10.09	43.23	-91.03	-91.03	0.00	0.00	5.00%
04 1 26.0	85.2	85.2	80.0	80.0	76.0	81.2	81.2	6.5	41.31	10.09	43.23	-91.03	-91.03	0.00	0.00	5.00%
04 1 29.0	85.2	85.2	80.0	80.0	76.0	81.2	81.2	6.5	41.31	10.09	43.23	-91.03	-91.03	0.00	0.00	5.00%
04 1 32.0	85.2	85.2	80.0	80.0	76.0	81.2	81.2	6.5	41.31	10.09	43.23	-91.03	-91.03	0.00	0.00	5.00%
04 1 35.0	85.2	85.2	80.0	80.0	76.0	81.2	81.2	6.5	41.31	10.09	43.23	-91.03	-91.03	0.00	0.00	5.00%
04 1 38.0	85.2	85.2	80.0	80.0	76.0	81.2	81.2	6.5	41.31	10.09	43.23	-91.03	-91.03	0.00	0.00	5.00%
04 1 41.0	85.2	85.2	80.0	80.0	76.0	81.2	81.2	6.5	41.31	10.09	43.23	-91.03	-91.03	0.00	0.00	5.00%
04 1 44.0	85.2	85.2	80.0	80.0	76.0	81.2	81.2	6.5	41.31	10.09	43.23	-91.03	-91.03	0.00	0.00	5.00%
04 1 47.0	85.2	85.2	80.0	80.0	76.0	81.2	81.2	6.5	41.31	10.09	43.23	-91.03	-91.03	0.00	0.00	5.00%
04 1 50.0	85.2	85.2	80.0	80.0	76.0	81.2	81.2	6.5	41.31	10.09	43.23	-91.03	-91.03	0.00	0.00	5.00%
04 1 53.0	85.2	85.2	80.0	80												

Table 6.1.11. Samples of Data Printout for Test No. 22 (25 and 35 mph)

E V M F RESULTS : 02-JUN-77 PAGE NO. 10 402 CIL 10 4/10-4																
ELAPSED TIME	BATT VOLT UNFIL	BATT VOLT FIL	U-H BATT DISCH	ROT VOLT FIL	BATT APP UNFIL	BATT APP FIL	U-H BATT REC'D	FIFTH WHEEL RPM	REC.C APP.T	REC.C MOTOR	U-H TO MOTOR	U-H FROM MOTOR	REC'D APP FIL	REC'D APP UNFIL	FINE CALI- BRATH	
MIN SEC	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
21 119.4	121.5	122.7	32.2	53.0	40.0	25.3	0.1	41.9	24.09	31.20	54.10	36.2	0.0	0.00	0.00	5.070
21 122.6	122.9	122.7	34.0	53.7	31.6	25.3	0.2	41.9	23.73	31.20	54.10	36.5	0.2	0.00	0.00	5.060
21 125.6	122.4	122.7	37.5	55.6	40.4	25.3	0.1	41.9	24.29	31.20	54.11	41.6	0.2	0.00	0.00	5.030
21 130.0	122.9	122.7	40.2	53.0	29.1	25.3	0.3	41.9	24.42	31.27	54.20	44.0	0.1	0.00	0.00	5.000
21 132.0	123.0	122.7	42.0	53.6	32.2	25.3	0.1	41.0	23.95	31.22	54.36	46.0	0.1	0.00	0.00	5.000
21 135.2	121.0	122.7	45.9	53.6	43.4	25.3	0.1	41.9	24.00	31.20	54.40	47.4	0.2	0.00	0.00	5.030
21 138.0	121.0	122.7	48.1	55.5	42.3	25.4	0.2	41.9	24.64	31.20	54.44	53.0	0.1	0.00	0.00	5.000
21 141.2	121.5	122.7	50.0	55.6	42.0	25.3	0.2	41.7	23.57	31.20	54.51	54.0	0.0	0.00	0.00	5.070
21 144.4	123.0	122.6	54.0	53.6	45.1	25.3	0.3	41.2	23.63	31.22	54.51	57.4	0.1	0.00	0.00	5.000
21 147.6	123.6	122.7	57.4	53.5	17.0	25.4	0.2	41.5	23.82	31.20	54.51	60.1	0.1	0.00	0.00	5.000
21 150.0	122.7	122.7	59.2	53.2	12.9	25.5	0.1	44.4	23.43	31.10	54.70	62.0	0.1	0.00	0.00	5.000
21 153.0	110.2	119.0	64.2	85.6	52.5	25.4	0.4	55.2	24.12	31.17	54.70	68.2	0.1	0.00	0.00	5.070
21 157.0	110.2	122.4	68.2	55.0	19.6	27.4	0.5	45.4	23.07	31.17	54.74	70.0	0.2	0.00	0.00	5.000
22 1.0	121.1	121.0	72.2	74.1	37.5	47.3	0.3	61.1	24.07	31.20	54.80	74.0	0.3	0.00	0.00	5.000
22 1.2	121.1	120.7	77.6	75.4	32.5	47.3	0.2	61.5	23.90	31.25	54.85	80.2	0.2	0.00	0.00	5.000
22 1.4	119.0	120.7	82.0	76.1	71.2	47.3	0.1	61.2	24.96	31.17	55.04	84.5	0.2	0.00	0.00	5.070
22 1.6	119.5	120.7	86.4	76.0	40.4	47.4	0.3	61.4	24.82	31.17	55.04	88.0	0.1	0.00	0.00	5.000
22 1.8	120.0	120.7	92.1	76.0	30.0	47.6	0.2	61.0	23.72	31.13	55.15	90.0	0.2	0.00	0.00	5.000
22 1.9	119.0	120.7	97.4	76.2	61.0	47.5	0.0	61.9	24.62	31.13	55.14	95.7	0.1	0.00	0.00	5.000
22 1.9	119.0	120.7	100.9	76.1	52.7	47.3	0.3	61.3	25.01	31.13	55.42	103.7	0.1	0.00	0.00	5.070
22 2.2	121.7	122.7	106.0	47.0	21.5	19.5	0.1	73.5	23.91	31.10	56.45	106.4	0.2	0.00	0.00	5.000
22 2.5	122.1	123.1	105.4	46.1	34.7	19.6	0.1	31.3	23.13	31.13	55.90	106.0	0.00	0.00	5.000	
22 2.8	122.0	122.9	112.0	50.5	26.2	30.3	0.2	51.5	22.74	31.00	55.96	111.7	0.1	0.00	0.00	5.000
22 3.1	121.4	121.0	116.0	86.4	45.3	56.6	0.1	78.1	22.97	31.13	56.15	116.4	0.2	0.00	0.00	5.000
22 3.4	110.7	119.0	122.7	83.1	70.5	57.3	0.2	71.0	23.96	31.00	56.15	121.0	0.1	0.00	0.00	5.000
22 3.7	120.4	120.2	120.2	77.4	50.7	40.7	0.2	54.7	24.59	31.00	56.35	129.0	0.1	0.00	0.00	5.000
22 4.0	120.9	121.5	132.1	67.4	46.7	37.3	0.2	54.4	24.52	31.00	56.39	132.9	0.3	0.00	0.00	5.000
22 4.4	121.7	121.5	136.1	67.1	37.6	37.2	0.1	51.7	24.10	31.13	56.43	135.4	0.1	0.00	0.00	5.000
22 4.7	122.5	121.5	139.9	66.7	56.0	41.1	0.3	51.5	23.57	31.03	56.70	138.2	0.1	0.00	0.00	5.000
22 5.0	121.3	121.5	145.5	66.2	30.0	30.0	0.2	59.6	23.82	31.06	56.47	143.5	0.1	0.00	0.00	5.000
22 5.3	119.6	120.9	149.5	72.0	50.0	44.3	0.1	61.9	23.31	31.03	56.50	149.0	0.1	0.00	0.00	5.070
22 5.6	110.7	120.2	154.9	72.2	68.5	42.1	0.1	51.5	24.30	31.03	56.50	154.5	0.2	0.00	0.00	5.000
22 5.9	119.6	121.2	160.3	69.5	56.0	41.1	0.3	51.5	23.34	31.03	56.50	158.0	0.1	0.00	0.00	5.000
23 1.0	120.4	121.2	164.3	69.7	34.2	41.1	0.1	51.0	23.06	31.01	56.70	162.5	0.1	0.00	0.00	5.000
23 1.4	120.7	121.2	168.4	49.5	45.0	41.0	0.2	51.9	23.44	30.99	56.74	167.0	0.2	0.00	0.00	5.000
23 1.7	121.6	121.2	173.0	65.4	34.0	41.1	0.3	51.2	23.66	30.99	56.66	171.7	0.2	0.00	0.00	5.000
23 2.0	121.1	121.2	176.9	68.4	40.7	41.2	0.2	61.7	23.45	31.00	56.66	176.0	0.2	0.00	0.00	5.000
23 2.3	120.0	120.5	182.4	77.5	46.7	51.1	0.2	61.9	23.96	31.03	56.90	181.5	0.1	0.00	0.00	5.000
23 2.6	120.0	120.5	187.6	81.3	61.5	56.1	0.0	71.9	23.57	31.01	56.10	186.6	0.2	0.00	0.00	5.000
23 2.9	121.0	121.0	192.9	70.6	41.9	41.0	0.1	57.0	24.74	31.03	57.02	192.0	0.1	0.00	0.00	5.000
23 3.2	121.7	121.1	197.0	70.4	58.6	41.0	0.2	51.0	24.05	30.94	57.06	196.0	0.2	0.00	0.00	5.000
23 3.5	121.0	121.1	202.4	70.3	30.5	41.0	0.2	51.2	23.05	30.94	57.10	200.0	0.2	0.00	0.00	5.000
23 3.8	121.6	121.6	206.0	73.4	50.0	49.0	0.2	67.3	23.03	30.94	57.10	207.4	0.3	0.00	0.00	5.000
23 4.1	120.0	120.2	211.7	80.1	70.0	52.5	0.2	61.1	24.35	30.91	57.10	214.0	0.1	0.00	0.00	5.000

E V M F RESULTS : 02-JUN-77 PAGE NO. 6 402 CIL 10 4/10-4																	
ELAPSED TIME	BATT VOLT UNFIL	BATT VOLT FIL	U-H BATT DISCH	ROT VOLT UNFIL	BATT APP UNFIL	BATT APP FIL	U-H BATT REC'D	ROT APP FIL	FIFTH WHEEL RPM	REC.C APP.T	REC.C MOTOR	U-H TO MOTOR	U-H FROM MOTOR	REC'D APP FIL	REC'D APP UNFIL	FINE CALI- BRATH	
MIN SEC	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
11 151.0	117.3	119.4	227.7	04.0	71.6	67.3	0.1	84.0	34.04	31.32	46.36	246.7	0.1	0.00	0.00	5.000	
11 155.0	117.9	119.4	234.4	04.9	53.6	67.3	0.2	84.7	33.44	31.29	46.51	253.5	0.2	0.00	0.00	5.000	
11 158.2	120.6	119.4	242.0	05.4	50.2	68.2	0.1	85.3	33.84	31.20	46.50	259.0	0.2	0.00	0.00	5.000	
12 1.0	119.6	119.3	249.1	05.6	82.3	68.3	0.2	83.3	34.26	31.27	46.50	266.5	0.1	0.00	0.00	5.000	
12 1.4	110.0	119.5	259.0	05.9	71.0	68.4	0.1	85.4	33.94	31.25	46.51	274.5	0.1	0.00	0.00	5.000	
12 1.7	120.7	119.2	263.7	06.6	46.9	69.4	0.2	86.1	33.64	31.25	46.70	281.1	0.3	0.00	0.00	4.950	
12 1.9	119.3	119.2	271.7	06.0	96.4	70.3	0.1	86.3	34.02	31.22	46.76	286.0	0.1	0.00	0.00	5.000	
12 1.9	119.3	119.1	278.4	07.4	66.3	71.4	0.1	88.1	33.21	31.22	46.92	295.9	0.2	0.00	0.00	5.000	
12 1.6	110.7	117.9	286.1	57.9	76.4	94.7	0.2	106.7	33.84	31.27	46.96	303.0	0.0	0.00	0.00	5.000	
12 2.0	117.6	119.1	295.0	87.2	72.5	65.1	0.1	81.0	34.95	31.22	46.92	311.0	0.3	0.00	0.00	5.000	
12 2.3	110.2	119.6	302.6	83.7	49.1	64.2	0.4	82.9	33.96	31.20	46.70	318.7	0.00	0.00	5.000		
12 2.6	119.2	119.3	309.2	85.9	44.9	67.7	0.2	84.2	34.26	31.22	47.04	325.3	0.1	0.00	0.00	4.950	
12 2.9	110.7	119.6	315.6	82.9	86.6	68.4	0.2	77.7	34.29	31.20	47.14	332.1	0.2	0.00	0.00	5.000	
12 3.2	122.6	122.3	319.9	322.7	81.0	66.6	61.7	0.1	79.0	34.04	31.20	47.26	338.8	0.1	0.00	0.00	5.000
12 3.5	119.2	110.2	330.7	96.9	72.0	94.0	0.1	106.9	34.22	31.27	47.33	345.0	0.0	0.00	0.00	5.000	
12 3.8	116.2	117.0	340.2	101.3	84.4	100.7	0.1	110.0	34.14	31.29	47.45	352.0	0.1	0.00	0.00	5.000	
12 4.2	120.3	120.2	347.7	77.7	79.5	96.1	0.2	79.3	34.10	31.27	47.52	359.5	0.1	0.00	0.00	5.000	
12 4.5	120.0	120.1	355.0	80.2	92.1	97.3	0.2	74.0	34.83	31.27	47.62	367.2	0.2	0.00	0.00	5.000	
12 4.8	120.1	120.1	362.1	80.0	92.7	97.4	0.1	71.6	35.02	31.32	47.52	373.5	0.1	0.00	0.00	5.000	
12 5.1	120.2	122.1	364.2	40.0	14.7	20.2	0.2	37.6	35.44	31.27	47.71	380.2	0.1	0.00	0.00	5.000	
12 5.4	122.5	122.4	367.7	44.7	9.6	19.4	0.1	37.3	33.89	31.22	47.71	387.5	0.1	0.00	0.00	5.000	
12 5.7	122.5	121.4	370.1	44.4	39.5	19.6	0.1	38.0	33.51	31.32	47.61	394.0	0.1	0.00	0.00	5.000	
13 1.0	121.0	121.6	380.0	74.1	52.7	69.2	0.1	93.3	33.57	31.25	47.33	405.4	0.2	0.00	0.00	5.000	
13 1.3	120.9	119.9	380.0	61.4	41.2	29.4	0.1	44.1	34.23	31.22	47.26	406.0	0.2	0.00	0.00	5.000	
13 1.7	121.1	122.5	41.5	35.7	41.0	29.7	0.3	46.4	34.36	31.25	47.20	413.4	0.4	0.00	0.00	5.000	
13 1.8	123.7	122.6	45.5	39.6	14.4	20.0	0.1	48.3	34.09	31.27	47.20	416.1	0.0	0.00	0.00	5.000	
13 1.9	120.4	120.0	48.0	40.0	14.4	20.0	0.1	48.3	34.09	31.27	47.20	416.1	0.0	0.00	0.00	5.000	
13 1.6	122.0	122.0	52.1	63.5	10.0	38.4	0.1	49.3	34.72	31.25	47.20	423.0	0.2	0.00	0.00	5.000	
13 1.9	121.1	121.6	56.2	66.5	31.9	41.5	0.1	61.7	33.58	31.27	47.42	430.0	0.2	0.00	0.00	5.000	
13 2.2	121.1	120.9	60.1	73.4	39.5	31.1	0.1	63.4	31.77	31.29	47.45	437.1	0.1	0.00	0.00	5.000	
13 2.5	121.6	119.6	66.0	76.0	34.0	34.0	0.1	64.0	31.77	31.29	47.45	444.2	0.1	0.00	0.00	5.000	
13 2.9	121.7	120.0	70.0	61.0	24.3	34.9	0.2	54.6	33.46	31.29	47.40	451.3	0.1	0.00	0.00	5.000	
13 3.2	121.2	121.9	74.6	61.7	31.9	34.9	0.1	54.0	33.99	31.29	47.61	458.4	0.1	0.00	0.00	5.000	
13 3.5	122.4	121.9	70.9	61.0	26.7	34.9	0.2	55.5	33.67	31.29	47.61	465.5	0.1	0.00	0.00	5.000	
13 3.8	122.1	121.7	75.0	61.7	35.2	35.7	0.1	56.2	33.67	31.29	47.61	472.7	0.1	0.00	0.00	5.000	
13 4.1	123.3	121.0	63.0	61.2	24.1	37.5	0.1	57.5	34.36	31.32	47.64	479.0	0.2	0.00	0.00	5.000	
13 4.4	120.5	121.7	90.7	67.0	20.9	37.5	0.1	57.7	34.55	31.36	47.67	486.7	0.2	0.00	0.00	5.000	
13 4.8	122.6	121.8	84.4	66.0	35.9	37.4	0.5	57.7	34.26	31.34	47.64	493.7	0.1	0.00	0.00	5.000	
13 5.1	120.0	121.7	90.0	62.1	44.0	37.5	0.1	58.4	34.73	31.37	47.65	497.0	0.1	0.00	0.00	5.000	
13 5.4	127.7	121.9	102.0	66.0	40.0	35.0	0.1	57.1	33.63	31.36	47.63	504.1	0.1	0.00	0.00	5.000	
13 5.7	122.4	122.0	166.7	62.6	62.4	34.2	0.2	57.7	33.97	31.36	47.90	511.4	0.1	0.00	0.00	5.000	
13 6.0	122.4	122.1	167.0	62.7	61.0	34.2	0.1	64.23	31.36	31.36	47.90	518.5	0.1	0.00	0.00	5.000	
14 1.3	125.0	121.1	114.7	70.6	37.0	40.0	0.2	62.7	34.40	31.46	48.12	525.0	0.2	0.00	0.00	5.000	
14 1.6	123.2	121.0	120.1	71.0	45.9	40.1	0.1	65.1	34.13	31.51	48.15	529.0	0.1	0.00	0.00	5.000	

Table 6.1.12. Samples of Data Printout for Test No. 22 (45 and Max Speed)

E V H F T		RESULTS 1				02-JUN-77				PAGE NO. 4				022 CHL 10 418-B			
ELAPSED TIME	BATT VOL UNF IL	BATT VOL FIL	U-M DISCON	POT FIL	BATT VOL UNF IL	BATT VOL FIL	U-M DISCON	POT FIL	FIFTH UNF IL	REG. C AN/T	B/C NOTAR	U-M POT	U-M POT	REGEN FIL	REGEN FIL	FINED GATH	
																	1
7 9.4	121.3	120.2	68.3	85.0	115.0	104.9	0.3	122.1	44.86	31.3	39.00	0.1	0.00	0.00	5.60	5.60	
7 112.4	118.1	116.4	70.9	106.6	118.0	95.2	0.1	07.8	44.14	31.38	39.99	95.6	0.1	0.00	0.00	5.60	
7 115.6	117.3	117.2	89.3	96.9	86.2	81.1	114.7	46.14	31.50	39.94	164.3	0.1	0.00	0.00	5.60	5.60	
7 118.7	118.7	118.7	96.9	96.9	102.9	96.9	0.0	0.0	46.12	31.50	39.94	164.3	0.1	0.00	0.00	5.60	
7 120.8	122.1	113.4	100.0	83.1	82.6	78.1	0.2	96.7	43.74	31.63	39.91	122.4	0.1	0.00	0.00	5.60	
7 121.8	118.5	117.5	100.0	86.0	80.1	70.1	0.1	97.7	47.30	31.50	39.91	178.3	0.1	0.00	0.00	5.60	
7 122.8	120.7	118.2	122.4	0.0	59.6	85.9	0.2	106.9	42.00	31.60	39.96	139.4	0.1	0.00	0.00	5.60	
7 123.8	116.3	115.6	115.6	96.9	102.9	96.9	0.2	135.3	41.19	31.63	40.00	155.5	0.1	0.00	0.00	5.60	
7 127.8	118.5	117.5	145.7	96.9	125.3	102.3	0.1	111.5	46.57	31.63	40.10	161.0	0.1	0.00	0.00	5.60	
7 131.8	114.9	117.0	154.6	92.8	105.6	91.6	0.2	107.5	43.65	31.55	40.15	178.3	0.1	0.00	0.00	5.60	
7 133.8	116.6	117.0	165.5	93.9	99.0	93.6	0.1	105.4	41.72	31.50	40.15	180.8	0.1	0.00	0.00	5.60	
7 135.8	119.9	117.0	164.7	94.3	111.9	94.7	0.2	105.6	41.90	31.55	40.15	178.3	0.1	0.00	0.00	5.60	
7 140.8	116.6	117.5	163.6	94.6	75.0	97.4	0.3	112.0	44.32	31.44	40.29	200.0	0.2	0.00	0.00	5.60	
7 146.0	116.4	117.2	154.3	93.6	63.3	100.7	0.1	112.5	43.93	31.53	40.29	210.7	0.2	0.00	0.00	5.60	
7 151.2	116.2	116.0	205.0	97.0	125.8	104.7	0.1	115.1	43.60	31.67	40.37	221.2	0.3	0.00	0.00	5.60	
7 156.2	116.6	116.6	215.0	100.0	116.6	100.0	0.2	125.3	43.68	31.67	40.37	221.2	0.3	0.00	0.00	5.60	
7 161.4	114.6	115.1	179.1	104.4	114.2	96.0	0.2	101.2	44.44	31.44	40.45	244.1	0.1	0.00	0.00	5.60	
7 159.4	120.0	118.2	230.4	92.7	92.3	92.5	0.2	118.4	43.71	31.48	40.56	253.5	0.0	0.00	0.00	5.60	
7 2.6	114.7	115.0	250.6	107.0	149.4	137.0	0.2	125.1	46.76	31.55	40.64	254.4	0.1	0.00	0.00	5.60	
7 5.8	115.7	117.4	261.0	108.9	144.0	137.4	0.1	141.9	46.91	31.60	40.64	277.0	0.1	0.00	0.00	5.60	
7 5.8	115.7	117.4	274.4	77.9	64.4	95.0	0.1	71.5	45.47	31.46	40.78	296.5	0.1	0.00	0.00	5.60	
7 11.0	120.0	120.1	281.1	77.4	46.2	60.0	0.1	91.5	45.67	31.44	40.73	291.0	0.1	0.00	0.00	5.60	
7 14.4	120.0	119.5	280.0	82.6	59.2	76.8	0.2	96.2	45.73	31.44	40.78	299.0	0.1	0.00	0.00	5.60	
7 16.0	121.1	118.7	290.0	88.1	52.7	75.0	0.2	98.9	45.81	31.41	40.87	301.0	0.1	0.00	0.00	5.60	
7 21.7	119.2	119.1	290.0	88.1	52.7	76.8	0.3	99.3	45.81	31.45	40.91	314.7	0.1	0.00	0.00	5.60	
7 23.3	122.0	119.6	387.9	59.7	21.5	33.3	0.2	35.4	43.21	31.44	40.95	317.2	0.1	0.00	0.00	5.60	
7 26.0	122.5	122.3	311.9	58.4	41.9	38.0	0.1	71.2	43.28	31.44	40.95	321.3	0.1	0.00	0.00	5.60	
7 30.0	122.5	122.5	308.9	58.3	44.4	39.9	0.1	66.4	43.28	31.44	40.95	321.3	0.1	0.00	0.00	5.60	
7 33.2	119.1	119.2	375.3	83.5	101.6	72.6	0.1	66.4	43.28	31.44	40.95	321.3	0.1	0.00	0.00	5.60	
7 35.8	119.0	119.1	388.4	84.1	78.2	68.5	0.1	61.3	43.04	31.46	41.03	315.0	0.1	0.00	0.00	5.60	
7 38.9	122.5	120.0	348.0	78.0	84.8	61.7	0.2	61.0	43.33	31.51	41.08	302.0	0.1	0.00	0.00	5.60	
7 42.2	118.7	118.7	377.9	77.9	64.4	95.0	0.1	71.5	45.47	31.46	40.78	296.5	0.1	0.00	0.00	5.60	
7 144.4	120.7	120.0	10.0	77.0	67.0	60.5	0.1	61.2	43.05	31.46	41.25	214.0	0.1	0.00	0.00	5.60	
7 147.2	120.0	119.9	388.4	84.1	78.2	68.5	0.2	61.2	43.05	31.46	41.28	26.9	0.4	0.00	0.00	5.60	
7 149.8	121.3	120.1	24.0	76.6	53.4	59.7	0.0	61.3	43.05	31.48	41.31	33.6	0.1	0.00	0.00	5.60	
7 152.4	119.0	119.0	388.4	84.1	78.2	68.5	0.1	61.2	43.05	31.46	41.28	26.9	0.4	0.00	0.00	5.60	
7 155.0	117.0	117.1	391.0	84.1	78.2	68.5	0.1	61.2	43.05	31.46	41.28	26.9	0.4	0.00	0.00	5.60	
7 157.6	121.1	120.0	42.0	77.3	51.0	57.1	0.1	61.3	43.04	31.5	41.28	32.1	0.1	0.00	0.00	5.60	
7 160.2	121.0	119.0	388.4	84.1	78.2	68.5	0.1	61.2	43.05	31.46	41.28	26.9	0.4	0.00	0.00	5.60	
7 162.8	121.0	119.0	388.4	84.1	78.2	68.5	0.1	61.2	43.05	31.46	41.28	26.9	0.4	0.00	0.00	5.60	
7 165.4	121.0	119.0	388.4	84.1	78.2	68.5	0.1	61.2	43.05	31.46	41.28	26.9	0.4	0.00	0.00	5.60	
7 168.0	121.0	119.0	388.4	84.1	78.2	68.5	0.1	61.2	43.05	31.46	41.28	26.9	0.4	0.00	0.00	5.60	
7 170.6	121.0	119.0	388.4	84.1	78.2	68.5	0.1	61.2	43.05	31.46	41.28	26.9	0.4	0.00	0.00	5.60	
7 173.2	121.0	119.0	388.4	84.1	78.2	68.5	0.1	61.2	43.05	31.46	41.28	26.9	0.4	0.00	0.00	5.60	
7 175.8	121.0	119.0	388.4	84.1	78.2	68.5	0.1	61.2	43.05	31.46	41.28	26.9	0.4	0.00	0.00	5.60	
7 178.4	121.0	119.0	388.4	84.1	78.2	68.5	0.1	61.2	43.05	31.46	41.28	26.9	0.4	0.00	0.00	5.60	
7 181.0	121.0	119.0	388.4	84.1	78.2	68.5	0.1	61.2	43.05	31.46	41.28	26.9	0.4	0.00	0.00	5.60	
7 183.6	121.0	119.0	388.4	84.1	78.2	68.5	0.1	61.2	43.05	31.46	41.28	26.9	0.4	0.00	0.00	5.60	
7 186.2	121.0	119.0	388.4	84.1	78.2	68.5	0.1	61.2	43.05	31.46	41.28	26.9	0.4	0.00	0.00	5.60	
7 188.8	121.0	119.0	388.4	84.1	78.2	68.5	0.1	61.2	43.05	31.46	41.28	26.9	0.4	0.00	0.00	5.60	
7 191.4	121.0	119.0	388.4	84.1	78.2	68.5	0.1	61.2	43.05	31.46	41.28	26.9	0.4	0.00	0.00	5.60	
7 194.0	121.0	119.0	388.4	84.1	78.2	68.5	0.1	61.2	43.05	31.46	41.28	26.9	0.4	0.00	0.00	5.60	
7 196.6	121.0	119.0	388.4	84.1	78.2	68.5	0.1	61.2	43.05	31.46	41.28	26.9	0.4	0.00	0.00	5.60	
7 199.2	121.0	119.0	388.4	84.1	78.2	68.5	0.1	61.2	43.05	31.46	41.28	26.9	0.4	0.00	0.00	5.60	
7 201.8	121.0	119.0	388.4	84.1	78.2	68.5	0.1	61.2	43.05	31.46	41.28	26.9	0.4	0.00	0.00	5.60	
7 204.4	121.0	119.0	388.4	84.1	78.2	68.5	0.1	61.2	43.05	31.46	41.28	26.9	0.4	0.00	0.00	5.60	
7 207.0	121.0	119.0	388.4	84.1	78.2	68.5	0.1	61.2	43.05	31.46	41.28	26.9	0.4	0.00	0.00	5.60	
7 209.6	121.0	119.0	388.4	84.1	78.2	68.5	0.1	61.2	43.05	31.46	41.28	26.9	0.4	0.00	0.00	5.60	
7 212.2	121.0	119.0	388.4	84.1	78.2	68.5	0.1	61.2	43.05	31.46	41.28	26.9	0.4	0.00	0.00	5.60	
7 214.8	121.0	119.0	388.4	84.1	78.2	68.5	0.1	61.2	43.05	31.46	41.28	26.9	0.4	0.00	0.00	5.60	
7 217.4	121.0	119.0	388.4	84.1	78.2	68.5	0.1	61.2	43.05	31.46	41.28	26.9	0.4	0.00	0.00	5.60	
7 220.0	121.0	119.0	388.4	84.1	78.2	68.5	0.1	61.2	43.05	31.46	41.28	26.9	0.4	0.00	0.00	5.60	
7 222.6	121.0	119.0	388.4	84.1	78.2	68.5	0.1	61.2	43.05	31.46	41.28	26.9	0.4	0.00	0.00	5.60	
7 225.2	121.0	119.0	388.4	84.1	78.2	68.5	0.1	61.2	43.05	31.46	41.28	26.9	0.4	0.00	0.00	5.60	
7 227.8	121.0	119.0	388.4	84.1	78.2	68.5	0.1	61.2	43.05	31.46	41.28	26.9	0.4	0.00	0.00	5.60	
7 230.4	121.0	119.0	388.4	84.1	78.2	68.5	0.1	61.2	43.05	31.46	41.28	26.9	0.4	0.00	0.00	5.60	
7 233.0	121.0	119.0	388.4	84.1	78.2	68.5	0.1	61.2	43.05	31.46	41.28	26.9	0.4	0.00	0.00	5.60	
7 235.6	121.0	119.0	388.4	84.1	78.2	68.5	0.1	61.2	43.05	31.46	41.28	26.9	0.4	0.00	0.00	5.60	
7 238.2	121.0	119.0	388.4	84.1	78.2	68.5	0.1	61.2	43.05	31.46	41.28	26.9	0.4	0.00	0.00	5.60	
7 240.8	121.0	119.0	388.4	84.1	78.2	68.5	0.1	61.2	43.05	31.46	41.28	26.9	0.4	0.00	0.00	5.60	
7 243.4	121.0	119.0	388.4	84.1	78.2	68.5	0.1	61.2	43.05	31.46	41.28	26.9	0.4	0.00	0.00	5.60	
7 246.0	121.0	119.0	388.4	84.1	78.2	68.5	0.1	61.2	43.05	31.46	41.28	26.9	0.4	0.00	0.00	5.60	
7 248.6	121.0	119.0	388.4	84.1	78.2	68.5	0.1	61.2	43.0								

E V M T F		RESULTS :										02-JUN-77		PAGE NO. 2		422 CALIB 4/10-A													
ELAPSED TIME		BATT VOLT UNFIL		BATT VOLT FIL		BATT VOLT UNFIL		BATT VOLT FIL		M-F POT RECHG		M-F POT RECHG		FIFTH UNFIL		DEG.C AMPT		DEG.C MOTOR		M-F FUEL TO MOTOR		M-F FUEL TO MOTOR		REGEN FUEL UNFIL		REGEN FUEL UNFIL		FUEL BURNTH	
MIN	SEC	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
2	22.0	116.5	116.4	114.7	114.9	110.5	119.6	0.5	116.0	51.63	31.89	31.70	135.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	28.0	116.4	116.3	126.0	114.0	120.1	119.7	0	117.5	52.63	31.91	31.06	147.0	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	31.2	116.4	116.2	130.9	114.0	118.6	120.0	0	116.0	52.62	31.91	31.77	159.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	34.4	116.4	116.2	135.7	114.0	119.0	119.7	0	116.0	52.62	31.91	31.84	184.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	37.6	116.2	116.2	164.1	114.0	117.4	119.7	0	116.2	52.77	31.89	31.89	184.0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	40.8	116.4	116.2	171.1	114.0	120.5	120.6	0	116.3	51.97	31.90	31.96	197.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	43.0	119.8	116.1	187.1	114.7	120.7	121.1	0	116.4	51.84	31.01	31.74	209.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	46.2	116.6	116.0	199.9	114.0	121.2	120.5	0	116.6	51.72	31.91	31.74	226.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	49.4	116.2	116.2	212.9	114.7	122.0	120.0	0	116.2	51.69	31.95	31.90	231.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	52.6	116.3	116.0	225.1	114.6	121.8	121.7	0	116.3	51.76	31.84	32.10	256.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	55.8	116.0	116.0	237.2	114.6	121.0	121.7	0	116.3	51.99	31.82	32.08	274.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	59.0	116.0	116.0	259.9	114.0	122.2	121.7	0	116.0	52.27	31.79	31.79	296.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	62.2	116.2	116.2	282.4	114.7	121.2	121.2	0	116.2	52.47	31.79	31.79	320.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	5	5.4	116.4	116.1	214.4	116.7	121.0	120.9	0	116.4	52.47	31.77	31.77	320.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	5.8	116.0	116.1	236.4	114.6	121.5	121.1	0	116.4	51.63	31.77	32.29	306.6	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	6.2	116.0	116.0	259.9	114.0	121.6	121.1	0	116.0	51.76	31.79	32.08	326.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	6.6	116.0	116.0	282.4	114.0	121.6	121.1	0	116.0	51.76	31.79	32.08	348.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	7.0	116.0	116.0	305.9	114.0	121.6	121.1	0	116.0	51.76	31.79	32.08	370.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	7.4	116.0	116.0	328.4	114.0	121.6	121.1	0	116.0	51.76	31.79	32.08	392.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	7.8	116.0	116.0	350.9	114.0	121.6	121.1	0	116.0	51.76	31.79	32.08	414.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	8.2	116.2	116.1	323.3	114.6	121.2	122.3	0	116.2	51.66	31.80	32.32	436.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	8.6	116.2	116.1	345.8	114.6	121.2	122.3	0	116.2	51.66	31.80	32.32	458.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	9.0	116.2	116.1	368.3	114.6	121.2	122.3	0	116.2	51.66	31.80	32.32	480.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	9.4	116.2	116.1	390.8	114.6	121.2	122.3	0	116.2	51.66	31.80	32.32	502.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	9.8	116.2	116.1	413.3	114.6	121.2	122.3	0	116.2	51.66	31.80	32.32	524.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	10.2	116.2	116.1	435.8	114.6	121.2	122.3	0	116.2	51.66	31.80	32.32	546.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	10.6	116.2	116.1	458.3	114.6	121.2	122.3	0	116.2	51.66	31.80	32.32	568.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	11.0	116.2	116.1	480.8	114.6	121.2	122.3	0	116.2	51.66	31.80	32.32	590.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	11.4	116.2	116.1	503.3	114.6	121.2	122.3	0	116.2	51.66	31.80	32.32	612.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	11.8	116.2	116.1	525.8	114.6	121.2	122.3	0	116.2	51.66	31.80	32.32	634.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	12.2	116.2	116.1	548.3	114.6	121.2	122.3	0	116.2	51.66	31.80	32.32	656.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	12.6	116.2	116.1	570.8	114.6	121.2	122.3	0	116.2	51.66	31.80	32.32	678.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	13.0	116.2	116.1	593.3	114.6	121.2	122.3	0	116.2	51.66	31.80	32.32	699.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	13.4	116.2	116.1	615.8	114.6	121.2	122.3	0	116.2	51.66	31.80	32.32	721.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	13.8	116.2	116.1	638.3	114.6	121.2	122.3	0	116.2	51.66	31.80	32.32	743.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	14.2	116.2	116.1	660.8	114.6	121.2	122.3	0	116.2	51.66	31.80	32.32	765.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	14.6	116.2	116.1	683.3	114.6	121.2	122.3	0	116.2	51.66	31.80	32.32	787.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	15.0	116.2	116.1	705.8	114.6	121.2	122.3	0	116.2	51.66	31.80	32.32	809.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	15.4	116.2	116.1	728.3	114.6	121.2	122.3	0	116.2	51.66	31.80	32.32	831.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	15.8	116.2	116.1	750.8	114.6	121.2	122.3	0	116.2	51.66	31.80	32.32	853.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	16.2	116.2	116.1	773.3	114.6	121.2	122.3	0	116.2	51.66	31.80	32.32	875.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	16.6	116.2	116.1	795.8	114.6	121.2	122.3	0	116.2	51.66	31.80	32.32	897.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	17.0	116.2	116.1	818.3	114.6	121.2	122.3	0	116.2	51.66	31.80	32.32	919.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	17.4	116.2	116.1	840.8	114.6	121.2	122.3	0	116.2	51.66	31.80	32.32	941.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	17.8	116.2	116.1	863.3	114.6	121.2	122.3	0	116.2	51.66	31.80	32.32	963.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	18.2	116.2	116.1	885.8	114.6	121.2	122.3	0	116.2	51.66	31.80	32.32	985.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	18.6	116.2	116.1	908.3	114.6	121.2	122.3	0	116.2	51.66	31.80	32.32	1007.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	19.0	116.2	116.1	930.8	114.6	121.2	122.3	0	116.2	51.66	31.80	32.32	1029.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	19.4	116.2	116.1	953.3	114.6	121.2	122.3	0	116.2	51.66	31.80	32.32	1051.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	19.8	116.2	116.1	975.8	114.6	121.2	122.3	0	116.2	51.66	31.80	32.32	1073.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	20.2	116.2	116.1	998.3	114.6	121.2	122.3	0	116.2	51.66	31.80	32.32	1095.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	20.6	116.2	116.1	1020.8	114.6	121.2	122.3	0	116.2	51.66	31.80	32.																	

6.2 MEASURED DATA-DRIVING CYCLE TESTS

In accordance with paragraph 5.3, Schedule B, C, and D driving cycle tests were run, both with and without regenerative braking. Initially, nine tests were performed - two Schedule C tests with and without regenerative braking, two Schedule B tests without regenerative braking (one complete and one incomplete test), two Scheduled B tests with regenerative braking (one complete and one incomplete test), and a third regenerative C test which was run because of the greater than 10 percent disparity between the first two.

In the course of these nine tests, an instrumentation error went undetected whereby the motor armature voltage was sensed rather than the total motor voltage. Upon correcting this condition, a group of short "calibration" tests was run (22F through 22L).

Figures 6.2.1 and 6.2.2 display the driving speed profiles and range and energy consumption results. Strip-Chart samples are recorded speed and displayed in Figures 6.2.3 through 6.2.7. The results of all 14 tests are displayed in Table 6.2.1.

Samples of driving cycle computer printouts are included in Tables 6.2.2 through 6.2.14.

Plots of motor and ambient temperature vs time are included in Figures 6.2.3 through 6.2.6.

Records of specific gravities are included in Appendix I.

Computer generated plots of speed and electrical data are included in Figures 6.2.7 through 6.2.10. All of this data was obtained directly from data tapes which were recorded during the tests.

Additional tests were performed which included the following:

Test 29 - Schedule C, no regenerative braking, LEV-115 batteries and Solitron transistors

Test 30 - Schedule C, with regenerative braking, LEV-115 batteries and Solitron transistors

Test 24 - 5 cycles of Schedule D, no regenerative braking, EV-106 batteries and 2N6251 transistors

Test 26 - Repeat of Test 24

Test 27 - Repeat of Test 25

Test 31 - 5 cycles of Schedule D, without regenerative braking, followed by 5 cycles of Schedule D with regenerative braking, LEV-115 batteries and SDT-12302 transistors.

The results of these tests are summarized in Table 6.2.1A. In all of these tests, total motor voltage was sensed. No computations, based on Table 6.2.1A data, were performed in paragraph 7.1

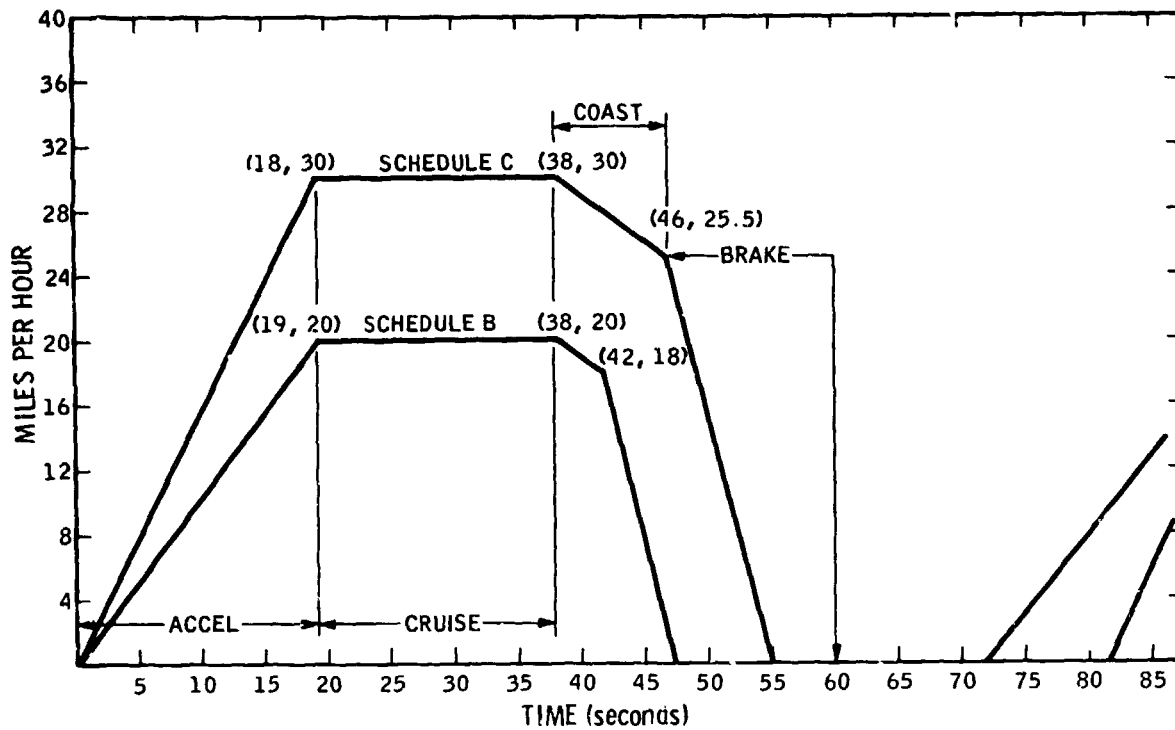


Figure 6.2.1. SAE J227a Driving Schedules B and C

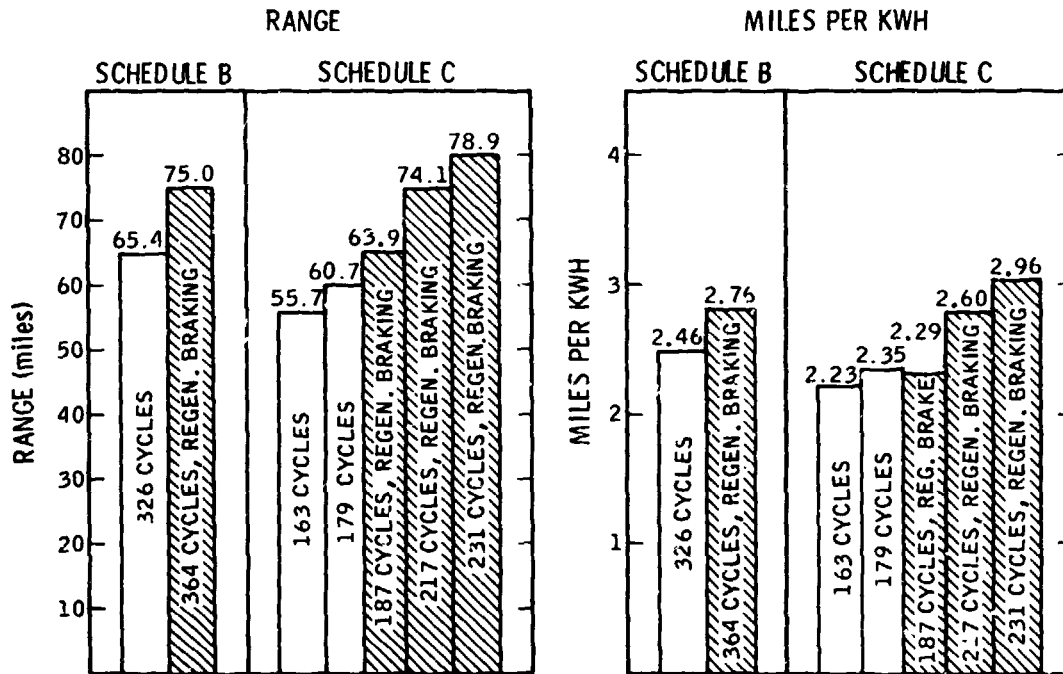


Figure 6.2.2. Range and Miles per KWH for B and C Schedules. Average Improvement Due to Regenerative Braking is: Schedule B Range - 46%, Schedule B Energy - 22%, Schedule C Range - 24%, Schedule C Energy - 14%



Figure 6.2.3. Strip Chart Speed Samples from Test 12, Schedule C without Regenerative Braking (Cycles 2 and 6). Time Axis Reads from Right to Left with Each Minor Division Equal to One Second. Minor Division of Speed Axis Equals One Mile Per Hour.

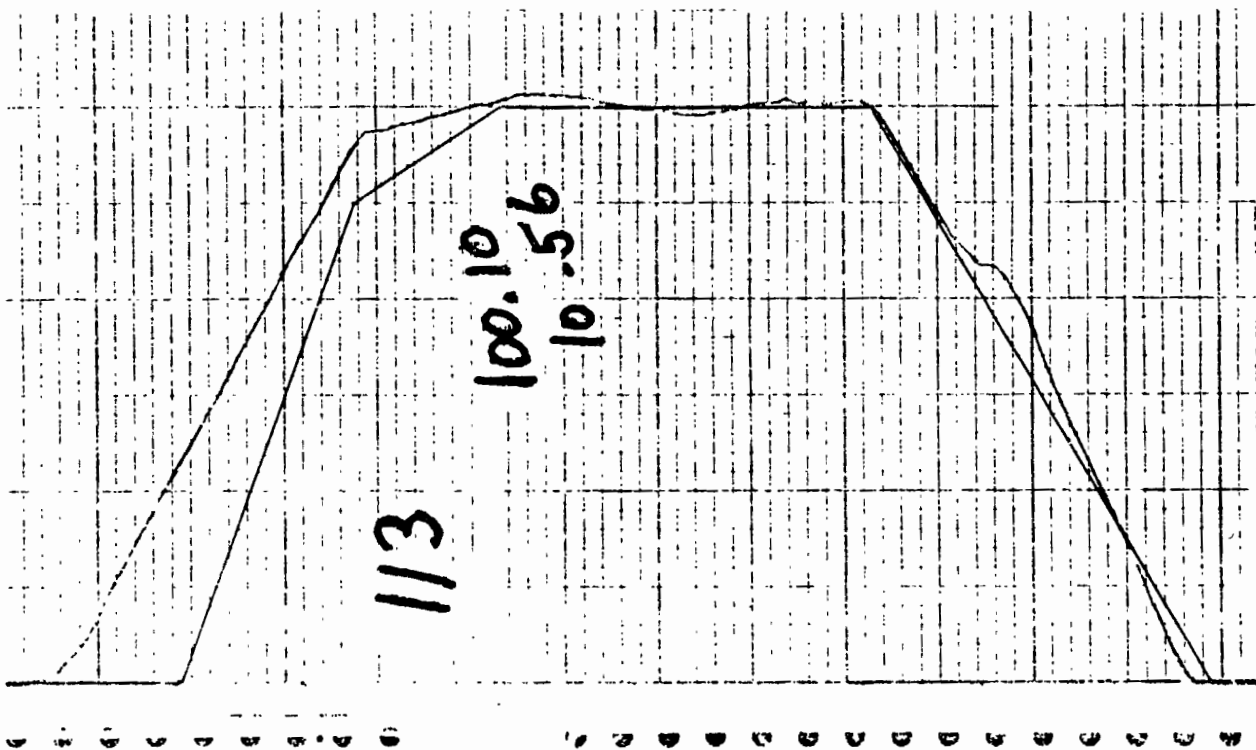
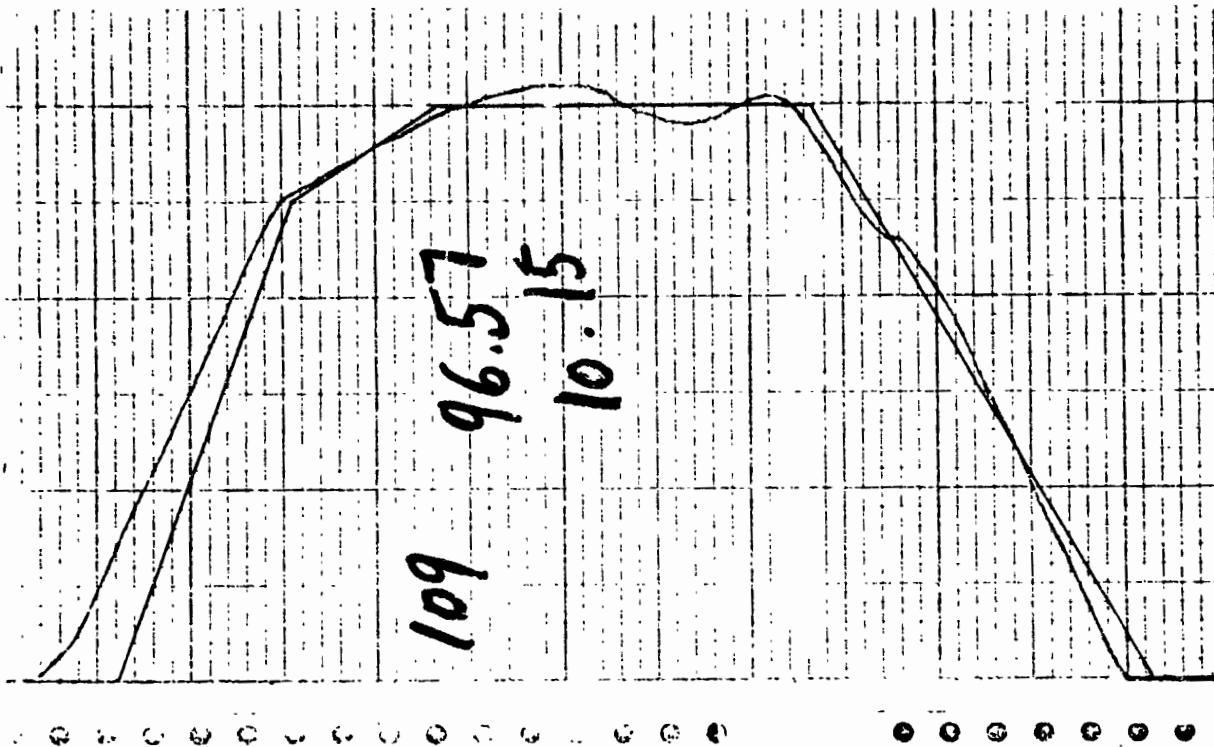


Figure 6.2.4. Strip Chart Speed Samples from Test 13, Schedule C with Regenerative Braking (Cycles 109 and 113)

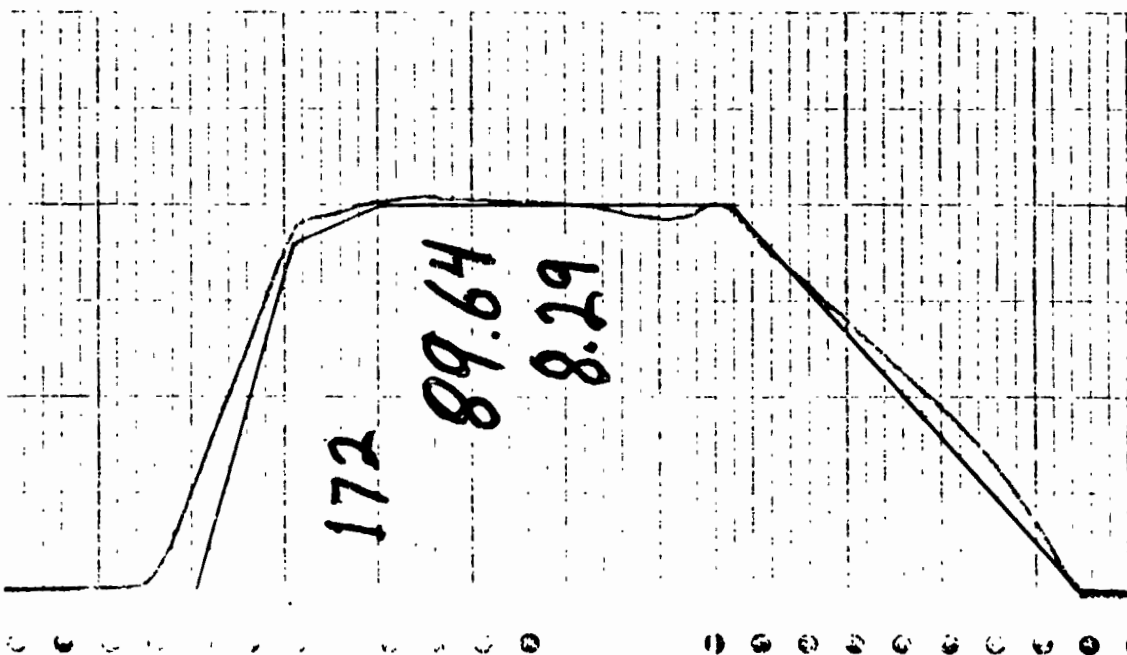
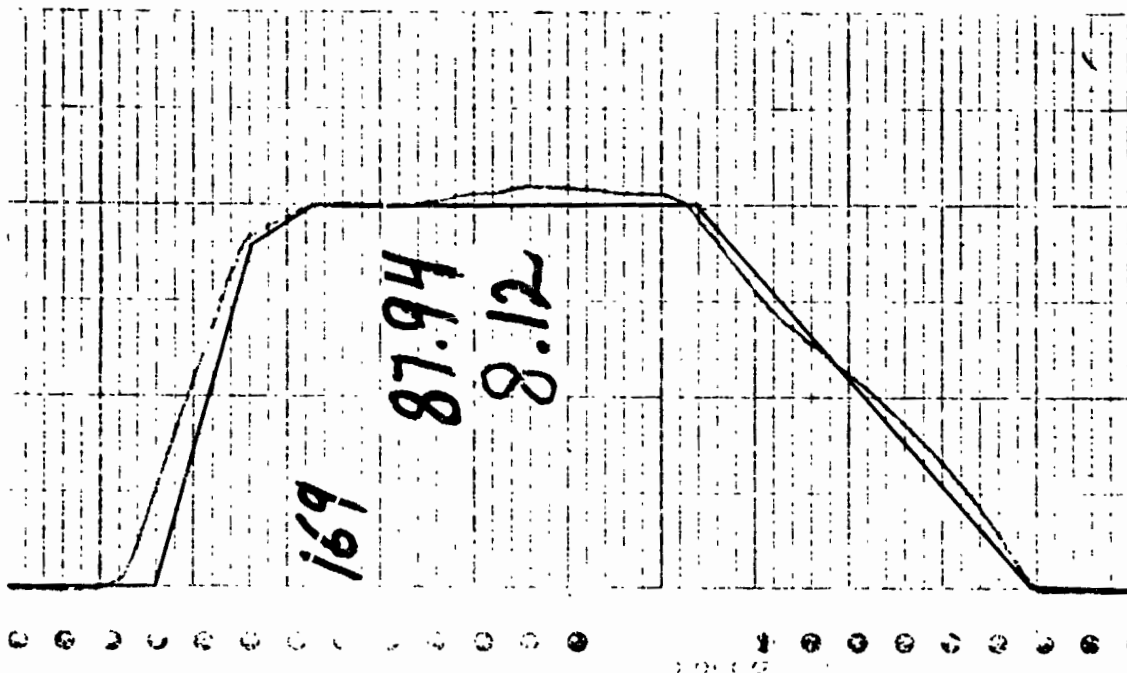


Figure 6.2.5. Strip Chart Speed Samples from Test 17, Schedule B with Regenerative Braking (Cycles 169 and 172)

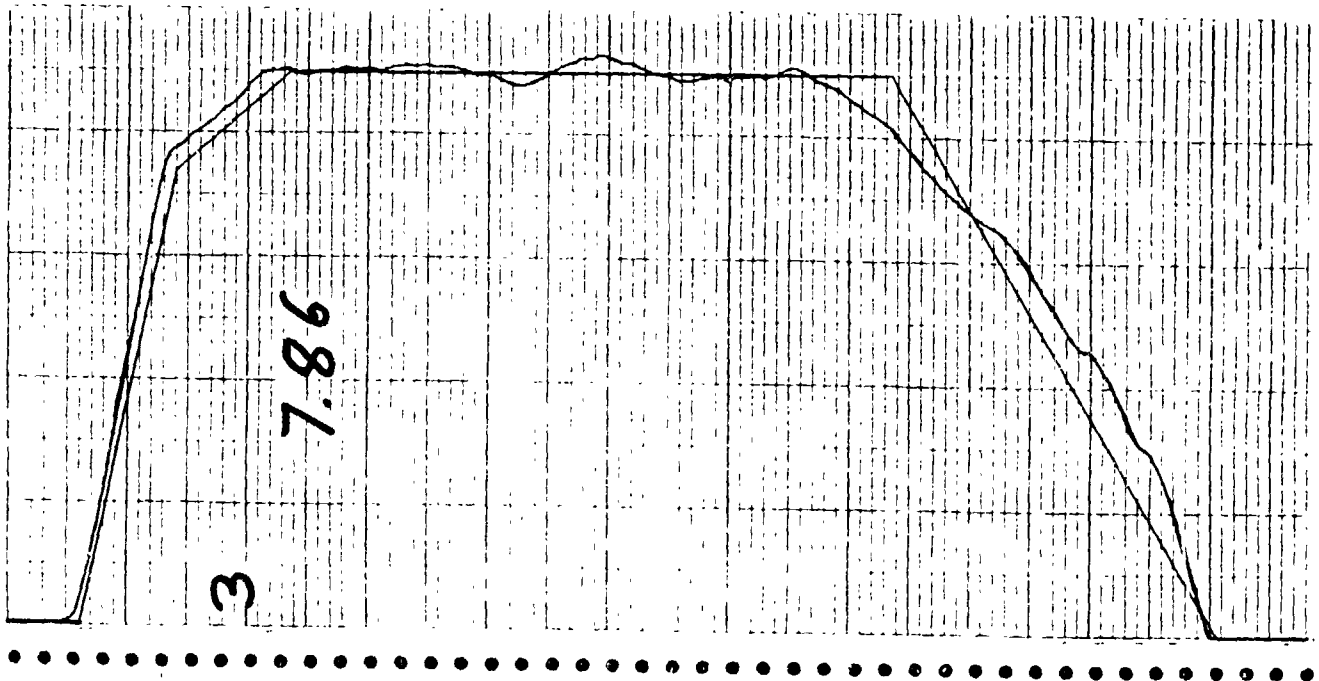
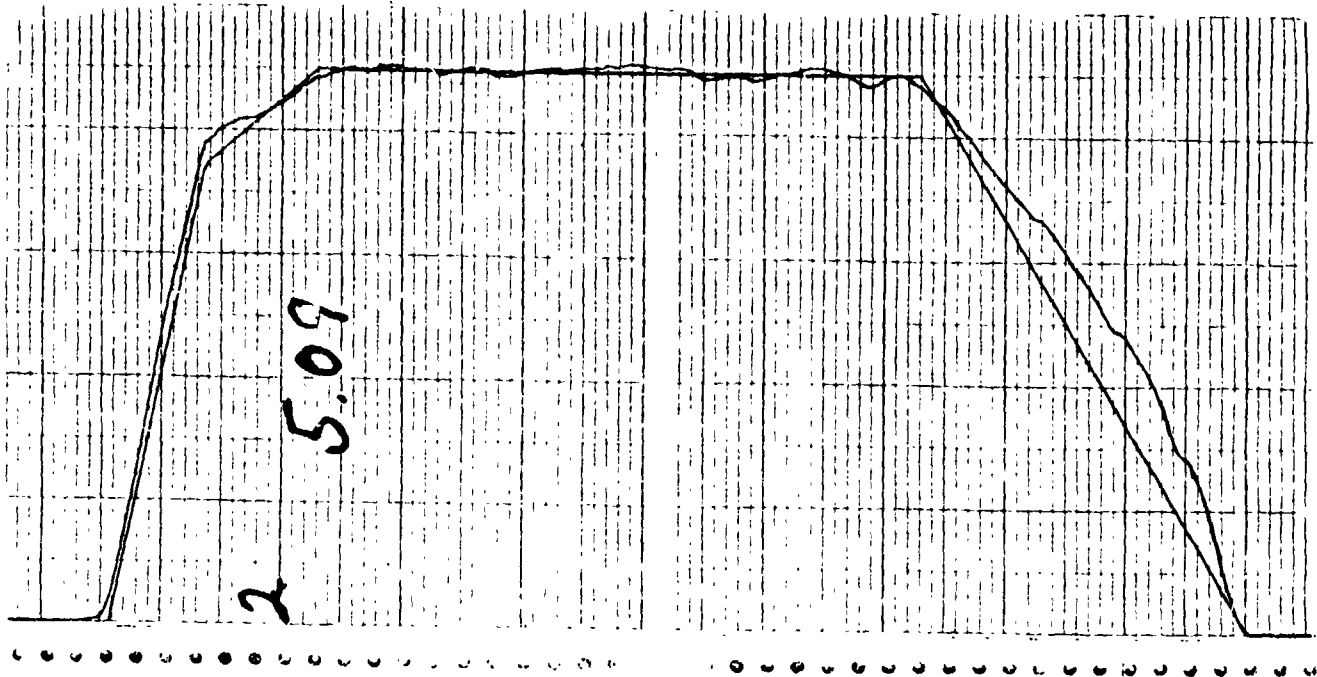


Figure 6.2.6. Strip Chart Speed Samples from Test 24, Schedule D without Regenerative Braking (Cycles 2 and 3)

ORIGINAL PAGE IS
OF POOR QUALITY

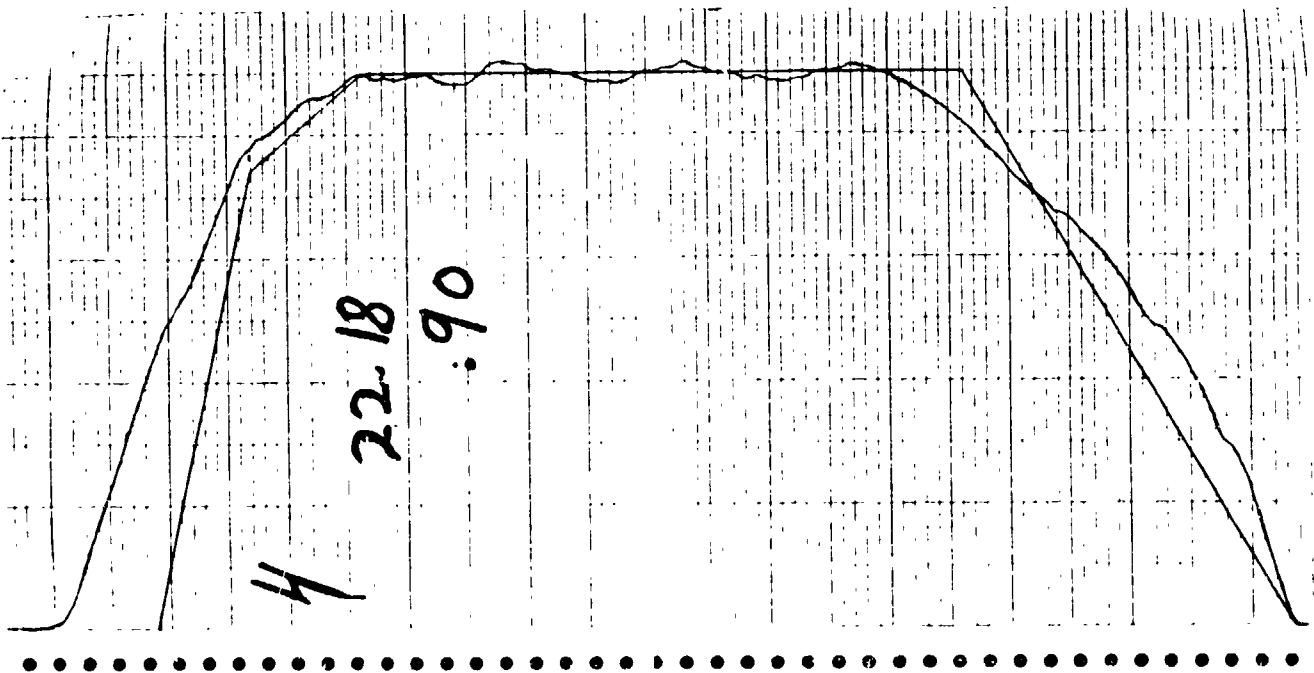
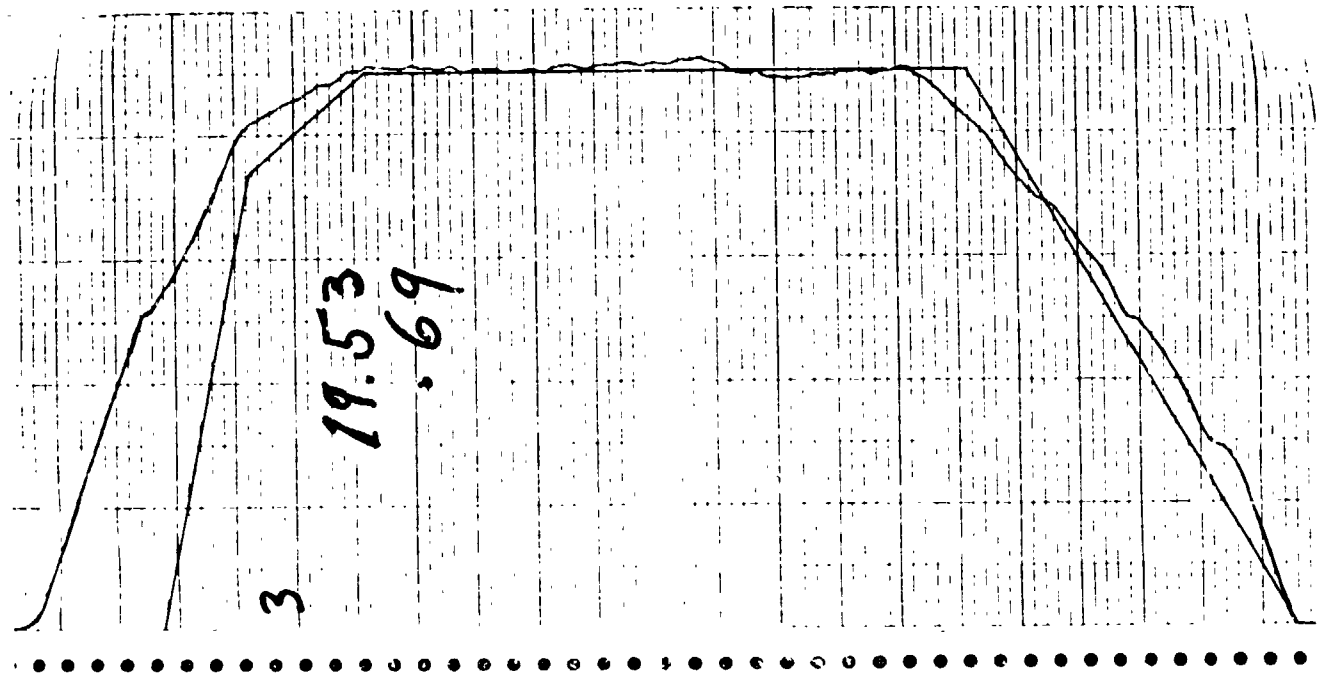


Figure 6.2.7. Strip Chart Speed Samples from Test 25, Schedule D
with Regenerative Braking (Cycles 3 and 4)

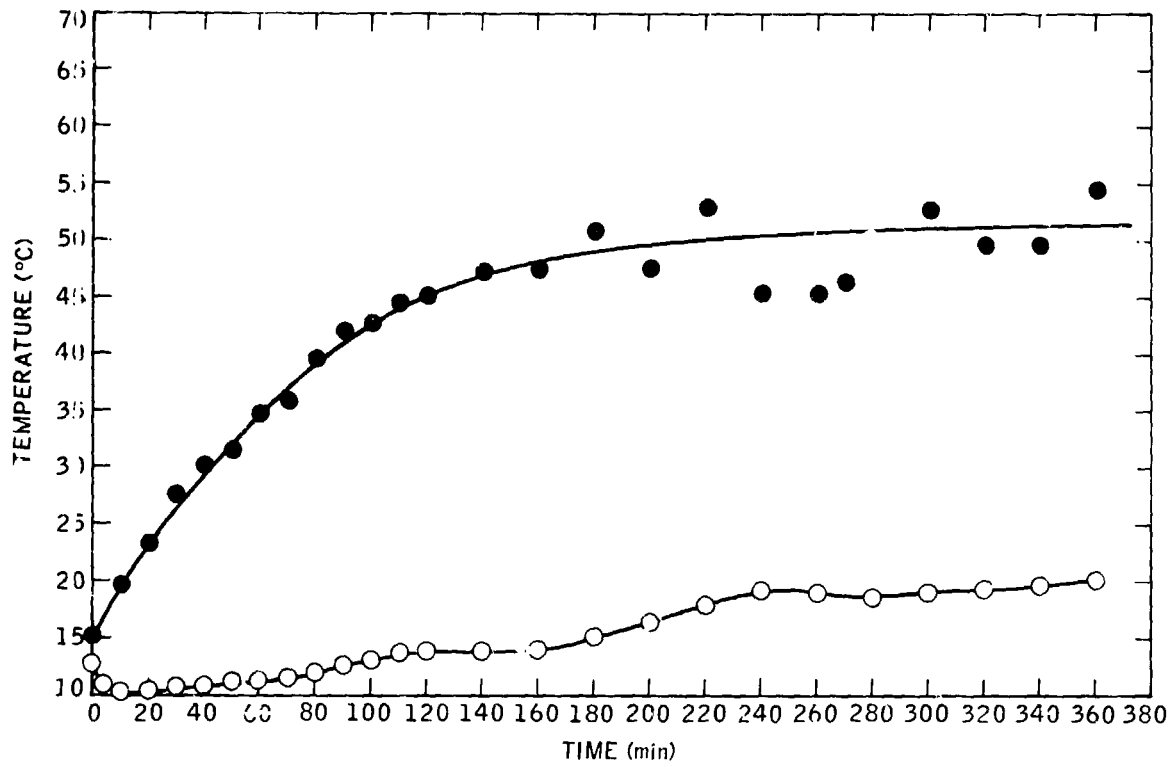


Figure 6.2.8. Motor Case and Ambient Temp. vs Time for Test No. 17, Schedule B with Regenerative Braking.

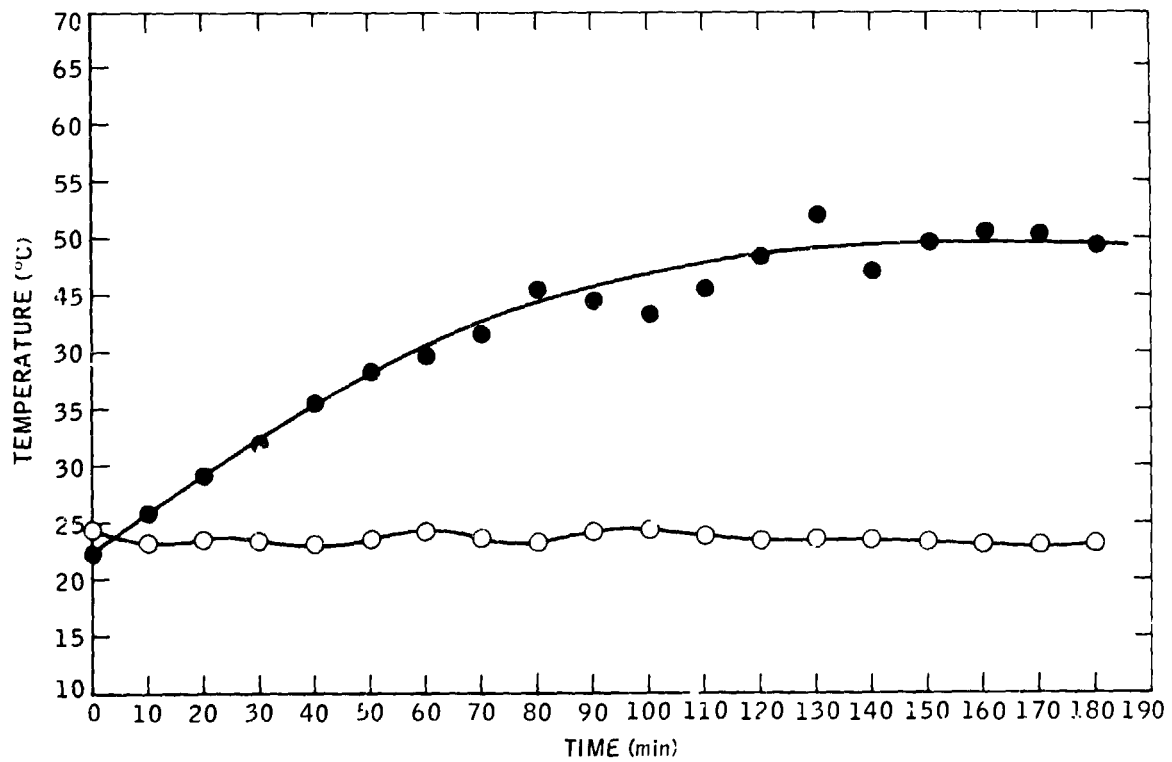


Figure 6.2.9. Motor Case and Ambient Temp. vs Time for Test No. 18, Schedule C without Regenerative Braking.

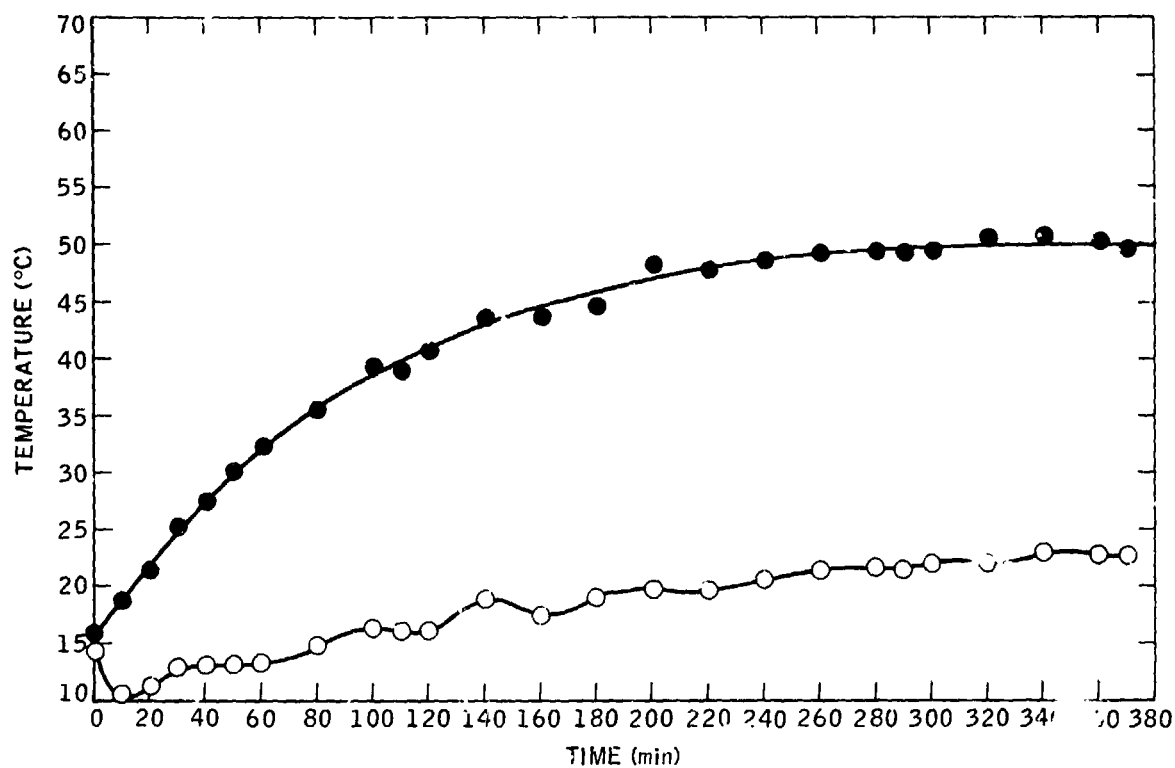


Figure 6.2.10. Motor Case and Ambient Temp. vs Time for Test No. 20, Schedule B without Regenerative Braking.

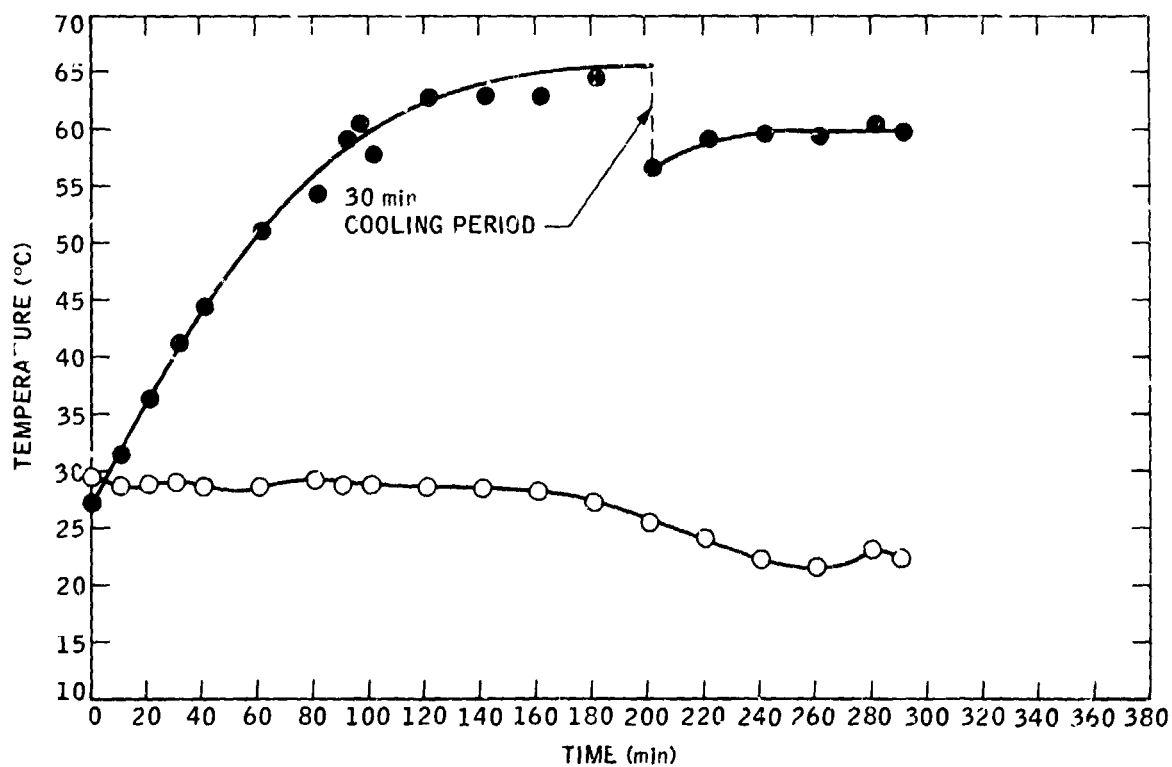


Figure 6.2.11. Motor Case and Ambient Temp. vs Time for Test No. 21, Schedule C with Regenerative Braking.

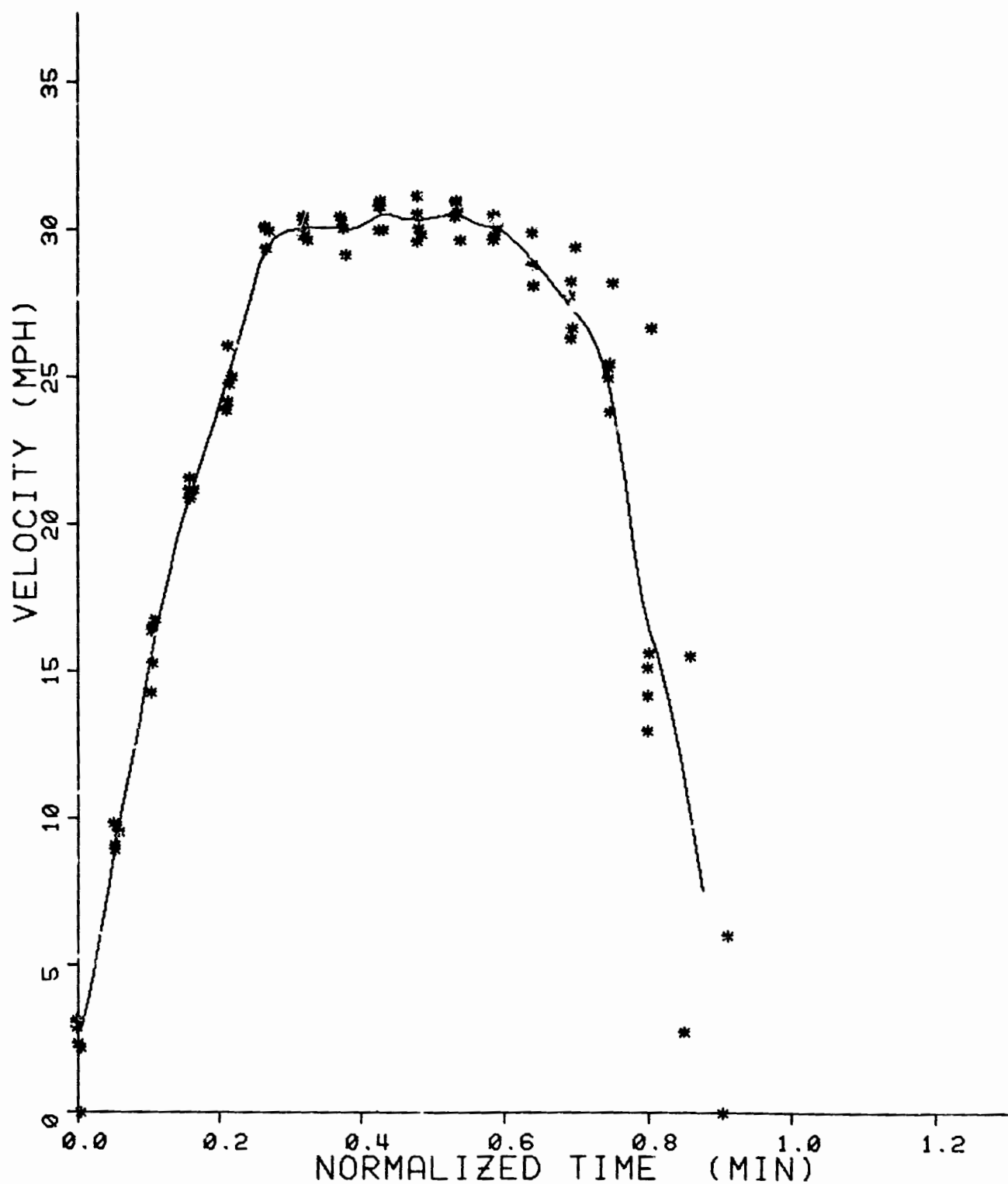


Figure 6.2.12. Computer Plot of Speed vs Time for Test 22. Schedule C without Regenerative Braking. Data Points are from Cycles 7, 8, 9, 10, and 11. Line is obtained by "X-Y Filter Function" applied to data points.

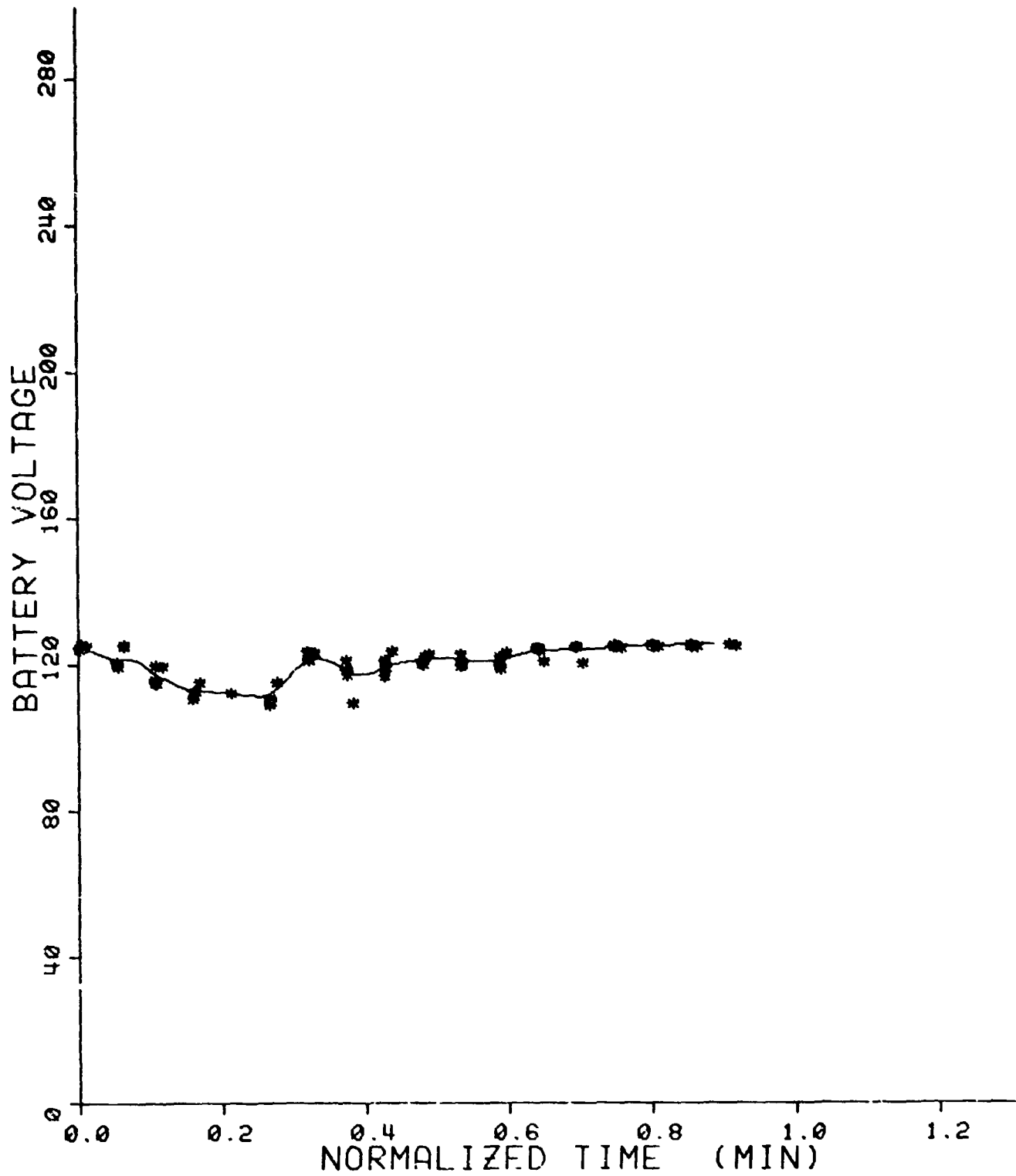


Figure 6.2.13. Computer Plot of Battery Voltage vs Time for Test 22. Schedule C without Regenerative Braking. Data points are from Cycles 7, 8, 9, 10, and 11. Line is obtained by "X-Y Filter Function" applied to data points.

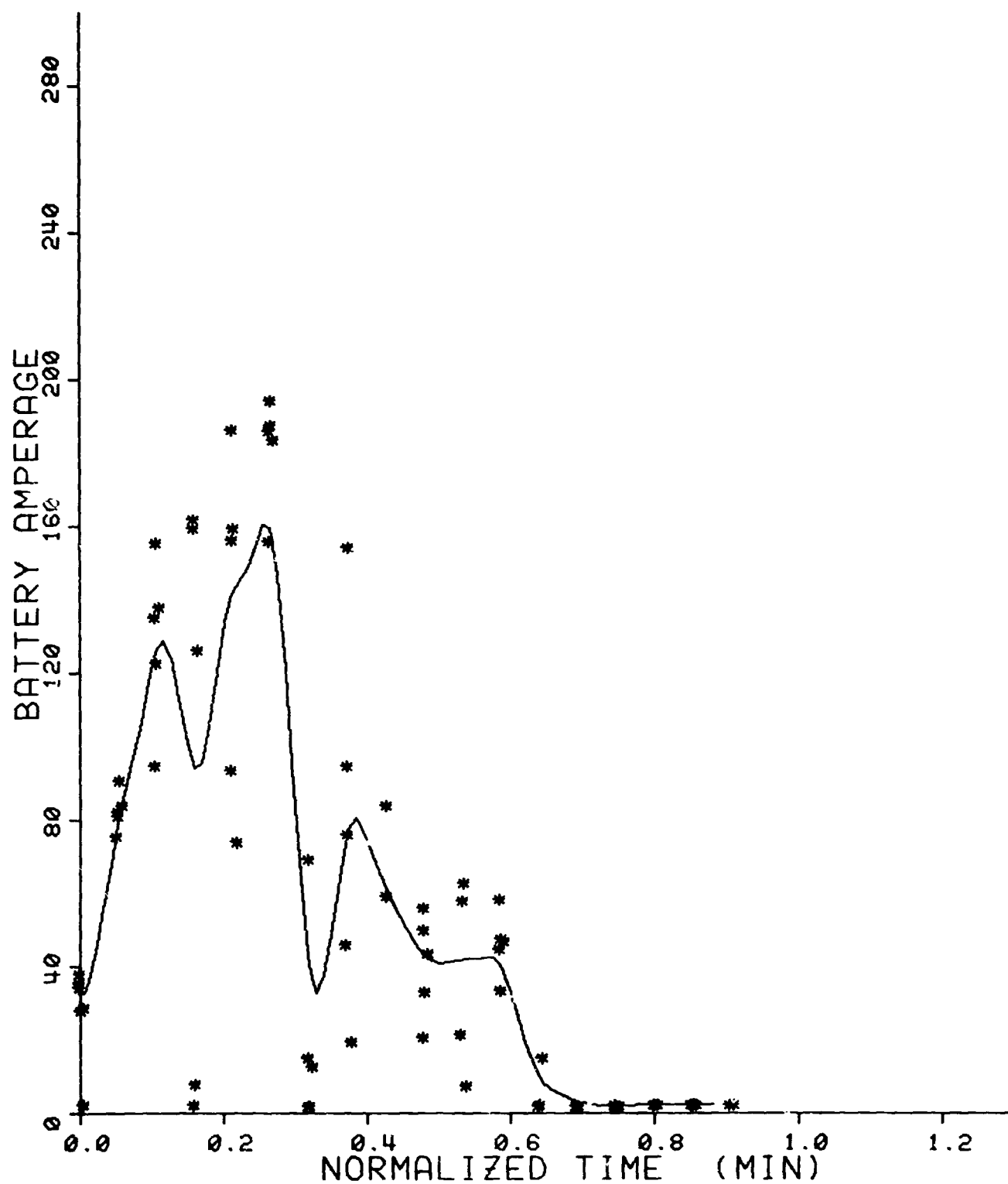


Figure 6.2.14 Complete Plot of Battery Current Vs. Time for Test 22 - Schedule C Without Regenerative Braking. Data Points are from Cycles 7, 8, 9, 10, and 11. Line is Obtained by "X-Y Filter Function" Applied to Data Points

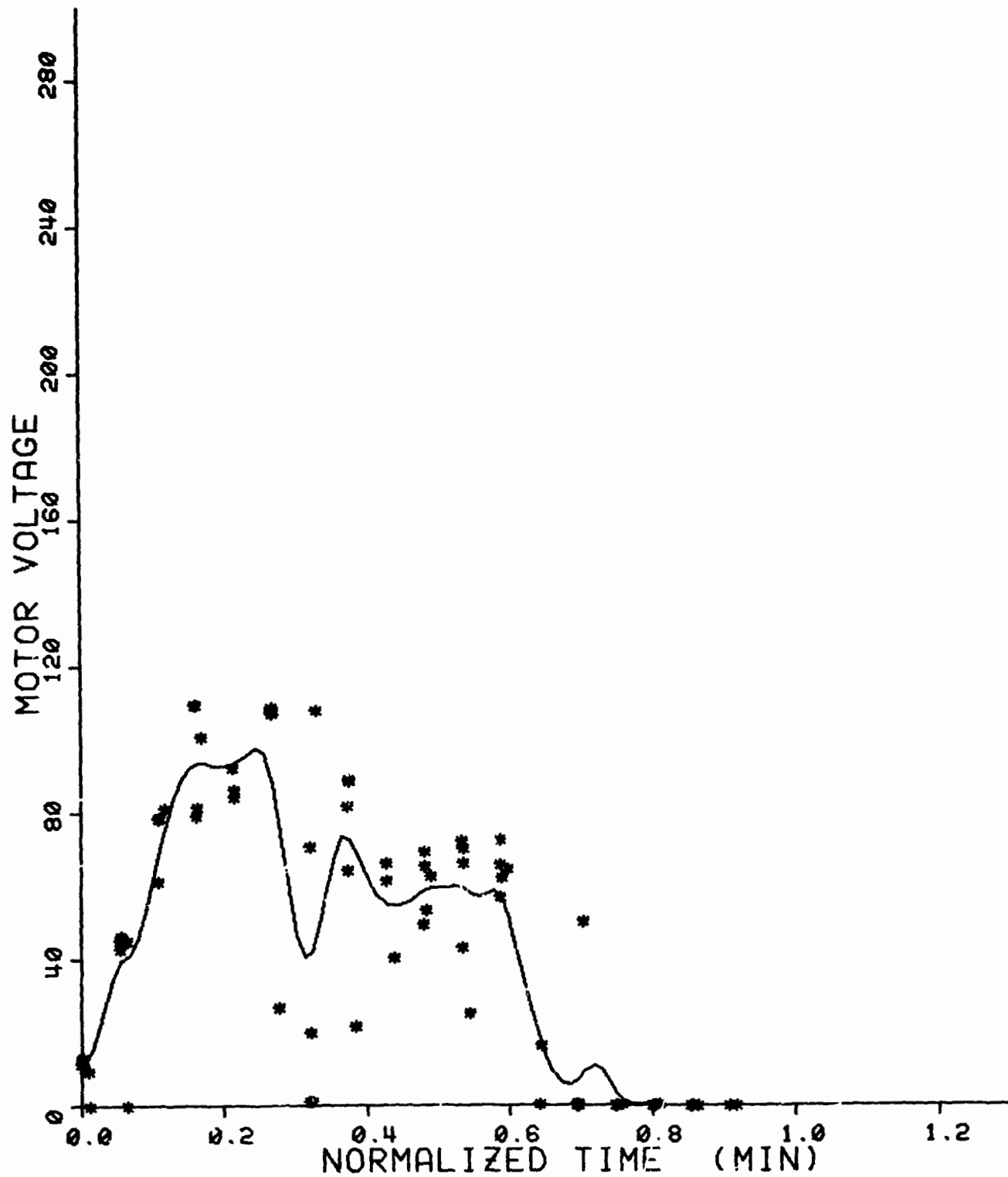


Figure 6.2.15. Computer Plot of Motor Voltage vs Time for Test 22. Schedule C without Regenerative Braking. Data points are from Cycles 7, 8, 9, 10, and 11. Line is obtained by "X-Y Filter Function" applied to data points.

Table 6.2.1. Driving Cycle, Uncorrected Raw Data

Test No.	12	13	15	16	17	18	19	20	21	22F	22G	22H	22K	22L
Date of Test	3/20	3/21	3/25	3/26	3/29	3/30	4/1	4/4	4/5	4/17	4/17	4/17	4/17	4/17
Test Description ¹	C	C, Br	B, Inc.	B, Br, Inc.	B, Br	C	C, Br	B	C, Br	C	C, Br	C	B	B, Br
Number of Cycles Driven	163	217	200	283	364	179	187	326	231	5	5	5	10	10
Uncorrected Distance	55.70	79.69	39.40	-	75.01	60.75	66.54	65.39	81.96	1.73	1.83	1.73	2.04	2.07
Corrected Distance ²	55.70	74.15	39.40	56.76	73.01	60.75	63.90	65.39	78.94	1.73	1.73	1.73	2.04	2.04
End of Test Batt. Voltage ³	98.8		112.6	110.3	94.9	98.2	92.6	89.6	92.8	-	-	-	-	-
BATTERY DISCHARGE														
Discharge Amp-Hours	151.21	196.65	101.52	144.08	192.33	163.20	177.16	170.67	202.56	4.31	4.39	4.50	4.73	4.66
Discharge KWH ⁴	HF	HF	HF	HF	HF	HF	HF	HF	24.62	0.505	0.511	0.523	0.604	0.592
ENERGY TO MOTOR														
KWH to Motor ⁵	15.23	19.85	10.44	14.74	19.52	16.66	18.17	17.16	21.50	0.475	0.489	0.493	0.556	0.551
BATTERY RECH. (Reg. Br.)														
Recharge Amp-Hours ¹⁹	-	20.96	-	14.18	18.66	-	17.04	-	19.54	-	0.50	-	-	0.53
Recharge KWH ²⁰	-	2.59	-	2.15	2.27	-	3.16	-	-	-	0.076	-	-	0.063
ENERGY FROM MOTOR (Reg. Br.)														
KWH	-	4.12	-	2.95	3.81	-	3.55	-	-	-	0.083	-	-	0.069
BATTERY RECHARGE														
Recharge Amp-Hours ⁸	163.77	175.53	138.94	135.38	184.20	174.15	158.75	122.28	-	-	-	-	-	-
Recharge KWH ¹⁰	17.50	16.84	18.43	-	20.15	18.47	23.48	-	-	-	-	-	-	-
CHARGER INPUT														
Line KWH	25.0	28.5	-	19.0	26.5	25.8	27.9	26.5	26.7	-	-	-	-	-
Recharge Time (hr.)	19.2	21.3	16.8	14.4	20.6	19.2	23.3	19.5	-	-	-	-	-	-
WEATHER CONDITIONS														
Ambient Temp. (°C)	18-24	18-20	19-21	14-19	10-23	12-24	10-18	10-22	21-29	30-31	30-31	30-31	30-32	30-32
Wind Speed (mph)	2-5	4-8	15-25	2-5	2-5	10-15	0-15	2-3	0-3	7-12	7-12	7-12	7-12	7-12
NOTES: HF = Hardware Failure inc = Test not run to completion														

Table 6.2.1A. Uncorrected Data for Driving Cycle Tests 24, 25, 26, 27, 29, and 31

Test No.	24	25	26	27	29	30	31A	31B
Test Date	4/19							
Test Description	D, inc	D, Br, inc	D, inc	D, Br, inc	C	C, Br, LEV-115's	D, inc LEV-115's	D, Br, inc LEV-115's
Number of Cycles Driven	5	5	5	5	165	190	5	2
Uncorrected Distance (mi)	4.89	4.93	4.90	5.16	57.60	69.71	4.86	-
Corrected Distance (mi)	4.89	4.89	4.89	4.89	57.60	66.33	4.86	1.96
End of Test Batt. Voltage	-	-	-	-	-	-	-	-
BATTERY DISCHARGE								
Discharge Amp-Hours	12.64	11.63	12.98	12.00	161.50	190.82	13.89	-
Discharge KWh	1.490	1.368	1.492	1.371	17.54	20.79	-	0.589
ENERGY TO MOTOR								
KWh to Motor	HF	HF	1.467	1.352	16.55	19.40	1.560	0.580
BATT. RECH (Reg. Br.)								
Recharge Amp-Hours	-	1.14	-	1.11	-	18.10	-	-
Recharge KWh	-	0.168	-	0.165	-	2.93	-	0.0263
ENERGY FROM MOTOR (Reg. Br.)								
KWh from Motor	-	HF	-	0.175	-	3.47	-	0.795
BATTERY RECHARGE								
Recharge Amp-Hours	-	-	-	-	174.30	159.19	-	-
Recharge KWh	-	-	-	-	21.09	19.33	-	-
CHARGER INPUT								
Line KWh	-	-	-	-	26.5	24.5	-	-
Recharge Time (hr)	-	-	-	-	18.6	16.8	-	-
WEATHER CONDITIONS								
Ambient Temperature (°C)	29	28-30	-	-	30-34	30-35	22-23	23
Wind Speed (mph)	5-10	3-6	8-15	8-12	2-4	2-20	2-3	2-3

Table 6.2.2. Samples of Data Printout for Test No. 12 (C Cycle, no Regen Br)

EVENT RESULTS: 05-APR-77 PAGE NO. 4 012 SCH-C 0-0 3/20																
SLAPPED TIME	BATT VOLT UNFIL	BATT VOLT FIL	U-M BATT VOLT DISCH	NOT VOLT FIL	BATT VOLT UNFIL	BATT VOLT FIL	U-M BATT VOLT BEING	NOT VOLT FIL	FIFTH WHEEL RPM	REG.C WGT	REG.C MOTOR	U-M TO MOTOR	U-M FROM MOTOR	REGEN WGT FIL	REGEN WGT UNF	FIFTH CALI-BATH
MIN SEC	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
6:40.0	112.0	113.7	111.3	104.0	205.3	202.7	1.1	175.1	19.93	10.35	20.30	63.0	73.0	0.00	0.00	5.000
6:40.2	115.7	115.7	114.5	100.7	231.7	203.4	4.6	175.1	22.25	10.39	20.40	69.7	73.0	0.00	0.00	5.000
6:41.2	110.7	114.5	110.7	100.7	231.7	203.4	4.6	175.1	22.25	10.39	20.40	69.7	73.0	0.00	0.00	5.000
6:44.0	116.0	113.0	7.9	107.3	201.4	196.5	1.2	180.1	20.41	10.61	20.40	70.9	73.0	0.00	0.00	5.000
6:47.0	123.4	122.3	22.7	104.0	201.4	196.5	1.2	180.1	20.41	10.61	20.40	70.9	73.0	0.00	0.00	5.000
7:0.0	126.1	126.1	22.7	104.0	201.4	196.5	1.2	180.1	20.41	10.61	20.40	70.9	73.0	0.00	0.00	5.000
7:3.0	126.1	126.1	22.7	104.0	201.4	196.5	1.2	180.1	20.41	10.61	20.40	70.9	73.0	0.00	0.00	5.000
7:6.0	126.1	126.1	22.7	104.0	201.4	196.5	1.2	180.1	20.41	10.61	20.40	70.9	73.0	0.00	0.00	5.000
7:9.0	126.1	126.1	22.7	104.0	201.4	196.5	1.2	180.1	20.41	10.61	20.40	70.9	73.0	0.00	0.00	5.000
7:10.0	126.1	121.7	40.1	74.7	32.2	36.7	1.1	182.2	20.57	10.57	19.40	124.5	97.5	0.00	0.00	5.000
7:12.0	116.4	113.0	33.6	66.5	163.5	103.0	1.2	90.1	20.52	10.57	20.40	132.4	97.5	0.00	0.00	5.000
7:15.0	126.1	126.1	22.7	104.0	201.4	196.5	1.2	180.1	20.41	10.61	20.40	70.9	73.0	0.00	0.00	5.000
7:18.0	126.1	126.1	22.7	104.0	201.4	196.5	1.2	180.1	20.41	10.61	20.40	70.9	73.0	0.00	0.00	5.000
7:19.4	126.6	126.7	37.7	1.5	3.2	3.2	1.1	0.4	20.52	10.57	20.40	132.4	97.5	0.00	0.00	5.000
7:22.0	126.3	126.0	50.9	1.3	3.6	3.6	1.1	0.4	20.71	10.57	20.40	132.4	97.5	0.00	0.00	5.000
7:25.0	127.1	127.0	59.0	0.0	3.6	3.6	1.1	0.4	20.28	10.59	20.49	132.4	97.5	0.00	0.00	5.000
7:26.0	127.0	127.0	59.9	7.6	4.1	4.1	1.1	0.4	20.35	10.57	20.38	132.4	97.5	0.00	0.00	5.000
7:32.0	127.3	127.3	60.3	0.4	3.7	3.7	1.2	0.4	20.17	10.63	20.35	132.4	97.5	0.00	0.00	5.000
7:33.2	127.3	127.3	60.3	0.4	3.6	3.6	1.3	0.4	20.19	10.63	20.30	132.4	97.5	0.00	0.00	5.000
7:34.4	127.3	127.6	60.3	0.4	3.8	3.8	1.1	0.4	20.17	10.72	20.67	132.4	97.5	0.00	0.00	5.000
7:36.7	127.7	127.7	60.3	0.4	3.7	3.7	1.1	0.4	20.17	10.72	20.62	132.5	97.9	0.00	0.00	5.000
7:40.6	127.6	127.0	61.7	0.4	3.3	3.2	1.1	0.4	20.17	10.75	20.75	132.4	97.5	0.00	0.00	5.000
7:40.8	127.9	127.9	61.6	0.4	3.2	3.1	1.1	0.4	20.17	10.65	19.80	132.4	97.5	0.00	0.00	5.000
7:51.0	127.9	128.0	61.7	0.4	3.2	3.2	1.1	0.4	20.17	10.67	20.62	132.4	97.5	0.00	0.00	5.000
7:53.0	128.1	128.1	62.9	0.4	2.6	2.6	1.1	0.4	20.17	10.65	20.62	132.4	97.5	0.00	0.00	5.000
7:57.0	126.3	126.3	64.4	24.1	13.4	60.7	1.1	107.2	5.53	10.66	9.31	120.2	150.4	0.00	0.00	5.000
8:0.0	123.7	129.4	72.4	59.7	166.7	110.0	1.3	104.2	12.61	19.12	20.59	149.9	150.1	0.00	0.00	5.000
8:1.3	113.5	111.6	67.1	106.3	200.7	193.0	1.2	104.2	19.33	19.07	21.62	160.9	150.1	0.00	0.00	5.000
8:1.4	115.4	114.4	67.1	106.3	200.7	193.0	1.2	104.2	19.33	19.07	21.62	160.9	150.1	0.00	0.00	5.000
8:1.6	113.5	112.7	115.4	96.3	231.9	201.0	2.0	210.4	25.33	19.25	21.25	190.7	150.3	0.00	0.00	5.000
8:12.0	112.4	112.3	136.9	109.0	177.4	174.9	1.1	124.7	29.02	19.25	21.12	213.4	150.1	0.00	0.00	5.000
8:14.0	116.0	114.0	108.0	67.3	81.2	50.2	6.0	99.7	19.33	19.31	21.21	213.4	150.1	0.00	0.00	5.000
8:15.0	121.6	121.6	108.0	67.3	81.2	50.2	6.0	99.7	19.33	19.31	21.21	213.4	150.1	0.00	0.00	5.000
8:22.0	119.9	120.1	102.5	01.0	80.6	75.0	6.5	96.1	25.40	19.38	21.17	237.6	150.2	0.00	0.00	5.000
8:25.4	110.7	120.1	170.7	01.0	80.6	75.0	6.7	96.1	25.42	19.35	21.12	244.2	150.1	0.00	0.00	5.000
8:26.1	118.1	120.0	170.1	01.2	41.4	75.0	6.5	92.1	25.16	19.31	21.17	252.6	150.4	0.00	0.00	5.000
8:31.6	117.0	120.0	106.3	01.0	80.7	75.0	6.7	96.1	25.44	19.40	21.19	250.0	150.1	0.00	0.00	5.000
8:34.0	126.0	126.1	191.5	1.4	3.3	3.4	6.0	0.1	25.27	19.35	21.21	250.7	150.1	0.00	0.00	5.000
8:38.0	126.6	126.6	191.5	1.4	3.4	3.4	6.0	0.1	25.27	19.35	21.21	250.7	150.1	0.00	0.00	5.000
8:40.0	126.9	126.9	191.5	1.4	3.5	3.5	6.0	0.1	25.27	19.35	21.21	250.7	150.1	0.00	0.00	5.000
8:44.0	127.2	127.1	192.5	0.5	3.1	3.1	6.0	0.1	25.11	19.45	21.19	250.0	150.1	0.00	0.00	5.000
8:47.2	127.3	127.2	193.0	0.5	3.6	3.7	6.5	0.1	1.04	19.25	21.23	250.1	150.5	0.00	0.00	5.000
8:50.4	127.5	127.3	194.2	0.4	3.6	3.7	6.5	0.1	1.17	19.40	21.32	252.7	150.1	0.00	0.00	5.000
8:53.3	127.3	127.4	194.2	0.4	3.6	3.6	6.5	0.1	0.17	19.42	21.42	250.0	150.1	0.00	0.00	5.000
8:56.6	127.6	127.6	194.2	0.4	2.9	3.2	6.5	0.4	0.19	19.42	21.42	250.0	150.1	0.00	0.00	5.000
9:00.5	127.6	127.7	194.4	0.4	3.2	3.3	6.0	0.5	0.10	19.37	21.50	250.7	150.1	0.00	0.00	5.000

EVENT RESULTS: 05-APR-77 PAGE NO. 35 012 CONT'D --2																
SLAPPED TIME	BATT VOLT UNFIL	BATT VOLT FIL	U-M BATT VOLT	NOT VOLT FIL	BATT VOLT UNFIL	BATT VOLT FIL	U-M BATT VOLT	NOT VOLT FIL	FIFTH WHEEL RPM	REG.C REG.C WGT	U-M TO MOTOR	U-M FROM MOTOR	REGEN WGT	REGEN WGT	FIFTH CALI- BATH	
MIN SEC	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
70:5.0	115.1	114.2	264.6	50.1	30.0	30.0	10.6	57.9	20.27	24.10	54.14	251.6	129.0	0.00	0.00	5.000
70:8.0	114.2	113.3	270.0	50.0	27.6	44.9	10.0	62.3	20.79	21.97	53.81	255.0	129.0	0.00	0.00	5.000
70:11.0	112.0	112.0	274.3	65.0	40.4	40.4	10.0	71.3	20.61	23.94	53.51	259.0	129.0	0.00	0.00	5.000
70:14.0	112.4	112.1	279.5	67.6	40.2	55.0	11.4	74.7	20.89	23.94	57.19	263.7	129.0	0.00	0.00	5.000
70:17.0	117.5	117.5	282.1	1.6	4.3	4.5	10.0	1.5	20.54	23.94	52.90	263.7	129.0	0.00	0.00	5.000
70:20.0	117.9	117.9	283.5	1.5	4.3	4.5	10.0	1.5	20.70	23.94	52.61	267.0	129.0	0.00	0.00	5.000
70:23.0	117.9	118.1	283.5	1.5	5.3	5.3	10.0	1.5	23.34	24.81	52.33	263.7	129.5	0.00	0.00	5.000
70:26.0	118.2	118.2	283.5	1.1	4.0	5.0	10.0	1.4	14.70	23.83	52.04	263.0	129.1	0.00	0.00	5.000
70:29.0	118.2	118.3	285.1	0.7	5.0	5.1	11.1	0.7	5.27	23.81	51.67	263.7	129.0	0.00	0.00	5.000
70:32.0	118.4	118.3	284.7	0.4	5.1	5.0	11.0	0.4	0.22	23.74	51.77	263.1	129.0	0.00	0.00	5.000
70:35.0	118.4	118.4	286.1	0.4	5.1	5.0	10.0	0.4	0.20	23.72	51.77	263.1	129.0	0.00	0.00	5.000
70:38.0	118.6	118.6	286.1	0.4	4.5	4.5	10.0	0.4	0.20	23.70	51.84	265.2	129.1	0.00	0.00	5.000
70:41.0	118.7	118.7	287.3	0.4	4.6	4.6	10.6	1.1	0.11	23.74	52.01	265.1	129.0	0.00	0.00	5.000
70:44.0	118.7	118.7	287.3	0.4	4.5	4.5	10.0	0.5	0.20	23.68	52.22	265.2	129.0	0.00	0.00	5.000
70:47.0	118.8	118.8	287.3	0.5	4.3	4.5	11.1	0.7	0.20	23.70	52.36	265.1	129.0	0.00	0.00	5.000
70:50.0	118.8	118.8	287.3	0.5	4.6	4.5	10.9	0.4	0.74	23.72	52.54	265.1	129.0	0.00	0.00	5.000
70:53.0	118.8	118.8	287.3	0.4	4.0	4.0	10.0	12.0	0.66	23.72	52.68	266.4	210.6	0.00	0.00	5.000
70:56.0	115.7	112.7	293.0	34.1	36.9	77.9	10.0	170.0	7.91	23.70	52.79	212.0	210.0	0.00	0.00	5.000
70:59.0	116.6	105.9	302.4	66.5	70.0	125.9	10.6	180.1	14.77	23.66	52.86	212.1	210.6	0.00	0.00	5.000
71:0.0	102.9	103.2	317.3	100.4	141.6	129.3	10.0	12.4	20.40	23.74	52.50	237.0	210.5	0.00	0.00	5.000
71:3.0	115.9	116.4	327.2	1.0	0.5	30.0	11.1	139.2	23.84	23.77	52.83	1.3	210.7	0.00	0.00	5.000
71:6.0	118.3	118.3	340.4	96.0	172.4	1										

1

ORIGINAL PAGE IS
OF POOR QUALITY

Table 6.2.4. Samples of Data Printout for Test No. 15 (B Cycle, no Regen Br)

E V N T F		RESULTS :				86-APR-77				PAGE NO. 7				*15 SCH-B W/O 3/25											
ELAPSED	TIME	BATT	BATT	U-H	U-H	U-H	U-H	U-H	U-H	U-H	U-H	U-H	U-H	U-H	U-H	U-H	U-H	U-H	U-H	U-H	U-H	U-H	U-H	U-H	U-H
VOLT	U-H	VOLT	U-H	U-H	U-H	U-H	U-H	U-H	U-H	U-H	U-H	U-H	U-H	U-H	U-H	U-H	U-H	U-H	U-H	U-H	U-H	U-H	U-H	U-H	U-H
U-H	U-H	U-H	U-H	U-H	U-H	U-H	U-H	U-H	U-H	U-H	U-H	U-H	U-H	U-H	U-H	U-H	U-H	U-H	U-H	U-H	U-H	U-H	U-H	U-H	U-H
MIN	SEC	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
13	144.8	127.5	127.5	245.6	0.4	4.2	4.4	341.3	0.7	0.19	20.45	26.00	260.5	6.5	0.00	0.00	5.000								
13	147.2	127.6	127.9	245.7	0.4	4.0	4.4	341.3	0.7	0.19	20.47	26.04	260.1	6.6	0.00	0.00	5.000								
13	150.4	127.6	127.8	245.6	0.4	3.8	4.8	341.3	0.7	0.14	20.42	26.06	260.1	6.6	0.00	0.00	5.000								
13	153.6	128.0	128.0	245.6	0.4	3.0	4.8	341.3	0.7	0.19	20.36	26.09	260.1	6.6	0.00	0.00	5.000								
13	156.4	128.1	128.1	245.6	0.3	4.1	4.8	341.3	0.8	0.22	20.53	26.27	260.6	6.2	0.00	0.00	5.000								
13	159.6	128.2	128.2	245.5	0.4	3.9	3.9	341.3	0.7	0.19	20.40	26.15	260.2	6.5	0.00	0.00	5.000								
14	1.0	128.2	128.2	245.5	0.4	4.0	4.0	341.3	0.7	0.23	20.39	26.22	260.1	6.6	0.00	0.00	5.000								
14	1.6	128.3	128.3	245.2	0.4	4.6	10.7	341.3	10.7	1.41	20.42	26.24	212.2	54.9	0.00	0.00	5.000								
14	1.9	128.3	128.3	252.2	34.7	104.0	36.3	341.3	131.0	7.47	20.42	26.27	216.1	64.6	0.00	0.00	5.000								
14	112.2	128.9	124.2	257.8	37.9	73.3	41.0	341.3	38.6	9.54	20.40	26.24	220.3	67.1	0.00	0.00	5.000								
14	115.4	124.3	122.5	262.5	40.4	35.7	60.1	341.3	111.0	11.71	20.47	26.35	225.6	67.1	0.00	0.00	5.000								
14	118.6	119.0	120.2	271.1	68.4	65.2	97.9	341.3	136.0	14.52	20.40	26.31	240.9	67.3	0.00	0.00	5.000								
14	121.6	123.1	120.1	280.5	76.6	65.2	89.7	341.3	132.0	17.17	20.40	26.31	243.1	67.2	0.00	0.00	5.000								
14	124.0	115.5	116.3	294.1	71.7	19.3	5.2	341.3	0.7	19.71	20.40	26.31	240.9	67.3	0.00	0.00	5.000								
14	126.8	125.3	122.7	296.7	72.5	32.3	64.5	341.3	67.0	19.61	20.34	26.31	254.1	67.2	0.00	0.00	5.000								
14	131.2	124.3	121.6	303.6	60.1	63.3	60.0	341.3	69.0	20.10	20.45	26.42	260.3	67.1	0.00	0.00	5.000								
14	134.2	122.0	122.0	300.0	65.0	24.0	40.2	341.3	69.0	19.84	20.27	26.22	264.3	67.1	0.00	0.00	5.000								
14	137.4	123.4	122.0	314.0	66.0	36.0	40.4	341.3	69.0	19.81	20.27	26.24	259.6	67.1	0.00	0.00	5.000								
14	140.6	124.0	122.0	319.6	66.0	70.1	1.1	341.3	69.0	19.17	20.18	26.22	275.1	68.2	0.00	0.00	5.000								
14	143.8	122.3	123.5	325.1	35.3	4.0	0.0	341.3	0.7	19.39	20.14	26.24	276.5	67.1	0.00	0.00	5.000								
14	146.6	127.0	127.0	325.1	1.3	4.0	4.8	341.3	0.7	16.04	20.00	26.10	276.2	67.2	0.00	0.00	5.000								
14	149.3	126.9	127.1	326.4	1.9	4.0	4.4	341.3	0.7	6.00	20.00	26.12	276.5	67.1	0.00	0.00	5.000								
14	153.0	127.5	127.4	326.6	0.4	4.0	4.4	341.3	0.7	0.19	19.54	26.06	276.7	67.3	0.00	0.00	5.000								
14	156.2	127.5	127.5	326.4	0.4	4.4	4.4	341.3	0.7	0.19	20.83	26.20	276.4	67.1	0.00	0.00	5.000								
14	159.2	127.6	127.7	327.7	0.4	4.3	4.4	341.3	0.7	0.19	19.59	26.27	277.9	67.2	0.00	0.00	5.000								
15	1.2	127.9	127.9	327.7	0.4	4.2	4.0	341.3	0.7	0.19	19.06	26.30	277.9	67.1	0.00	0.00	5.000								
15	1.6	128.0	128.0	327.2	0.4	3.1	3.1	341.3	0.7	0.19	19.59	26.33	277.0	67.1	0.00	0.00	5.000								
15	1.0	128.1	128.1	329.2	0.4	4.0	4.0	341.3	0.7	0.19	19.54	26.36	278.1	67.1	0.00	0.00	5.000								
15	111.0	129.1	129.2	329.3	0.3	4.0	4.0	341.3	0.7	0.19	19.94	26.45	277.8	67.1	0.00	0.00	5.000								
15	115.0	129.2	129.2	329.2	0.4	4.0	4.0	341.3	0.7	0.19	19.06	26.40	277.8	67.1	0.00	0.00	5.000								
15	118.2	129.3	129.2	330.6	0.4	3.7	3.7	341.3	190.1	2.40	19.54	26.50	279.3	64.9	0.00	0.00	5.000								
15	121.4	119.9	123.4	336.1	33.4	53.3	40.3	341.3	124.0	7.63	19.00	26.72	282.3	59.9	0.00	0.00	5.000								
15	124.4	125.0	123.2	341.3	42.9	50.7	53.9	341.3	114.0	9.47	19.52	26.50	289.7	100.4	0.00	0.00	5.000								
15	127.6	123.0	122.3	352.7	2.5	57.6	64.5	341.3	135.0	12.17	19.01	26.60	327.9	160.4	0.00	0.00	5.000								
15	130.8	116.0	117.7	353.4	62.6	86.2	137.9	341.3	162.3	17.12	19.00	26.63	347.5	163.4	0.00	0.00	5.000								
15	134.0	123.2	122.0	364.1	66.4	71.4	65.6	341.3	124.7	10.43	19.00	26.63	347.5	163.4	0.00	0.00	5.000								
15	136.8	124.1	124.1	344.9	6.9	4.1	4.3	341.3	24.1	10.92	19.01	26.60	321.2	100.4	0.00	0.00	5.000								
15	140.0	120.4	118.5	359.9	81.7	68.6	54.5	341.3	71.1	20.00	19.01	26.60	327.9	160.4	0.00	0.00	5.000								
15	143.2	123.5	122.5	365.9	68.5	39.1	50.4	341.3	76.1	20.23	19.01	26.60	327.9	160.4	0.00	0.00	5.000								
15	146.4	120.0	122.0	372.3	67.0	82.6	50.2	341.3	70.3	20.42	19.01	26.60	327.9	160.4	0.00	0.00	5.000								
15	149.4	120.5	122.6	372.3	68.1	76.3	50.1	341.3	70.3	20.00	19.01	26.60	327.9	160.4	0.00	0.00	5.000								
15	152.6	123.1	122.6	372.3	68.1	15.3	23.6	341.3	38.1	19.90	19.53	26.54	341.3	100.4	0.00	0.00	5.000								
15	155.8	125.5	125.9	372.3	20.4	6.0	13.0	341.3	1.1	17.68	19.53	26.60	341.3	100.4	0.00	0.00	5.000								
15	159.0	127.0	127.1	372.3	1.5	3.9	3.9	341.3	0.7	16.55	19.40	26.40	341.3	100.4	0.00	0.00	5.000								

E V N T F		RESULTS :				87-APR-77				PAGE NO. 22				*15A-BU-D 3/25 2											
ELAPSED TIME		BATT VOLT UNFIL	BATT VOLT FIL	U-H DISCH	U-H FIL	BATT VOLT UNFIL	BATT VOLT FIL	U-H RECHG	U-H FIL	FIFTH UNFIL	DEC.C AMPT	DEC.C MOTOR	U-H FROM MOTOR	U-H TO MOTOR	RECHG FIL	RECHG UNFIL	FIXED CRATH								
MIN	SEC	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16								
40	118.2	121.7	120.1	229.6	64.2	59.3	45.2	4.1	64.6	20.12	19.33	45.60	20.3	254.3	0.00	0.00	5.000								
40	119.4	116.2	118.3	239.1	81.2	49.2	73.0	0.00	89.7	19.81	19.31	45.51	35.1	259.3	0.00	0.00	5.000								
40	116.4	121.1	121.6	240.5	44.7	27.0	13.1	4.1	21.5	19.56	1.07	45.41	37.0	254.5	0.00	0.00	5.000								
40	119.6	121.0	120.5	243.3	63.0	29.3	47.0	4.2	60.7	19.26	19.33	45.30	40.5	250.3	0.00	0.00	5.000								
40	122.8	123.7	123.7	247.2	1.4	4.0	4.5	4.1	1.0	16.30	19.33	45.35	40.5	250.6	0.00	0.00	5.000								
40	126.0	124.1	124.1	247.5	0.8	5.1	5.1	4.1	1.0	0.62	19.30	45.35	40.5	252.3	0.00	0.00	5.000								
40	129.0	124.1	124.2	240.7	0.4	5.3	5.0	4.1	1.0	0.22	19.42	45.30	40.7	250.3	0.00	0.00	5.000								
40	134.6	124.3	124.3	246.6	0.4	5.4	5.4	4.1	1.0	0.22	19.46	45.31	40.7	250.3	0.00	0.00	5.000								
40	135.4	124.4	124.4	240.6	0.4	5.1	5.0	4.2	1.0	0.23	19.46	45.31	40.2	250.1	0.00	0.00	5.000								
40	136.0	124.4	124.1	219.4	0.4	4.9	5.0	4.1	1.0	0.22	19.46	45.33	41.0	250.3	0.00	0.00	5.000								
40	140.4	124.4	124.5	250.0	0.4	5.1	5.0	4.2	1.0	0.22	19.46	45.31	41.0	250.3	0.00	0.00	5.000								
40	144.6	124.4	124.4	241.5	0.4	5.3	5.3	4.2	1.0	0.22	19.46	45.31	41.0	250.3	0.00	0.00	5.000								
40	147.0	124.0	124.7	251.2	0.5	4.7	4.5	4.1	1.0	0.22	19.46	45.31	41.0	250.3	0.00	0.00	5.000								
40	151.0	124.0	124.0	252.6	0.5	4.5	4.5	4.1	1.0	0.22	19.46	45.33	41.0	250.3	0.00	0.00	5.000								
40	154.0	123.4	121.9	254.4	20.4	50.0	55.5	4.2	101.4	4.06	19.46	46.02	40.2	313.3	0.00	0.00	5.000								
40	157.2	116.0	115.0	257.0	0.0	105.0	104.0	4.2	111.9	11.97	19.35	46.00	53.4	315.4	0.00	0.00	5.000								
40	160.4	115.7	110.3	266.1	54.6	96.6	71.2	4.1	111.9	11.97	19.35	46.00	59.3	315.0	0.00	0.00	5.000								
40	163.6	110.7	117.7	274.1	65.4	39.9	70.5	4.1	113.6	14.00	19.42	46.00	67.2	311.4	0.00	0.00	5.000								
40	169.2	113.5	115.5	262.1	0.0	120.0	120.1	4.2	14.7	17.06	19.42	46.15	76.8	314.4	0.00	0.00	5.000								
40	170.0	112.6	116.6	261.0	0.0	77.0	77.0	4.2	2.6	19.31	19.46	46.00	114.4	0.00	0.00	5.000									
40	173.0	127.1	120.3	300.0	68.0	64.3	69.5	4.2	91.2	19.29	19.49	46.11	89.3	313.9	0.00	0.00	5.000								
40	176.2	119.2	120.1	306.6	64.6	57.4	65.1	4.1	67.0	21.04	19.40	45.93	100.0	314.4	0.00	0.00	5.000								
40	181.2	120.0	121.0	311.0	49.0	49.0	49.7	4.2	69.0	19.31	19.40	45.93	104.0	314.4	0.00	0.00	5.000								
40	182.4	120.6	120.0	316.0	75.3	65.0	63.2	4.3	81.7	19.30	19.40	45.93	104.0	314.4	0.00	0.00	5.000								
40	185.5	120.0	116.0	322.0	63.0	62.5	39.0	4.1	59.9	20.50	19.40	45.70	109.9	314.3	0.00	0.00	5.000								
40	188.0	119.6	121.6	326.7	45.7	71.3	21.2	4.1	37.4	19.35	19.35	45.70	109.9	314.3	0.00	0.00	5.000								
40	191.6	121.6	121.6	327.0	32.0	52.0	52.0	4.1	37.0	19.35	19.35	45.70	109.9	314.3	0.00	0.00	5.000								
40	194.4	123.0	123.0	330.0	1.3	5.1	5.0	4.1	1.0	0.79	19.33	45.81	113.9	314.5	0.00	0.00	5.000								
40	198.0	124.1	124.1	331.1	0.4	5.1	5.1	4.1	1.0	0.22	19.39	45.81	113.9	314.3	0.00	0.00	5.000								
40	141.2	124.3	124.2	332.2	0.4	5.1	5.1	4.1	1.0	0.22	19.42	45.99	113.9	314.3	0.00	0.00	5.000								
40	144.2	124.1	124.1	334.5	0.5	4.9	4.9	4.1	1.0	0.22	19.42	45.99	113.9	314.4	0.00	0.00	5.000								
40	147.4	124.4	124.4	333.5	0.4	4.0	4.0	4.1	1.0	0.22	19.46	46.27	113.9	314.5	0.00	0.00	5.000								
40	150.6	124.6	124.5	333.5	0.6	4.9	4.6	3.9	5.0	0.00	19.64	46.45	113.9	314.3	0.00	0.00	5.000								
40	153.0	124.5	124.5	333.6	0.4	5.0	5.0	4.1	1.0	0.22	19.53	46.41	113.9	314.6	0.00	0.00	5.000								
40	156.6	124.6	124.6	333.6	0.4	4.9	4.9	4.1	1.0	0.24	19.47	46.75	113.9	314.7	0.00	0.00	5.000								
40	160.0	124.0	124.7	334.5	0.5	4.6	4.5	4.1	1.0	0.22	19.60	46.92	113.9	314.6	0.00	0.00	5.000								
40	163.2	124.0	124.4	336.7	0.4	4.6	4.6	4.1	1.0	0.22	19.70	46.99	120.7	31.5	0.00	0.00	5.000								
40	166.4	122.0	120.0	340.4	20.0	26.0	32.0	4.1	171.6	6.32	19.79	47.17	126.1	13.5	0.00	0.00	5.000								
40	169.6	117.0	117.0	341.9	0.0	101.0	101.0	4.2	14.9	19.39	19.40	46.99	130.0	314.4	0.00	0.00	5.000								
40	172.6	112.6	117.1	344.0	0.0	51.1	91.1	4.1	133.5	13.13	19.81	46.00	140.0	31.0	0.00	0.00	5.000								
40	175.0	114	115.7	349.0	79.0	90.0	107.5	4.3	137.4	16.04	19.00	47.50	151.7	47.1	0.00	0.00	5.000								
40	178.0	113.7	115.5	352.3	87.3	87.0	64.0	4.2	74.7	10.76	19.47	47.64	159.0	47.1	0.00	0.00	5.000								
40	181.0	113.0	115.0	357.1	87.1	87.1	131.0	4.1	9.0	19.70	19.49	47.0	160.0	47.0	0.00	0.00	5.000								
40	185.0	121.6	123.3	401.4	1.0	4.7	4.9	4.1	1.0	10.74	19.97	46.64	165.3	47.6	0.00	0.00	5.000								

Table 6.2.5. Samples of Data Printout for Test No. 16 (B Cycle, with Regen Br)

E V H T F		RESULTS 1				06-APR-77				PAGE NO. 6				*16 CONTD 3/26			
ELAPSED TIME		BATT VOLT	BATT VOLT	U-H	POT	BATT	BATT	U-H	POT	FIFTH	REG.C	REG.C	U-H	U-H	REGEN	REGEN	FIXED
		UNFIL	FIL	DISCH	FIL	UNFIL	FIL	RECNG	FIL	WHEEL	APP/T	APP/T	MOTOR	MOTOR	APP	FIL	UNFIL
MIN	SEC	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
11	110.8	119.5	120.7	201.0	52.0	117.4	71.7	317.0	121.6	11.09	14.61	49.16	296.6	146.1	0.00	0.00	0.000
11	122.0	118.2	119.3	202.2	67.1	127.4	84.0	310.4	121.5	14.67	14.46	49.22	286.4	146.2	0.00	0.00	0.000
11	125.2	120.1	118.7	219.0	81.2	70.0	93.0	310.3	118.7	17.32	14.64	49.16	315.6	146.1	0.00	0.00	0.000
11	122.4	121.1	120.4	200.0	73.7	40.0	61.4	310.3	82.2	19.30	14.61	49.09	321.2	146.1	0.00	0.00	0.000
11	131.4	119.5	120.5	234.1	59.9	14.4	24.5	310.3	45.0	29.01	14.46	49.06	325.2	146.1	0.00	0.00	0.000
11	134.6	122.9	122.4	236.3	64.6	73.1	47.3	310.3	67.2	19.09	14.66	49.06	327.5	146.9	0.00	0.00	0.000
11	137.0	117.9	122.0	241.6	62.0	46.9	43.4	310.3	67.0	19.77	14.50	48.77	331.0	146.2	0.00	0.00	0.000
11	141.0	121.0	122.0	241.6	62.0	31.2	44.6	310.7	62.4	19.44	14.51	48.64	337.4	146.1	0.00	0.00	0.000
11	146.0	122.7	121.7	251.1	64.6	26.5	45.0	310.2	60.1	19.67	14.50	48.54	341.3	146.2	0.00	0.00	0.000
11	147.0	120.9	121.0	256.6	65.3	46.7	46.0	310.2	67.5	19.19	14.53	48.38	1.3	146.2	0.00	0.00	0.000
11	150.4	124.2	122.3	259.0	6.6	3.2	3.3	319.2	0.7	10.92	14.48	48.25	2.7	146.2	0.00	0.00	0.000
11	153.6	125.6	125.5	260.1	73.6	0.0	0.0	319.7	0.0	14.19	14.48	47.22	2.6	150.3	-40.42	-0.55	0.000
11	156.6	129.7	120.1	260.4	33.0	0.0	0.0	323.0	0.0	5.10	14.39	48.13	2.7	155.9	0.00	0.00	0.000
11	159.0	126.3	126.5	264.3	0.3	4.7	4.0	325.1	0.6	0.19	14.42	48.20	2.6	157.0	0.00	0.00	0.000
12	1.0	126.7	126.7	264.3	0.4	3.0	3.0	324.9	0.0	0.19	14.46	48.35	2.6	157.0	0.00	0.00	0.000
12	1.6	126.7	126.7	267.1	0.4	2.4	2.9	324.9	0.0	0.19	14.46	48.35	2.6	157.0	0.00	0.00	0.000
12	2.0	126.7	126.7	265.6	0.3	3.1	3.0	324.7	0.0	0.13	14.44	48.70	2.6	157.0	0.00	0.00	0.000
12	12.2	126.7	126.7	275.6	0.4	2.7	2.9	325.0	0.0	0.19	14.42	48.90	2.6	157.1	0.00	0.00	0.000
12	15.4	126.7	126.7	265.0	0.5	3.4	2.9	324.9	0.0	0.19	14.46	48.10	2.6	157.0	0.00	0.00	0.000
12	18.4	126.6	126.7	267.1	0.4	2.4	2.9	324.9	0.0	0.19	14.46	48.35	2.6	157.0	0.00	0.00	0.000
12	21.6	126.7	126.7	267.1	0.4	3.0	2.9	325.1	0.0	0.19	14.53	49.59	2.6	157.0	0.00	0.00	0.000
12	24.4	123.9	124.0	268.0	17.0	63.0	34.2	325.1	149.7	3.95	14.59	49.05	5.3	192.6	0.00	0.00	0.000
12	26.0	120.7	122.9	272.5	34.2	26.9	40.3	325.0	121.6	7.90	14.53	50.02	5.3	194.3	0.00	0.00	0.000
12	27.1	121.0	121.7	270.1	46.3	53.5	56.6	325.0	114.4	10.43	14.59	50.29	14.8	194.3	0.00	0.00	0.000
12	34.2	119.2	120.5	204.6	50.9	66.0	70.3	325.0	114.4	15.23	14.57	50.29	20.1	194.4	0.00	0.00	0.000
12	37.4	118.2	119.6	292.0	69.3	64.9	77.1	325.0	119.0	15.09	14.59	50.36	20.2	194.3	0.00	0.00	0.000
12	40.1	119.3	117.3	302.2	70.6	97.0	114.2	325.1	131.5	10.47	14.49	50.22	39.0	194.4	0.00	0.00	0.000
12	43.4	124.0	124.5	311.2	59.3	71.4	43.2	324.0	02.4	0.00	14.52	50.19	64.2	194.4	0.00	0.00	0.000
12	46.6	123.0	119.9	319.7	79.7	21.4	20.6	325.1	40.7	20.30	14.57	50.19	49.6	194.6	0.00	0.00	0.000
12	50.0	123.3	123.6	323.9	40.3	33.2	33.3	324.9	71.4	19.44	14.81	49.09	52.3	194.3	0.00	0.00	0.000
12	53.2	122.9	122.0	327.0	40.7	15.3	26.3	324.9	4.0	19.61	14.31	49.09	54.9	194.3	0.00	0.00	0.000
12	56.4	121.1	120.5	333.2	79.2	33.6	30.6	325.0	53.5	0.00	0.00	49.72	64.4	194.3	0.00	0.00	0.000
12	59.2	122.9	123.0	337.4	50.0	10.5	37.0	324.0	53.5	19.32	14.81	49.65	63.0	194.4	0.00	0.00	0.000
13	2.4	125.0	125.1	330.1	1.6	3.4	3.3	325.0	0.7	10.19	14.59	49.59	64.4	194.4	0.00	0.00	0.000
13	5.2	126.4	121.1	341.3	67.6	0.0	0.0	327.9	1.0	13.81	14.40	49.51	61.4	201.0	-12.01	-25.33	0.000
13	8.0	131.1	120.7	341.3	27.7	0.0	0.0	331.0	1.0	4.07	14.53	49.51	64.5	203.0	0.00	0.00	0.000
13	11.0	125.4	126.4	1.4	0.4	3.7	3.4	311.7	0.0	0.19	14.53	49.52	61.4	203.0	0.00	0.00	0.000
13	15.1	126.7	125.7	2.5	0.4	2.7	2.7	313.4	1.0	0.20	14.53	49.59	64.4	203.0	0.00	0.00	0.000
13	18.1	126.7	126.6	2.5	0.4	2.1	2.1	313.4	1.0	0.17	14.57	49.72	64.4	203.0	0.00	0.00	0.000
13	21.4	126.6	126.6	2.5	0.4	2.0	3.0	313.3	1.0	0.15	14.47	49.62	64.4	203.0	0.00	0.00	0.000
13	24.4	126.7	126.7	2.6	0.4	2.9	2.9	313.3	1.0	0.19	14.50	50.12	64.4	203.0	0.00	0.00	0.000
13	27.6	126.7	126.7	3.9	0.4	2.1	2.0	313.3	1.0	0.17	14.56	50.32	64.4	203.0	0.00	0.00	0.000
13	30.7	126.7	126.6	2.9	0.4	2.9	3.0	313.3	1.0	0.17	14.55	50.51	64.4	203.0	0.00	0.00	0.000
13	34.0	126.0	126.7	3.6	0.2	2.0	2.9	313.3	2.0	0.21	14.55	50.76	93.4	0.00	0.00	0.000	

E V H T F RESULTS 06-APR-77 PAGE NO. 20 *16 CONTD 3/26 T2/															
ELAPSED	BATT	BATT	U-H	POT	BATT	BATT	U-H	POT	FIFTH	REG.C	REG.C	U-H	U-H	REGEN	FIXED
TIME	VOLT	VOLT	DISCH	VOLT	APP	APP	DISCH	VOLT	WHEEL	APP	APP	TO	FROM	APP	CHG
MIN SEC	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
43 37.0	122.0	122.0	193.2	0.5	3.2	3.2	135.6	0.1	0.22	15.99	49.65	107.2	107.4	0.00	0.00
43 40.2	122.7	122.7	193.2	0.5	1.1	1.2	135.6	0.1	0.22	16.02	49.72	107.3	107.4	0.00	0.00
43 43.2	122.7	122.7	193.0	0.6	1.2	2.9	134.9	0.0	0.20	16.02	49.89	107.2	107.4	0.00	0.00
43 46.2	122.6	122.6	193.3	0.5	3.2	3.2	135.7	0.0	0.22	15.97	50.02	107.3	107.4	0.00	0.00
43 49.4	122.6	122.6	194.9	0.6	3.7	3.2	135.6	0.1	0.22	15.99	50.26	107.2	107.4	0.00	0.00
43 52.4	122.5	122.5	194.5	0.5	3.3	3.2	135.0	0.0	0.22	16.02	50.39	107.2	107.4	0.00	0.00
43 55.6	121.0	121.1	200.0	0.0	0.0	0.0	135.6	147.7	3.59	15.99	50.56	109.9	106.6	0.00	0.00
43 58.0	117.0	117.6	210.0	36.2	53.0	54.5	135.0	125.1	0.37	15.91	50.00	113.6	105.0	0.00	0.00
44 1.2	114.1	115.0	209.3	47.7	26.9	54.3	135.7	100.7	11.50	15.95	49.73	114.4	106.6	0.00	0.00
44 1.4	115.2	115.9	210.9	50.0	30.0	50.2	135.9	53.3	13.91	15.95	50.63	114.9	106.6	0.00	0.00
44 1.7	114.0	114.0	217.4	47.2	29.9	74.0	135.9	0.0	15.51	16.04	50.73	110.1	105.4	0.00	0.00
44 10.4	114.9	112.2	225.0	09.9	105.4	109.9	135.9	114.4	20.05	16.06	50.76	110.1	106.4	0.00	0.00
44 13.6	110.9	119.3	234.3	41.2	11.6	22.5	135.6	41.2	15.97	16.13	50.46	110.1	106.6	0.00	0.00
44 16.6	110.3	110.6	234.3	47.0	13.7	27.3	135.7	40.7	15.91	15.93	50.36	142.1	103.5	0.00	0.00
44 19.0	119.0	119.3	237.6	49.5	19.7	20.6	135.7	40.3	19.51	15.91	49.99	143.6	103.4	0.00	0.00
44 22.0	115.4	110.4	243.2	40.7	19.3	26.5	135.7	40.3	19.54	16.04	50.02	146.3	103.1	0.00	0.00
44 26.0	119.4	110.5	245.7	40.7	10.0	26.3	135.7	40.5	20.07	15.93	49.79	140.8	103.1	0.00	0.00
44 29.3	119.2	110.5	240.5	47.2	13.7	29.3	135.7	40.5	20.12	15.62	49.79	150.3	102.2	0.00	0.00
44 32.2	120.7	120.0	250.0	1.7	3.9	3.0	135.7	1.2	19.19	16.10	49.99	150.3	102.2	0.00	0.00
44 35.0	121.2	121.2	251.9	79.0	0.0	0.0	136.9	0.0	15.61	15.91	49.65	150.4	200.0	-26.43	-49.52
44 38.2	120.2	120.4	251.6	42.6	0.0	0.0	144.1	0.0	7.00	15.97	49.62	150.4	200.5	-7.99	-12.64
44 41.2	123.4	123.7	256.0	4.0	4.4	4.3	143.2	0.0	0.46	15.00	49.65	150.3	200.6	0.00	0.00
44 44.4	125.0	122.9	259.1	0.5	3.7	3.4	143.1	0.0	0.23	15.95	49.72	150.3	200.6	0.00	0.00
44 47.4	127.7	127.7	256.1	0.5	3.4	3.4	143.2	0.0	0.23	15.91	49.85	150.4	200.7	0.00	0.00
44 50.6	122.5	1.4	257.4	0.3	7.3	0.0	143.1	0.0	0.22	15.95	50.12	150.3	200.6	0.00	0.00
44 53.6	122.5	122.6	259.2	0.5	3.4	3.4	143.3	0.0	0.22	15.91	50.26	150.0	310.0	0.00	0.00
44 56.0	122.6	122.5	259.1	0.5	3.4	3.5	143.0	0.0	0.22	15.95	50.40	150.6	310.2	0.00	0.00
44 59.0	122.6	122.6	259.1	0.5	3.4	3.5	143.0	0.0	0.22	15.95	50.40	150.6	310.2	0.00	0.00
44 59.0	122.6	122.6	259.1	0.5	3.4	3.5	143.0	0.0	0.22	15.95	50.40	150.6	310.2	0.00	0.00
44 59.0	122.6	122.6	259.1	0.5	3.4	3.5	143.0	0.0	0.22	15.95	50.40	150.6	310.2	0.00	0.00
44 59.0	122.6	122.6	259.1	0.5	3.4	3.5	143.0	0.0	0.22	15.95	50.40	150.6	310.2	0.00	0.00
44 59.0	122.6	122.6	259.1	0.5	3.4	3.5	143.0	0.0	0.22	15.95	50.40	150.6	310.2	0.00	0.00
44 59.0	122.6	122.6	259.1	0.5	3.4	3.5	143.0	0.0	0.22	15.95	50.40	150.6	310.2	0.00	0.00
44 59.0	122.6	122.6	259.1	0.5	3.4	3.5	143.0	0.0	0.22	15.95	50.40	150.6	310.2	0.00	0.00
44 59.0	122.6	122.6	259.1	0.5	3.4	3.5	143.0	0.0	0.22	15.95	50.40	150.6	310.2	0.00	0.00
44 59.0	122.6	122.6	259.1	0.5	3.4	3.5	143.0	0.0	0.22	15.95	50.40	150.6	310.2	0.00	0.00
44 59.0	122.6	122.6	259.1	0.5	3.4	3.5	143.0	0.0	0.22	15.95	50.40	150.6	310.2	0.00	0.00
44 59.0	122.6	122.6	259.1	0.5	3.4	3.5	143.0	0.0	0.22	15.95	50.40	150.6	310.2	0.00	0.00
44 59.0	122.6	122.6	259.1	0.5	3.4	3.5	143.0	0.0	0.22	15.95	50.40	150.6	310.2	0.00	0.00
44 59.0	122.6	122.6	259.1	0.5	3.4	3.5	143.0	0.0	0.22	15.95	50.40	150.6	310.2	0.00	0.00
44 59.0	122.6	122.6	259.1	0.5	3.4	3.5	143.0	0.0	0.22	15.95	50.40	150.6	310.2	0.00	0.00
44 59.0	122.6	122.6	259.1	0.5	3.4	3.5	143.0	0.0	0.22	15.95	50.40	150.6	310.2	0.00	0.00
44 59.0	122.6	122.6	259.1	0.5	3.4	3.5	143.0	0.0	0.22	15.95	50.40	150.6	310.2	0.00	0.00
44 59.0	122.6	122.6	259.1	0.5	3.4	3.5	143.0	0.0	0.22	15.95	50.40	150.6	310.2	0.00	0.00
44 59.0	122.6	122.6	259.1	0.5	3.4	3.5	143.0	0.0	0.22	15.95	50.40	150.6	310.2	0.00	0.00
44 59.0	122.6	122.6	259.1	0.5	3.4	3.5	143.0	0.0	0.22	15.95	50.40	150.6	310.2	0.00	0.00
44 59.0	122.6	122.6	259.1	0.5	3.4	3.5	143.0	0.0	0.22	15.95	50.40	150.6	310.2	0.00	0.00
44 59.0	122.6	122.6	259.1	0.5	3.4	3.5	143.0	0.0	0.22	15.95	50.40	150.6	310.2	0.00	0.00
44 59.0	122.6	122.6	259.1	0.5	3.4	3.5	143.0	0.0	0.22	15.95	50.40	150.6	310.2	0.00	0.00
44 59.0	122.6	122.6	259.1	0.5	3.4	3.5	143.0	0.0	0.22	15.95	50.40	150.6	310.2	0.00	0.00
44 59.0	122.6	122.6	259.1	0.5	3.4	3.5	143.0	0.0	0.22	15.95	50.40	150.6	310.2	0.00	0.00
44 59.0	122.6	122.6	259.1	0.5	3.4	3.5	143.0	0.0	0.22	15.95	50.40	150.6	310.2	0.00	0.00
44 59.0	122.6	122.6	259.1	0.5	3.4	3.5	143.0	0.0	0.22	15.95	50.40	150.6	310.2	0.00	0.00
44 59.0	122.6	122.6	259.1	0.5	3.4	3.5	143.0	0.0	0.22	15.95	50.40	150.6	310.2	0.00	0.00
44 59.0	122.6	122.6	259.1	0.5	3.4	3.5	143.0	0.0	0.22	15.95	50.40	150.6	310.2	0.00	0.00
44 59.0	122.6	122.6	259.1	0.5	3.4	3.5	143.0	0.0	0.22	15.95	50.40	150.6	310.2	0.00	0.00
44 59.0	122.6	122.6	259.1	0.5	3.4	3.5	143.0	0.0	0.22	15.95	50.40	150.6	310.2	0.00	0.00
44 59.0	122.6	122.6	259.1	0.5	3.4	3.5	143.0	0.0	0.22	15.95	50.40	150.6	310.2	0.00	0.00
44 59.0	122.6	122.6	259.1	0.5	3.4	3.5	143.0	0.0	0.22	15.95	50.40	150.6	310.2	0.00	0.00
44 59.0	122.6	122.6	259.1	0.5	3.4	3.5	143.0	0.0	0.22	15.95	50.40	150.6	310.2	0.00	0.00
44 59.0	122.6	122.6	259.1	0.5	3.4	3.5	143.0	0.0	0.22	15.95	50.40	150.6	310.2	0.00	

Table 6.2.6. Samples of Data Printout for Test No. 17 (B Cycle, with Regen Br)

E V N T F RESULTS 1 05-APR-77 PAGE NO. 33 0170 3/26 1															
ELAPSED TIME	BATT VOLT	BATT VOLT	U-H DISCH	POT VOLT	BATT VOLT	BATT VOLT	U-H DISCH	POT VOLT	FIFTH UNFIL	REG.C	REG.C	U-H TO	U-H FROM	REGEN VOLT	FIXED CALI-1
MIN SEC	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
73 129.7	123.4	121.9	101.0	69.4	31.0	56.3	205.7	01.2	10.70	12.01	37.21	206.0	172.6	0.05	5.000
73 132.0	118.5	119.6	107.5	82.7	56.0	73.7	205.7	93.4	19.81	11.97	37.21	215.1	172.9	0.00	5.000
73 133.2	121.0	122.0	199.3	61.0	46.4	37.6	205.6	56.1	20.14	11.97	37.14	210.0	172.6	0.00	5.000
73 130.4	122.2	122.1	199.7	64.0	23.0	45.3	206.1	72.1	19.35	11.92	37.06	224.6	172.9	0.00	5.000
73 141.6	122.0	120.9	205.0	31.5	2.4	2.4	205.6	0.0	19.00	11.94	37.03	225.3	172.6	0.00	5.000
73 144.6	125.7	125.0	206.5	1.5	2.1	2.3	208.3	0.7	17.70	11.96	36.90	225.3	172.6	0.00	5.000
73 147.0	130.0	134.0	206.5	62.0	0.0	0.0	292.6	0.1	12.07	12.01	36.96	225.7	182.1	-19.71	31.06
73 151.0	129.2	129.3	206.5	22.2	0.0	0.0	294.1	0.0	2.63	14.12	37.03	225.1	185.0	0.00	5.000
73 154.2	126.7	127.0	206.6	0.3	2.2	2.0	210.1	0.3	0.16	11.96	36.90	235.1	184.0	0.00	5.000
73 157.4	127.3	128.1	200.1	0.5	2.2	2.1	331.9	0.0	0.19	11.90	37.09	235.1	184.7	0.00	5.000
74 1 0.4	127.2	127.3	207.7	0.4	1.0	2.0	331.7	0.3	0.19	11.90	37.21	235.1	184.7	0.00	5.000
74 1 3.1	127.3	127.3	207.6	0.4	2.0	2.0	331.7	0.0	0.19	12.01	37.34	235.1	184.7	0.00	5.000
74 1 6.0	127.3	127.3	207.0	0.4	1.0	2.0	331.0	0.3	0.19	11.90	37.50	244.6	184.3	-0.22	0.00
74 110.0	127.3	127.3	207.7	0.4	1.7	2.0	331.7	0.3	0.19	12.03	37.50	235.1	184.7	0.00	5.000
74 112.0	127.3	127.3	209.3	0.4	2.1	2.1	67.3	0.3	0.19	11.96	37.65	235.1	185.0	0.00	5.000
74 116.0	127.3	127.0	203.1	0.5	0.3	10.0	67.2	155.4	1.00	12.09	37.07	236.4	213.2	0.00	5.000
74 119.2	124.6	124.2	211.0	27.0	22.4	40.1	67.2	126.3	6.13	12.09	30.62	239.1	221.1	0.00	5.000
74 122.4	124.5	124.7	200.0	39.7	24.2	49.2	67.2	113.0	0.91	12.12	30.10	245.9	221.1	0.00	5.000
74 125.4	118.0	121.7	222.0	32.7	64.0	63.5	66.0	116.5	11.82	12.23	30.20	251.2	221.0	0.00	5.000
74 129.6	119.7	118.0	230.0	73.3	154.7	109.2	67.3	149.4	14.92	12.16	30.26	244.4	221.3	0.00	5.000
74 131.0	114.9	115.7	243.0	97.2	124.2	142.7	67.3	122.7	10.69	12.10	30.23	272.6	221.0	0.00	5.000
74 135.0	117.9	120.3	252.1	71.1	53.1	73.3	67.2	93.4	19.46	12.21	30.20	274.1	221.1	0.00	5.000
74 138.0	122.0	121.6	206.0	71.1	31.3	42.6	67.3	74.7	19.22	12.21	30.21	284.6	221.0	0.00	5.000
74 141.2	125.5	120.2	267.1	7.0	44.5	65.4	67.3	87.3	19.52	12.24	30.41	289.5	220.5	0.00	5.000
74 144.4	122.0	121.9	273.0	69.0	13.4	37.9	67.2	56.7	10.59	12.16	30.10	234.1	221.1	0.00	5.000
74 147.6	120.3	120.9	278.1	72.7	84.0	67.0	67.0	117.7	10.99	12.14	30.17	300.0	221.0	0.00	5.000
74 150.6	124.6	124.6	26.32	51.7	32.2	39.9	67.0	6.5	19.74	12.14	30.07	303.4	221.1	0.00	5.000
74 153.6	123.0	124.7	207.1	2.2	2.3	2.4	67.3	1.0	10.49	12.12	37.07	304.4	221.1	0.00	5.000
74 157.0	126.0	125.9	207.1	1.6	2.1	2.4	67.3	1.0	17.73	12.09	37.09	307.0	223.0	-31.72	55.24
75 1 0.2	135.5	132.3	206.6	52.0	8.0	8.0	67.0	1.0	9.61	12.05	37.92	307.5	239.6	-12.57	22.34
75 1 3.0	130.3	128.0	301.5	14.5	0.0	0.0	67.0	1.0	1.41	11.90	37.01	307.5	233.7	0.00	5.000
75 1 6.2	127.4	127.3	303.4	0.4	1.9	2.1	83.5	1.0	0.19	12.05	37.94	307.4	233.2	-0.00	5.000
75 1 9.4	127.4	127.4	303.4	0.4	1.6	1.0	83.4	1.0	0.19	12.05	37.99	307.4	233.2	0.00	5.000
75 112.6	127.5	127.4	307.4	0.4	1.6	1.0	83.4	1.0	0.19	12.05	38.10	307.5	233.2	0.00	5.000
75 115.6	127.4	127.4	303.3	0.5	2.0	1.0	83.2	1.0	0.11	12.07	38.03	307.4	233.2	0.00	5.000
75 118.6	127.5	127.4	304.7	0.4	1.7	1.0	143.9	1.0	0.19	12.05	38.31	307.6	233.4	0.00	5.000
75 122.0	127.4	127.4	304.9	0.5	2.1	2.1	144.2	1.0	0.19	12.05	38.41	307.4	233.2	0.00	5.000
75 125.1	127.3	127.4	254.7	0.4	1.9	2.1	144.2	1.0	0.19	12.07	38.55	307.4	233.2	0.00	5.000
75 128.2	125.5	124.7	304.7	10.0	35.0	27.0	145.5	14.1	1.41	12.07	38.55	307.4	233.2	0.00	5.000
75 131.4	125.1	124.0	304.9	31.2	19.5	39.9	145.0	11.4	7.40	12.16	40.16	322.7	13.1	0.00	5.000
75 134.6	124.6	124.9	314.2	43.4	51.5	40.3	145.0	10.7	10.63	12.00	39.97	327.0	13.3	0.00	5.000
75 137.0	118.4	121.5	319.0	55.0	36.4	57.6	125.1	9.9	10.00	12.07	39.00	323.3	13.4	0.00	5.000
75 140.0	123.5	119.9	326.4	74.9	120.3	91.1	144.4	12.1	16.02	12.11	39.13	341.3	13.5	0.00	5.000
75 144.0	116.4	117.6	337.2	93.1	99.6	82.7	145.2	05.1	19.94	12.07	39.13	5.3	13.3	0.00	5.000

C V N T F RESULTS 1 05-APR-77 PAGE NO. 27 0170 3/26 2															
ELAPSED TIME	BATT VOLT UNFIL	BATT VOLT FIL	U-H DISCH	POT VOLT	BATT VOLT UNFIL	BATT VOLT UNFIL	U-H DISCH	POT VOLT	FIFTH UNFIL	REG.C	REG.C	U-H TO	U-H FROM	REGEN VOLT FIL	FIXED CALI-1
MIN SEC	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
59 132.2	120.2	119.9	52.6	7.3	17.7	20.1	233.9	133.1	4.01	15.79	52.31	114.2	25.0	0.01	5.000
59 135.0	117.0	117.1	53.3	23.2	36.6	39.0	234.0	12.6	5.50	15.77	52.51	114.2	60.7	0.00	5.000
59 138.2	116.4	115.0	59.3	34.3	41.1	42.6	233.7	0.0	0.20	15.77	52.47	110.1	60.6	0.00	5.000
60 1 1.4	115.0	113.1	66.0	51.0	33.9	67.0	234.0	1.5	12.07	15.73	52.33	123.6	60.7	0.00	5.000
60 1 4.6	100.7	111.6	73.0	67.1	113.0	80.2	233.9	1.1	15.56	15.62	52.22	131.4	60.7	0.00	5.000
60 1 7.6	100.7	110.7	81.0	81.0	113.0	91.1	234.0	10.0	16.47	15.70	52.01	139.6	60.7	0.00	5.000
60 110.0	117.5	117.7	00.0	20.0	15.9	31.6	234.0	14.6	19.45	15.66	51.04	143.5	60.0	0.00	5.000
60 114.0	111.4	113.6	91.5	71.3	56.1	54.7	234.0	14.6	20.74	15.62	51.66	147.0	60.7	0.00	5.000
60 117.2	117.1	117.5	93.3	31.7	9.3	13.0	233.4	1.0	19.75	15.59	51.57	147.6	60.0	0.00	5.000
60 120.2	110.3	117.7	96.9	31.4	0.0	14.5	234.1	-0.2	19.15	15.57	51.20	149.1	60.7	0.00	5.000
60 123.4	114.0	115.5	99.2	50.2	26.5	40.6	234.0	10.3	19.15	15.57	51.11	151.6	60.6	0.00	5.000
60 126.6	113.6	114.9	103.6	59.4	23.1	29.0	234.1	1.7	20.10	15.57	51.10	154.5	60.6	0.00	5.000
60 129.0	110.3	110.2	104.9	14.9	4.2	4.2	233.9	1.0	19.07	15.57	50.90	154.4	60.6	0.00	5.000
60 132.0	119.2	119.2	104.9	1.7	4.0	0.0	235.6	0.0	17.22	15.62	50.76	154.5	60.2	-37.22	55.24
60 136.0	125.0	125.0	104.9	50.0	0.0	0.0	240.1	6.0	9.25	15.59	50.66	154.5	72.0	-31.41	19.41
60 139.2	122.1	122.0	109.1	12.7	2.0	1.4	247.6	0.0	1.11	15.47	50.56	162.7	74.7	0.00	5.000
60 142.4	121.3	121.3	109.2	0.5	4.0	4.0	247.6	0.0	0.27	15.57	50.53	164.6	74.3	0.00	5.000
60 145.2	121.0	121.0	110.3	0.5	3.7	3.0	247.5	0.0	0.74	15.57	50.53	164.6	74.2	0.00	5.000
60 148.4	120.9	120.0	110.4	0.9	3.0	3.0	247.5	0.0	0.24	15.57	50.63	160.0	74.2	0.00	5.000
60 151.6	120.0	120.0	110.4	0.5	3.9	3.7	247.5	0.0	0.24	15.51	50.73	160.1	74.3	0.00	5.000
60 154.0	120.0	120.0	111.5	0.6	3.7	3.2	246.7	0.0	0.23	15.57	50.90	160.0	74.7	0.00	5.000
60 150.0	120.7	120.7	111.7	0.5	4.7	3.7	247.5	1.0	0.15	15.57	51.11	160.0	74.3	0.00	5.000
61 1 1.0	120.7	120.7	112.0	0.5	4.1	4.0	247.6	0.2	0.24	15.59	51.20	160.0	74.2	0.00	5.000
61 1 4.2	120.1	119.1	112.0	11.0	13.1	25.3	247.5	1.4	3.09	15.62	51.49	169.3	99.0	0.00	5.000
61 1 7.4	117.0	117.1	115.7	27.1	17.9	35.6	247.5	10.1	6.07	15.66	51.66	172.0	111.5	0.00	5.000
61 110.6	116.0	115.0	119.0	37.1	40.7	42.1	247.6	0.3	9.52	15.64	51.73	176.4	111.5	0.00	5.000
61 113.6	114.9	114.0	125.1	52.4	39.4	67.3	246.0	1.1	12.07	15.64	51.07	181.5	111.4	0.00	5.000
61 116.0	114.0	113.1	132.0	67.5	54.9	82.6	245.0	1.9	15.73	15.63	51.29	184.5	111.5	0.00	5.000
61 120.0	111.5	110.3	140.3	81.9	61.2	95.0	247.5	1.0	19.40	15.79	51.94	190.6	111.5	0.00	5.000
61 123.2	112.0	114.5	146.0	46.6	11.7	20.3	247.5	1.4	20.24	15.75	51.90	200.4	111.4	0.00	5.000
61 126.2	117.2	117.0	130.9	30.0	19.0	24.0	247.5	1.7	19.17	15.79	51.87	201.0	111.5	0.00	5.000
61 129.2	116.2	116.0	136.7	24.5	16.6	21.7	247.5	0.6	31.01	15.81	51.87	201.0	111.5	0.00	5.000
61 132.6	116.0	115.3	137.3	30.7	53.0	30.0	246.6	4.0	6.34	15.00	51.77	201.0	111.4	0.00	5.000
61 135.0	116.3	117.0	138.0	30.0	27.0	16.6	247.5	1.3	20.15	15.86	51.64	210.0	111.6	0.00	5.000
61 138.0	117.9	117.1	145.2	49.1	17.6	21.7	247.5	1.7	20.11	15.81	51.63	210.0	111.6	0.00	5.000
61 141.0	116.4	116.4	146.3	1.9	4.9	4.2	246.7	0.0	2.11	15.77	51.53	214.0	111.4	0.00	5.000
61 145.0	119.9	119.1	163.7	47.2	0.0	0.0	251.3	0.6	16.49	15.84	51.52	214.1	111.3	-36.22	55.24
61 148.0	121.9	125.2	165.7	45.2	0.0	0.0	254.5	1.0	0.13	15.93	51.45	214.1	122.0	-37.22	55.24
61 151.2	121.0	122.5	163.7	7.9	6.7	6.7	254.5	0.6	0.46	15.93	51.45	214.1	122.0	0.00	5.000
61 154.4	121.1	122.1	167.0	0.0	3.4	3.7	255.6	0.0	0.23	15.77	51.52	217.9	115.0	0.00	5.000
61 157.6	121.0	120.9	167.4	0.5	3.7	3.0	255.4	0.2	0.29	15.77	51.70	217.9	115.0	0.00	5.000
62 0 1.0	120.0	120.0	167.0	0.5	3.9	3.0	255.6	0.0	0.24	15.77	51.77	217.9	124.9	0.00	5.000
62 0 4.0	120.0	120.0	167.0	0.5	3.7	3.0	255.6	0.0	0.23	15.77	51.77	217.9	124.9	0.00	5.000
62 1 7.0	120.0	120.0	167.0	0.5	3.7	3.0	255.6	0.0	0.23	15.79	52.17	225.1	125.1	0.00	5.000

Table 6.2.7. Samples of Data Printout for Test No. 18 (C Cycle, no Regen Br)

E V M T F RESULTS : 87-APR-77 PAGE NO. 5 0180 3/20 1																	
ELAPSED	BATT	BATT	U-H	NOT	BATT	BATT	U-H	NOT	FIFTH	REG.C	REG.C	U-H	U-H	REGEN	REGEN	FIFTH	
TIME	VOLT	VOLT	BATT	VOLT	UNFIL	UNFIL	BATT	VOLT	UNFIL	AMP	AMP	TO	FROM	AMP	AMP	CALL	
MIN	SEC	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
9	13	123.1	121.0	272.1	77.4	43.0	70.1	57.0	92.1	29.50	23.32	25.59	64.3	330.7	0.00	0.00	5.000
9	6	123.9	121.7	272.2	72.5	42.7	71.0	57.9	92.1	29.51	23.66	25.55	78.9	330.6	0.00	0.00	5.000
9	9	122.3	121.7	291.5	78.6	62.3	71.2	57.0	92.1	29.09	23.78	25.37	77.4	330.5	0.00	0.00	5.000
9	12	120.7	121.0	270.1	78.0	52.3	1.4	57.6	92.1	29.96	23.05	25.53	84.6	330.5	0.00	0.00	5.000
9	15	125.1	123.1	284.0	67.6	75.0	33.2	58.5	90.1	29.40	27.69	25.53	89.4	330.4	0.00	0.00	5.000
9	18	123.3	120.6	313.6	79.2	82.6	24.7	57.9	89.1	29.13	23.68	25.59	94.0	330.4	0.00	0.00	5.000
9	21	127.2	127.2	315.7	1.4	4.5	4.2	57.0	89.1	28.66	23.74	25.57	95.0	330.4	0.00	0.00	5.000
9	24	127.0	127.6	315.7	1.3	4.2	4.2	57.0	89.1	24.94	23.69	25.59	94.9	330.5	0.00	0.00	5.000
9	27	127.0	127.7	317.1	1.1	4.0	4.0	57.0	89.1	17.51	23.63	25.57	94.9	329.9	0.00	0.00	5.000
9	30	129.5	127.9	317.9	0.7	4.0	4.0	57.0	89.1	0.66	23.61	25.64	94.0	330.4	0.00	0.00	5.000
9	33	127.5	140.0	31.1	0.4	4.0	4.0	57.0	89.1	0.07	23.54	25.55	95.0	330.7	0.00	0.00	5.000
9	36	146.1	124.2	317.3	0.4	4.1	4.2	57.0	89.1	0.17	24.61	25.66	94.0	330.4	0.00	0.00	5.000
9	39	146.1	129.4	310.3	0.4	4.2	4.2	57.0	89.1	0.17	23.61	25.68	94.0	330.4	0.00	0.00	5.000
9	42	129.4	128.4	319.7	0.4	4.4	4.2	57.0	89.1	0.17	23.63	25.70	94.9	330.4	0.00	0.00	5.000
9	45	144.5	110.5	319.7	0.4	4.3	4.3	57.0	89.1	0.17	23.66	25.77	96.1	330.5	0.00	0.00	5.000
9	48	129.0	129.6	321.2	0.4	4.1	4.2	57.0	89.1	0.17	23.61	25.67	96.2	330.6	0.00	0.00	5.000
9	51	120.7	120.7	321.5	0.5	4.3	4.4	57.0	89.1	0.17	23.70	25.86	96.1	330.5	0.00	0.00	5.000
9	54	120.8	129.7	321.1	0.4	4.1	4.2	57.0	89.1	0.17	23.68	25.43	96.1	330.5	0.00	0.00	5.000
9	57	120.8	122.7	322.5	0.4	4.0	4.3	57.0	111.1	0.17	23.65	25.50	96.2	330.5	0.00	0.00	5.000
9	60	125.7	125.4	325.2	27.3	86.3	54.1	57.0	150.0	5.65	23.66	26.02	102.9	13.4	0.00	0.00	5.000
9	63	124.0	121.0	333.3	59.2	55.0	115.0	57.0	182.0	12.04	23.68	26.02	112.3	13.2	0.00	0.00	5.000
9	66	121.7	116.3	3.2	96.4	213.6	217.0	57.0	184.0	18.56	23.59	25.91	120.9	13.4	0.00	0.00	5.000
9	69	116.3	114.0	3.0	95.9	55.0	162.4	57.0	110.0	21.07	23.61	26.00	144.9	13.2	0.00	0.00	5.000
9	72	115.5	114.5	34.0	99.6	211.2	182.4	58.0	196.0	26.9	23.63	26.00	159.9	12.3	0.00	0.00	5.000
9	75	113.4	114.0	55.1	110.4	109.4	40.1	57.0	18.0	29.06	23.61	26.15	171.7	13.3	0.00	0.00	5.000
9	78	121.2	110.0	61.0	103.0	168.6	151.9	58.0	96.0	29.64	23.79	26.11	179.9	13.2	0.00	0.00	5.000
9	81	121.1	110.0	61.0	103.0	168.6	151.9	58.0	96.0	29.64	23.79	26.11	179.9	13.2	0.00	0.00	5.000
9	84	121.1	110.0	61.0	103.0	168.6	151.9	58.0	96.0	29.64	23.79	26.11	179.9	13.2	0.00	0.00	5.000
9	87	121.1	110.0	61.0	103.0	168.6	151.9	58.0	96.0	29.64	23.79	26.11	179.9	13.2	0.00	0.00	5.000
9	90	121.1	110.0	61.0	103.0	168.6	151.9	58.0	96.0	29.64	23.79	26.11	179.9	13.2	0.00	0.00	5.000
9	93	121.1	110.0	61.0	103.0	168.6	151.9	58.0	96.0	29.64	23.79	26.11	179.9	13.2	0.00	0.00	5.000
9	96	121.1	110.0	61.0	103.0	168.6	151.9	58.0	96.0	29.64	23.79	26.11	179.9	13.2	0.00	0.00	5.000
9	99	121.1	110.0	61.0	103.0	168.6	151.9	58.0	96.0	29.64	23.79	26.11	179.9	13.2	0.00	0.00	5.000
9	102	121.1	110.0	61.0	103.0	168.6	151.9	58.0	96.0	29.64	23.79	26.11	179.9	13.2	0.00	0.00	5.000
9	105	121.1	110.0	61.0	103.0	168.6	151.9	58.0	96.0	29.64	23.79	26.11	179.9	13.2	0.00	0.00	5.000
9	108	121.1	110.0	61.0	103.0	168.6	151.9	58.0	96.0	29.64	23.79	26.11	179.9	13.2	0.00	0.00	5.000
9	111	121.1	110.0	61.0	103.0	168.6	151.9	58.0	96.0	29.64	23.79	26.11	179.9	13.2	0.00	0.00	5.000
9	114	121.1	110.0	61.0	103.0	168.6	151.9	58.0	96.0	29.64	23.79	26.11	179.9	13.2	0.00	0.00	5.000
9	117	121.1	110.0	61.0	103.0	168.6	151.9	58.0	96.0	29.64	23.79	26.11	179.9	13.2	0.00	0.00	5.000
9	120	121.1	110.0	61.0	103.0	168.6	151.9	58.0	96.0	29.64	23.79	26.11	179.9	13.2	0.00	0.00	5.000
9	123	121.1	110.0	61.0	103.0	168.6	151.9	58.0	96.0	29.64	23.79	26.11	179.9	13.2	0.00	0.00	5.000
9	126	121.1	110.0	61.0	103.0	168.6	151.9	58.0	96.0	29.64	23.79	26.11	179.9	13.2	0.00	0.00	5.000
9	129	121.1	110.0	61.0	103.0	168.6	151.9	58.0	96.0	29.64	23.79	26.11	179.9	13.2	0.00	0.00	5.000
9	132	121.1	110.0	61.0	103.0	168.6	151.9	58.0	96.0	29.64	23.79	26.11	179.9	13.2	0.00	0.00	5.000
9	135	121.1	110.0	61.0	103.0	168.6	151.9	58.0	96.0	29.64	23.79	26.11	179.9	13.2	0.00	0.00	5.000
9	138	121.1	110.0	61.0	103.0	168.6	151.9	58.0	96.0	29.64	23.79	26.11	179.9	13.2	0.00	0.00	5.000
9	141	121.1	110.0	61.0	103.0	168.6	151.9	58.0	96.0	29.64	23.79	26.11	179.9	13.2	0.00	0.00	5.000
9	144	121.1	110.0	61.0	103.0	168.6	151.9	58.0	96.0	29.64	23.79	26.11	179.9	13.2	0.00	0.00	5.000
9	147	121.1	110.0	61.0	103.0	168.6	151.9	58.0	96.0	29.64	23.79	26.11	179.9	13.2	0.00	0.00	5.000
9	150	121.1	110.0	61.0	103.0	168.6	151.9	58.0	96.0	29.64	23.79	26.11	179.9	13.2	0.00	0.00	5.000
9	153	121.1	110.0	61.0	103.0	168.6	151.9	58.0	96.0	29.64	23.79	26.11	179.9	13.2	0.00	0.00	5.000
9	156	121.1	110.0	61.0	103.0	168.6	151.9	58.0	96.0	29.64	23.79	26.11	179.9	13.2	0.00	0.00	5.000
9	159	121.1	110.0	61.0	103.0	168.6	151.9	58.0	96.0	29.64	23.79	26.11	179.9	13.2	0.00	0.00	5.000
9	162	121.1	110.0	61.0	103.0	168.6	151.9	58.0	96.0	29.64	23.79	26.11	179.9	13.2	0.00	0.00	5.000
9	165	121.1	110.0	61.0	103.0	168.6	151.9	58.0	96.0	29.64	23.79	26.11	179.9	13.2	0.00	0.00	5.000
9	168	121.1	110.0	61.0	103.0	168.6	151.9	58.0	96.0	29.64	23.79	26.11	179.9	13.2	0.00	0.00	5.000
9	171	121.1	110.0	61.0	103.0	168.6	151.9	58.0	96.0	29.64	23.79	26.11	179.9	13.2	0.00	0.00	5.000
9	174	121.1	110.0	61.0	103.0	168.6	151.9	58.0	96.0	29.64	23.79	26.11	179.9	13.2	0.00	0.00	5.000
9	177	121.1	110.0	61.0	103.0	168.6	151.9	58.0	96.0	29.64	23.79	26.11	179.9	13.2	0.00	0.00	5.000
9	180	121.1	110.0	61.0	103.0	168.6	151.9	58.0	96.0	29.64	23.79	26.11	179.9	13.2	0.00	0.00	5.000
9	183	121.1	110.0	61.0	103.0	168.6	151.9	58.0	96.0	29.64	23.79	26.11	179.9	13.2	0.00	0.00	5.000
9	186	121.1	110.0	61.0	103.0	168.6	151.9	58.0	96.0	29.64	23.79	26.11	179.9	13.2	0.00	0.00	5.000
9	189	121.1	110.0	61.0	103.0	168.6	151.9	58.0	96.0	29.64	23.79	26.11	179.9	13.2	0.00	0.00	5.000
9	192	121.1	110.0	61.0	103.0	168.6	151.9	58.0	96.0	29.64	23.79	26.11	179.9	13.2	0.00	0.00	5.000
9	195	121.1	110.0	61.0	103.0	168.6	151.9	58.0	96.0	29.64	23.79	26.11	179.9	13.2	0.00	0.00	5.000
9	198	121.1	110.0	61.0	103.0	168.6	151.9	58.0	96.0	29.64	23.79	26.11	179.9	13.2	0.00	0.00	5.000
9	201	121.1	110.0	61.0	103.0	168.6	151.9	58.0	96.0	29.64	23.79	26.11	179.9	13.2	0.00	0.00	5.000
9	204	121.1	110.0	61.0	103.0	168.6	151.9	58.0	96.0	29.64	23.79	26.11	179.9	13.2	0.00	0.00	5.000
9	207	121.1	110.0	61.0	103.0	168.6	151.9	58.0	96.0	29.64	23						

Table 6.2.8. Samples of Data Printout for Test No. 19 (C Cycle, with Regen Br)

EVENTS RESULTS 07-APR-77 PAGE NO. 6																0150-02/ 4/1 1	
ELAPSED TIME	BATT VOLT UNFIL	BATT VOLT FIL	U-M DISCH	U-M FIL	BATT APP UNFIL	BATT APP FIL	U-M APP RECHG	U-M APP FIL	FIFTH WHEEL RPM	REG. C APP T	REG. C MOTOR	U-M TO MOTOR	U-M FROM MOTOR	REGEN APP FIL	REGEN APP UNFIL	FIELD CIL-1 WORTH	
MIN SEC	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
11 4.2	125.3	125.9	36.2	36.5	0.0	0.0	164.8	0.0	10.56	9.00	19.97	250.0	10.5	-85.12	-40.73	5.000	
11 7.4	123.0	131.0	41.6	38.0	0.0	0.0	169.3	0.0	11.92	9.06	20.00	250.0	14.1	-11.72	-22.56	5.000	
11 10.6	129.0	126.0	39.0	10.6	0.0	0.0	165.0	0.0	5.21	9.03	19.99	250.0	7.3	-3.00	-1.90	5.000	
11 13.6	125.2	125.2	67.1	0.2	1.1	1.0	172.9	0.3	0.22	9.03	20.03	250.0	17.3	-2.05	-2.56	5.000	
11 16.0	125.1	125.1	67.0	0.4	0.0	0.0	172.0	3.0	0.17	9.90	20.12	253.9	17.3	-1.03	-2.12	5.000	
11 20.0	125.2	125.1	67.1	0.4	0.0	0.0	172.0	3.0	0.17	9.92	20.21	250.0	17.4	-1.03	-2.12	5.000	
11 23.2	126.9	129.1	57.0	0.4	0.0	0.0	172.0	3.0	0.17	9.90	20.29	250.0	17.4	-2.20	-2.27	5.000	
11 26.0	125.1	125.0	66.7	0.3	0.0	0.0	172.0	3.0	0.14	9.04	20.42	250.0	17.2	-2.34	-2.56	5.000	
11 29.2	125.1	125.1	67.0	0.4	0.0	0.0	172.0	3.0	0.17	9.90	20.47	253.2	17.3	-2.56	-2.71	5.000	
11 32.4	125.1	125.1	67.0	0.4	0.0	0.0	172.7	3.0	0.17	9.99	20.64	250.7	17.3	-2.42	-2.70	5.000	
11 35.6	125.2	129.2	67.0	0.4	0.0	0.0	172.0	103.7	0.00	10.01	20.73	261.6	71.2	0.00	0.00	5.000	
11 38.6	127.1	125.4	69.0	29.0	114.1	54.0	195.9	103.6	6.23	10.01	20.82	265.6	83.7	0.00	0.00	5.000	
11 41.0	125.4	122.4	76.7	33.1	83.0	91.6	196.3	175.0	11.26	10.00	20.83	275.1	103.4	0.00	0.00	5.000	
11 44.0	114.0	116.3	82.4	90.1	132.1	174.3	195.0	201.0	17.57	10.03	20.97	292.7	83.0	0.00	0.00	5.000	
11 46.2	115.4	115.5	111.0	112.0	147.0	144.2	196.0	133.0	22.12	0.00	21.04	300.7	83.4	0.00	0.00	5.000	
11 51.2	119.0	118.0	122.2	89.4	206.4	181.2	206.5	212.3	24.26	10.00	21.04	322.5	83.1	0.00	0.00	5.000	
11 54.4	112.0	112.3	142.6	106.6	193.0	190.1	207.0	103.0	29.63	10.10	21.12	330.7	83.2	-1.75	-2.05	5.000	
11 57.6	126.1	125.0	150.4	0.4	15.0	21.6	216.4	61.9	20.23	10.17	21.17	341.3	82.9	0.00	0.00	5.000	
12 0.0	122.4	121.6	157.4	77.1	59.3	45.3	216.0	73.0	29.09	10.14	0.00	0.00	83.3	0.00	0.00	5.000	
12 3.0	121.7	122.3	162.7	74.3	31.4	63.4	217.0	94.1	29.30	10.05	20.97	10.0	83.1	0.00	0.00	5.000	
12 7.0	121.4	123.0	170.9	65.7	32.7	41.0	215.9	64.1	29.60	10.12	20.95	16.0	83.2	0.00	0.00	5.000	
12 10.2	122.7	122.7	174.4	61.5	17.4	54.0	216.0	61.9	29.84	10.19	20.91	18.7	81.3	0.00	0.00	5.000	
12 13.4	124.0	123.1	179.3	2.4	0.0	0.0	216.1	3.4	25.42	10.04	0.00	0.00	83.4	-2.12	-2.64	5.000	
12 16.2	127.5	127.5	180.3	1.3	0.0	0.0	217.3	3.4	27.64	10.00	20.06	20.0	83.2	-2.12	-2.49	5.000	
12 19.4	127.0	127.0	180.6	1.5	0.0	0.0	217.3	3.4	26.30	10.00	20.00	20.0	83.4	-1.32	-2.00	5.000	
12 22.6	134.1	134.0	180.6	0.4	0.0	0.0	221.5	3.0	25.61	10.00	20.02	20.0	90.9	-20.21	-32.45	5.000	
12 25.0	135.5	133.2	180.0	51.6	0.0	0.0	220.7	3.0	17.37	10.01	20.00	20.1	0.00	-33.19	-37.22	5.000	
12 28.0	133.0	132.2	191.6	35.0	0.0	0.0	233.6	3.0	11.56	9.99	20.00	20.0	103.6	-11.79	-22.27	5.000	
12 31.0	136.3	131.1	207.9	19.3	0.0	0.0	233.6	3.0	6.15	10.01	20.02	21.6	103.7	-3.01	-5.64	5.000	
12 34.2	129.4	129.7	219.0	2.0	0.3	0.0	237.5	3.0	1.24	9.94	20.06	37.5	107.5	-1.39	-1.60	5.000	
12 38.0	129.0	129.0	220.0	0.3	0.0	0.0	236.3	3.0	0.19	9.94	20.97	37.5	107.0	0.00	-2.93	5.000	
12 41.1	129.7	129.7	219.0	0.4	0.0	0.0	236.4	3.0	6.17	9.94	21.00	37.5	107.0	-2.71	-3.00	5.000	
12 44.6	129.7	129.7	219.0	0.4	0.0	0.0	237.5	3.0	0.19	9.94	21.19	37.5	107.0	-2.64	-3.00	5.000	
12 47.0	129.6	129.6	219.0	0.4	0.0	0.0	237.6	3.0	0.20	10.01	21.39	37.3	106.0	-2.05	-2.91	5.000	
12 51.0	129.6	129.6	219.0	0.4	0.0	0.0	237.6	3.0	0.17	9.96	21.43	37.5	107.0	-2.64	0.00	5.000	
12 54.0	129.6	129.6	220.0	0.4	0.0	0.0	238.1	3.0	0.22	9.92	21.50	37.5	107.2	0.00	0.00	5.000	
12 57.2	126.4	126.3	221.2	25.5	9.2	56.0	230.6	173.5	5.96	10.01	21.63	41.6	132.7	0.00	0.00	5.000	
13 0.4	122.4	121.0	220.3	61.5	97.1	105.4	250.6	163.2	12.74	9.76	21.03	51.6	132.5	0.00	0.00	5.000	
13 3.6	119.2	116.3	244.1	101.1	104.5	101.5	259.1	173.7	19.46	9.99	21.00	71.1	133.2	0.00	0.00	5.000	
13 6.4	117.3	117.1	260.0	114.5	59.0	14.9	250.6	24.5	23.52	10.01	21.91	80.7	127.6	0.00	0.00	5.000	
13 9.6	117.4	115.9	271.2	97.1	191.1	175.3	250.7	151.7	26.36	9.96	21.70	90.9	133.4	0.00	0.00	5.000	
13 12.0	117.2	119.6	269.0	72.0	63.0	45.5	259.6	74.0	25.02	10.01	21.03	100.2	132.0	0.00	0.00	5.000	
13 16.0	125.2	125.2	292.6	41.3	9.2	17.6	290.1	41.2	29.03	9.92	21.76	109.5	134.6	0.00	0.00	5.000	
13 19.2	124.3	295.3	95.6	50.3	33.6	207.0	63.1	29.07	9.96	21.69	115.0	132.4	0.00	0.00	0.00	5.000	

EVENTS RESULTS 07-APR-77 PAGE NO. 21																*190 CM 4/1		1	
ELAPSED TIME		BATT VOLT UNFIL	BATT VOLT FIL	U-M DISCH	U-M FIL	BATT APP UNFIL	BATT APP FIL	U-M APP RECHG	FIFTH WHEEL RPM	REG. C APP T	REG. C MOTOR	U-M TO MOTOR	U-M FROM MOTOR	REGEN APP FIL	REGEN APP UNFIL	FIVE MIN. BIRTH			
MIN	SEC	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15			
46	0.6	120.0	120.1	133.1	0.3	3.7	9.3	250.1	173.6	1.51	0.00	42.40	209.6	70.0	0.00	0.00	5.00		
46	3.6	115.0	113.9	197.2	37.9	30.4	73.3	250.4	159.5	0.71	16.35	42.69	215.6	69.3	0.00	0.00	0.70		
46	6.0	110.1	100.7	206.6	69.2	113.3	110.6	250.1	155.6	14.37	10.31	42.06	227.1	69.9	0.00	0.00	0.00		
46	10.0	102.6	102.9	210.6	100.2	146.2	142.1	250.5	123.0	20.23	10.22	42.91	239.5	70.2	-1.35	-1.17	0.00		
46	13.2	115.2	100.1	220.2	80.4	210.7	210.2	250.5	205.3	23.06	0.00	0.00	251.5	70.1	0.00	0.00	0.00		
46	16.0	101.5	101.5	240.0	90.2	162.9	160.0	250.2	153.0	20.37	10.17	43.06	267.2	70.1	0.00	0.00	0.00		
46	19.2	104.0	103.9	259.1	67.7	17.9	22.0	250.2	10.7	30.25	10.39	42.97	274.1	70.2	0.00	0.00	0.00		
46	22.4	116.3	115.2	261.5	54.9	57.9	37.4	257.6	62.1	29.94	10.42	40.06	276.6	69.9	0.00	0.00	0.00		
46	25.6	113.3	113.3	265.7	62.0	00.0	49.3	250.2	72.7	29.40	10.40	42.71	0.00	71.0	0.00	0.00	0.00		
46	29.0	113.5	112.4	271.4	69.1	34.9	55.2	250.1	77.9	29.00	10.44	42.40	286.1	69.9	0.00	0.00	0.00		
46	31.0	113.5	111.9	276.6	70.6	37.9	56.9	250.2	70.6	29.32	10.42	42.29	292.0	69.9	0.00	0.00	0.00		
46	35.0	114.0	114.3	281.9	54.0	21.9	20.4	250.1	29.5	29.65	10.42	42.12	295.6	69.9	0.00	0.00	0.00		
46	38.2	115.3	116.2	295.2	30.3	10.7	1.0	250.4	0.6	20.47	10.35	41.92	295.1	0.00	-54.19	-70.75	0.00		
46	41.2	123.4	125.5	294.8	60.9	0.0	0.0	264.2	0.0	23.41	10.37	41.70	295.6	82.3	-94.56	-55.94	0.00		
46	44.4	122.3	124.6	294.7	51.7	0.0	0.0	269.0	0.0	17.46	10.24	41.86	295.0	80.7	-40.42	-30.64	0.00		
46	47.6	122.3	123.7	294.6	36.1	0.0	0.0	273.6	0.0	11.31	10.31	41.53	295.5	92.4	-37.55	-23.00	0.00		
46	50.0	124.2	122.4	294.6	20.2	0.0	0.0	276.4	0.0	6.21	12.31	41.47	295.6	95.1	0.00	-5.79	0.00		
46	53.0	120.7	120.6	286.1	2.9	1.4	1.5	26.0	0.0	1.00	10.29	41.40	295.7	96.9	0.00	-0.73	0.00		
46	57.0	120.2	120.3	285.0	0.6	0.0	0.0	26.3	0.0	0.11	10.31	41.50	295.6	96.4	-1.54	-1.61	0.00		
47	0.2	120.2	120.2	286.0	0.3	0.4	0.7	26.6	0.0	0.20	10.26	41.64	295.6	96.4	-1.32	-1.61	0.00		
47	3.4	120.2	120.1	296.4	0.6	1.0	0.9	26.7	0.0	0.22	10.29	41.04	295.5	96.4	0.00	0.00	0.00		
47	6.2	120.1	120.1	296.0	0.3	0.4	0.7	26.6	0.0	0.20	10.29	42.01	295.5	96.4	-1.47	-1.40	0.00		
47	9.4	119.0	120.1	296.0	0.3	0.6	0.6	26.6	0.0	0.22	10.29	42.11	295.5	96.4	-1.61	-1.90	0.00		
47	12.6	120.1	120.0	296.1	0.3	0.7	0.7	26.7	0.0	0.22	10.26	42.49	295.4	96.3	-1.25	-1.54	0.00		
47	15.0	119.6	119.7	296.0	0.5	0.7	0.7	26.6	0.0	0.20	10.29	42.69	295.6	96.4	-1.39	-1.54	0.00		
47	18.0	119.9	119.9	296.1	0.3	11.5	26.5	29.6	200.2	2.00	10.20	42.09	300.1	143.9	0.00	0.00	0.00		
47	22.0	111.9	114.3	290.1	24.5	24.4	74	0.0	6.19	6.16	41.99	300.1	143.9	0.00	0.00	0.00			
47	25.0	120.0	120.0	296.0	64.1	131.1	120.0	296.0	10.4	10.03	10.26	42.35	115.1	133.9	0.00	0.00	0.00		
47	28.0	122.1	122.6	313.2	99.9	144.5	142.3	256.6	133.6	20.25	10.24	43.32	336.7	159.9	0.00	0.00	0.00		
47	31.6	101.2	101.1	322.7	99.9	179.6	213.6	256.6	299.5	22.05	11.42	43.00	341.3	153.9	0.00	0.00	0.00		
47	35.0	101.2	101.1	320.0	99.9	180.0	152.1	256.6	299.5	22.05	11.42	43.00	341.3	153.9	0.00	0.00	0.00		
47	37.0	101.2	101.1	320.0	99.9	180.0	152.1	256.6	299.5	22.05	11.42	43.00	341.3	153.9	0.00	0.00	0.00		
47	41.0	111.0	112.3	14.9	67.2	60.2	61.7	57.1	93.2	20.97	10.10	42.06	29.3	159.9	0.00	0.00	0.00		
47	44.2	100.5	100.5	21.6	76.7	46.4	64.0	56.7	63.2	20.94	10.09	42.69	33.7	159.9	0.00	0.00	0.00		
47	47.6	113.3	113.3	31.0	75.0	29.12	64.0	56.7	63.2	20.94	10.10	42.69	33.7	159.9	0.00	0.00	0.00		
47	50.6	100.4	101.3	31.0	75.0	29.12	64.0	56.7	63.2	20.94	10.10	42.69	33.7	159.9	0.00	0.00	0.00		
47	53.6	100.9	110.3	39.0	77.1	0.0	70.0	56.6	63.9	20.94	10.10	42.15	51.1	151.1	0.00	0.00	0.00		
47	56.6	110.0	110.0	39.0	77.1	0.0	70.0	56.6	63.9	20.94	10.10	42.15	51.0	150.9	-0.44	-1.17	0.00		
47	59.6	117.7	117.7	39.0	77.1	0.0	70.0	56.6	63.9	20.94	10.10	42.15	51.0	150.9	-0.44	-1.17	0.00		
47	6.0	119.1	119.1	49.0	1.0	1.0	1.0	56.7	9.0	24.23	10.15	42.06	53.0	164.0	-90.55	-61.01	0.00		
47	12.0	122.0	124.2	49.1	55.1	0.0	0.0	63.3	9.0	10.07	10.37	42.35	174.0	174.0	-21.47	-40.61	0.00		
47	15.2	121.9	129.1	49.2	55.1	0.0	0.0	63.3	9.0	11.04	10.15	42.15	53.0	170.0	-11.67	-22.11	0.00		
47	18.0	120.0	120.0	49.2	55.1	0.0	0.0	63.3	9.0	11.04	10.15	42.15	53.0	170.0	-11.67	-22.11	0.00		
47	19.4	120.0	120.0	54.2	19.2	2.3	1.7	70.2	1.6	11.04	10.15	42.15	53.0	170.0	-11.67	-22.11	0.00		

Table 6.2.9. Samples of Data Printout for Test No. 20 (B Cycle, no Regen Br)

E V H T F RESULTS 1 12-APR-77 PAGE NO. 7																
ELAPSED TIME	BATT VOLT UNFIL	BATT VOLT FIL	U-H BATT DISCH	POT FIL	BATT APP UNFIL	BATT APP FIL	U-H BATT RECHG	POT FIL	FIFTH WHEEL RPM	REG. C AMB'T	REG. C MOTOR	U-H TO FROM MOTOR	U-H FROM MOTOR	REGEN APP FIL	REGEN APP UNFIL	FIXED CALI-BRNTH
MIN SEC	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
13 123.2	122.8	121.4	13.3	73.2	27.8	55.8	100.9	81.8	29.38	11.28	19.46	22.6	135.1	0.00	0.00	5.000
13 142.4	120.6	122.3	10.6	63.3	70.3	39.9	106.2	63.9	26.14	11.09	19.38	20.8	135.2	-2.12	-2.43	5.000
13 145.6	126.2	126.4	21.3	1.5	0.0	0.0	109.2	3.7	10.24	11.09	19.33	29.3	135.1	-1.18	-2.31	5.000
13 148.8	126.8	126.8	21.3	1.2	0.0	0.0	108.2	3.9	11.62	11.09	19.33	29.3	134.8	-1.68	-1.98	5.000
13 151.6	127.8	127.1	21.3	0.5	0.0	0.0	106.4	7.1	10.23	11.09	19.27	29.3	135.2	-2.28	-2.24	5.000
13 154.8	127.3	127.3	21.3	0.3	0.0	0.0	109.7	0.8	8.19	10.90	19.18	23.3	135.2	-2.05	-2.34	5.000
13 158.0	127.5	127.4	21.3	0.3	0.0	0.0	109.6	1.0	8.18	11.09	19.33	29.3	135.1	-2.05	-2.34	5.000
14 1.2	127.5	127.5	21.3	0.3	0.0	0.0	109.3	3.8	8.16	11.07	19.48	29.7	135.1	-2.28	-2.34	5.000
14 4.2	127.6	127.6	21.3	0.3	0.0	0.0	109.5	3.8	8.16	11.07	19.45	29.4	135.1	-2.27	-2.71	5.000
14 7.4	127.9	127.8	20.9	0.2	0.0	0.0	109.5	3.7	8.16	11.07	19.37	29.3	135.1	-1.98	-2.56	5.000
14 10.6	127.7	127.9	21.3	0.3	0.0	0.0	109.6	3.7	8.16	11.09	19.62	29.3	135.4	-2.28	-2.71	5.000
14 13.8	128.0	127.9	21.3	0.4	0.0	0.0	109.5	3.7	8.16	11.16	19.79	29.3	135.1	-2.28	-2.64	5.000
14 16.8	127.9	128.0	27.9	0.3	0.0	0.0	110.9	8.5	8.19	11.18	19.80	29.3	135.1	0.00	0.00	5.000
14 20.0	122.3	125.0	25.3	21.2	26.4	31.6	110.9	131.0	4.84	11.22	20.01	33.4	135.3	0.00	0.00	5.000
14 23.2	125.5	123.7	33.4	34.0	85.8	41.4	110.6	113.9	7.04	11.27	20.01	37.4	215.3	0.00	0.00	5.000
14 26.4	122.3	121.8	38.8	54.8	76.8	58.8	110.9	131.0	11.81	11.31	20.12	45.3	215.7	0.00	0.00	5.000
14 29.6	122.8	121.8	48.3	69.3	138.8	87.5	111.1	121.5	15.11	11.34	20.14	52.5	215.7	0.00	0.00	5.000
14 32.8	121.9	118.3	57.6	84.5	129.6	99.9	111.2	121.0	18.68	11.34	20.16	64.3	215.7	0.00	0.00	5.000
14 36.0	117.5	117.4	68.3	87.7	11.4	10.3	111.0	43.5	19.32	11.36	20.16	78.9	215.3	0.00	0.00	5.000
14 39.2	125.6	125.6	72.3	61.4	49.1	48.1	111.3	61.3	19.46	11.41	20.16	74.9	215.3	0.00	0.00	5.000
14 42.4	121.7	121.7	77.8	61.9	24.2	48.1	111.3	75.8	19.05	11.54	20.01	84.4	215.3	0.00	0.00	5.000
14 45.6	121.7	121.9	83.4	69.5	34.7	48.2	111.4	73.9	19.07	11.25	19.94	84.6	215.3	0.00	0.00	5.000
14 48.8	124.6	122.0	88.4	87.7	68.2	36.3	111.1	61.5	19.04	11.34	19.94	87.9	215.3	0.00	0.00	5.000
14 52.0	124.9	122.5	93.8	71.0	84.8	56.1	110.9	104.8	19.78	11.34	19.98	93.3	215.6	0.00	0.00	5.000
14 55.2	121.7	121.7	98.4	61.9	51.3	48.1	121.0	11.3	19.33	11.28	19.94	96.1	215.6	-2.42	-2.48	5.000
14 58.4	126.6	125.4	106.8	1.4	0.0	0.0	121.0	3.7	17.28	11.31	19.98	96.1	215.6	-2.05	-2.47	5.000
15 1.6	126.9	126.9	100.3	1.1	0.0	0.0	121.0	3.7	7.91	11.25	19.75	96.2	216.0	-2.27	-2.56	5.000
15 4.8	127.1	127.1	106.4	0.3	0.0	0.0	121.7	3.8	7.91	11.27	19.75	96.2	216.0	-2.05	-2.42	5.000
15 8.0	127.3	127.3	106.4	0.3	0.0	0.0	121.7	3.8	7.91	11.27	19.75	96.2	216.0	-2.27	-2.42	5.000
15 11.2	127.3	127.3	106.4	0.3	0.0	0.0	121.0	3.8	7.91	11.25	19.75	96.2	216.0	-2.27	-2.42	5.000
15 14.4	127.3	127.3	106.4	0.4	0.0	0.0	121.4	3.4	8.11	11.31	19.97	96.1	215.3	-2.05	-2.42	5.000
15 17.6	127.8	127.8	106.4	0.4	0.0	0.0	121.1	3.7	8.11	11.31	19.97	96.1	215.3	-2.05	-2.42	5.000
15 20.8	127.8	127.8	106.4	0.4	0.0	0.0	121.1	3.7	8.11	11.31	19.97	96.1	215.3	-2.05	-2.42	5.000
15 24.0	127.8	127.8	106.4	0.4	0.0	0.0	121.1	3.7	8.11	11.31	19.97	96.1	215.3	-2.05	-2.42	5.000
15 27.2	127.8	127.8	106.4	0.4	0.0	0.0	121.1	3.7	8.11	11.31	19.97	96.1	215.3	-2.05	-2.42	5.000
15 30.4	127.8	127.8	106.4	0.4	0.0	0.0	121.1	3.7	8.11	11.31	19.97	96.1	215.3	-2.05	-2.42	5.000
15 33.6	127.8	127.8	106.4	0.4	0.0	0.0	121.1	3.7	8.11	11.31	19.97	96.1	215.3	-2.05	-2.42	5.000
15 36.8	127.8	127.8	106.4	0.4	0.0	0.0	121.1	3.7	8.11	11.31	19.97	96.1	215.3	-2.05	-2.42	5.000
15 40.0	127.8	127.8	106.4	0.4	0.0	0.0	121.1	3.7	8.11	11.31	19.97	96.1	215.3	-2.05	-2.42	5.000
15 43.2	127.8	127.8	106.4	0.4	0.0	0.0	121.1	3.7	8.11	11.31	19.97	96.1	215.3	-2.05	-2.42	5.000
15 46.4	127.8	127.8	106.4	0.4	0.0	0.0	121.1	3.7	8.11	11.31	19.97	96.1	215.3	-2.05	-2.42	5.000
15 49.6	127.8	127.8	106.4	0.4	0.0	0.0	121.1	3.7	8.11	11.31	19.97	96.1	215.3	-2.05	-2.42	5.000
15 52.8	127.8	127.8	106.4	0.4	0.0	0.0	121.1	3.7	8.11	11.31	19.97	96.1	215.3	-2.05	-2.42	5.000
15 56.0	127.8	127.8	106.4	0.4	0.0	0.0	121.1	3.7	8.11	11.31	19.97	96.1	215.3	-2.05	-2.42	5.000
15 59.2	127.8	127.8	106.4	0.4	0.0	0.0	121.1	3.7	8.11	11.31	19.97	96.1	215.3	-2.05	-2.42	5.000
16 1.2	127.8	127.8	106.4	0.4	0.0	0.0	121.1	3.7	8.11	11.31	19.97	96.1	215.3	-2.05	-2.42	5.000
16 4.4	127.8	127.8	106.4	0.4	0.0	0.0	121.1	3.7	8.11	11.31	19.97	96.1	215.3	-2.05	-2.42	5.000
16 7.6	127.8	127.8	106.4	0.4	0.0	0.0	121.1	3.7	8.11	11.31	19.97	96.1	215.3	-2.05	-2.42	5.000
16 10.8	127.8	127.8	106.4	0.4	0.0	0.0	121.1	3.7	8.11	11.31	19.97	96.1	215.3	-2.05	-2.42	5.000
16 14.0	127.8	127.8	106.4	0.4	0.0	0.0	121.1	3.7	8.11	11.31	19.97	96.1	215.3	-2.05	-2.42	5.000
16 17.2	127.8	127.8	106.4	0.4	0.0	0.0	121.1	3.7	8.11	11.31	19.97	96.1	215.3	-2.05	-2.42	5.000
16 20.4	127.8	127.8	106.4	0.4	0.0	0.0	121.1	3.7	8.11	11.31	19.97	96.1	215.3	-2.05	-2.42	5.000
16 23.6	127.8	127.8	106.4	0.4	0.0	0.0	121.1	3.7	8.11	11.31	19.97	96.1	215.3	-2.05	-2.42	5.000
16 26.8	127.8	127.8	106.4	0.4	0.0	0.0	121.1	3.7	8.11	11.31	19.97	96.1	215.3	-2.05	-2.42	5.000
16 30.0	127.8	127.8	106.4	0.4	0.0	0.0	121.1	3.7	8.11	11.31	19.97	96.1	215.3	-2.05	-2.42	5.000
16 33.2	127.8	127.8	106.4	0.4	0.0	0.0	121.1	3.7	8.11	11.31	19.97	96.1	215.3	-2.05	-2.42	5.000
16 36.4	127.8	127.8	106.4	0.4	0.0	0.0	121.1	3.7	8.11	11.31	19.97	96.1	215.3	-2.05	-2.42	5.000
16 39.6	127.8	127.8	106.4	0.4	0.0	0.0	121.1	3.7	8.11	11.31	19.97	96.1	215.3	-2.05	-2.42	5.000
16 42.8	127.8	127.8	106.4	0.4	0.0	0.0	121.1	3.7	8.11	11.31	19.97	96.1	215.3	-2.05	-2.42	5.000
16 46.0	127.8	127.8	106.4	0.4	0.0	0.0	121.1	3.7	8.11	11.31	19.97	96.1	215.3	-2.05	-2.42	5.000
16 49.2	127.8	127.8	106.4	0.4	0.0	0.0	121.1	3.7	8.11	11.31	19.97	96.1	215.3	-2.05	-2.42	5.000
16 52.4	127.8	127.8	106.4	0.4	0.0	0.0	121.1	3.7	8.11	11.31	19.97	96.1	215.3	-2.05	-2.42	5.000
16 55.6	127.8	127.8	106.4	0.4	0.0	0.0	121.1	3.7	8.11	11.31	19.97	96.1	215.3	-2.05	-2.42	5.000
16 58.8	127.8	127.8	106.4	0.4	0.0	0.0	121.1	3.7	8.11	11.31	19.97	96.1	215.3	-2.05	-2.42	5.000
17 1.2	127.8	127.8	106.4	0.4	0.0	0.0	121.1	3.7	8.11	11.31	19.97	96.1	215.3	-2.05	-2.42	5.000
17 4.4	127.8	127.8	106.4	0.4	0.0	0.0	121.1	3.7	8.11	11.31	19.97	96.1	215.3	-2.05	-2.42	5.000
17 7.6	127.8	127.8	106.4	0.4	0.0	0.0	121.1	3.7	8.11	11.31	19.97	96.1	215.3	-2.05	-2.42	5.000
17 10.8	127.8	127.8	106.4	0.4	0.0	0.0	121.1	3.7	8.11	11.31	19.97	96.1	215.3	-2.05	-2.42	5.000
17 14.0	127.8	127.8	106.4	0.4	0.0	0.0	121.1	3.7	8.11	11.31	19.97	96.1	215.3	-2.05	-2.42	5.000
17 17.2	127.8	127.8	106.4	0.4	0.0	0.0	121.1	3.7	8.11	11.31	19.97	96.1	215.3	-2.05	-2.42	5.000
17 20.4	127.8	127.8	106.4	0.4	0.0	0.0	121.1	3.7	8.11	11.31	19.97	96.1	215.3	-2.05	-2.42	5.000
17 23.6	127.8	127.8	106.4	0												

Table 6.2.10. Samples of Data Printout for Test No. 21 (C Cycle, with Regen Br)

E V N T F RESULTS				12-APR-77				PRL NO. 7				CCL4 BAP 6-4				1			
ELAPSED TIME	BATT VOLT	BATT VOLT	U-M	RT	BATT VOLT	BATT VOLT	U-M	RT	FIFTH	REC.C	REC.C	U-M	U-M	RECEN	RECEN	FIXED			
MIN SEC	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16			
13 122.2	122.8	121.4	12.3	73.2	27.8	55.8	100.9	81.8	20.30	11.20	15.45	22.6	135.1	0.00	0.00	3.000			
13 142.4	123.6	122.5	10.6	62.5	70.3	30.9	100.2	61.9	20.14	11.09	15.30	20.0	135.2	-2.12	-2.40	3.000			
13 140.6	126.7	126.4	21.3	1.5	1.0	0.0	100.2	41.7	10.34	11.09	15.33	20.3	135.1	-1.15	-2.34	3.000			
13 140.0	125.0	125.0	1.2	0.0	0.0	0.0	100.2	1.9	11.62	11.09	15.33	20.3	134.0	-1.00	-1.50	3.000			
13 151.6	127.0	127.1	21.3	0.5	0.0	0.0	100.4	1.7	0.23	11.09	15.27	20.3	135.2	-2.20	-2.24	3.000			
13 154.0	127.3	127.3	21.3	0.5	0.0	0.0	100.7	1.0	0.19	10.50	15.10	20.3	135.2	-2.05	-2.24	3.000			
13 150.0	127.0	127.4	21.3	0.5	0.0	0.0	100.6	1.0	0.16	11.09	15.33	20.3	135.1	-2.05	-2.34	3.000			
14 1.12	127.5	127.5	21.3	0.0	0.0	0.0	100.5	1.0	0.16	11.07	15.40	20.3	135.1	-2.27	-2.34	3.000			
14 1.42	127.6	127.6	21.3	0.3	0.0	0.0	100.5	1.0	0.16	11.07	15.40	20.3	135.2	-2.27	-2.71	3.000			
14 1.74	127.9	127.0	20.9	0.7	0.0	0.0	100.5	1.7	0.16	11.07	15.37	20.3	135.1	-1.90	-1.56	3.000			
14 110.6	127.7	127.0	21.3	0.5	0.0	0.0	100.6	1.7	0.16	11.09	15.32	20.3	135.4	-2.20	-2.71	3.000			
14 113.0	127.0	127.3	21.3	0.4	0.0	0.0	100.5	1.7	0.16	11.16	15.79	20.3	135.1	-2.20	-2.64	3.000			
14 116.0	127.9	127.9	27.9	0.3	0.0	0.0	100.9	0.5	0.19	11.10	15.00	20.3	135.1	0.00	0.00	3.000			
14 120.0	122.1	1.0	25.3	21.2	26.4	31.6	105.9	131.0	4.64	11.22	20.01	32.4	135.9	0.00	0.00	3.000			
14 123.2	125.5	127.7	75.4	34.0	85.0	41.4	110.6	117.9	7.04	11.27	20.01	37.4	215.5	0.00	0.00	3.000			
14 126.4	122.5	121.0	30.0	54.0	76.0	0.0	110.9	131.0	11.01	11.31	20.12	40.3	215.7	0.00	0.00	3.000			
14 129.4	122.0	119.6	40.3	69.3	130.0	07.5	111.1	127.5	15.11	11.29	20.14	54.5	215.5	0.00	0.00	3.000			
14 132.6	121.5	118.5	57.6	84.5	129.6	59.9	111.2	125.0	16.60	11.34	20.16	64.2	215.7	0.00	0.00	3.000			
14 135.0	117.5	117.4	65.1	91.7	11.4	10.5	111.7	43.9	19.42	11.36	20.16	70.9	215.5	0.00	0.00	3.000			
14 139.4	123.6	122.6	72.3	61.4	49.1	0.0	110.9	61.4	19.46	11.43	20.16	74.9	215.3	0.00	0.00	3.000			
14 141.0	120.2	122.1	77.0	50.1	24.1	40.1	111.3	71.0	19.05	11.34	20.01	80.4	215.6	0.00	0.00	3.000			
14 145.0	121.7	121.9	83.4	69.5	34.1	40.2	111.4	71.5	19.07	11.25	19.54	84.6	215.5	0.00	0.00	3.000			
14 140.2	124.0	122.0	80.4	69.7	60.0	36.3	111.1	61.5	19.04	11.30	19.54	80.9	215.5	0.00	0.00	3.000			
14 151.4	124.9	122.5	93.0	71.0	04.4	56.1	110.9	0.0	19.70	11.34	19.50	93.3	215.6	0.00	0.00	3.000			
14 154.4	121.7	121.4	99.1	61.9	5.0	4.0	121.0	11.3	12.33	11.29	19.06	96.1	215.6	-2.40	-2.70	3.000			
14 157.6	126.6	126.4	170.0	1.4	0.0	0.0	121.0	1.7	17.00	11.31	19.00	96.0	215.6	-2.05	-2.40	3.000			
15 1.0	125.9	125.9	125.5	1.1	0.0	0.0	121.0	1.7	7.31	11.27	15.01	96.0	215.3	-2.05	-2.40	3.000			
15 1.40	127.1	127.1	100.4	0.3	0.0	0.0	121.7	1.0	0.16	11.27	15.01	96.0	215.3	-2.05	-2.40	3.000			
15 1.71	127.3	127.3	100.4	0.3	0.0	0.0	121.7	1.0	0.16	11.27	15.01	96.1	215.6	-2.27	-2.40	3.000			
15 110.2	127.5	127.5	100.4	0.3	0.0	0.0	121.0	1.0	0.16	11.26	15.02	96.1	215.6	-2.12	-2.40	3.000			
15 113.4	127.5	127.6	100.4	0.4	0.0	0.0	121.4	1.0	0.16	11.31	15.07	96.1	215.5	-2.27	-2.56	3.000			
15 116.6	127.7	127.0	100.4	0.4	0.0	0.0	123.1	1.7	0.14	11.36	20.05	96.1	215.6	-2.40	-2.53	3.000			
15 119.6	127.0	127.9	100.6	0.0	0.0	0.0	123.1	1.7	0.16	11.36	20.14	96.0	215.7	-2.27	-2.67	3.000			
15 122.9	127.9	127.9	100.4	4.4	0.0	0.0	123.1	1.7	0.16	11.36	20.27	96.1	215.5	-2.27	-2.67	3.000			
15 126.0	127.1	127.1	100.4	4.3	0.0	0.0	123.1	1.7	0.16	11.43	20.26	96.0	215.6	-2.27	-2.67	3.000			
15 129.2	123.6	127.7	100.4	7.5	11.1	19.4	123.2	17.3	1.92	11.43	20.26	96.0	215.6	-2.27	-2.67	3.000			
15 132.5	125.0	125.0	104.5	29.3	34.0	40.2	123.1	12.9	6.23	11.45	20.23	112.2	303.1	0.00	0.00	3.000			
15 135.2	115.4	115.3	103.7	38.1	26.6	43.1	123.4	11.1	0.52	11.56	20.04	116.3	303.1	0.00	0.00	3.000			
15 130.4	122.6	121.7	113.9	34.4	26.1	62.4	123.3	12.3	1.70	11.56	20.04	121.6	303.1	0.00	0.00	3.000			
15 141.6	119.1	110.7	122.0	74.5	114.5	117.1	123.3	101.3	15.13	11.50	20.02	122.3	303.1	0.00	0.00	3.000			
15 144.6	120.0	117.1	122.0	35.5	16.0	91.5	123.4	11.1	10.09	11.50	20.04	144.3	303.1	0.00	0.00	3.000			
15 147.7	119.7	117.0	122.0	83.2	14.1	15.7	123.1	1.9	19.81	11.54	20.04	149.9	303.1	0.00	0.00	3.000			
15 151.0	124.2	120.9	124.9	62.1	22.1	64.3	124.1	71.0	12.72	11.63	20.00	152.8	303.1	0.00	0.00	3.000			
15 154.4	122.7	119.4	127.0	61.2	55.7	12.4	124.9	111.1	20.21	11.47	20.56	162.0	303.1	0.00	0.00	3.000			

E V N T F RESULTS :				12-APR-77				PRL NO. 35				CCL4 BAP 6-4				2			
ELAPSED TIME	BATT VOLT	BATT VOLT	U-M	RT	BATT VOLT	BATT VOLT	U-M	RT	FIFTH	REC.C	REC.C	U-M	U-M	RECEN	RECEN	FIXED			
MIN SEC	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16			
70 5.1	117.0	117.7	269.1	0.5	2.3	1.9	94.2	1.0	0.27	23.74	30.76	313.3	39.3	-0.66	-0.66	3.000			
70 11.2	117.0	117.0	260.0	0.5	1.0	1.9	94.0	1.0	0.23	23.22	30.57	313.3	39.2	-0.44	-0.73	3.000			
70 112.4	117.9	117.9	260.7	0.5	1.0	1.9	94.0	1.0	0.23	23.22	31.11	313.3	39.2	-0.27	-0.64	3.000			
70 115.4	117.9	117.9	260.7	0.5	2.0	1.9	110.1	1.0	0.23	23.20	31.14	313.3	39.3	-0.22	-0.73	3.000			
70 118.6	118.0	1.0	270.3	0.6	1.0	2.1	110.1	1.1	0.22	23.50	31.64	313.9	39.0	-0.37	-0.64	3.000			
70 121.0	118.5	118.0	270.1	0.5	1.9	1.9	110.2	1.0	0.23	23.32	31.52	314.7	39.2	0.00	0.00	3.000			
70 125.0	118.0	118.0	271.7	20.9	54.6	54.3	110.4	122.5	5.13	23.28	31.52	319.1	35.4	0.00	0.00	3.000			
70 127.0	114.3	112.5	275.4	35.0	40.4	45.1	110.3	194.0	0.50	23.39	31.77	322.9	35.3	0.00	0.00	3.000			
70 131.0	105.7	111.4	280.9	46.0	55.0	50.9	110.2	95.1	11.92	23.41	31.00	326.9	35.4	0.00	0.00	3.000			
70 134.2	100.9	110.7	285.1	55.7	64.0	55.7	110.1	91.4	14.52	23.20	31.73	332.4	35.3	0.00	0.00	3.000			
70 137.1	105.7	100.1	280.0	73.3	87.9	83.4	110.2	106.9	17.11	23.39	31.07	340.0	34.7	0.00	0.00	3.000			
70 140.4	104.7	105.1	280.0	89.1	92.4	97.4	110.2	75.7	20.17	23.46	31.52	340.0	35.3	0.00	0.00	3.000			
70 143.6	113.3	115.3	304.1	27.4	7.9	10.1	110.3	24.5	19.97	23.20	31.20	3.2	95.3	0.00	0.00	3.000			
70 146.3	115.5	115.7	305.2	27.2	15.4	10.1	110.2	23.2	15.62	23.34	31.14	4.3	95.3	0.00	0.00	3.000			
70 150.2	112.2	114.8	306.7	27.0	17.3	20.3	110.2	34.7	19.39	23.54	30.87	6.3	95.3	0.00	0.00	3.000			
70 156.0	112.0	114.0	310.0	27.0	35.0	35.0	110.2	34.7	20.25	23.50	30.57	11.0	95.3	0.00	0.00	3.000			
70 158.2	114.0	114.3	313.6	40.3	17.1	12.0	110.3	37.7	19.59	23.50	30.43	13.6	94.6	0.00	0.00	3.000			
70 159.4	114.2	114.2	317.5	44.1	14.4	22.3	110.1	42.4	19.12	23.58	30.15	15.0	95.3	0.00	0.00	3.000			
70 161.6	116.9	116.9	317.6	1.7	10.9	1.9	110.2	1.0	10.89	23.37	30.95	15.2	95.3	-0.22	-0.44	3.000			
70 165.6	117.2	117.6	344.2	0.5	2.4	2.3	110.1	1.0	0.26	23.41	31.07	14.5	95.3	0.00	0.00	3.000			
70 168.0	117.3	117.3	310.3	0.5	2.6	2.3	110.1	1.0	0.26	23.41	45.59	15.0	95.1	0.00	-0.22	3.000			
70 112.0	117.3	117.4	310.0	0.5	2.3	2.4	110.2	1.0	0.27	23.39	45.46	15.0	95.3	0.00	-0.15	3.000			
70 115.2	117.6	117.5	319.0	0.5	2.6	2.6	110.2	1.1	0.26	23.42	45.42	15.3	94.5	0.00	0.00	3.000			
70 118.0	117.7	117.6	344.2	0.5	2.4	2.4	110.1	1.0	0.26	23.41	45.59	15.0	95.3	0.00	0.00	3.000			
70 121.2	117.8	117.8	329.3	0.5	1.0	1.9	110.3	3.9	0.23	23.26	45.22	16.4	94.5	-0.71	-0.25	3.000			
70 124.4	118.0	117.9	320.2	0.5	1.9	1.9	110.1	1.0	0.23	23.17	45.42	16.3	95.4	0.00	-0.73	3.000			
70 127.6	117.9	117.9	320.2	0.5	2.2	2.2	110.2	1.0	0.23	23.32	45.42	16.3	95.3	0.00	-0.37	3.000			
70 130.9	118.0	118.0	320.2	0.5	2.2	2.2	110.1	1.0	0.23	23.32	45.42	16.3	95.3	0.00	-0.22	3.000			
70 133.0	118.1	116.1	321.7	12.6	24.6	33.6	110.2	152.7	3.66	23.29	45.12	17.9	136.0	0.00	0.00	3.000			
70 137.0	118.3	116.6	325.6	32.4	40.1	27.5	110.2	59.4	20.00	23.42	45.12	23.0	137.4	0.00	0.00	3.000			
70 140.2	111.9	112.4	329.7	35.5	25.5	41.9	110.3	59.4	15.23	23.26	45.02	27.2	137.4	0.00	0.00	3.000			
70 143.6	115.3	115.3	329.7	35.5	25.5	41.9	110.3	59.4	15.23	23.26	45.02	27.2	137.4	0.00	0.00	3.000			
70 146.3	115.3	115.3	329.7	35.5	25.5	41.9	110.3	59.4	15.23	23.26	45.02	27.2	137.4	0.00	0.00	3.000			
70 149.6	115.3	115.3	329.7	35.5	25.5	41.9	110.3	59.4	15.23	23.26	45.02	27.2	137.4	0.00	0.00	3.000			
70 152.9	115.3	115.3	329.7	35.5	25.5	41.9	110.3	59.4	15.23	23.26	45.02	27.2	137.4	0.00	0.00	3.000			
70 156.2	115.3	115.3	329.7	35.5	25.5	41.9	110.3	59.4	15.23	23.26	45.02	27.2	137.4	0.00	0.00	3.000			
70 159.4	115.3	115.3	329.7	35.5	25.5	41.9	110.3	59.4	15.23	23.26	45.02	27.2	137.4	0.00	0.00	3.000			
70 162.7	115.3	115.3	329.7	35.5	25.5	41.9	110.3	59.4	15.23	23.26	45.02	27.2	137.4	0.00	0.00	3.000			
70 166.0	115.3	115.3	329.7	35.5	25.5	41.9	110.3	59.4	15.23	23.26	45.02	27.2	137.4	0.00	0.00	3.000			
70 169.3	115.3	115.3	329.7	35.5	25.5	41.9	110.3	59.4	15.23	23.26	45.02	27.2	137.4	0.00	0.00	3.000			
70 172.6	115.3	115.3	329.7	35.5	25.5	41.9	110.3	59.4	15.23	23.26	45.02	27.2	137.4	0.00	0.00	3.000			
70 175.9	115.3	115.3	329.7	35.5	25.5	41.9	110.3	59.4	15.23	23.26	45.02	27.2	137.4	0.00	0.00	3.000			
70 179.2	115.3	115.3	329.7	35.5	25.5	41.9	110.3	59.4	15.23	23.26	45.02	27.2	137.4	0.00	0.00	3.000			
70 182.5	115.3	115.3	329.7	35.5	25.5	41.9	110.3	59.4	15.23	23.26	45.02	27.2	137.4	0.00	0.00	3.000			
70 185.8	115.3	115.3	329.7	35.5	25.5	41.9	110.3	59.4	15.23	23.26	45.02	27.2	137.4	0.00	0.00	3.000			
70 189.1	115.3	115.3	329.7	35.5	25.5	41.9	110.3	59.4	15.23	23.26	45.02	27.2	137.4	0.00	0.00	3.000			
70 192.4	115.3	115.3	329.7	35.5	25.5	41.9	110.3	59.4	15.23	23.26	45.02	27.2	137.4	0.00	0.00	3.000			
70 195.7	115.3	115.3	329.7	35.5	25.5	41.9	110.3	59.4	15.23	23.26	45.02	27.2	137.4	0.00	0.00	3.000			
70 199.0	115.3	115.3	329.7	35.5	25.5	41.9	110.3	59.4	15.23	23.26	45.02	27.2	137.4	0.00	0.00	3.000			
70 202.3	115.3	115.3	329.7	35.5	25.5	41.9	110.3	59.4	15.23	23.26	45.02	27.2	137.4	0.00	0.00	3.000			
70 205.6	115.3	115.3	329.7	35.5	25.5	41.9	110.3	59.4	15.23	23.26	45.02	27.2	137.4	0.00	0.00	3.000			
70 208.9	115.3	115.3	329.7	35.5	25.5	41.9	110.3	59.4	15.23	23.26	45.02	27.2	137.4	0.00	0.00	3.000			
70 212.2	115.3	115.3	329.7	35.5	25.5	41.9	110.3	59.4	15.23	23.26	45.02	27.2	137.4	0.00	0.00	3.000			
70 215.5	115.3	115.3	329.7	35.5	25.5	41.9	110.3	59.4	15.23	23.26	45.02	27.2	137.4	0.00	0.00	3.000			
70 218.8	115.3	115.3	329.7	35.5	25.5	41.9	110.3	59.4	15.23	23.26	45.02	27.2	137.4	0.00	0.00	3.000			
70 222.1	115.3	115.3	329.7	35.5	25.5	41.9	110.3	59.4	15.23	23.26	45.02	27.2	137.4	0.00	0.00	3.000			
70 225.4	115.3	115.3	329.7	35.5	25.5	41.9	110.3	59.4	15.23	23.26	45.02	27.2	137.4	0.00	0.00	3.000			
70 228.7	115.3	115.3	329.7	35.5	25.5	41.9	110.3	59.4	15.23	23.26	45.02	27.2	137.4	0.00	0.00	3.000			
70 232.0	115.3	115.3	329.7	35.5	25.5	41.9	110.3	59.4	15.23	23.26	45.02	27.2	137.4	0.00	0.00	3.000			
70 235.3	115.3	115.3	329.7	35.5	25.5	41.9	110.3	59.4	15.23	23.26	45.02	27.2	137.4	0.00	0.00	3.000			
70 238.6	115.3	115.3	329.7	35.5	25.5	41.9	110.3	59.4	15.23	23.26	45.02	27.2	137.4	0.00	0.00	3.000			
70 241.9	115.3	115.3	329.7	35.5	25.5	41.9	110.3	59.4	15.23	23.26	45.02	27.2	137.4	0.00	0.00	3.000			
70 245.2	115.3	115.3	329.7	35.5	25.5	41.9	110.3	59.4	15.23	23.26	45.02	27.2	137.4	0.00	0.00	3.000			
70 248.5	115.3	115.3	329.7	35.5	25.5	41.9	110.3	59.4	15.23	23.26	45.02	27.2	137.4	0.00	0.00	3.000			
70 251.8	115.3	115.3	329.7	35.5	25.5	41.9	110.3	59.4	15.23	23.26	45.02	27.2	137.4	0.00	0.00	3.000			
70 255.1	115.3	115.3	329.7	35.5	25.5	41.9	110.3	59.4	15.23	23.26	45.02	27.2	137.4	0.00	0.00	3.000			
70 258.4	115.3	115.3	329.7	35.5	25.5	41.9	110.3	59.4	15.23	23.26	45.02	27.2	137.4	0.00	0.00	3.000			
70 261.7	115.3	115.3	329.7	35.5	25.5	41.9	110.3	59.4	15.23	23.26	45.02	27.2	137.4	0.00	0.00	3.000			
70 265.0	115.3	115.3	329.7	35.5	25.5	41.9	110.3	59.4	15.23	23.26	45.02								

6.3 MEASURED DATA - ACCELERATION TESTS

The test schedule at Dynamic Science did not provide sufficient time for the execution of acceleration tests as per section 5.4. Data, however, was obtained from a total of eight Schedule D cycles wherein maximum accelerations were used in an attempt to meet the schedule profile requirements.

Acceleration data with EV-106 batteries and RCA 2N6251 transistors is listed in Table 6.3.1; runs 1 and 3 are downhill on the north stretch of the track and runs 2 and 4 are uphill on the south stretch of the track. This data was extracted from the first four cycles of Test No. 24.

Acceleration data with LEV-115 batteries and Solitron SDT-12302 transistors is listed in Table 6.3.2; runs 1 and 3 are downhill and runs 2 and 4 are uphill. This data was extracted from the first four cycles of Test No. 31.

All data listed in Section 5.4.3 was recorded with the exception of battery amp-hours.

6.3.1 Test Weight

Gross vehicle weight for Test No. 24 was 3288 lb.

Gross vehicle weight for Test No. 31 was 3363 lb.

6.3.2 Measured Wind Speeds

Wind speeds for Test No. 24 did not exceed 10 mph.

Wind speeds for Test No. 31 did not exceed 5 mph.

6.3.3 Ambient Temperatures

Data Logger recorded ambient temperatures ranged as follows:

83.3°F (28.5°C) to 84.2°F (29.0°C) for Test No. 24

72.3°F (22.38°C) to 73.5°F (23.0°C) for Test No. 31

Table 6.3.1. Uncorrected Acceleration Data from Data
Logger System (Test No. 24)

Computer Time	Elapsed Time (sec.)	Speed (mph)	Batt. Volts	Batt. Amps	Batt. Energy (w-hr)	Motor Volts	Motor Amps	Motor Energy (w-hr)
Run No. 1								
1:31.0	0.31	1.25	129.0	10.8	0.0	0.0	131.7	
1:34.2	3.51	12.05	124.5	211.9	6.7	91.0	165.3	
1:37.4	6.71	18.70	122.6	198.1	20.0	113.4	208.4	
1:40.6	9.91	24.06	117.4	132.2	37.3	116.2	125.2	
1:43.6	12.91	28.04	114.7	215.7	50.7	108.1	202.9	
1:46.8	16.11	32.31	115.5	163.7	70.7	113.9	156.5	
1:50.0	19.31	35.65	115.8	181.5	83.9	92.0	195.6	
1:53.2	22.51	39.23	112.9	213.6	104.2	110.2	205.7	
1:56.0	25.31	42.59	114.7	181.8	125.7	112.6	176.1	
Run No. 2								
3:30.4	2.79	7.02	125.0	99.3	1.0	44.9	183.5	
3:33.6	5.99	15.07	118.1	119.9	16.0	117.3	109.5	
3:36.8	9.19	20.57	—	181.8	—	112.0	166.8	
3:39.6	11.99	24.20	124.4	112.8	42.7	2.0	172.1	
3:42.8	15.19	28.61	112.9	207.9	58.8	110.6	197.1	
3:46.0	18.39	32.97	115.7	163.2	77.6	113.9	89.3	
3:49.2	21.59	34.83	116.9	162.3	92.5	—	187.5	
3:52.2	24.59	37.79	114.4	210.8	110.9	106.3	217.4	
3:55.4	27.79	40.42	113.8	196.6	131.1	111.6	190.2	
3:58.6	30.99	43.24	115.1	177.1	151.1	112.9	171.1	
Run No. 3								
5:26.4	1.87	5.24	126.9	70.9	1.4	28.3	179.1	
5:29.6	5.07	14.21	115.7	136.0	13.7	115.6	121.8	
5:32.6	8.07	20.73	113.2	173.9	27.6	112.4	160.1	
5:35.8	11.27	25.28	118.3	119.8	42.1	117.1	0.8	
5:39.0	14.47	30.50	113.7	189.0	57.4	111.7	179.9	
5:42.2	17.67	33.18	116.4	151.3	76.2	114.8	143.8	
5:45.2	20.67	37.03	114.8	204.8	89.8	98.0	206.4	
5:48.4	23.87	40.75	113.5	199.3	111.1	111.3	191.4	
5:51.6	27.07	42.98	115.1	173.4	129.6	113.2	168.5	

Table 6.3.1. Uncorrected Acceleration Data from Data Logger
System (Test No. 24) (Continuation 1)

Computer Time	Elapsed Time (sec.)	Speed (mph)	Batt. Volts	Batt. Amps	Batt. Energy (w-hr)	Motor Volts	Motor Amps	Motor Energy (w-hr)
Run No. 4								
7:22.6	0.00	0.01	128.7	1.8	1.4	0.0	0.7	
7:25.8	3.20	8.88	122.7	129.5	4.1	61.2	172.5	
7:28.8	6.20	15.05	118.8	31.8	18.1	117.9	18.7	
7:32.0	9.40	22.01	115.7	151.4	32.9	114.3	141.0	
7:35.2	12.60	24.68	118.6	16.3	46.0	117.3	74.8	
7:38.4	15.80	29.53	113.9	--	62.3	112.1	175.1	
7:41.4	18.80	33.04	116.3	152.8	81.1	114.7	147.2	
7:44.6	22.00	35.75	114.0	174.1	94.4	97.4	193.8	
7:47.8	25.20	38.68	112.9	210.9	114.5	110.4	204.2	
7:51.0	28.40	41.38	114.2	--	134.4	112.2	180.7	
7:53.8	31.20	43.58	115.5	169.5	153.4	113.5	164.8	

Table 6.3.2. Uncorrected Acceleration Data from Data Logger System (Test No. 31)

Computer Time	Elapsed Time (sec.)	Speed (mph)	Batt. Volts	Batt. Amps	Batt. Energy (w-hr)	Motor Volts	Motor Amps	Motor Energy (w-hr)
Run No. 1								
1:30.8	.06	.17	126.3	1.8	1.5	--	66.4	0.0
1:34.0	3.14	8.95	120.0	102.9	2.3	43.5	207.3	9.3
1:37.2	6.34	17.64	113.3	199.4	17.5	91.3	216.7	26.8
1:40.4	9.54	21.91	114.0	12.5	36.4	107.9	13.7	37.4
1:43.4	12.54	26.43	111.0	217.2	48.3	104.1	208.5	55.8
1:46.6	15.74	31.36	112.2	163.7	66.8	110.8	158.3	73.3
1:49.8	18.94	33.23	123.5	169.8	80.2	80.4	207.3	86.2
1:53.0	22.14	36.82	110.1	216.2	98.8	106.1	211.6	--
1:55.8	24.94	40.41	111.2	184.9	118.8	109.4	181.0	124.8
1:59.0	28.14	42.94	112.4	165.9	136.0	110.7	163.7	140.7
2:02.2	31.34	44.20	113.3	96.0	153.3	111.6	53.6	152.8
Run No. 2								
3:30.2	1.56	4.32	125.7	59.3	0.0	11.7	212.3	4.1
3:33.4	4.76	13.16	111.8	132.0	13.4	112.4	23.7	16.1
3:36.6	7.96	18.75	111.4	206.2	--	--	186.4	32.2
3:39.4	10.76	21.89	114.1	12.5	40.3	112.9	21.3	42.5
3:42.6	13.96	26.46	110.9	214.6	53.2	102.2	213.3	63.1
3:45.8	17.16	29.86	111.9	172.7	73.8	110.0	168.7	80.4
3:49.0	20.36	32.08	112.5	178.1	87.1	90.4	208.2	95.2
3:52.0	23.36	35.25	110.8	199.9	105.8	99.2	213.9	113.6
3:55.2	26.56	37.56	109.6	209.4	127.1	107.4	204.7	135.0
3:58.4	29.76	39.95	111.0	187.8	147.3	109.1	182.9	153.3
4:01.6	32.96	41.10	112.0	--	164.1	110.1	172.3	170.8
4:04.6	35.96	42.10	112.5	164.9	181.6	110.7	163.0	186.4
Run No. 3								
5:26.2	2.46	5.80	125.0	83.0	0.1	23.4	207.3	6.3
5:29.4	5.66	13.34	114.4	18.9	13.3	113.9	25.1	16.9
5:32.4	8.66	20.64	111.5	161.5	26.9	110.3	152.5	36.1
5:35.6	11.86	25.64	113.0	195.2	40.2	94.2	215.7	49.9
5:38.8	15.06	29.75	111.5	172.6	60.2	109.8	168.1	69.9
5:42.0	18.26	33.44	117.1	182.9	73.8	91.7	211.0	84.5
5:45.0	21.26	37.35	109.8	217.7	93.6	105.6	212.7	104.4
5:48.2	24.46	40.08	111.0	184.3	113.8	109.1	181.7	122.9
5:51.4	27.66	42.92	112.2	165.1	131.1	110.5	163.1	139.0

Table 6.3.2. Uncorrected Acceleration Data from Data Logger
System (Test No. 31) (Continuation 1)

Computer Time	Elapsed Time (sec.)	Speed (mph)	Batt. Volts	Batt. Amps	Batt. Energy (w-hr)	Motor Volts	Motor Amps	Motor Energy (w-hr)
Run No. 4								
7:22.4	0.00	0.03	125.7	1.1	0.0	--	3.0	0.0
7:25.6	3.20	10.93	116.6	--	4.5	78.6	202.9	13.0
7:28.6	6.20	14.84	124.1	83.9	17.5	50.3	199.0	24.2
7:31.8	9.40	21.29	112.2	152.6	32.2	111.0	146.2	39.4
7:35.0	12.60	24.15	112.4	190.0	44.2	91.7	214.6	54.4
7:38.2	15.80	28.53	110.4	185.2	64.1	108.8	180.7	72.9
7:41.2	18.80	30.96	112.6	155.1	81.1	111.0	19.8	87.9
7:44.4	22.00	33.92	111.1	194.1	95.9	95.9	213.4	106.1
7:47.6	25.20	36.47	109.4	216.9	116.4	105.8	212.5	126.9
7:50.8	28.40	39.10	110.5	190.0	137.9	108.5	--	145.6
7:53.6	31.20	40.85	111.5	174.7	155.2	109.6	173.6	165.9
7:56.8	34.40	42.49	112.1	163.9	172.5	110.5	163.5	183.2
8:00.0	37.60	43.14	112.7	157.8	189.9	110.9	156.7	199.3

6.4 MEASURED DATA - COAST-DOWN TESTS

Tests were conducted in accordance with Section 5.5 of the report and Section 2.8.6 of ERDA document EHV-TEP (May, 1977). On March 15, 1977, a total of ten coast-down tests were run on the North Stretch of Dynamic Science's Oval Track; six tests were run east to west and four tests were run west to east. Each of the east to west tests was started at a green marker reading 0.8 mi., and each of the west to east tests was started at a green marker reading 1.4 mi. (From crude measurements made by Rippel, it was determined that the 0.8 mi marker corresponds to the 3234 foot mark on the track survey, while the 1.4 mi marker corresponds to the 66 foot mark on the track survey.) Peak wind speeds, as recorded at the vehicle shed did not exceed 5 mph during the tests. Ambient temperature were approximately 65°F.

Speed-time data was recorded both on the Data Logger System and on a Strip Chart. See Table 6.4.1 for data recorded on the Data Logger System, and see Table 6.4.2 for Strip Chart data. See Table 6.4.3 for track survey generated by Dynamic Science.

Table 6.4.1. Uncorrected Coast-Down Data from Data Logger System

Run No. 1 (East to West)		Run No. 2 (West to East)		Run No. 3 (East to West)	
Elapsed Time (sec.)	Speed (mph)	Elapsed Time (sec.)	Speed (mph)	Elapsed Time (sec.)	Speed (mph)
0.0	48.32	0.0	44.07	0.0	47.85
2.8	47.17	3.0	41.14	3.0	46.48
6.0	45.19	6.2	38.10	6.2	45.42
9.2	44.57	9.4	36.33	9.4	44.37
12.4	42.78	12.8	34.04	12.6	42.49
14.8	41.33	15.8	32.42	15.6	41.18
17.8	39.85	18.8	29.99	18.8	40.03
21.0	38.37	22.0	27.64	22.0	39.50
24.2	37.02	25.2	25.58	25.2	38.28
27.0	35.58	28.4	23.95	28.2	37.10
30.0	35.31	31.2	21.69	31.4	36.31
33.2	34.03	34.4	19.64	34.6	35.55
36.4	32.79	37.6	18.20	37.8	34.88
39.6	32.13	40.8	16.06	40.6	33.44
42.4	31.09	43.8	14.80	43.8	33.14
45.6	30.32	47.0	13.07	47.0	32.19
48.8	28.43	50.2	11.46	50.2	30.84
52.0	27.84	53.4	10.33	53.2	30.41
54.8	27.06	56.4	8.63	56.4	28.77
58.0	26.16	59.6	7.51	59.6	28.72
61.2	24.63	62.8	5.65	62.8	27.47
64.4	23.70	66.0	4.48	65.8	25.99
67.4	22.11	69.0	3.12	69.0	24.52
70.6	21.25	72.2	1.59	72.2	23.04
73.8	19.59	75.4	.43	78.4	21.06
77.0	18.34			81.6	20.04
79.8	16.86			84.8	18.14
83.0	15.38			90.8	14.78
86.2	13.53			94.0	13.83
89.4	12.08			100.4	11.06
				106.6	9.08
				113.0	6.74
				119.2	5.10
				125.6	3.10
				131.8	.57

Table 6.4.1. Uncorrected Coast-Down Data from
Data Logger System (Continuation 1)

Run No. 4 (West to East)		Run No. 5 (East to West)		Run No. 6 (West to East)	
Elapsed Time (sec.)	Speed (mph)	Elapsed Time (sec.)	Speed (mph)	Elapsed Time (sec.)	Speed (mph)
0.0	45.18	0.0	39.07	0.0	43.12
2.8	42.36	3.2	37.76	3.2	40.31
6.0	40.12	6.4	36.70	6.4	38.78
9.2	37.79	9.4	35.52	9.6	36.95
12.4	36.79	12.6	34.82	12.8	34.37
15.4	33.46	15.8	33.61	15.8	32.49
18.6	31.34	19.0	32.44	19.0	30.42
21.8	29.23	22.2	30.80	22.2	28.67
25.0	27.32	25.2	29.75	25.4	26.83
28.0	24.56	28.4	29.03	28.2	24.72
31.2	22.88	31.6	28.86	31.4	23.06
34.4	21.23	34.8	28.18	34.6	22.32
37.6	19.74	37.6	26.64	37.8	20.00
40.6	18.06	40.8	25.90	40.8	18.16
43.8	16.89	44.0	25.96	44.0	16.58
47.0	14.74	47.2	25.86	47.2	15.64
50.2	13.04	50.2	25.37	50.4	14.39
53.0	11.76	53.4	24.06	53.4	12.60
56.2	9.42	56.6	23.46	56.6	11.78
59.4	7.69	59.8	22.95	59.8	9.94
62.6	6.15	62.8	21.98	63.0	8.73
65.6	5.20	66.0	21.30	66.0	7.57
68.8	4.07	69.2	20.66	69.2	6.16
72.0	2.77	72.4	20.01	72.4	4.61
75.2	1.34	75.4	19.56	75.6	3.17
84.4	.14	78.6	18.44	78.4	1.75
		81.8	17.71	81.6	.27
		85.0	16.95		
		87.8	16.07		
		91.0	15.21		
		94.2	13.88		
		97.4	12.53		
		100.4	11.69		

Run No. 7 (East to West)		Run No. 8 (East to West)		Run No. 9 (West to East)	
Elapsed Time (sec.)	Speed (mph)	Elapsed Time (sec.)	Speed (mph)	Elapsed Time (sec.)	Speed (mph)
0.0	41.17	0.0	24.43	0.0	46.71
3.0	40.74	3.2	23.67	3.2	44.30
6.2	39.19	6.2	22.85	6.4	41.44
9.4	38.11	9.4	23.13	9.6	34.53
12.6	36.99	12.6	22.61	12.8	36.70
15.6	35.95	15.8	22.16	15.8	34.56

Table 6.4.1. Uncorrected Coast-Down Data from Data Logger System (Continuation 2)

Run No. 7 (cont) (East to West)		Run No. 8 (cont) (East to West)		Run No. 9 (cont) (West to East)	
Elapsed Time (sec.)	Speed (mph)	Elapsed Time (sec.)	Speed (mph)	Elapsed Time (sec.)	Speed (mph)
18.8	35.42	18.6	21.25	19.0	32.92
22.0	34.29	21.8	21.13	22.2	30.58
25.2	33.50	25.0	20.34	25.4	28.40
28.0	32.03	28.2	19.85	28.2	27.22
31.2	31.26	31.2	18.88	31.4	25.22
34.4	30.86	34.4	18.83	34.6	23.59
37.6	29.82	37.6	18.27	37.6	21.91
40.6	29.56	40.8	17.44	40.8	20.24
43.8	28.37	43.8	17.64	44.0	18.88
47.0	28.33	47.0	16.92	47.2	17.60
50.2	27.03	50.2	16.15	50.4	16.46
53.2	26.36	56.4	15.36	53.4	14.88
56.4	25.67	59.6	15.14	56.6	13.88
59.6	24.26	62.8	14.68	59.8	11.91
65.8	22.91	68.8	14.22	63.0	10.44
69.0	23.54	72.0	13.69	66.0	9.09
72.2	21.78	75.2	13.22	69.2	7.60
78.2	20.15	78.4	12.40	72.4	6.08
81.4	17.60	81.4	12.04	75.6	4.61
		84.6	12.02	78.4	3.26
		87.8	11.52	81.6	1.88
		91.0	11.39	84.8	.57
		94.0	11.33	88.0	.04
		97.2	10.67		
		100.4	10.16		
		103.6	9.77		
		106.6	10.10		
		109.8	9.57		
		113.0	9.01		

Run No. 10 (East to West)		Run No. 10 (cont) (East to West)		Run No. 10 (cont) (East to West)	
Elapsed Time (sec.)	Speed (mph)	Elapsed Time (sec.)	Speed (mph)	Elapsed Time (sec.)	Speed (mph)
0.0	14.59	37.6	10.31	75.2	6.26
3.2	14.12	40.8	10.00	78.4	6.05
6.4	14.31	44.0	9.50	81.6	5.67
9.6	13.26	47.2	9.15	84.8	5.40
12.6	13.52	50.2	8.98	87.8	5.36
15.8	13.11	53.4	8.78	91.0	4.81
19.0	12.90	56.6	8.49	94.2	4.40
22.2	12.20	59.8	8.37	97.4	4.71
25.0	11.84	62.8	7.51	100.4	4.30
28.2	11.49	66.0	7.27	125.4	2.83
31.4	11.42	69.2	6.67	166.4	1.01
34.6	11.15	72.4	5.56		

Table 6.4.2. Coast-Down Data from Strip Chart

Run No. 1 (East to West)		Run No. 2 (West to East)		Run No. 3 (East to West)	
Elapsed Time (sec.)	Speed (mph)	Elapsed Time (sec.)	Speed (mph)	Elapsed Time (sec.)	Speed (mph)
0	50.2	0	44.9	0	51.5
5	48.1	5	40.9	5	49.1
10	45.8	10	37.0	10	46.9
15	43.2	15	33.6	15	44.8
20	40.7	20	30.0	20	42.5
25	38.7	25	26.8	25	40.5
30	36.8	30	23.6	30	38.4
35	35.0	35	20.5	35	37.5
40	33.4	40	17.6	40	36.0
45	31.8	45	15.1	45	34.8
50	30.2	50	12.5	50	33.4
55	28.5	55	10.2	55	31.9
		60	8.0		
		65	5.8		
		70	3.6		
		75	1.4		
		79	0.0		

Run No. 4 (West to East)		Run No. 5 (East to West)		Run No. 6 (West to East)	
Elapsed Time (sec.)	Speed (mph)	Elapsed Time (sec.)	Speed (mph)	Elapsed Time (sec.)	Speed (mph)
0	44.3	0	39.2	0	44.9
5	40.4	5	37.6	5	41.3
10	36.7	10	35.7	10	38.1
15	33.1	15	34.1	15	34.7
20	29.9	20	32.5	20	3
25	26.7	25	31.1	25	2
30	23.6	30	29.7	30	2
35	20.8	35	28.1	35	2.5
40	18.1	40	27.2	40	20.5
45	15.6	45	26.4	45	17
50	13.0	50	25.5	50	
55	10.7	55	24.4	55	
60	8.6	60	23.2	60	11.0
65	6.4	65	22.1	65	8.9
70	4.6	70	21.0	70	6.8
75	2.6			75	4.7
80	0.4			80	2.2
				85	0.0

Table 6.4.2. Coast-Down Data from Strip Chart (Continuation 1)

Run No. 7 (East to West)		Run No. 8 (East to West)		Run No. 8 (cont) (East to West)	
Elapsed Time (sec.)	Speed (mph)	Elapsed Time (sec.)	Speed (mph)	Elapsed Time (sec.)	Speed (mph)
0	42.7	0	24.7	70	14.3
5	41.0	5	24.1	75	13.6
10	39.5	10	23.3	80	13.0
15	37.6	15	22.5	85	12.5
20	35.8	20	21.7	90	11.9
25	34.3	25	20.9	95	11.4
30	33.0	30	20.0	100	10.9
35	31.8	35	19.2	110	9.9
40	30.6	40	18.3	120	8.9
45	29.4	45	17.6	130	7.8
50	28.2	50	16.8	140	7.0
55	27.0	55	16.2	150	6.0
60	26.2	60	15.5		
65	24.8	65	14.9		

Run No. 9 (West to East)		Run No. 10		Run No. 10 (cont)	
Elapsed Time (sec.)	Speed (mph)	Elapsed Time (sec.)	Speed (mph)	Elapsed Time (sec.)	Speed (mph)
0	49.6	0	14.9	95	5.2
5	43.3	5	14.5	100	4.9
10	41.2	10	14.1	105	4.5
15	37.5	15	13.7	110	4.1
20	34.1	20	13.3	115	3.9
25	30.9	25	12.9	120	3.5
30	27.9	30	12.3	125	3.1
35	25.2	35	11.6	130	3.0
40	22.4	40	11.0	135	2.9
45	20.0	45	10.4	140	2.5
50	17.7	50	9.7	145	2.1
55	15.4	55	9.0	150	1.8
60	13.2	60	8.6	155	1.4
65	11.0	65	8.1	160	1.2
70	8.5	70	7.5	165	1.2
75	6.3	75	6.8	170	1.1
80	4.0	80	6.3	175	0.9
85	1.8	85	6.0	180	0.6
89.5	0.0	90	5.6	185	0.3

Table 6.4.3. Track Survey Data

Survey Location (ft)	Elevation (ft)	Distance from 0.8 mi Marker (ft)	Distance from 1.4 mi Marker (ft)	Average Grade between Surveys
0	2.35	3234	-66	
50		3184	-16	.563
100	2.92	3134	34	
150		3084	84	.667
200	3.58	3034	134	
250		2984	184	.875
300	4.58	2934	234	
350		2884	284	.729
400	5.19	2834	334	
450		2784	384	.563
500	5.75	2734	434	
550		2684	484	.625
600	6.38	2634	534	
650		2584	584	.979
700	7.35	2534	634	
750		2484	684	.875
800	8.23	2434	734	
850		2384	784	.500
900	8.73	2334	834	
950		2284	884	.563
1000	9.29	2234	934	
1050		2184	984	.979
1100	10.27	2134	1034	
1150		2084	1084	.979
1200	11.25	2034	1134	
1250		1984	1184	.750
1300	12.00	1934	1234	
1350		1884	1284	.625
1400	12.63	1834	1334	
1450		1784	1384	.979
1500	13.60	1734	1434	
1550		1684	1484	.813
1600	14.42	1634	1534	
1650		1584	1584	.708
1700	15.13	1534	1634	
1750		1484	1684	.625
1800	15.75	1434	1734	
1850		1384	1784	.917
1900	16.67	1334	1834	
1950		1284	1884	.917
2000	17.58	1234	1934	
2050		1184	1984	.521
2100	18.10	1134	2034	
2150		1084	2084	.563
2200	18.68	1034	2134	
2250		984	2184	.708
2300	19.38	934	2234	
2350		884	2284	.729

Table 6.4.3. Track Survey Data (Continuation 1)

Survey Location (ft)	Elevation (ft)	Distance from .8 mi Marker (ft)	Distance from 1.4 mi Marker (ft)	Average Grade between Surveys
2400	20.10	834	2334	.542
2450		784	2384	
2500	20.65	734	2434	
2550		684	2484	.438
2600	21.08	634	2534	
2650		584	2584	
2700	21.96	534	2634	.875
2750		484	2684	
2800	22.83	434	2734	
2850		384	2784	.792
2900	23.63	334	2834	
2950		284	2884	
3000	24.46	234	2934	.833
3050		184	2984	
3100	25.21	134	3034	
3150		84	3084	.771
3200	25.98	34	3134	
3250		-16	3184	
3300	26.48	-66	3234	.500

C-41

6.5 MEASURED DATA - WEIGHT SENSITIVITY TESTS

6.5.1 Constant Speed Tests

Tests were conducted as per Section 5.6.2.

Measured $W_o = 3288$ lb; measured tire pressures were 28 PSI for front tires and 37 PSI for rear tires. Ambient temperatures ranged between 57°F and 80°F during the tests; wind velocities were below 10 mph with occasional gusts reaching 15 mph. Data is summarized in Table 6.5.1.

6.5.2 Driving Cycle Tests

Tests were conducted as per Section 5.6.3.

Measured $W_o = 3288$ lb; measured tire pressures were 28 PSI for front tires and 37 PSI for rear tires. Ambient temperature ranged between 57°F and 80°F during the tests; wind velocities were below 10 mph with occasional gusts reaching 15 mph. Data is summarized in Table 6.5.2.

Table 6.5.1 Constant Speed Weight Sensitivity

Run No.	Date	Speed, Gear	ΔW (lb)	Batt. Disch. Energy (WH)	Energy to Motor (WH)*	A.H. Disch.	Fifth Wheel Feet
1	3/24	45,4	202	562.5	506.6	4.63	10698
2	3/24	35,3	202	477.3	416.0	3.86	10657
3	3/24	25,2	202	442.6	362.7	3.51	10662
4	3/24	45,4	0	530.6	484.0	4.39	10712
5	3/24	35,3	0	448.0	392.0	3.31	10659
6	3/24	25,2	0	416.0	340.0	3.31	10677
7	3/24	45,4	202	525.3	478.6	4.37	10697
8	3/24	35,3	202	448.0	393.3	3.64	10680
9	3/24	25,2	202	418.6	342.6	3.33	10675
10	3/24	45,4	0	498.6	453.3	4.15	10681
11	3/24	35,3	0	432.0	376.0	3.50	10689
12	3/24	25,2	0	406.6	329.3	3.22	10671
13	4/18	Top	400	571.8	561.2	4.86	10689
14	4/18	Top	400	547.9	439.9	4.65	10695
15	4/18	45,4	400	466.6	461.2	3.97	10708
16	4/18	35,3	400	400.0	395.9	3.39	10686
17	4/18	25,2	400	375.9	370.5	3.20	10693
18	4/18	Top	0	533.2	526.5	4.57	10671
19	4/18	45,4	0	453.2	447.9	3.91	10673
20	4/18	35,3	0	381.2	375.9	3.24	10663
21	4/18	25,2	0	350.6	342.6	2.98	10676
22	4/18	Top	0	517.2	510.5	4.53	10675
23	4/18	45,4	0	435.9	429.2	3.82	10684
24	4/18	35,3	0	374.6	369.2	3.21	10676
25	4/18	25,2	0	343.9	335.9	2.91	10684
26	4/18	Top	400	531.9	525.2	4.80	10707
27	4/18	45,4	400	449.2	442.6	4.05	10714
28	4/18	35,3	400	383.9	378.6	3.36	10698
29	4/18	25,2	400	355.9	347.9	3.06	10727

*In tests one through twelve, motor energy was measured at armature and does not include field losses. In tests thirteen through twenty nine, total motor energy was measured (including field circuit).

Table 6.5.2. Driving Cycle Weight Sensitivity Data

Run No.	Date	Description of Test	ΔW (lb)	Batt. Disch Energy (WH)	Batt. Rech. Energy (WH)	Energy to Motor (WH)	Energy from Motor (WH)	Disch.	Rech.	Fifth Wheel Feet
1	3/24	C, no regen.	0	670.6	-	560.0	-	5.46	-	10702
2	3/24	C, no regen.	202	597.3	-	597.3	-	5.83	-	10768
3	3/24	C, W. regen.	202	596.0	86.6	597.3	118.6	5.78	.60	11346
4	3/24	C, W. regen.	0	653.3	70.7	557.3	105.3	5.45	.53	11248
5	4/18	C, no regen.	400	678.5	-	637.2	-	5.66	-	10898
6	4/18	C, W. regen.	400	662.5	93.3	629.2	106.0	5.53	.58	11637
7	4/18	C, no regen.	0	629.2	-	589.2	-	5.21	-	10983
8	4/18	C, W. regen.	0	599.9	88.0	567.9	102.6	5.00	.57	11569

7.1 REDUCED DATA - CONSTANT SPEED TESTS

Data from Table 6.1.1, along with instrument correction factors, will now be used to compute energy and efficiency parameters. These computations, along with the corrected primary data, are summarized in Table 7.1.1. Corrections and Computations are as follows:

7.1.1 Average Speed Achieved (1)

With each of Constant Speed Tests (Nos. 2 through 9), computer computations were performed to provide various derived quantities, one of which was "mean velocity". The mean velocity was computer-calculated by averaging all recorded speed numbers. Due to finite acceleration and deceleration times, the resulting calculation should be slightly low.

All speed data printed by the computer was low by a factor of 1.045 due to use of an incorrect scale factor. (See Section 4.4.1.4.) Accordingly, the mean velocity print-outs were multiplied by 1.045 to give corrected values of "Average Speed Achieved".

In the case of the "Calibration Tests" (Nos. 22A through 22E), average speed was computed by hand averaging a number of evenly spaced printed velocities and correcting by 1.045 factor.

7.1.2 Distance Traveled (2)

With each of the tests, distance measurements were obtained from the Nucleus Distance Totalizer; no correction factors were employed. With Tests 2 through 9, distance includes acceleration and deceleration. With calibration Tests 22A through 22E, the Totalizer was enabled at a specific location - after achieving constant speed. After exactly two laps, the distance counter was switched off. Since the Totalizer switch was ganged with enable switches for the Current Integrator and the Energy Counter, corresponding Amp-Hour and KWH measures were obtained.

7.1.3 End of Test Battery Voltage (3)

This value is the last entry recorded (on tape) prior to deceleration.

7.1.4 Discharge Amp-Hours

This value was taken directly from the Current Integrator; no corrections were used.

7.1.5 Discharge KWH (4)

This value was taken directly from the Battery Discharge portion of the Energy Counter. Values listed are counter increments multiplied by 0.01333.

7.1.6 Discharge KWH, corrected (5).

In accordance with lines 1 and 2 of Table 4.6.2 (Energy Counter Cal. Test), a correction factor of $1.316/1.333 = 0.9870$ was used for each of the 14 entries.

7.1.7 KWH to Motor (6)

This value was taken directly from the "To Motor" portion of the Energy Counter. Values listed are counter increments multiplied by 0.01333.

7.1.8 KWH to Motor, corrected (7)

In accordance with lines 8 and 9 of Table 4.6.2 (Energy Counter Cal. Test), a correction factor of $1.302/1.333 = 0.9765$ was used for 25 and 35 mph tests, and a correction factor of $1.305/1.333 = 0.9787$ was used for 45 mph and top speed tests.

7.1.9 Recharge Amp-Hours (8)

This value was taken directly from the charge portion of the current Integrator.

7.1.10 Recharge Amp-Hours, corrected (9)

From Section 4.6.2, an off-set associated with the Current Integrator was determined as $5A \times (0.92-1.00) = -0.4A$. (This off-set is only approximate due to drift and temperature effects.) Corrections were achieved by multiplying off-set by time and subtracting from uncorrected Amp-Hours.

7.1.11 Recharge KWH (10)

This value was taken directly from the Battery Recharge portion of the Energy Counter. Values listed are counter increments multiplied by 0.01333.

7.1.12 Recharge KWH, corrected (11)

During Tests 2 through 11, an off-set associated with the AC Battery Current Sensor resulted in a voltage off-set at the Energy Counter of +0.031 volts (see Section 4.6.1.2). Noting that this voltage corresponded to 1.86A and that the time-averaged recharge voltage was about 150 volts, the following off-set is subtracted:

$$\Delta E = - 1.86 \times 150 \times \text{Elapsed Recharge Time} \times 10^{-3} \text{ KWH}$$

From line 3 and 4 of Table 4.6.2, (Energy Counter Cal. Test), a correction factor of $1.120/1.333 = 0.840$ was derived for the Recharge

portion of the Energy Counter. Both the off-set correction and the Energy Counter correction were used to compute corrected Recharge KWH values.

7.1.13 Charger Input

Line KWH was read directly from the GE AC KWH meter. Recharge Time was obtained from either a wall clock or wrist watch.

7.1.14 Weather Conditions

Ambient Temperatures were obtained from magnetic tape data; numbers listed are round-offs of low and high readings.

Wind Speed numbers were derived from a portable weather station apparatus JPL set up at Dynamic Science.

7.1.15 Miles per Line KWH (12)

For each test, this number is the Distance Traveled (2), divided by the Line KWH.

7.1.16 Miles per Amp-Hour Discharged (13)

For each test, this number is the Distance Traveled (2) divided by the Amp-Hours Discharged.

7.1.17 Charger Efficiency (14)

For each test, this number is the ratio of Recharge KWH corrected (11) to the Line KWH. While values ranged from between 82.4% to 107.5%, careful measurements made by Rippel indicate this number to be $95 \pm 1\%$.

A careful calculation was done with test 12 (driving cycle test) and computed charger efficiency was found as 96.4%.

7.1.18 Coulombic Efficiency (15)

For each test, this number is the ratio between Amp-Hours Discharged and corrected Amp-Hours Recharged (9).

7.1.19 Voltaic Efficiency (16)

For each test, this number is the ratio of Mean Discharge Voltage to Average Recharge Voltage. The Mean Discharge Voltage was provided by Computer Averaging all Battery Voltage entries, and the Average Recharge Voltage is the ratio between Cycle Efficiency (17) and Coulombic Efficiency (15).

7.1.20 Cycle Efficiency (17)

For each test, this number is the ratio of Discharge KWH, corrected (5) to Recharge KWH corrected (11).

7.1.21 Controller Efficiency (18)

For each test, this number is the ratio of KWH to Motor, corrected (7) to Discharge KWH, corrected (5).

7.1.22 Average Motor Amps (19)

For Tests 2 through 11, this number is the ratio between Motor Amp-Hours (a computer "time-integral" of motor current) and Elapsed Time (also provided by the computer).

For Tests 22A through 22E, this number was found by averaging a number of evenly spaced current print-out values. (Typically 15 values of motor Current were hand averaged.)

7.1.23 Average Motor Volts (20)

For each test, this value was found analogously to the corresponding value for Average Motor Amps.

7.1.24 Average Motor Torque (21)

Each of these values was derived as a function of Motor Current by using current-torque data from Table 3.6.1.

7.1.25 Average Motor RPM (22)

For each test, the Average Motor RPM was found from the Average Speed (2) by using tire and gear ratio data.

Gear ratio data was obtained from Sections 3.9.2 and 3.9.3, and the rolling distance per tire revolution.

7.1.26 Average Motor-Controller Efficiency (23)

Using Motor Current and Voltage information, data in Table 3.6.1 was used to determine system efficiency. Observing the data in the table and the plots, it is noted that efficiency is a weak function of motor current and depends mainly on motor voltage. Observing several operating points of nearly equal current, it was found that efficiency is closely proportionate to $V_{mot}^{.263}$. This relation was used for scaling and interpolating Table 3.6.1 efficiency data.

7.1.27 Average Motor Efficiency (24)

In each case, this number was found as the ratio between the Average Motor-Controller Efficiency (23) and the Controller Efficiency (18). Ideally, it is true measure of the efficiency of

the motor itself, operating under the conditions imposed by the controller.

7.1.28 DC Motor Efficiency (25)

Using Motor Current and Voltage information, data in Table 3.4.1 was used to predict the motor efficiency operating under equivalent pure DC conditions. Analysis of the Table 3.4.1 data revealed that efficiency is a weak function of motor current and that efficiency scales in close proportion to $v_{\text{mot}}^{.130}$. This relation was used for scaling and interpolating Table 3.4.1 efficiency data.

7.1.29 Chopper Induced Losses (25)

For each test, this is the difference between DC Motor Efficiency (25) and Average Motor Efficiency (24). Ideally, this parameter serves to measure increased motor losses due to the AC components in applied voltages and currents.

7.1.30 Road Load KWH (27)

In Section 7.4, an approximate model for Road Load was derived. Equation 7.4.9 expresses Road Load Horsepower as a function of vehicle speed in miles per hour (GVW = 3288 lb as with Constant Speed Tests). Equation 7.4.9 may be integrated to give Road Load Energy:

$$\text{KWH} = 0.0858 R + 5.60 \times 10^{-5} \int v^3 dt \quad (7.1.1)$$

where R is distance traveled in miles and v is instantaneous speed in mph.

Where v is maintained essentially constant, Eqn. 7.1.1 may be written as:

$$\text{KWH} = 0.0858 R [1 + 6.53 \times 10^{-4} v^2] \quad (7.1.2)$$

Using Eqn. 7.1.2, Road Load Energies were found as functions of Distances Traveled and Average Speeds.

7.1.31 Average Gear Train Efficiency

In each case, this number was taken as the ratio between Road Load Energy and Motor Energy. The Motor Energy was found as the product of Energy to the Motor and Motor Efficiency.

Table 7.1.1. Constant Speed, Uncorrected, Corrected, and Computed Data

Test No.	2	3	4	5	6	7	9	10	11	22A	22B	22C	22D	22E
Date of Test	3/4	3/7	3/8	3/10	3/11	3/14	3/15	3/16	3/17	4/17	4/17	4/17	4/17	4/17
Test Description	25 mph	35 mph	45 mph	"Top"	35 mph	"Top"	25 mph	35 mph	45 mph	25 mph Cal.	35 mph Cal.	45 mph Cal.	"Top" Cal.	"Top" Cal.
Av. Speed Achieved (mph) ¹	25.92	34.78	45.13	49.34	35.97	49.87	25.74	35.96	45.19	25.27	35.48	45.81	55.24	53.57
Distance Traveled (mi) ²	101.2	94.75	75.31	52.82	73.05	55.70	101.5	80.87	66.69	4.045	4.049	4.059	4.052	4.050
End of Test Batt. Voltage ³	92	90.3	88.3	91.7	92	91.5	91.0	90.8	91.5	-	-	-	-	-
Gear	2	3	4	4	3	4	2	3	4	2	3	4	4	4
BATTERY DISCHARGE														
Discharge Amp-Hours	159.23	154.49	145.85	126.13	140.94	127.95	162.35	155.36	137.18	5.77	6.19	7.33	8.95	9.07
Discharge KWH ⁴	18.10	18.50	16.90	14.22	16.51	14.53	17.68	18.20	15.94	0.715	0.749	0.865	1.011	1.027
Discharge KWH, Corrected ⁵	17.86	18.26	16.68	14.04	16.30	14.34	17.45	17.96	15.73	0.706	0.739	0.854	0.998	1.014
ENERGY TO MOTOR														
KWH to Motor ⁶	15.54	15.98	15.29	13.46	14.90	13.72	16.07	15.73	14.78	0.680	0.727	0.845	1.012	0.991
KWH to Motor, Corrected ⁷	14.98	15.60	14.97	13.17	14.55	13.43	15.65	15.35	14.47	0.664	0.710	0.827	0.990	0.970
BATTERY RECHARGE														
Recharge Amp-Hours ⁸	211.43	170.23	167.80	149.28	153.12	147.35	178.48	-	162.91	-	-	-	-	-
Recharge Amp-Hours, Corrected ⁹	221.63	177.75	175.40	156.80	159.9	153.30	185.8	-	170.39	-	-	-	-	-
Recharge KWH ¹⁰	30.3	19.24	18.22	16.55	-	19.86	20.10	-	-	-	-	-	-	-
Recharge KWH, Corrected ¹¹	32.6	21.40	20.61	19.23	-	20.92	22.00	-	-	-	-	-	-	-
CHARGER INPUT														
Line KWH	30.3	25.3	25.0	22.0	22.4	-	24.8	14.6	23.6	-	-	-	-	-
Recharge Time (hr.)	25.5	18.8	19.0	18.8	-	15.1	18.3	18.0	18.7	-	-	-	-	-
WEATHER CONDITIONS														
Ambient Temp (°C)	18-20	25-27	26-28	18-19	12-15	18-20	12-22	17-18	16-19	11-32	31-32	31-32	31-32	29-30
Wind Speed (mph)	5-10	3-7	5-10	10-20	10-20	10-15	0-5	10-20	4-6	5-10	5-10	5-10	5-10	5-10
COMPUTED QUANTITIES														
Miles per Line KWH ¹²	3.34	3.74	3.01	2.40	3.26	-	4.09	-	2.82	-	-	-	-	-
Miles per A.H. Discharged ¹³	0.636	0.613	0.516	0.418	0.518	0.415	0.625	0.520	0.486	0.701	0.654	0.554	0.453	0.446
Charger Eff. (%) ¹⁴	107.5	84.6	82.4	87.4	-	-	88.6	-	-	-	-	-	-	-
Coulombic Eff. (%) ¹⁵	71.8	86.9	83.2	80.4	88.1	83.4	87.4	-	-	-	-	-	-	-
Voltatic eff. (%) ¹⁶	76.3	91.1	97.2	90.7	-	82.1	90.8	-	-	-	-	-	-	-
Cycle Eff. (%) ¹⁷	54.8	85.3	80.9	73.0	-	68.5	79.4	-	-	-	-	-	-	-
Controller Eff. (%) ¹⁸	87.0	87.5	91.7	95.9	91.4	95.7	91.9	87.6	94.0	94.1	96.1	96.8	97.6	97.2
Av. Motor Amps ¹⁹	56.2	83.3	96.2	111.2	83.9	175.9	52.8	77.2	100.1	55.9	71.6	99.9	116.0	121.2
Av. Motor Volts ²⁰	69.2	74.1	86.2	105.2	78.8	103.7	67.5	82.7	88.7	66.8	74.6	87.2	114.9	116.0
Av. Motor Torque (ft-lb) ²¹	9.1	16.7	21.2	26.2	16.8	25.9	8.1	15.5	22.8	8.5	13.6	22.5	28.1	30.4
Av. Motor RPM ²²	3221	2797	2586	2826	2893	2857	2198	2892	2589	3140	2854	2625	3165	3069
Av. Motor - Cont. Eff. (%) ²³	73.2	78.5	82.9	85.1	78.6	85.2	73.2	82.0	81.8	72.3	76.3	80.7	86.5	86.5
Av. Motor Eff. (%) ²⁴	76.8	79.4	83.4	88.6	79.4	88.6	76.8	79.4	83.4	76.8	79.4	83.4	88.6	89.0
DC Motor Eff. (%) ²⁵	78.1	84.5	84.7	86.3	83.9	86.9	77.9	83.7	85.0	81.2	82.6	84.9	86.8	86.7
Chopper Induced Losses (%) ²⁶	1.3	5.1	1.3	-2.3	4.5	-1.7	1.1	4.3	1.6	4.4	3.2	1.5	-1.6	-2.1
Road Load KWH ²⁷	12.21	14.57	15.08	11.76	11.57	12.56	12.27	12.50	13.31	0.492	0.663	0.826	0.999	1.040
Av. Gear Train Eff. (%) ²⁸	93.4	101.6	109.1	98.4	96.3	102.8	88.2	84.8	103.4	96.4	112.7	119.8	115.7	117.0

7.2 REDUCED DATA - DRIVING CYCLE TESTS

Data from Table 6.2.1, along with instrument correction factors, will now be used to compute energy and efficiency parameters. These computations, along with the corrected primary data, are summarized in Table 7.2.1. Corrections and computations are as follows:

7.2.1 Corrected Distance (2)

For each test where regenerative braking was not included, the ideal speed-time profiles were followed fairly closely. Accordingly for each of these tests, no corrections were made to the original Fifth Wheel distance.

For each test where regenerative braking was included, the deceleration times exceeded the profile times by two to five seconds. To correct for the extra distances driven, corrected distances were found by multiplying the corresponding distance per non-regenerative cycle by the number of regenerative cycles.

7.2.2 End-of-Test Battery Voltage (3)

This value is the last entry from the cruise portion of the last cycle driven; it was derived from the computer printout.

7.2.3 Discharge KWH (4). See Paragraph 7.1.5

7.2.4 Discharge KWH, corrected (5). See Paragraph 7.1.6

7.2.5 KWH to Motor (6). See Paragraph 7.1.7

7.2.6 KWH to Motor, corrected (7). See Paragraph 7.1.8

7.2.7 Recharge Amp-Hours (8). See Paragraph 7.1.9

7.2.8 Recharge Amp-Hours, corrected (9). See Paragraph 7.1.10

7.2.9 Recharge KWH (10). See Paragraph 7.1.11

7.2.10 Recharge KWH, corrected (11). See Paragraph 7.1.12

7.2.11 Charger Input. See Paragraph 7.1.13

7.2.12 Weather Conditions. See Paragraph 7.1.14

7.2.13 Miles per Line KWH (12). See Paragraph 7.1.15

7.2.14 Miles per Net Amp-Hour Discharged (13). For each driving cycle test, this number is equal to the corrected distance divided by the difference between amp-hours discharged and amp-hours recharged via regenerative braking.

- 7.2.15 Charger Efficiency (14). See Paragraph 7.1.17
- 7.2.16 Coulombic Efficiency (15). See Paragraph 7.1.18
- 7.2.17 Voltaic Efficiency (16). See Paragraph 7.1.19
- 7.2.18 Cycle Efficiency (17). For each driving cycle test, this number is equal to the ratio of Discharge KWH, corrected (5) to the sum of Recharge KWH, corrected (11) and regenerative braking Recharge KWH, Corrected (21).
- 7.2.19 Forward Controller Efficiency (18a). See Paragraph 7.1.21
- 7.2.20 Reverse Controller Efficiency (18b)

For each driving cycle test, this number is equal to the ratio of regenerative braking Recharge KWH, corrected (21) and KWH from motor, corrected.

- 7.2.21 Regenerative Braking Recharge Amp-Hours (19)

This number was taken directly from the charge portion of the current integrator at the end of each test with regenerative braking. No corrections were applied.

- 7.2.22 Regenerative Braking Recharge KWH (20)

For each test with regenerative braking, this number was taken directly from the recharge portion of the energy counter. Values listed are counter increments multiplied by 0.01333.

- 7.2.23 Regenerative Braking Recharge KWH, corrected (21)

Insufficient data was obtained to enable meaningful corrections. Data listed in Table 4.6.2 indicates that corrections will likely be small (at 40 amps recharge, the correction factor is $1.321/1.333 = 0.991$)

- 7.2.24 Kinetic Energy prior to braking (KWH) (22)

This number is the total kinetic at the end of the coasting phase; rotating kinetic energy associated with the power train has been neglected. In each case, $KE = 1/2 MV^2N$ where M is the vehicle mass corresponding to 3288 lb, V is taken as 18.0 mph for the B cycles and 25.5 mph for the C cycles, and N is the number of cycles driven. Conversion factors used: 1 slug = 32.16 lb, 1 mph = 1.4666 ft/sec, 1 KWH = 2.654×10^6 ft-lb.

7.2.25 Tire KWH (23)

Using Coast-Down Equation 7.4.9, the tire component of power dissipated may be assumed as $P_T = 0.115V$, where P_T is in horsepower and V is in mph. (It should be noted that this number is expected to be high since it includes such things as bearing friction and transmission spin losses).

The above equation is integrated over time to give $E_T = 0.11R$ where E_T is energy in horsepower-hours and R is distance traveled in miles. Converting E_T to KWH, $E_T = 0.0858R$.

7.2.26 Aerodynamic KWH (24)

Using Coast-Down Equation 7.4.9, the aerodynamic component of road-load is taken as $P_A = 7.51 \times 10^{-5} V^3$, where P_A is in horsepower and V is in mph. Using $V(t)$ as defined in Fig. 6.2.1 for the B and C Cycles, the aerodynamic energy is found by integration over time. Using the conversion constants listed in Section 7.2.25, the energy per B Cycle is 0.003495 KWH and the energy per C Cycle is 0.013252 KWH. The numbers listed in the table are found by multiplying the appropriate energy per cycle times the number of cycles driven.

7.2.27 Road Load KW (25)

For each test, this number is the sum of Tire KWH (23) and Aerodynamic KWH (24).

7.2.28 Forward Propulsion Efficiency (26)

This quantity is defined and computed as

$$\frac{\text{Road Load (25)} + \text{Kinetic Energy (22)}}{\text{Discharge Energy (5)}}$$

The intent of this number is to express the propulsion system efficiency with respect to forward energy flow. Besides the errors which result from neglecting rotating inertia, an added error results in that a small portion of the Road Load (25) is provided from stored Kinetic Energy (22) during the braking interval (i.e., a small amount of energy is counted twice).

7.2.29 Reverse Propulsion Efficiency (27)

This quantity is defined and computed as

$$\frac{\text{Recharge Energy (21)}}{\text{Kinetic Energy (22)}}$$

The intent of this number is to express the propulsion system efficiency with respect to reverse energy flow which occurs during regenerative braking. Besides the errors which result from neglecting rotating inertia, an added error results in that road load absorbs some kinetic energy during regenerative braking.

7.2.30 Net Propulsion Efficiency (28)

This quantity is defined and computed as

$$\frac{\text{Road Load (25)}}{\text{Discharge Energy (5)} - \text{Recharge Energy (21)}}$$

This number, which accounts for "Round-Robbin" Energy Efficiency may be taken as a figure of merit for the entire system. As stated, there are no mathematical errors in this equation.

Table 7.2.1. Driving Cycle, Uncorrected, Corrected, and Computed Data

Test No.	12	13	15	16	17	18	19	20	21	22P	22C	23H	23E	23L
Date of Test	3/20	3/21	3/25	3/26	3/29	3/30	4/1	4/6	4/5	4/17	4/17	4/17	4/17	4/17
Test Description ¹	C	C, Dr	B, Inc.	B, Dr, Inc.	B, Dr	C	C, Dr	B	C, Dr	C	C, Dr	C	B	B, Dr
Number of Cycles Driven	163	217	200	203	304	179	187	326	231	5	5	5	10	10
Uncorrected Distance	55.70	79.09	30.40	-	75.01	60.75	66.54	65.30	81.96	1.73	1.83	1.73	2.04	2.07
Corrected Distance ²	55.70	76.15	30.40	56.76	73.01	60.75	63.90	65.30	78.94	1.73	1.73	1.73	2.04	2.04
End of Test Batt Voltage	96.8	-	112.6	110.5	94.9	98.2	92.4	89.6	92.8	-	-	-	-	-
BATTERY RECHARGE														
Recharge Amp-Hours	153.21	196.65	101.52	144.08	142.55	163.20	177.16	170.67	202.56	4.31	4.39	4.50	4.73	4.66
Recharge ERM ⁴	HF	HF	HF	HF	HF	HF	HF	HF	24.62	0.505	0.511	0.513	0.604	0.592
Recharge ERM, Corrected ⁵	-	-	-	-	-	-	-	-	24.62	0.505	0.511	0.513	0.604	0.592
ENERGY TO MOTOR														
ERM to Motor ⁶	15.23	19.85	10.44	14.74	19.52	16.66	18.17	17.16	21.50	0.475	0.489	0.493	0.556	0.551
ERM to Motor, Corrected ⁷	15.23	19.85	10.44	14.74	19.52	16.66	18.17	17.16	21.50	0.475	0.489	0.493	0.556	0.551
BATTERY RECHARGE (Inc. Dr.)														
Recharge Amp-Hours ¹⁰	-	20.96	-	14.18	18.66	-	17.04	-	19.54	-	0.50	-	-	0.53
Recharge ERM ²⁰	-	2.50	-	2.15	2.27	-	3.16	-	-	-	0.076	-	-	0.063
Recharge ERM, Corrected ²¹	-	2.50	-	2.15	2.27	-	3.16	-	-	-	0.076	-	-	0.063
ENERGY FROM MOTOR (Inc. Dr.)														
ERM	-	4.12	-	2.95	3.81	-	3.55	-	-	-	0.083	-	-	0.069
ERM, Corrected	-	4.12	-	2.95	3.81	-	3.55	-	-	-	0.083	-	-	0.069
BATTERY RECHARGE														
Recharge Amp-Hours ⁸	163.77	175.53	138.94	135.58	184.20	174.15	158.75	172.28	-	-	-	-	-	-
Recharge Amp-Hours, Corrected ⁹	171.45	184.05	145.46	140.98	192.44	181.81	168.07	180.08	-	-	-	-	-	-
Recharge ERM ¹⁰	17.50	18.84	18.43	-	20.15	18.47	25.48	-	-	-	-	-	-	-
Recharge ERM, Corrected ¹¹	20.09	20.09	20.17	-	22.67	20.87	22.63	-	-	-	-	-	-	-
VEHICLE INPUT														
Line ERM	25.0	28.5	-	19.0	26.5	25.8	27.9	26.5	26.7	-	-	-	-	-
Recharge Time (hr)	19.2	21.1	18.8	14.4	20.6	19.2	21.3	19.5	-	-	-	-	-	-
WEATHER CONDITIONS														
Ambient Temp (°C)	18-24	-	19-21	14-19	10-23	22-24	10-18	10-22	21-29	10-31	10-31	10-31	10-32	10-32
Wind Speed (mph)	2-5	4-8	15-25	2-5	2-5	10-15	0-15	2-3	0-5	7-12	7-12	7-12	7-12	7-12
COMPUTED QUANTITIES														
Miles per Line ERM ¹²	2.23	2.60	-	2.98	2.76	2.35	2.29	2.66	2.96	-	-	-	-	-
Miles per Net A H Disch. ¹³	0.363	0.422	0.368	0.437	0.422	0.372	0.399	0.363	0.431	0.401	0.445	0.384	0.431	0.483
Charger Eff (%) ¹⁴	80.2	70.5	-	85.5	80.6	81.1	-	-	-	-	-	-	-	-
Coulombic Eff (%) ¹⁵	89.4	85.5	89.7	92.1	90.2	89.8	95.3	94.8	-	-	-	-	-	-
Voltage Eff (%) ¹⁶	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cycle Eff (%) ¹⁷	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Controller Eff Forward (%) ¹⁸	-	-	-	-	-	-	-	-	87.3	94.1	95.7	96.3	92.1	85.1
Controller Eff Reverse (%) ¹⁹	-	82.9	-	72.9	58.5	-	89.0	-	-	-	91.6	-	-	91.3
Electic Energy prior to Dr (KWH) ²²	4.58	5.84	2.88	1.79	4.88	4.82	5.04	4.37	6.22	0.135	0.135	0.135	0.134	0.134
Tire ERM ²³	4.78	6.36	1.38	4.87	6.26	5.21	5.71	5.61	6.77	0.148	0.148	0.148	0.175	0.175
Aerodynamic ERM ²⁴	2.21	2.94	0.699	0.999	1.27	2.42	2.33	1.14	3.13	0.067	0.0676	0.0676	0.0350	0.0350
Road Load ERM ²⁵	6.98	9.30	4.08	5.86	7.53	7.63	8.24	6.75	9.90	0.216	0.216	0.216	0.210	0.210
Forward Propulsion Eff. (%) ²⁶	-	-	-	-	-	-	-	-	-	69.5	68.7	67.1	57.0	58.1
Reverse Propulsion Eff. (%) ²⁷	-	44.3	-	56.7	48.6	-	92.7	-	-	-	56.3	-	-	47.0
Net Propulsion Eff (%) ²⁸	-	-	-	-	-	-	-	-	-	42.8	49.7	41.3	0.148	16.7

Notes: HF = Hardware Failure
Inc = Test not run to completion

UP
OF
QUALITY

7.3 REDUCED DATA - ACCELERATION TESTS

In this section, data from Tables 6.3.1 and 6.3.2 is corrected and plotted.

7.3.1 Fifth Wheel Errors, Corrected Speeds

Based on calibration tests run at JPL and Dynamic Science, corrections for these tests were determined to be:

$$V = 1.045 V' \quad (7.3.1)$$

Additional details are contained in Paragraph 7.4.1. Unlike the coast-down tests, no offset error was observed; accordingly, Equation 7.3.1 differs from 7.4.1.

Corrected speed data corresponding to Tables 6.3.1 and 6.3.2 is tabulated in Table 7.3.1.

7.3.2 Time Corrections

7.3.2.1 Elapsed Time. The elapsed-time numbers listed in Tables 6.3.1 and 6.3.2 are found by subtracting a constant time, T_0 , from the computer time. This constant time, which corresponds to the test start, is found by assuming linear acceleration during the interval between the test start and the second speed-time data point. Accordingly,

$$T_0 = T_1 - \frac{V_1 (T_2 - T_1)}{V_2 - V_1}$$

where,

T_1 = time of first data point

T_2 = time of second data point

V_1 = speed at first data point

V_2 = speed at second data point

7.3.2.2 Time Differences between Data Channels. The Data Logger System does not simultaneously record all 16 channels, instead channel n is recorded .2 n seconds after the computer time. Accordingly, the elapsed times listed in Tables 6.3.1, 6.3.2, and 7.3.1 are correct for

Table 7.3.1. Corrected Speeds for Acceleration Data

Test No. 24 Run No. 1		Test No. 24 Run No. 3		Test No. 31 Run No. 1		Test No. 31 Run No. 3	
Time (sec.)	Speed (mph)	Time (sec.)	Speed (mph)	Time (sec.)	Speed (mph)	Time (sec.)	Speed (mph)
0.31	1.31	1.87	5.48	0.06	0.18	2.46	6.06
3.51	12.59	5.07	14.85	3.14	9.35	5.66	13.94
6.71	19.54	8.07	21.66	6.34	18.43	8.66	21.56
9.91	25.14	11.27	26.42	9.54	22.90	11.86	26.79
12.91	29.30	14.47	31.87	12.54	27.62	15.06	31.09
16.11	33.76	17.67	34.67	15.74	32.77	18.26	34.94
19.31	37.25	20.67	38.70	18.94	34.73	21.26	39.03
22.51	41.00	23.87	42.58	22.14	38.48	24.46	41.88
25.31	44.51	27.07	44.91	24.94	42.23	27.66	44.85
				28.14	44.87		
				31.34	46.19		

Test No. 24 Run No. 2		Test No. 24 Run No. 4		Test No. 31 Run No. 2		Test No. 31 Run No. 4	
Time (sec.)	Speed (mph)	Time (sec.)	Speed (mph)	Time (sec.)	Speed (mph)	Time (sec.)	Speed (mph)
2.79	7.34	0.00	0.01	1.56	4.51	0.00	0.03
5.99	15.75	3.20	9.28	4.76	13.75	3.20	11.42
9.19	21.50	6.20	15.73	7.96	19.59	6.20	15.51
11.99	25.29	9.40	23.00	10.76	22.88	9.40	22.25
15.19	29.90	12.60	25.79	13.96	27.65	12.60	25.24
18.39	34.45	15.80	30.86	17.16	31.20	15.80	29.81
21.59	36.40	18.80	34.53	20.36	33.52	18.80	32.35
24.59	39.49	22.00	37.36	23.36	36.84	22.00	35.44
27.79	42.24	25.20	40.42	26.56	39.25	25.20	38.11
30.99	45.19	28.40	43.24	29.76	41.75	28.40	40.81
		31.20	45.54	32.96	42.95	31.20	42.69
				35.96	43.99	34.20	44.40
						37.60	45.08

only the vehicle speeds. The following time corrections are required for the other data channels:

Battery Voltage - subtract 1.4 sec. for correct time
 Battery Energy - subtract 1.2 sec. for correct time
 Motor Voltage - subtract 1.0 sec. for correct time
 Battery Current - subtract 0.6 sec. for correct time
 Motor Current - subtract 0.2 sec. for correct time
 Motor Energy - add 0.6 sec. for correct time

These corrections were used throughout in the plotting of data shown in Figures 7.3.1 through 7.3.10.

7.3.3 Data Plots

Figure 7.3.1 is a plot of Speed vs Time for Test No. 24 data (EV-106 Batteries and RCA 2N6251 Transistors).

Figure 7.3.2 is a plot of Speed vs Time for Test No. 31 data (LEV-115 Batteries and Solitron SDT-12302 Transistors).

Figure 7.3.3 is a plot of Acceleration vs Speed for Test No. 24 data. Acceleration values were obtained by "differentiating" graph of Figure 7.3.1.

Figure 7.3.4 is a plot of Acceleration vs Speed for Test No. 31 data. Acceleration were values obtained as above.

Figure 7.3.5 is a plot of Battery Voltage and Battery Current vs Time for Test No. 24 data.

Figure 7.3.6 is a plot of Battery Voltage and Battery Current vs Time for Test No. 31 data.

Figure 7.3.7 is a plot of Motor Voltage and Motor Current vs Time for Test No. 24 data.

Figure 7.3.8 is a plot of Motor Voltage and Motor Current vs Time for Test No. 31 data.

Figure 7.3.9 is a plot of Battery Discharge Energy vs Time for Test No. 24 data.

Figure 7.3.10 is a plot of Battery Discharge Energy and Energy to Motor vs Time for Test No. 31 data.

7.3.4 Acceleration Times

7.3.4.1 Test No. 24 Data (EV-106 Batteries, 2N6251 Transistors).
From Figure 7.3.1, the following acceleration times are determined:

0-10 mph	3.4 sec.
0-20 mph	8.2 sec.
0-30 mph	14.5 sec.
0-40 mph	22.6 sec.
0-45 mph	28.3 sec.

7.3.4.2 Test No. 31 Data (LEV-115 Batteries, SDT-12302 Transistors).
From Figure 7.3.2, the following acceleration times are determined:

0-10 mph	3.3 sec.
0-20 mph	8.4 sec.
0-30 mph	15.2 sec.
0-40 mph	24.8 sec.
0-45 mph	31.4 sec.

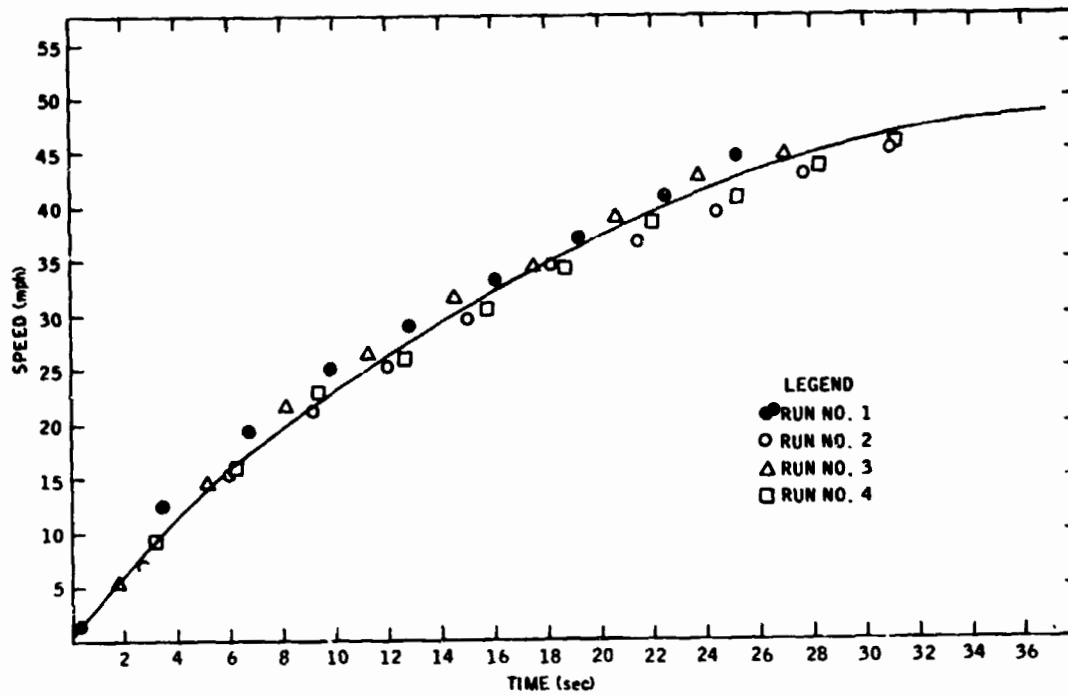


Figure 7.3.1. Plot of Speed vs Time for Test No. 24 Data
(EV-106 Batteries, 2N6251 Transistors)

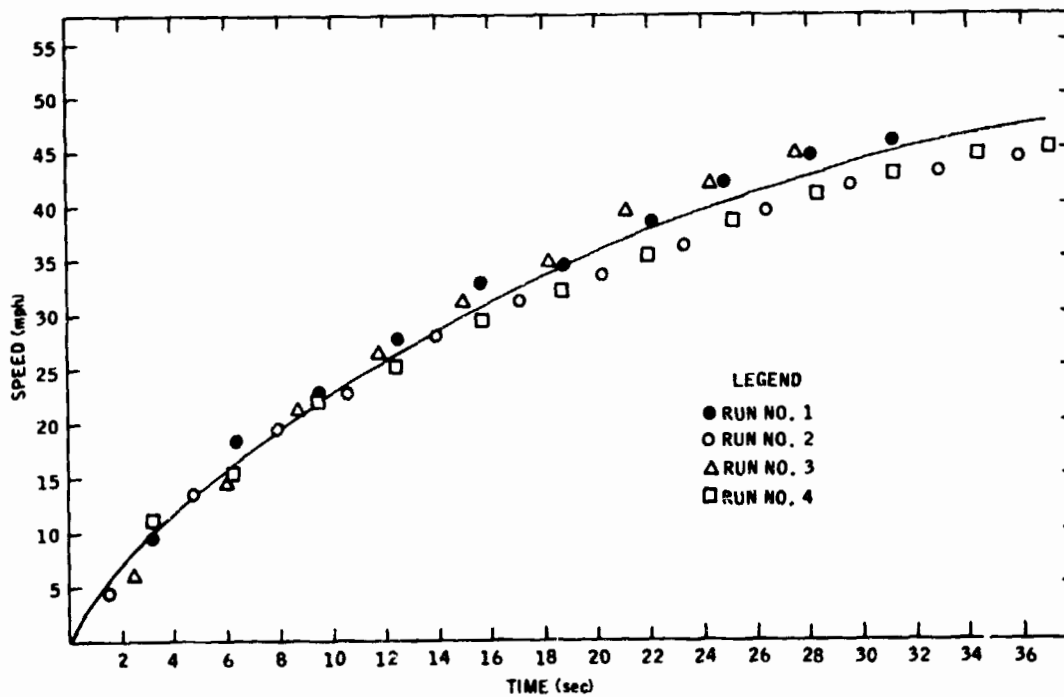


Figure 7.3.2. Plot of Speed vs Time for Test No. 31 Data
(LEV-115 Batteries, SDT012302 Transistors)

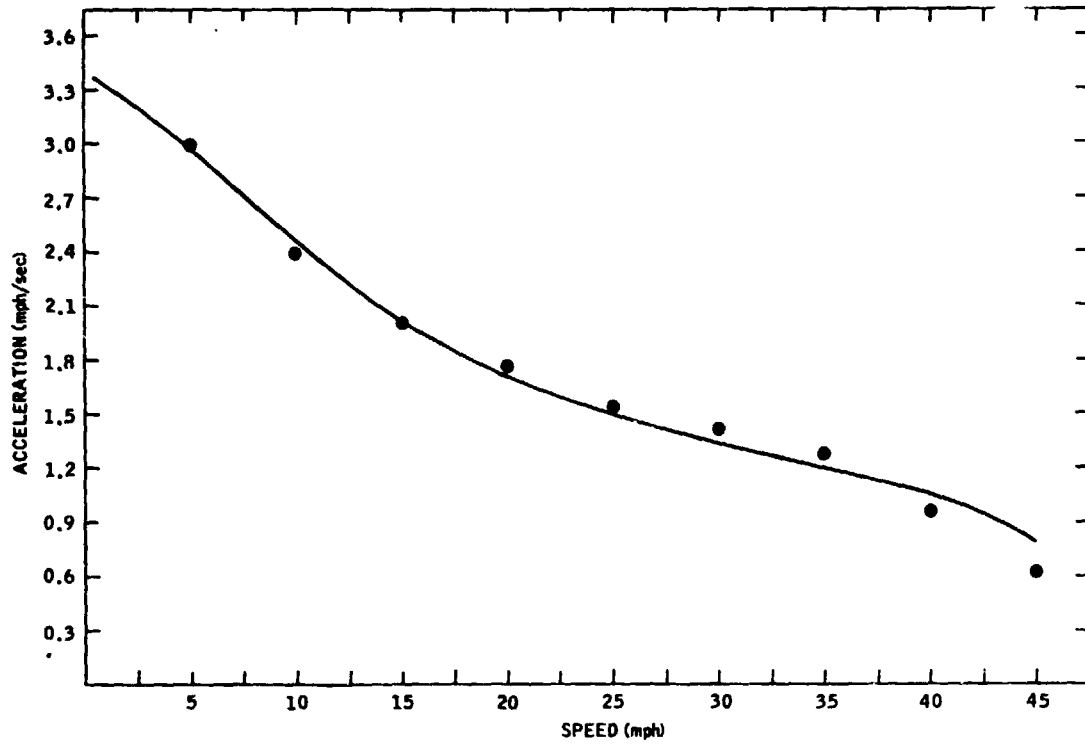


Figure 7.3.3. Plot of Acceleration vs Speed for Test No. 24 Data

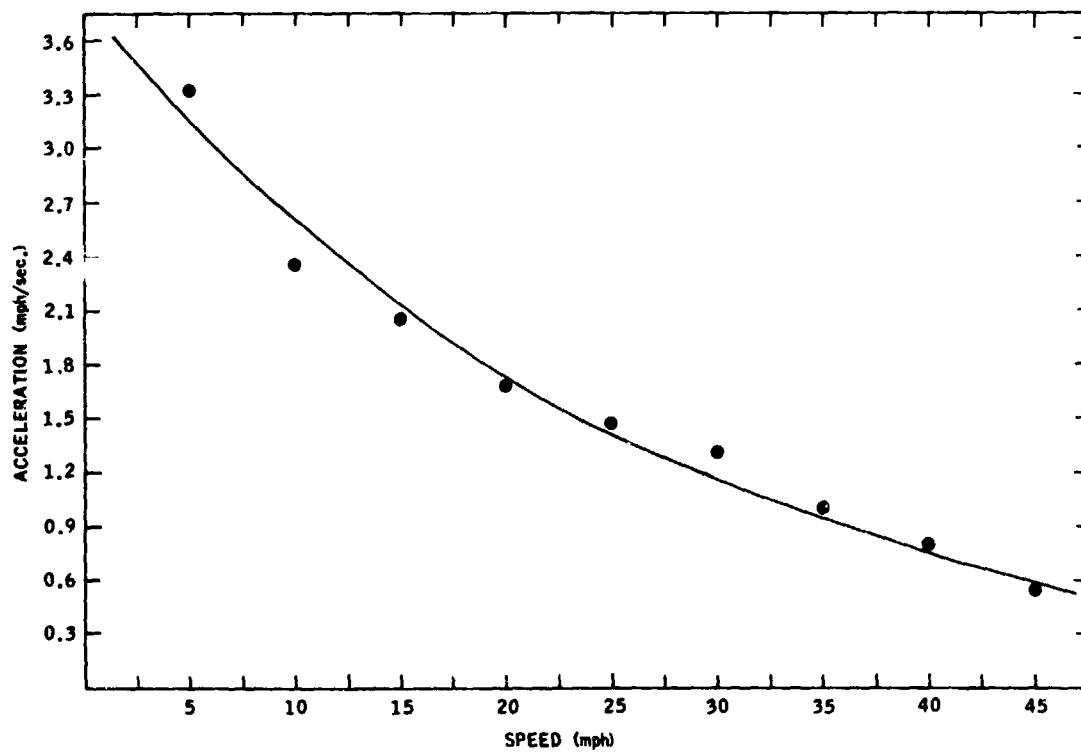


Figure 7.3.4. Plot of Acceleration vs Speed for Test No. 31 Data

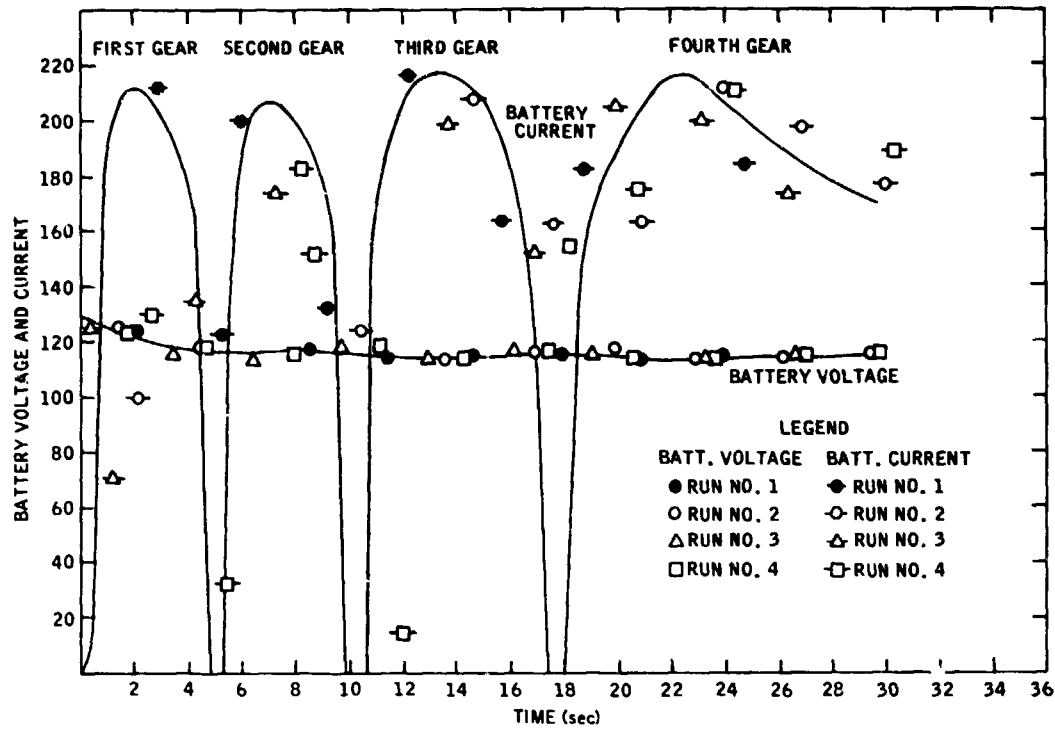


Figure 7.3.5. Plot of Battery Voltage and Current vs Time for Test No. 24 Data

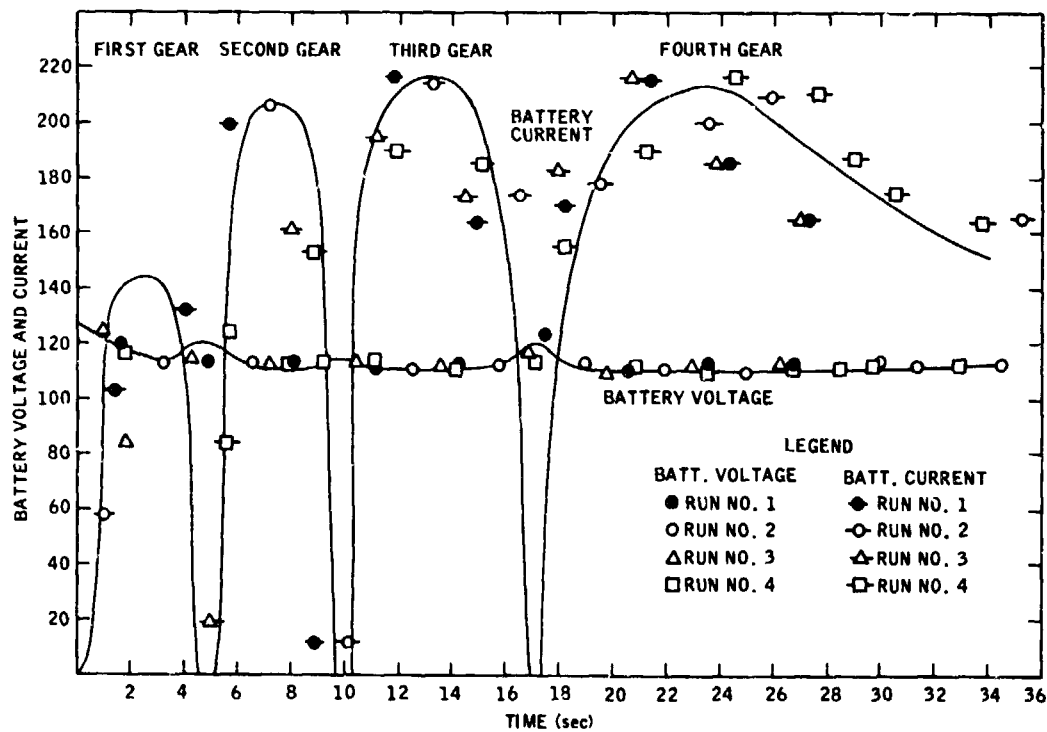


Figure 7.3.6. Plot of Battery Voltage and Current vs Time for Test No. 31 Data

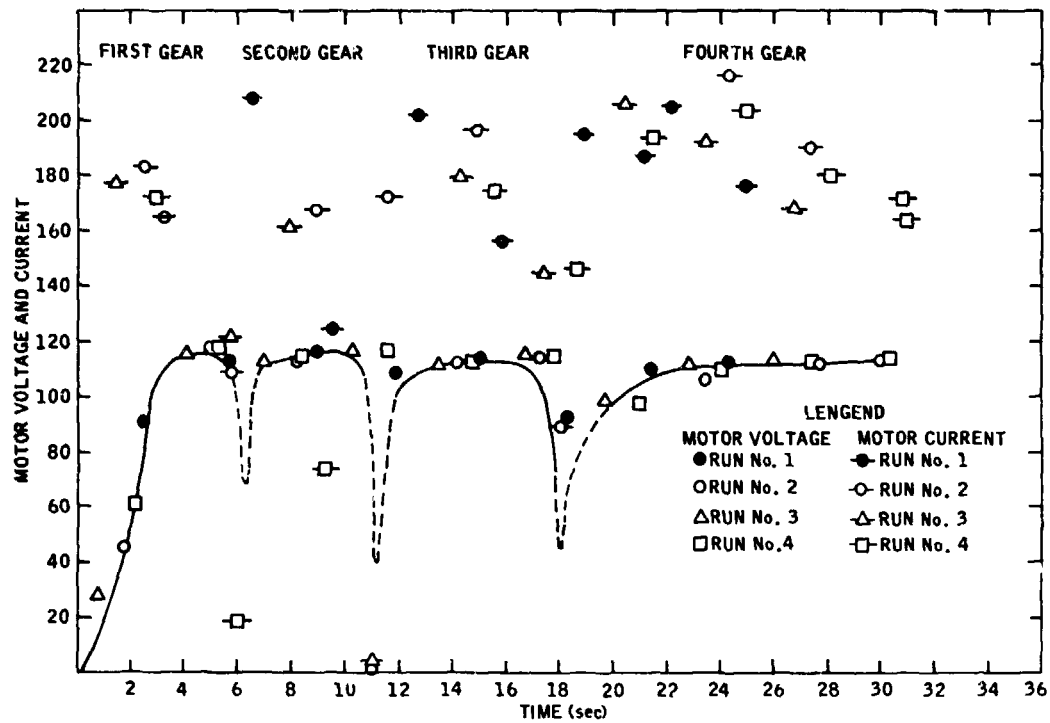


Figure 7.3.7. Plot of Motor Voltage and Current vs Time for Test No. 24 Data

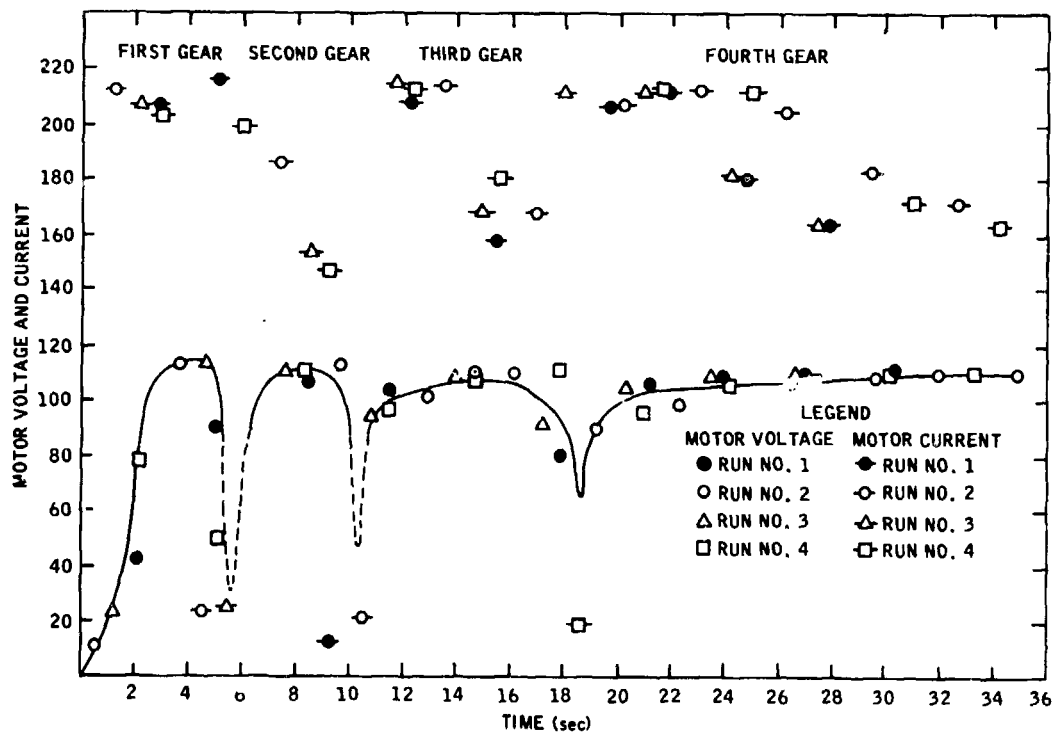


Figure 7.3.8. Plot of Motor Voltage and Current vs Time for Test No. 31 Data

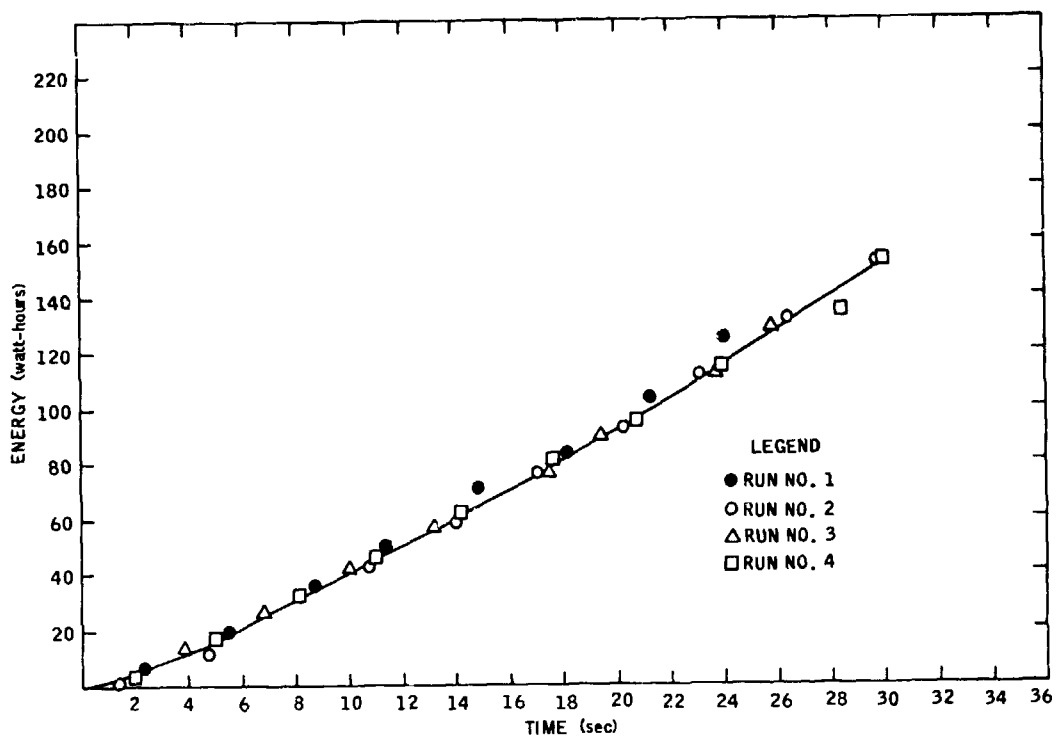


Figure 7.3.9. Plot of Battery Discharge Energy vs Time for Test No. 24 Data

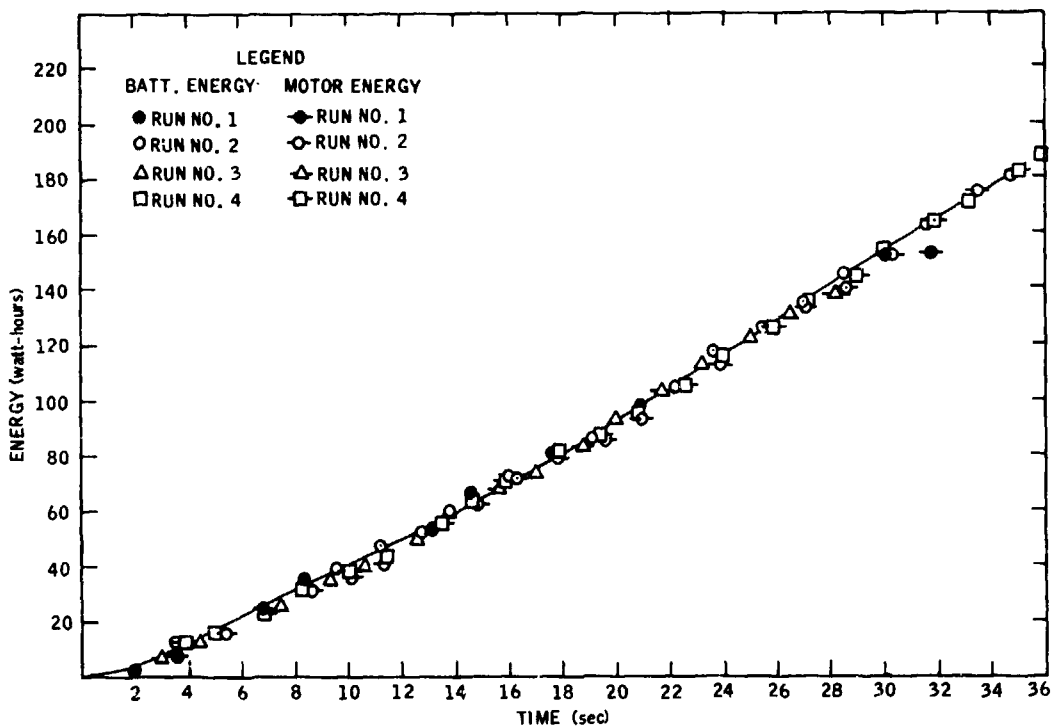


Figure 7.3.10. Plot of Battery Discharge and Motor Energy vs Time for Test No. 31 Data

7.4 REDUCED DATA - COAST-DOWN TESTS

In this paragraph, speed-time data listed in Tables 6.4.1 and 6.4.2 will be converted into road load-speed information. In order to accomplish this, corrections need be made for Fifth Wheel errors and local track slope.

7.4.1 Fifth Wheel Errors

Calibration tests run at JPL (Dec. 16, 1976) on the NC-5 Fifth Wheel provided a calibration constant of $(.0823 \pm .0003)$ V/mph (eight data points ranging from 6.5 through 40 mph). (See Figure 4.6.1 for Calibration Plot.)

Calibration tests run at Dynamic Science (March 14, 1977) provided a calibration constant of .0813 V/mph (only one calibration point corresponding to 4.305 volts at 52.95 mph).

The computer program which generated the data in Table 6.4.1 used an effective constant of .0850 V/mph.

Calibration on the data system indicates a throughput error corresponding to an offset of .22 mph and an error at 50 mph of less than .4 mph.

The calibration constant obtained at Dynamic Science will be used in place of the JPL constant for three reasons:

- (1) The same calibration means were used for testing other electric vehicles at Dynamic Science.
- (2) The DS calibration method simulates road operation better than the JPL procedure.
- (3) Calibration was performed closer to the time of use. Using the .0813 V/mph calibration constant and accounting for the .2 mph offset, the following speed correction formula is obtained:

$$V = 1.045 (V' - .22) \quad (7.4.1)$$

where

V is the corrected velocity, and

V' is the uncorrected velocity

In the case of Strip Chart data, systematic errors were calibrated out and no corrections are required.

7.4.2 Generalized Road Load

If at time t_n , the corrected vehicle velocity is V_n and the vehicle elevation is h_n , and if at time t_{n+1} the corrected vehicle velocity is V_{n+1} and the vehicle elevation is h_{n+1} , then the average road load occurring between times t_n and t_{n+1} (based on energy conservation) is given by:

$$P_{av} = \frac{1/2 M (V_n^2 - V_{n+1}^2) + Mg (h_n - h_{n+1})}{t_{n+1} - t_n}$$

or

(7.4.2)

$$P_{av} = \frac{W/2g (V_n^2 - V_{n+1}^2) + W (h_n - h_{n+1})}{t_{n+1} - t_n}$$

where

M is the gross vehicle mass,

W is the corresponding weight, and

g is the gravitational acceleration.

During the time interval between t_n and t_{n+1} , the average velocity is

$$V_{av} = \frac{V_n + V_{n+1}}{2} \quad (7.4.3)$$

In the case where the decelerations at times t_n and t_{n+1} are nearly the same, P_{av} may be correlated with V_{av} without significant error. However, in those cases where high speeds are involved, caution should be exercised to avoid errors due to aerodynamically caused nonlinear decelerations.

Before Equation 7.4.2 can be used, track location at times t_n must be determined. Once track location is known, survey data from Table 6.4.3 may be applied.

If t_1 is defined as the time at which distance from the marker is zero, then the distance from the marker at time t_n is given by:

$$S_n = 1/2 \sum_{j=1}^{j=n-1} (V_j + V_{j+1}) (t_{j+1} - t_j) \quad (7.4.4)$$

Knowing the track location from Equation 7.4.4, linear interpolation may be applied to Table 6.4.3 to give corresponding elevations, h_n . h_n is found by:

$$h_n = \frac{(S_{hu} - S_h) h_{n1} + (S_h - S_{h1}) h_{nu}}{S_{nu} - S_{n1}} \quad (7.4.5)$$

where

S_{n1} is the closest distance in Table 6.4.3 below S_n ,

h_{n1} is the elevation that corresponds to S_{n1} ,

S_{nu} is the closest tabular distance above S_n , and

h_{nu} is the elevation that corresponds to S_{nu} .

In addition to the systematic errors associated with the tape recorded data - previously mentioned, two other types of errors are to be noted. Since the Data Logger was not synchronized with the track marker, there exists a timing uncertainty of up to 3.2 seconds. Secondly, small fluctuations due to either Fifth Wheel bounce or track unevenness added "noise" to the tape data. Because of these two problems, it was found that Strip Chart data yielded somewhat better results than the Data Logger data. Accordingly, Strip Chart data will be used for the following calculations.

It was also noted that the down-hill (East to West) data produced relatively poor results (i.e., the data appears very "noisy"). Accordingly, calculations are tabulated for only one East to West run (Run No. 1) all other data is from the West to East tests.

Applying Equations 7.4.2 through 7.4.5 to the data in Table 6.4.2, Distance, Elevation, Kinetic Energy, Potential Energy, and Total Energy is computed. This data is listed in Table 7.4.1 and a plot of road load vs speed is shown in Figure 7.4.1.

In Table 7.4.2, summaries are made of average speed and the corresponding road load; also listed are corresponding values of V^2 and P/V , which are used graphically to reduce road load into rolling resistance and aerodynamic components (see Section 7.4.3).

7.4.3 Road Load Resolved into Rolling Resistance and Aerodynamic Components

It is assumed that the road load may be expressed as

$$P = C_1 V + C_3 V^3 \quad (7.4.6)$$

where the first term is due to tire rolling resistance and the second term is due to aerodynamic friction. In general, a viscous term ($C_2 V^2$) should be included, but experience has shown that this term is small compared with the other two terms and its inclusion complicates the analysis.

Values of C_1 and C_3 are easily derived by plotting P/V vs V^2 . If the P - V data conforms to Eqn (7.4.6), then such a plot should be a straight line with the y intercept equal to C_1 and the slope equal to C_3 . Data from Table 7.4.2 was thusly plotted in Figures 7.4.2 through 7.4.6.

7.4.3.1 Rolling Resistance. From the plots, four values of C_1 were obtained. Noting that hp/mph has the dimensions of a force, each of the values of C_1 may be converted into pounds to give respective values of 47.3, 45.0, 42.4, and 37.5 lbs. The mean value is 43.1 lbs and the standard deviation is 1.4 lb. With a vehicle weight of 3288 lb and a rotating inertia assumed equivalent to 3% of the vehicle mass, the rolling resistance is:

$$RC = \frac{43.1 \times 1.03}{3288} = 1.350\%$$

and

$$RC \text{ standard deviation} = 0.044\%$$

7.4.3.2 Aerodynamic Resistance, $C_D A$. At 25°C and at a standard atmospheric pressure of 760 mm mercury, the aerodynamic force is given by:

$$F = 0.00246 C_D A V^2 \quad (7.4.7)$$

where F is force in pounds, $C_D A$ is in square feet, and V is in miles per hour. Multiplying Equation 7.4.7 by V and then converting $F \times V$ into horsepower, the following is obtained:

$$P = 6.56 \times 10^{-6} C_D A V^3 \quad (7.4.8)$$

Equating (7.4.8) with the graphical slope data yields $C_D A$ values of 11.8, 11.3, 10.2, and 12.4 ft^2 .

$C_D A$ expected and standard deviation values are:

$$C_D A = 11.4 \text{ ft}^2$$

and

$$C_D A \text{ standard deviation} = 0.3 \text{ ft}^2$$

7.4.3.3 Road Load Model. Averaging intercept and slope numbers derived from Figures 7.4.3 through 7.4.6, the following equation is obtained:

$$P = 0.115V + 7.51 \times 10^{-5} V^3 \quad (7.4.9)$$

where P is power in horsepower and V is speed in mph.

Expressed in metric units,

$$P' = 192V' + 0.627 V'^3 \quad (7.4.10)$$

where P' is power in watts, and V' is speed in meters per second.

Table 7.4.1. Intermediate Coast-Down Calculations

Run No. 1 (East to West)							
Elapsed Time (sec.)	Speed (mph)	Speed (fps)	Distance (ft)	Elevation (ft)	Kinetic Energy (ft-lb x 10 ³)	Potential Energy (ft-lb x 10 ³)	Total Energy (ft-lb x 10 ³)
0	50.2	73.6	0	26.15	278.3	86.0	364.3
5	48.1	70.5	360	23.42	255.3	77.0	332.4
10	45.8	67.2	705	20.78	232.0	68.3	300.3
15	43.2	63.4	1031	18.70	206.5	61.5	268.0
20	40.7	59.7	1339	16.69	183.1	54.9	238.0
25	38.7	56.8	1630	14.45	165.7	47.5	213.3
30	36.8	54.0	1907	12.17	149.8	40.0	189.8
35	35.0	51.3	2170	9.92	135.2	32.6	167.8
40	33.4	49.0	2421	8.30	123.4	27.3	150.5
45	31.8	46.7	2660	6.22	112.0	20.4	132.5
50	30.2	44.3	2888	4.87	100.8	16.0	116.8
55	28.5	41.8	3103	3.12	89.8	10.3	100.0

Run No. 2 (West to East)							
Elapsed Time (sec.)	Speed (mph)	Speed (fps)	Distance (ft)	Elevation (ft)	Kinetic Energy (ft-lb x 10 ³)	Potential Energy (ft-lb x 10 ³)	Total Energy (ft-lb x 10 ³)
0	44.9	65.9	0	2.72	223.1	8.9	232.0
5	40.9	60.0	315	5.07	185.0	16.7	201.6
10	37.0	54.3	601	7.03	151.5	23.1	174.6
15	33.6	44.3	860	8.87	124.9	29.1	154.0
20	30.0	44.0	1093	10.95	994.6	36.0	135.5
25	26.8	39.3	1301	12.42	79.3	40.8	120.2
30	23.6	34.6	1486	14.03	61.5	46.1	107.6
35	20.5	30.1	1648	15.22	46.5	50.0	96.6
40	17.6	25.8	1787	16.26	34.2	53.5	87.7
45	15.1	22.1	1907	17.33	25.1	57.0	82.1
50	12.5	18.3	2008	17.96	17.2	59.1	76.3
55	10.2	15.0	2091	18.43	11.6	60.6	72.2
60	8.0	11.7	2158	18.84	7.0	61.9	69.0
65	5.8	8.5	2209	19.21	3.7	63.2	66.9
70	3.6	5.3	2243	19.44	1.4	63.9	65.4
75	1.4	2.1	2262	19.58	0.2	64.4	64.6
79	0.0	0.0	2267	19.62	0.0	64.5	64.5

Table 7.4.1. Intermediate Coast-Down Calculations (Continuation 1)

Run No. 4 (West to East)							
Elapsed Time (sec.)	Speed (mph)	Speed (fps)	Distance (ft)	Elevation (ft)	Kinetic Energy (ft-lb x 10 ³)	Potential Energy (ft-lb x 10 ³)	Total Energy (ft-lb x 10 ³)
0	44.3	65.0	0	2.72	216.9	9.0	225.8
5	40.4	59.3	311	5.11	180.4	16.8	197.2
10	36.7	53.8	593	6.95	148.9	22.9	171.7
15	33.1	48.6	849	8.81	121.1	29.0	150.1
20	29.9	43.9	1080	10.62	98.8	3.9	133.7
25	26.7	39.2	1289	12.34	78.8	40.6	119.4
30	35.6	34.6	1472	13.91	61.5	45.7	107.3
35	20.8	30.5	1635	15.14	47.8	49.8	97.6
40	18.1	26.6	1778	16.15	36.2	53.1	89.3
45	15.6	22.9	1901	17.28	26.9	56.8	83.7
50	13.0	19.1	2006	17.95	18.7	59.0	77.7
55	10.7	15.7	2093	18.44	12.6	60.6	73.3
60	8.6	12.6	2164	18.89	8.2	62.1	70.3
65	6.4	9.4	2219	19.27	4.5	63.3	67.9
70	4.6	6.8	2259	19.49	2.3	64.1	66.4
75	2.6	3.8	2286	19.75	0.7	64.9	65.7
80	0.4	0.6	2297	19.83	0.2	65.2	65.2

Run No. 6 (West to East)							
Elapsed Time (sec.)	Speed (mph)	Speed (fps)	Distance (ft)	Elevation (ft)	Kinetic Energy (ft-lb x 10 ³)	Potential Energy (ft-lb x 10 ³)	Total Energy (ft-lb x 10 ³)
0	44.9	65.9	0	2.72	223.1	8.9	232.1
5	41.3	60.6	316	5.08	188.7	16.7	205.3
10	38.1	55.9	609	7.16	160.6	23.3	183.9
15	34.7	50.9	876	8.96	133.1	29.5	162.6
20	31.3	45.9	1118	11.07	108.2	36.4	144.6
25	28.2	41.4	1336	12.65	88.1	41.6	129.6
30	25.2	36.9	1532	14.40	69.9	47.3	117.3
35	22.5	33.0	1707	15.58	55.9	51.2	107.2
40	20.0	29.3	1862	16.92	44.1	55.6	99.7
45	17.9	26.3	2002	17.93	35.5	58.9	94.5
50	15.5	22.7	2125	18.62	26.5	61.2	87.7
55	13.3	19.5	2230	19.35	19.5	63.6	83.2
60	11.1	16.1	2319	19.99	13.3	65.7	79.0
65	9.9	13.1	2342	20.42	8.8	67.1	76.0
70	6.8	10.0	2450	20.72	5.1	68.1	73.2
75	4.7	6.9	2492	20.90	2.5	68.7	71.2
80	2.2	3.2	2517	21.00	0.5	69.0	69.6
85	0.0	0.0	2525	21.04	0.0	69.2	69.2

Table 7.4.1. Intermediate Coast-Down Calculations (Continuation 2)

Run No. 9 (West to East)							
Elapsed Time (sec.)	Speed (mph)	Speed (fps)	Distance (ft)	Elevation (ft)	Kinetic Energy (ft-lb x 10 ³)	Potential Energy (ft-lb x 10 ³)	Total Energy (ft-lb x 10 ³)
0	49.6	72.7	0	2.72	270.2	8.9	279.1
5	45.3	66.4	348	5.27	225.4	17.3	242.7
10	41.2	60.4	665	7.60	186.5	25.0	211.5
15	37.5	55.0	830	8.71	154.6	28.6	183.2
20	34.1	50.0	1042	10.83	127.8	35.6	163.4
25	30.9	45.3	1330	12.60	104.9	41.4	146.3
30	27.9	40.9	1546	14.51	85.5	47.7	133.2
35	25.2	37.0	1741	15.81	70.0	52.0	122.0
40	22.4	32.9	1916	17.42	55.3	57.3	112.6
45	20.0	29.3	2071	18.30	43.9	60.2	104.1
50	17.7	26.0	2209	19.21	34.6	63.2	97.7
55	15.4	22.6	2331	20.08	26.1	66.0	92.1
60	13.2	19.4	2536	21.10	19.2	69.4	88.6
65	11.0	16.1	2625	21.88	13.3	71.9	85.2
70	8.5	12.5	2696	22.50	8.0	74.0	82.0
75	6.3	9.2	2750	22.96	4.3	75.5	79.8
80	4.0	5.9	2788	23.26	1.8	76.5	78.3
85	1.8	2.6	2810	23.43	0.3	77.0	77.4
89.5	0.0	0.0	2816	23.49	0.0	77.2	77.2

Table 7.4.2. Coast-Down Calculations

Run No. 1 (East to West)					
Time Interval (sec.)	Average Speed (mph)	Energy Lost During Interval (ft-lb x 10 ³)	Road-Load Horsepower	P/V (hp/mph)	v ² (mph ²)
5	49.2	31.9	11.6	.235	2421
5	47.0	32.0	11.6	.247	2209
5	44.5	32.3	11.8	.265	1480
5	42.0	37.4	13.6	.324	1764
5	39.7	17.4	6.31	.159	1576
5	37.8	23.4	8.52	.225	1429
5	35.9	22.0	8.00	.223	1289
5	34.2	17.2	6.25	.183	1170
5	32.6	18.1	6.60	.202	1063
5	31.0	15.7	5.69	.184	961
5	29.4	16.8	6.11	.207	864

Run No. 2 (West to East)					
Time Interval (sec.)	Average Speed (mph)	Energy Lost During Interval (ft-lb x 10 ³)	Road-Load Horsepower	P/V (hp/mph)	v ² (mph ²)
5	42.9	30.4	11.1	.258	1840
5	39.0	27.0	9.83	.252	1521
5	35.3	20.6	7.48	.212	1246
5	31.8	18.6	6.75	.212	1011
5	28.4	15.3	5.56	.196	807
5	25.2	12.6	4.56	.181	635
5	22.1	11.0	4.02	.182	488
5	19.1	8.93	3.25	.170	365
5	16.4	5.59	2.03	.124	269
5	13.8	5.82	2.11	.153	190
5	11.4	4.10	1.49	.131	130
5	9.1	3.18	1.16	.127	83
5	6.9	2.11	0.77	.111	48
5	4.7	1.51	0.55	.117	22
5	2.5	0.75	0.28	.110	6
4	0.7	0.10	0.04	--	--

Table 7.4.2. Coast-Down Calculations (Continuation 1)

Run No. 4 (West to East)					
Time Interval (sec.)	Average Speed (mph)	Energy Lost During Interval (ft-lb x 10 ³)	Road-Load Horsepower	P/V (hp/mph)	V ² (mph ²)
5	42.4	28.7	10.4	.246	1794
5	38.6	25.4	9.25	.240	1486
5	34.9	21.7	6.03	.173	1156
5	31.5	16.4	5.95	.189	992
5	28.3	14.3	5.22	.184	801
5	25.2	12.1	4.39	.175	633
5	22.2	9.67	3.52	.158	493
5	19.5	8.29	3.01	.154	378
5	16.9	5.60	2.04	.121	284
5	14.3	6.01	2.19	.153	204
5	11.9	4.43	1.61	.136	140
5	9.7	3.00	1.09	.113	93
5	7.5	2.39	0.87	.115	56
5	5.5	1.47	0.53	.096	30
5	3.6	.74	0.27	.075	13
5	1.5	.47	0.17	.112	2

Run No. 6 (West to East)					
Time Interval (sec.)	Average Speed (mph)	Energy Lost During Interval (ft-lb x 10 ³)	Road-Load Horsepower	P/V (hp/mph)	V ² (mph ²)
5	43.1	26.7	9.70	.225	1857
5	39.7	21.5	7.31	.197	1576
5	36.4	21.3	7.75	.206	1325
5	33.0	17.9	6.52	.198	1089
5	29.8	15.0	5.45	.183	885
5	26.7	12.3	4.49	.168	713
5	23.9	10.1	3.68	.154	569
5	21.3	7.44	2.70	.127	452
5	19.0	5.25	1.91	.101	359
5	16.7	6.79	2.47	.148	279
5	14	4.54	1.65	.115	207
5	12.2	4.12	1.50	.123	146
5	10.0	3.09	1.12	.112	99
5	7.9	2.72	0.99	.126	62
5	5.8	2.01	0.73	.127	33
5	3.5	1.64	0.60	.172	12
5	1.1	0.41	0.15	.134	1

Table 7.4.2. Coast-Down Calculations (Continuation 2)

Run No. 9 (West to East)					
Time Interval (sec.)	Average Speed (mph)	Energy Lost During Interval (ft-lb x 10 ³)	Road-Load Horsepower	P/V (hp/mph)	V ² (mph ²)
5	47.4	36.4	13.2	.279	2247
5	43.3	31.2	11.4	.262	1875
5	39.4	28.3	10.3	.261	1552
5	35.8	19.8	7.20	.201	1282
5	32.5	17.1	6.22	.191	1056
5	29.4	13.1	4.76	.162	864
5	26.6	11.2	4.07	.153	708
5	23.8	9.35	3.40	.143	566
5	21.2	8.55	3.11	.147	449
5	18.9	6.34	2.31	.122	357
5	16.6	5.58	2.03	.122	276
5	14.3	3.52	1.28	.090	204
5	12.1	3.43	1.25	.103	146
5	9.8	3.22	1.17	.119	96
5	7.4	2.15	0.78	.106	55
5	5.2	1.57	0.57	.109	27
5	2.9	0.86	0.31	.108	8
4.5	0.9	0.15	0.05	--	--

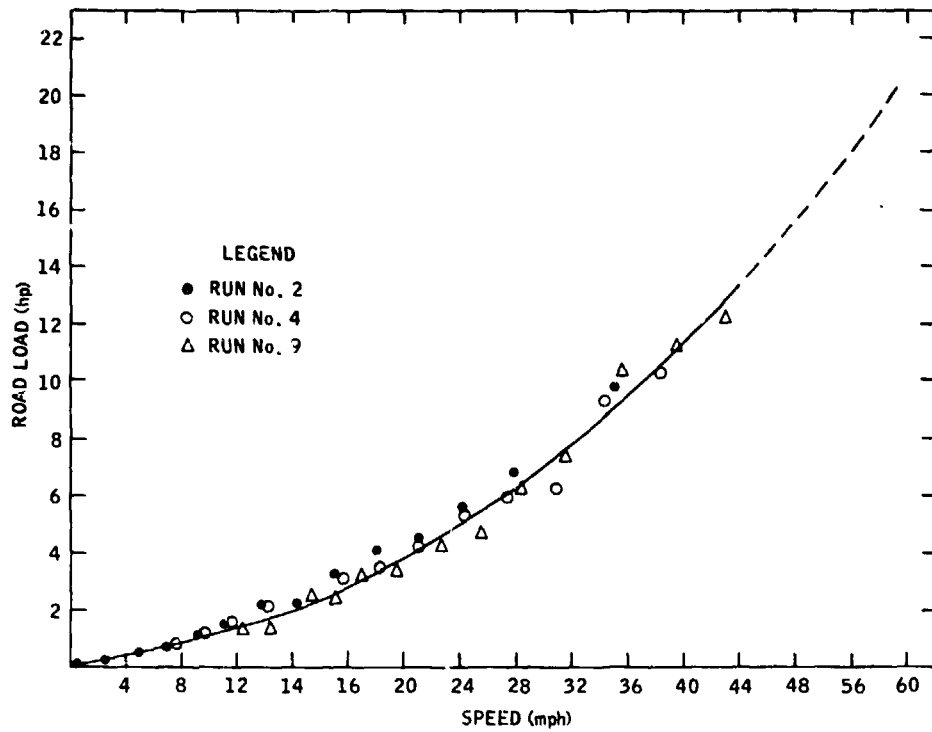


Figure 7.4.1. Plot of Road Load vs Speed; Data from Table 7.4.2

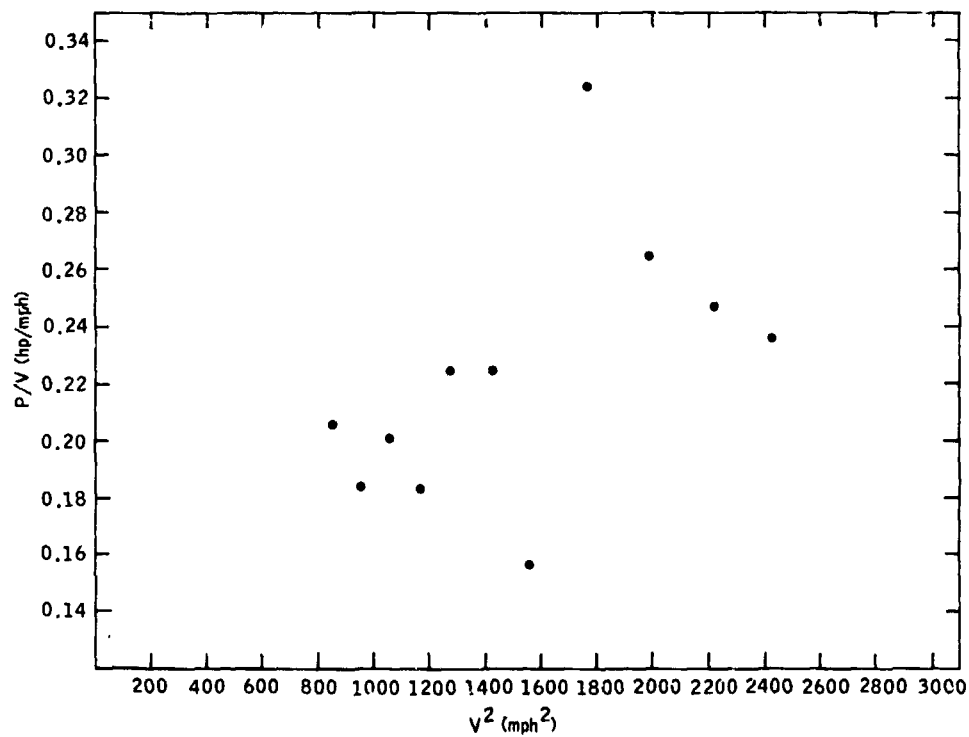
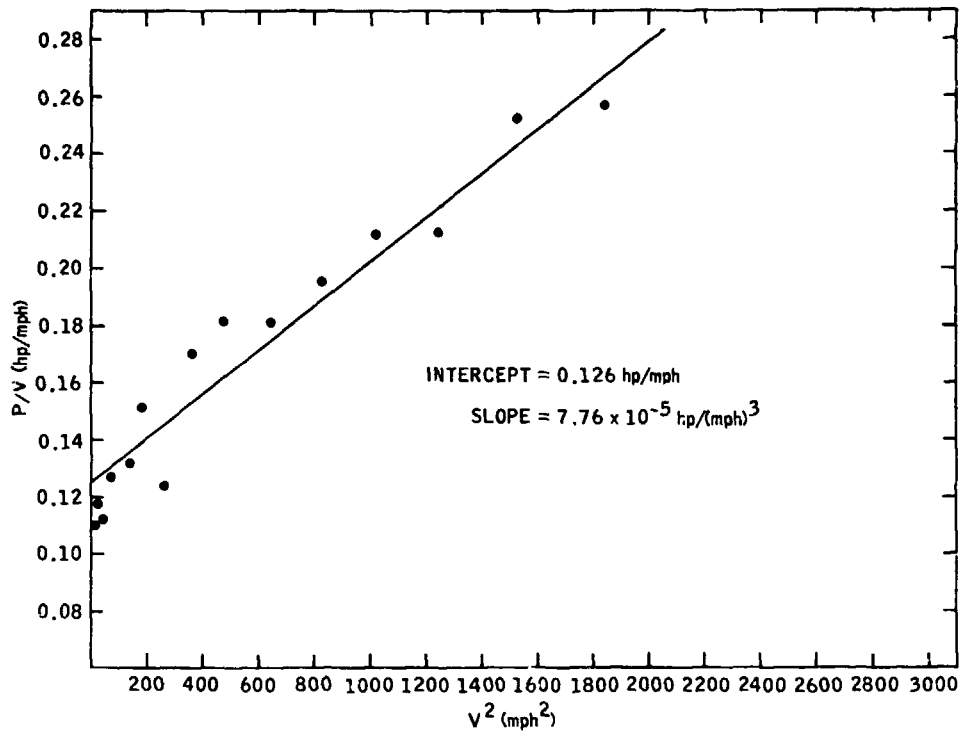
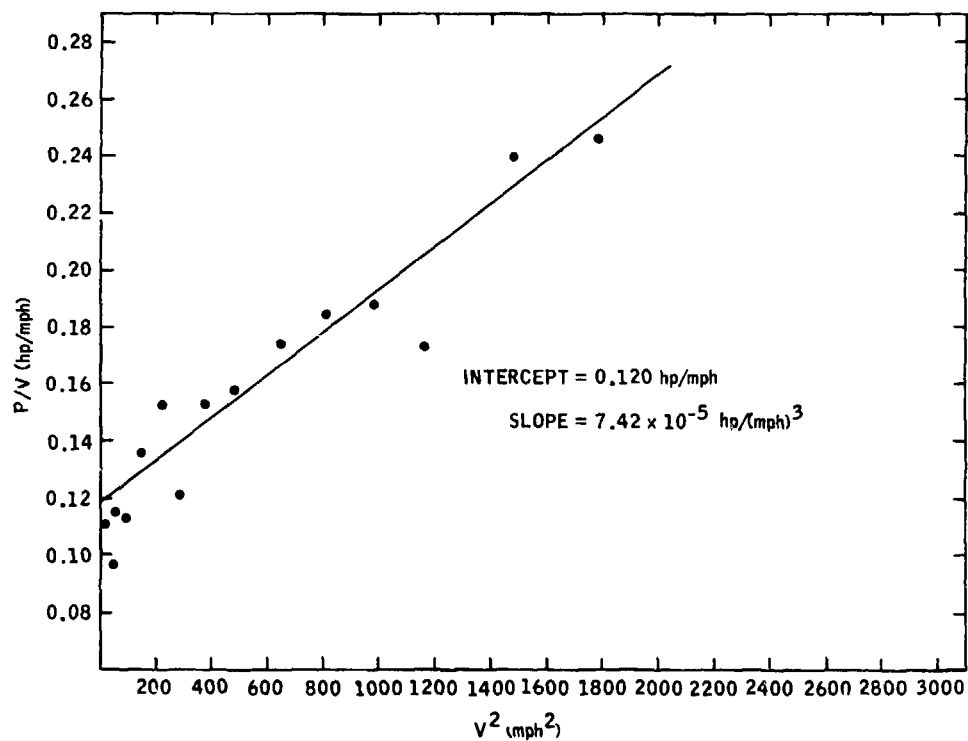
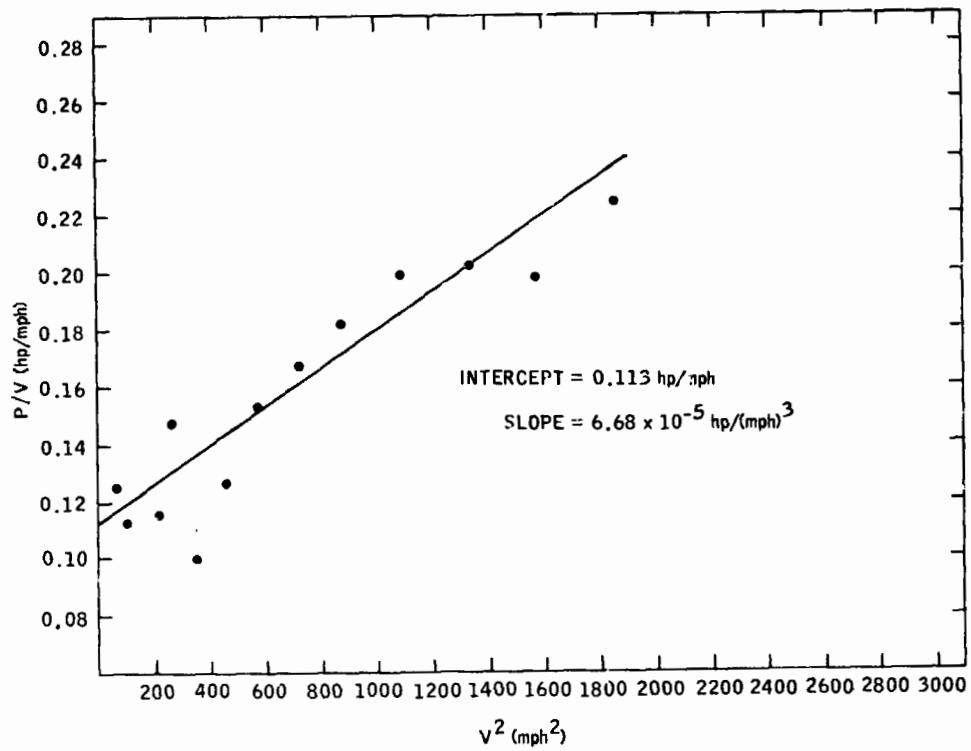
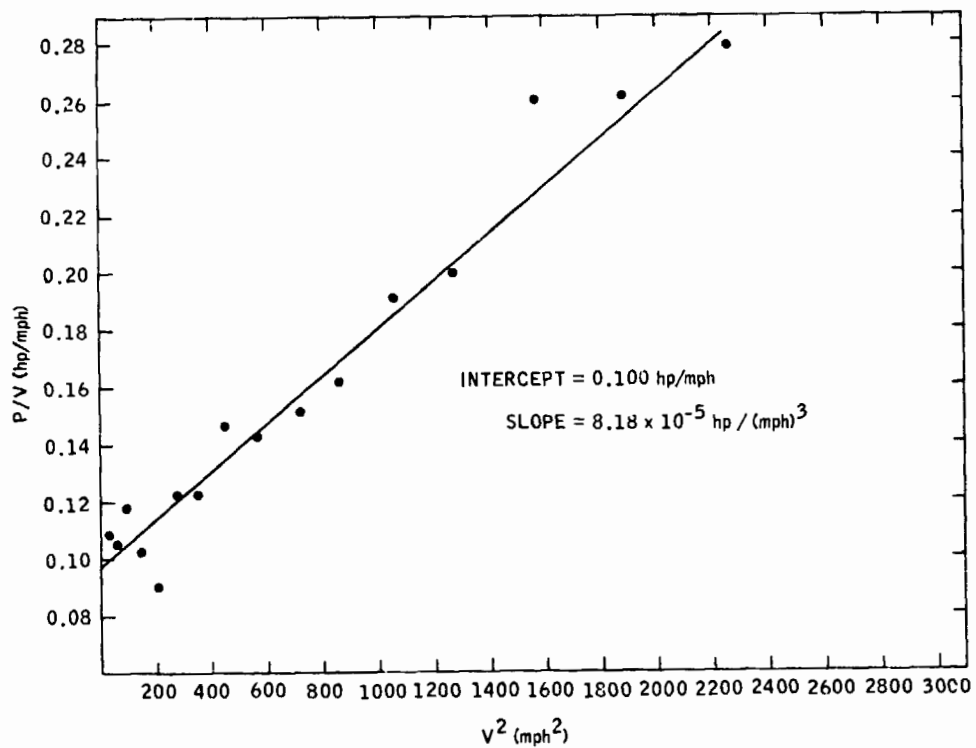


Figure 7.4.2. Plot of P/V vs V^2 for Run No. 1 Data

Figure 7.4.3. Plot of P/V vs V^2 for Run No. 2 DataFigure 7.4.4. Plot of P/V vs V^2 for Run No. 4 Data

Figure 7.4.5. Plot of P/V vs V^2 for Run No. 6 DataFigure 7.4.6. Plot of P/V vs V^2 for Run No. 9 Data

7.5 REDUCED DATA - WEIGHT SENSITIVITY TESTS

7.5.1 Instrument Errors

Systematic errors associated with both the Energy Counter and Charge Counter need not be considered here, since, to first order, these errors will cancel. However, corrections to the Energy and Charge data of Sections 6.1 and 6.2 are required if such data is used for other purposes (e.g., control system efficiency).

7.5.2.1 Corrections for Distance Variations

To account for the minor variations in distance over which energy and charge parameters were measured, these parameters will be dealt with on a "per-foot" basis. Accordingly, new variables Y will be used, where:

$$Y = \frac{X}{D} \quad (7.5.1)$$

where

X is the energy or charge associated with a given test

and

D is the distance over which X is measured

7.5.2.2 Corrections for Road Load Variations

Observing the data in Table 6.5.1, it is noted in each case that energy and charge consumptions were reduced when given tests were repeated. Comparing, for example, Run 7 with Run 1, Battery Discharge Energy is down 6.6%, Energy to Motor is down 5.5%, and Amp-Hours Discharged is down 5.6%. The apparent explanation of this effect is that tire and gear losses diminish as temperatures rise.

Since no details are known concerning road load variations with time, a linear trend will be assumed.

In Runs 1 through 12, tests were performed in the sequence: LOAD, NO LOAD, LOAD, NO LOAD. Corresponding to this sequence, energy and charge parameters are defined as Y_1 , Y_2 , Y_3 , and Y_4 . Based on the linear trend hypothesis, two values of Δy may be found - namely:

$$\begin{aligned}\Delta Y_A &= .5(Y_1 + Y_3) - Y_2 \\ \Delta Y_B &= Y_3 - .5(Y_2 + Y_4)\end{aligned}\tag{7.5.2}$$

ΔY_A and ΔY_B may be averaged to give

$$\Delta Y = .75(Y_3 - Y_2) + .25(Y_1 - Y_4)\tag{7.5.3}$$

In Runs 13 through 29, tests were performed in the sequence: LOAD, NO LOAD, NO LOAD, LOAD. In this case, the linear trend hypothesis gives the following two values for ΔY

$$\begin{aligned}\Delta Y_A &= 1/3(2Y_1 + Y_4) - Y_2 \\ \Delta Y_B &= 1/3(Y_1 + 2Y_4) - Y_3\end{aligned}\tag{7.5.4}$$

Averaging ΔY_A and ΔY_B ,

$$\Delta Y = .5(Y_1 + Y_4) - .5(Y_2 + Y_3)\tag{7.5.5}$$

7.5.2.3 Constant Speed Weight Sensitivity Formulae

Equations (5.6.1) and (7.5.1) may be combined to give:

$$S_X = \frac{\Delta Y/Y_0}{\Delta W/W_0}\tag{7.5.6}$$

where

ΔY is given by Equation 7.5.3 for Runs 1 through 12, and by Equation 7.5.5 for Runs 13 through 29,

and

Y_0 is the average of Y_1 , Y_2 , Y_3 , and Y_4 in all cases.

7.5.2.3.1 Formulas for Runs 1 through 12

Equation 7.5.6 may be expanded to give:

$$S_X = \left[\frac{3 (X_3/D_3 - X_2/D_2) + (X_1/D_1 - X_4/D_4)}{X_1/D_1 + X_2/D_2 + X_3/D_3 + X_4/D_4} \right] \frac{W_0}{\Delta W} \quad (7.5.7)$$

7.5.2.3.2 Formula for Runs 13 through 24

Equation 7.5.6 may similarly be expanded to give

$$S_X = \left[\frac{2 (X_1/D_1 - X_2/D_2) + 2 (X_4/D_4 - X_3/D_3)}{X_1/D_1 + X_2/D_2 + X_3/D_3 + X_4/D_4} \right] \frac{W_0}{\Delta W} \quad (7.5.8)$$

7.5.2.4 Computed Weight Sensitivity Parameters

Applying Equation 7.5.7 to Data in Table 6.5.1, Runs 1 through 12, values for the parameters listed in Table 5.6.1 are determined (see Table 7.5.1). Similarly, Table 7.5.2 is generated from the Run 13 through 29 data.

Table 7.5.1. Constant Speed Weight Sensitivity Measurements

(Runs 1 through 12)

	25 mph	35 mph	45 mph	Top Speed
Batt. Energy	$S_{BE\ 25} = .438$	$S_{BE\ 35} = .407$	$S_{BE\ 45} = .391$	-
Motor Energy	$S_{ME\ 25} = .504$	$S_{ME\ 35} = .449$	$S_{ME\ 45} = .569$	-
A.H. Disch.	$S_{AH\ 25} = .402$	$S_{AH\ 35} = .398$	$S_{AH\ 45} = .412$	-

Table 7.5.2. Constant Speed Weight Sensitivity Measurements

(Runs 13 through 29)

	25 mph	35 mph	45 mph	Top Speed
Batt. Energy	$S_{BE\ 25} = .407$	$S_{BE\ 35} = .283$	$S_{BE\ 45} = .218$	$S_{BE\ top} = .205$
Motor Energy	$S_{ME\ 25} = .446$	$S_{ME\ 35} = .302$	$S_{ME\ 45} = .222$	$S_{ME\ top} = .198$
A.H. Disch.	$S_{AH\ 25} = .478$	$S_{AH\ 35} = .355$	$S_{AH\ 45} = .247$	$S_{AH\ top} = .288$

7.5.3 Driving Cycle Tests

In these tests, no corrections for Road Load variations will be used. For Runs 1 through 4 (see Table 6.2.1 for Data).

$$S_X = \frac{2 (X_2/D_2 - X_1/D_1)}{(X_2/D_1 + X_2/D_2)} \frac{W_o}{\Delta W} \quad 7.5.9$$

For Runs 5 through 8 (see Table 6.5.2 for Data),

$$S_X = \frac{2 (X_2/D_2 - X_1/D_2)}{(X_1/D_1 + X_2/D_2)} \frac{W_o}{\Delta W} \quad 7.5.10$$

7.5.3.1 Computed Weight Sensitivity Parameters

Applying Equations 7.5.9 and 7.5.10 to Data in Table 6.5.2, values for the parameters listed in Table 5.6.2 are determined (see Tables 7.5.3 and 7.5.4).

Table 7.5.3. Driving Cycle Weight Sensitivity Measurements
(Runs 1 through 4: $\Delta W = 202$ lb)

	Sch. C, No Reger.	Sch C, W. Ragen.
Batt. Disch. Energy	$S_{BE \text{ cnr}} = .833$	$S_{BE \text{ cr}} = .914$
Batt. Rech. Energy	$S_{RBE \text{ cnr}} = -$	$S_{RBE \text{ cr}} = 3.50$
Energy to Motor	$S_{ME \text{ cnr}} = .737$	$S_{ME \text{ cr}} = 1.015$
Energy from motor	$S_{RHE \text{ cnr}} = -$	$S_{RME \text{ cr}} = 1.90$
A.H. Disch	$S_{AH \text{ cnr}} = .995$	$S_{AH \text{ cr}} = .837$
A.H. Rech.	$S_{RAH \text{ cnr}} = -$	$S_{RAH \text{ cr}} = 1.90$

Table 7.5.4. Driving Cycle Weight Sensitivity Measurements
(Runs 5 through 8: $\Delta W = 400$ lb)

	Sch. C, No Regen.	Sch. C, W. Regen.
Batt. Disch. Energy	$S_{BE \text{ cnr}} = .683$	$S_{BE \text{ cr}} = .768$
Batt. Rech. Energy		$S_{RBE \text{ cr}} = .71$
Energy to Motor	$S_{ME \text{ cnr}} = .707$	$S_{ME \text{ cr}} = .724$
Energy from Motor		$S_{RME \text{ cr}} = .265$
A.H. Disch.	$S_{AH \text{ cnr}} = .745$	$S_{AH \text{ cr}} = .779$
A.H. Rech.		$S_{RAH \text{ cr}} = .096$

Section 8

ENERGY FLOW MODELING

In this section, data presented in 7.1 (Reduced Data-Constant Speed Tests) and 7.2 (Reduced Data-Driving Cycle Tests) will be reassembled into energy flow models whereby the flow of energy is traced through each of the propulsion components. At the outset, it had been hoped that energy efficiencies, for each component could be determined for all points of operation (e.g., motor and controller efficiencies vs all possible speed-acceleration points). For a variety of reasons, including instrumentation deficiencies and time limitations, a less comprehensive set of data was acquired and analyzed. Instead, energy flow analyses have been carried out for constant speed and driving cycle modes of operation.

In the analyses to follow, the KWH has been used as the standard energy unit ($1 \text{ KWH} = 2.652 \times 10^6 \text{ ft-lb} = 4.825 \times 10^3 \text{ hp-sec} = 1.340 \text{ hp-hr}$). For each case to be analyzed, the energy values listed are associated with a known distance of vehicle travel. Accordingly, all of the energy numbers listed (KWH) may be converted into KWH/mi values. It should be noted that energy per distance is equal to force and that 1 KWH per mile is equal to a force of 502.3 lb. Converting KWH per mile figures to forces makes direct physical sense in the case of tire and air drag. In the case of "upstream" components, such as the charger, the physical meaning is virtually lost. None the less, such a measure, in terms of comparative system evaluations may be quite meaningful.

8.1 CONSTANT SPEED ANALYSES

All energy number were derived from Table 7.1.1. In most cases, the numbers used were averages from repeat tests. In those cases where "out-liers" were identified, the averages do not include these numbers.

8.1.1 Charger Input

For 25 mph, Test 9 data only was used since Test 2 involved considerable amounts of over-charge. All other numbers were averages from corresponding tests.

8.1.2 Charger Efficiency, Battery Input

Averages of Battery Input Energy were separately computed for 25, 35, 45 mph and max speed. Each of these numbers was compared with the corresponding average Charger Input to determine a charger efficiency (numbers ranged between 84.4% and 100%). Based on the belief that charger efficiency should be fairly constant, an average charger efficiency was determined - 91.3%. This number was then used for all subsequent analyses. (Note that lab tests on charger indicated efficiency to be about 95%). Using the 91.3% figure, "corrected" KWH values for the Battery Input were then obtained.

8.1.3 Control System Efficiency, Motor Input

All efficiency numbers were derived from calibration Tests 22A through 22E - where the instrumentation was connected to measure the total energy applied to the motor. For each speed, Motor Input Energy was found by multiplying the average Battery Discharge Energy times the above efficiency numbers.

8.1.4 Motor Efficiency, Motor Output

The motor speed was determined from the vehicle speed, gear selection, and data from Section 3.9. The average battery current was found from vehicle speed and battery discharge per mile. Using motor speed and battery current, data from Table 3.6.2 was used to find the efficiency of the motor-control combination; this number divided by the controller efficiency was used to obtain motor efficiency. Motor Output was taken as Motor Input times the Motor Efficiency.

8.1.5 Road-Load Energy, Gear Train Efficiency

Tire and Aerodynamic Energy losses were computed for each tests on the basis of Road-Load Equation 7.4.9. Using these results, it was noted that gear train efficiencies in the "high nineties" were observed. As a result, road-load numbers were lowered by 5% to 10% to yield what are believed more credible gear train efficiencies.

8.1.6 Summary of Constant Speed Energy Flow Analyses

Figures 8.1.1 through 8.1.4 summarize results for constant speed operations at 25, 35, 45 mph and max. speed, respectively.

8.2 DRIVING CYCLE ANALYSES (NO REGENERATIVE BRAKING)

All energy numbers were derived from Table 7.2.1. In most cases the numbers used were averages from repeat tests. In those cases where "out-liers" identified, the averages did not include these numbers.

8.2.1 Charger Input

Same methods used as in Section 8.1.1.

8.2.2 Charger Efficiency, Battery Input

Same methods used as in Section 8.1.2.

8.2.3 Control System Efficiency, Motor Input

Same methods used as in Section 8.1.3, except Calibration Tests 22F through 22L were used to determine controller efficiency.

8.2.4 Motor Efficiency, Motor Output

For constant speed portions of the driving cycles, the methods of Section 8.1.4 were used to obtain efficiency. Estimates of discrete, point efficiencies during acceleration corresponding to 5-mph increments were obtained as above.

The net efficiency was then found as a time-weighted average of both the constant speed and acceleration portions of B and C Driving Cycles.

8.2.5 Road-Load Energy

Road-Load Equation 7.4.9 was integrated over time for Cycles B and C to find tire and aerodynamic losses during acceleration and constant speed segments (upper arrows in Figs. 8.2.1 through 8.2.4).

During the coast and brake intervals, road load energy was derived entirely from stored kinetic energy. The integral of Equation 7.4.9 was again used to compute tire and aerodynamic losses. These losses are displayed separately since they derive from kinetic energy, and not directly from propulsion. Road load numbers were reduced from zero to 5% for the reasons mentioned in Section 8.1.5.

8.2.6 Kinetic Energy

Kinetic is $1/2 MV^2N$ where M is the gross vehicle mass, V is the cruise speed, and N is the number of cycles driven.

8.2.7 Gear Train Efficiency

The gear train efficiency was found as the ratio between the sum of Kinetic Energy and the Road Load Energy (during acceleration and cruise only) and the Motor Output.

8.2.8 Energy Dissipated on Brakes

This energy was found as the difference between road load energy from coast and brake intervals and the Kinetic Energy.

8.2.9 Summary of Driving Cycle Energy Flow Analyses

Figs. 8.2.1 and 8.2.2 summarize results for non-regenerative tests C and B respectively.

8.3 DRIVING CYCLE ANALYSES (REGENERATIVE BRAKING)

All energy numbers were derived from Table 7.2.1. In most cases, the numbers used were averages from repeat tests. In those cases where "out-liers" were identified, the averages did not include these numbers.

8.3.1 Charger Input

Same methods used as in Section 8.1.1.

8.3.2 Charger Efficiency, Battery Input

Same methods used as in Section 8.1.1 except that Battery Input includes recharge energy obtained during regenerative braking.

8.3.3 Control System Efficiency, Motor Input (forward flow)

The forward flow of energy was treated as in Section 8.2.3.

8.3.4 Control System Efficiency, Motor Return (reverse flow)

Data from Tests 22F through 22L was used to obtain controller efficiency. No data was available for motor efficiency so the assumption that reverse direction gear efficiency approximates the forward efficiency was initially used to solve for the regenerative motor efficiency. Since lower than expected motor efficiencies were found, gear efficiencies were then lowered by about 5%. This approach indicates that a good deal of uncertainty exists here.

8.3.5 Road-Load Energy

Same methods used as in Section 8.2.5. No consideration was given to increased Road Load Energy due to brake intervals longer than the specified time.

8.3.6 Kinetic Energy

Same methods used as in Section 8.2.6.

8.3.7 Energy Returned to Wheels

This energy was found as the difference between road load during coast and brake intervals and the Kinetic Energy.

8.3.8 Energy Dissipated on Brakes

During the tests, the hydraulic brakes were applied when the vehicle speed dropped to about 2 mph. The numbers computed are equal to $1/2 MV^2/N$ where V is 2 mph.

8.3.9 Summary of Driving Cycle Energy Flow Analyses

Figs. 8.2.3 and 8.2.4 summarize results for regenerative tests C and B, respectively.

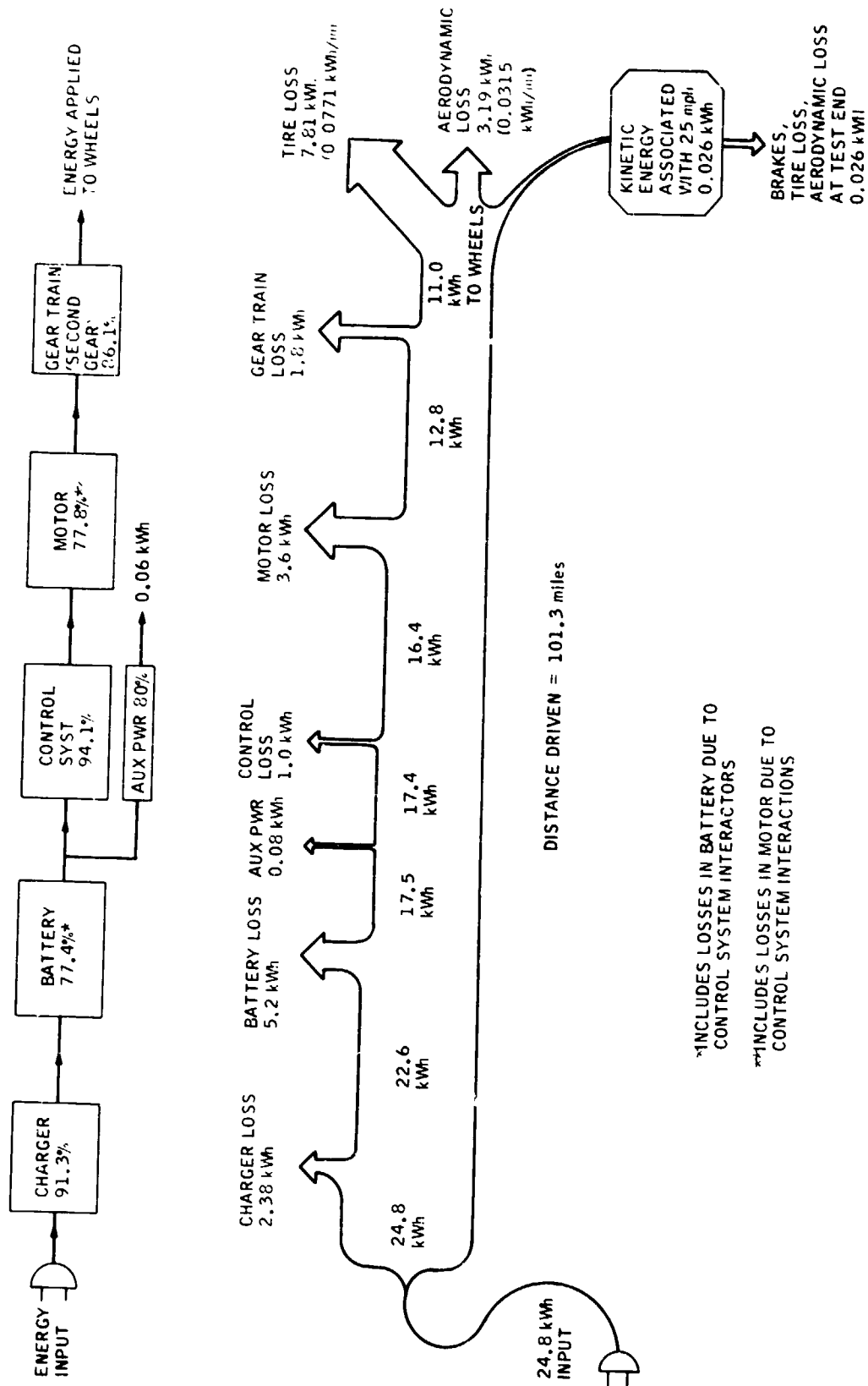


Figure 8.1.1. Energy Flow Model for Ripp-Electric Operating at Constant 25 mph. Data was Obtained from Tests 2 and 9 (Charger Efficiency is Average of Tests 2 Through 11)

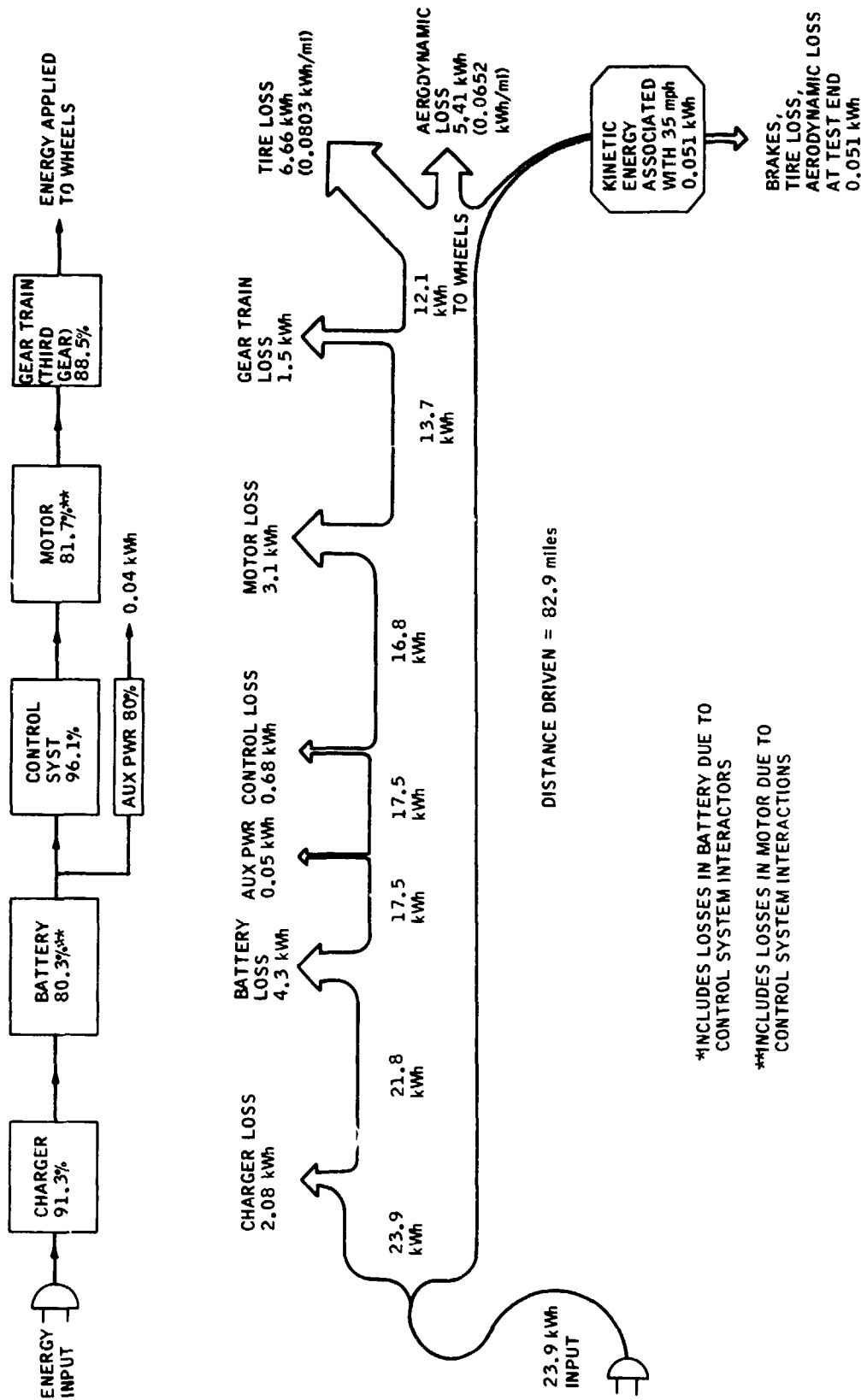


Figure 8.1.2. Energy Flow Model for Ripp-Electric Operating at Constant 35 mph. Data was Obtained from Tests 3, 6, and 10 (Charger Efficiency is Average of Tests 2 Through 11)

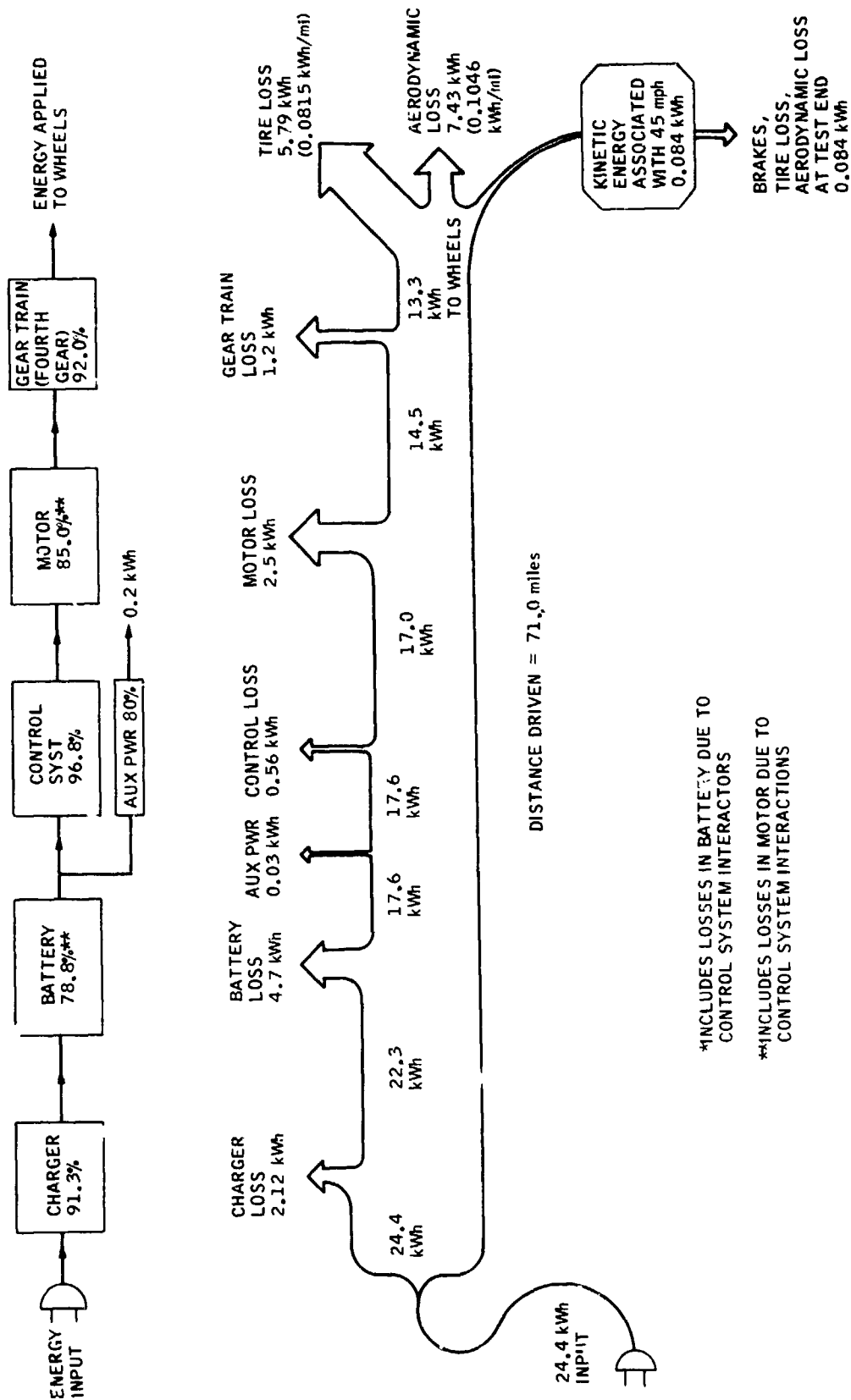


Figure 8.1.3. Energy Flow Model for Ripp-Electric Operating at Constant 45 mph. Data was Obtained from Tests 4 and 11 (Charger Efficiency is Average of Tests 2 Through 11)

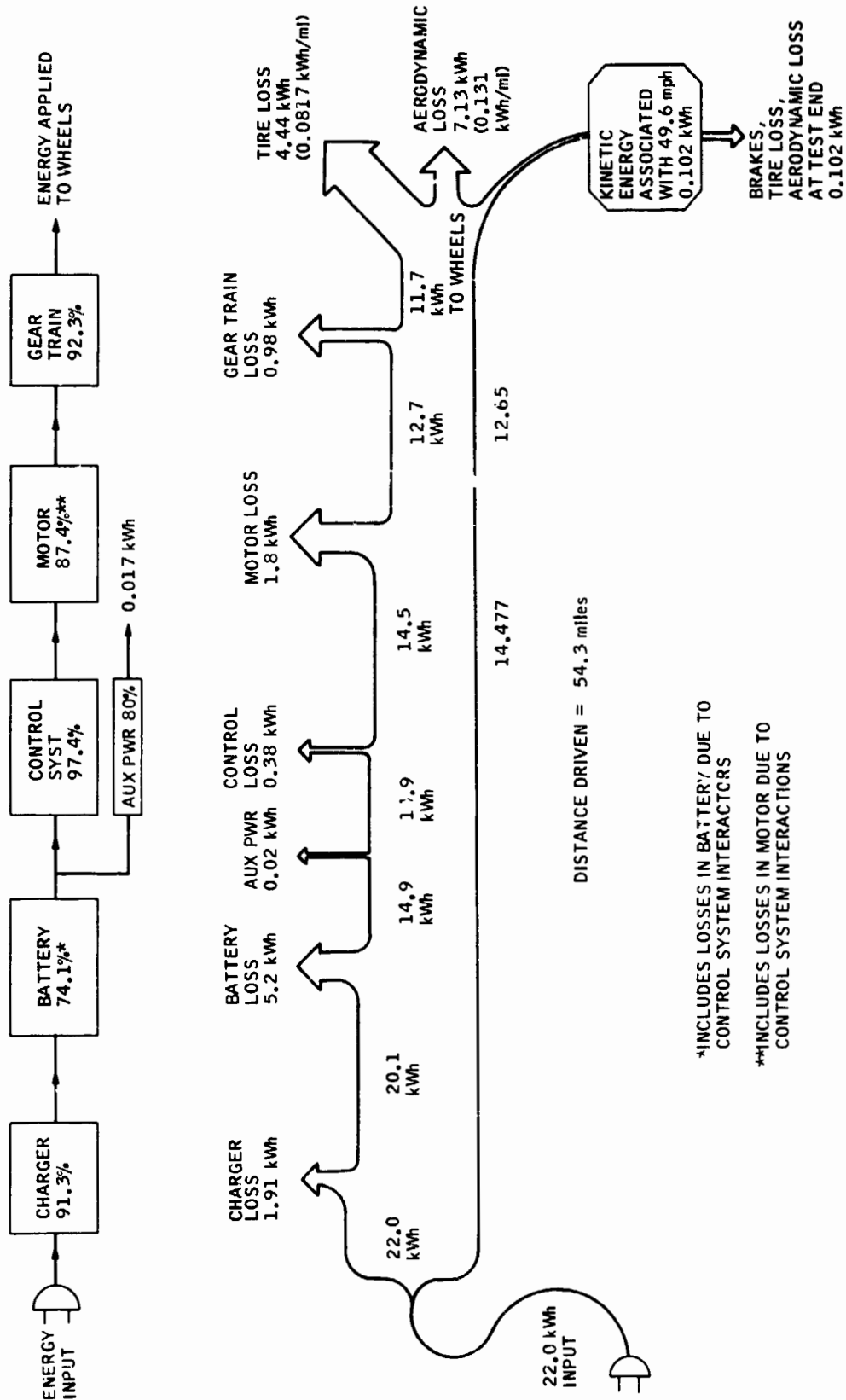
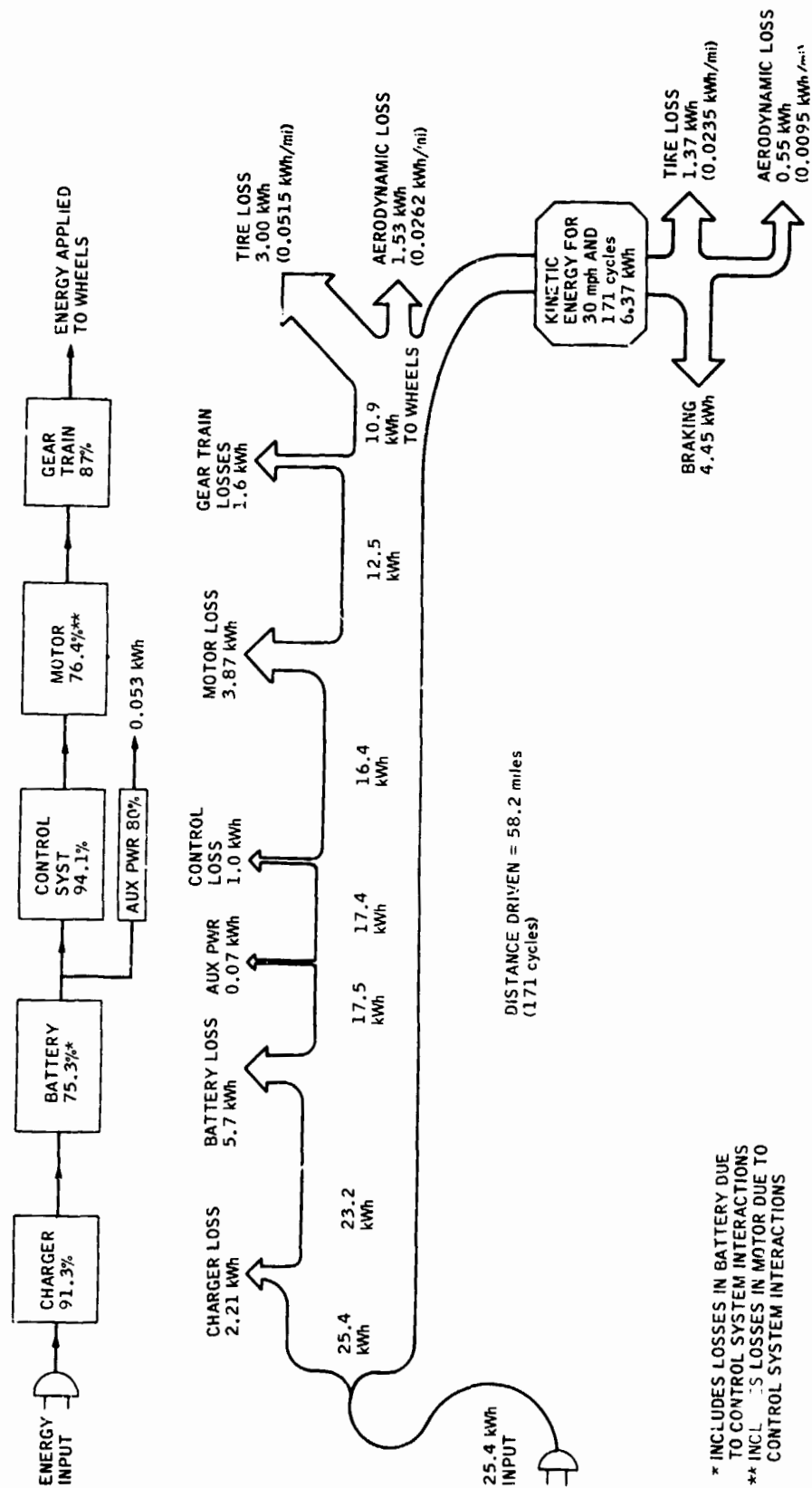


Figure 8.1.4. Energy Flow Model for Ripp-Electric Operating at Max. Speed (A_v Speed = 49.60 mph) Data was obtained from Tests 5 and 7. (Charger Efficiency is Average of Tests 2 Through 11)



* INCLUDES LOSSES IN BATTERY DUE TO CONTROL SYSTEM INTERACTIONS
 ** INCLUDES LOSSES IN MOTOR DUE TO CONTROL SYSTEM INTERACTIONS

Figure 8.2.1. Energy Flow Model for Ripp-Electric Operating under J227a, Schedule C without Regenerative Braking. Data was obtained from Tests 12 and 18

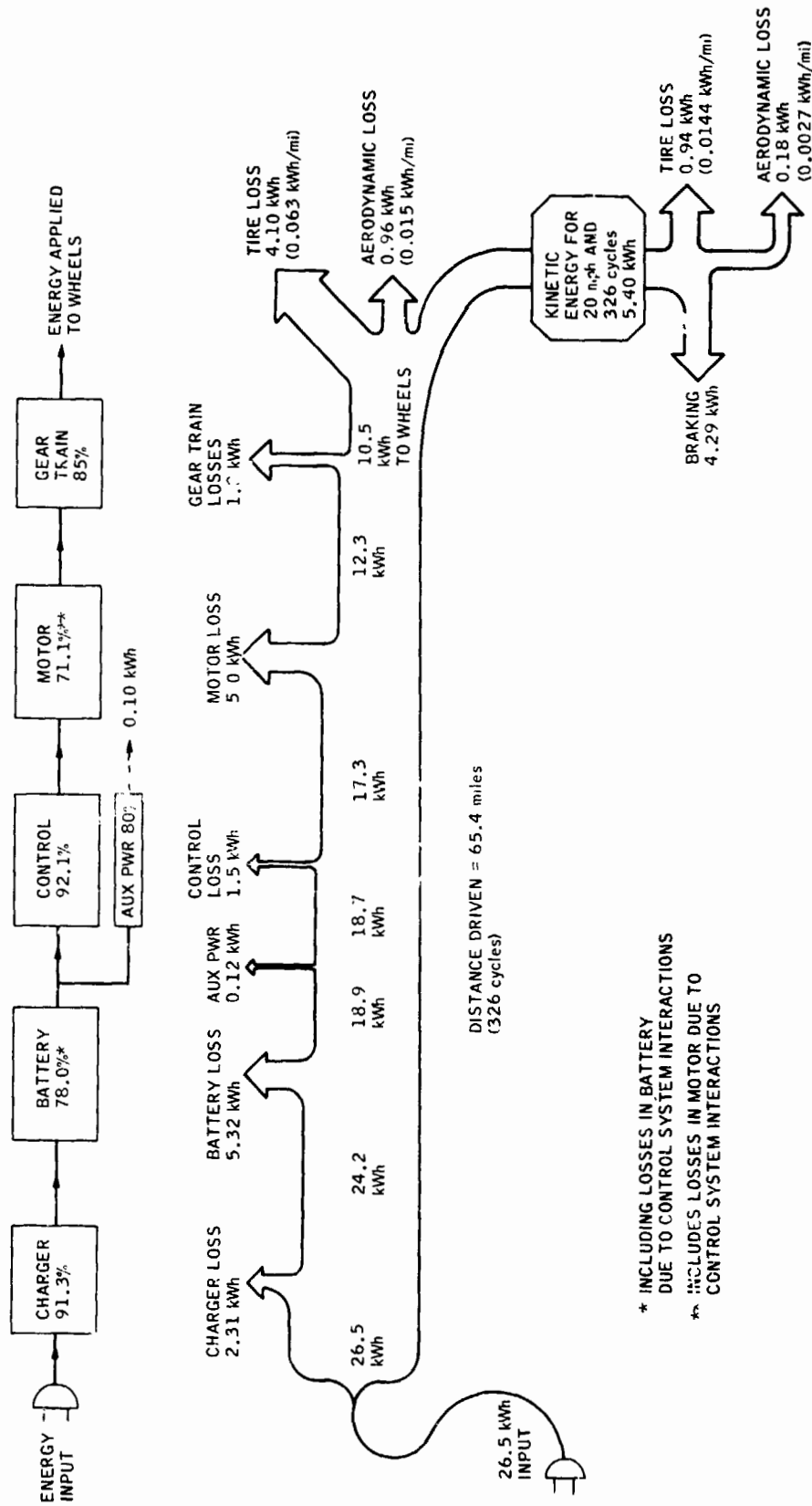
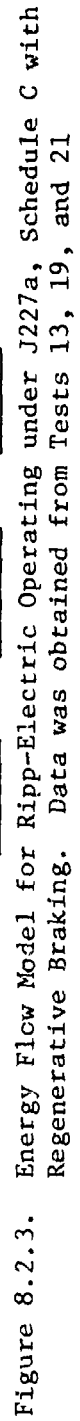


Figure 8.2.2. Energy Flow Model for Ripp-Electric Operating under J227a, Schedule B without Regenerative Braking. Data was obtained from Test 20.



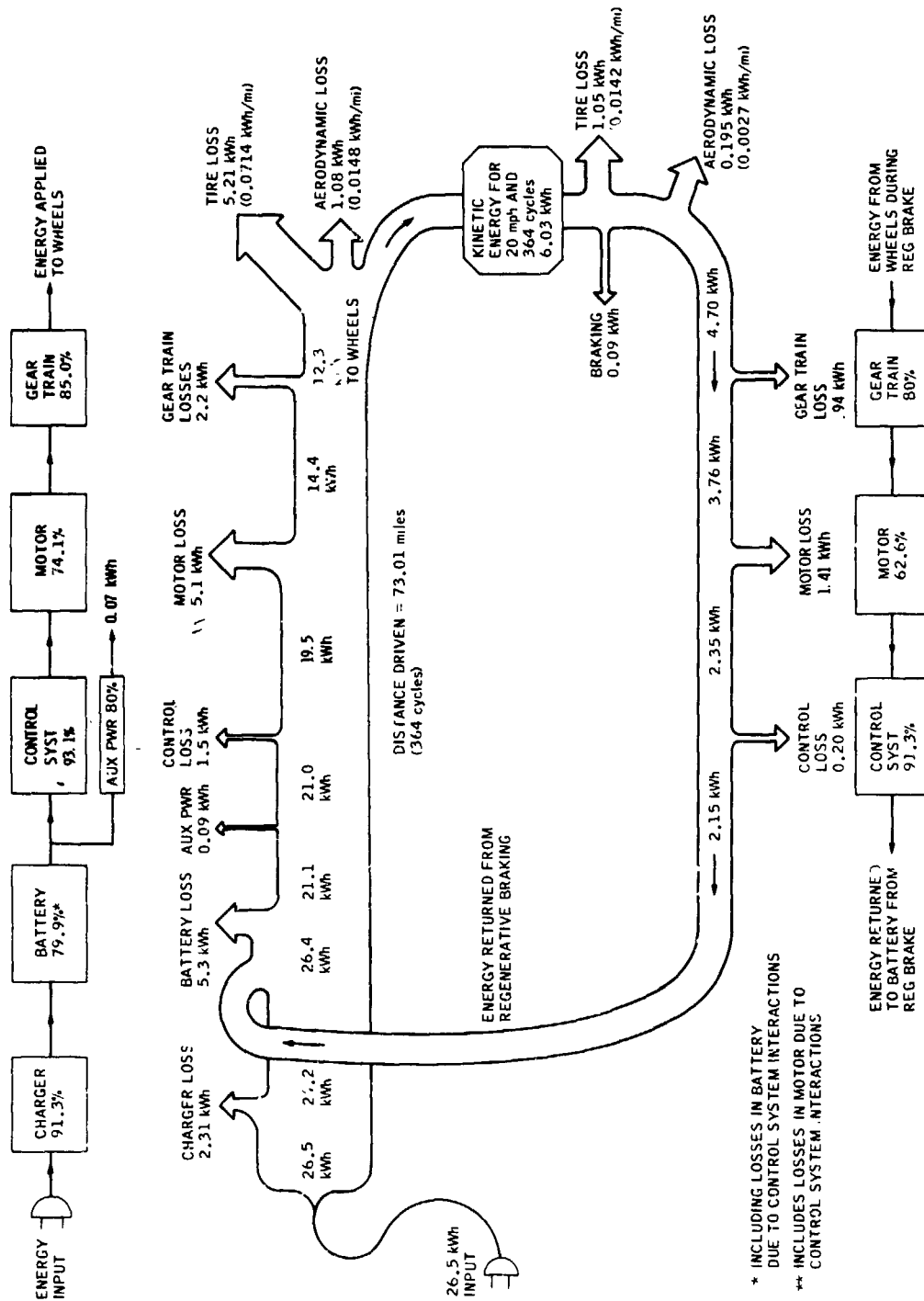


Figure 8.2.4. Energy Flow Model for Ripp-Electric Operating under J227a, Schedule B with Regenerative Braking. Data was obtained from Test 17

Section 9

OBSERVATIONS AND CONCLUSIONS

9.1 TEST PROCEDURES

For a variety of technical reasons, the recommended ERDA and JPL test methods appear lacking in effectiveness. For both the constant speed the driving cycle tests, repeats of certain tests produced range electrical measurements which varied by more than 20%. While some these variations may have been due to fluctuations within the vehicle, such as the front disc brakes, it is believed that most of the variations resulted from changing weather conditions (ambient temperature and wind). The conclusion is that improved repeatability could be obtained by either running tests in a region of more stable climate or by running tests on an indoor dynamometer.

Converting coast-down raw data into road-load parameters proved particularly troublesome. A large part of the problem was due to both the slope of the track and the unevenness of the slope. Electrical noise generated by the fifth wheel (and possibly elsewhere) also played a part in degrading this data. While brakes were periodically checked for drag, it is possible that small amounts of fluctuating brake drag added to the problems.

The following recommendations for improved road-load data are provided, based on the experience of this report:

- (1) Improved road surface. Coast-down tests should be performed on surfaces having less than a 0.1% grade (measured between any two points 25 m apart).
- (2) Improved data collection method. Ideally, distance-time data, rather than speed-time data should be acquired. This technique which has been used successfully by JPL and Detroit programs has the advantage of inherent accuracy since the location and elevation of track-mounted pressure switches (or photo sensors) may be surveyed to within fractions of a centimeter while signal time placements may be easily determined to within one part in 10^5 . Furthermore, with this type of "track-based" data system, wind sensing at various track locations may be added to enable further refinement of the processed data.
- (3) Improved "In-Vehicle Instrumentation". In the case where vehicle instrumentation is used to provide speed-time data, a major improvement could be achieved by replacing the NC-5 electro-mechanical speed sensor with an electronic tachometer system. This would

enable a large reduction in noise, enable improved linearity, and provide an easy, electronic means of calibration.

- (4) Wind Tunnel Tests. Wind tunnel testing would enable the most comprehensive and accurate results. Besides surmounting the problem of environmental effects, wind tunnel testing could provide data which cannot be obtained from track tests - such as the determination of drag vs yaw angle and aerodynamic lift.

9.1.1 Chassis Dynamometer Testing

As indicated, varying environmental conditions lead to varying test results. For this reason, it is strongly recommended that the bulk of future "long duration" tests, such as range tests be performed on a precision chassis dynamometer, but where careful calibrations be first run on a "high grade" test track under "good" weather conditions. Once the above calibration data is obtained, accurate dynamometer testing may be carried out, "rain or shine". While this approach promises optimal accuracy, it has the added advantages of reduced cost, direct interface with data processing hardware, and improved driver safety.

9.1.2 Application of Battery Models

Through the application of an "accepted" battery model, it now appears that extensive test data could be derived without having to actually run the required tests over entire charge-discharge cycles. In particular, a few track tests could be run to determine electrical loads under various conditions of operation. This data could then be applied to a computer contained battery model whereby extensive range and energy parameters could be obtained. In a few minutes of computer time, results could be obtained which presently require months of track tests and tens of thousands of dollars.

9.1.3 Bench Tests for Sub-Components

Prior to the Phoenix Tests, it was hoped that track data could be reduced to provide models for each of the power-train sub-components. Data analysis, after running the tests, produced results which pointed up the extreme difficulty in obtaining component data this way.

An example of this situation was in determining gear-train efficiencies. Here, the option was to determine efficiencies by noting energy to motor, motor efficiency, and the corresponding road load. Inaccuracies in determining any of the above parameters, in turn resulted in a "multiplied" inaccuracy for the gear train efficiency. Because of this situation, it appears that the best method for determining sub-component efficiencies is through "isolated measurement". In the case of the charger, the battery, and the controller, isolated data can be obtained in situ. In the case of the motor, isolated

data cannot be obtained in situ since shaft torque measurements cannot be effected with the motor in the vehicle. However, even a partial bench test characterization of the motor (such as torque vs current for a series machine) would permit electrical and RPM (or speed) data to provide a full characterization of the motor, while operating in the vehicle.

In the case of the transmission and differential, in situ input and output torques cannot be measured. For that reason, the best approach in dealing with these items is to obtain all characterizing data from bench tests. Besides achieving good accuracy, this approach affords the control of boundary conditions, such as temperature control, lubricant selection, and of course, the selection of torque-speed operating points.

9.2 INSTRUMENTATION

The instrumentation used at Dynamic Science, while likely "a stride in the right direction" suffered accuracy and flexibility limitations plus some reliability problems.

In the area of accuracy limitations, the most severe problems were thermally induced off-set drifts encountered with the Hall Effect Current Sensors (in addition to current errors, this problem resulted in significant recharge Amp-Hour and Watt-Hour errors). The Hall Sensors possessed the further disadvantages of poor frequency response and high cost. All three of these problems could potentially be solved with a "frequency compensated" meter shunt followed by a low drift op-amp. While this approach suffers from an inherent lack of isolation, various schemes have been considered where digital isolation is achieved after analog processing.

The NC-5 Fifth Wheel used in the Phoenix Tests suffered three problems - no means of electrical calibration, commutator-brush noise, and slight nonlinearities. All three problems could be solved through the use of an electronic encoder type system.

Other areas of needed improvement include the capability of running complete "sensor-to-tape" field calibrations and complete field tests of all instrumentation functions. To this end, future instrumentation should include read capabilities plus a means of injecting calibration test signals into the various sensor inputs.

In the future, added focus should be given to "integrated parameters" such as charge, energy, and distance measurements, as opposed to instantaneous measures such as voltage, current, and speed. This follows in that "noise" factors are very effectively suppressed by integration. At the same time, the required data acquisition is tremendously reduced (which saves computer time and money).

Increased flexibility is extremely important. Accordingly, future systems should feature selection of which signal channels are scanned, control of scan rate priorities so that temperature data, for

example is not scanned as frequently as speed and electrical data, control of scale factors, and control of modes of "pre-processing".

Most important of all is the element of standardization. A standardized system should be developed which will be used for all future EV testing. With this accomplishment, future test procedures could be written in closed form, systematic errors could more easily be handled, tests could be run by less specialized personnel, and set-up and execution times could be reduced.

9.2 OBSERVATIONS ON THE RIPP-ELECTRIC

9.2.1 Chopper Induced Losses

Efficiency and Thermal Data indicates that significant chopper-induced losses exist under conditions of low speed and driving-cycle operation. This situation points up the need for improvement, such as might be achieved with a laminated field yoke, a filter, or by an altogether different propulsion scheme, such as the separately excited approach.

9.2.2 Regenerative Braking

Results of driving cycle tests indicate that regenerative braking leads to a range increase of more than 20% and an energy consumption that is reduced by about 15% for Schedules B, C, and D. Furthermore, recorded data indicates that, for even the Schedule D tests, the battery voltage is well below the gassing point during regenerative braking. With future, more efficient systems, the impact of regenerative braking is expected to be even greater.

9.2.3 Transformerless Charger

Complete recharge efficiencies of between 90% and 95% are achieved with the transformerless charger. Improved recharge algorithms will be desired in the future so that operator adjustments are not required.

900-850

APPENDIX I

Data Tables 3.6.1 and 3.6.2

Figures 3.6.1 through 3.6.5

Table 3.6.1. Data on Combination of Motor and Control System

(August 1974 - Trojan 217 Batteries, 2N6251 Transistors)

Control Voltage ⁽¹⁾	Battery Voltage	Battery Current	Battery Power ⁽²⁾	Motor Voltage	Motor Current	Torque (ft-lb)	RPM	HP ⁽³⁾	Eff. (%) ⁽⁴⁾
3.00	121.9	4.1	499.8	6.6	31.3	2.0	391	0.149	22.1
3.00	122.0	3.5	427.0	8.1	26.4	1.3	581	0.143	24.9
3.50	121.4	7.6	922.6	9.0	67.0	11.1	233	0.493	39.8
3.50	121.0	9.4	1137	15.1	51.6	6.7	614	0.783	51.4
3.50	120.7	10.0	1207	22.0	36.3	3.0	1330	0.760	47.0
3.50	120.7	9.4	1135	23.5	32.0	2.2	1563	0.655	43.0
3.50	120.7	9.4	1135	24.9	29.0	1.5	1754	0.501	32.9
4.00	120.9	13.0	1572	13.8	82.3	15.7	344	1.03	48.8
4.00	120.3	14.7	1768	17.4	73.8	12.9	517	1.27	53.6
4.00	120.0	17.1	2052	23.9	61.4	9.0	869	1.49	54.1
4.00	119.7	17.7	2119	31.7	48.6	5.3	1437	1.45	51.1
4.00	119.7	17.7	2118	35.6	42.4	3.8	1848	1.34	47.1
4.00	119.8	17.1	2049	40.4	34.4	2.9	2436	1.34	49.0
4.00	120.0	15.3	1836	40.2	30.7	1.8	2693	0.923	37.5

Notes:

1. Control Voltage appears at output of accelerator potentiometer.
2. Battery Power (apparent power) is product of Battery Voltage and Battery Current.
3. HP, motor shaft power, is product Torque and RPM divided by 5252.
4. Eff, motor-control efficiency, is ratio of HP to Battery Power times 746.
5. Motor and Battery voltages measured with Fluke 8100A DVM.
6. Motor and Battery Currents measured with Fluke 8100A DVM and calibrated 300A, 50 MV shunts.
7. Torque measured with Rippel-built in-line torque sensor and Fluke 8100A DVM.
8. RPM measured with optical tachometer and Monsanto 101A frequency counter.

Table 3.6.1. Data on Combination of Motor and Control System (contd)

Control Voltage	Battery Voltage	Battery Current	Battery Power	Motor Voltage	Motor Current	Torque (ft-lb)	RPM	HP→	Eff. (%)
4.50	120.8	14.7	1776	11.3	111	26.0	189	0.936	39.3
4.50	120.2	17.1	2055	15.3	102	22.8	319	1.38	50.3
4.50	119.8	20.6	2468	20.2	90.4	19.2	522	1.91	57.7
4.50	119.2	24.7	2944	26.9	78.7	15.2	821	2.38	60.2
4.50	119.0	25.9	3082	35.5	67.0	11.3	1266	2.72	65.9
4.50	118.8	28.2	3350	43.9	55.9	8.5	1793	2.90	64.6
4.50	118.6	27.6	3273	50.3	47.9	6.4	2295	2.80	63.7
4.50	118.7	27.0	3205	54.2	44.2	5.4	2640	2.72	63.2
4.50	118.9	25.8	3068	60.3	37.4	2.7	3312	1.70	41.4
5.00	121.2	18.6	2254	14.8	121	29.8	243	1.38	45.6
5.00	120.0	24.0	2880	20.1	107	25.2	445	2.13	55.3
5.00	119.3	28.2	3364	26.7	96.5	21.2	678	2.74	60.7
5.00	118.6	32.4	3843	35.0	84.2	17.0	1031	3.34	64.8
5.00	118.3	36.0	4259	44.2	75.6	13.8	1447	3.80	66.6
5.00	118.0	37.8	4460	52.0	64.5	11.6	1920	4.24	70.9
5.00	117.8	39.0	4594	58.2	61.4	10.2	2218	4.31	70.0
5.00	117.7	39.0	4590	64.1	56.5	9.1	2545	4.41	71.7
5.00	117.7	38.4	4520	71.2	52.2	8.0	2975	4.53	74.8
5.50	121.2	19.7	2388	13.6	142	37.4	168	1.20	37.4
5.50	120.0	26.4	3168	19.7	126	31.4	374	2.24	52.7
5.50	119.1	31.8	3787	25.6	114	27.6	575	3.02	59.5
5.50	118.2	37.8	4468	34.6	102	23.2	871	3.85	64.3
5.50	117.7	44.4	5226	44.8	90.4	19.2	1285	4.70	67.1

Table 3.6.1. Data on Combination of Motor and Control System (contd)

Control Voltage	Battery Voltage	Battery Current	Battery Power	Motor Voltage	Motor Current	Torque (ft-lb)	RPM	HP→	Eff. (%)
5.50	117.0	50.4	5897	60.3	78.7	15.8	1904	5.73	72.5
5.50	116.5	53.4	6221	72.9	71.9	13.7	2452	6.40	76.7
5.50	116.4	53.4	6216	82.8	65.8	12.3	2828	6.62	79.5
5.50	116.5	53.4	6221	87.1	63.9	11.4	3073	6.67	80.0
6.00	120.7	25.8	3114	16.7	143	38.6	273	2.01	48.1
6.00	119.2	33.9	4041	24.6	128	33.2	509	3.22	59.4
6.00	118.4	38.7	4582	30.6	120	30.2	694	3.99	65.0
6.00	117.6	48.6	5715	41.2	107	26.0	1046	5.18	67.6
6.00	116.5	59.3	6908	58.8	95.3	21.8	1649	6.85	73.9
6.00	115.2	69.2	7972	85.0	85.4	18.4	2544	8.92	83.4
6.00	114.6	74.3	8515	101.8	79.9	17.2	3057	10.01	87.7
6.50	114.5	33.6	3847	22.2	147	37.8	408	2.93	56.9
6.50	117.8	47.1	5548	35.8	129	31.2	814	4.84	65.0
6.50	116.9	56.0	6546	45.6	117	28.2	1109	5.95	67.9
6.50	115.9	66.6	7719	59.2	108	25.4	1532	7.41	71.6
6.50	113.5	89.0	10,102	113.0	87.3	19.4	3215	11.88	87.7
7.00	118.7	37.1	4404	22.6	156	42.4	400	3.23	54.7
7.00	118.1	46.6	5503	30.3	144	38.4	616	4.50	61.1
7.00	116.7	58.9	6874	43.0	132	34.0	974	6.30	68.4
7.00	115.6	71.9	8312	56.5	123	31.2	1351	8.03	72.0
7.00	113.7	86.6	9846	83.0	123	30.0	1853	10.59	80.2
7.00	112.3	104	11,679	111.7	103	25.2	2893	13.89	88.7

Table 3.6.1. Data on Combination of Motor and Control System (contd)

Control Voltage	Battery Voltage	Battery Current	Battery Power	Motor Voltage	Motor Current	Torque (ft-lb)	RPM	HP→	Eff. (%)
7.50	119.6	35.9	4294	19.7	172	49.2	299	2.80	48.7
7.50	118.7	43.6	5175	25.5	162	45.2	459	3.95	56.9
7.50	117.9	50.1	5907	30.7	154	42.2	602	4.83	61.1
7.50	116.1	69.5	8069	49.0	138	36.4	1094	7.58	70.1
7.50	113.7	99.6	11,324	74.4	131	34.2	1784	11.62	76.5
8.00	120.0	38.3	4596	20.6	181	53.2	307	3.11	50.5
8.00	119.0	49.5	5891	27.3	168	48.4	496	4.57	57.9
8.00	116.4	66.6	7752	41.4	154	43.0	852	6.98	67.1
8.00	114.0	80.7	9200	56.0	145	40.0	1166	8.88	72.0
8.00	109.8	144	15,811	109.1	143	39.6	2470	18.63	87.9
8.00	112.0	113	12,656	111.6	111	28.4	2804	15.16	89.4
8.00	114.0	94.8	10,807	113.6	93.4	21.0	3149	12.60	86.9
3.00	123.0	3.0	369	2.70	47.9	5.4	0	0.0	0.0
3.50	122.2	5.4	660	4.20	82.3	15.3	0	0.0	0.0
4.00	121.6	7.8	948	5.17	107	24.2	0	0.0	0.0
4.50	121.2	9.6	1164	5.80	129	32.2	0	0.0	0.0
5.00	120.6	11.4	1374	6.30	144	39.0	0	0.0	0.0
5.50	120.3	13.8	1660	6.70	158	44.6	0	0.0	0.0
6.00	120.0	15.0	1800	7.16	171	49.2	0	0.0	0.0
6.50	119.8	16.8	2013	7.56	181	53.4	0	0.0	0.0
7.00	120.5	18.6	2241	8.14	190	58.2	0	0.0	0.0
7.50	119.5	20.4	2438	8.48	200	62.0	0	0.0	0.0
8.00	119.1	21.6	2573	8.70	208	66.0	0	0.0	0.0

Table 3.6.2. Data on Combination of Motor and Control System

(April 1976 - Degraded Trojan 217 Batteries, SDT-12302
Transistors, Modified 1265 Motor with Laminated Frame)

Control Voltage ⁽¹⁾	Battery Voltage	Battery Current	Battery Power ⁽²⁾	Motor Voltage	Motor Current	Torque (ft-lb)	RPM	HP ⁽³⁾	Eff (%) ⁽⁴⁾
4.50	123.7	4.96	614	9.0	41.6	3.6	450	0.308	37.4
4.50	123.4	4.24	523	6.0	52.0	6.1	226	0.260	37.1
4.50	123.7	2.64	327	1.6	64.2	11.2	0	0	0
5.00	121.7	11.5	1400	2.9	48.2	5.1	1031	1.00	53.3
5.00	122.8	10.3	1265	15.1	61.6	8.7	574	0.947	56.1
5.00	122.3	8.00	978	9.1	76.0	12.8	257	0.626	47.7
5.50	120.0	19.8	2376	35.0	46.7	4.8	1945	1.78	55.8
5.50	120.2	19.2	2308	30.7	61.0	8.5	1223	1.97	64.0
5.50	121.2	11.5	1394	10.7	99.6	19.8	255	0.960	51.3
6.00	119.2	27.8	3314	56.4	49.4	5.4	2545	2.62	58.9
6.00	118.9	29.2	3472	48.5	59.8	8.1	1937	2.98	64.2
6.00	119.1	27.6	3287	36.6	74.2	12.2	1290	2.99	68.0
6.00	119.6	21.4	2559	21.1	98.9	19.4	614	2.27	66.1
6.00	120.5	16.5	1988	13.5	113	24.0	341	1.56	58.5

Notes:

1. Control Voltage appears at output of accelerator potentiometer.
2. Battery Power (apparent power) is product of Battery Voltage and Battery Current.
3. HP, motor shaft power, is product of Torque and RPM divided by 5252.
4. Eff, motor-control Efficiency is ratio of HP to Battery Power times 746.
5. Motor and Battery Voltages measured with Dana 5400 DVM.
6. Motor and Battery Currents measured with Dana 5400 DVM and calibrated 300A, 50 MV shunts.
7. Torque measured with Rippel-built in-line torque sensor and Dana 5400 DVM.
8. RPM measured with optical tachometer and Monsanto 101A frequency counter.

Table 3.6.2. Data on Combination of Motor and Control System (contd)

Control Voltage	Battery Voltage	Battery Current	Batter, Power	Motor Voltage	Motor Current	Torque (ft-lb)	RPM	HP	Eff. (%)
6.50	117.5	39.9	4688	66.5	63.0	8.9	2528	4.27	68.2
6.50	117.6	39.0	4586	51.2	77.6	13.2	1741	4.38	71.1
6.50	118.4	31.2	3694	31.7	100	20.1	934	3.57	72.1
6.50	119.1	27.6	3287	22.3	114	24.6	611	2.86	65.0
6.50	119.8	29.0	3474	14.6	129	23.5	347	1.95	41.9
7.00	115.9	52.4	6073	75.2	74.8	12.2	2587	6.01	73.8
7.00	116.0	50.2	5823	62.6	84.9	15.4	2029	5.95	76.2
7.00	116.4	45.4	5285	45.0	97.8	19.6	1413	5.28	74.4
7.00	118.1	31.0	3661	22.8	129	29.6	588	3.32	67.5
7.00	119.3	20.2	2410	11.7	153	37.3	226	1.61	49.7
7.00	120.0	16.2	1944	7.6	161	40.6	117	0.905	34.8
7.00	119.2	18.7	2229	9.9	157	38.4	92	0.673	22.4
7.00	118.3	25.8	3052	16.4	141	33.5	383	2.45	59.8
7.00	117.1	34.6	4052	27.3	122	27.3	735	3.82	70.3
7.00	116.5	39.8	4637	35.0	111	23.9	998	4.54	73.0
7.00	115.9	43.4	5030	42.0	102	21.3	1249	5.07	75.1
7.00	115.2	48.6	5599	53.7	90.4	17.7	1685	5.68	75.7
7.00	114.7	52.0	5964	67.0	79.9	14.4	2201	6.03	75.6
7.00	114.4	52.9	6052	78.1	72.2	12.0	2705	6.18	76.2
7.00	114.3	52.2	5966	84.4	67.6	10.5	3015	6.03	75.4
7.50	114.1	67.0	7645	94.3	77.0	12.8	3179	7.75	75.6
7.50	113.9	70.6	8041	84.6	84.4	14.9	2735	7.76	72.0
7.50	114.4	59.6	6818	62.9	98.1	19.6	1881	7.01	76.7

Table 3.6.2. Data on Combination of Motor and Control System (contd)

Control Voltage	Battery Voltage	Battery Current	Battery Power	Motor Voltage	Motor Current	Torque (ft-lb)	RPM	HP	Eff. (%)
7.50	115.3	40.3	5800	43.7	114	24.8	1238	5.85	75.2
7.50	117.1	34.8	4075	23.0	143	34.1	559	3.63	66.5
7.50	118.2	25.2	2979	13.6	160	40.3	276	2.11	53.0
7.50	118.8	21.7	2578	10.1	168	43.3	174	1.44	41.5
7.50	117.6	25.8	3034	14.0	162	40.6	284	2.20	54.0
7.50	116.8	31.0	3621	19.0	151	36.9	436	3.07	63.1
7.50	115.9	36.0	4172	24.4	141	33.7	601	3.85	69.0
7.50	115.2	41.1	4735	29.3	133	31.3	750	4.47	70.4
7.50	115.7	43.6	5045	32.9	129	29.7	863	4.88	72.2
7.50	114.0	48.3	5506	39.3	120	27.0	1075	5.53	74.9
7.50	113.0	54.2	6125	49.2	110	23.8	1395	6.33	77.1
7.50	112.1	60.2	6748	60.3	102	20.9	1765	7.03	77.6
7.50	111.6	62.4	6963	65.2	97.0	19.7	1940	7.29	78.1
7.50	110.9	65.6	7275	74.7	91.6	17.8	2275	7.71	79.1
7.50	110.3	68.0	7500	83.5	86.4	16.4	2594	8.10	80.6
7.50	109.9	69.0	7583	83.4	84.0	15.9	2700	8.17	80.5
8.00	111.6	80.4	8973	88.7	98.0	18.5	2624	9.24	76.8
8.00	112.8	67.1	7569	58.9	114	25.0	1656	7.89	77.7
8.00	114.7	47.1	5402	33.2	141	33.5	835	5.32	73.6
8.00	116.5	33.6	3914	17.9	163	41.6	390	3.09	58.8
8.00	117.7	23.6	2778	10.0	180	47.9	165	1.50	40.3
8.00	115.3	29.1	3355	13.9	172	44.9	272	2.33	51.8
8.00	113.7	38.3	4355	22.0	157	39.4	508	3.81	65.2

Table 3.6.2. Data on Combination of Motor and Control System (contd)

Control Voltage	Battery Voltage	Battery Current	Battery Power	Motor Voltage	Motor Current	Torque (ft-lb)	RPM	HP	Eff. (%)
8.00	112.8	42.0	4738	26.0	150	37.2	620	4.40	69.1
8.00	111.8	48.2	5389	32.1	143	34.5	797	5.23	72.5
8.00	110.3	57.6	6353	42.6	130	30.4	1121	6.48	76.1
8.00	109.0	63.4	6911	50.1	122	28.2	1350	7.24	78.2
8.00	107.6	71.2	7661	62.2	114	25.2	1722	8.27	80.6
8.00	106.0	78.8	8353	73.7	108	23.3	2079	9.23	82.4
8.00	104.8	82.6	8656	80.0	104	22.2	2264	9.56	82.5
8.00	103.0	89.0	9167	93.4	99.3	20.6	2637	10.35	84.3
8.00	102.0	88.3	9007	100.3	89.0	17.6	3038	10.18	84.3
8.50	116.0	28.8	3341	12.7	188	50.2	217	2.08	46.4
8.50	113.7	38.3	4355	19.9	171	44.7	424	3.61	61.8
8.50	112.0	43.7	4895	23.6	165	42.4	535	4.32	65.9
8.50	110.8	49.2	5451	28.5	157	39.9	671	5.10	69.8
8.50	109.0	57.0	6213	34.9	150	37.1	863	6.11	73.2
8.50	106.7	69.4	7405	46.5	136	33.2	1215	7.69	77.5
8.50	102.7	89.8	9222	68.0	122	28.0	1893	10.10	81.7
9.00	119.7	23.4	2801	8.6	212	58.8	98	1.10	29.2
9.00	118.6	33.2	3937	14.2	195	53.0	257	2.60	49.1
9.00	117.1	43.0	5035	21.3	180	47.9	464	4.23	62.7
9.00	116.0	49.2	5707	26.8	174	52.4	600	5.99	78.3
9.00	115.0	56.9	6544	32.8	165	42.3	775	6.25	71.3
9.00	113.3	67.8	7682	43.2	154	38.5	1061	7.77	75.5
9.00	111.1	86.4	9599	62.0	138	33.6	1585	10.15	78.9

Table 3.6.2. Data on Combination of Motor and Control System (contd)

Control Voltage	Battery Voltage	Battery Current	Battery Power	Motor Voltage	Motor Current	Torque (ft-lb)	RPM	HP	Eff. (%)
9.00	109.0	94.7	10,322	70.8	136	32.3	1840	11.31	81.7
9.00	105.7	107.6	11,373	80.0	133	31.0	2183	12.89	84.5
9.00	101.5	125.6	12,748	98.8	126	29.2	2604	14.48	84.7
9.50	100.0	126.4	12,640	98.0	126	28.7	2601	14.2	83.8
9.50	119.3	33.6	4008	12.8	210	58.2	210	2.33	43.4
9.50	118.0	39.9	4708	18.2	199	54.1	350	3.60	57.0
9.50	117.2	46.1	5403	22.7	192	51.4	470	4.60	63.5
9.50	116.3	53.6	6234	27.6	184	49.0	605	5.64	67.5
9.50	115.2	63.5	7315	35.6	173	45.1	850	7.31	74.5
9.50	114.1	72.2	8238	43.5	168	41.6	1000	7.92	71.8
9.50	112.0	92.8	10,394	60.9	152	38.4	1500	10.97	78.7
9.50	109.7	114.8	12,594	79.0	147	36.0	2000	13.71	81.2
9.50	107.0	144.0	15,408	100.1	146	35.6	2500	16.95	82.0
10.00	117.4	33.0	3874	11.5	227	64.4	160	1.96	37.8
10.00	116.3	41.7	4850	16.9	214	60.5	290	3.34	51.4
11.00	117.0	39.8	4657	15.4	242	70.5	180	2.41	38.6
11.00	111.3	89.6	9972	42.2	197	54.7	1000	10.42	78.0
13.00	98.0	212.8	20,854	94.0	212	58.0	2065	22.81	81.6
13.00	98.8	175.7	17,359	95.5	176	45.9	2247	19.64	84.4
13.00	101.8	136.6	13,906	99.3	137	32.1	2276	15.74	84.5
13.00	103.4	116.0	11,994	101.3	116	25.6	2785	13.58	84.3
13.00	105.2	91.2	9574	36.0	246	71.4	666	9.06	70.4

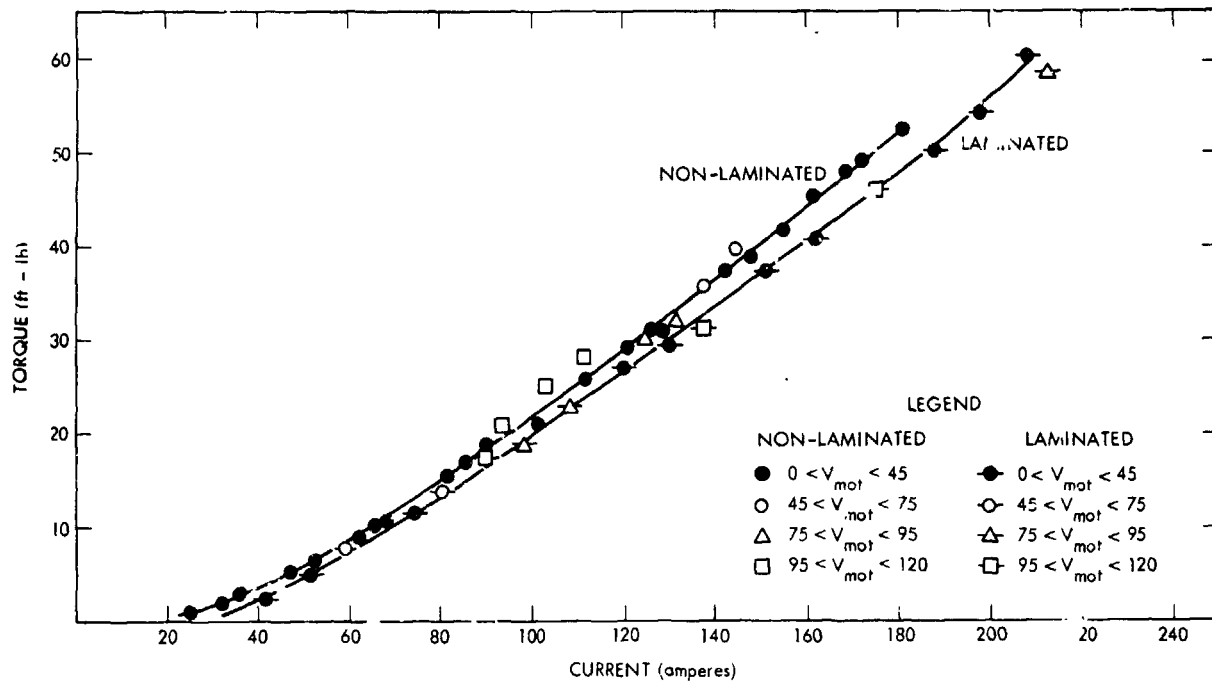


Figure 3.6.1. Plot of Torque vs Motor Current for Non-Laminated and Laminated versions of 1265 Motor operating with Control System. Note that Torque is virtually independent of Voltage and RPM. (See Tables 3.6.1 and 3.6.2 for data.,

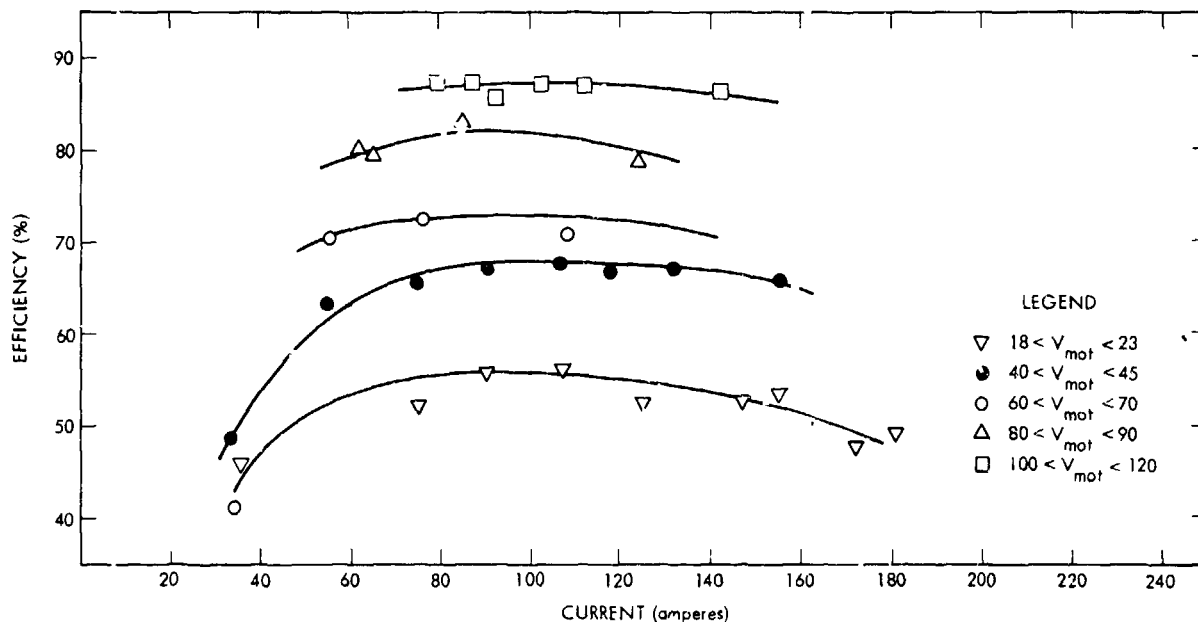


Figure 3.6.2. Plot of System Efficiency vs Motor Current for Combination of Non-Laminated Motor and Control System. Note Efficiency degradation compared with Figure 3.4.2. (See Table 3.6.1 for data.)

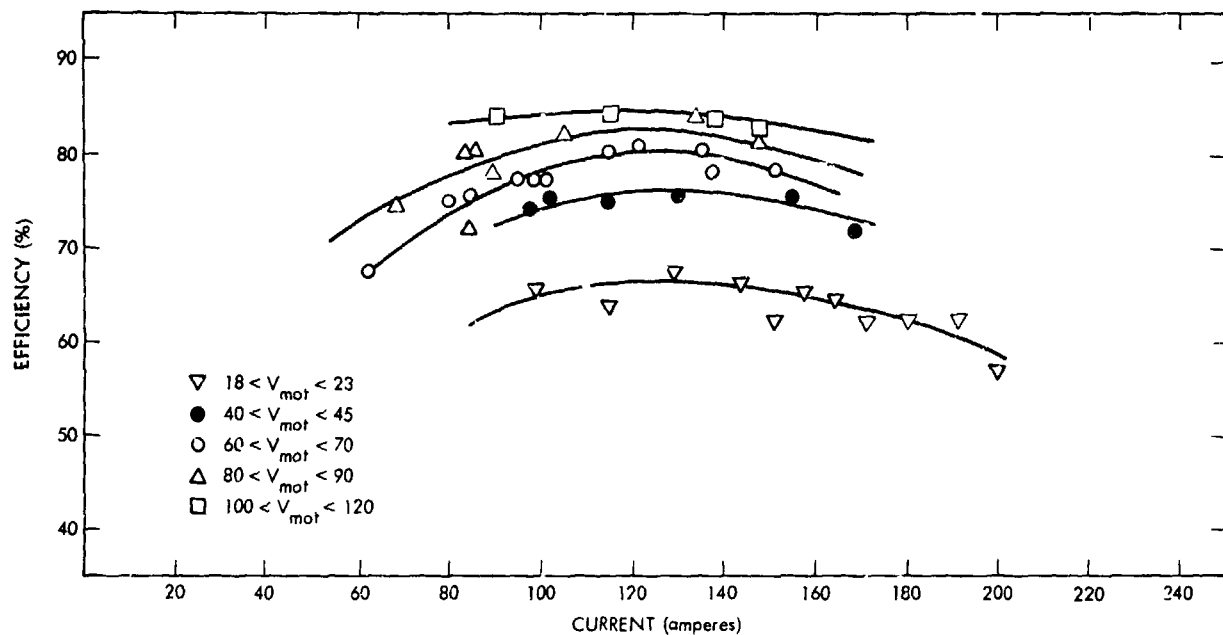


Figure 3.6.3. Plot of System Efficiency vs Motor Current for Combination of Laminated Motor and Control System. Note that efficiencies are lower than those of Figure 3.4.2, but higher than those of Figure 3.6.2.

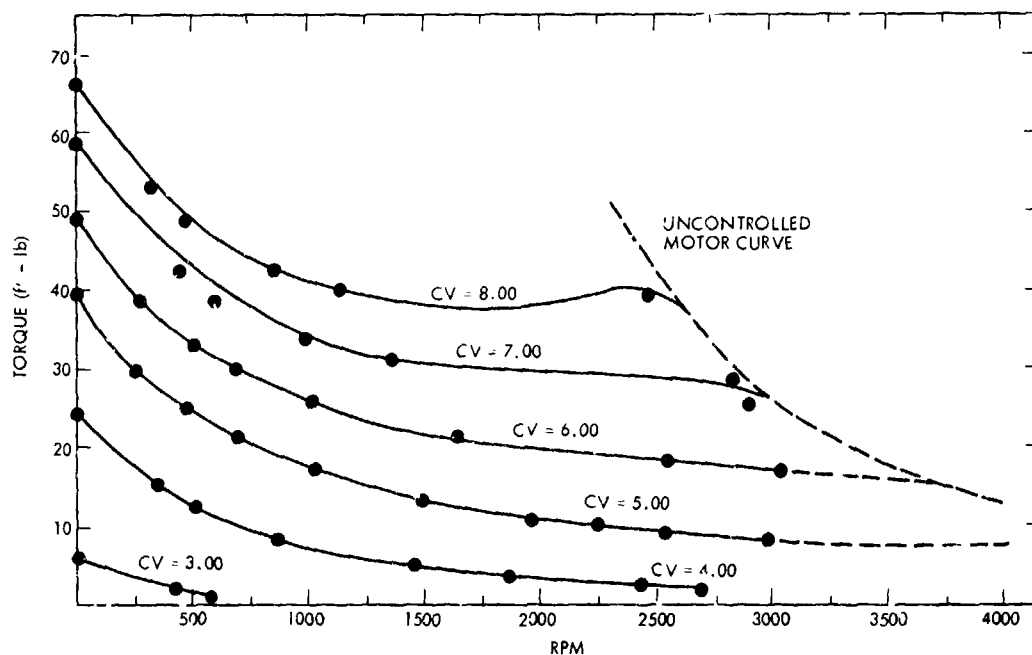


Figure 3.6.4. Plot of Non-Laminated Motor-Controller Characteristics for various values of CV (Control Voltage from Accelerator Potentiometer). Data is from Table 3.6.1.

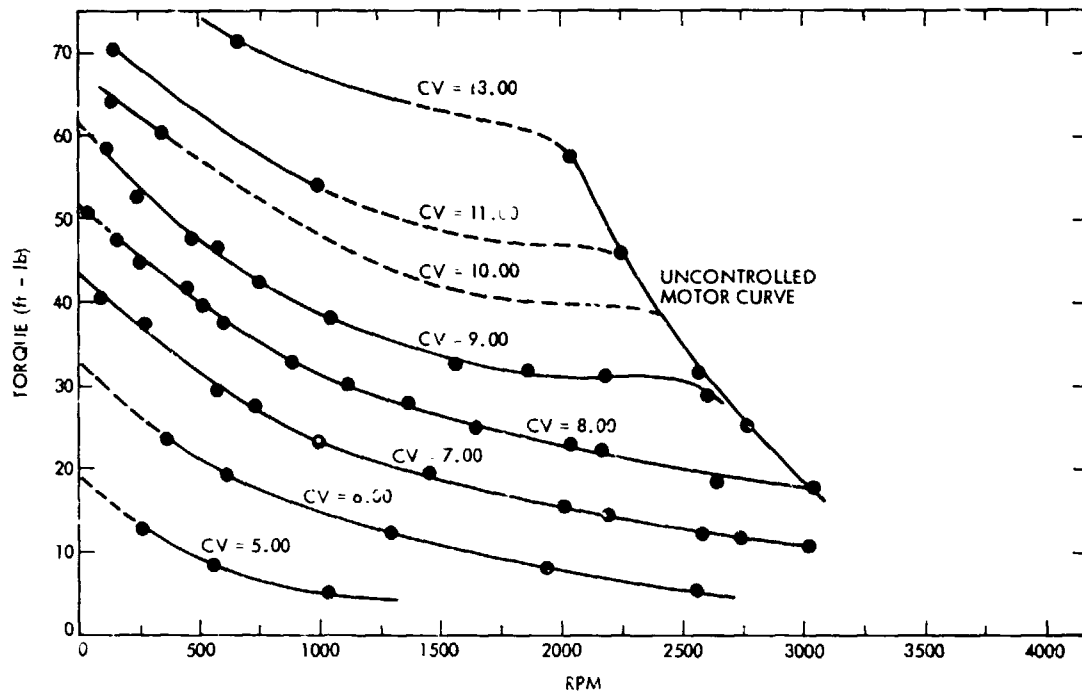


Figure 3.6.5. Plot of Laminated Motor-Controller Characteristics for various values of CV (control voltage from accelerator potentiometer). Data is from Table 3.6.2.

Report #3

Volkswagen Taxi Hybrid Passenger Vehicle

Section III

900-851

VOLKSWAGEN TAXI
HYBRID TEST PROGRAM

15 December 1977

D. Griffin

JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CALIFORNIA

ABSTRACT

The VW Research and Development Center of Wolfsburg, West Germany, built a parallel heat engine-electric hybrid vehicle. Although primarily intended to operate in the normal hybrid mode where power from both the motor and engine were available at all vehicle speeds, it can also operate in an on/off mode where only the motor propels the vehicle at speeds below about 25 mph. The vehicle includes regenerative braking. It has been driven over 8000 miles, mostly on public roads in West Germany.

Tests to determine its energy performance were conducted according to the Federal Test Procedure. Electrical power into and out of the batteries was measured to determine the net power used during a test. This was converted to an equivalent quantity of gasoline, then added to the gasoline consumed to determine an equivalent miles per gallon for the test. Allowances for typical efficiencies were included in the conversion.

The energy economy of the normal hybrid mode was 15.2 mpg for a baseline configuration of 3500 lb inertia weight. This decreased to 14.6 mpg (-4%) and 14.3 mpg (-6%) for inertia weights of 4000 lb and 4500 lb. A slight improvement in energy economy was obtained when the engine throttle, which was electrically controlled, was opened and closed more slowly than in the baseline condition. The affect of a 10% change in the maximum motor current on energy could not be detected.

The most noticeable energy improvement was obtained in the on/off mode. The engine cut-in and cut-out speeds were variable and tests were conducted at several points. With the baseline 3500 lb inertia weight, cut-in and cut-out speeds of 22/19 mph gave 17.4 mpg while 26/21 gave 19.4 mpg. The relatively small effect of increased inertia weight in the hybrid mode was also shown in the on/off mode. The 22/19 mph speeds and 4500 lb reduced the energy economy to 17.2 mpg (-1%).

This vehicle had a very limited amount of emissions development work, particularly in the on/off mode, so its emissions performance cannot be considered to be representative of any benefits that may reside in such a hybrid.

ACKNOWLEDGMENTS

The cooperative efforts of Bob Burleson, Don Greeley, Lou Johnson, James Allison, and James Bryant of the Jet Propulsion Laboratories and Reiner Miersch of Volkswagen made it possible to accomplish this work in the constrained time period of two months. The time constraint can be appreciated better in the knowledge that during the same time period, the JPL dynamometer facility required upgrading and test procedures had to be established for a new and sophisticated hybrid vehicle.

PREFACE

This report presents data of the energy and emissions performance of a heat engine-electric hybrid vehicle. The report presents only test data and does not include any interpretation or analysis of this data. Originally, the final report was planned to include analytical work adequate to explain the interesting energy performance of this vehicle but funding limitations precluded this effort.

The testing program consisted of two parts. Originally, the tests were intended only to support a state-of-the-art assessment of electric and hybrid vehicles by defining the energy and emissions performance of the most sophisticated hybrid available at the time. During these tests, some unexpected energy economy results indicated that a continuation of the tests would be necessary to understand the vehicle's energy performance. The second part of the tests were then conducted to acquire the necessary data. Data from both parts are included in this report.

The tests reported here followed the Federal Test Procedure which specifies units of miles per gallon (energy), grams per mile (emissions) and miles per hour (vehicle speed). These units are widely recognized since the Federal Test Procedure is used throughout the world. Accordingly, these English units are used in this report.

GLOSSARY

Federal Test Procedures

A comprehensive procedure, specified in the Federal Register, used to define emission and fuel economy performance. The procedure lists measurement techniques, vehicle handling processes, reporting methods, etc. Tests are conducted on a chassis dynamometer. A speed-time profile covering a test of approximately 41 min is defined. This profile consists of three phases:

- 1) Cold Transient - The vehicle is started after being stored at a controlled temperature, so the cold start devices (such as the automatic choke) operate during this phase. A distance of 3.6 miles is covered in 505 sec.
- 2) Stabilized - This phase is conducted immediately after the cold transient phase. A distance of 3.9 miles is covered in 864 sec.
- 3) Hot Transient - After the Stabilized phase is completed, the vehicle engine is shut off and the car is inactive for 10 min. The Hot Transient phase is then started. This phase follows the same speed-time profile as the Cold Transient phase.

Hot 505

A series of three tests separated by one minute intervals. Each test consists of the Hot Transient phase of the Federal Test Procedure. The vehicle starts a Hot 505 test in a fully warm condition.

On/Off Mode

A power train operating mode where the gasoline engine is turned off below a vehicle speed of approximately 25 mph. The electric motor provides the propulsive power below this speed.

TABLE OF CONTENTS

<u>Paragraph</u>		<u>Page</u>
SECTION 1 - SUMMARY		
1.1	VEHICLE DESCRIPTION	1-1
1.1.1	Taxi	1-1
1.1.2	Bus	1-5
1.2	TEST PROCEDURES	1-5
1.3	TEST RESULTS	1-5
SECTION 2 - INTRODUCTION		
2.1	VEHICLE SELECTION	2-2
2.2	VEHICLE AND REPORT CONSIDERATIONS	2-2
2.2.1	Test Cycle	2-3
2.2.2	VW Project Engineer	2-4
2.3	ORDER OF REPORTING	2-4
SECTION 3 - TEST DATA		
3.1	APPROACH TO THE TESTING PROGRAM	3-2
3.2	ENERGY REPORTING	3-7
3.2.1	Test Measurements	3-7
3.2.2	Battery Recharging Energy	3-7
3.3	TEST INFORMATION	3-10
3.3.1	Federal Test Procedure Tests	3-10
3.3.2	SAE J227C and J227D Tests	3-11
3.3.3	Other Considerations	3-11
3.3.4	Reporting Sequence	3-12

TABLE OF CONTENTS (Contd)

<u>Paragraph</u>		<u>Page</u>
3.4	FEDERAL TEST PROCEDURE TESTS	3-13
3.4.1	Hybrid Mode Data	3-14
3.4.2	On/Off Mode Tests	3-34
3.4.3	FTP Data Results	3-60
3.5	SAE J227a 'C' AND 'D' CYCLE TESTS	3-63
3.6	VW BUS TEST DATA	3-65
3.6.1	Bus Background Information	3-65
3.6.2	Bus Test Data	3-66
3.6.3	Bus Oxidizing Converter	3-70

SECTION 4 - VEHICLE DESCRIPTION

4.1	TAXI'S BACKGROUND	4-1
4.2	MECHANICAL MODIFICATIONS	4-3
4.3	POWER TRAIN	4-5
4.4	ENGINE	4-6
4.5	MOTOR	4-8
4.6	BATTERIES	4-8
4.7	MODE SELECTION	4-9
4.8	POWER CONTROLLER	4-9
4.9	SYSTEM CONTROLLER	4-10
4.9.1	Maximum Motor Current	4-11
4.9.2	Time Constant Between the Accelerator Pedal and Throttle	4-12
4.9.3	Operating Mode	4-12
4.9.4	"BATTERIE" Meter	4-13

TABLE OF CONTENTS (Contd)

<u>Paragraph</u>		<u>Page</u>
SECTION 5 - MEASUREMENT PERFORMANCE		
5.1	FACILITY CALIBRATIONS	5-1
5.1.1	Dynamometer	5-1
5.1.2	Constant Volume Sampler (CVS)	5-2
5.1.3	Emission Instruments	5-2
5.1.4	Power Measurements	5-3
5.1.5	Gasoline Weight Measurements	5-4
5.2	SYSTEM CHECKS	5-4
5.2.1	Reference Vehicle Tests	5-4
5.2.2	Power Measurement Checks	5-9
SECTION 6 - TESTING SEQUENCE		
6.1	PHILOSOPHY	6-1
6.1.1	Prior to Vehicle Arrival	6-1
6.1.2	After Vehicle Arrival	6-2
6.1.3	Testing Sequence	6-3
6.2	TESTING PROGRAM	6-4
6.2.1	Checkout	6-4
6.2.2	Primary Data Acquisition	6-5
6.2.3	Completion of Tests	6-6
SECTION 7 - FACILITY AND INSTRUMENTATION		
7.1	BATTERY AND MOTOR POWER MEASUREMENTS	7-1
7.1.1	Description of Power Measurement Circuits	7-1
7.1.2	Real-Time Data Readout	7-9
7.1.3	Computer Plots of Power Data	7-12
7.1.4	Circuit Design Problems	7-12
7.2	GASOLINE FLOW MEASUREMENTS	7-14

TABLE OF CONTENTS (Contd)

LIST OF ILLUSTRATIONS

<u>Figure</u>	<u>Title</u>	<u>Page</u>
1-1	Volkswagen Taxi	1-2
1-2	Cutaway View of the VW Taxi	1-3
1-3	Test Data Summary	1-6
1-4	Relationship of Electrical/Gasoline Energy Ratio to Gasoline-Equivalent MPG	1-7
3-1	Averaged FTP Test Data	3-14
3-2	Test Results for Baseline Configuration	3-15
3-3	Graph of Baseline FTP Test Data	3-16
3-4	Typical FTP Speed Time Profile Chart for Baseline Tests	3-18
3-5	Test Results for Baseline Configuration Except for 2.5 Sec Throttle Time Constant	3-19
3-6	Graph of 2.5 Sec Throttle Time Constant Tests	3-20
3-7	Typical FTP Speed-Time Profile Chart for 2.5 Sec Throttle Time Constant	3-21
3-8	Test Results for Hybrid Mode 4000 lb Inertia Weight	3-23
3-9	Graph of Hybrid Mode 4000 lb Inertia Weight Tests	3-24
3-10	Typical FTP Speed-Time Profile Chart for Hybrid Mode 4000 lb Inertia Weight Test	3-25
3-11	Test Results for Hybrid Mode 4500 lb Inertia Weight	3-26
3-12	Graph of Hybrid Mode 4500 lb Inertia Weight Tests	3-27
3-13	Typical FTP Speed-Time Profile Chart for Hybrid Mode 4500 lb Inertia Weight Tests	3-28
3-14	Data Variability Throughout the Test Period	3-30
3-15	Summary of Hybrid Mode Tests	3-31
3-16	Hybrid Mode Energy Economy	3-32
3-17	Hybrid Mode-Electrical Power Use	3-35
3-18	On/Off Mode-Electrical Power Use	3-36
3-19	Data From On/Off Mode Hot 505 Tests	3-38
3-20	On/Off Mode Acceleration Performance With 230 Amp Maximum Motor Current	3-39
3-21	On/Off Mode Acceleration Performance With 260 Amp Maximum Motor Current	3-40

TABLE OF CONTENTS (Contd)

<u>Figure</u>	<u>Title</u>	<u>Page</u>
3-22	Comparison of Hybrid and On/Off Mode Hot 505 Tests	3-41
3-23	On/Off Engine Cut-In and Cut-Out Operation	3-48
3-24	Test Results for On/Off Mode, 3500 lb Inertia Weight FTP Tests	3-49
3-25	Graph of On/Off Mode, 3500 lb Inertia Weight FTP Tests	3-50
3-26	Typical FTP Speed-Time Profile for On/Off Mode (22/19 mph) 3500 lb Inertia Weight Tests	3-51
3-27	Test Results for On/Off Mode, 4500 lb Inertia Weight	3-53
3-28	Graph of On/Off Mode, 4500 lb Inertia Weight FTP Tests	3-54
3-29	Typical FTP Speed-Time Profile Chart for On/Off Mode, (22/19 mph) 4500 lb Inertia Weight Tests	3-55
3-30	Engine Cut-In and Cut-Out Speeds for Test 51	3-56
3-31	Test Results for On/Off Mode, 3500 lb Inertia Weight 26/21 MPH Engine Cut-In/Cut-Out Speeds	3-57
3-32.	FTP Speed-Time Profile Chart for On/Off Mode, (26/21 mph) 3500 lb Inertia Weight Tests	3-58
3-33	Summary of On/Off Mode Tests	3-59
3-34	Energy Economy of Hybrid and On/Off Modes	3-61
3-35	Energy Economy Without Battery Recharge	3-62
3-36	SAE J227a Driving Cycle Tests	3-64
3-37	VW Bus Emission Fuel Economy (Miles per Gallon)	3-67
3-38	VW Bus NO _x Data (Weighted Grams per Mile)	3-67
3-39	VW Bus CO Data (Weighted Grams per Mile)	3-68
3-40	VW Bus HC Data (Weighted Grams per Mile)	3-68
3-41	Test Data Summary	3-73
4-1	VW Taxi	4-2
4-2	Cutaway View of the VW Taxi	4-4
4-3	VW Electric Motor Correction	4-5
4-4	Throttle Actuation Mechanism	4-7
4-5	Bosch Power	4-10
4-6	VW System Control Logic	4-11

TABLE OF CONTENTS (Contd)

<u>Figure</u>	<u>Title</u>	<u>Page</u>
5-1	Power Measurement Circuit Calibration	5-5
5-2	Gasoline Weighing System	5-5
5-3	Correct Waveforms at Low Power Levels	5-5
5-4	Reference Chevrolet Gasoline Fuel Economy	5-7
5-5	Reference Chevrolet NO _x Data	5-7
5-6	Reference Chevrolet CO Data	5-7
5-7	Reference Chevrolet HC Data	5-8
5-8	Agreement Between Weigh Tank and Emissions Fuel Economy - Reference Chevrolet	5-9
5-9	Agreement Between Weigh Tank and Emissions Fuel Economy - VW Taxi	5-11
5-10	Test Setup for Power Measurement Checks	5-11
5-11	Calibration of Electrical Power Measurements - VW Taxi	5-12
5-12	Isolation Amplifier Response	5-12
5-13	Current Waveforms of Low Power Levels	5-14
5-14	Data Display Showing Typical Power Measurements at 1000 rpm	5-15
5-15	Data Display Showing Typical Power Measurements at 1100 rpm	5-15
7-1	VW Taxi Installed on Chassis Dynamometer	7-2
7-2	Rear View of VW Taxi Test Installation	7-2
7-3	Rear View of VW Taxi Test Installation	7-3
7-4	Constant Volume Sampler	7-3
7-5	Central Instrumentation Area	7-4
7-6	Emission Measuring Instruments	7-5
7-7	Electrical Power Measurement Chassis	7-6
7-8	Power Measurement Block Diagram	7-7
7-9	Connector Panel	7-10
7-10	Kilowatt and Watt-hour Power Readings; Single Channel Format	7-11
7-11	Four Channel Power Display	7-11

TABLE OF CONTENTS (Contd)

<u>Figure</u>	<u>Title</u>	<u>Page</u>
7-12	Plot of Battery and Motor Power From Test 13, The Baseline Hybrid Configuration	7-13
7-13	Plot of Battery and Motor Power From Test 22, an On/Off Configuration. Test was Terminated at End of The Stabilized Phase Because of Battery Discharge	7-13
7-14	Gasoline Weighing System	7-15
7-15	Calibration Weights for the Gasoline Weighing System	7-15
7-16	Calibration of the Gasoline Weighing System	7-16

TABLE OF CONTENTS (Contd)

LIST OF TABLES

<u>Table</u>	<u>Title</u>	<u>Page</u>
3-1	Hybrid Test Index	3-3
3-2	Summary of VW Taxi Test Data	3-5
3-3	Equivalent MPG Units	3-9
3-4	Test Repeatability	3-10
3-5	Federal Test Procedure Tests	3-13
3-6	Comparison of On/Off Mode Hot 505 Tests	3-44
3-7	Comparison of Data from the Hot Transient Phase for FTP and 505 Tests	3-45
3-8	Composite Taxi On/Off Mode FTP	3-46
3-9	Composite VW Bus FTP Test	3-72

SECTION 1

SUMMARY

Tests on a Volkswagen (VW) Taxi, a prototype vehicle constructed at the VW Research and Development Center in Wolfsburg, West Germany were conducted at JPL to determine the energy and emissions performance of a gasoline-electric hybrid vehicle. The VW Taxi was selected for these tests because it is the world's most advanced operational hybrid vehicle. The Taxi has been driven over 8000 miles, mostly on public roads in Europe, and so has a proven record as a practical vehicle. Its control strategy is more sophisticated than other hybrids and permits considerable flexibility simply by changing adjustments or circuit cards. Because of these characteristics, the VW Taxi provided the best available vehicle for the hybrid tests.

A standard 1977 production VW Bus was also tested in order to provide a comparison between the hybrid Taxi and a similar conventional vehicle.

1.1 VEHICLE DESCRIPTION

The two vehicles were both based on the familiar VW microbus chassis. The Taxi was modified to add an electric power system to the conventional VW power train. Other changes provided characteristics which would make it suitable for use as a taxi in a major city. The Bus had no modifications and therefore represented current VW production.

1.1.1 Taxi

The VW Taxi is shown in Figures 1-1 and 1-2. The rear engine and transaxle configuration of the standard VW bus permitted the electric power system to be added in a relatively simple manner. The result is a parallel hybrid vehicle with a torque converter, automatically operated clutch, and system control hardware separate from the electric motor power controller.

This report is not concerned with the modifications necessary to provide the Taxi functions.



Figure 1-1. Volkswagen Taxi

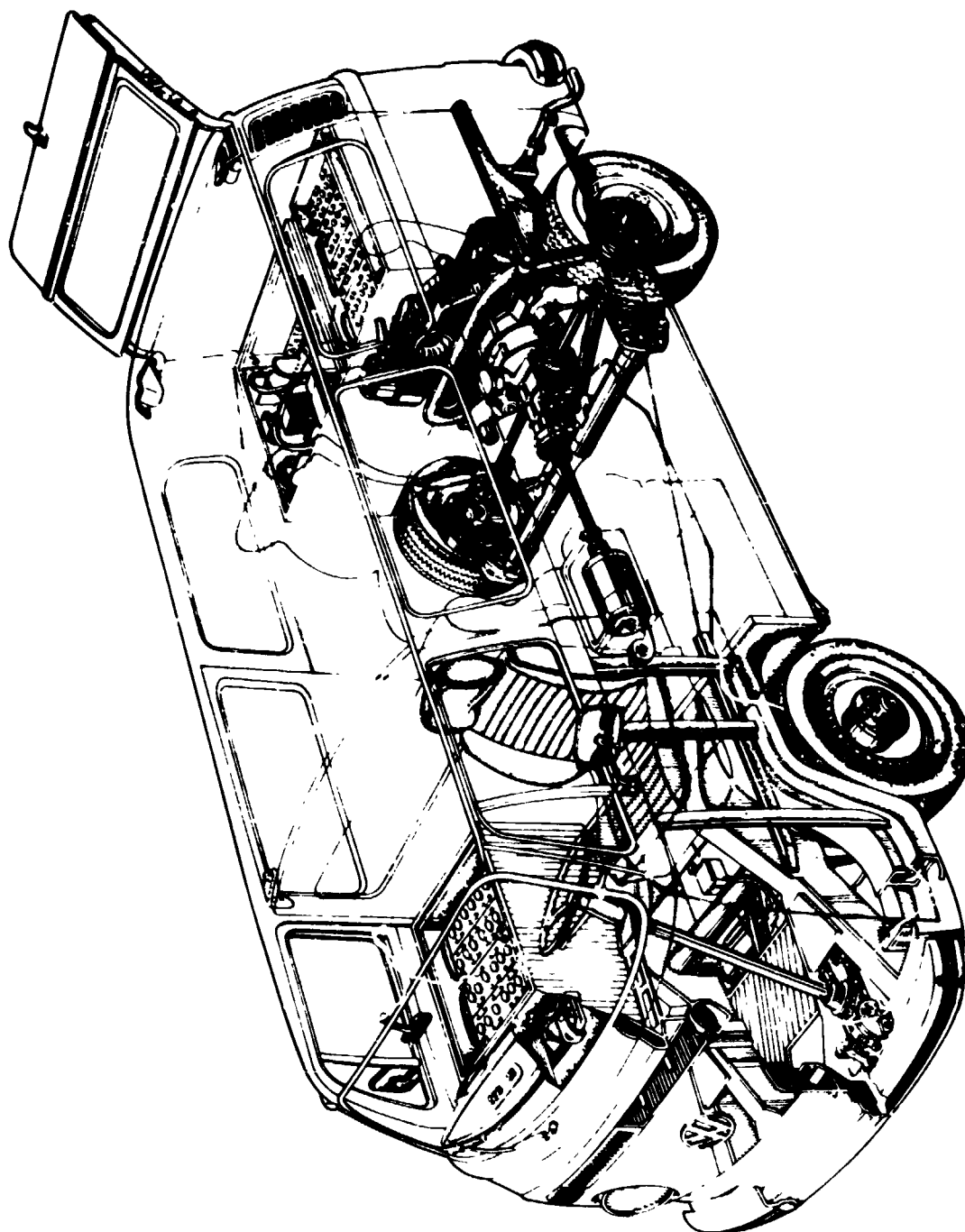


Figure 1-2. Cutaway View of the VI Taxi

The Taxi's control hardware permitted simple adjustments of three parameters:

- 1) The time constant between the accelerator pedal actuation and the throttle response
- 2) Maximum current applied to the electric motor
- 3) The operational mode of the gasoline engine.

The latter would permit one operating mode where the gasoline engine ran at all times, including idling when the vehicle was stopped, but whose response to the accelerator pedal input was controlled by the time constant mentioned previously. In the other mode, the engine started and stopped at vehicle speeds on the order of 25 mph. Below this speed, the vehicle operated in the electric-only mode. Above this speed, both the electric and gasoline engines provided power.

The Taxi has a parallel configuration, so both the electric motor and the gasoline engine can provide power to the rear wheels simultaneously. The electric power unit can also act as a generator. The control strategy permits the gasoline engine to charge the batteries while the vehicle is operating at higher speeds. Regenerative braking is also included.

A new engine was installed in the Taxi immediately before it was shipped to the U.S. However, the engine design is that of the VW "Beetle" whose production was terminated in 1974 so its emission characteristics represent early 1960 technology. An EGR system was installed but no catalytic converter was included. These engine characteristics must be considered when interpreting the test results.

Even though the Taxi has had considerable road driving, it does not have an optimum control strategy. Discussions with the VW project engineer, who accompanied the vehicle for one month, indicated that only limited testing had been done to optimize the Taxi's control strategy. In particular, the throttle time constant, maximum motor current, EGR flow, and detailed throttle opening characteristics have not been thoroughly investigated and then optimized. Therefore, the Taxi's performance reported here should not be considered to represent the optimum or even near-optimum performance of a parallel hybrid.

1.1.2 Bus

The VW Bus was a production vehicle. Its engine was a two liter, fuel-injected engine with a catalytic converter. It is reasonable to assume that this engine was optimized since it is a production vehicle with international markets.

1.2 TEST PROCEDURES

All tests followed the Federal Test Procedure (FTP). Energy and emissions performance were measured and reported according to this internationally known cycle. The Taxi's variety of operational modes made it necessary to investigate the general characteristics of each configuration, then conduct FTP tests to obtain the reportable data. No attempt was made to conduct road tests or to consider the vehicle driveability characteristics.

1.3 TEST RESULTS

Test results of the Taxi's two basic operational modes are listed in Figure 1-3. The measured performance of the VW bus is also listed. When comparing the results of Figure 1-3, the Taxi's old engine technology and lack of control optimization should be considered. Note that the CO and HC emissions of the Bus have been increased by a factor that approximates the catalytic converter efficiency. This has been done to permit a better comparison of the Taxi and Bus performance.

The Taxi's energy performance for actual test data is shown in Figure 1-4. The energy economy advantages of the On/Off mode are apparent. The small energy consumption increase for larger inertia weights is surprising and requires further analysis.

<u>Equivalent Gasoline</u>								
<u>Fuel Consumption¹</u>		0	5	10	15	20	25	30
VW Taxi - Hybrid mode ²					15.2	17.4 @ 22 mph		
VW Taxi - On/Off mode ³						19.4 @ 26 mph		
VW Bus - EEC configuration ⁴					16.8			
<u>NO_x Emissions⁵</u>		0	1	2	3	4	5	
VW Taxi - Hybrid mode								4.78
VW Taxi - On/Off mode				1.83				
VW Bus - EEC configuration				1.33				
<u>CO Emissions</u>		0	5	10	15	20	25	30
VW Taxi - Hybrid mode								36.0
VW Taxi - On/Off mode								28.3
VW Bus - EEC configuration								24.6
<u>HC Emissions</u>		0	1	2	3	4	5	
VW Taxi - Hybrid mode				2.18				
VW Taxi - On/Off mode					2.36			
VW Bus - EEC configuration				1.01				

1. Contribution of electrical energy from battery discharge is included, but is stated in miles per gallon units.
2. Average of 18 tests on 4 configurations in the Hybrid mode. Differences between the 4 configurations were relatively small.
3. The On/Off mode used only electric power below a vehicle speed that could be varied from 22 to 26 mph. The 26 mph configuration represented a case with high battery discharge and limited range. Range is greatly influenced by the driving cycle and would be 30 miles for the FTP cycle and 100 miles for the SAE J2272 '0' cycle.
4. The Equivalent Emission Control (EEC) configuration considers the Bus HC & CO performance without a catalytic converter to compare Bus and Taxi emissions on an equivalent emission control basis.
5. Emissions are reported as weighted grams/mile per the Federal Test Procedure.

Figure 1-3. Test Data Summary

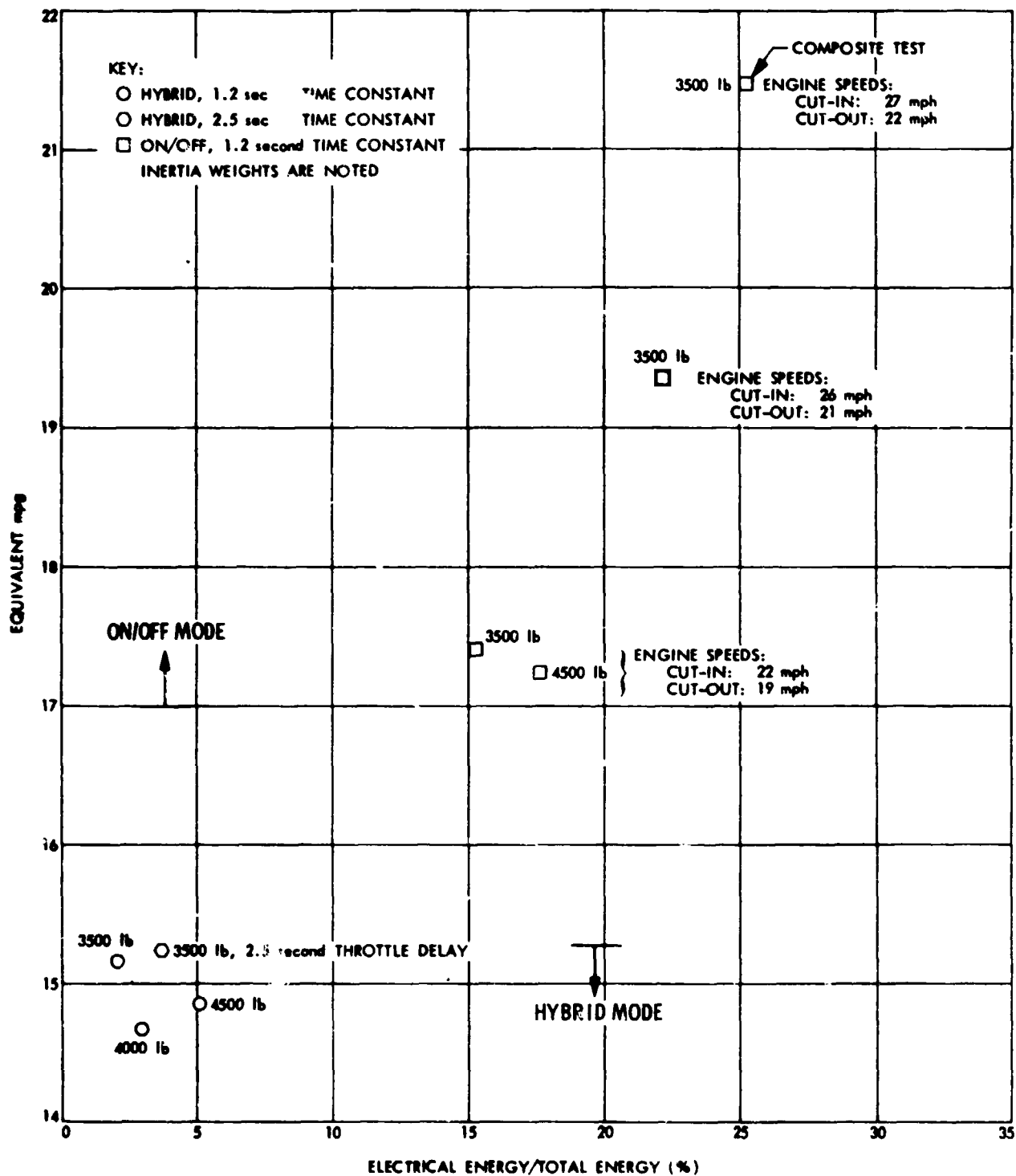


Figure 1-4. Relationship of Electrical/Gasoline Energy Ratio to Gasoline-Equivalent MPG

SECTION 2

INTRODUCTION

This report is concerned with tests on a gasoline/electric hybrid vehicle. The test program was conducted to support a state-of-the-art (SOA) report on electric and hybrid vehicles. This report was required by Public Law 94-413, the Electric and Hybrid Research, Development, and Demonstration Act of 1976. This Law required that the administrator of ERDA shall develop data characterizing the present SOA with respect to electric and hybrid vehicles within a year after the passage of the Act. The data that was developed from the SOA work was to serve as baseline data to be utilized to:

- 1) Compare improvements on electric and hybrid vehicle technology.
- 2) Assist in establishing performance standards for electric and hybrid vehicles.
- 3) Otherwise assist in carrying out the intent of the Public Law.

ERDA requested that NASA provide the necessary data. Primary responsibility for the program was given to Lewis Research Center (LeRC). LeRC tested nine electric vehicles and assigned JPL responsibility for testing two additional electric vehicles and a hybrid vehicle.

Only one hybrid vehicle was thus tested in direct support of the SOA report, but LeRC would include other data on hybrid vehicles for the SOA report. The JPL testing was thus only one part of the overall hybrid SOA assessment.

The tests to support the state-of-the-art report were conducted from June 14 to July 15, 1977. These tests indicated that the energy economy in the On/Off mode should be investigated further, so the Taxi's lease period was extended to September 1. Tests during the second period concentrated on the energy economy of the On/Off mode and effects of inertia weight changes.

Results of the test series were surprising, particularly the very small influence of inertia weight on energy economy. Investigation of this characteristic and potential energy advantages of a heat engine-electric hybrid operated in an On/Off mode are continuing. This work will require development

of computer programs to process test data; this is being done at the present time. However, the test results and information related to the tests is being disseminated now so interested persons can use the test data and also comment on additional information that would be helpful in the final report.

2.1 VEHICLE SELECTION

Data on other hybrid vehicles was somewhat limited, so it was essential that the vehicle tested by JPL be representative of the best hybrid technology available at this time. Discussions with persons familiar with hybrid vehicles indicated that the most sophisticated operational hybrid vehicle at the present time was a VW Taxi. This Taxi was constructed by the VW Research and Development Center in Wolfsburg, West Germany, as part of a VW interest in electric and hybrid vehicles. Arrangements to lease the vehicle for a period of 60 days were negotiated through VW of America. In addition, the leasing arrangements provided for the services of a VW engineer to accompany the vehicle to JPL for a period of approximately one month. After the contractual negotiations were complete, the vehicle was flown to the U.S. and arrived at JPL on May 24.

Although the primary objective of the program was to investigate the performance of the VW Taxi, it was desired to obtain a comparison with a conventional gasoline powered vehicle. Accordingly, arrangements for a loan of a production VW Bus were made. The VW Bus was supplied by the VW of America Emission Test Lab at Woodland Hills, CA. This lab is located approximately 45 min from JPL and so provided a convenient resource to check emission results as well as providing accessible support for the VW Taxi and Bus.

2.2 VEHICLE AND REPORT CONSIDERATIONS

Two vehicle-related factors should be considered when reviewing the data presented in this report:

- a. The VW engine, which is the old "Beatle" carbureted design, and control strategy were apparently not optimized to obtain the maximum performance for this particular vehicle configuration. This is particularly true of emissions performance. The Taxi is described in Section 4, which discusses its

development work. The Taxi's performance should thus be considered to represent only an early attempt to produce an energy and emissions efficient hybrid vehicle. The mechanical implementation and many of the components represent good technology, but the control strategy, EGR, and electronic throttle actuation have not received the extensive fine tuning that is common with present day emission control systems. However, it is reasonable to expect that the VW Bus received the extensive engineering development necessary to optimize the performance of its modern two liter fuel injected engine and related emission controls.

It should therefore be expected that the Taxi's performance could be improved with additional detailed development work.

b. No attempt has been made to test the Taxi in either the gasoline-only or electric-only mode. Initial thoughts may be that such operation could be used to compare the two operating modes with pure gasoline or electric vehicles. However, such comparisons can be expected to be highly unfavorable to the Taxi since it attempts to size both the heat engine and electrical power sources for a combined propulsion system. If the Taxi's analytical and engineering design work are properly done, neither power source will be adequate to provide good performance separately. In the case of the Taxi, it appears that the combined gasoline engine and the electric motor power sources are reasonably well matched to provide the performance necessary to meet the FTP driving cycle requirements.

Because of the system design that shares the propulsive effort between the two power sources, it does not appear reasonable to make any direct comparisons between the Taxi's gasoline-only mode or the electric-only mode to pure gasoline or electric vehicles.

2.2.1 Test Cycle

JPL was directed to conduct only chassis dynamometer tests on the hybrid vehicle, so this report does not consider:

- 1) Road-to-dynamometer data correlation.
- 2) Driveability characteristics.
- 3) Performance (acceleration, deceleration, handling) characteristics.

Since chassis dynamometer tests were to be used to acquire all data, the Federal Test Procedure (FTP) was used as the base for all tests. The FTP uses chassis dynamometer tests; its method of reporting fuel economy and emissions data is internationally known. VW had conducted FTP tests on the Taxi prior to its shipment, so it was known that the Taxi could be tested on this cycle. Only the urban part of the tests were conducted. The JPL chassis dyno facility is not air conditioned, so temperatures approaching 100°F were noticed in the VW electronics compartment during the urban test cycle. The warmup procedure and higher speeds of the highway cycle were certain to increase the room temperature. Since the Taxi was a leased and valuable vehicle, risks associated with the highway cycle operation were not incurred. The VW project engineer strongly supported this decision.

2.2.2 VW Project Engineer

The lack of detailed information on the Taxi and its degree of flexibility placed certain limitations on the testing plans before its arrival at JPL. However, the VW project engineer accompanied the Taxi and was thoroughly familiar with its construction, history, and characteristics. Since the project engineer was going to be available at JPL for a period of approximately 30 days, it was decided to follow his general direction concerning testing activities and care of the vehicle during this period. The initial testing activities and some details related to the testing, particularly the battery energy and electrical power measurements, were thus conducted in the general manner defined by the VW project engineer.

2.3 ORDER OF REPORTING

The next section discusses the results of the testing program. In general, this discussion is limited to treatment of the major features; more detailed data is contained in an Appendix. The next section is concerned with a description of the overall test results. Section 4 describes the VW Taxi. Sections 5 and 6 discuss the measurement performance of the JPL facility and the testing sequence that was used to derive the test data. The former describes the most important measurements while the latter section includes a description of the test philosophy, problems, and related activities that occurred during the testing program.

Section 7 contains a brief description of the major facility equipment and instrumentation.

References are listed at the end of this text. A short glossary that includes terms unique to this report or a general understanding of the emissions testing technology is included before the Table of Contents.

SECTION 3

TEST DATA

This section is concerned with presentation and discussion of the VW Taxi tests that were conducted over a period of approximately 2 1/2 months. Interpretation of this data and comments concerning its implication to heat engine-electric hybrids will be contained in a future report.

Tests were also conducted on a 1977 production VW Bus to provide an approximate comparison between the hybrid Taxi and a conventional vehicle. These data are included after the Taxi data and are discussed only briefly since the Taxi's energy economy is of primary interest.

As discussed in Section 4, the VW control strategy and hardware permitted changes to three parameters to be made easily:

a. Engine operating mode - A circuit card changed the operating mode of the gasoline engine from the normal hybrid to one when the engine was off at low vehicle speeds. In the hybrid mode, the engine was on at all times, including idle, so torque from both the engine and motor were available to propel the Taxi. In the On/Off mode, the engine would automatically turn on and off at certain vehicle speeds. The cut-in speed and the difference between the cut-in and cut-out speeds were individually adjustable. The cut-in speed was set in the range of 22 to 27 mps for the tests; cut-out speeds were approximately 3 to 5 mph lower than the cut-in speed. In this mode, the electric motor provided all the torque whenever the engine was off. This mode is termed the "On/Off" mode in this report.

b. Maximum motor current - The maximum allowable motor current limit could be continuously varied from 200 to 290 amperes. However, early tests showed that the current had to be set to at least 230 amps to provide acceleration close to that specified by the FTP speed-time profile. Further tests indicated that settings of 260 amps caused small changes in the energy data. Accordingly, the motor current was set at 230 amps for all tests except those used to investigate the On/Off mode performance and the program concentrated on variables that produced a more significant change.

c. Throttle time constant - A circuit card provided a time constant between the accelerator pedal motion and the throttle response. The time constant could be changed to 1.2 or 2.5 sec by switching circuit cards; no other values were available. The objective of this time constant was to permit the engine to respond relatively slowly to accelerator pedal motions, thus reducing emissions which are greatly increased by rapid engine transients. During the time the engine speed was changing, the torque change required to meet the accelerator pedal input command was provided by the electric power train.

The inertia weight was the other test variable.

The data presentation in this section is generally related to a specific test, or the average of several tests on the same test configuration. Test number is frequently used as the reference for tables and graphs, so a listing of the test numbers and basic information of the 51 tests conducted in this program is shown in Table 3-1. Table 3-2 gives a summary of the primary measurements.

3.1 APPROACH TO THE TESTING PROGRAM

The emphasis of this program was the investigation of the effect of different parameters on the energy utilization of a heat engine-electric hybrid. Because of the flexibility offered by the VW control implementation and chassis dyno testing, it was possible to conduct tests with several combinations of test parameters without disturbing the Taxi's mechanical configuration. Results from the different combinations can then be compared to investigate the effect of the different parameters.

The general approach to the test series was thus to obtain comparative data for different test configurations. Even though the Taxi's specific heat engine-electric hybrid implementation may not be optimum, the test results should show the effect of the parameters that were changed.

Table 3-1. Hybrid Test Index

This index defines all tests that have been conducted since system-level checkout was completed.

TEST NO.	DATE	VEHICLE	TEST TYPE	TEST PARAMETERS			MAX MOTOR CURRENT	COMMENTS
				INERTIA WEIGHT	THROTTLE TIME CONSTANT (SEC)	MODE ¹		
1	6/14	Bus	FTP	3500	2.5	H	230	For Bus/Taxi comparison. Emissions were high
2	6/14	Taxi	FTP	3500			230	Void. Gasoline leak
3	6/15	Bus	FTP	3500				Second test on Bus. Emissions continue high.
4	6/16	Taxi	FTP	3500	2.5	H	230	First test of this configuration
5	6/17	Taxi	FTP	3500	2.5	H	230	Second test of this configuration
6	6/21	Taxi	Hot 505	3500	2.5	H	230	Hot 505 test for comparison with 1.2 sec.
7	6/21	Taxi	Hot 505	3500	1.2	H	230	Baseline configuration for system repeatability.
8	6/22	Taxi	FTP	3500	1.2	H	230	No emissions data; CVS problem
9	6/22	Taxi	Hot 505	3500	1.2	H	230	Second baseline test
10	6/23	Taxi	FTP	3500	1.2	H	230	First test of this configuration
11	6/23	Taxi	Hot 505	3500	1.2	O	230	Taxi backfired. No data
12	6/24	Bus	FTP	3500				Bus test after repair by VW Emissions Lab
13	6/24	Taxi	FTP	3500	1.2	H	230	Second test; compare to test 10
14	6/24	Taxi	Hot 505	3500	1.2	O	230	Second try at On/Off mode test
15	6/27	Taxi	FTP	3500	2.5	H	230	Check results of 4 & 5, but void
16	6/27	Taxi	Hot 505	3500	2.5	O	230	On/Off with 2.5 second throttle time constant
17	6/28	Taxi	FTP	3500	2.5	H	230	Check results of 4 & 5. Good test
18	6/28	Bus	FTP	3500				Verify results of 12. Last bus test
19	6/28	Taxi	Hot 505	3500	2.5	O	260	On/Off with 260 amps
20	6/29	Taxi	FTP	3500	2.5	O	260	First try for FTP, On/Off. Batteries too low
21	6/29	Taxi	Hot 505	3500	1.2	H	230	Third baseline test
22	6/30	Taxi	FTP	3500	1.2	O	230	Second FTP On/Off. Completed first 2 phases.
23	7/6	Taxi	FTP	3500	1.2	O	230	Check on 22, but backfire voided test
24	7/6	Taxi	Hot 505	3500	1.2	H	230	Baseline check after backfire
25	7/7	Taxi	FTP	4000	1.2	H	230	4000 lb inertia weight comparison
26	7/8	Taxi	FTP	4000	1.2	H	230	Second 4000 lb test
27	7/11	Taxi	FTP	4500	1.2	H	230	Invalid; facility failure
28	7/15	Taxi	Hot 505	3500	1.2	H	230	Baseline at end of first set of tests

¹Key for the mode is: "H" = Hybrid, "O" = On/Off.

Table 3-1. Hybrid Test Index (Contd)

This index defines all tests that have been conducted since system-level checkout was completed.

TEST NO.	DATE	VEHICLE	TEST TYPE	TEST PARAMETERS			MAX MOTOR CURRENT	COMMENTS
				INERTIA WEIGHT	THROTTLE TIME CONSTANT (SEC)	MODE ¹		
29	8/1	Taxi	Hot 505	3500	1.2	H	230	Baseline at start of extended test series
30	8/2	Taxi	FTP	3500	1.2	H	230	First FTP of extended test series.
31	8/3	Taxi	Hot 505	3500	1.2	H	230	Baseline verification
32	8/4	Taxi	FTP	4000	1.2	H	230	Third 4000 lb test. Data void because of procedure error
33	8/5	Taxi	Hot 505	3500	1.2	H	230	Comparison to Test 31
34	8/9	Taxi	Hot 505	3500	1.2	O	230	Baseline On/Off Mode
35	8/9	Taxi	Hot 505	3500	1.2	O	230	On/Off modified to lower engine speeds
36	8/10	Taxi	FTP	4500	1.2	O	230	On/Off with engine speeds @22 MPN on/19 MPH off
37	3/11	Taxi	FTP	4500	1.2	O	230	Repeat of Test 36
38	8/12	Taxi	FTP	3500	1.2	O	230	Comparison of tests 36 & 37 with 3500 lb IW
39	8/15	Taxi	FTP	3500	1.2	O	230	Repeat of Test 38
40	8/16	Taxi	FTP	3500	1.2	O	230	Repeat of Test 39
41	8/17	Taxi	FTP	3500	1.2	O	230	On/Off with engine speeds @ 24 MPH on, 19 MPH off. Terminated because of backfire
42	8/19	Taxi	FTP	3500	1.2	H	230	Baseline configuration for system repeatability
43	8/19	Taxi	Hot 505	3500	1.2	H	230	Baseline
44	8/22	Taxi	FTP	4500	1.2	H	230	Second try for 4500 lb FTP Test
45	8/23	Taxi	FTP	4500	1.2	H	230	Third 4500 lb FTP Test
46	8/23	Taxi	SAE J227a C	3500	1.2	H	230	First electric cycle test (C cycle)
47	8/24	Taxi	SAE J227a D	3500	1.2	H	230	Second electric cycle test (D cycle)
48	8/25	Taxi	FTP	3500	2.5	H	230	Comparison with 2.5 sec throttle delay. Void because of test problems
49	8/25	Taxi	FTP	3500	2.5	H	230	Repeat of Test 48
50	8/31	Taxi	SAE J227a D	3500	1.2	O	230	Repeat of electric cycle test (D cycle) in On/Off Mode
51	9/1	Taxi	FTP	3500	1.2	O	230	On/Off with higher engine on and off speeds

Table 3-2. Summary of VW Taxi Test Data

TEST NO.	DATE	FUEL ECONOMY ¹ (MPG)		ELECTRICAL POWER ² (WATT HOURS)		EMISSIONS (WEIGHTED GRAMS/MILE)		
		WEIGHT	EMISSIONS	BATTERY	MOTOR	NOX	CO	HC
1	6/14	VW Bus test						
2	6/14	Void - gasoline leak						
3	6/15	VW Bus test						
4	6/16	16.15	16.71			4.731	28.573	3.228
5	6/17	15.93	16.66			4.698	31.076	2.092
6	6/21	17.29	17.61			5.388	28.499	1.647
7	6/21	17.19	17.56			5.547	24.755	1.648
8	6/22	15.21	(3)	- 258	77	(3)	(3)	(3)
9	6/22	17.02	17.84	- 117	- 30	5.299	24.676	1.600
10	6/23	15.54	15.99	- 350	58	4.814	33.459	2.107
11	6/23	Void - Taxi backfire						
12	6/24	VW Bus test						
13	6/24	15.17	15.99	- 276	148	4.732	40.738	2.354
14	6/24	25.36	26.56	- 608	- 535	-3.488	22.530	1.836
15	6/27	Void - operational error						
16	6/27	25.74	26.97	- 522	- 556	-3.848	20.466	2.271
17	6/28	15.73	16.55	- 314	116	4.546	35.445	2.192
18	6/28	VW Bus test						
19	6/28	25.23	26.30	- 620	- 529	-3.539	21.162	2.145
20	6/29	29.41	24.50	-2041	-1779	.956	19.945	1.694
21	6/29	16.97	17.60	- 47	37	5.377	29.944	1.742
22	6/30	28.76	24.42	-2126	-1841	.874	23.249	1.885
23	7/6	Void - Taxi backfire						
24	7/6	16.89	11.44	- 66	6	5.683	28.615	2.217

¹Conventional mpg units based on the weigh tank gasoline consumption or the emissions measurements as defined by the FTP.

²Electrical power data is based on JPL measurements. Data to test 008 had a known error of approximately 10% so is not included here. Negative battery power indicates battery discharge; negative motor power indicates power into motor was greater than power out of motor.

³No emissions data on Test 8 because of equipment failure

Table 3-2. Summary of VW Taxi Test Data (Continued)

TEST NO.	DATE	FUEL ECONOMY ¹ (MPG)		ELECTRICAL POWER ² (WATT HOURS)		EMISSIONS (WEIGHTED GRAMS/MILE)		
		WEIGHT	EMISSIONS	BATTERY	MOTOR	NOx	CO	HC
25	7/7	15.07	15.76	- 307	99	4.930	37.387	2.127
26	7/8	15.11	15.91	- 332	72	4.913	39.157	2.189
27	7/11	Void - facility failure						
28	7/15	16.87	17.20			5.918	31.255	1.789
29	8/1	17.17	17.37	- 119	146	4.722	49.246	1.944
30	8/2	15.55	16.21	- 373	38	4.335	48.274	2.731
31	8/3	17.54	18.03	- 412	- 200	4.028	46.002	2.094
32	8/4	15.95	16.44	- 663	- 296	4.069	44.210	2.358
33	8/5	17.21	18.22	- 432	- 159	4.772	31.320	1.789
34	8/9	26.05	27.36	-1972	-1738	3.045	23.228	1.717
35	8/9	Checkout of on/off speed settings						
36	8/10	20.82	22.04	-2094	-1644	2.826	37.201	3.051
37	8/11	21.07	22.56	-2099	-1698	2.659	37.134	2.800
38	8/12	20.28	21.58	-1476	-1051	3.002	35.377	2.739
39	8/15	20.66	22.32	-1791	-1366	2.927	36.985	2.791
40	8/16	20.40	21.86	-1804	-1393	2.892	38.946	2.893
41	8/17	Void - Taxi backfire						
42	8/19	15.93	16.62	- 269		3.950	44.223	2.844
43	8/19	17.11	17.78			5.235	34.216	1.945
44	8/22	15.50	16.12	- 821	- 678	4.633	43.518	2.556
45	8/23	15.75	16.42	- 610	- 346	4.813	44.317	2.622
46	8/24	14.11	15.21	12	90	1.304	9.391	.510
47	8/24	17.18	17.71	176	230	7.739	33.429	2.017
48		Void - Taxi backfire						
49	8/25	15.95	16.73	- 657	- 198	4.263	43.986	1.905
50	8/31	J 227 C and D cycle tests						
51	9/1	24.85	27.50	-2324	-2130	1.760	38.853	2.644

3.2 ENERGY REPORTING

The two energy sources made it necessary to report the overall energy economy in an easily understood manner. Since the Taxi uses gasoline as its primary energy source with a relatively small proportion of electrical energy, the total energy will be reported in the familiar miles per gallon units. The term "equivalent mpg" will be used to define the total gasoline and electrical energy consumption. The equivalent mpg values were derived from measurements of the on-board gasoline and electrical energy required to complete a test plus the energy necessary to recharge the batteries.

3.2.1 Test Measurements

Energy measurements were concerned with the gasoline and electrical energy that were consumed during a test. Since these two measurements defined the energy economy of the vehicle, considerable work was done to provide accurate measurements. The gasoline measurement was based on weigh tank data that measured the total weight of gasoline consumed during a test. The electrical power was measured by a special circuit that provided data of power into and out of both batteries and motor. Basic calibration data for these two measurements are given in Paragraphs 5.1.4 and 5.1.5.

3.2.2 Battery Recharging Energy

The VW Project Engineer provided an external charger that was matched to the VW control system. This charger had been designed for the Taxi and included a special multi-conductor cable and connector that provided interlocks between the charger and the on-board control system. The charger was a separate device designed for the Taxi but with no consideration for its overall efficiency. Its exact efficiency was not known.

Because of the interlocks, it would have been a significant task to replace the charger. The VW Project Engineer had a strong preference to use the unit that had proven to be compatible with the Taxi so no attempt was made to use a different charger.

Since the charger could not be readily replaced and its efficiency was unknown, only minimal effort was made during the tests to define the energy required to recharge the batteries after a test. Using energy based on the inefficient VW charger would certainly not give a good comparison to current technology, so this procedure was adopted:

- 1) Measure the battery power out (discharge) and power in (charge) during a test. Subtract the two to obtain the net battery power used during a test.
- 2) Assume an overall charge/discharge efficiency of 0.7 during a test. The net battery power consumed during a test was thus increased by the 0.77 efficiency to estimate the energy remaining in the battery after the test.
- 3) Assume that a 10 percent overcharge is necessary during the charging cycle.
- 4) Assume an efficiency of 0.77 for the charger and batteries during the recharging cycle. This value is the average of the efficiencies reported for a recent vehicle that represents good current technology (ref. 1)

Gasoline provided the dominant energy source; electrical energy accounted for 2 to 25 percent of the total energy. Since the gasoline weight measurement was repeatable to within 0.5 percent, this procedure should minimize overall variations in the energy economy values by providing a consistent treatment of the recharging energy.

In order to report the combined gasoline and electrical energy in easily understood units, energy values are defined in "equivalent miles per gallon" units. This term includes both the gasoline and electrical energy used during a test plus the recharging energy defined above. Table 3-3 shows the derivation and constants used for this value. It should be noted that the gasoline data is based on the weight of gasoline consumed during a test, not emissions-based calculations of gasoline that are defined by the FTP. Potential errors of the FTP techniques, particularly as related to the Taxi, are discussed in Paragraph 5.2.1. Actual mileage driven for all tests is also used, not the nominal value used for the FTP cycle of SAE J227a cycles.

Fossil fuel conversion efficiencies to either energy or emissions at the vehicle are not considered in this report.

Table 3-3. Equivalent MPG Units

MEASURED PARAMETERS

Gasoline weight for the test (grams)

Power out of the batteries (discharge) for the test (watt hrs)

Power into the batteries (charge) for the test (watt hrs)

GASOLINE 10 KW-hr CONVERSION

Energy of gasoline: 19,600 BTU/lb

BTU to kW-hr: 2.93×10^{-4} kW-hr/BTU

$$(\text{Grams of gasoline})(1.266 \times 10^{-2}) = \text{kW-hrs of gasoline energy}$$

BATTERY POWERPower required to conduct a test

Power out-power in = net measured battery power

$$\frac{\text{Net measured battery power}}{0.77 \text{ battery charge/discharge efficiency}^1} = \text{kW-hrs removed from battery}$$

Power required to recharge the batteries

$$\frac{(\text{kW-hrs removed from battery}) + (10\% \text{ for overcharge})}{0.77 \text{ battery charge} + \text{charger efficiency}^2} = \text{kW-hrs of electrical energy}$$

EQUIVALENT MPGGrams to gallons conversion: 2798 grams/gallon³

$$\left[(\text{kW-hrs gasoline}) + (\text{kW-hrs electrical}) \right] \left(\frac{1}{1.266 \times 10^{-2}} \right) = \text{Equivalent grams of gasoline}$$

$$\frac{\text{Equivalent grams of gasoline}}{2798 \text{ grams/gallon}} = \text{Equivalent gallons for the test}$$

$$\frac{\text{Equivalent gallons}}{\text{Actual miles driven}^4} = \text{Equivalent mpg}$$

% ELECTRICAL ENERGY

$$\left(\frac{\text{kW-hrs of electrical energy}}{\text{kW-hrs of gasoline energy} + \text{kW-hrs of electrical energy}} \right) 100 = \% \text{ electrical energy}$$

1. Value provided by W. Rippel of JPL as representative of current technology
2. Value taken from reference 1
3. Conversion factor specified by the Federal Test Procedure
4. Actual miles driven, with a resolution of 0.01 miles, was used because the Taxi's power was inadequate to meet the test profile under certain conditions. This resulted in less miles actually driven than specified by the test's speed-time profile.

3.3 TEST INFORMATION

Since the heat engine-electric hybrid configuration will have exhaust emissions, it was necessary to define emission performance for the work that supported the state-of-the-art report. Tests according to the Federal Test Procedure (FTP) were thus given primary emphasis because they provided an internationally-understood method of reporting both gasoline fuel economy and emissions performance. The widely accepted SAE J227C and J227D cycles were also used to provide performance comparison with electric vehicles. In addition, these cycles are more amenable to analytical treatment than the FTP so J227 data would be useful for future analytical work.

3.3.1 Federal Test Procedure Tests

FTP tests were conducted throughout the 2-1/2 month test period. The variability of the FTP (ref. 1) is recognized, so tests to define the facility repeatability were conducted at intervals throughout the testing activities. Paragraph 5.2.1 describes these repeatability tests in detail. A summary of these results is shown in Table 3-4.

Table 3-4. Test Repeatability

	Repeatability $\pm$ (%)	
	Full FTP Urban Cycle	Hot 505 Cycle
Gasoline fuel economy (mpg)	3	2
Emissions-weight tank fuel economy agreement	5	2
Emissions		
HC	10	5
CO	20	10
NO _x	5	4

Two methods were used to measure fuel economy. The FTP specifies a procedure that is based on emission measurements; JPL also uses a weighing system as an independent check. The values in Table 3-4 show the maximum spread of the data for the baseline configuration over a two month period. Data from two or more tests on a single vehicle configuration were conducted within a few days time and have better agreement.

Only the FTP urban cycle was run; the combination of hot weather in the Los Angeles area during the summer months and limited air conditioning in the test facility did not permit the EPA highway cycle tests to be conducted. Experience early in the program showed that temperatures within the vehicles, particularly the torque converter fluid and in the electronics area, were very near the maximum limits specified by VW. The additional heat load of the highway cycle would certainly have caused the temperatures to exceed these limits. Accordingly, all references to the FTP in this report assume the urban driving cycle.

3.3.2 SAE J227C and J227D Tests

These tests were conducted near the end of the test program. A series of tests that included several inertia weights and different speed settings of the engine On/Off mode would have been desirable, but time limitations precluded getting all the desired data.

3.3.3 Other Considerations

Several other factors entered into the testing program. The most apparent was the combination of the value of the vehicle and its unfamiliarity to JPL personnel. The vehicle was insured for \$400,000; its maintenance was dependent on the VW project engineer who accompanied the vehicle for the first 45 days of testing. After this period, he returned to West Germany for his scheduled vacation and so was unavailable for even phone conversations. Testing continued, but conservative approaches were used at all times since a mistake could make the vehicle useless for the remainder of the lease period. Tests were therefore limited to those that could be conducted with minimum risk while obtaining the maximum information concerning the vehicle's energy performance

3.3.4 Reporting Sequence

The tests obtained both energy (gasoline weight and battery electrical power) and emissions data. Even though the emissions data are available, this section emphasizes energy considerations and only reports the emission data. This is necessary because the scope of the test program did not permit the complex work necessary to thoroughly investigate emissions parameters. In addition, the vehicle characteristics discussed in Section 4 makes it probable that the Taxi's emission performance does not represent the state-of-the-art nearly as well as does its energy performance. Accordingly, the emission data are reported but have relatively little discussion.

A baseline configuration of the Hybrid mode, 1.2 sec throttle time constant, 230 amps motor current, and 3500 lb inertia weight was established for the Taxi. This configuration was defined by discussions with the VW Project Engineer and from early test data. In particular, the Hybrid mode and 1.2 sec time constant provided the best driving characteristics; this was important for the repeatability tests discussed in Paragraph 5.2.1.

As discussed, previously the test program included two types of tests and three different combinations of test parameters. Test results of general interest include energy economy, emissions, and range. This number of divisions in the data makes it necessary to subdivide this section in as clear a manner as possible. Since the test type (FTP or SAE J227a) is probably the division of interest to most readers, test type will be used as the major subdivision of this section. Paragraphs 3.4 and 3.5 will thus deal with these test types. The engine operating mode, either Hybrid or On/Off, has the dominant affect on energy performance so the next subdivision will concern the two engine operating modes. The affect of inertia weight and throttle time constant will be discussed for both engine modes. The VW Bus tests are included in Paragraph 3.6.

3.4 FEDERAL TEST PROCEDURE TESTS

There were 18 successful Federal Test Procedure (FTP) tests conducted during the 2-1/2 month test period. Table 3-5 shows the number of tests conducted for each test configuration.

The average data for these tests of each configuration are shown in Figure 3-1. The abscissa defines the ratio of electrical energy to the total energy required for a test; the ordinate includes both gasoline and electrical energy in the "Equivalent MPG" values.

For this section, a set of bar graphs shows the energy and emission performance for each test configuration. These graphs include gasoline energy; battery power; and NO_x, CO, and HC emissions (weighted grams per mile). Gasoline consumption is based on weigh tank data and is stated in mpg units. Battery power for these graphs is defined as the net battery watt-hours during a test, and is the difference between the measured charge and discharge power. The battery power data in these bar graphs included a battery efficiency of 77 percent for the charge/discharge during a test. The energy needed to restore the batteries to their initial charge is included in all the Equivalent MPG and electrical energy ratio values for the plots with the format of Figure 3-1. This shows the average results of the FTP tests as a reference for the rest of this section.

Table 3-5. Federal Test Procedure Tests

Mode	Throttle Time Constant (Seconds)	Number of Tests at Different Inertia Weights		
		3500 lb	4000 lb	4500 lb
Hybrid	1.2	5	2	2
Hybrid	2.5	4		
On/Off	1.2	3		2

ID NUMBER	MODE	INERTIA WEIGHT	THROTTLE TIME CONSTANT	ENGINE SPEEDS CUT-IN CUT-OUT	
1	HYBRID	3500	1.2		
2	HYBRID	3500	2.5		
3	HYBRID	4000	1.2		
4	HYBRID	4500	1.2		
5	ON/OFF	3500	1.2	22	19
6	ON/OFF	4500	1.2	22	19
7	ON/OFF	3500	1.2	26	21

1 APPLICABLE ONLY TO THE ON/OFF MODE

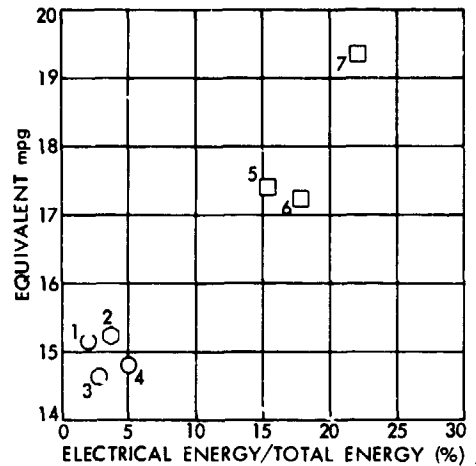


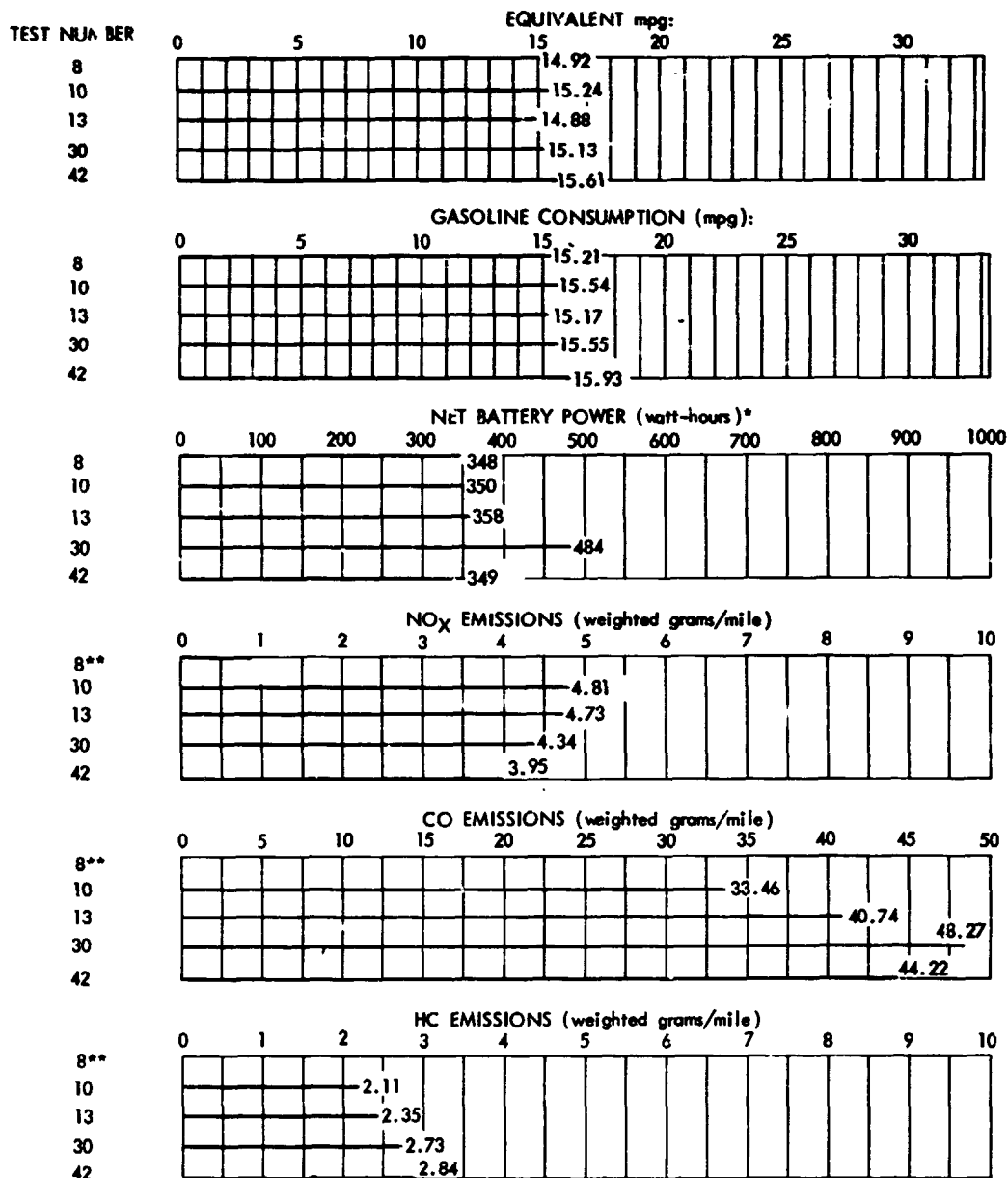
Figure 3-1. Averaged FTP Test Data

3.4.1 Hybrid Mode Data

Energy and emission results from four Hybrid mode test configurations are shown in Figures 3-2 through 3-16.

a. Baseline Configuration - Figure 3-2 shows data for the 15 tests (8, 10, 13, 30, and 42) of the baseline configuration. No emissions data are available for Test 8 because of equipment failure in the emissions measuring system, but the energy data are valid. With the exception of Test 42, the energy data are within ± 2 percent of the average. Test 42 was conducted late in the series. There was a severe backfire one day prior to the test, but there is no evidence of any unusual characteristics in this test. Figure 3-3 shows the energy data in the same format as that used for the average

MODE: HYBRID
 THROTTLE TIME CONSTANT: 1.2 sec
 INERTIA WEIGHT: 3500 lb



* MEASURED CHARGE AND DISCHARGE BATTERY POWER PLUS BATTERY EFFICIENCY OF 0.77, OR

$$\text{NET BATTERY POWER} = \frac{\text{DISCHARGE} - \text{CHARGE}}{0.77}$$

** NO EMISSIONS DATA FROM TEST 8 BECAUSE OF EQUIPMENT FAILURE

Figure 3-2. Test Results for Baseline Configuration

900-851

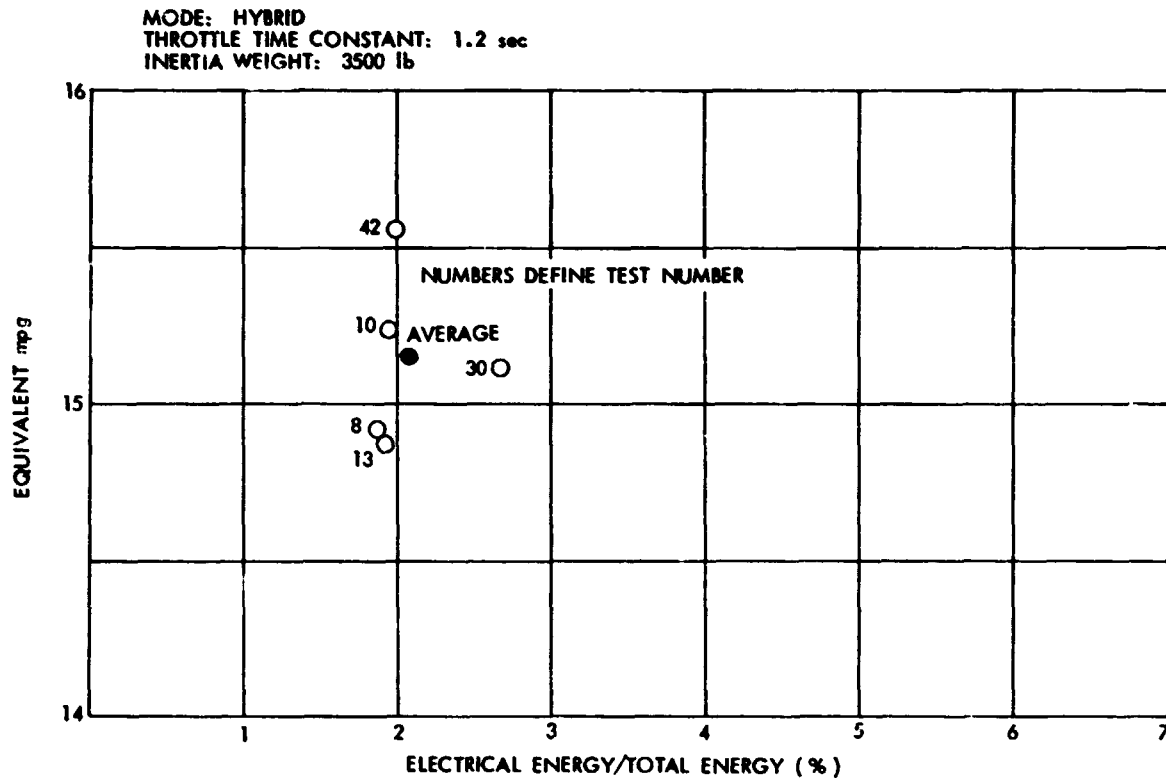


Figure 3-3. Graph of Baseline FTP Test Data

data of Figure 3-1. Since the electrical energy accounted for only 1.5 percent of the total energy for the test, a small deviation in the battery power (either charge or discharge) can cause a significant shift in the abscissa value of Figure 3-3. This characteristic is true of all the Hybrid mode tests.

Tests were conducted at inertia weights of 3500 lb, 4000 lb, and 4500 lb. The Taxi's performance was not quite adequate to meet the acceleration of one part of the FTP speed-time profile as shown in Figure 3-4. The greatest lag between the specified and actual acceleration occurred during the ramp from 187 to 204 sec into the transient phase, so this particular segment will be shown for all the test configurations. With the 3500 lb inertia weight, the Taxi's performance was inadequate for about half this ramp as shown in Figure 3-4. The speed lags the specified value by about 1.5 mph in this case. Since this particular acceleration ramp represents the area where the Taxi's performance lagged the FTP the greatest amount, it will be used as a reference for all configurations.

The dip at 175 sec in Figure 3-4 was caused by driver error. This particular section of chart was selected to show a relatively large error. The throttle time constant made the Taxi rather difficult to drive to match the FTP driving cycle when compared to other cars. As an example, the driver used for all the Taxi tests was able to closely match the driving cycle with few deviations with either a conventional VW Bus or a Chevrolet.

b. 2.5 Second Throttle Time Constant - The next data set shows the effect of changing the throttle time constant from the baseline configuration value of 1.2 sec to 2.5 sec. With this change, the throttle position will lag the accelerator pedal input signal to a greater degree than that of the baseline configuration. Results are shown in Figures 3-5 and 3-6, which correspond to those for the baseline data.

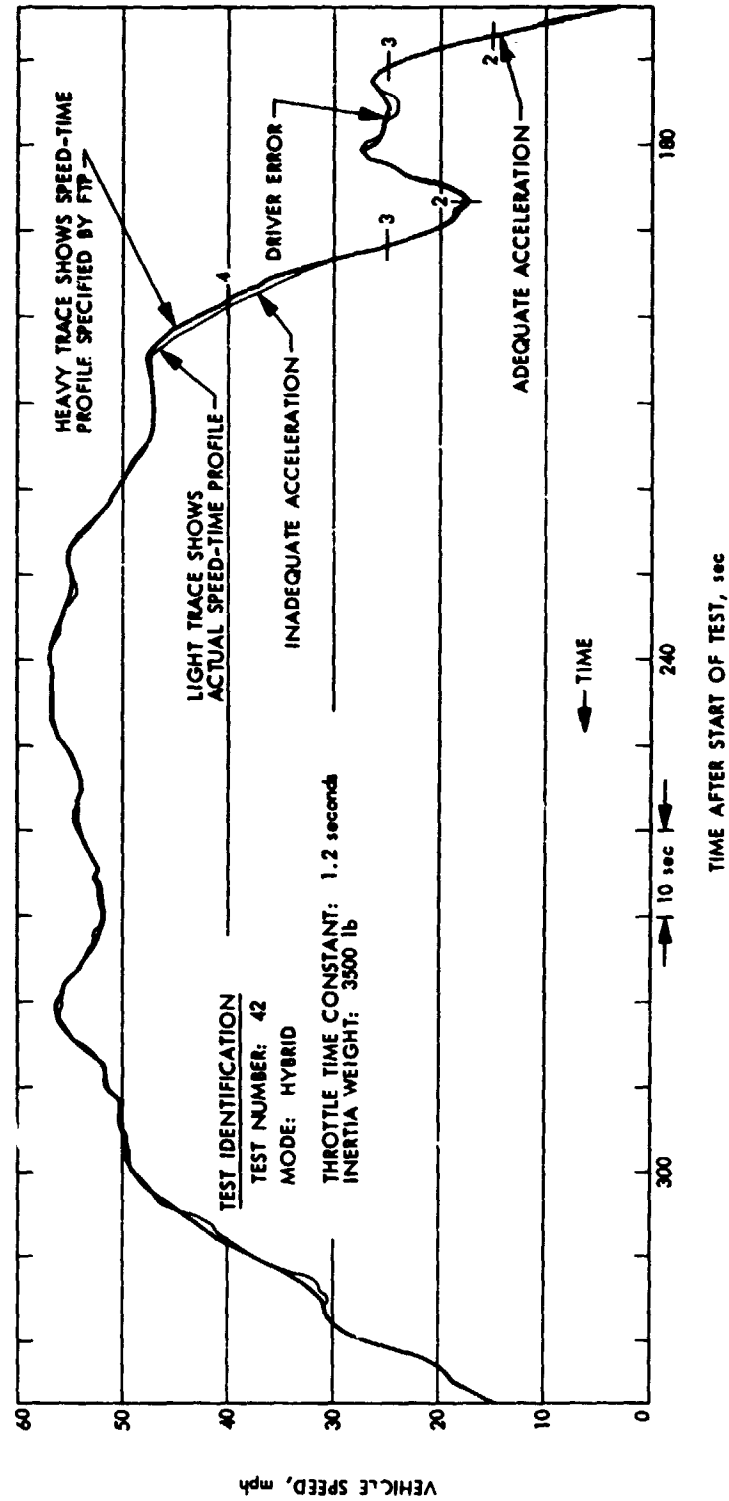


Figure 3-4. Typical FTP Speed Time Profile Chart for Baseline Tests

900-851

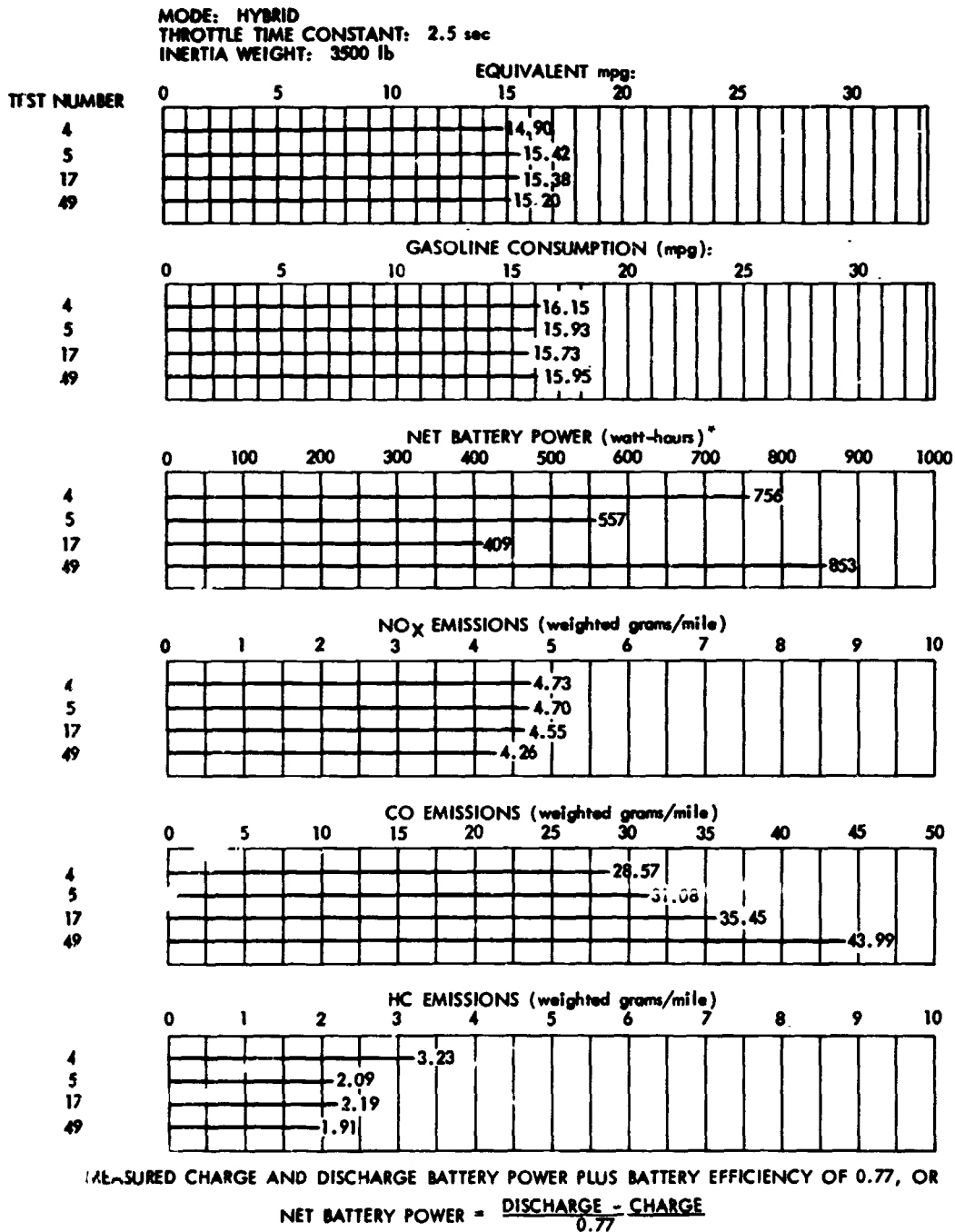


Figure 3-5. Test Results for Baseline Configuration Except for 2.5 Sec Throttle Time Constant

900-851

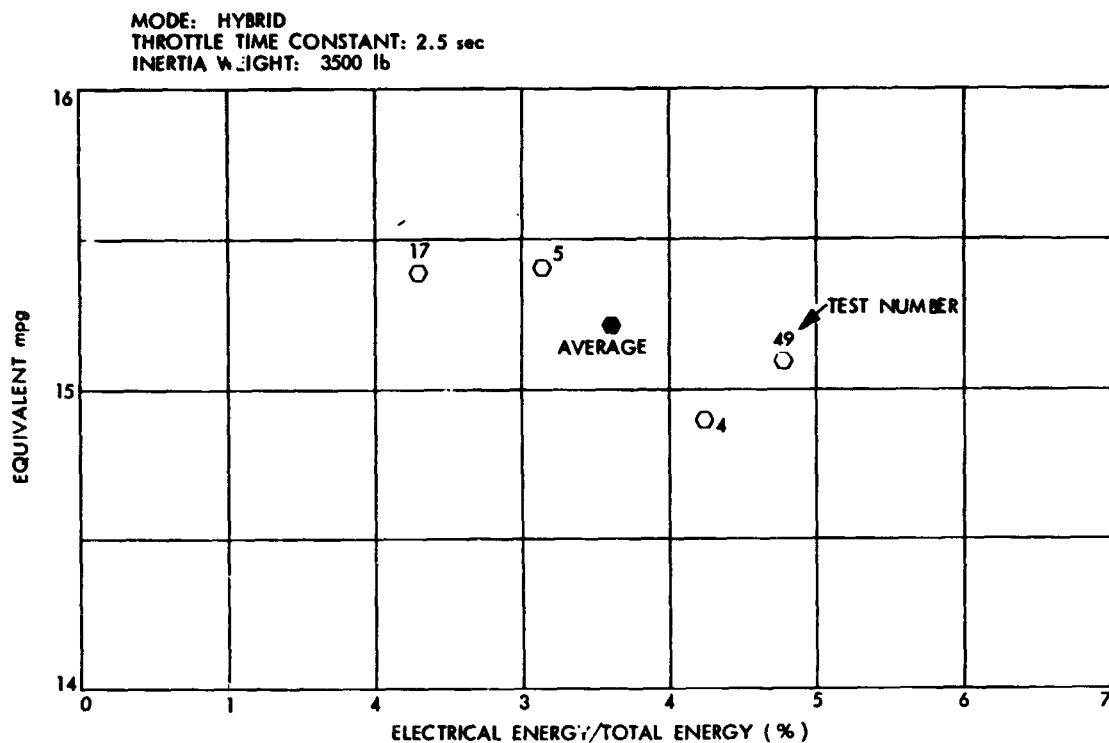


Figure 3-6. Graph of 2.5 Sec Throttle Time Constant Tests

The speed lag in the vicinity of 200 sec shown in Figure 3-7 is slightly less than that for the 1.2 sec throttle delay shown in Figure 3-4. This is caused by a too rapid acceleration at the start of the ramp. There should be no difference between the 1.2 and 2.5 sec test configurations after the maximum power condition, when the throttle has reached its maximum opening, is reached. The driver's difficulty in controlling the speed-time profile with the 2.5 sec throttle delay is shown by the trace during the initial ramp (about 170 sec) and at nearly steady-state speeds after the accelerations were completed (about 240 sec). The actual speed time trace of the other Hybrid mode tests during the initial ramp closely follows the FTP profile (Figures 3-4 and 3-10).

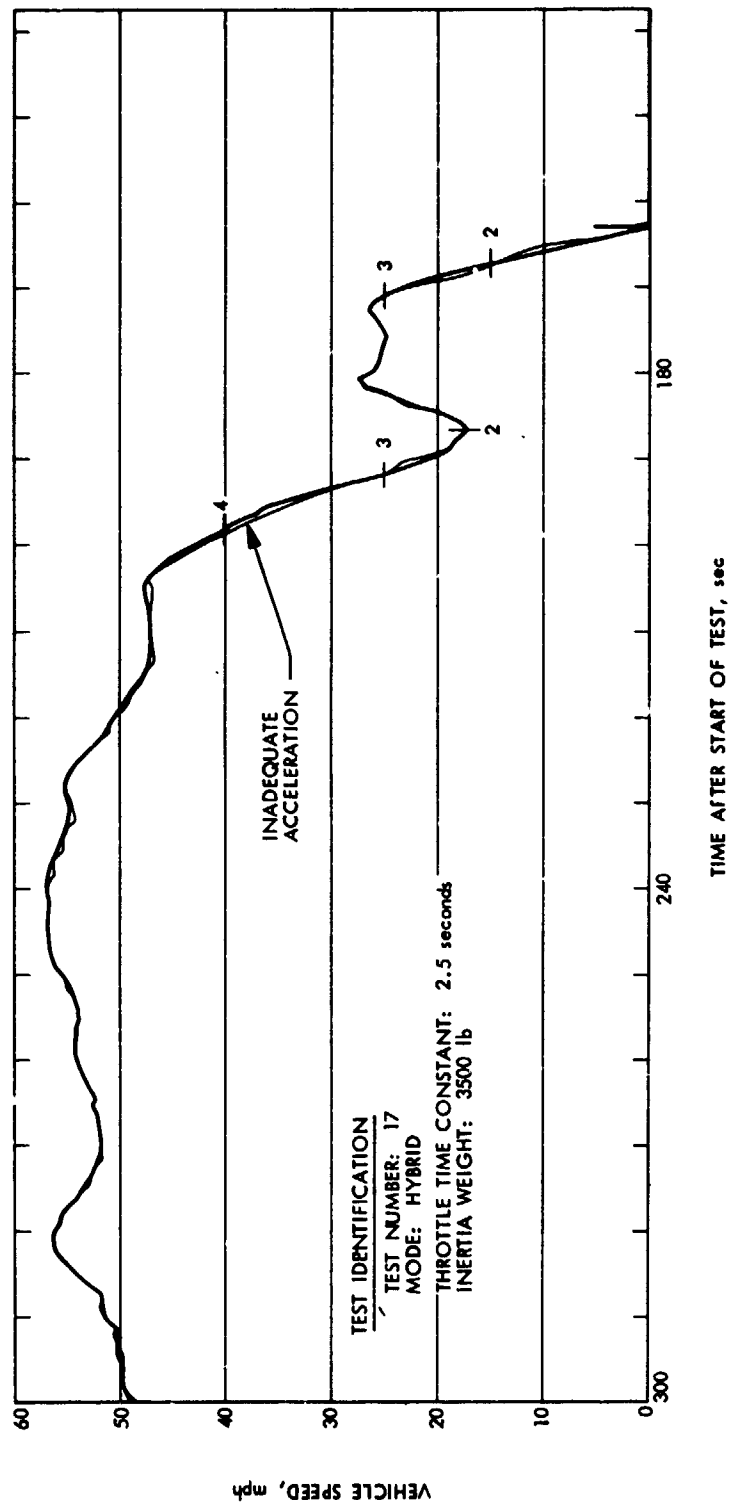


Figure 3-7. Typical FTP Speed-Time Profile Chart for 2.5 Sec Throttle Time Constant

c. 4000 Pound Inertia Weight - The effect of changing the inertia weight from the 3500 lb baseline value to 4000 lb is shown in Figures 3-8 and 3-9. Note that the throttle time constant is 1.2 sec, so these two tests should be compared to the baseline configuration shown in Figures 3-2 and 3-3. Since the two 4000 lb tests showed good repeatability, no further tests were conducted.

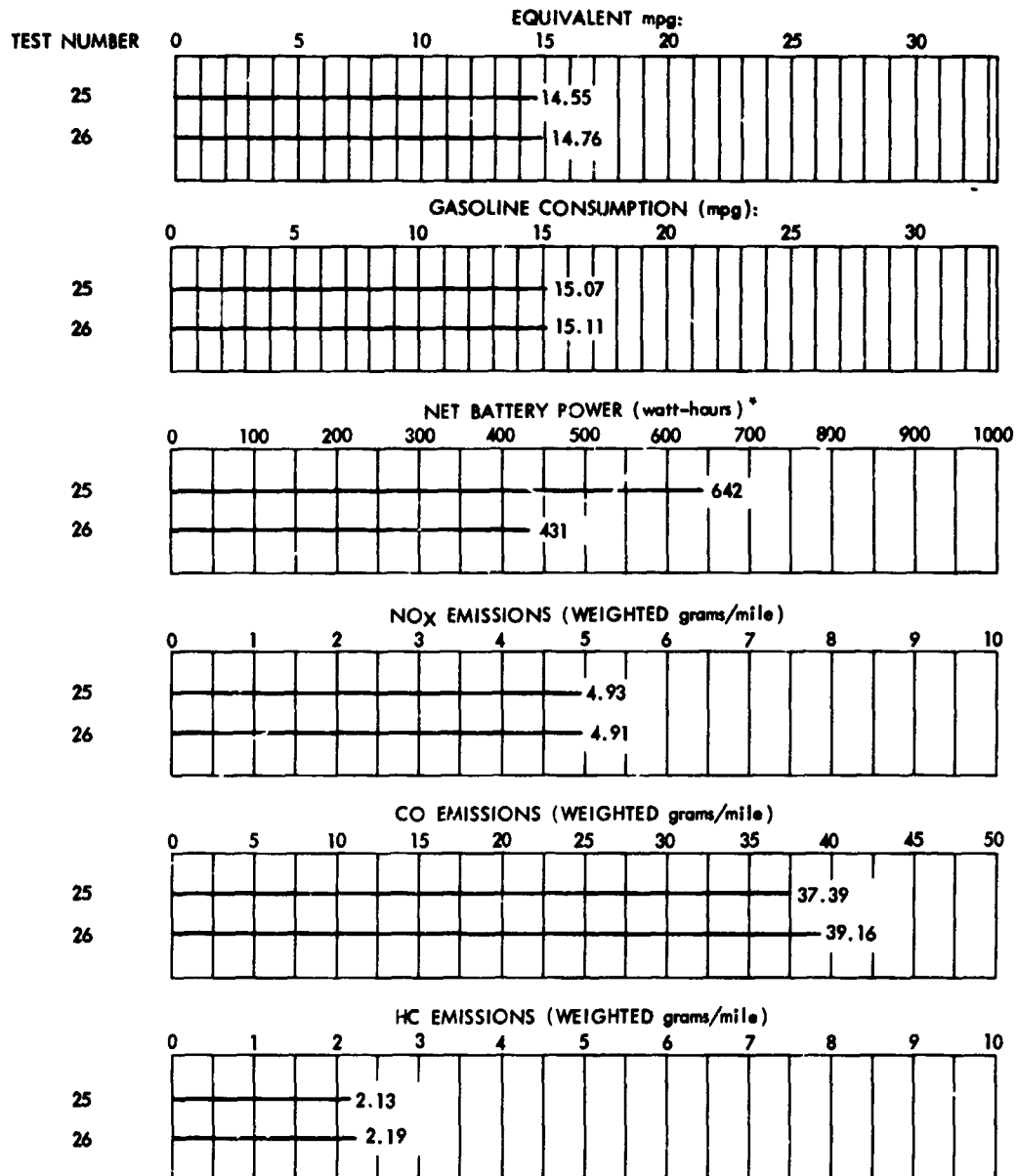
The acceleration with the 4000 lb inertia weight, shown in Figure 3-10, is very similar to that of the 3500 lb inertia weight of Figure 3-4. This indicates no substantial differences between the adherence to the FTP speed-time profile for the 3500 lb and 4000 lb configurations. Since these two tests were run on consecutive days, repeatability is good. The 211 watt-hour difference in the battery power represents less than 0.8 percent of the total energy required for a test, yet causes a significant shift in the abscissa value of Figure 3-9.

d. 4500 Pound Inertia Weight - Two additional tests provide another point for the inertia weight effect. The throttle time constant remains at 1.2 sec. Figures 3-11 and 3-12 show this data. These tests were also run on consecutive days so the repeatability is similar to that of the 4000 lb tests.

A review of the speed-time profile of Figure 3-13 shows that the Taxi definitely had inadequate power to maintain the accelerations of the FTP with the 4500 lb inertia weight. This was particularly true of the ramp near 205 sec. Note that the Taxi's performance was slightly below the specified profile during the time at about 170 sec, although this part of the trace was followed with the 4000 lb inertia weight. The total distance actually travelled was about 3.52 miles instead of the 3.6 miles specified by the FTP, which is another indication of the lack of adequate acceleration at this inertia weight. Since all data use the actual distance travelled, not the nominal FTP distance, the reported energy economy values consider the shorter distance.

900-851

MODE: HYBRID
THROTTLE TIME CONSTANT: 1.2 sec
INERTIA WEIGHT: 4000 lb



* MEASURED CHARGE AND DISCHARGE BATTERY POWER PLUS BATTERY EFFICIENCY OF 0.77, OR
NET BATTERY POWER = $\frac{\text{DISCHARGE} - \text{CHARGE}}{0.77}$

Figure 3-8. Test Results for Hybrid Mode 4000 lb Inertia Weight

900-851

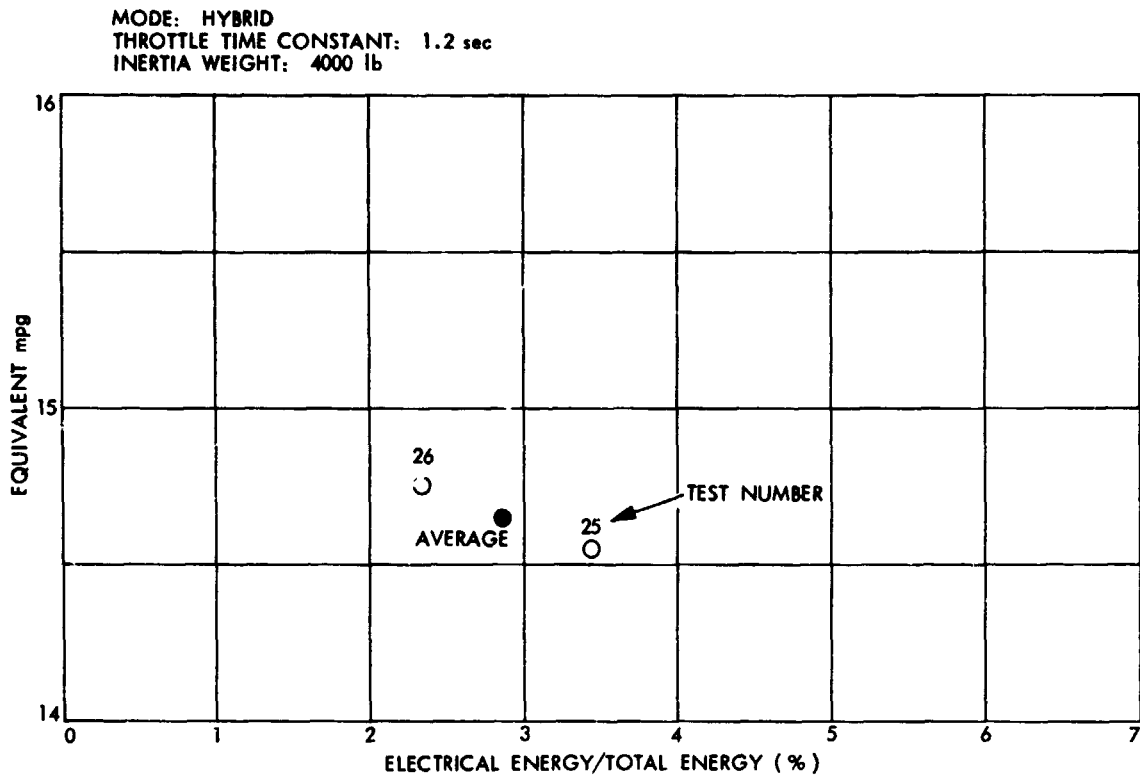


Figure 3-9. Graph of Hybrid Mode 4000 lb Inertia Weight Tests

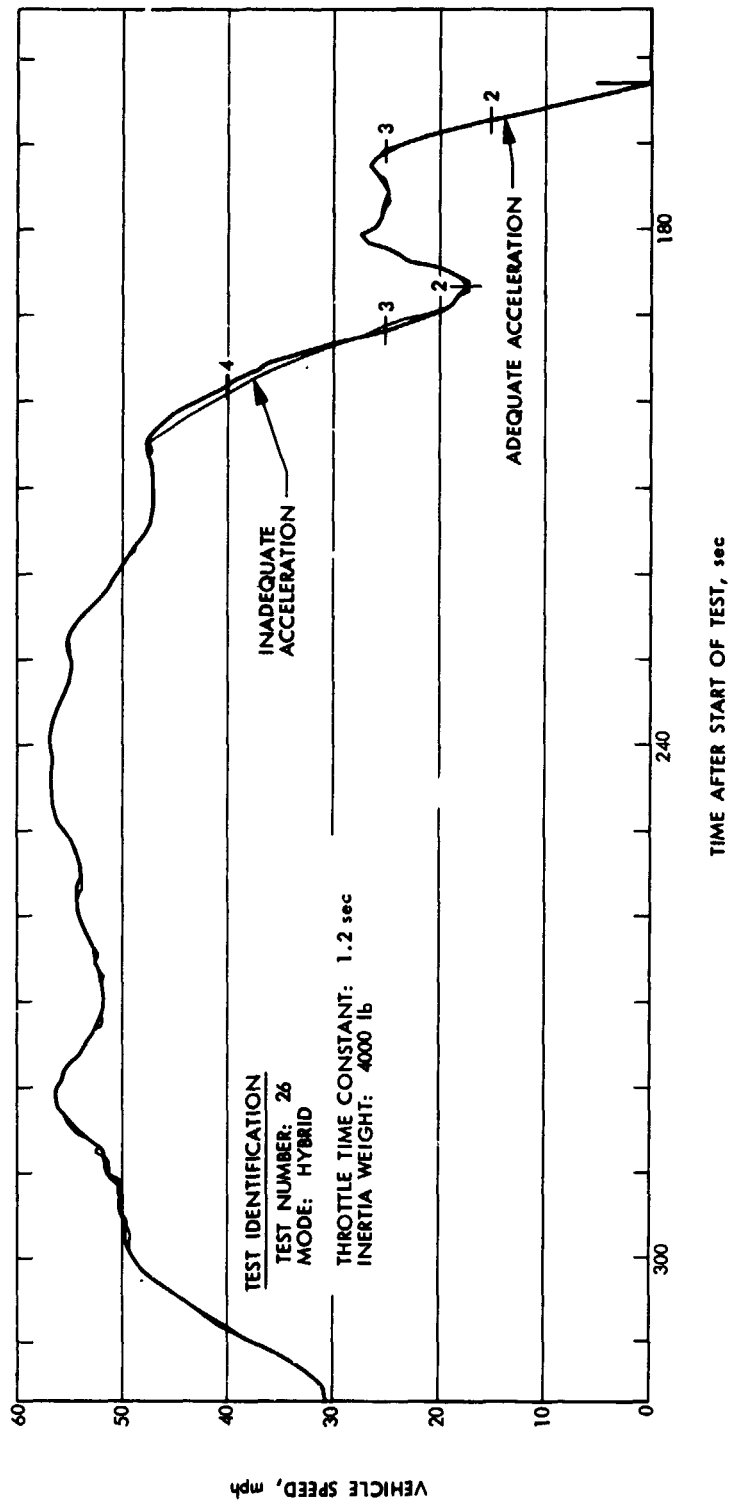
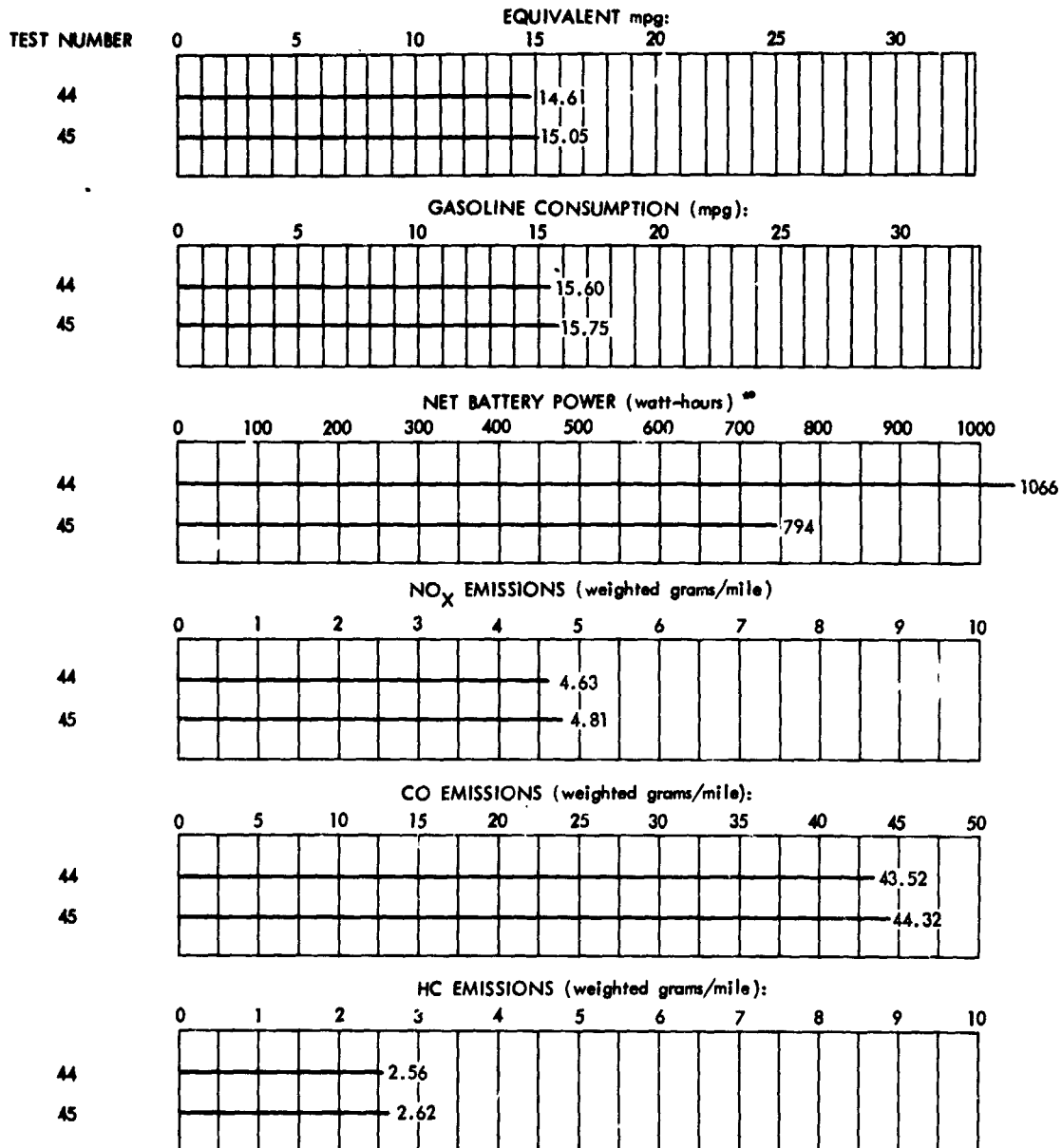


Figure 3-10. Typical FTP Speed-Time Profile Chart for Hybrid Mode 4000 lb Inertia Weight Test

900-851

MODE: HYBRID
THROTTLE TIME CONSTANT: 1.2 sec
INERTIA WEIGHT: 4500 lb



* MEASURED CHARGE AND DISCHARGE BATTERY POWER PLUS BATTERY EFFICIENCY OF 0.77, OR
 NET BATTERY POWER = $\frac{\text{DISCHARGE} - \text{CHARGE}}{0.77}$

Figure 3-11. Test Results for Hybrid Mode 4500 lb Inertia Weight

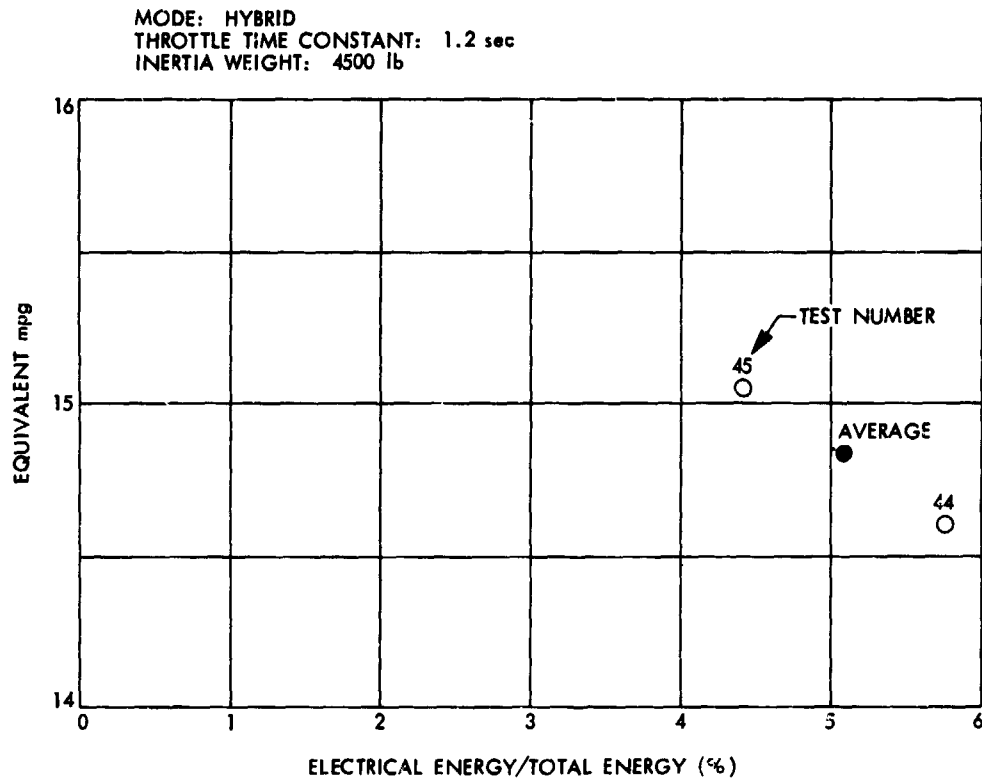


Figure 3-12. Graph of Hybrid Mode 4500 lb Inertia Weight Tests

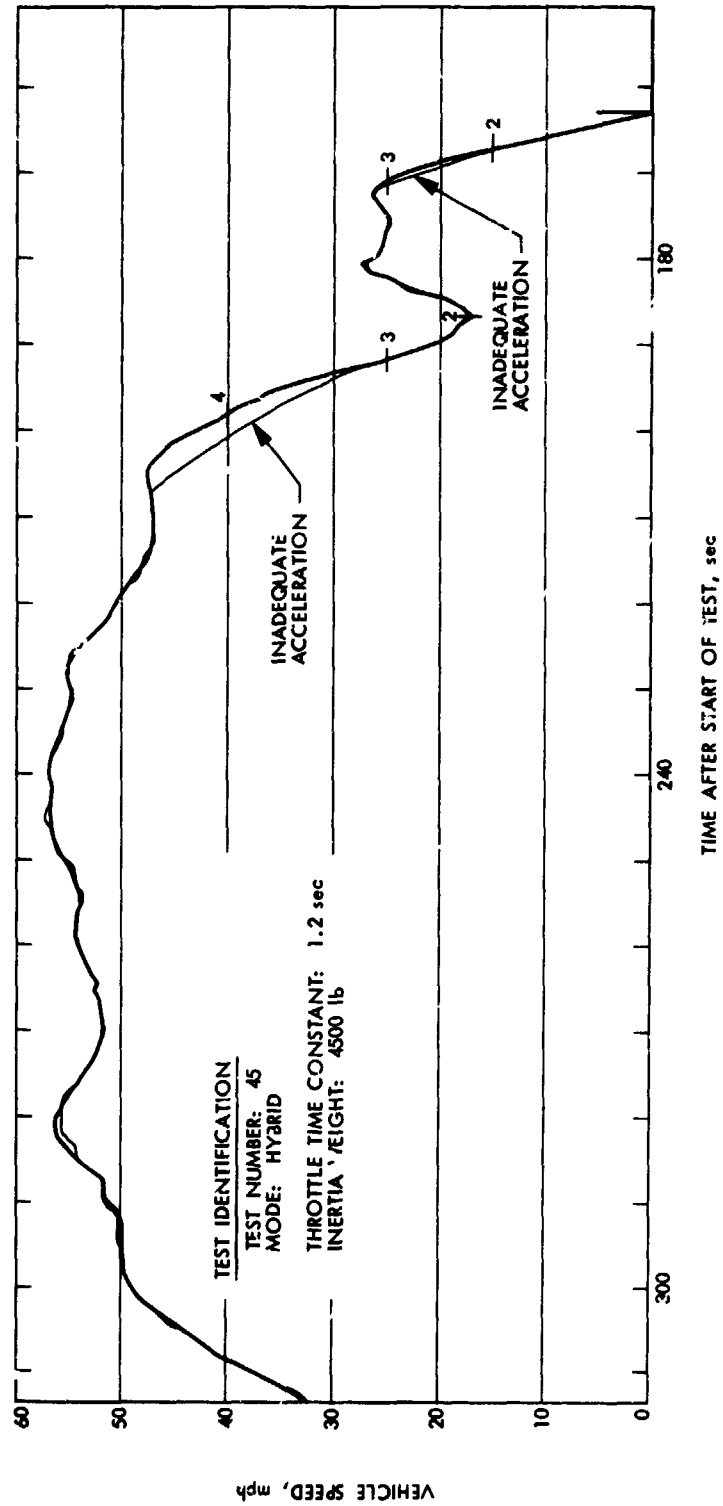


Figure 3-13. Typical FTP Speed-Time Profile Chart for Hybrid Mode 4500 lb Inertia Weight Tests

e. Test Repeatability - Since test results over a 2-1/2 month period using a test cycle with known variability problems (ref. 1) are used to compare energy performance, it is necessary to consider the variability of the data shown in the previous figures. The variability can best be estimated by reviewing the results of the two data sets for the baseline configuration and those with only the throttle time constant changed. These 9 tests (5 baseline and 4 with the 2.5 sec throttle time constant) were conducted throughout the 2-1/2 month test period. Since the throttle time constant had a relatively small affect on the energy performance, both data sets have similar characteristics. The energy data for these two configurations are plotted against time in Figure 3-14 to show the energy repeatability during the test period. The two or three tests for other configurations were generally conducted within a few days so their energy data spread is typically ± 1 percent. The data spread of Figure 3-14 thus provides a good indication of the probable variation in the energy data for all tests including those in the On/Off mode discussed in the next section. A reasonable value is ± 3 percent; all the results for the 9 tests are within this range.

f. Summary of the Hybrid Mode Data - The energy economy and emissions performance for the four Hybrid mode test configurations are shown in the bar graphs of Figure 3-15. The energy economy is also shown in the graph format of Figure 3-16. In this graph, the points are the averages of the previous graphs; the maximum spread of the tests used for each average is also shown.

In all the hybrid configurations, the gasoline energy provides the dominant energy source. The electrical energy used during a test is on the order of 1-1/4 percent (3500 lb) to 3-3/4 percent (4,000 lb) of the total energy; these amounts include the battery recharge energy so the amount actually used during the test is less by the recharge efficiency. Since the gasoline energy is dominant, the energy variation caused by the scatter of the battery power data will have a relatively small effect on the overall energy results.

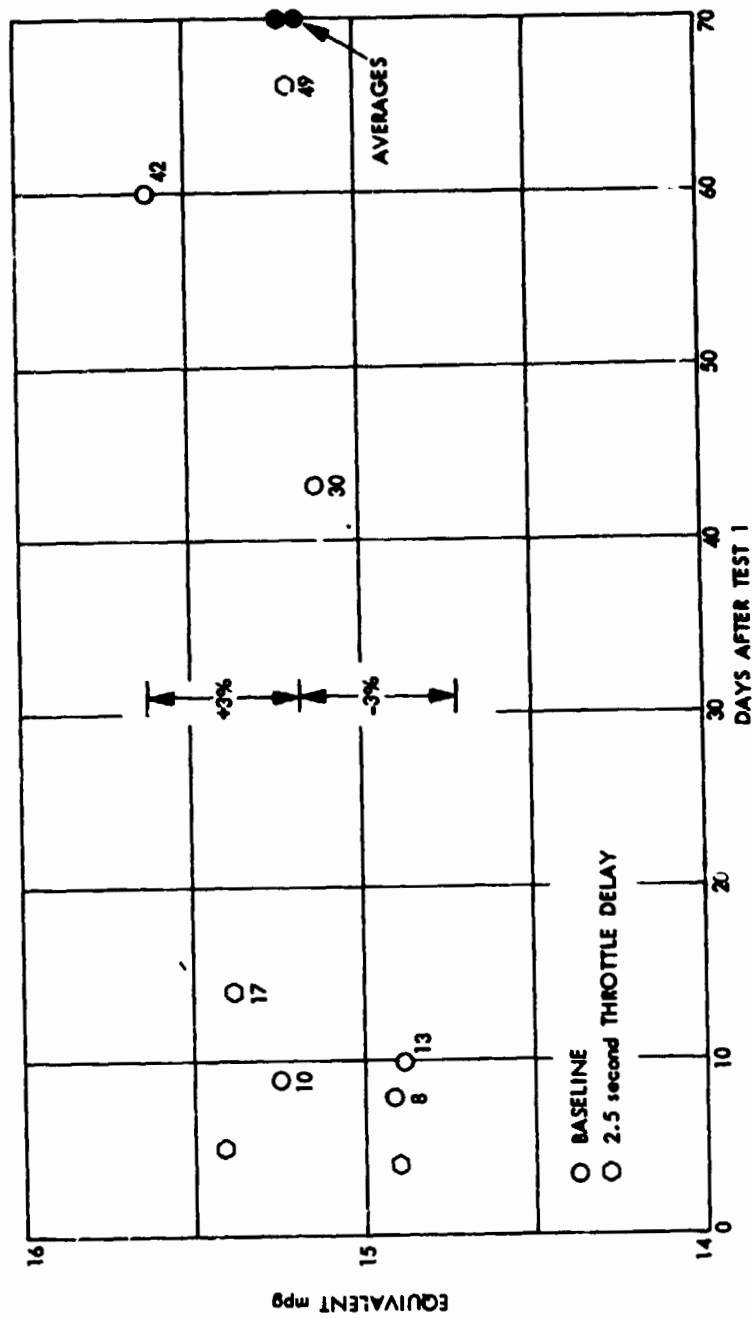
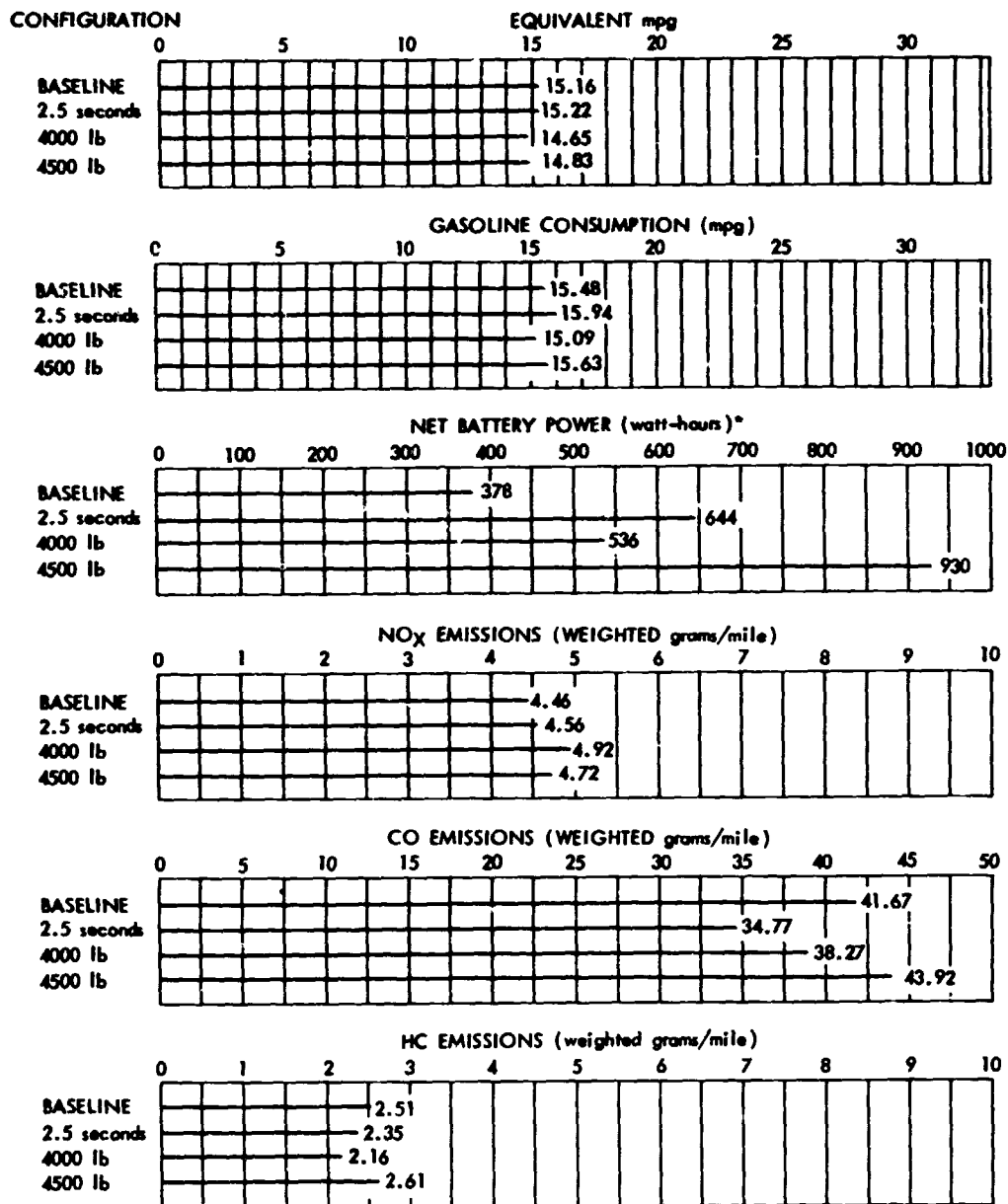


Figure 3-14. Data Variability Throughout the Test Period

MODE: HYBRID 1.2 AND 2.5 sec
 THROTTLE TIME CONSTANT: 1.2 AND 2.5 sec
 INERTIA WEIGHT: 3500 lb, 4000 lb, 4500 lb



* MEASURED CHARGE AND DISCHARGE POWER PLUS BATTERY EFFICIENCY OF 0.77, OR

$$\text{NET BATTERY POWER} = \frac{\text{DISCHARGE} - \text{CHARGE}}{0.77}$$

Figure 3-15. Summary of Hybrid Mode Tests

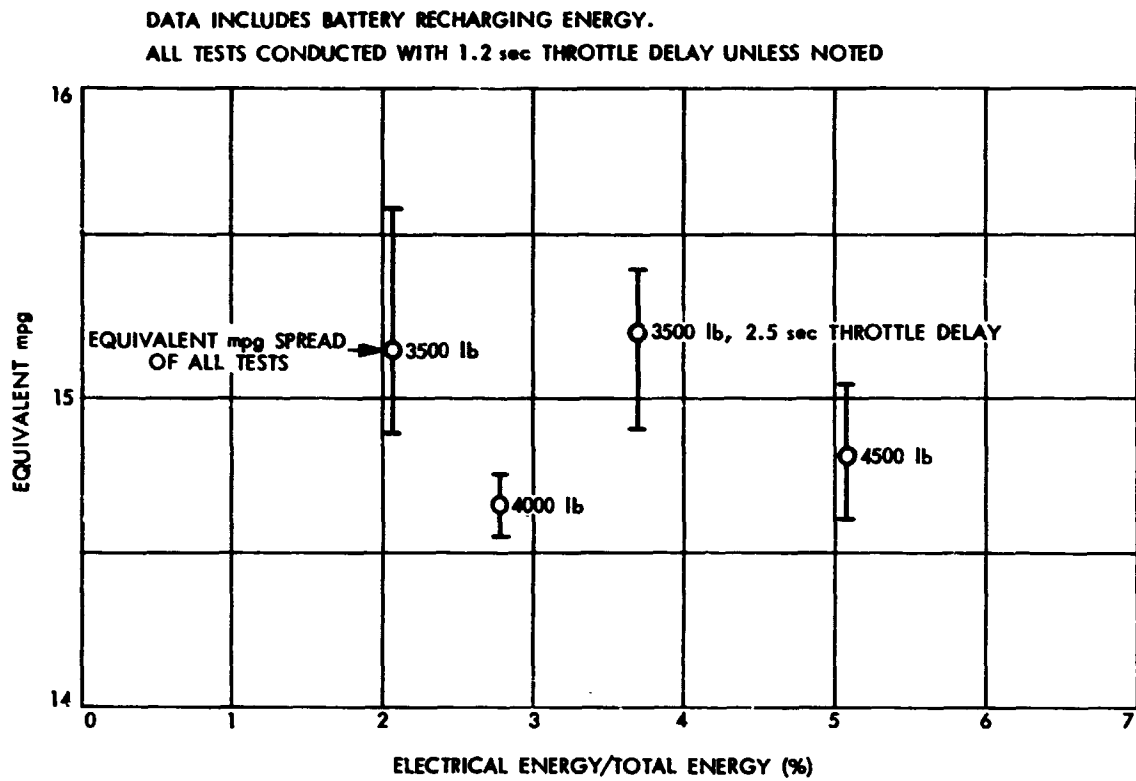


Figure 3-16. Hybrid Mode Energy Economy

Perhaps the only clear trend of the data in Figures 3-15 and 3-16 is the general direction of the tradeoff between the gasoline consumption and battery power discharge between the baseline (1.2 sec throttle time constant) and the 2.5 sec time constant tests. As this time constant is increased, the engine's throttle will open more slowly so the motor must provide more power to accelerate the vehicle. The electrical energy will thus increase while the gasoline consumption decreases. The gasoline decreased 0.80 kW-hr while the electrical power increased 0.27 kW-hr.

The energy differences between the three inertia weights need considerable analysis to explain the values shown in Figures 3-15 and 3-16. Results of a program that predicts vehicle performance over the FTP cycle show that an energy increase of about 9 percent would be expected when the inertia weight was changed from 3500 lb to 4000 lb for a vehicle with the Taxi's general characteristics. Other references (ref. 3 and 4) agree with the 9 percent value. A similar magnitude would be required when the inertia weight was further increased to 4500 lb. These values assume that the vehicle actually followed the entire FTP profile. This was not the case for the 4500 lb configuration, as shown in Figure 3-13, but the speed-time trace followed the specified profile for all but 49 of the 1874 sec driving time, or 2.6 percent. The trace of Figure 3-13 shows the most serious deviation; no other part of the profile has a deviation that approaches the one shown in Figure 3-13. Both the Cold Transient and Hot Transient phases of the FTP cycle include this identical profile, so this error is included twice. However, the traces of Figures 3-4 (3500 lb) and 3-10 (4000 lb) are essentially the same during these ramps so acceleration performance differences should not have a large influence on the energy required for the FTP cycle for these two inertia weights.

The differences in the emission performance for the four hybrid configurations are within normal test-to-test variations in the FTP. Perhaps the decrease in the CO emissions (16.5 percent) and HC (6 percent) between the 1.2 and 2.5 sec throttle time constant configurations represent the effect of the slower throttle opening, but carefully controlled tests (preferably on an engine dynamometer) would be required to verify this. The gradual increase in the CO emissions shown in Figures 3-2 and 3-5 may represent a change in the Taxi's

engine or throttle control mechanism. Nine Hot 505 tests throughout the test period also show an increase in CO emissions, but correlation between the Hot 505 and full FTP cannot be made with the available data.

3.4.2 On/Off Mode Tests

The first attempt to conduct a test in the On/Off mode was made about 2 weeks after the initial tests. Because the VW Project Engineer was uncertain of the performance in this mode, a series of Hot 505 tests were run to investigate the approximate performance and also provide time for driver familiarity. Later tests were concerned with different inertia weights and engine On/Off speed settings.

a. Initial On/Off Tests - The On/Off mode will require considerably more electrical energy than the Hybrid since the engine is not operating at lower vehicle speeds. The difference in the amount of electrical energy is clearly shown by computer plots of battery and motor power for the Hybrid and On/Off configurations. The plot format shows the difference between the power out of the battery and the power into the battery that is provided by charging currents during a test. The difference between the motor power out and motor power in is also shown. No battery or motor efficiencies are included in these plots. In this plot format, the battery power can be identified by its greater magnitude. Time is shown along the X axis. Figures 3-17 and 3-18 are both for a Hot 505 test, so the duration of the actual test period is 505 sec. The short time before the traces move is the time between the start of the data recording process and the actual start of the test. The upper of the two plots shows the instantaneous power during a test, while the lower shows the power integral.

Figure 3-17 shows the electrical power during a Hybrid Hot 505 test; Figure 3-18 shows an On/Off Hot 505 test. The differences between the integral data for the Hybrid and On/Off modes clearly show that the On/Off mode has a greater dependency on electrical power. Since the Hot 505 test includes one period where the vehicle operates in the vicinity of 50 mph, the batteries are charged during this time. This is shown in Figure 3-17 in the time around the 473 sec marking.

900-851

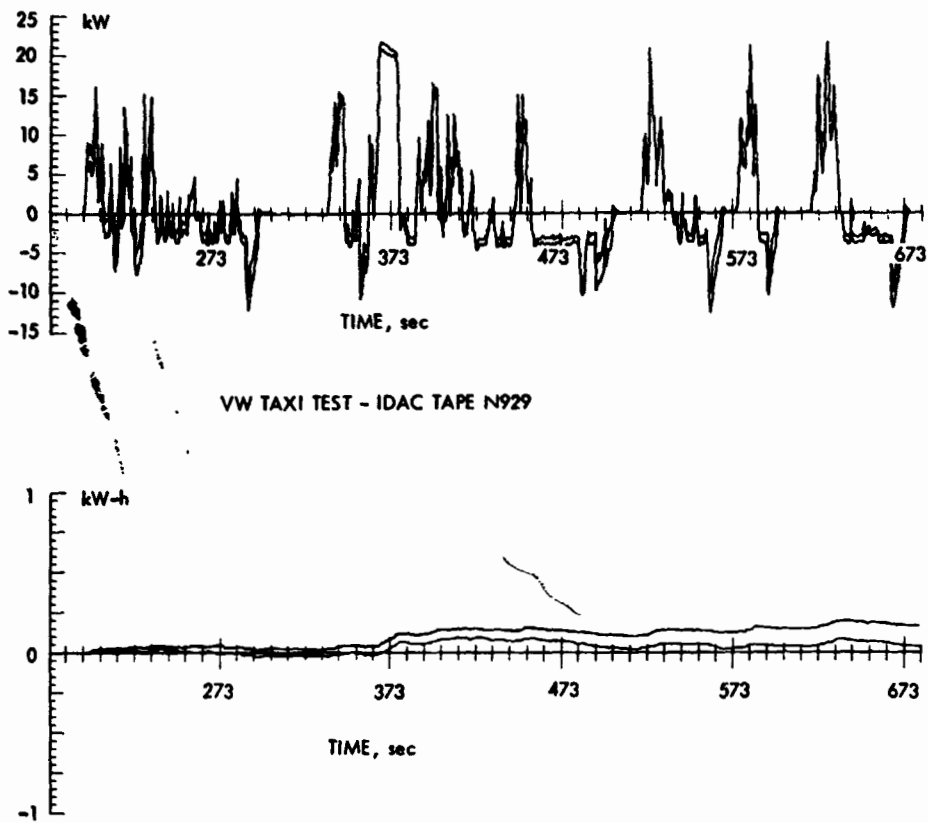
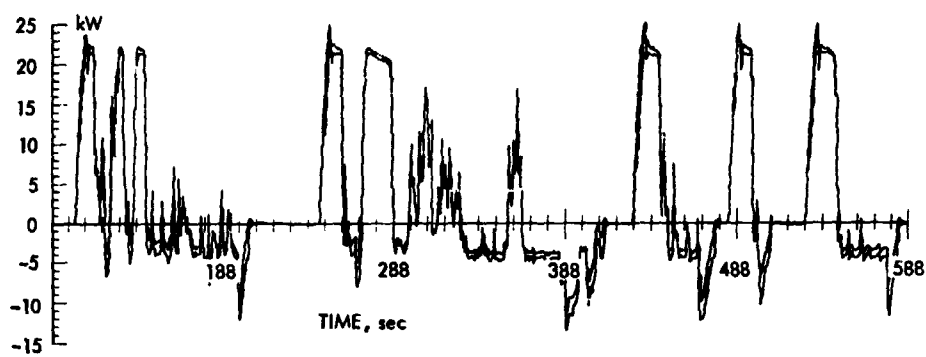


Figure 3-17. Hybrid Mode-Electrical Power Use

900-851



VW TAXI TEST - IDAC TAPE 0032

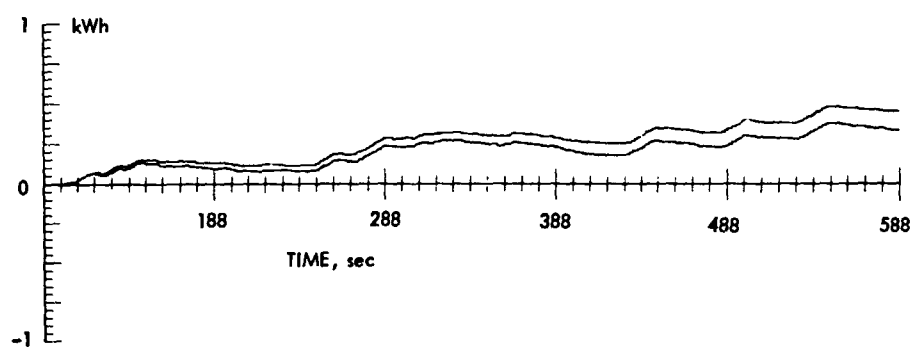


Figure 3-18. On/Off Mode-Electrical Power Use

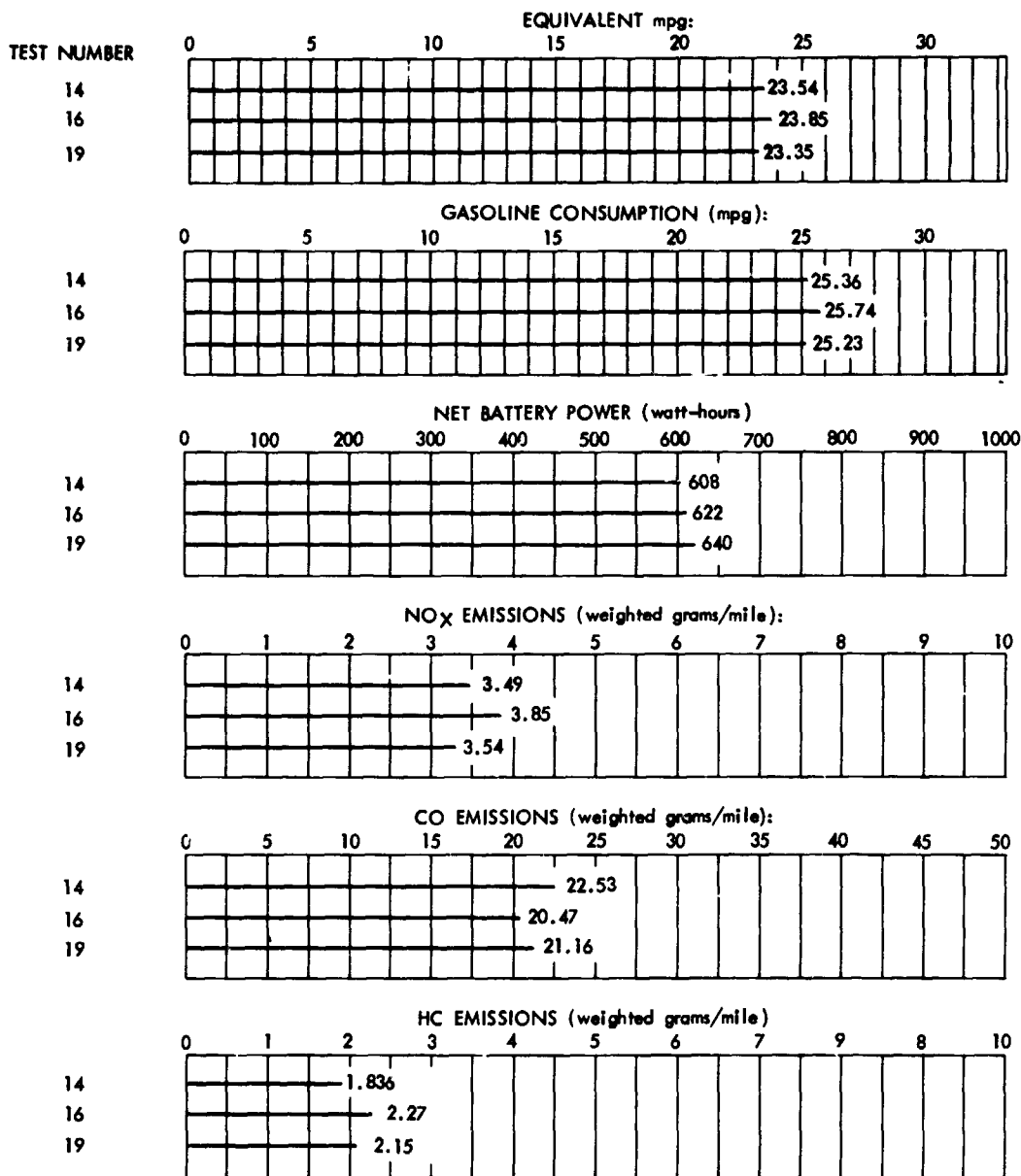
The general characteristics of the On/Off mode were initially determined by Tests 14, 16, and 19. These tests were conducted with engine cut-in and cut-out speeds of approximately 27 and 22 mph. Due to control system characteristics, the cut-in and cut-out speeds varied during the testing cycle. In general, the variations were ± 0.5 mph (cut-in) and ± 1 mph (cut-out) although the cut-out variation appeared to increase to about ± 2 mph at the lower speeds used in the later tests. All these investigatory tests used the Hot 505 Procedure to speed the testing process. The first test in the On/Off mode, Test 14, showed a large reduction in the gasoline consumption and a relatively small increase in the net watt-hours out of the battery. Since the total energy consumed during this test was much less than in the Hybrid mode, additional tests were conducted to verify the results. Figure 3-19 shows the data from three On/Off Hot 505 tests. During the first cycle of Test 16, the driver commented that he was unable to maintain the acceleration required to follow some segments of the FTP driving cycle. The motor current was thus increased from 230 amps to 260 amps during the second and third cycles of Test 16. The same configuration was continued for Test 19. Even with the increased motor current, the Taxi's performance was not inadequate to meet the higher acceleration parts of the FTP driving cycle. Differences between the 230 and 260 amp performance are shown in Figures 3-20 and 3-21.

The difference between the Hybrid and On/Off modes is evident from the three Hot 505 tests shown in Figure 3-22. These tests were conducted at a 3500 lb inertia weight; the throttle time constant and maximum motor current parameters used for the tests are listed. It should be noted that these tests included only the Hot Transient phase of the FTP and so reflect only part of the FTP driving conditions. In particular, the effects of the cold starting mechanism are not included.

900-851

MODE: ON/OFF
THROTTLE TIME CONSTANT: 1.2 OR 2.5 sec¹
INERTIA WEIGHT: 3500 lb
MAXIMUM MOTOR CURRENT: 230 OR 260 amps¹

ENGINE SPEEDS:
CUT-IN: 26.5 mph
CUT-OUT: 22 mph



1. TIME CONSTANTS AND MAXIMUM MOTOR CURRENTS WERE:

TEST	TIME CONSTANT	MOTOR CURRENT
14	1.2	230
16	2.5	230 (FIRST CYCLES), 260 (SECOND AND THIRD CYCLE)
19	2.5	260

* MEASURED CHARGE AND DISCHARGE BATTERY POWER PLUS BATTERY EFFICIENCY OF 0.77, OR

$$\text{NET BATTERY POWER} = \frac{\text{DISCHARGE} - \text{CHARGE}}{0.77}$$

Figure 3-19. Data From On/Off Mode Hot 505 Tests

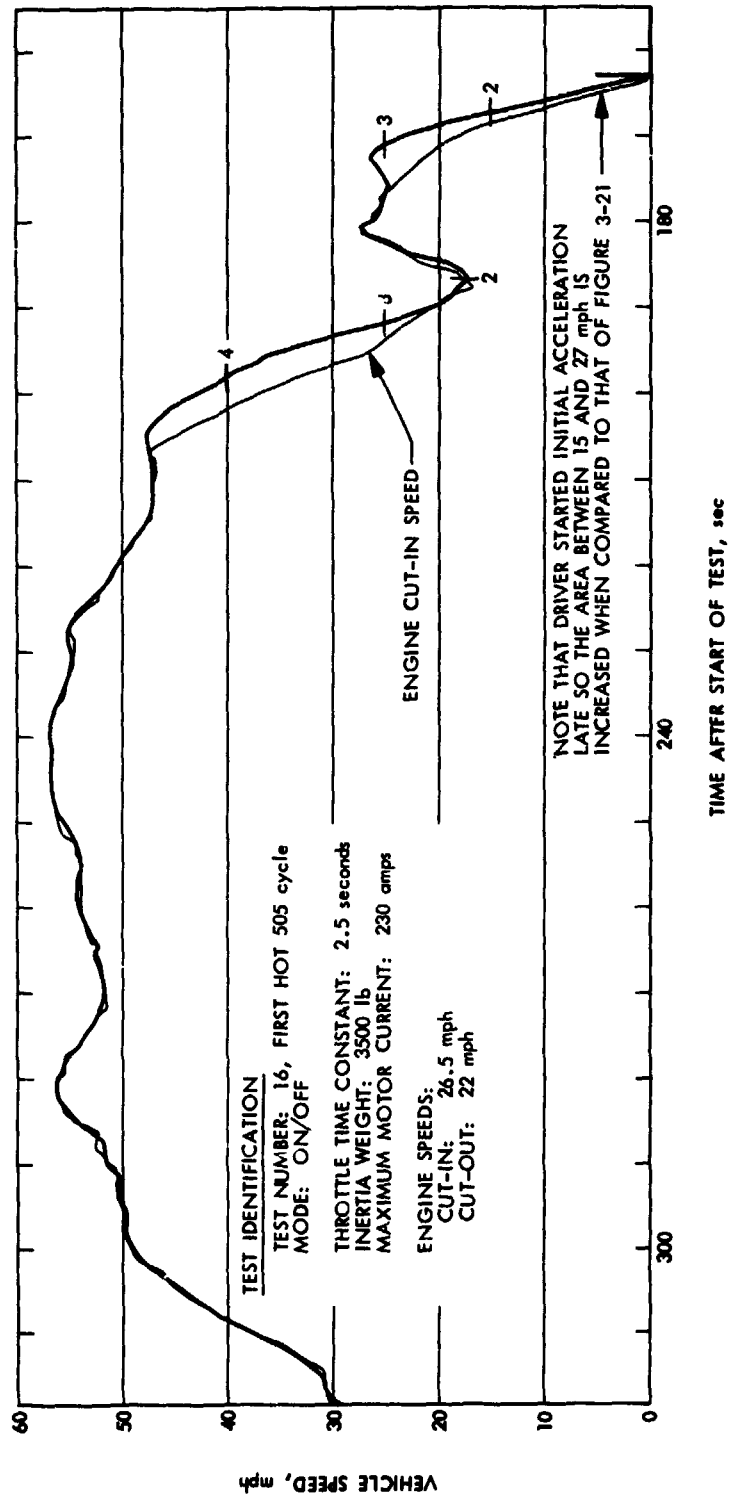


Figure 3-20. On/Off Mode Acceleration Performance With 230 Amp Maximum Motor Current

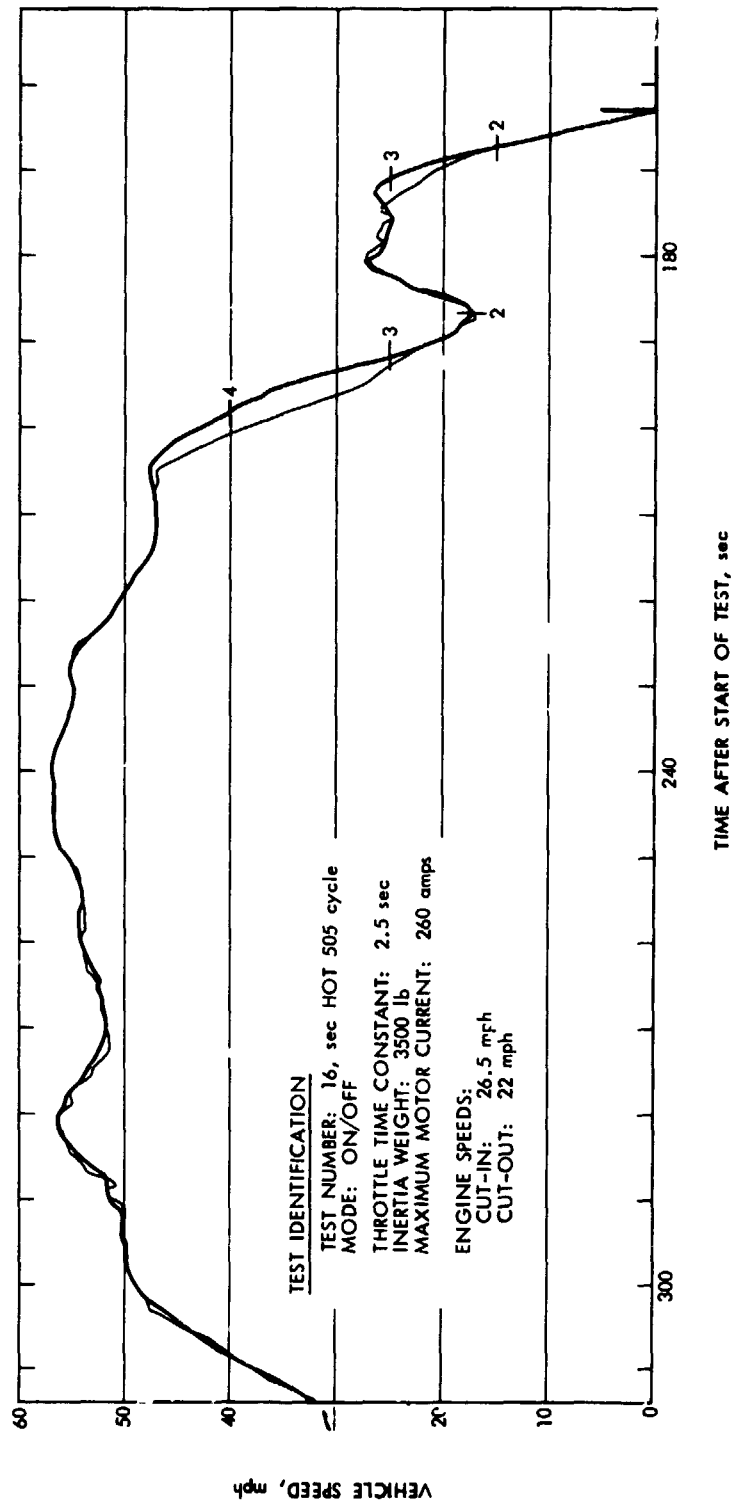
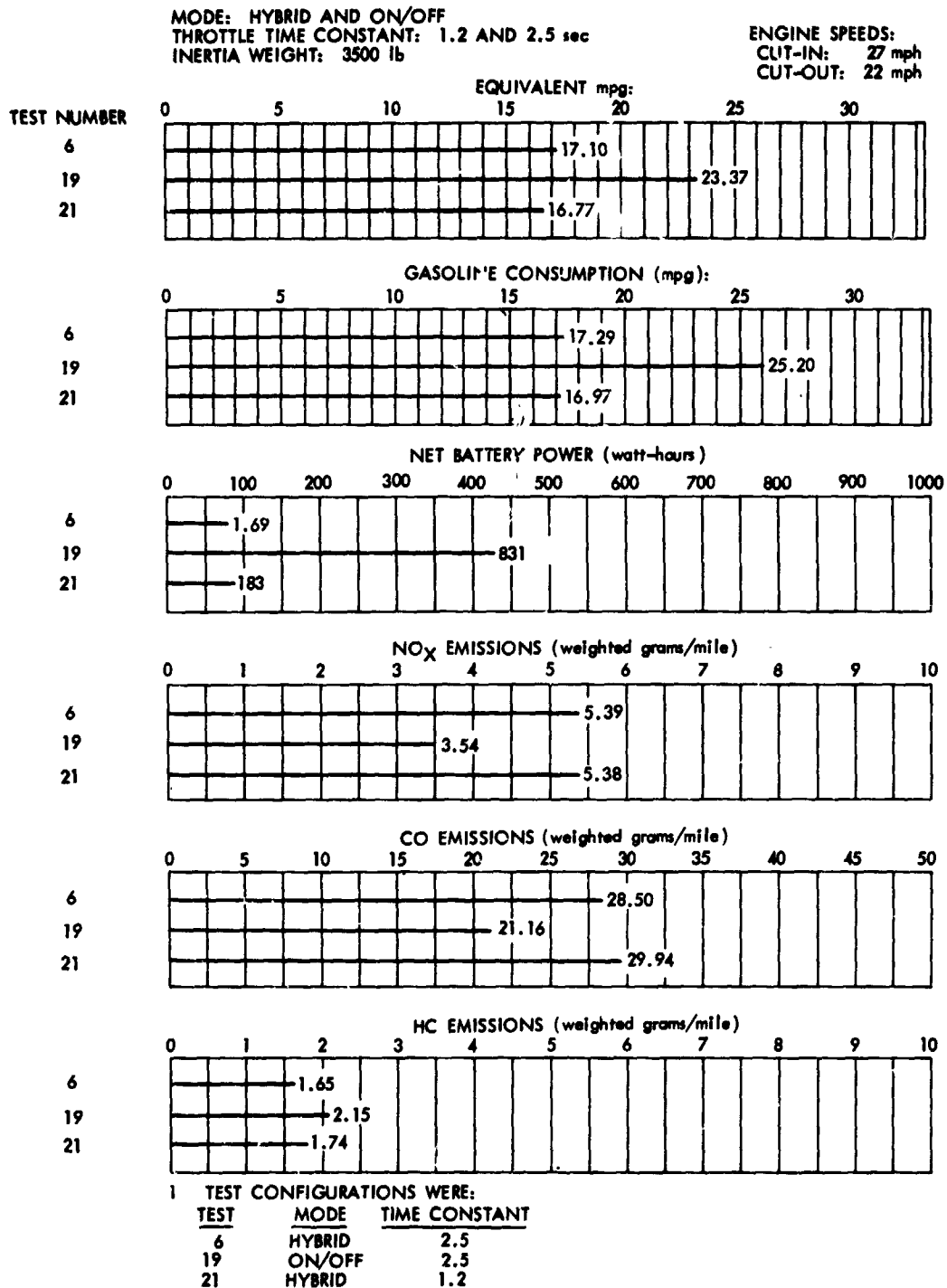


Figure 3-21. On/Off Mode Acceleration Performance With 260 Amp Maximum Motor Current

900-851



* MEASURED CHARGE AND DISCHARGE BATTERY POWER PLUS BATTERY EFFICIENCY OF 0.77, OR
NET BATTERY POWER = $\frac{\text{DISCHARGE} - \text{CHARGE}}{0.77}$

Figure 3-22. Comparison of Hybrid and On/Off Mode Hot 505 Tests

Data from Tests 14, 16, and 19 indicated that it would be difficult for the Taxi to negotiate the entire FTP cycle without exceeding the battery discharge limitations defined by the VW Project Engineer. Accordingly, the first attempt to conduct the On/Off FTP was started with fully charged batteries instead of following the normal procedure of reducing the battery discharge to the 85 percent value indicated by the VW Taxi's BATTERIE meter. Test 20 was thus conducted with the 2.5 sec throttle time constant and 260 amp maximum motor current settings unchanged from Test 19. Even though Test 20 was started with the batteries fully charged, both the Taxi's BATTERIE meter and the minimum battery voltage reached the limitations (110 volts, 40 percent discharge) defined by the VW Project Engineer. Accordingly, the test was terminated approximately 3 min before the Stabilized phase; the second of the three FTP phases, was completed. However, data from the first phase, the Cold Transient phase, appeared to be valid. After results of Test 20 were reviewed, it was decided to decrease the maximum motor current to 230 amps and change the throttle time constant from 2.5 to 1.2 sec in order to conserve the battery energy. Although Test 20 was terminated prematurely because of battery discharge, it was evident that the FTPs first and second phases could be completed with the minor reduction to the battery energy usage that would be caused by these changes. Changes in the cut-in and cut-out speeds, which were difficult to adjust, were not made.

Test 22 was conducted with the changed parameters. It was possible to complete both the Cold Transient and Stabilized phases of the FTP with this test, although both the BATTERIE meter and the minimum battery voltage had slightly exceeded the nominal battery discharge limits. In particular, the battery meter read 55 percent, while the minimum value desired by VW was 60 percent. However, constant monitoring of the battery voltage during the tests showed that the voltage fell below the 110V minimum value (1.67 volts/cell) only briefly during maximum acceleration. The Hot 505 tests had shown that the battery discharge during the Hot Transient phase would be too great to even attempt continuing the test, so Test 22 was terminated at the end of the Stabilized phase.

Since the Taxi's batteries could not complete the entire FTP test at the 27/22 mph on/off engine speed settings without exceeding the discharge limitations, construction of a composite On/Off FTP based on the two partial FTP tests (20 and 22) and the Hot 505 tests had different throttle time constant and motor current limit settings, but their energy and emissions had reasonable agreement as shown in Table 3-6. Further, comparison of the data from the Hot Transient phase of the full FTP and the three identical cycles of Hot 505 tests for the Hybrid mode showed good agreement; this data is shown in Table 3-7. It thus appeared reasonable to construct a composite On/Off FTP based on the Cold Transient phase of Tests 20 and 22, the Stabilized phase of Test 22, and the Hot Transient phase of the On/Off Hot 505 tests. Test 14 was selected for the latter since it had the 1.2 sec throttle time constant and the 230 amp motor current limit used for Test 22. Data used for this composite On/Off test are shown in Table 3-8. The fuel economy and emissions data at the bottom of Table 3-7 are used as a good estimate of the On/Off FTP performance with the limitations imposed by the battery discharge.

The Taxi's logic card for the On/Off mode permitted adjustment of the engine cut-in and cut-out speeds, but time limitations did not permit further tests to be conducted during the initial test period. In addition, the taxi's mechanical configuration made it impossible to set the engine cut-in and cut-out speeds for the On/Off mode over a wide speed range. The torque converter imposed the primary limitation. The converter's low speed characteristics made it impossible for adequate torque to be transmitted from the electrical motor to crank the engine to a starting speed. During testing activities, it was observed that the initial engine rotation would usually consist of a partial revolution at an electric motor speed of approximately 1600 rpm. The engine was generally rotating steadily when the motor reached 2000 rpm, but infrequent stops occurred at this speed. The engine rotation was steady at 2200 rpm so reliable starting was possible. Since the motor speed/vehicle speed ratio is very close to 100:1, the lowest engine cut-in speed that could be achieved was about 22 mph.

Table 3-6. Comparison of On/Off Mode Hot 505 Tests

Test No.	Cycle	Fuel Economy		Battery Power	Emissions		
		Weigh Tank	Emissions		NO _x	CO	HC
14	1	24.74	26.14	-614	3.487	22.007	1.920
	2	25.58	26.64	-620	3.490	23.031	1.824
	3	25.76	26.90	-590	3.485	22.045	1.794
	Ave	25.36	26.56	-608	3.488	22.530	1.836
16	1	25.43	26.95	-638	3.747	19.488	2.609
	2	25.73	26.58	-601	3.840	21.327	1.990
	3	26.07	27.40	-626	3.938	19.691	2.510
	Ave	25.74	26.97	-622	3.848	20.466	2.271
19	1	23.98	25.38	-634	3.543	23.033	3.044
	2	25.66	26.49	-616	3.545	20.332	1.912
	3	26.06	27.02	-610	3.527	21.205	1.877
	Ave	25.23	26.30	-620	3.539	21.162	2.145

Table 3-7. Comparison of Data from the Hot Transient Phase for FTP and 505 Tests

Test Type	Test No. and Cycle	Date	Fuel Economy			Net Electrical Power (watt/hours)		Emissions (weighted grams/mile)		
			Weigh Tank (mpg)	Emissions (mpg)	% Agreement	Battery	Motor	NO _x	CO	HC
Hot 505	007-1	6/21	17.259	17.625	2.12			5.449	23.161	1.622
	-2		17.222	17.590	2.14			5.508	25.176	1.680
	-3		17.081	17.454	2.18			5.687	25.218	1.611
	avg		17.187	17.556	2.15			5.547	24.755	1.648
Hot 505	009-1	6/23	16.779	17.419	3.81			5.139	24.720	1.620
	-2		16.939	17.927	5.83			5.309	24.787	1.620
	-3		17.355	18.162	4.65			5.402	24.519	1.549
	avg		17.024	17.836	4.77	-117	-30	5.299	24.696	1.600
Hot 505	021-1	6/29	16.792	17.451	3.92	61.7	24.1	5.108	29.856	2.008
	-2		17.067	17.539	2.77	37.2	48.5	5.407	29.913	1.684
	-3		17.039	17.820	4.58	42.5	39.2	5.527	30.065	1.643
	avg		16.966	17.603	3.75	47.1	37.3	5.377	29.944	1.742
Hot 505	028-1	7/15	16.807	17.044	1.41	43.4	44.4	5.733	30.958	1.790
	-2		17.007	17.290	1.66	38.0	51.1	6.003	31.149	1.796
	-3		16.807	17.259	2.69	37.5	50.2	5.909	31.665	1.777
	avg		16.873	17.198	1.93	39.6	48.6	5.918	31.255	1.789
FTP	010-3		16.975	17.462	2.87			5.502	24.304	1.751
FTP	013-3		16.583	17.559	5.88			5.076	26.609	2.089

Table 3-8. Composite Taxi On/Off Mode FTP

Test No.	Phase	Fuel Economy ¹ (mpg)	Net Battery Power (watt-hours)	Emissions (grams per phase)		
				NO _x	CO	HC
Test Data						
020	Cold Transient	21.13	-2125	6.487	257.85	13.842
022	Cold Transient	19.41		6.414	294.42	14.766
	Stabilized	50.84		3.796	47.762	7.789
014	Hot Transient ²	25.36	-608	12.554	80.50	6.65
Composite Test						
020, 022	Cold Transient	20.27	-2125	6.45	276.1	14.30
022	Stabilized	50.84		3.80	47.76	7.79
014	Hot Transient ²	25.36		12.55	80.50	6.65
<u>Energy Consumption</u>						
Total gallons		.3837				
Battery power						
Test data			2733			
With battery efficiency			3215			
With recharge energy			3537			
Equivalent mpg		21.47				
<u>Emissions</u> (weighted grams/mile)				1.83	28.3	2.36

NOTES:

1. Based on weigh tank data.

2. Average of three consecutive cycles

The On/Off mode data for the composite test were obtained from tests with an engine cut-in at a motor speed close to 2700 rpm, which corresponds to a vehicle speed of about 27 mph. The cut-in speed could thus be lowered to approximately 2200 motor rpm or 22 mph vehicle speed. However, adjustment in the vicinity of 2000 to 2200 rpm motor speed was felt to be risky. On two occasions, there was significant backfiring when the Taxi was operated in the On/Off mode. Since the engine start up consists of turning on the spark and opening the throttle in a closely coordinated time sequence, adequate engine rpm must be assured before the engine turn-on signal is given.

Engine operation in the On/Off mode with the 27/22 mph cut-in and cut-out speeds is shown in the x-y plot of vehicle speed versus engine rpm shown in Figure 3-23. The concentrated areas of the pen trace provide a good indication of the areas where the engine spent a relatively large part of its operating time.

b. 3500 Pound Inertia Weight Tests - After the On/Off performance of the composite test was known, the next set of tests were done to obtain data at intermediate on/off engine speed settings. Two tests, at 3500 lb and 4500 lb inertia weights, were conducted. Plans for 4000 lb tests had to be cancelled because of the test time available within the lease period.

Figures 3-24 and 3-25 show the results of the 3500 lb inertia weight tests with engine cut-in and cut-out speeds of 22 and 19 mph. As noted previously, 22 mph was the lowest cut-in speed that could be used and have reliable engine rotation when the start sequence was initiated. The lack of power during the engine-off period is shown in Figure 3-26 during the initial ramp at about 170 sec. The engine cut-in speed is shown; after this, the acceleration is adequate to match the FTP profile for the short time until 25 mph was reached. It appears that the engine did not turn off at the 19 mph speed at about 187 sec. For the ramp starting at 190 sec, the acceleration is essentially the same as that for the Hybrid mode when the engine was on all the time (Figure 3-4). Motor-only power is inadequate for the required acceleration above 15 mph as demonstrated by the trace at 190 sec so the engine evidently did not turn off in the brief time below 19 mph. The cut-out speed showed considerable scatter when set for 19 mph; a ± 2 mph variation was noted. It is thus assumed that the control circuit did not operate during this particular time.

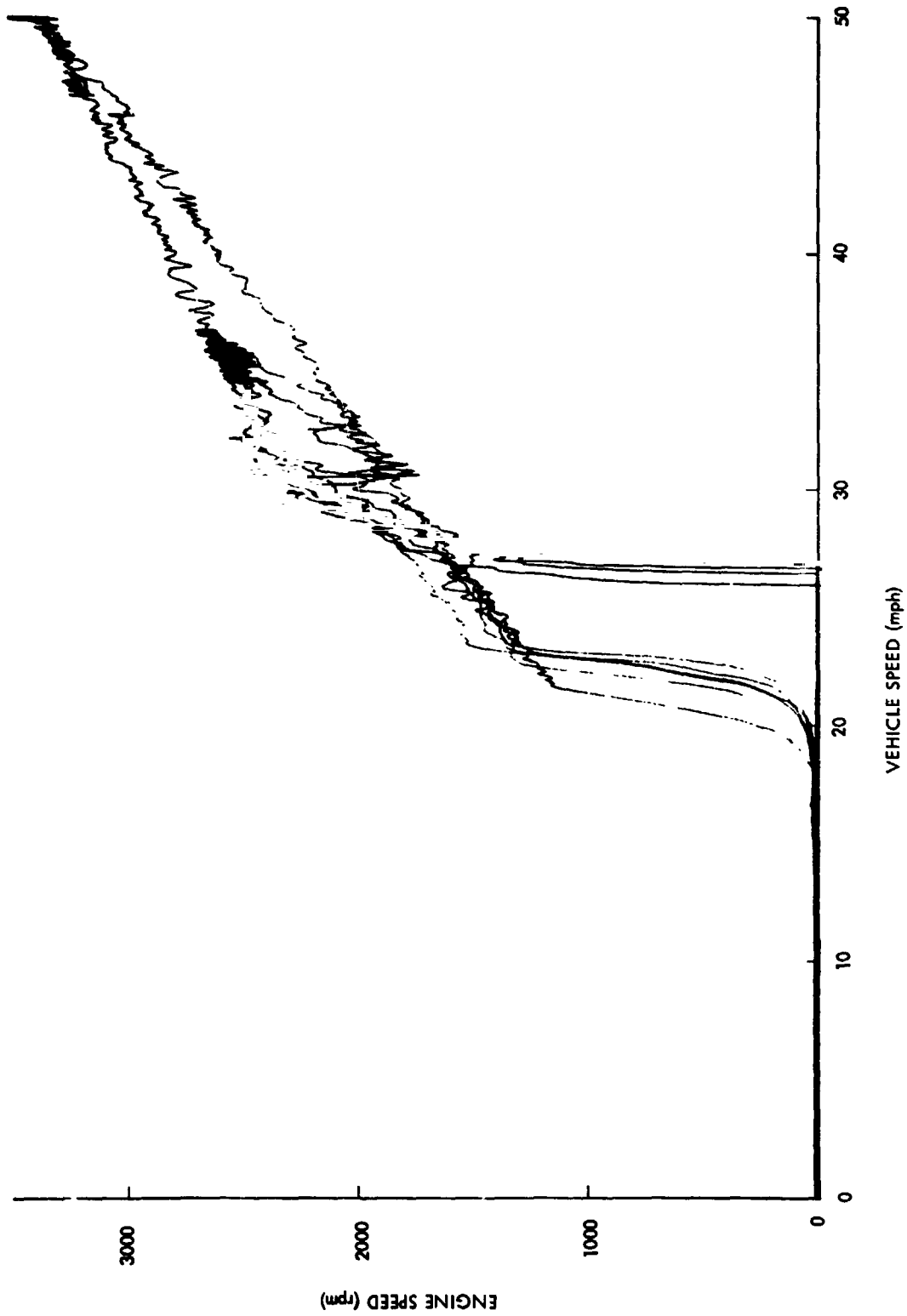
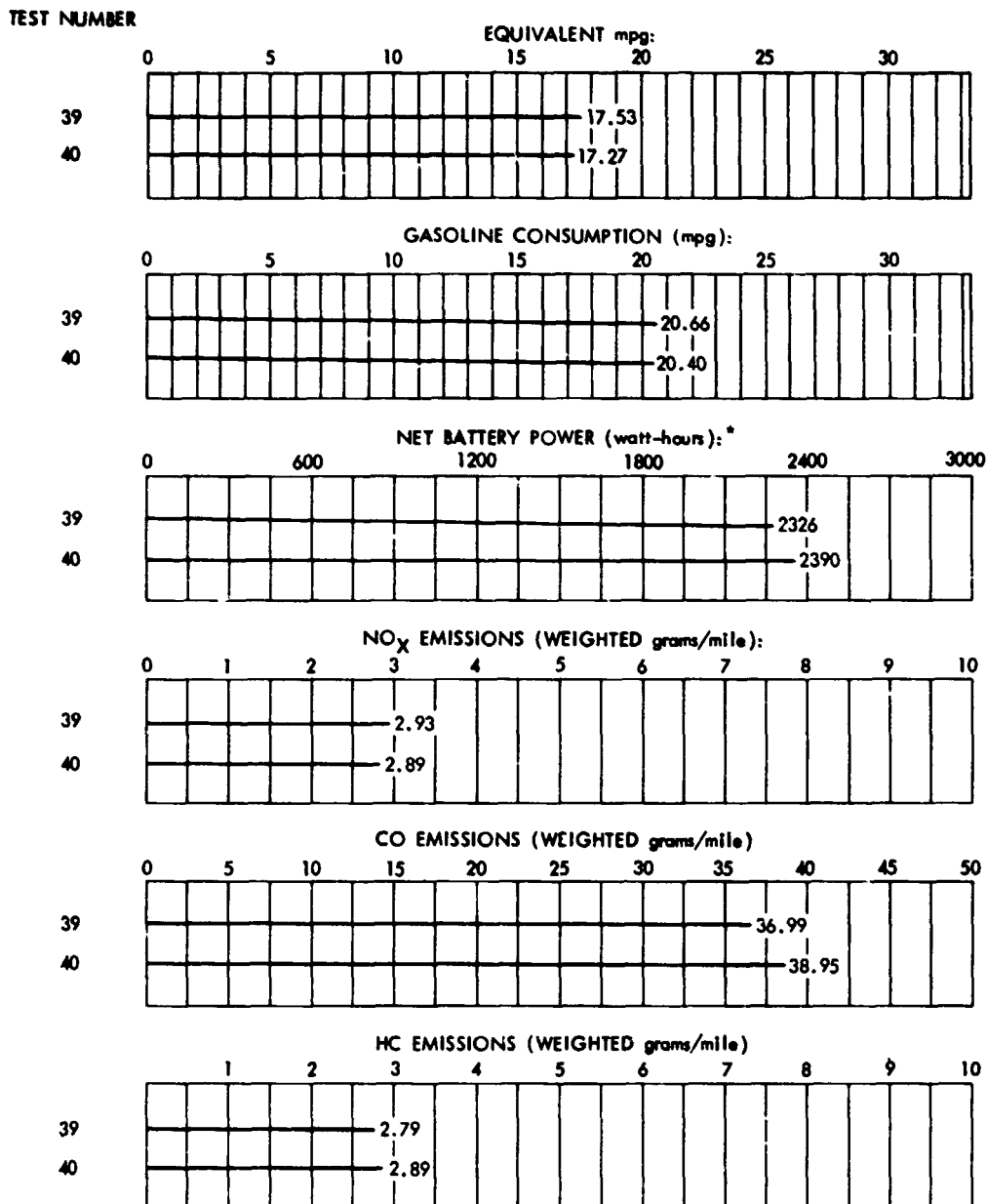


Figure 3-23. On/Off Engine Cut-In and Cut-Out Operation

900-851

MODE: ON/OFF
THROTTLE TIME CONSTANT: 1.2 sec
INERTIA WEIGHT: 3500 lb

ENGINE SPEEDS:
CUT-IN: 22 mph
CUT-OUT: 19 mph



* MEASURED CHARGE AND DISCHARGE BATTERY POWER PLUS BATTERY EFFICIENCY OF 0.77, OR
NET BATTERY POWER = $\frac{\text{DISCHARGE} - \text{CHARGE}}{0.77}$

Figure 3-24. Test Results for On/Off Mode, 3500 lb Inertia Weight FTP Tests

900-851

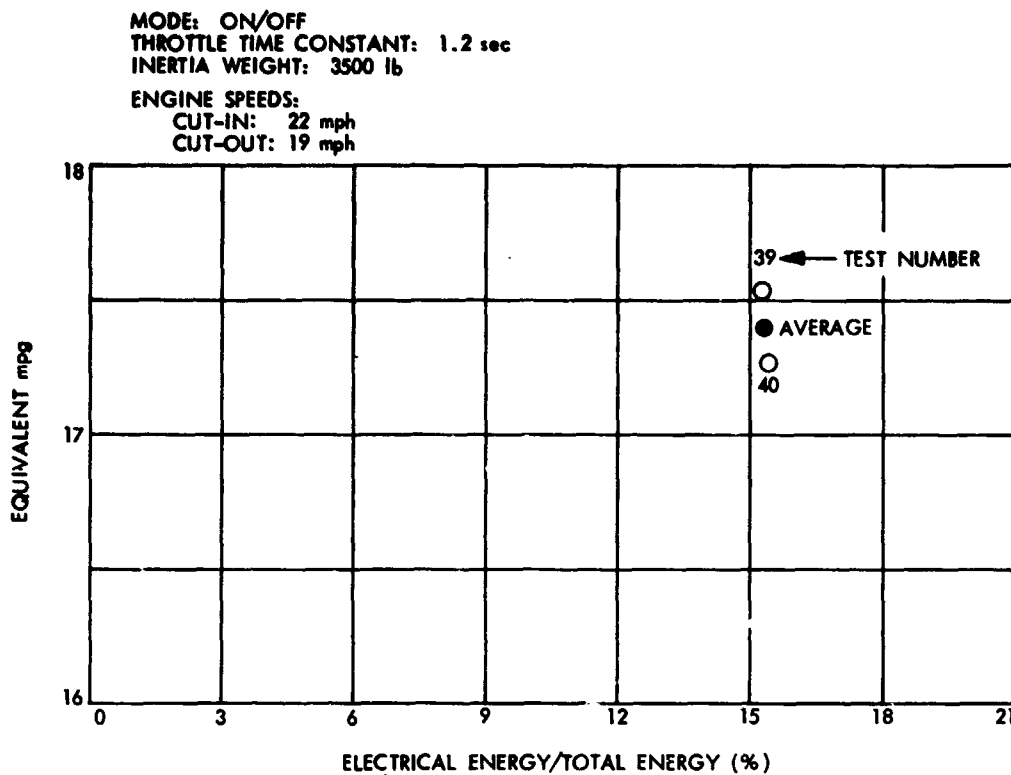


Figure 3-25. Graph of On/Off Mode, 3500 lb Inertia Weight FTP Tests

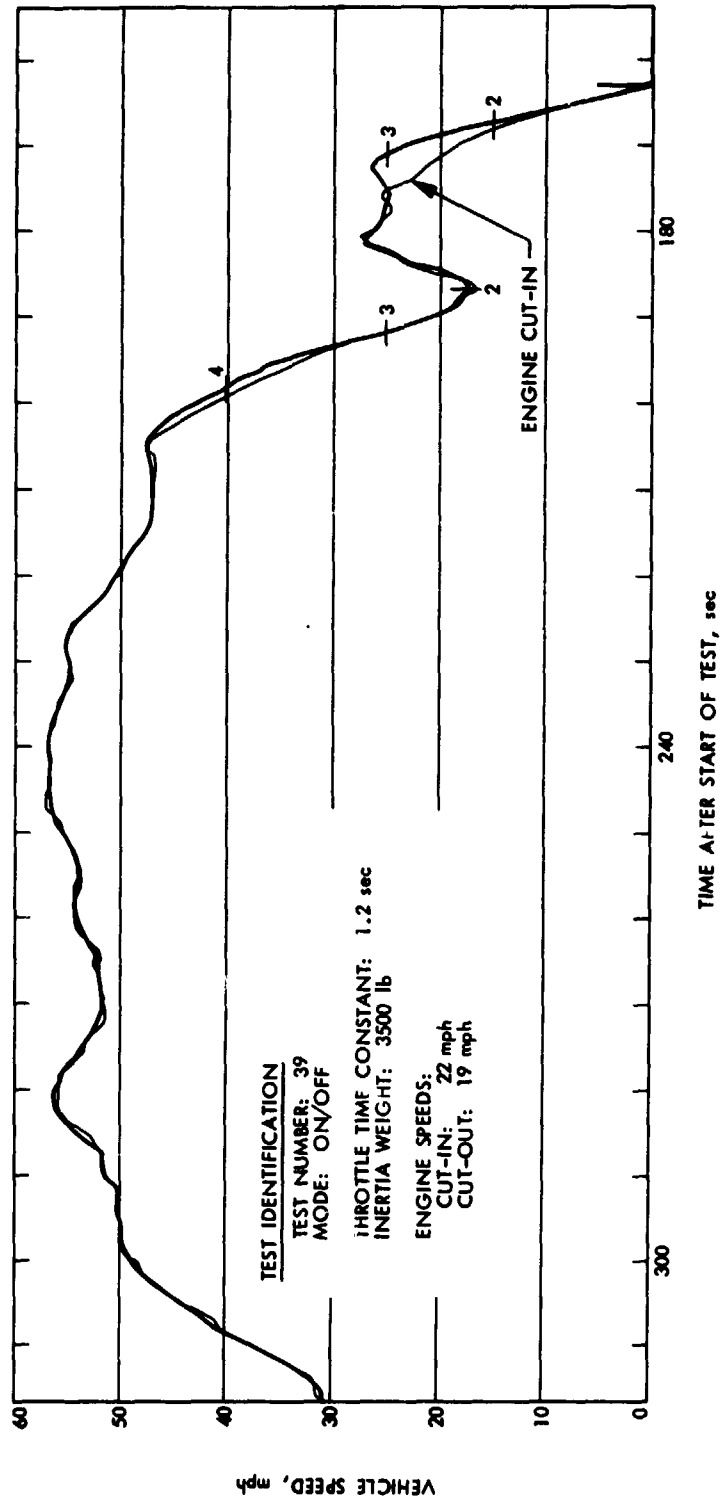


Figure 3-26. Typical FTP Speed-Time Profile for On/Off Mode
 (22/19 mph) 3500 lb Inertia Weight Tests

c. 4500 Pound Inertia Weight Tests - Two tests were conducted with the 22 and 19 mph cut-in and cut-out speeds at 4500 lb inertia weight. Results are shown in Figures 3-27 and 3-28. The acceleration in the motor-only mode has a considerable lag from the specified FTP profile as shown in Figure 3-29. The engine cut-off characteristic is the same in this figure as that for the 3500 lb inertia weight test; the engine did not turn off during the brief period below 19 mph at 187 sec. In this trace, the engine turned on at 19 mph. In general, the cut-in repeatability was ± 0.5 mph and had considerably less variation than the cut-out speed.

d. 3500 Pound Inertia Weight, 26/21 mph Engine Speed Tests - Test 51 was intended to duplicate the conditions of the composite tests discussed in part (a) of this section. The speed adjustments were rather difficult to set at a specific speed, so the cut-in and cut-out speeds did not exactly match those for the tests that comprised the composite test. Figure 3-30 shows the vehicle speed-engine speed graph comparable to that of Figure 3-23, the conditions for the composite test. The increased scatter of the engine cut-off compared to Figure 3-23 is evident.

Test results are shown in Figure 3-31. Only one test could be conducted in this configuration because of time limitations. The speed-time profile of Figure 3-32 shows a significant departure from the FTP profile with this engine cut-in and cut-out settings. Note that the engine did turn off during the time near 187 sec, so the acceleration during the initial part of the ramp starting at 190 sec depended only on motor power and was inadequate.

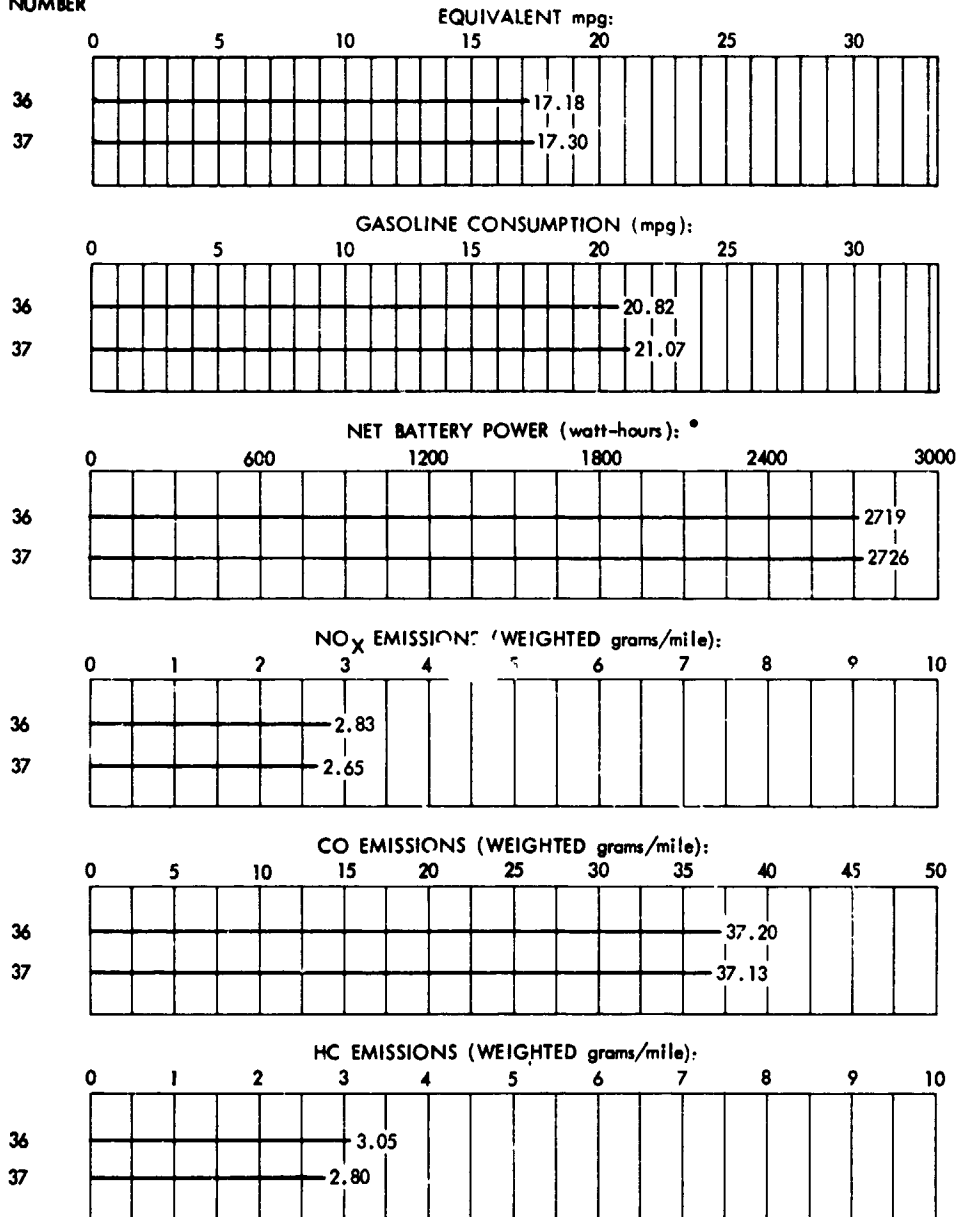
e. Summary of On/Off Mode Data - The relative insensitivity of energy economy to inertia weight changes is shown in the Equivalent MPG bar chart of Figure 3-33. The relationship of the 3500 lb and 4500 lb tests is essentially the same as that of the Hybrid mode shown in Figure 3-15. The NO_x emissions reduction for the tests with the higher engine speeds is greater than the ± 5 percent test-to-test variation and so is significant. The lower CO data for the 27/22 mph engine speed (the composite test) is probably not significant because of the variations in CO data throughout the test series.

00-851

MODE: ON/OFF
THROTTLE TIME CONSTANT: 1.2 sec
INERTIA WEIGHT: 4500 lb

ENGINE SPEEDS:
CUT-IN: 22 mph
CUT-OUT: 19 mph

TEST NUMBER



* MEASURED CHARGE AND DISCHARGE BATTERY POWER PLUS BATTERY EFFICIENCY OF 0.77, OR
NET BATTERY POWER = $\frac{\text{DISCHARGE} - \text{CHARGE}}{0.77}$

Figure 3-27. Test Results for On/Off Mode,
4500 lb Inertia Weight

900-851

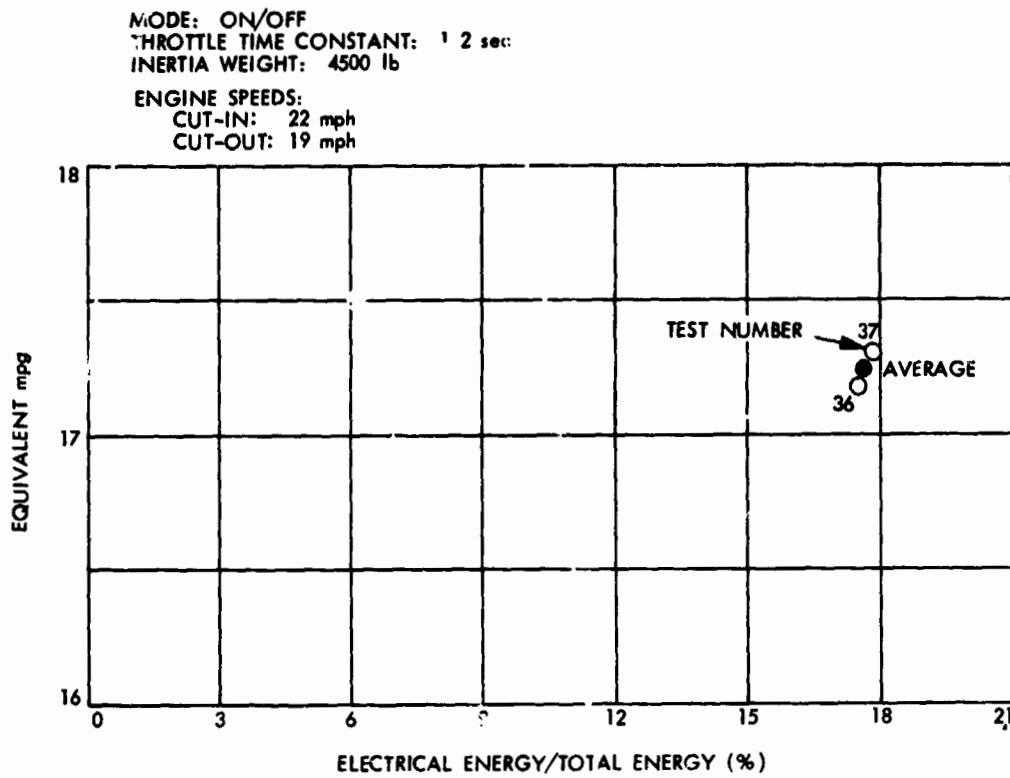


Figure 3-28. Graph of On/Off Mode,
4500 lb Inertia Weight FTP Tests

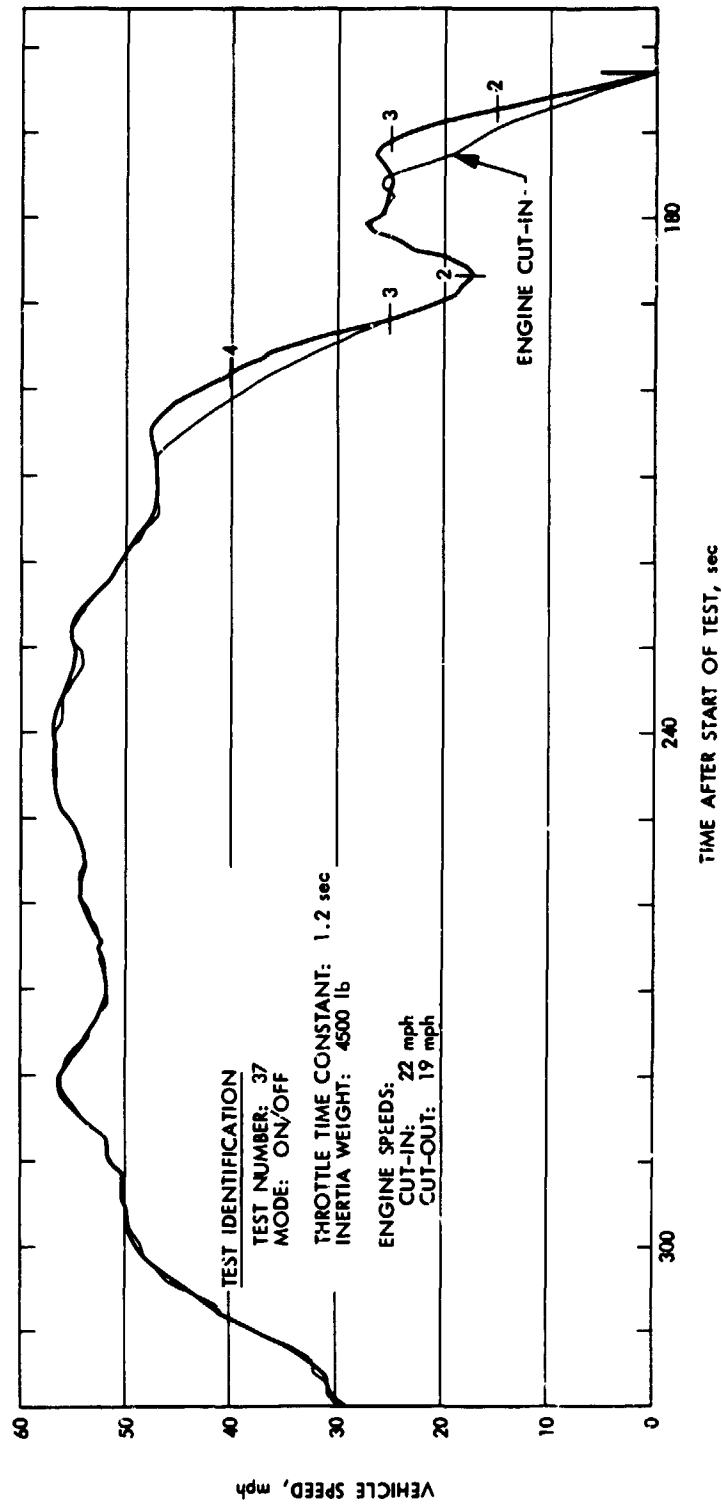


Figure 3-29. Typical FTP Speed-Time Profile Chart for On/Off Mode, (22/19 mph) 4500 lb Inertia Weight Tests

900-851

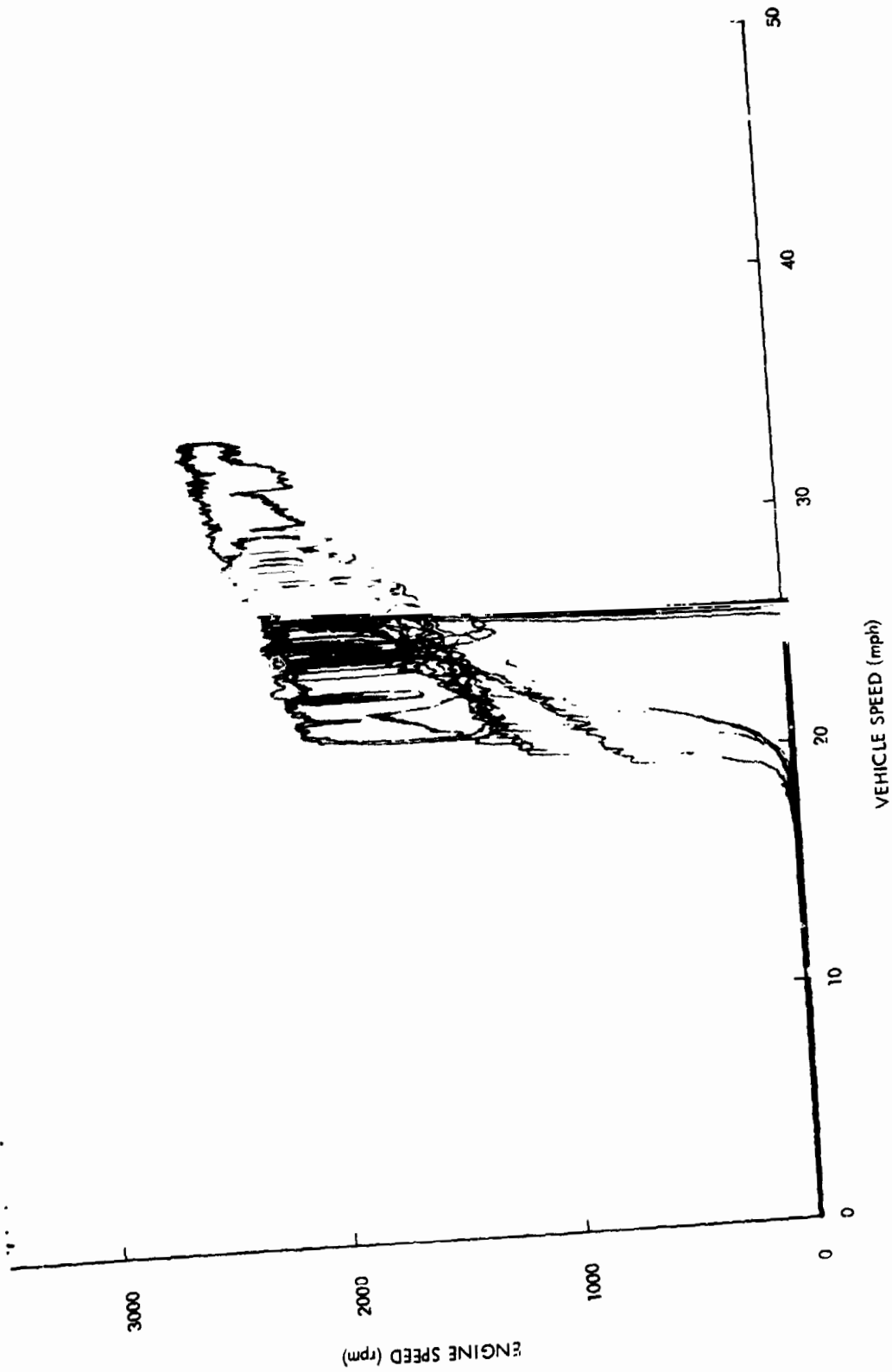


Figure 3-30. Engine Cut-In and Cut-Out Speeds for Test 51

900-851

MODE: ON/OFF
THROTTLE TIME CONSTANT: 1.2 seconds
INERTIA WEIGHT: 3500 lb

ENGINE SPEEDS:
CUT-IN: 26 mph
CUT-OUT: 21 mph

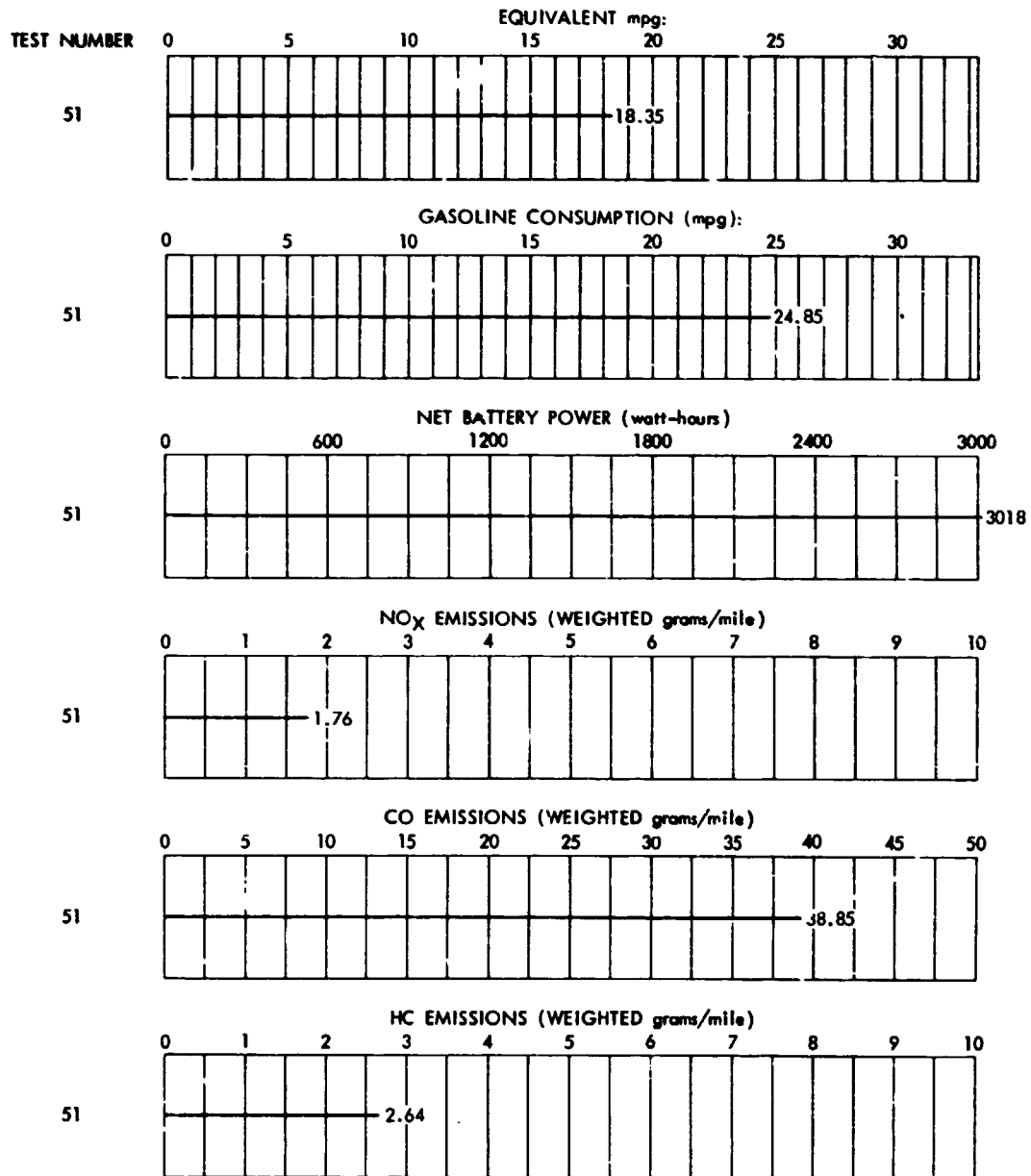


Figure 3-31. Test Results for On/Off Mode, 3500 lb Inertia Weight 26/21 MPH Engine Cut-In/Cut-Out Speeds

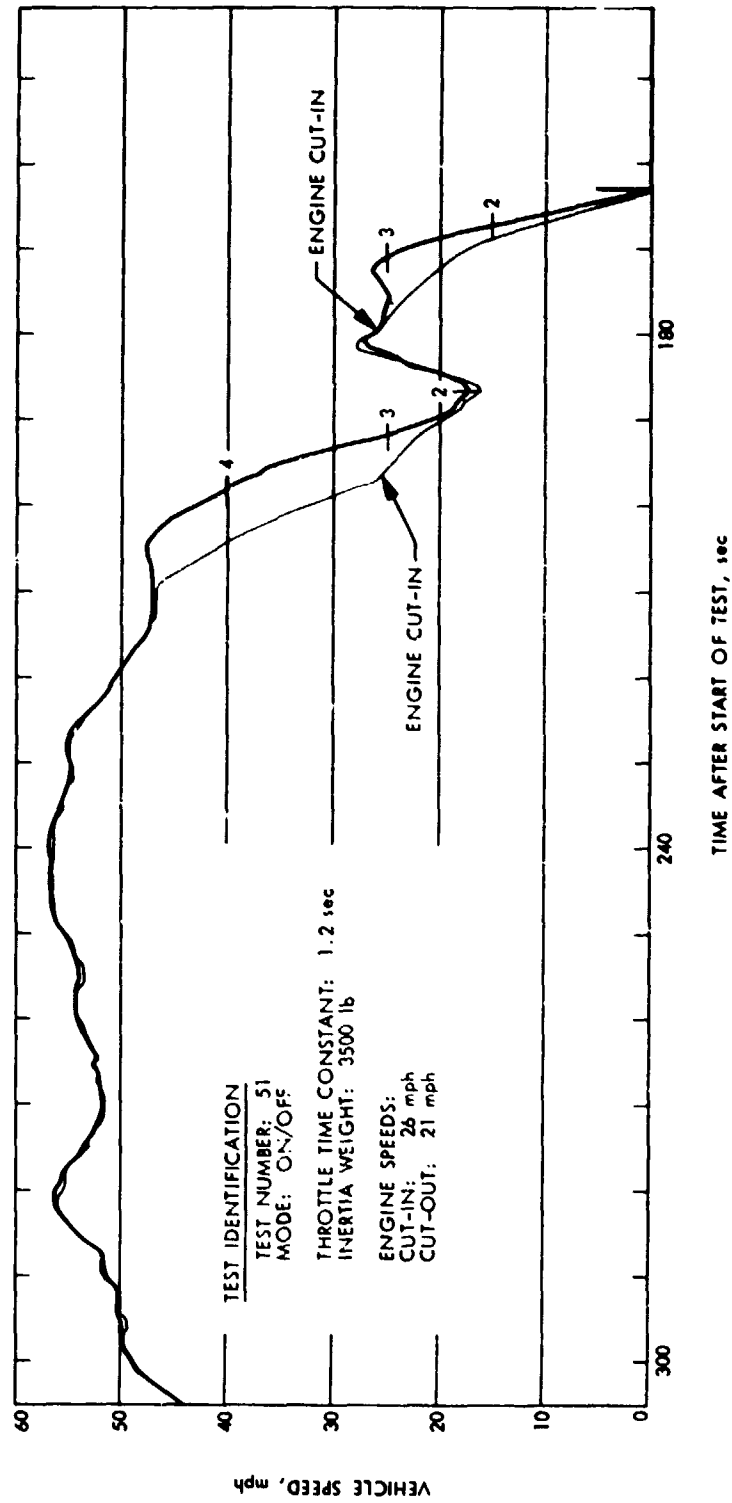
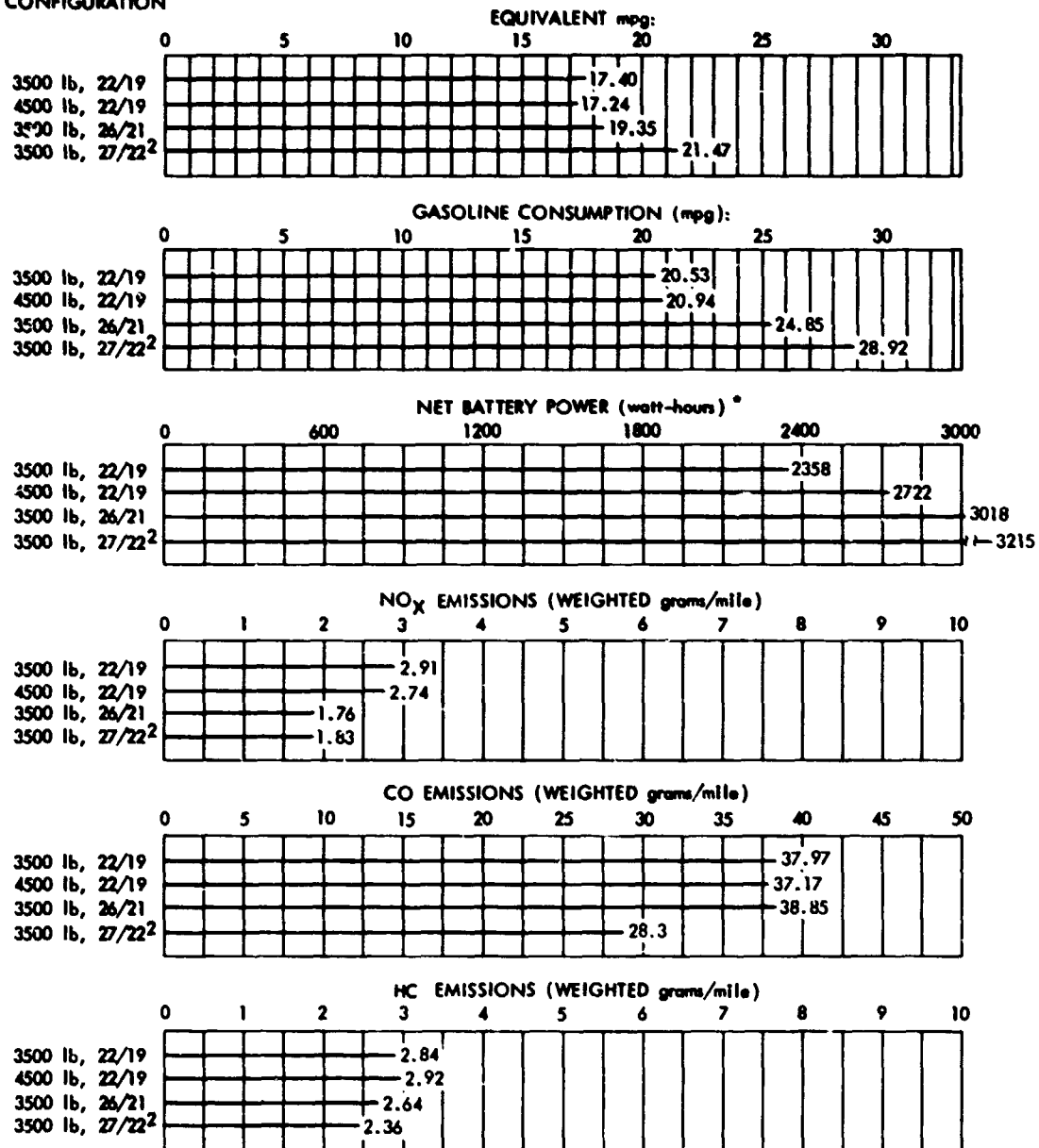


Figure 3-32. FTP Speed-Time Profile Chart for On/Off Mode,
 (26/21 mph) 3500 lb Inertia Weight Tests

MODE: ON/OFF
THROTTLE TIME CONSTANT: 1.2 sec
INERTIA WEIGHT: NOTED BELOW

ENGINE SPEEDS:
NOTED BELOW

CONFIGURATION ¹

* MEASURED CHARGE AND DISCHARGE BATTERY POWER PLUS BATTERY EFFICIENCY OF 0.77, OR

$$\text{NET BATTERY POWER} = \frac{\text{DISCHARGE} - \text{CHARGE}}{0.77}$$

1. FORMAT IS: INERTIA WEIGHT, CUT-IN SPEED/CUT-OUT SPEED
2. THIS IS THE COMPOSITE TEST DISCUSSED IN SECTION 4.1.2 (a)

Figure 3-33. Summary of On/Off Mode Tests

3.4.3 FTP Data Results

The FTP data are shown in Figure 3-34. The energy advantages of the On/Off mode are clear. However, the increased energy economy is gained at the expense of range when only the FTP urban cycle is considered. If a 60 percent discharge is assumed, the Taxi would have a range of about 3 slightly over 30 miles when driving consecutive FTP urban cycles in the On/Off mode with 22/19 mph cut-in and cut-out speeds. The range for the SAE J227a 'D' cycle is 100 miles, so any conclusions regarding range for a vehicle similar to the Taxi must give primary consideration to the driving cycle. A test sequence of the FTP urban cycle followed by the EPA highway cycle, then repeating this sequence, could extend the range to the limit of the gasoline supply; but a more thorough analysis of the charging characteristics is necessary to define the range limit under these conditions. Range will be limited by the gasoline supply at average speeds above approximately 45 mph with the On/Off mode. Since the On/Off speed settings will have a strong influence in driving cycles with stop-and-go profiles, the range of a heat engine-electric hybrid similar to the Taxi requires careful definition of its operating parameters.

The energy economy with the battery recharge considered is shown in Figure 3-34. The use of on-board energy, which does not consider the recharge, is shown in Figure 3-35. The On/Off mode, with 26/21 cut-in and cut-out speed settings, provides a 40 percent better increase in the on-board energy economy. When the recharge energy is included, this drops to about 25 percent as shown in Figure 3-34.

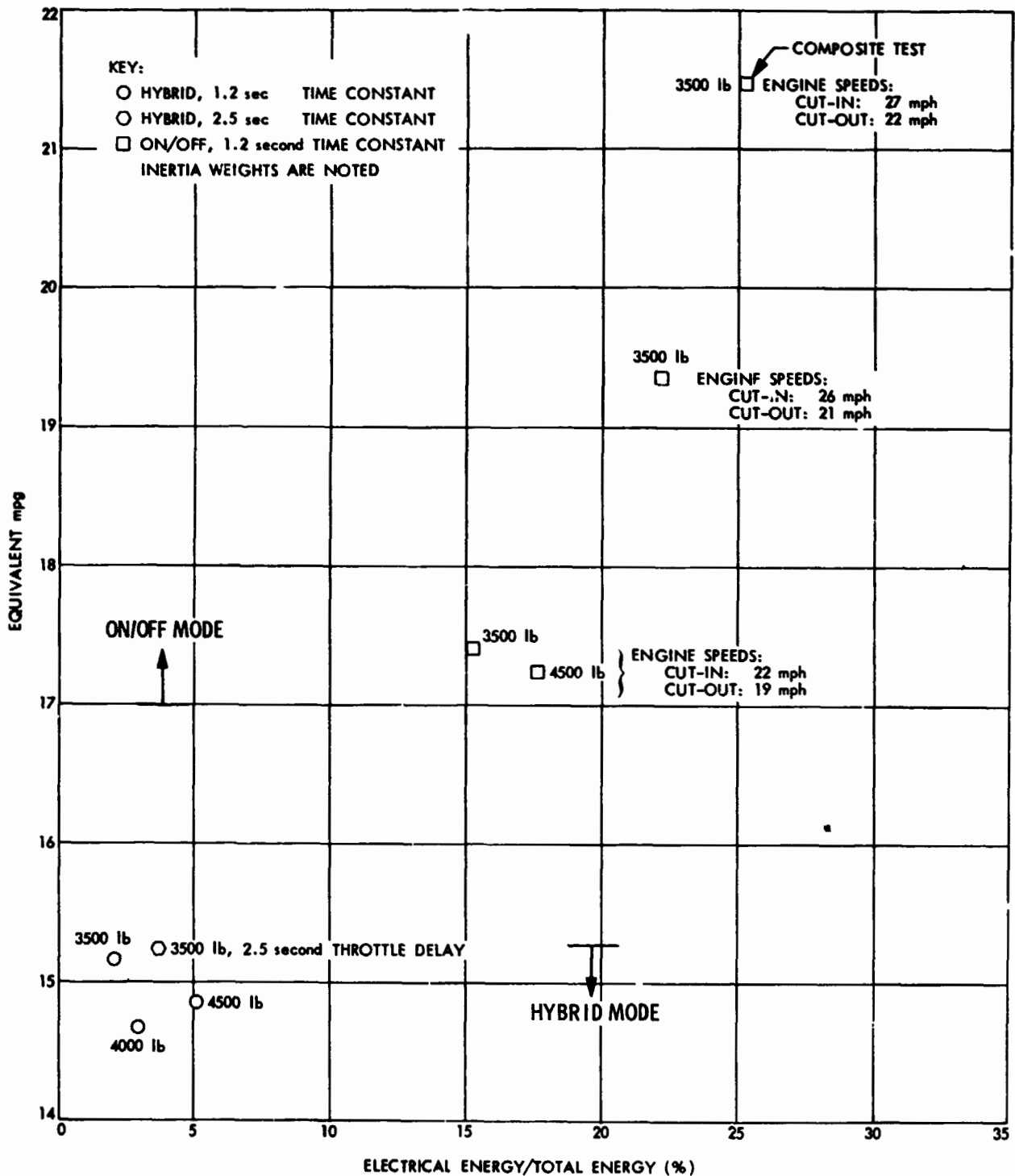


Figure 3-34. Energy Economy of Hybrid and On/Off Modes

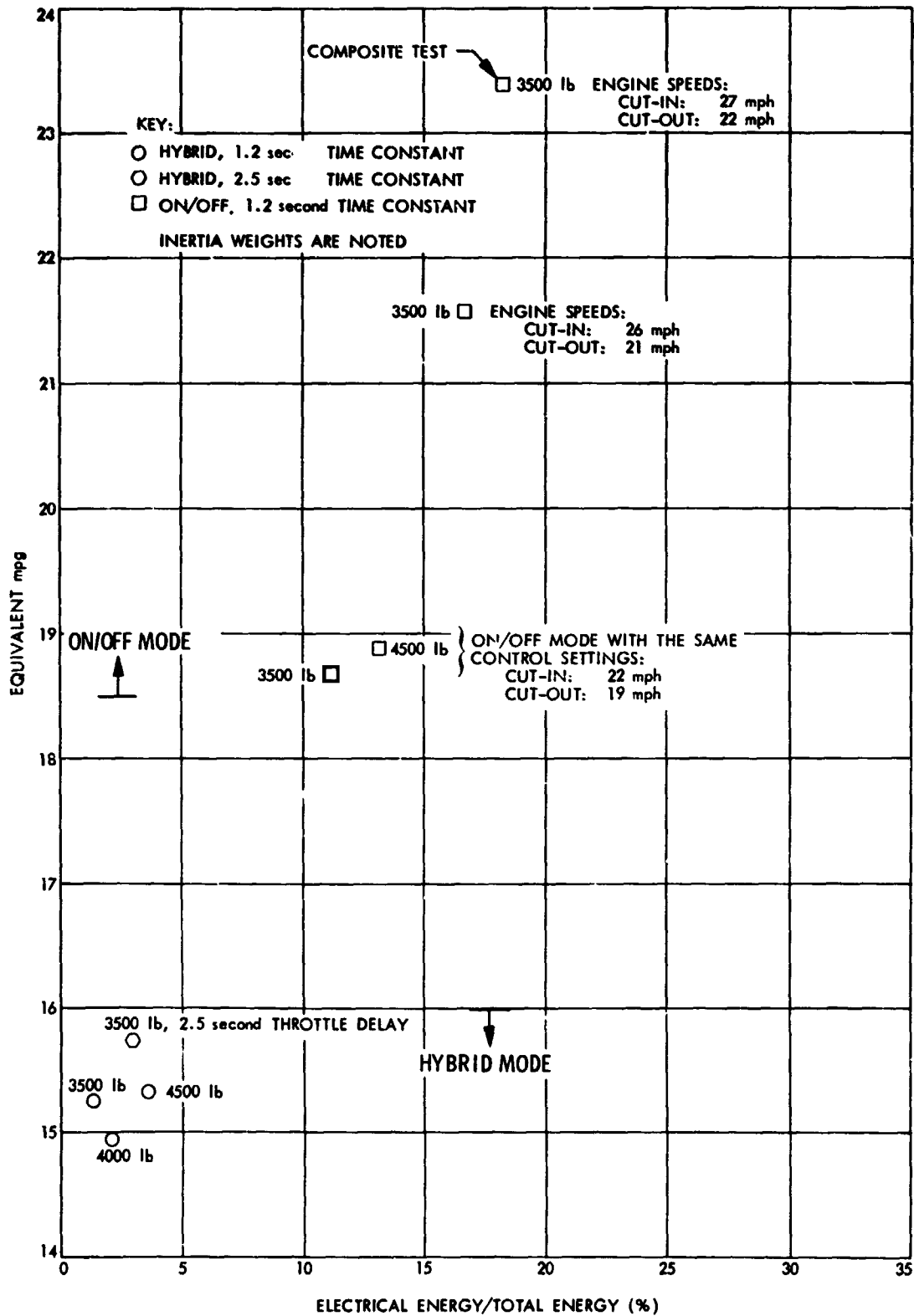


Figure 3-35. Energy Economy Without Battery Recharge

3.5 SAE J227a 'C' AND 'D' CYCLE TESTS

Three sets of the SAE J227a tests commonly used for electric vehicles were conducted late in the test series. These tests were conducted in both the Hybrid and On/Off modes.

The first two were the Hybrid mode for the 'C' and 'D' cycles. A problem with the Taxi's controller caused the vehicle to be out of service after the Hybrid tests until the VW Project Engineer arrived to return the vehicle at the end of the lease period. Only a short testing period was then available, so all the desired SAE cycle tests could not be conducted.

Test results are shown in Figure 3-36. The On/Off mode shows a 12.5 percent improvement in energy economy over the Hybrid mode for the J227a 'D' cycle. Comparable FTP results are 12.9 percent for the 22/19 mph engine speed and 21.7 percent for the 26/21 mph engine speeds.

Energy economy in the kW-hr/mile units normally used for electric vehicles is shown in Figure 3-36.

VEHICLE CONFIGURATION

THROTTLE TIME CONSTANT: 1.2 sec
 INERTIA WEIGHT: 3500 lb

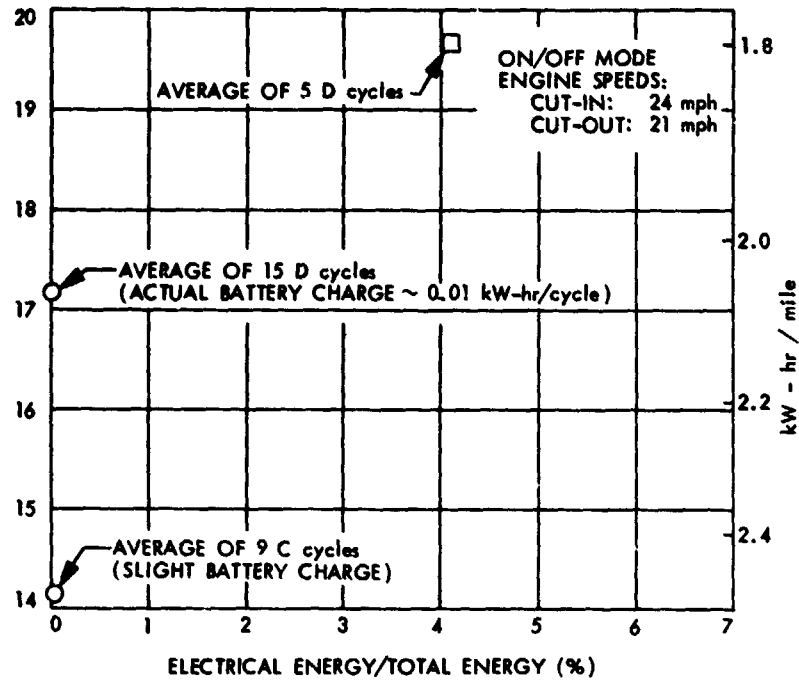


Figure 3-36. SAE J227a Driving Cycle Tests

3.6 VW BUS TEST DATA

The VW Bus tests were conducted to provide a comparison between the emissions and fuel economy of a vehicle that is approximately comparable to the VW Taxi. Both vehicles are based on the same chassis. However, there are three major differences when energy and emissions data are considered:

- 1) The Taxi is a heavier vehicle. The additional weight is comprised of features that are required for a taxi as well as those that are related to the extra weight of the electrical propulsion system.
- 2) The VW Taxi has a 1.6 liter carbureted engine as compared to the 2.0 liter fuel injected engine for the Bus. The Taxi's engine represents technology about 10 years earlier than that of the Bus.
- 3) The Bus has an oxidizing catalytic converter; the Taxi does not. The HC and CO emissions from the Bus will be significantly reduced by the converter.

Even though the vehicles have different engines, the comparison of these two vehicles offered the only reasonable way to assess the potential of a hybrid vehicle within the time constraints of this program. If the hybrid vehicle, with its old engine, has comparable emissions and fuel economy to the bus it would appear that the hybrid concept may offer significant advantages if it were fully developed and optimized.

3.6.1 Bus Background Information

The Bus was delivered to JPL on May 25, 1977. It had been driven approximately 200 miles; a vehicle with approximately 2000 miles was requested, but this Bus was the only one available for the tests. The Bus had been tested twice at the VW emissions lab in Woodland Hills, California. Results of these tests were:

Fuel Economy	16.0 mpg
Emissions (weighted grams/mile)	
NO _x	1.562
CO	15.13
HC	0.695

3.6.2 Bus Test Data

Test data are shown in Figures 3-37 and 3-40; fuel economy and emissions data for several tests are shown. Tests at both the VW Emissions Lab and JPL are included. The vehicle was tested at JPL for the first time on May 25. At this time, the JPL driver had no experience with the Bus so the test results could not be expected to compare with that of the VW facility, which had an experienced driver. The Bus was tested the next day, May 26. Results of this test were:

		Difference from VW (%)
Fuel Economy	16.77 mpg	4.6
Emissions (weighted grams/mile)		
NO _x	1.297	-20.4
CO	16.388	7.7
HC	0.574	-21.1

Although the fuel economy and CO data are within nominal facility-to-facility deviation, the NO_x and HC are well outside the expected deviation.

In order to confirm the JPL data, the Bus was tested again on June 1. Results from this test were significantly different from the May 26 data. Driver and/or facility errors were suspected at this time. Further tests showed even greater test-to-test variation. The reason for this deviation was not clear because data from the reference Chevrolet, using the same driver as that for the bus, showed good repeatability during this time as discussed in Paragraph 5.2.1. Tests conducted on June 14 and 15 showed excellent repeatability, so the VW Emissions Lab was contacted to determine if the Bus was still operating in its normal manner. The Bus was sent to the VW Emissions Lab for a check. The initial test at this facility agreed with the JPL data, thus indicating that the Bus was not operating properly and that the scatter experienced in the JPL tests was probably caused by a failing part in the Bus.

900-851

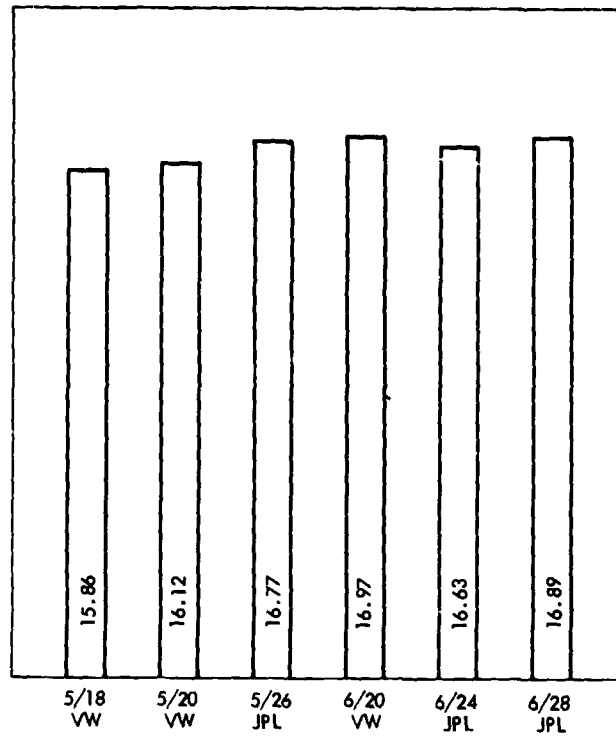


Figure 3-37. VW Bus Emission Fuel Economy (Miles per Gallon)

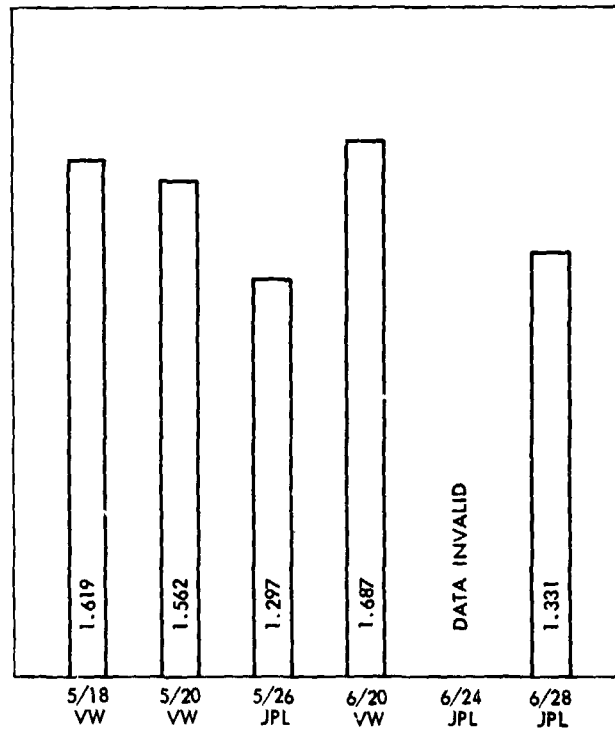


Figure 3-38. VW Bus NO_x Data (Weighted Grams per Mile)

900-851

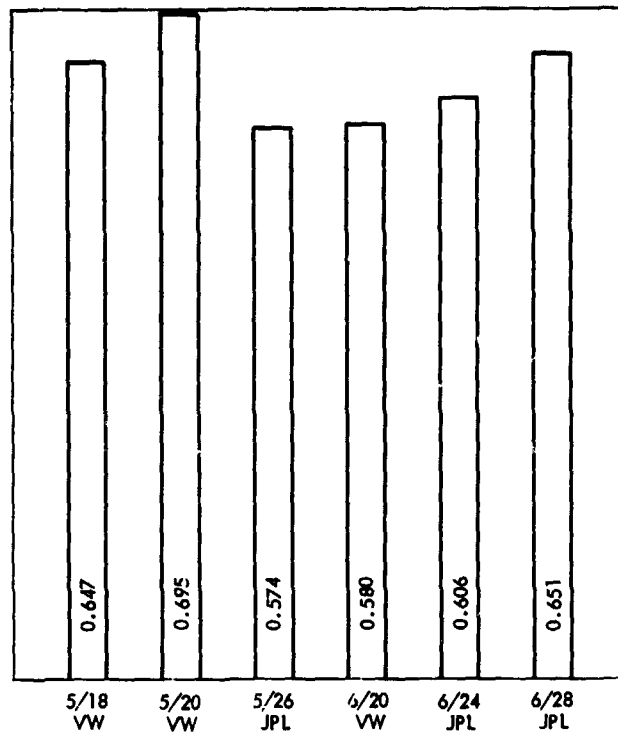


Figure 3-39. VW Bus CO Data (Weighted Grams per Mile)

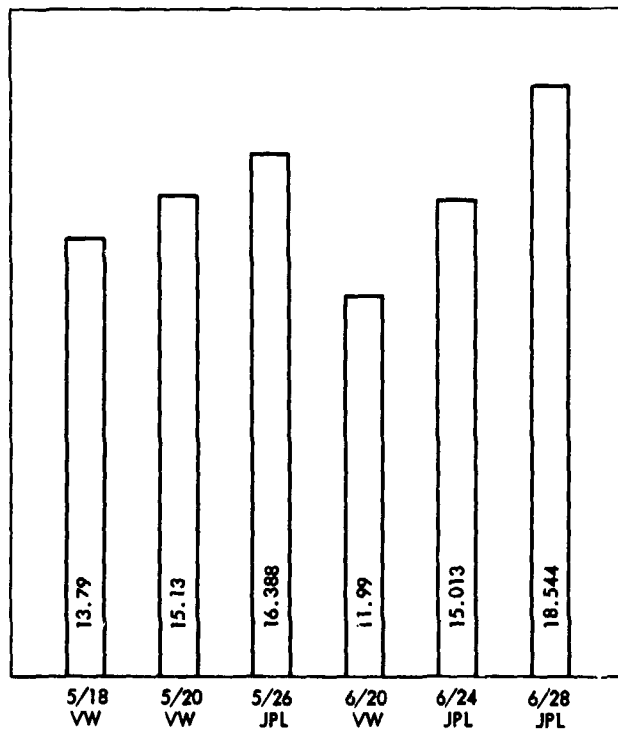


Figure 3-40. VW Bus HC Data (Weighted Grams per Mile)

The VW Emissions Lab found a failure in the air flow metering section of the fuel injection controller. The part was replaced, the bus was tested, adjusted, tested again, and then returned to JPL. JPL then conducted two additional tests, 12 and 18, to obtain reportable data on the VW Bus. Data from the May 26 JPL test has reasonable agreement with that from Tests 12 and 18, so the May 26 test data has been considered in the following discussion.

The fuel economy data from all tests agree well. The data from the May 26, June 24, and June 28 tests agree within 2 percent. The average of these values will be used.

The NO_x data from Test 12 are invalid. The instrument to measure NO_x has two operating modes. One measures only NO, while the other measures both NO and NO_2 ; the combination of NO and NO_2 is defined as NO_x . This instrument had been set to the NO mode for a different test and the switch setting was not returned to the NO_x mode to read the data from Test 12. Consequently, the readings were only for NO and were thus lower than that which would be read if both NO and NO_2 were measured. This particular data point, the NO_x data from Test 12, is thus invalid. The NO_x data from the JPL tests of May 26 and June 28 agree within 3 percent, so the data from Test 18 will be used.

CO emission data typically show a greater scatter than any of the other measurements. Tests conducted on May 18, 20, and 26 show increasing CO. It cannot be definitely established if this continuous increase is the result of the failure of the VW Bus air flow measurement or simply normal scatter typical of CO measurements. However, the same characteristic is noticed on the tests of June 20, 24, and 28. Since the retest at the VW facility, after the Bus was returned from JPL, showed good agreement between JPL's CO measurement and that of the VW emissions Lab, there is no reason to suspect measurement errors in the JPL facility. Further tests were impossible because of time limitations. The data from the May 26 test, Test 12 and Test 18 agree within ± 10 percent with the May 26 test data near the center. The average of Tests 12 and 18 will thus be used.

The test-to-test deviation of hydrocarbon data typically shows less scatter than that of the CO emissions. This is the case for the VW Bus data. The average data from the June 24 and June 28 tests, which agree with 3 percent, will be used.

JPL's VW Bus tests show that the best values for this vehicle are:

Fuel Economy	16.75	
Emissions (weighted grams/mile)		
	<u>JPL Tests</u>	<u>Federal Standards</u>
NO _x	1.33	2.0
CO	16.78	20.0
HC	0.628	3.1

Testing the VW Bus on the same facility as that used for the Taxi tests provides assurance that the data from the two vehicles are comparable by eliminating normal facility-to-facility variations. Without this approach, normal facility-to-facility variations (ref. 1) would have a high probability of masking significant differences between the Bus and the Taxi.

3.6.3 Bus Oxidizing Converter

One significant difference between the Taxi and Bus emission data concerns the oxidizing converter installed on the Bus, but not the Taxi. In order to obtain more comparable emission data, estimated oxidizing converter efficiencies were used to indicate the Bus emissions if no converter were installed. Converter efficiencies were:

<u>Phase</u>	<u>Efficiency</u>	<u>Rationale</u>
Cold Transient	30%	Converter efficiency is low during warmup
Stabilized	60%	Converter efficiency is higher, but relatively slow vehicle speeds will limit its temperature
Hot Transient	70%	Converter is warm

A composite FTP cycle for the Bus was constructed with the data from Tests 12 and 18, then this data were used to derive emission values with and without the oxidizing converter. Results are shown in Table 3-9 and Figure 3-41, which permits comparison of the Taxi's performance for the average Hybrid configuration and the On/Off mode.

Figure 3-41 indicates that the parallel hybrid shows reasonable performance in the Hybrid mode when its relatively young development state is considered. The On/Off mode may offer significant energy advantages, but extensive work to define its exact potential and practical limitations will be required.

Table 3-9. Composite VW Bus FTP Test

Test	Phase	Fuel Economy (Emission-based mpg)	Emissions (grams-phase)		
			NO _x	CO	HC
012	Cold transient	15.087	-----	163.54	7.392
	Stabilized	17.004	-----	13.567	0.525
	Hot transient	17.809	-----	50.362	1.478
018	Cold transient	15.216	5.309	159.77	6.941
	Stabilized	17.278	5.339	18.868	0.555
	Hot transient	18.188	4.139	90.372	2.357
Composite-with catalytic converter					
	Cold transient	15.15	5.31	161.7	7.17
	Stabilized	17.14	5.34	16.22	1.08
	Hot transient	18.00	4.14	70.37	1.92
Composite-without catalytic converter					
	Cold transient	15.15	5.31	210.1	9.32
	Stabilized	17.14	5.34	25.95	1.73
	Hot transient	18.00	4.14	119.6	3.26
FTP Urban Cycle Data					
			Emissions (weighted grams/mile)		
Composite - with converter		16.76	1.33	16.78	.70
Composite - without converter		16.76	1.33	24.59	1.01

<u>Equivalent Gasoline Fuel Consumption¹</u>		0	5	10	15	20	25	30
VW Taxi - Hybrid mode ²					15.2	17.4 @ 22 mph		
VW Taxi - On/Off mode ³								
VW Bus - EEC configuration ⁴					16.8	19.4 @ 26 mph		
<u>NO_x Emissions⁵</u>		0	1	2	3	4	5	
VW Taxi - Hybrid mode								4.78
VW Taxi - On/Off mode				1.83				
VW Bus - EEC configuration				1.33				
<u>CO Emissions</u>		0	5	10	15	20	25	30
VW Taxi - Hybrid mode								36.0
VW Taxi - On/Off mode								28.3
VW Bus - EEC configuration							24.6	
<u>HC Emissions</u>		0	1	2	3	4	5	
VW Taxi - Hybrid mode				2.18				
VW Taxi - On/Off mode				2.36				
VW Bus - EEC configuration				1.01				

1. Contribution of electrical energy from battery discharge is included, but is stated in miles per gallon units.
2. Average of 18 tests on 4 configurations in the Hybrid mode. Differences between the 4 configurations were relatively small.
3. The On/Off mode used only electric power below a vehicle speed that could be varied from 22 to 26 mph. The 26 mph configuration represented a case with high battery discharge and limited range. Range is greatly influenced by the driving cycle and would be 30 miles for the FTP cycle and 100 miles for the SAE J2272 '0' cycle.
4. The Equivalent Emission Control (EEC) configuration considers the Bus HC & CO performance without a catalytic converter to compare Bus and Taxi emissions on an equivalent emission control basis.
5. Emissions are reported as weighted grams/mile per the Federal Test Procedure.

Figure 3-41. Test Data Summary

SECTION 4

VEHICLE DESCRIPTION

The current VW Taxi is the second gasoline/electric hybrid built by the VW Research and Development Center in Wolfsburg, West Germany. The Taxi is shown in Figure 4-1.

The first hybrid was based on a production VW Microbus and had a configuration similar to the vehicle tested at JPL. This first hybrid vehicle had been developed to the point where one of the key variables, the time constant between the accelerator pedal motion and throttle response, was optimized. The optimum value for this time constant from both emissions and energy economy considerations was 2.3 sec.

After the engineering data on the first prototype had been obtained, VW was considering building a second hybrid vehicle to determine the technical advantages of a more advanced vehicle. At this time, the New York Museum of Modern Art started their Taxi Project. This project was concerned with developing a taxi which will be suitable for use in the city of New York and also considered both energy economy and low air pollution (ref. VW decided to participate in this Museum of Modern Art Project, so the VW Taxi is the result of previous VW research and the New York Museum of Modern Art Taxi Project.

The remaining part of this section will be concerned with only technical aspects of the vehicle, and will not discuss items related to its use as a taxi.

4.1 TAXI'S BACKGROUND

This particular vehicle is rather unusual when compared to the treatment of many research vehicles. Most research vehicles represent considerable expenditures, typically well over \$100,000, and so are treated with extreme care to minimize risk to the vehicle. Consequently, a research vehicle is typically limited to proving ground roads if it is an experimental engineering vehicle or auto shows if it is intended for publicity purposes. The VW Taxi has both

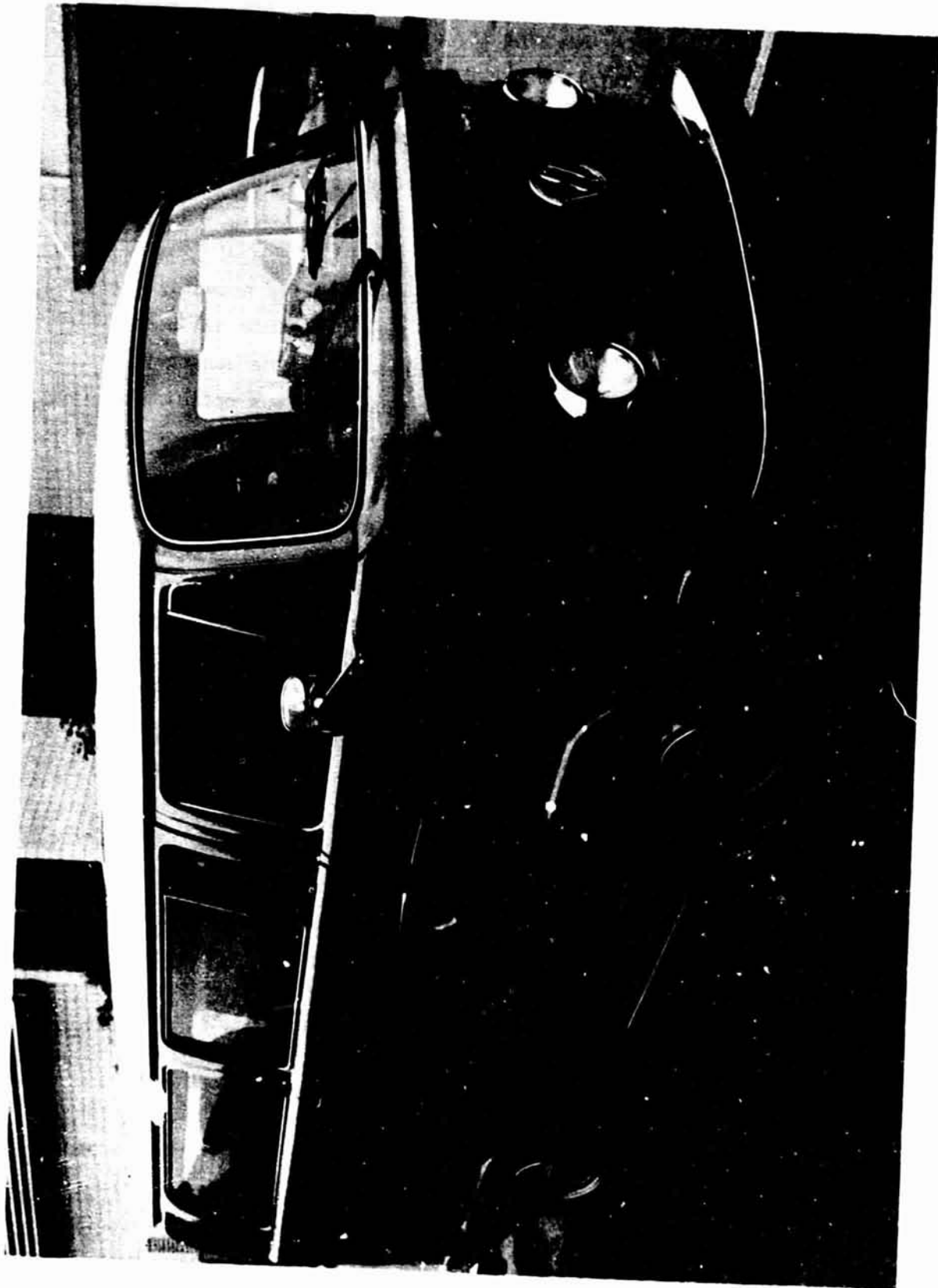


Figure 4-1. VW Taxi

of these characteristics. From the technical viewpoint, the VW Taxi is the world's most sophisticated operational hybrid vehicle at this time. In addition, it is a show car. It has been to many auto shows throughout Europe and the U.S. and was on an extended trip of the Eastern and Midwestern parts of the U.S. approximately one year ago.

However, the VW Taxi is certainly a practical vehicle, not merely a show car or one that is confined to proving ground roads. It has been driven approximately 8000 miles; since the vehicle was developed for the New York Museum Taxi Project, the odometer is calibrated in miles, not kilometers. Most of these miles have been driven over public highways in normal West German traffic. The VW Project Engineer used this vehicle as his daily transportation to and from work for about a year. It has also been driven to and from auto shows throughout Germany and other parts of Europe. Because of this use, this particular vehicle has reasonably demonstrated its applicability for normal highway usage.

In the remaining parts of this vehicle description, the term "engine" will refer to the gasoline internal combustion engine (ICE): "motor" will refer to the electric motor. All other terminology will follow normal practices for either the ICE or electric components.

4.2 MECHANICAL MODIFICATIONS

Only relatively minor modifications to the basic VW power train were necessary because of the rear engine configuration and the interior room of the production VW microbus. This basic VW power train made it possible to remove the front cover of the production VW transaxle assembly, add a special gear box that coupled the power from the gasoline engine and the electrical motor, add a drive shaft from the electric motor into this special gear box, and install an electric motor in the center of the vehicle's passenger compartment. Figure 4-2 shows a drawing of the key elements of this mechanical assembly. From the mechanical viewpoint, this appears to be the major modification necessary to convert the VW production power train into a parallel electric hybrid.

It should be noted that the vehicle contains many other modifications necessary for use as a taxi, but these are not pertinent to this discussion.

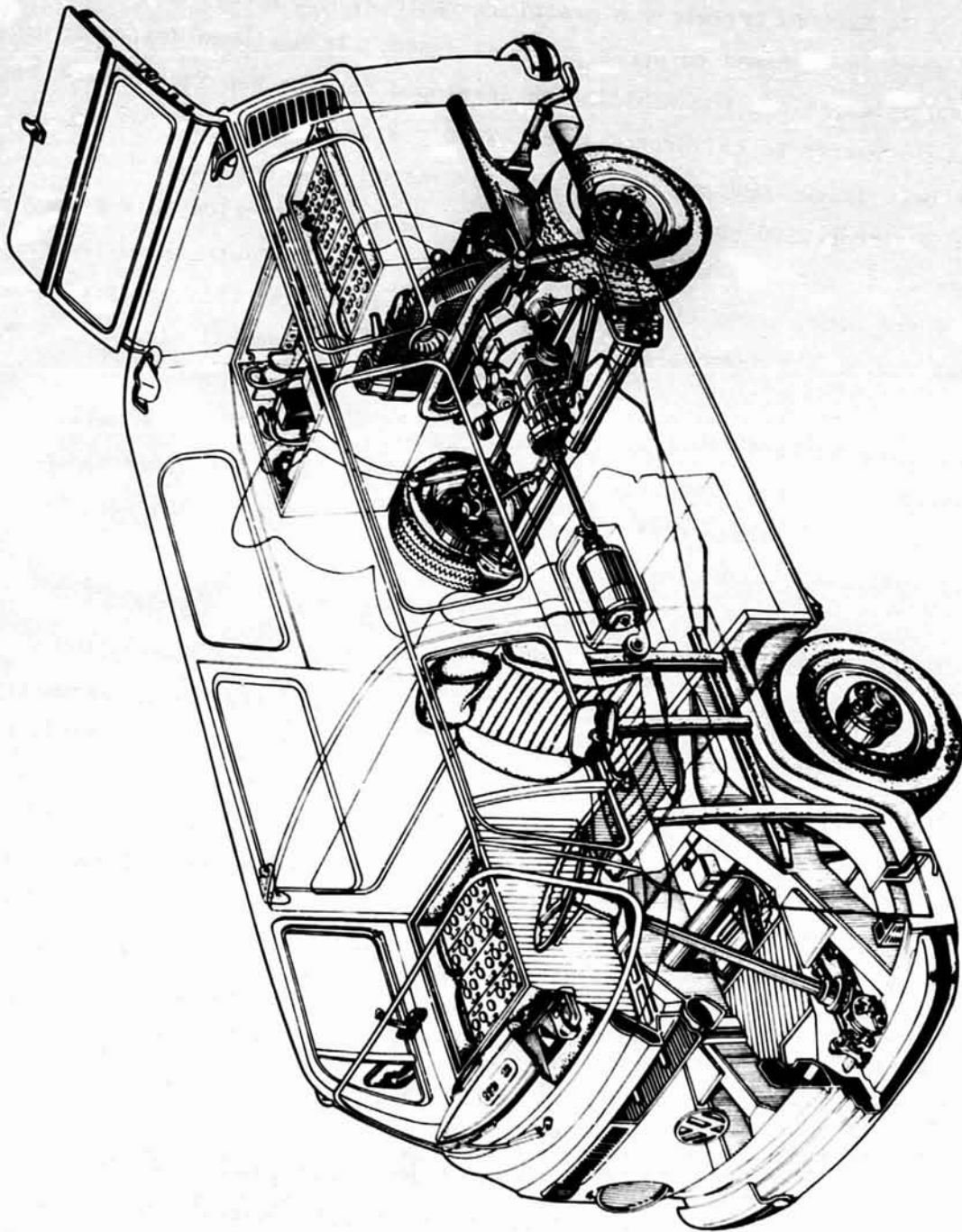


Figure 4-2. Cutaway View of the VW Taxi

4.3 POWER TRAIN

The basic power train is shown in Figure 4-3. The inset shows the gearing between the engine and the motor that provides the parallel hybrid mechanical configuration. The gear ratio between the engine and the motor is approximately 1 to 1.7, with the motor operating at a higher speed. Since the engine and the motor are continuously and directly coupled by the hybrid gear box, power to the rear wheels can be driven by both the engine and motor at any time. This parallel hybrid configuration thus permits the system control strategy to provide very flexible operation between the two power sources.

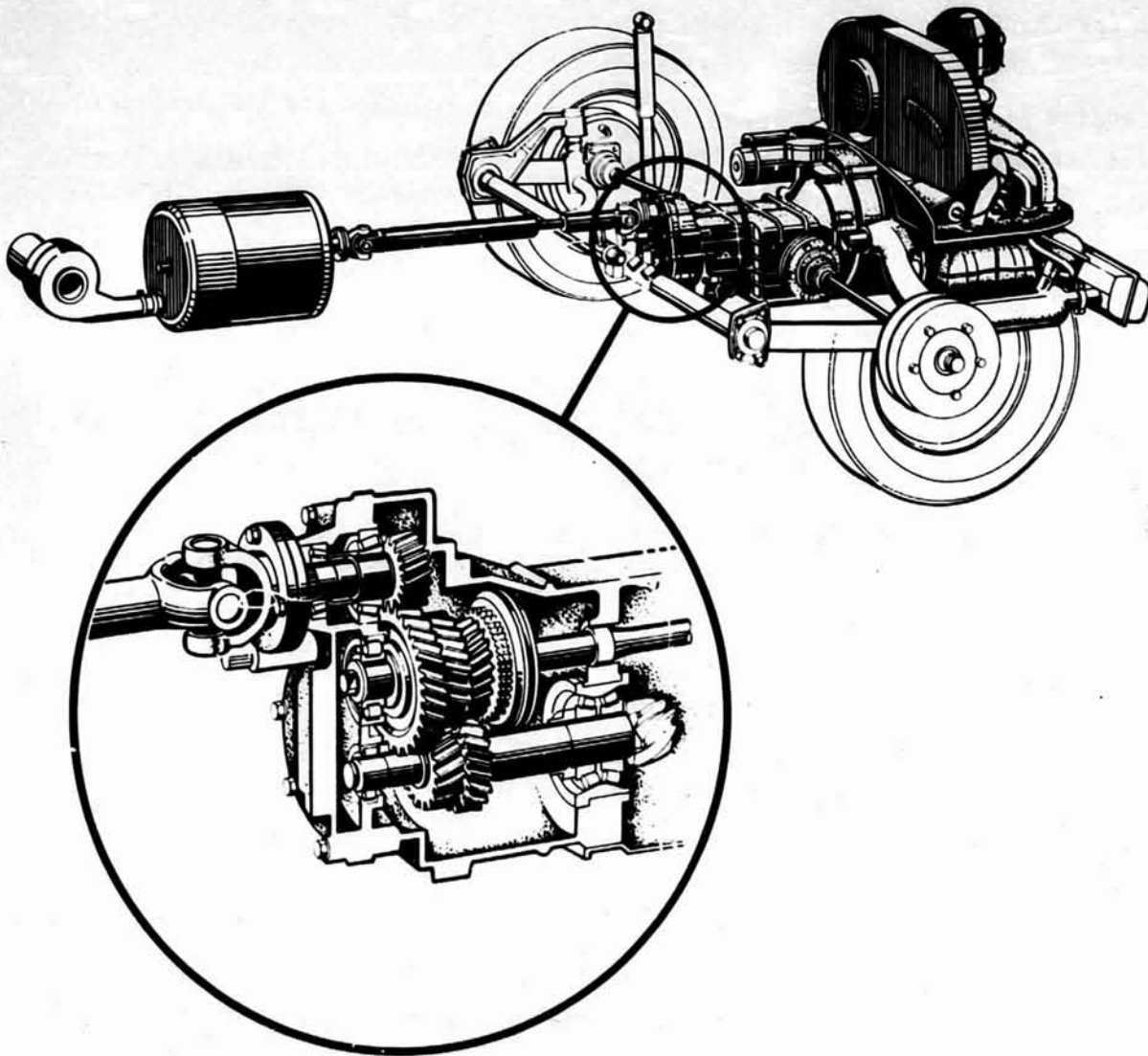


Figure 4-3. VW Electric Motor Correction

4.4 ENGINE

The engine is the basic 1600 cc carbureted VW engine that has been installed in millions of vehicles up to 1974, when production of this engine was stopped for U.S. sales because it was unable to meet emissions constraints. However, it is still produced for nations with less stringent emissions. The production termination date is a key point; the engine does not represent current emissions or fuel economy technology. Even though the engine design is old, the particular engine installed in the Taxi is new. The engine was run about 24 hours at high power on an engine dynamometer, then tested before it was installed in the Taxi. After brief testing in the vehicle, it was shipped to the U.S. for the SOA tests.

The engine is fitted with a production EGR system designed for the Japanese market. No testing was done to optimize the EGR system for the hybrid application, so it is reasonable to expect that better tradeoffs between NO_x emissions and fuel economy would result if the EGR were optimized for the hybrid's unique operating characteristics.

The vehicle has no other emissions control systems. In particular, there is no catalytic converter. HC and CO emissions should be significantly reduced if a catalytic converter were installed.

The engine has a standard VW carburetor with normal production calibration selected for low CO idle emissions. Spark timing is also standard.

The throttle is actuated by a small servo motor and gear reduction unit (Figure 4-4) that receives its electrical signals from the system controller. There is no mechanical linkage in this system, nor provision for any. The throttle is set to open very slightly in the "off" position for idle air flow. The system control scheme also limits the maximum throttle opening to a value that provides a maximum of about 35 HP from the engine, even though its normal rating is 50 HP. This limitation is part of the overall control strategy and is intended to minimize emissions while providing performance that is essentially equal to that required to negotiate the speed-time profile of the Federal Test

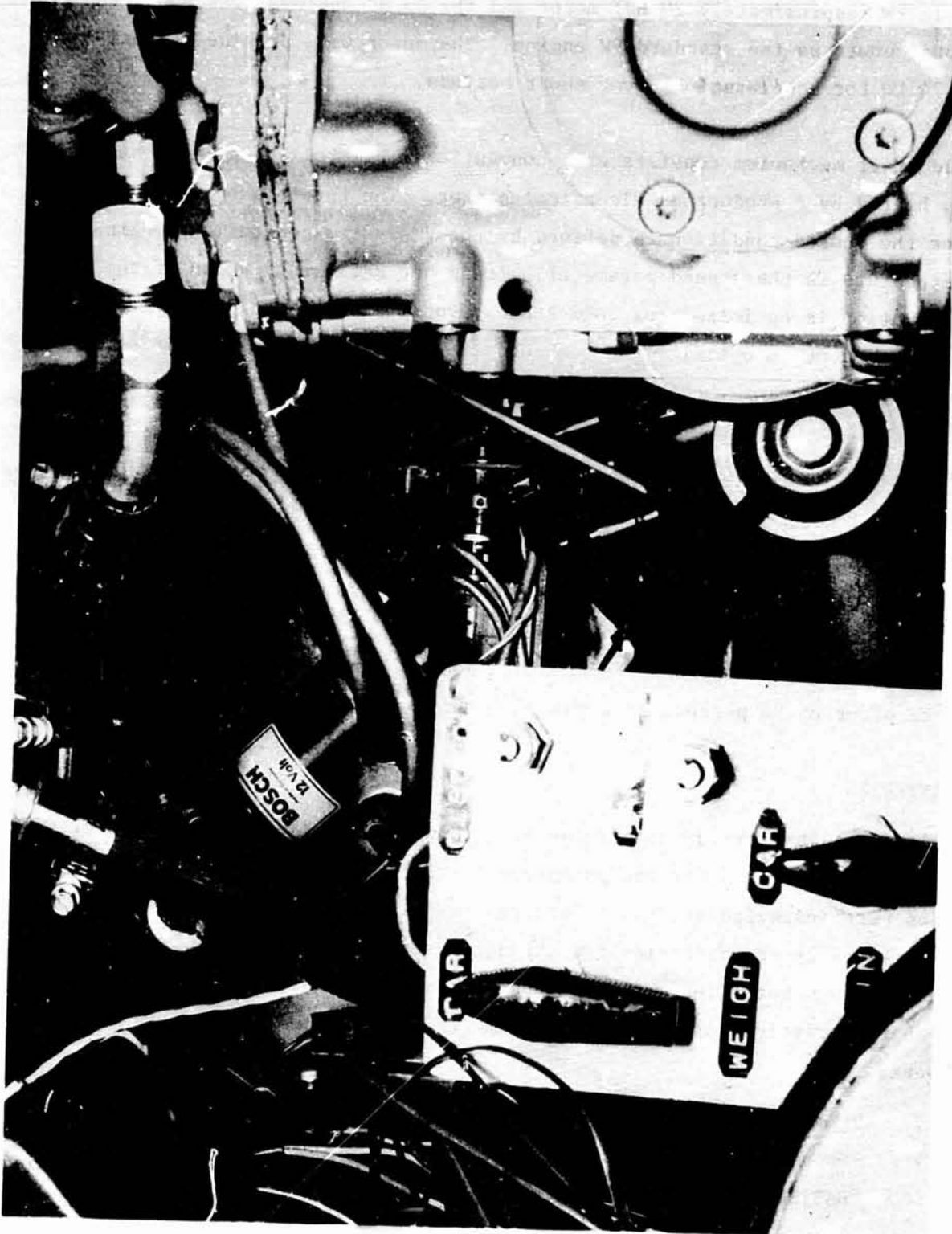


Figure 4-4. Throttle Actuation Mechanism

Procedure (FTP) for the urban test cycle. It should be noted that a combination of the 16 kW (approximately 20 HP) motor and the 35 HP engine gives about the same total power as the standard VW engine. The motor will provide approximately 24 kW for accelerations over short periods.

The cold start mechanism consists of a conventional bimetallic choke mechanism. This is heated by a production electrical heater. The throttle opening necessary for the choked condition is defined by the VW system controller; engine oil temperature is the sensed parameter. It is not definitely known if the choke actuation is optimized for cold starts, but it is believed that little work has been done to optimize the combined effects of the choke actuation, engine operation during the initial start, and motor power during this period.

4.5 MOTOR

The electrical motor is rated at 16 kW, or about 2/3 the power of the engine when the engine's reduced power is considered. Up to 2000 rpm, the armature current controls the motor power. From 2000 rpm to the maximum rated speed of 6000 rpm, field weakening is used to control the power. The motor can provide full torque throughout the armature control range. Maximum efficiency is on the order of 90 percent at about 2500 rpm.

4.6 BATTERIES

Eleven lead-acid batteries, each rated at 90 ampere hours at a 20 ampere-hour discharge rate, are used for the primary electrical propulsion system. The batteries were installed shortly before the Taxi was shipped to the U.S. and so were treated as new batteries for the JPL tests. Since detailed characteristics of the new batteries were not known, maximum permissible battery discharge characteristics during tests were defined by the VW Project Engineer. These were:

- 1) Primary limitation - minimum voltage of 110V during testing.
- 2) Secondary limitation - a minimum reading of 60 percent on the VW "BATTERIE" meter. (This meter is discussed in Paragraph 4.9).

The primary limitation was not to be exceeded.

4.7 MODE SELECTION

The vehicle includes a vacuum actuated clutch. The clutch is used only when a mode selector lever, equivalent to a transmission selector lever, is moved into or out of the "Hybrid" position. In the "Hybrid" operating mode, both the gasoline and electric power systems are operational. When the lever is moved into the "Hybrid" position, the clutch automatically actuates for a short period of time while the gear shift lever mechanically moves the transmission gear into position.

The other positions of the mode selector lever are:

- N Neutral. The electrical power system is off. The primary relay for the electrical power system is not actuated so the entire electrical power system is active.
- E Electrical Drive Mode. The vehicle is powered by the electrical system in the forward direction.
- HR Hybrid Reverse. In this mode, the vehicle is driven in the reverse direction by the electric motor; the ICE engine is inactive.
- H Hybrid. This mode used both power systems in the forward direction.

Only the shift to and from the HR to the H mode requires any appreciable force since this motion mechanically engages the transmission third gear. Only the standard VW third gear is used in the Taxi. Shifts to and from other modes require essentially zero force and actuate only switches that send signals to the controller.

In the E Mode, there is normally a small vacuum motor that provides vacuum for the power brakes. This pump was disconnected for the tests since it was not needed.

4.8 POWER CONTROLLER

The electrical power controller is a standard Bosch product with slight modifications for the VW Taxi. VW has an electrical car program with 20 vehicles that use the same, but unmodified, controller. The power controller occupies the majority of the space on the top right side of the engine (Figure 4-5).

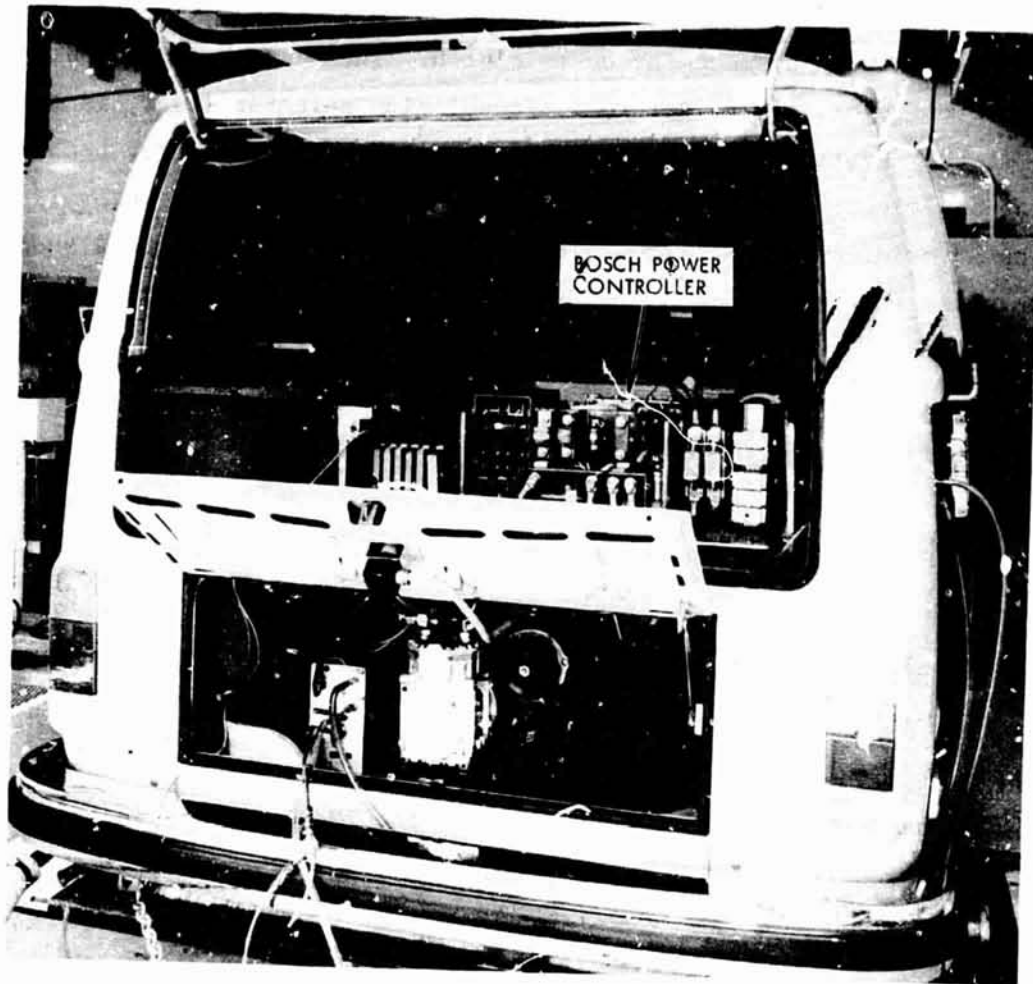


Figure 4-5. Bosch Power

4.9 SYSTEM CONTROLLER

The system controller (Figure 4-6) was built by VW. The system receives signals from the accelerator pedal, throttle opening feedback transducer, vehicle speed, and the Bosch controller to control the normal driving mode. In addition, engine oil temperature is used to determine if the engine is cold. The VW system controller then provides output signals to the Bosch controller and the throttle servo motor.

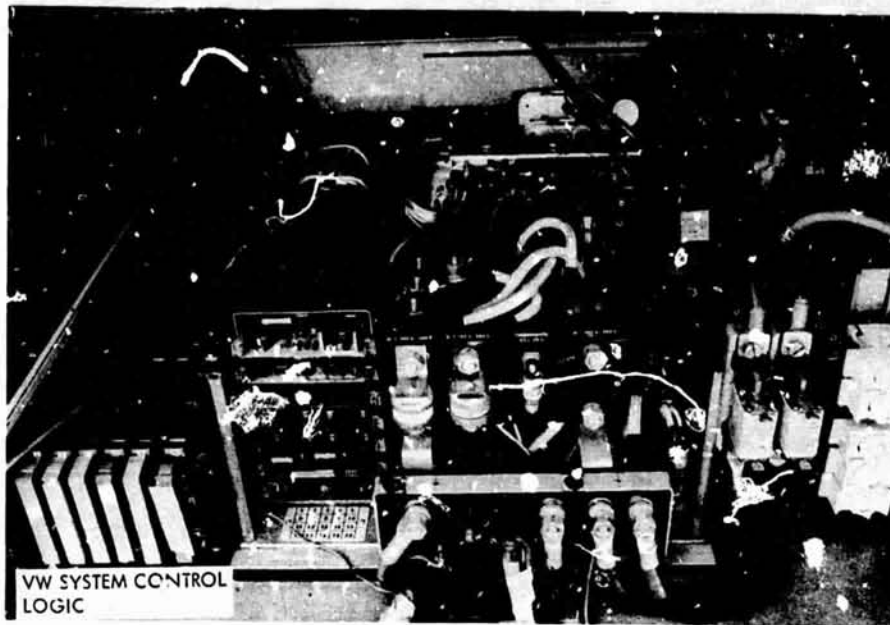


Figure 4-6. VW System Control Logic

The regenerative braking current is limited to 100 amps. The VW Project Engineer stated that this value was selected for several reasons. In addition to the normal limitation concerning the maximum power that can be absorbed by the batteries, vehicle handling was also considered. If more regenerative braking power were used, it was stated that the vehicle handling under maximum braking conditions would be adversely effected. The regenerative braking limitation was not a test variable because of time limitations. In addition, both VW theoretical studies and long-term data from their fleet of 20 electrical vehicles indicated that the maximum regenerative efficiency that could be practically obtained was about 20 percent.

4.9.1 Maximum Motor Current

The maximum motor current could be set from 200 amps, a practical lower limit that would provide adequate power, up to a maximum of 290 amps by changing an adjustment pot. The procedure was straightforward and appeared to be repeatable from the viewpoint of the adjustment rotation/current relationship. Verification of the setting was also simple, so changes could readily be made.

4.9.2 Time Constant Between the Accelerator Pedal and Throttle

A basic element of the VW control strategy is to open and close the throttle slowly regardless of the accelerator pedal velocity. The time constant between the two could be set to either 1.2 or 2.5 sec by changing a card in the VW controller (Figure 4-6). When the accelerator pedal is depressed quickly, the throttle will open slowly with a velocity defined by the selected time constant until it reaches the position defined by accelerator pedal input signal. In a conventional ICE engine, the slow throttle opening will cause an objectionable delay hesitation in the torque response requested by the accelerator pedal motion. However, the hybrid motor provides the necessary torque to meet the requested load increase while the ICE engine accelerates more slowly than in a conventional power train. This strategy is intended to reduce the HC and CO emissions that are greatly effected by engine transients.

4.9.3 Operating Mode

A SAE paper on Hybrid Vehicle for Fuel Economy (ref. 4) indicated that considerable fuel economy savings could be realized if the engine were shut off during idle periods. A card in the VW controller (Figure 4-6) permitted an approximation to this control strategy to be investigated. This card permitted the engine to be turned on and off during normal driving operation. The spark was turned off to stop the engine. The carburetor includes an electrically actuated valve to completely shut off fuel flow, so fuel flow was blocked during the engine off period. The Taxi operates as an all-electric vehicle when the engine is off. Engine startup is initiated by turning the spark and fuel on when the engine speed is adequate. Engine cranking is provided from motor power driving the torque converter's output shaft via the hybrid gear box.

The engine cut-in and cut-out speeds were both adjustable. One adjustment sets the cut-in speed, while another defines the difference between the cut-in and cut-out speeds. A minimum cut-in speed of about 22 mph exists because of the torque converter. At speeds below 22 mph, converter slip is too great to transmit power adequate to crank the engine.

A change in this card thus permitted the vehicle to be operated in the normal hybrid mode or the engine on/off mode. This mode had evidently been investigated to a minimum extent by VW since the VW Project Engineer termed this the "Kangaroo" mode because of potential jerking motion when the engine started.

The clutch is automatically actuated, and so could be opened when the engine speed was off and then closed shortly before the engine was started. However, this type of operation probably would have resulted in uneven operation if closely timed phasing between the clutch actuation and the engine starting was not attained. The VW Project Engineer conducted some brief investigations of the clutch On/Off mode, but preferred not to include this capability in the normal tests.

4.9.4 "BATTERIE" Meter

The VW controller provided an output signal that was an indication of the battery state-of-charge (SOC). This signal was derived from a circuit that measured the net ampere-hour flow to/from the batteries; the circuit included an approximation to the non-linear SOC-ampere hour relationship that exists near the fully charged condition. This circuit was designed for, and matched to, the previous batteries and was not changed when the new batteries were installed. It was thus only an approximation of the SOC for the new batteries.

The output signal was connected to a "BATTERIE" meter on the dash. This meter read from 0 to 100 percent. The meter reading was manually adjusted to read 100 percent after the batteries were fully charged, then monitored during a testing sequence to obtain real-time information on the battery SOC.

The SOC signal was not used by the VW controller.

SECTION 5

MEASUREMENT PERFORMANCE

This section is concerned with the measurement performance of the hybrid vehicle tests; the basic facility and instrumentation are described in Appendix B. It discusses the calibration of the major elements in the JPL facility, the checks made to verify satisfactory performance during the hybrid testing program, and comments concerning specific items that may influence the hybrid testing data.

This section is divided into two parts. The first describes the facility calibrations that were done prior to the hybrid testing program to provide maximum assurance of accurate data for the hybrid testing program. The second part discusses two system-level calibrations and procedures used to verify the overall measurement performance.

5.1 FACILITY CALIBRATIONS

The facility calibrations discussed here are concerned with the key elements of the JPL test facility: chassis dynamometer, constant volume sampler (CVS) emission instruments, gasoline weigh tank, and the data system. Detailed information is contained in the appendices; only the primary points are discussed in this text.

5.1.1 Dynamometer

The JPL chassis dynamometer inertia weights were changed from a belt drive system to a direct drive system immediately before the hybrid testing program to eliminate the uncertainties associated with the belt losses. In previous test activities on an electric vehicle (ref. 6), it was determined that the belt losses were significant, particularly when the vehicle being tested had relatively low power. Other internal JPL documentation also verifies that the belt losses are unacceptable for tests of low-power vehicles (ref. 7). Because of this, it was essential that the direct drive inertia weights be installed to eliminate a major uncertainty in the VW Taxi tests. After the new weights were installed, a break-in process was conducted to reduce bearing friction changes

to essentially zero. Calibrations were made at regular intervals during this break-in process; when the change from a previous calibration was undetectable, final dynamometer calibrations were made.

The manufacturer's dynamometer power measurement components had been previously augmented by a load cell to measure force and a digital transducer to measure dynamometer roll rpm. The data system converted these measurements into real-time power measurements. Data were displayed with a resolution of 0.01 HP. Overall measurement system errors, including transducers and real-time calculations, are less than 0.05 HP during the time required to conduct an FTP test. However, the primary limitation to attaining repeatable test-to-test dynamometer loads was the settability of the power absorption controls and temperature-dependent dynamometer characteristics. The test-to-test variation of these factors is approximately 0.1 HP.

5.1.2 Constant Volume Sampler (CVS)

The CVS was given a complete calibration prior to the start of the hybrid testing program. This calibration accuracy is directly dependent on the measurement of an airflow transducer. This transducer, a laminar flow element (LFE) was sent to a specific source to be calibrated. Previous JPL experience has shown that this is the only known vendor that can provide calibrations of various airflow transducers and have intercomparison data of these transducers agree within the specified accuracy.

5.1.3 Emission Instruments

Emission instruments were calibrated in the conventional manner. This requires introduction of calibration gasses with known concentrations into the emission instruments to derive the calibration curve. Experience has shown that the concentrations specified by a vendor are not always correct. Correlation of several gasses, measured on the same range of one instrument, can assist resolution of this problem. However, JPL has been able to use the resources of a local emission testing facility that has a large supply of calibration gasses that have extensive correlation with other gasses throughout the nation. This resource has been used to resolve conflicts between the specified concentrations and agreement with other gasses of similar concentration.

5.1.4 Power Measurements

The overall power measurement accuracy is derived from two lab calibrations plus the system-level check discussed in paragraph 5.2.2. This discussion will be limited to the two lab calibrations.

- a) Transducers -- The two current transducers and two voltage dividers were calibrated by the JPL Standards Lab. These calibrations were stated to be within 1/4 percent, the requested accuracy.

The Standards Lab found that the current transducers were susceptible to drift during a warm-up period. The drift was essentially within 0.1 percent after a period of about 15 min. Adequate warmup time for each hybrid test was provided by connecting the measurement system to the power in the vehicle storage area for a period of at least 30 min prior to the time that the vehicle was driven to the test area. Power was the last item to be disconnected when the vehicle left the storage buildings, but was on for a period of about 15 min between the time the test site. Typically, the power was off for 3 to 4 min between buildings but was on for a period of about 15 min between the time the vehicle arrived at the test site until the test was started.

- b) Power Measurement Circuit -- These circuits were calibrated to within 0.1 percent on a dc basis after construction and lab checkout was completed. Calibration data is shown in Figure 5-1.

The voltage dividers contain a compensation network to trim their response. This compensation network and other circuit adjustments were set to provide minimum distortion to a square wave input. The response of the power measurement circuits inside the chassis is less than 10 microseconds except for the voltage-to-frequency converter. This unit, which has a full-scale output of 10 kHz, is specified to reach the new frequency within one cycle after the input voltage is changed.

5.1.5 Gasoline Weight Measurements

All gasoline fuel economy measurements were based on a gasoline weighing system (Figure 5-2). The lightweight tank is filled before a test and contains enough fuel to conduct an urban FTP test. The gasoline weight measurement is within ± 0.5 percent, and probably better; the most recent calibration data is shown in Figure 5-3.

The total weight of gasoline consumed during a test is a more certain measurement than one based on the complex emission measurement system, so the weigh tank data are used as the basis for the gasoline energy consumption data in this report. Paragraph 5.2.1 discusses use of the weigh tank data.

5.2 SYSTEM CHECKS

Two different system-level checks were used to verify the energy and emission measurements for the Hybrid testing program. The first concerned use of a reference vehicle to conduct repeated tests at intervals of several weeks to determine the repeatability of the facility. The second checked the calibration of the power measurement circuits used to measure battery and motor power.

5.2.1 Reference Vehicle Tests

A common approach to verification of facility repeatability for the complex Federal Test Procedure (FTP) tests is use of a specific vehicle to conduct repeated tests over a period of time. Auto firms use this technique to determine the time-varying repeatability of a single test site and also to correlate the measurements between various test sites. Typically, the reference vehicle is modified to remove items that could create varying economy or emissions performance. Modifications include:

- 1) Remove the alternator and supply vehicle power from an external power source.
- 2) Remove the fuel pump and supply gasoline from an external pressurized source.

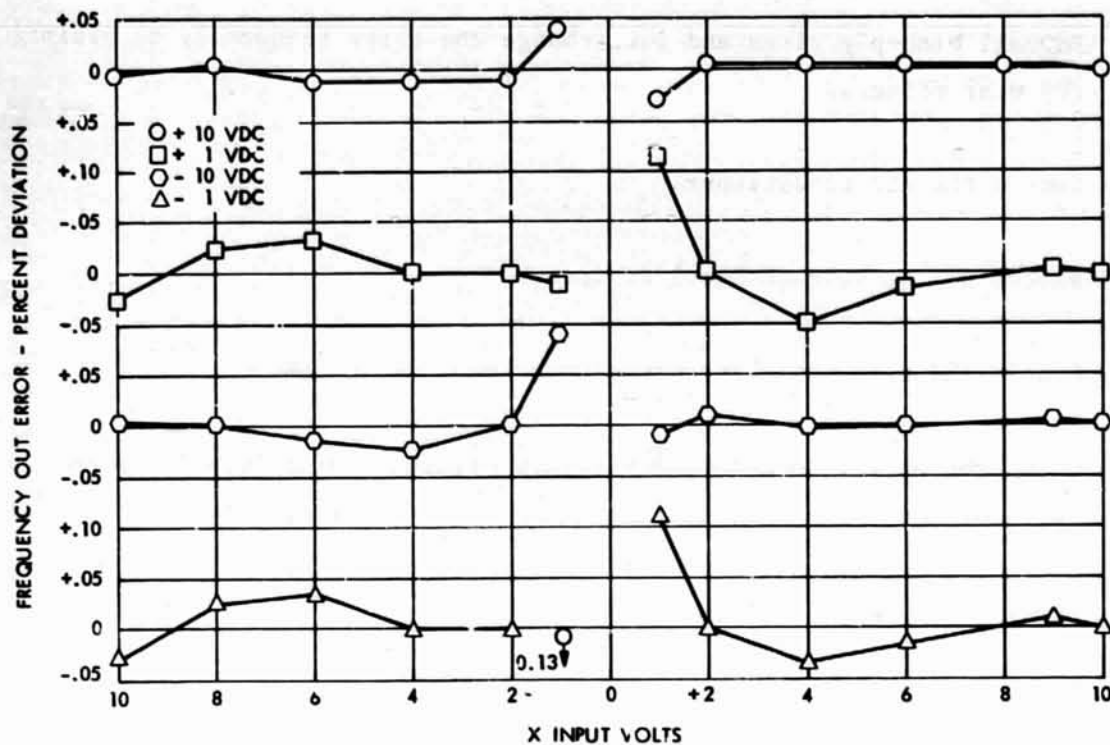


Figure 5-1. Power Measurement Circuit Calibration

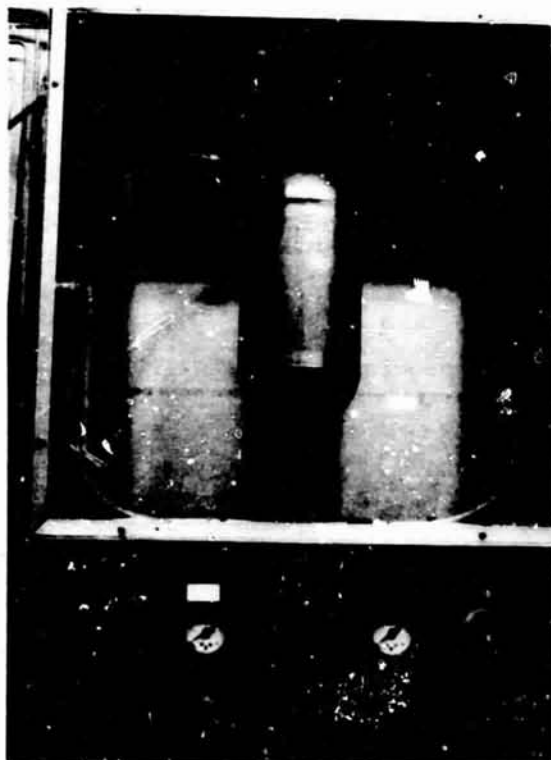


Figure 5-2. Gasoline Weighing System

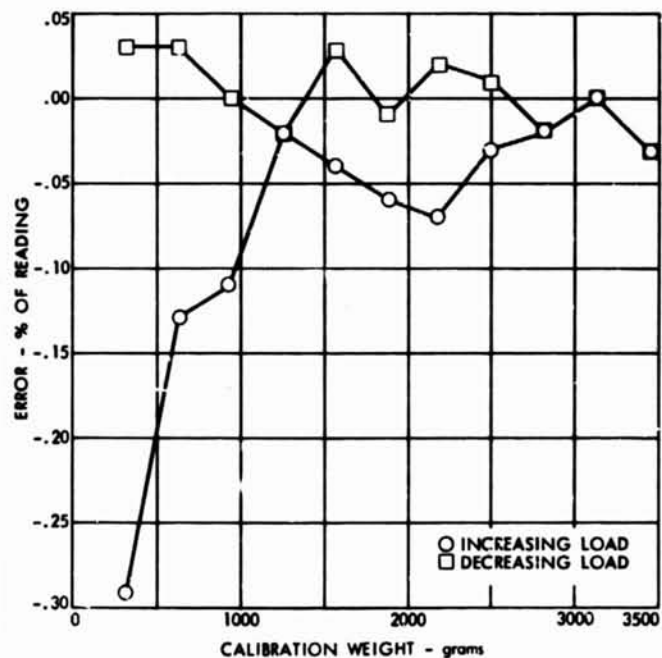


Figure 5-3. Gasoline Weighing System Calibration

- 3) Install bias-ply tires and interchange the tires frequently to minimize the wear effects.
- 4) Remove the air conditioner.
- 5) Remove all emission control devices.
- 6) Remove the rear brake automatic adjustment mechanism.
- 7) Check the engine to accurately verify critical parameters (compression ratio of each cylinder, distributor characteristics, carburetor, etc.).
- 8) Controlled break-in for at least 4000 miles.
- 9) Install special rear wheels to measure torque at the dynamometer rolls.

JPL uses a 1975 Chevrolet for its reference vehicle. The vehicle does not include all the listed changes, but does have a reasonable history of recent testing performance. Its fuel economy and emissions repeatability during the time of the hybrid tests is shown in Figures 5-4 through 5-7. Three consecutive cycles of the hot transient phase of the FTP are used for JPL repeatability tests. Each cycle is 505 seconds long, so these tests are referred to as "Hot 505" tests. The graphs show the results of the three individual cycles as well as the average of the three cycles.

Cycle-to-cycle and test-to-test repeatability are good indicators of overall facility performance, including the driver.

Although facility repeatability can be established with this technique, the agreement between the fuel economy calculated from the weigh tank fuel measurement, discussed in Paragraph 7.2, and the economy calculated from the emission instrument data is more important. Use of the two entirely different measurement techniques, weigh tank and emissions, to determine fuel economy provides an excellent check that all components of both measuring processes are operating satisfactorily. The emission instrument fuel economy measurement is specified

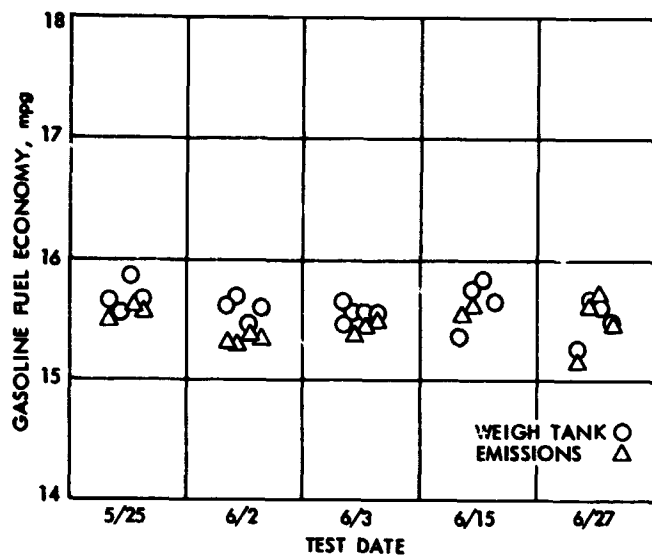


Figure 5-4. Reference Chevrolet Gasoline Fuel Economy

Figure 5-5. Reference Chevrolet NO_x Data

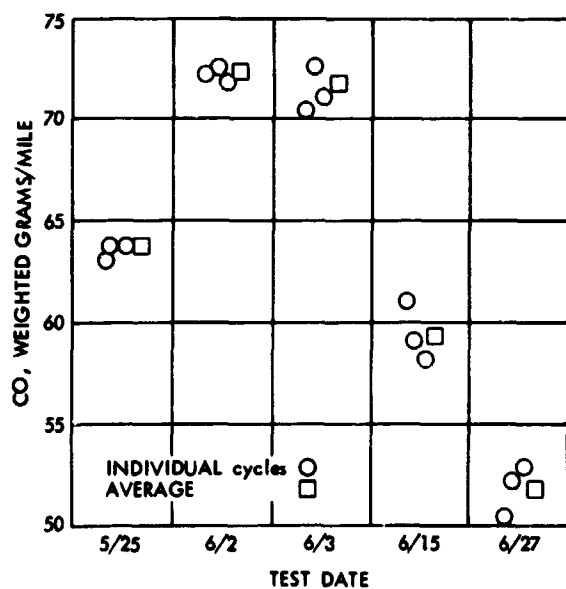
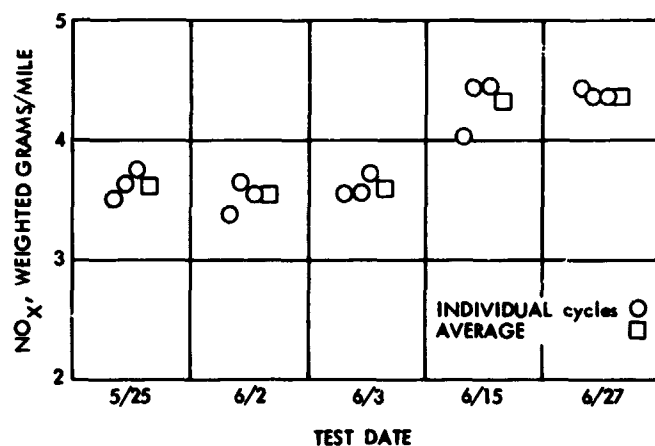


Figure 5-6. Reference Chevrolet CO Data

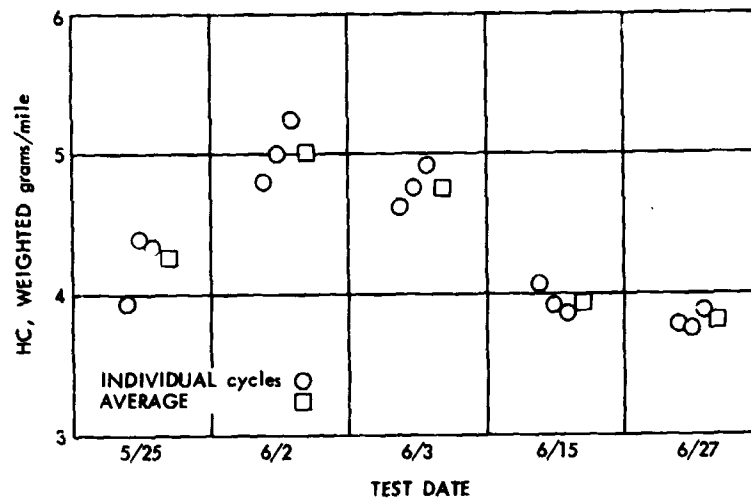


Figure 5-7. Reference Chevrolet
HC Data

by the FTP. However, the emissions based fuel economy measurement will include effects of exhaust leaks in the vehicle, flexible hose and all related fittings between the vehicle exhaust pipe and the CVS, the CVS and all its related calibrations, and the emissions instruments and all their related calibrations. There is the possibility of many leaks in this flow path; about 50 solenoid valves are included as well as many flexible hoses and tubing fittings. If the fuel economy calculated from the emissions instruments agrees within ± 3 percent of the economy calculated from the weigh tank, the entire emissions measurement system is in good condition.

Figure 5-8 shows the agreement between the emissions and weigh tank fuel economy for the reference vehicle. Twelve of the 15 individual cycles provide agreement within ± 1 percent; only one point is outside of 2 percent. This shows that the JPL facility has good performance for both the emissions and weigh tank data during the hybrid testing period.

The good agreement between the weigh tank and emissions fuel economy for the reference vehicle during the hybrid testing program was used to deduce that the VW

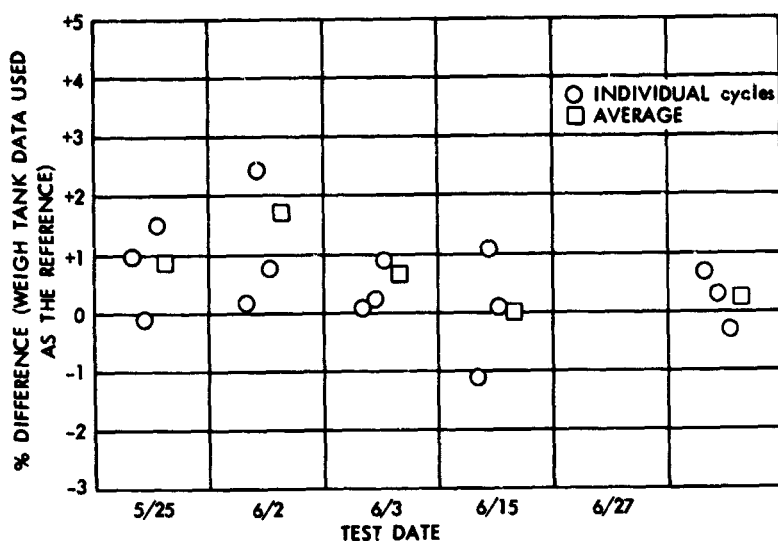


Figure 5-8. Agreement Between Weigh Tank and Emissions
Fuel Economy - Reference Chevrolet

Taxi had developed a leak in its exhaust. The agreement between the two fuel economy measurements for two early Taxi Hot 505 tests was less than 2 percent as shown in Figure 5-9. The agreement became poorer, but careful inspections disclosed no leaks. After the reference vehicle tests conducted on June 27 continued to show good agreement, the Taxi's exhaust system was examined by searching with a gas sample probe connected to the emission measurement instruments. This technique found one leak. During disassembly to correct the leak, another leak source was indicated by black discoloration in a normally inaccessible area.

Retests of the Taxi on July 15, after the leak had been located and repairs made, showed agreement between the weigh tank and emissions based fuel economy within 2 percent, the value originally obtained on June 21.

5.2.2 Power Measurement Checks

After the power measurement circuits had been installed, initial checkout completed and the circuits were operating satisfactorily, a check of the calibration of all components except for the transducers and buffer amplifiers was conducted. For this check, the input signals to the power measurement circuits were disconnected by removing the input connectors for both the voltage and current signals.

Voltages equivalent to specific current and voltage values were then introduced into the measurement circuit at the same point as the input connector signal. These input signals were derived from stable, accurate voltage sources as shown in Figure 5-10. The calibration voltage was set to the desired value when measured by a digital voltmeter with specified accuracy of 0.02 percent. The calibration voltages were selected to provide signals proportional to 135 volts and two different currents, 100 and 200 amps. The 135 volt level was selected as an approximation of a typical Taxi operating point.

The output of the power measurement circuit was sent through the entire measurement system and recorded on the data system printer. The printer was set to automatically print at 1 min intervals. The internal timing of the data system and its priority structure will start the printout well within a millisecond of the exact 1 min interval, so time deviation between the 1 min printout is negligible. The test was continued for at least 6 min. The printed record thus contained six values of the instantaneous power, in kilowatts, and six values of the integrated watt hours. The data were averaged and are shown in Figure 5-11. The dc calibration accuracy of the measurement system from the input to the measurement chassis to the output data is thus better than 0.5 percent.

Response of the isolation amplifiers was defined by removing the connections to the motor voltage terminals and inserting a calibration voltage from an oscilloscope into these measurement terminals. The signal flowed through the voltage divider and isolation amplifier, then was measured at the input to the electronic circuits on the voltage measurement card. The response is shown in Figure 5-12. Since the frequency response checks conducted on the internal electronic circuits, discussed in Paragraph 5.1.4, showed that these circuits were much faster than the isolation amplifiers, the response of the entire power measurement circuit for the voltage channel is defined by the waveform shown in Figure 5-12.

The response of the current transducers is stated as 5 kHz by the manufacturer. Checks which showed the current rise and fall under square wave response inputs indicated that this specification is conservative.

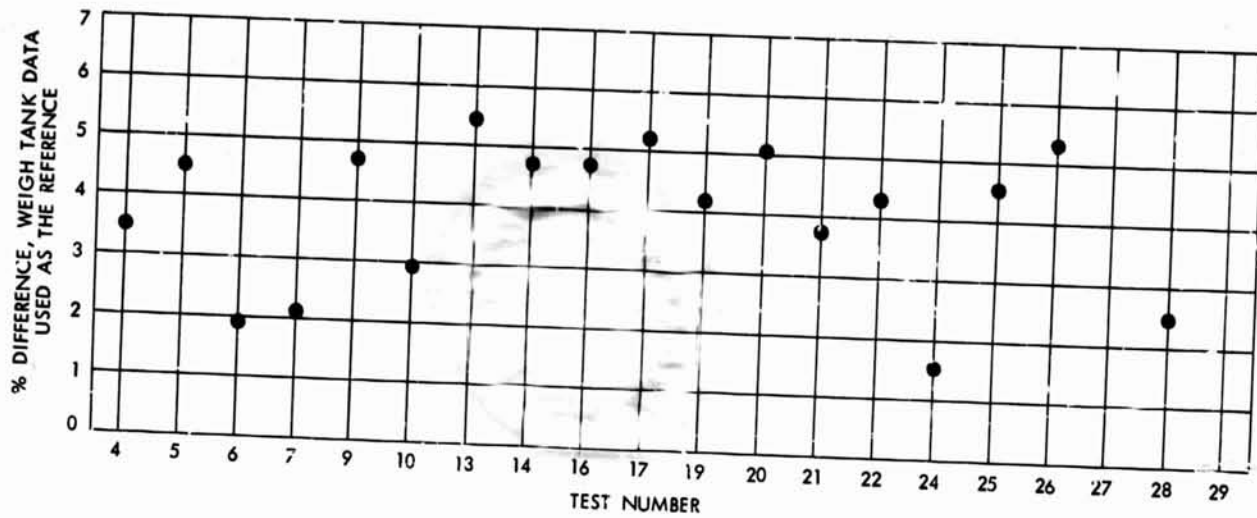


Figure 5-9. Agreement Between Weigh Tank and Emissions Fuel Economy - VW Taxi

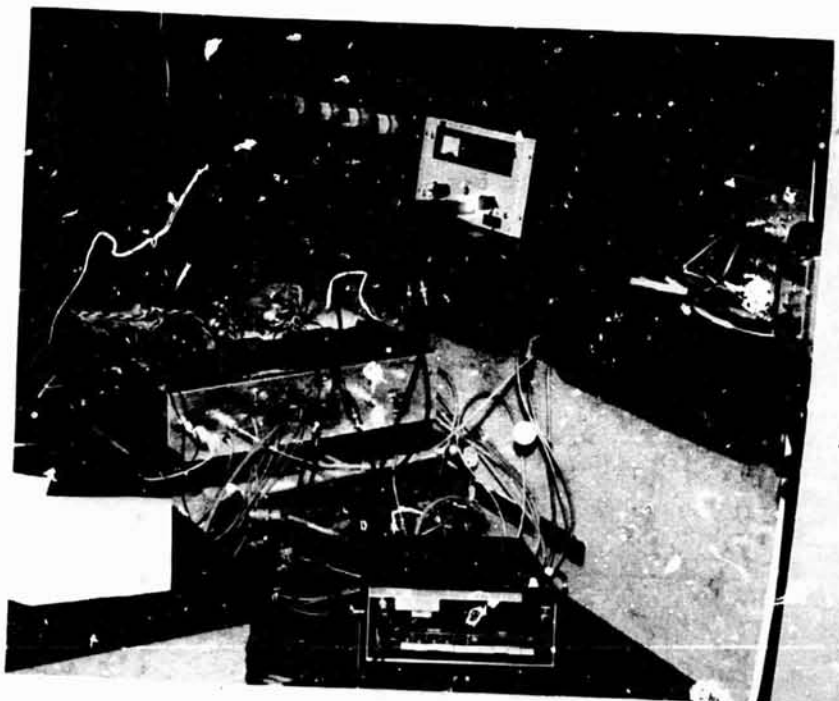


Figure 5-10. Test Setup for Power Measurement Checks

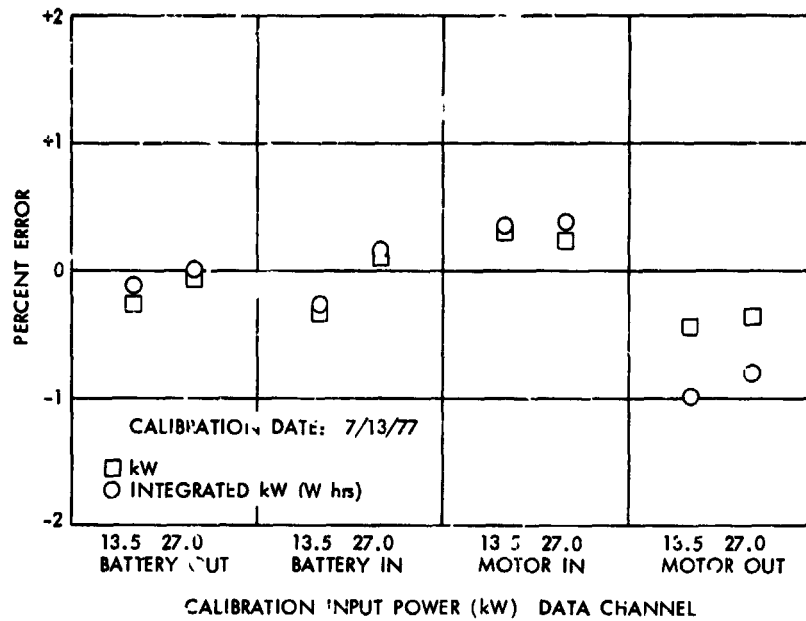


Figure 5-11. Calibration of Electrical Power Measurements - VW Taxi

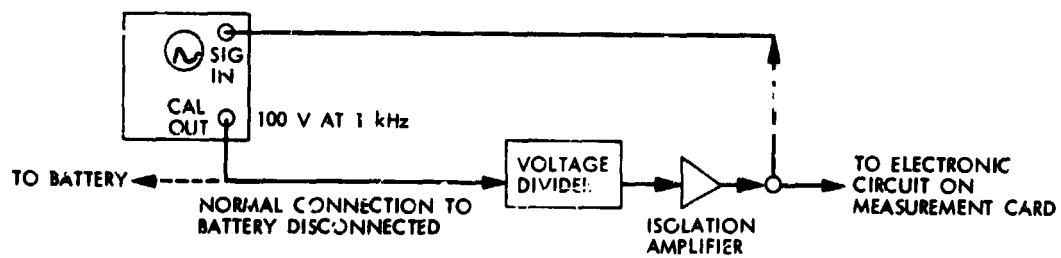
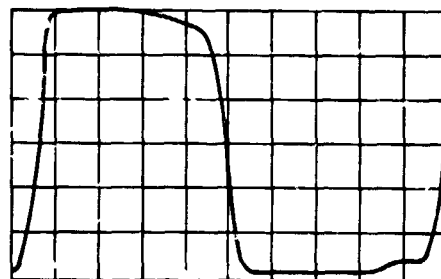


Figure 5-12. Isolation Amplifier Response

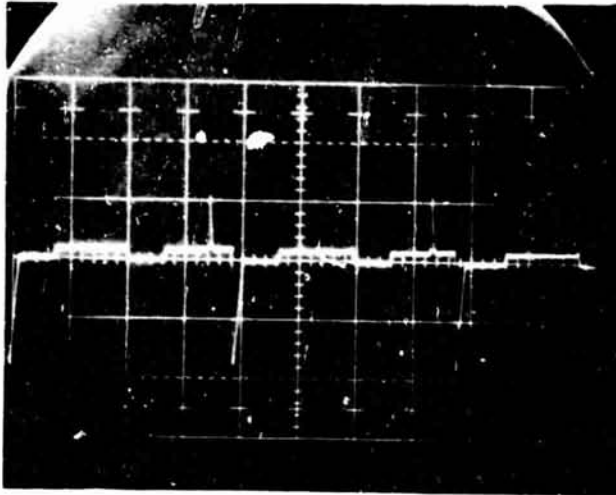
The circuit response permits measurement of very short negative pulses that may occur when the average signal level is positive. This signal characteristic is typical of a chopper power controller operating at low power levels. Waveforms of three different current signals, each at relatively low power, are shown in Figure 5-13. The negative spikes represent a significant portion of the total power. The JPL measurements sum the power for a period of 0.1 sec, then transfers the power data for this time to the data system memory. Separate measurement circuits are used for the current flow into and out of the battery. If both positive and negative areas occur within the 0.1 sec measurement period, the data system will measure both positive and negative powers. The resulting display is shown in Figures 5-14 and 5-15. In these photos, the sequence of readings from the top is:

- 1) Power out of the battery
- 2) Power into the battery
- 3) Power into the motor
- 4) Power out of the motor.

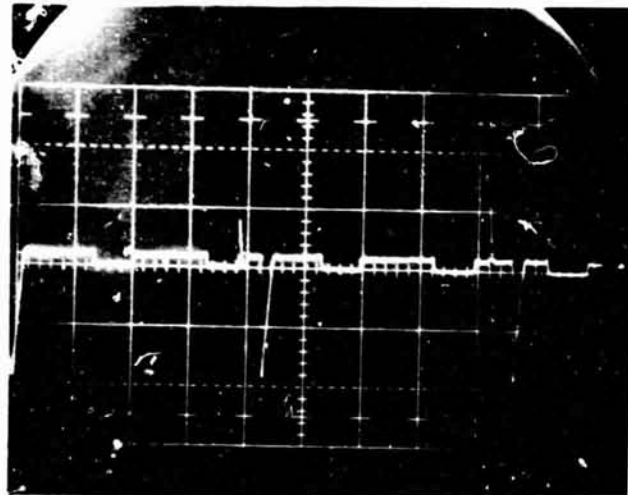
Readings are in kilowatts. The right display shows motor rpm.

This measurement technique will probably provide different data than one which has a slower response, so JPL data will not necessarily compare directly to other power measurements.

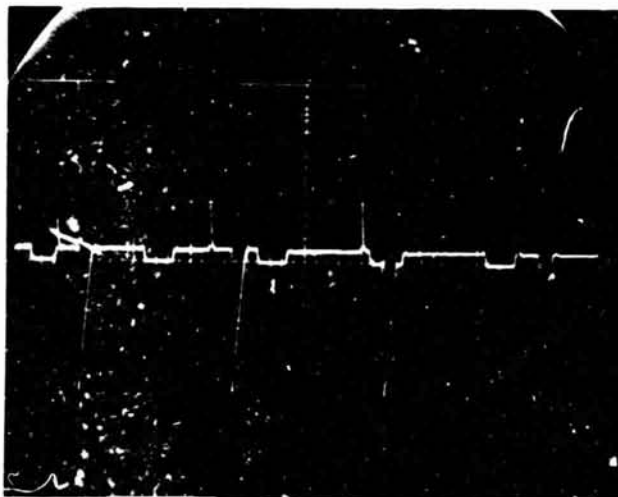
C-6



7 + 18



1 + 2



9 + 10

ORIGINAL PAGE IS
OF POOR QUALITY

Figure 5-13. Current Waveforms of Low Power Levels

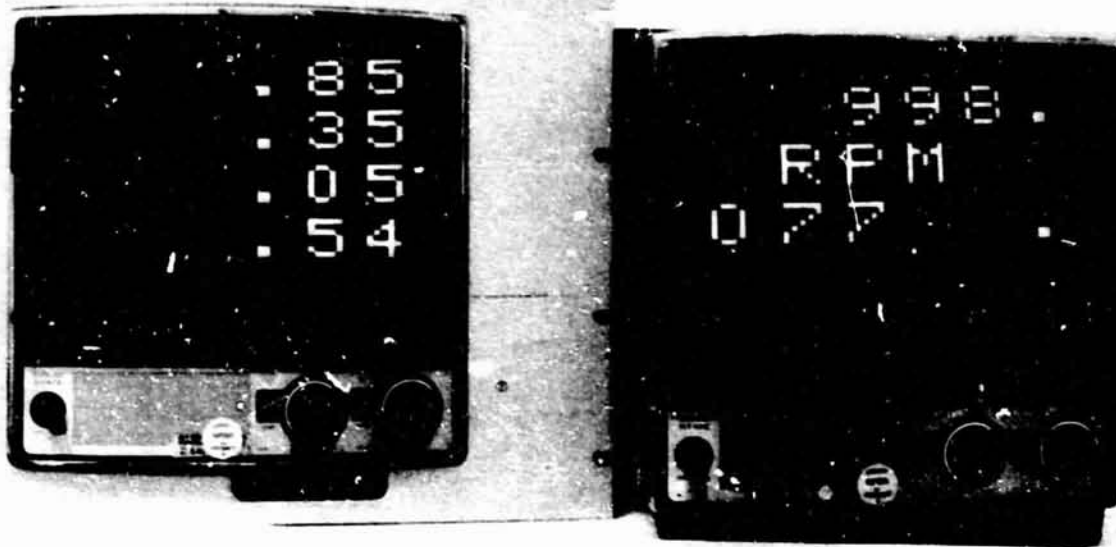


Figure 5-14. Data Display Showing Typical Power Measurements at 1000 rpm

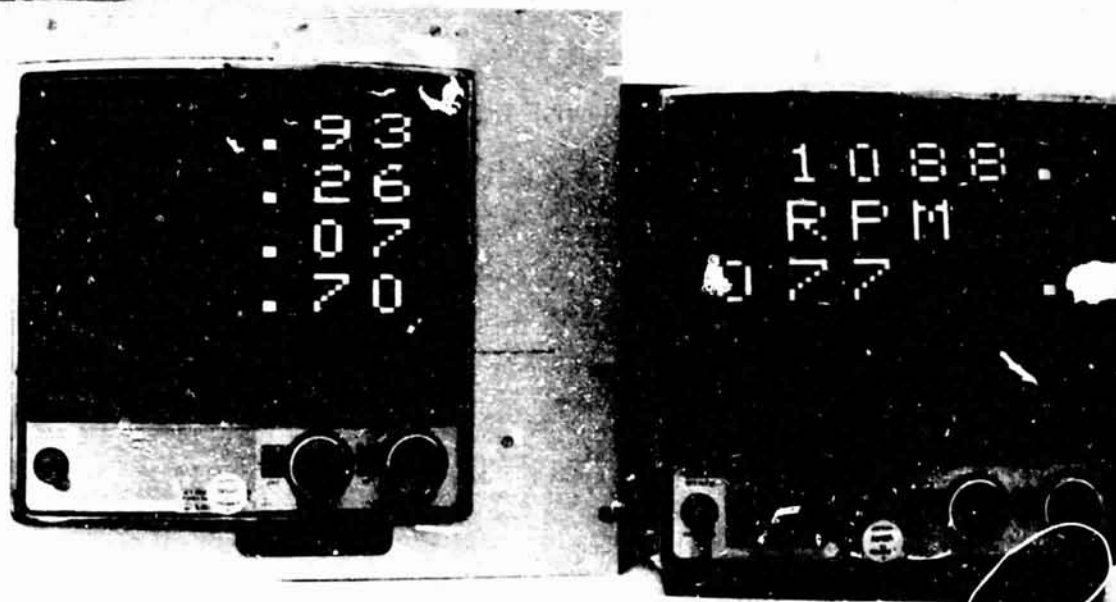


Figure 5-15. Data Display Showing Typical Power Measurements at 1100 rpm

SECTION 6

TESTING SEQUENCE

This section outlines the basic philosophy and the testing program that was used to define the performance of the VW Taxi. In general, the testing sequence was dictated by the necessity to test a valuable and unfamiliar vehicle in a short period of time.

6.1 PHILOSOPHY

6.1.1 Prior to Vehicle Arrival

Several discussions prior to the time the VW Taxi arrived at JPL provided preliminary information on the vehicle, its configuration, and its characteristics. Several key points were clear:

- 1) Valuable Vehicle. The initial discussions with VW of America, which had the contractual responsibility for the VW Taxi, indicated the vehicle would be insured for \$400,000 during its stay at JPL. This is a reasonable figure for a vehicle which represents both an engineering prototype and a show vehicle. Accordingly, it was clear that the vehicle would have to be treated with a great deal of care in the testing program. As an example, it would be impossible to drill holes to facilitate cable routing or mechanical installation of testing components. This would be normal practice with a vehicle which was only an engineering prototype or even a standard American passenger vehicle. The initial plans for the instrumentation that would be required on the Taxi included this limitation because of the Taxi's value.
- 2) VW Project Engineer. The contract called for the assistance of a VW engineer at the JPL testing site for a period of up to 45 days. During the initial discussions, including several phone calls to the VW Research and Development Center in Germany, the exact status of this engineer was not clear. Only one phone call was made directly to R. Miersch, the project engineer in charge of the Taxi. During this particular call, it was apparent that he was thoroughly familiar with the vehicle and spoke English. However,

it was not defined at this time that Mr. Miersch would actually be the person who would accompany the vehicle to the U.S. It was possible that a senior person, possibly from the upper management level, would accompany the vehicle to represent VW and provide assurance that the vehicle was treated properly during the testing program. If this were the case, the assistance available for the vehicle and the test program could be relatively limited. However, it was certain that the VW representative would be a key person in all test activities.

- 3) Available Information. The available information prior to the vehicle's arrival consisted of a copy of the excerpts dealing with the VW Taxi from a New York Museum of Modern Art publication (ref. 5) and some detailed technical information provided by VW. The latter information was sent in answer to a JPL request for certain technical information that would assist testing preparations prior to the time the Taxi arrived in the U.S.

The VW reply was comprehensive and included information on the engine, torque converter, electric motor, and electric motor controller. There was essentially no information available on details of the system control strategy. Consequently, plans for a key part of the testing program had to be delayed until the details of the control strategy were specifically known.

This summarizes the information that was available to define the test sequence prior to the arrival of the VW Taxi at JPL.

6.1.2 After Vehicle Arrival

The vehicle arrived at the Los Angeles Airport accompanied by R. Miersch, the VW project engineer. Mr. Miersch has been associated with electric and hybrid vehicles for over five years at VW. He had participated in both the design and construction of the previous prototype and did a great deal of the detail work of the present Taxi. He therefore knows the vehicle very well. As mentioned in the previous paragraph, JPL was uncertain as to the amount of

modification to the vehicle or even the addition of measurement instruments that would be permitted. However, early discussions with Mr. Miersch indicated that JPL would have the freedom to implement measurements which were far beyond the scope permitted by time and funding constraints. The combination of Mr. Miersch's personal knowledge of the vehicle and his extreme interest in obtaining test data promised to make the test program very interesting.

Mr. Miersch also defined some of the basic control aspects of the Taxi and related its characteristics to other publications dealing with hybrid vehicles. Since data from publications concerned with other hybrids were of interest to the JPL testing program, his personal knowledge promised to be very beneficial.

6.1.3 Testing Sequence

The events described in the previous two sections made it clear that the testing sequence should be divided into two general phases:

- 1) Tests During Presence of VW Project Engineer. R. Miersch's knowledge of the vehicle and his interest in obtaining all possible information make it apparent that the maximum testing rate should be done during the time that Mr. Miersch would be available. He was scheduled to leave on June 29th, so the testing program was directed toward conducting a maximum number of tests during June. It was hoped that these tests would adequately define the basic operating characteristics of the VW Taxi and also provide the learning curve necessary so JPL could continue at least limited tests after Mr. Miersch returned to Germany. The contract called for the Taxi to stay in the U.S. for 60 days, so a period of approximately three weeks was available for testing after Mr. Miersch returned to Germany.
- 2) Completion of Tests. After Mr. Miersch left for Germany, it was planned to conduct repeat tests necessary to verify previous tests, fill in gaps between previous tests, and conduct other activities which would be either time consuming or not profitably use Mr. Miersch's technical knowledge of the Taxi.

In general, this testing sequence was followed.

There is one specific consequence of this testing sequence; detailed battery tests were not conducted during the time that Mr. Miersch was available at JPL. In order to closely check the battery energy, it was necessary to measure the specific gravity of each cell after the batteries were fully charged, conduct the test, and then return the vehicle to its storage place for a period of approximately four hours before the specific gravities of each cell were checked again. The delay was necessary to allow adequate diffusion time in the electrolyte. After this, it would be necessary to fully recharge the batteries prior to the next day's testing activities. This entire procedure would require a long working day and clearly would limit the number of tests to one per day. In addition, it would preclude any experimental work on the Taxi, the instrumentation, or the facility that is normal in the checkout period when a new vehicle arrives for engineering tests. Consequently, the detailed battery tests were delayed until after Mr. Miersch returned to Germany.

6.2 TESTING PROGRAM

The testing program was divided into three phases: checkout, primary test, and completion of test data.

6.2.1 Checkout

The checkout phase was associated with the normal checkout necessary to define the correct information and procedure problems. It was expected that the checkout phase would be more difficult than usual because the program dealt with an unfamiliar and sophisticated vehicle. This degree of difficulty occurred. However, unexpected problems had a severe impact on the schedule. In particular, problems associated with the gasoline supply to the VW Taxi caused a large gasoline flow from the gasoline source into the carburetor, intake manifold, combustion chamber, and other parts of the Taxi's engine. Two such problems were encountered. The cause of these problems was traced to a very small nylon particle which probably came from the seat of a valve that was installed to connect the JPL gasoline weigh tank system to the VW carburetor. Even though the valve was new and shipped in a sealed package, it is believed that the valve contained a very small particle of the seat material loose within the valve. This small particle eventually worked its

way into the VW carburetor needle valve, causing the needle valve to be stuck open. The JPL weigh tank system provides gasoline to the Taxi during tests. The system is operated at a pressure of approximately 3 psi, so the combination of this constant pressure and the leaking needle valve caused a continuous gasoline flow into the VW engine even when the engine was shut off.

The checkout also disclosed a design error in the power measurement circuitry provided by JPL. This error, which was corrected shortly after Taxi tests started, is discussed in Paragraph 7.1.

There were also some problems associated with the Taxi. On five occasions, the taxi backfired, its engine stopped during a test, or the transmission would not shift into the Hybrid operating mode. Each of these problems made retests necessary.

The overall result in dealing with an unfamiliar vehicle, the gasoline flow problem, and the Taxi problems resulted in an extended and rather frantic checkout phase.

6.2.2 Primary Data Acquisition

During the primary data acquisition period, it was imperative that the maximum number of tests be conducted while the VW project engineer was available. This was particularly true because of the problems associated with the Taxi mentioned in the previous section. It was also apparent that the Taxi's detailed performance was only approximately known at this stage in the Taxi's development. Even though the vehicle had been driven for 8000 miles, the opportunities to conduct comprehensive tests at the VW Research and Development Center were relatively limited. This limitation was imposed by two VW activities; the public relation aspects of the taxi and the electric vehicle program, which used the same resources as those for the hybrid vehicle. The VW project engineer stated that the public relations efforts were a major limitation to obtaining comprehensive engineering information on the VW Taxi. Because of this limitation, the VW project engineer indicated that he could not accurately predict the detailed performance that would result from some of the operating modes that were within the Taxi's capabilities. It

therefore became necessary to conduct a series of tests which would provide guidelines concerning the Taxi's nominal performance with several of the variables that could be readily changed. These tests were conducted immediately after the checkout was complete. After these tests were completed, it was felt that the nominal performance that could be expected of the Taxi's basic operating modes was reasonably well known. In addition, performance of both the facility and Taxi had also been reliable for a series of tests.

After the period starting about June 20, the testing rate was good. A typical day's activity would consist of specific gravity tests to verify the state of charge of each battery, conducting a FTP Urban Cycle Test with the Taxi configuration defined by the tests of the previous several days, recharging the batteries for a period of about two hours, and then conducting a set of three hot 505 tests in a different operating mode. The data from the later tests would be combined with that of previous tests to define the FTP test that would be conducted the next day. After this, the batteries were recharged, the vehicle was allowed to sit in the temperature controlled room for the 12 hour period specified by the FTP, and the cycle would be repeated. This sequence made it possible to get one FTP test and a set of three hot 505 cycle tests in one day along with the required battery charging, normal test support, and related work.

The VW Bus tests were also conducted during this time. The VW Bus was stored in the same room as the Taxi, and would be tested in the morning according to the FTP immediately before or after the Taxi test.

6.2.3 Completion of Tests

After the VW project engineer left JPL, the testing pace was slowed to get the data necessary to fill in voids between the previous tests, verify previous tests, and obtain comprehensive battery performance data. The latter was especially important, since it had not been obtained during June. In addition to the emphasis on FTP and hot 505 tests during late June, there were four separate occasions when the daily test plan called for a test sequence that

900-851

would provide battery data. However, failures either with the Taxi or the facility prohibited following the plan on the first three occasions. Battery data were finally obtained in early July.

A suspected leak in the Taxi's exhaust, discussed in Paragraph 5.2.1, was found and corrected July 15. A baseline test was conducted to verify the fix; this was the last test of the program.

SECTION 7

FACILITY AND INSTRUMENTATION

JPL's chassis dyno test facility includes the normal complement of equipment needed to conduct Federal Test Procedure (FTP) tests. Photos of the test area and Constant Volume Sampler are shown in Figures 7-1 through 7-4.

The instrumentation for the VW Taxi tests includes both analog and digital equipment. Digital data are recorded on magnetic tape and reduced by a large central computer. The digital data system provides real-time display of test data to facilitate tests and checkout procedures. Emission instruments are located in the instrumentation area. Photos of the central instrumentation and emission benches are shown in Figures 7-5 and 7-6.

In addition to the normal facility equipment, two measurements were basic to the VW Taxi testing program, the electrical power measurements and the gasoline weigh system. These are discussed in the next sections.

7.1 BATTERY AND MOTOR POWER MEASUREMENTS

A photo and block diagram of the battery and motor power measurement circuits are shown in Figures 7-7 and 7-8. Identical circuits, within normal construction technology, were used for these battery and motor power measurements.

7.1.1 Description of Power Measurement Circuits

Functions of the blocks are:

- 1) Isolation amplifiers. The Taxi electrical power grounding technique was unknown until the Taxi arrived and had been initially tested. The entire electrical power circuit floats; common mode voltages of 60V with rise times of $1V/\mu s$ were observed. Initial plans were to isolate the entire battery and motor power measurement circuits from the chassis and let each circuit float at the voltage established by the low side of its voltage terminal, as shown in Figure 7-8. However, this approach appeared to be marginal during initial checkout since the power

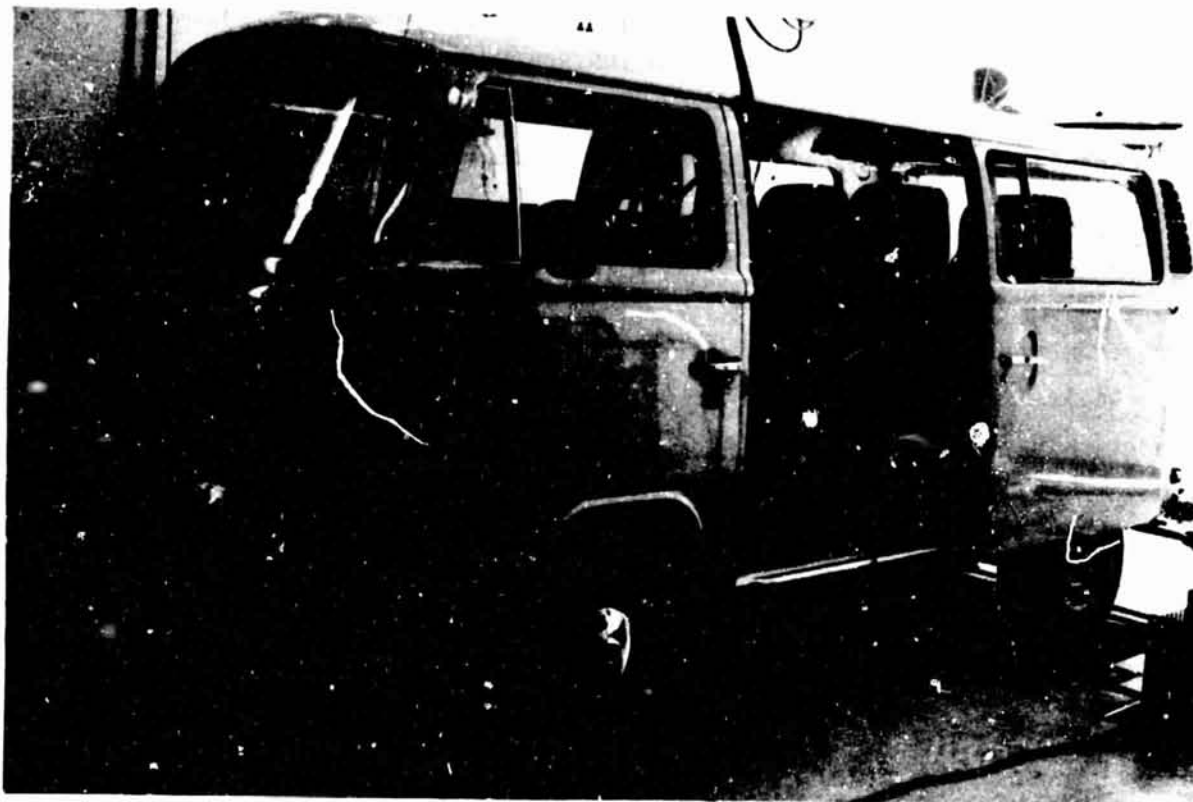


Figure 7-1. VW Taxi Installed on Chassis Dynamometer

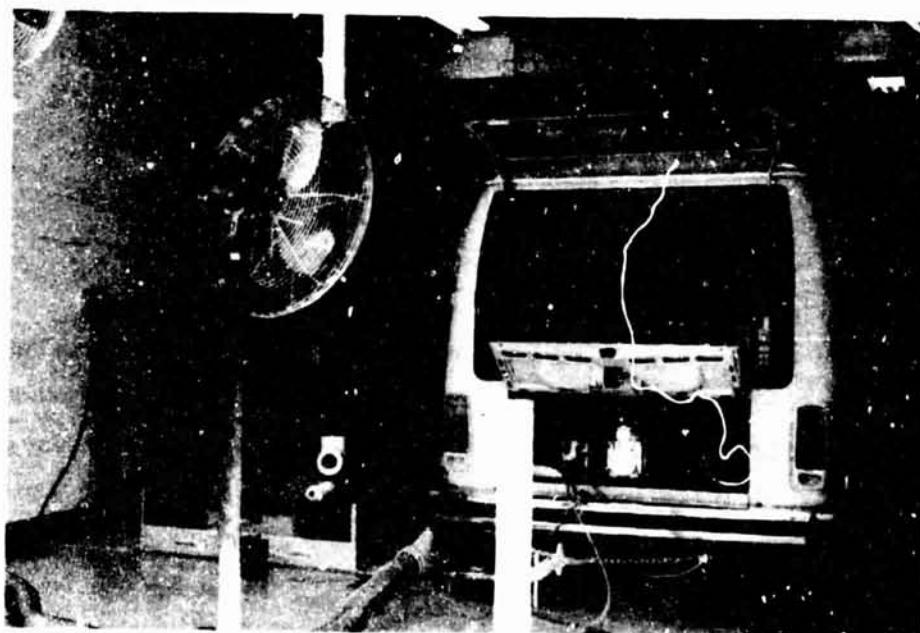


Figure 7-2. Rear View of VW Taxi Test Installation

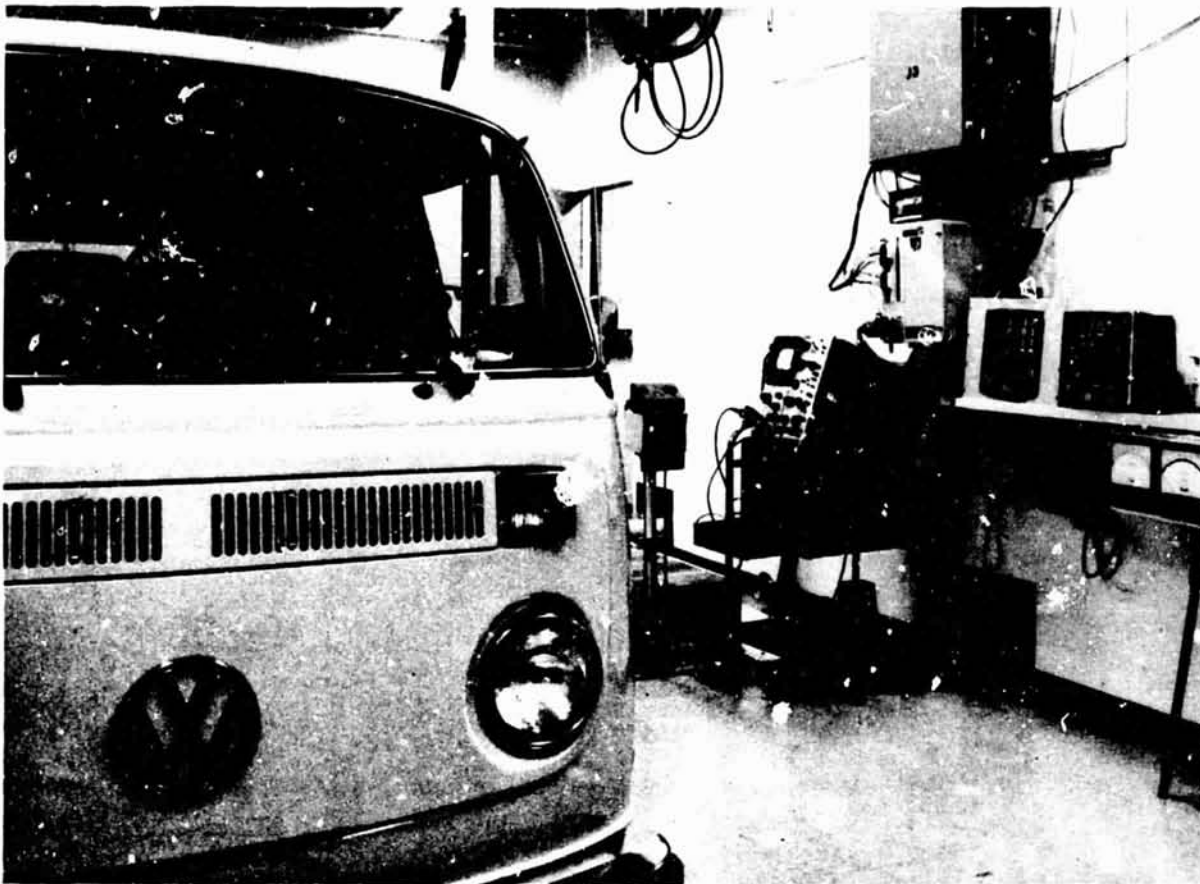


Figure 7-3. Rear View of VW Taxi Test Installation

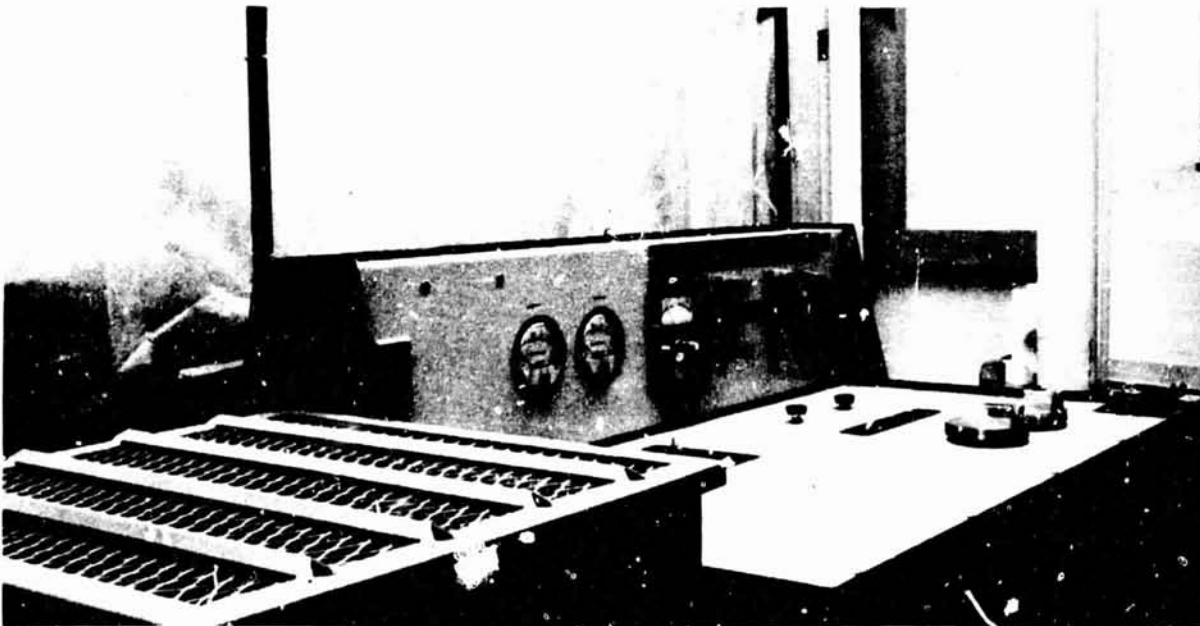


Figure 7-4. Constant Volume Sampler

900-851

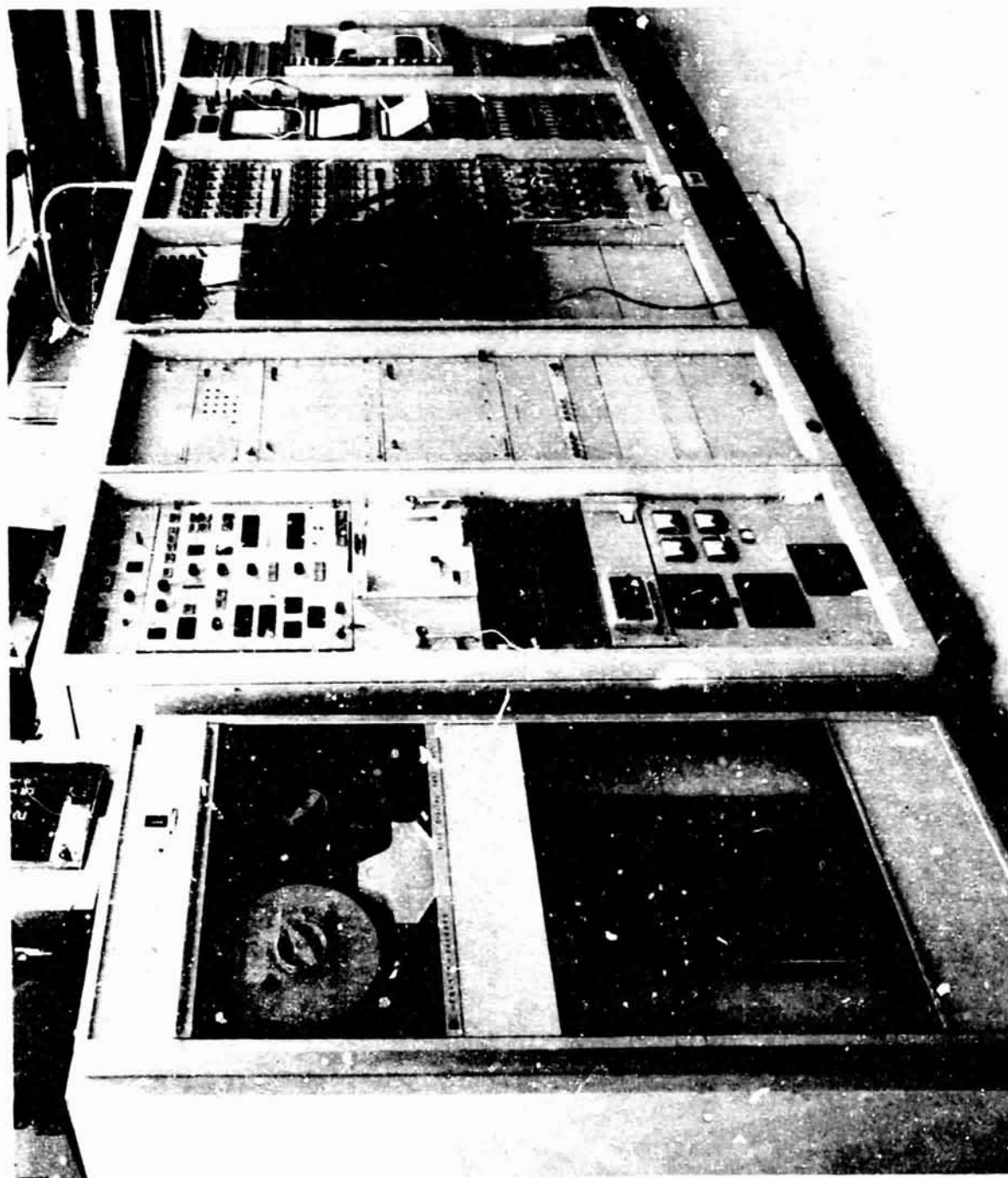


Figure 7-5. Central Instrumentation Area

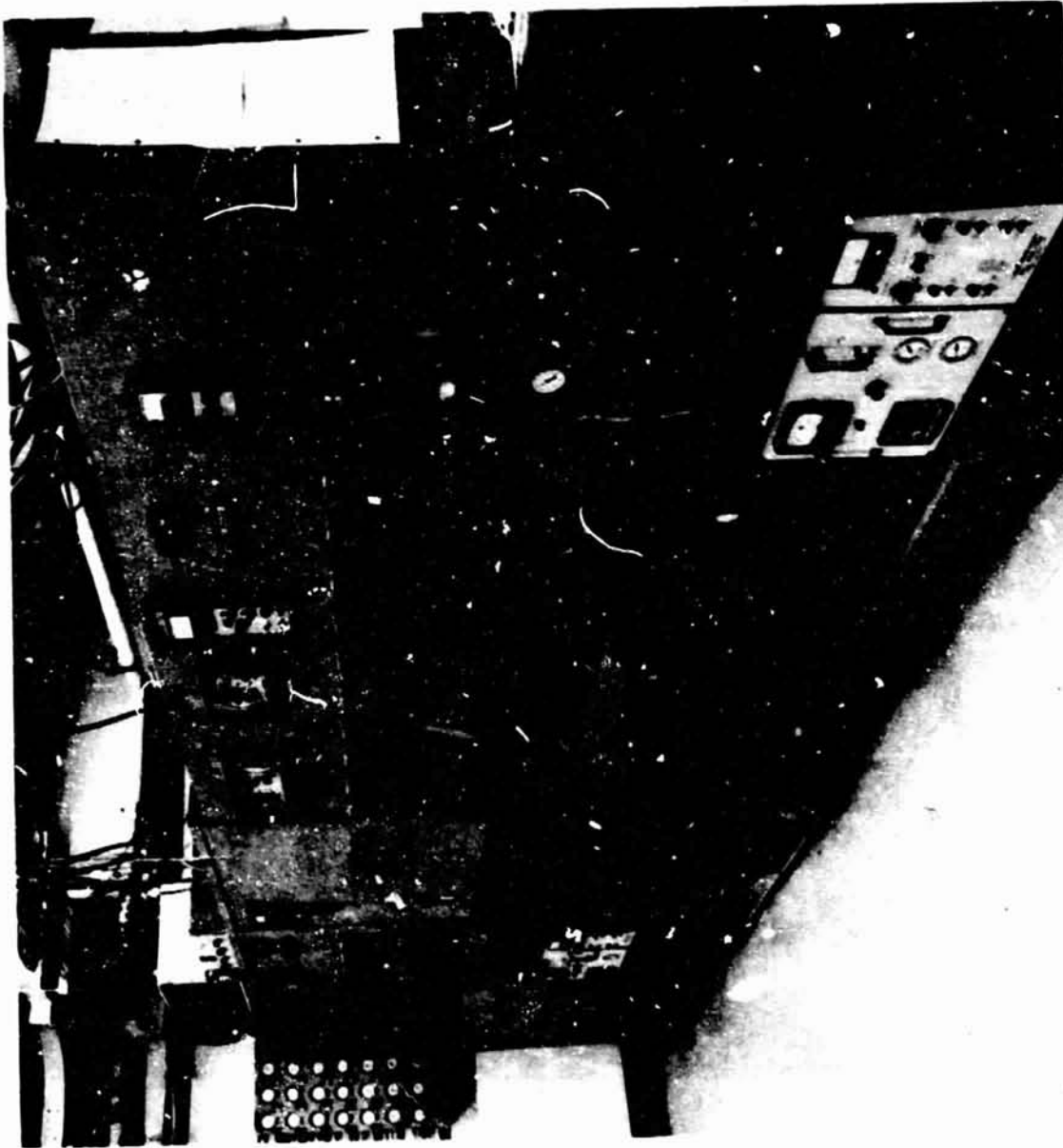


Figure 7-6. Emission Measuring Instruments

ORIGINAL PAGE IS
OF FOUR QUALITY

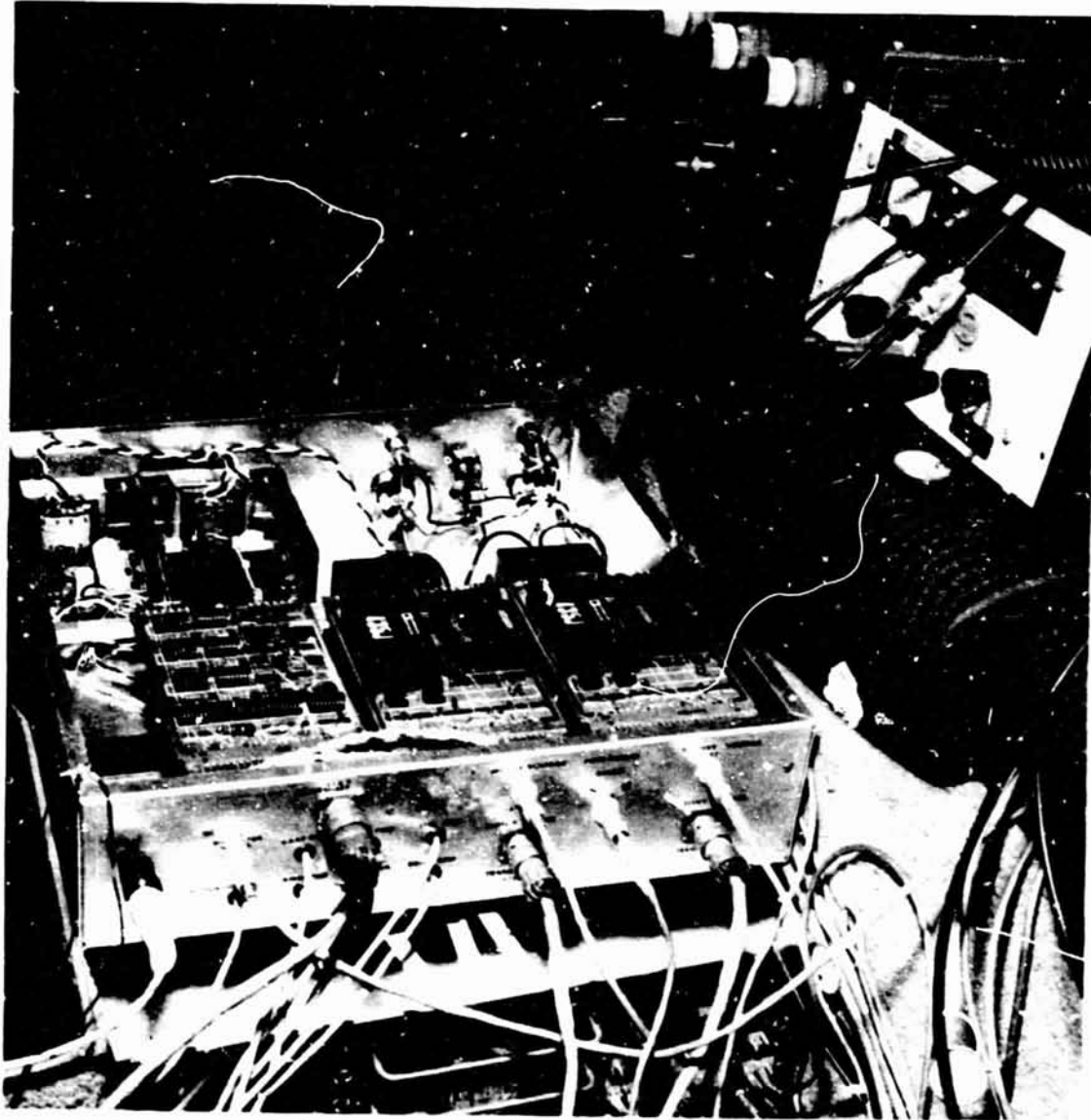


Figure 7-7. Electrical Power Measurement Chassis

RECEIVED PAGE 13
OF POOR QUALITY

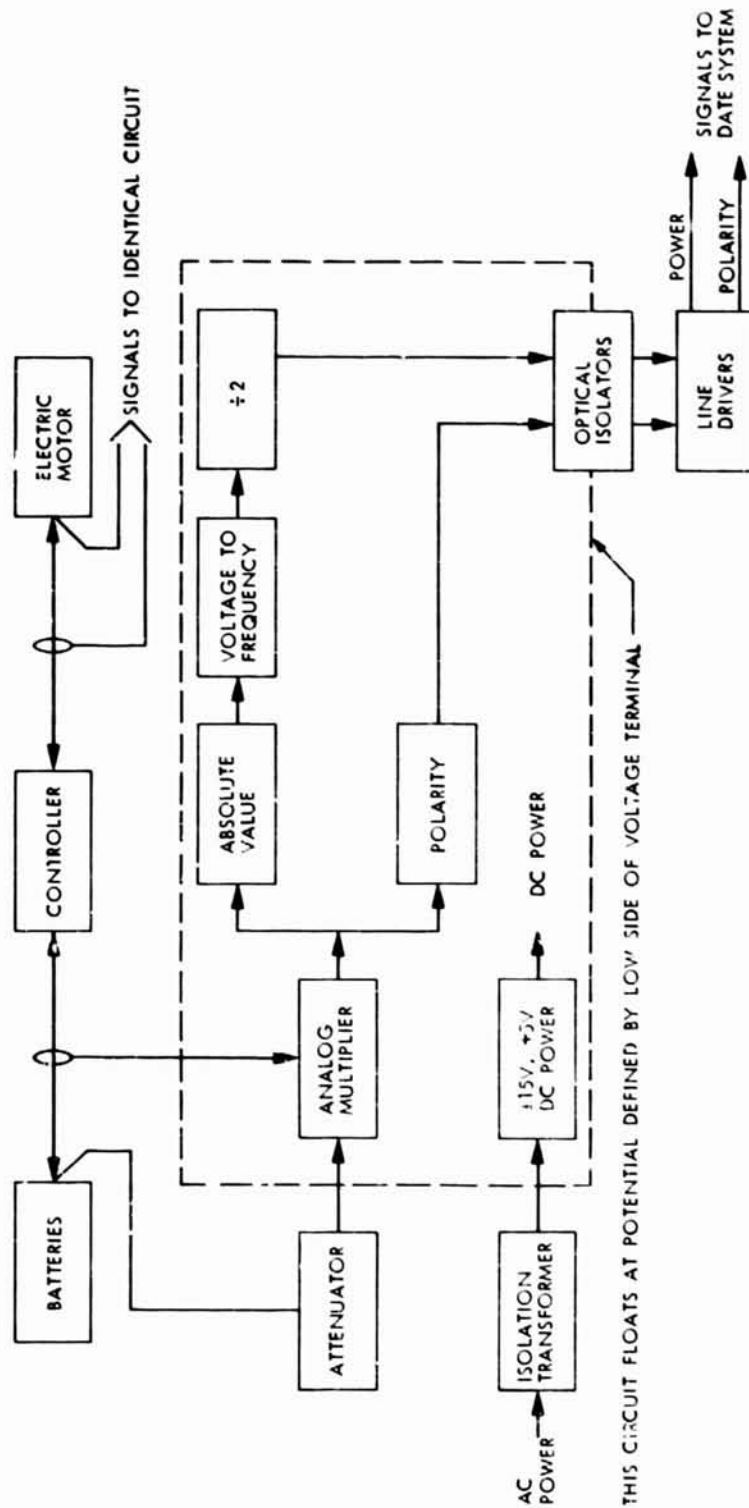


Figure 7-8. Power Measurement Block Diagram

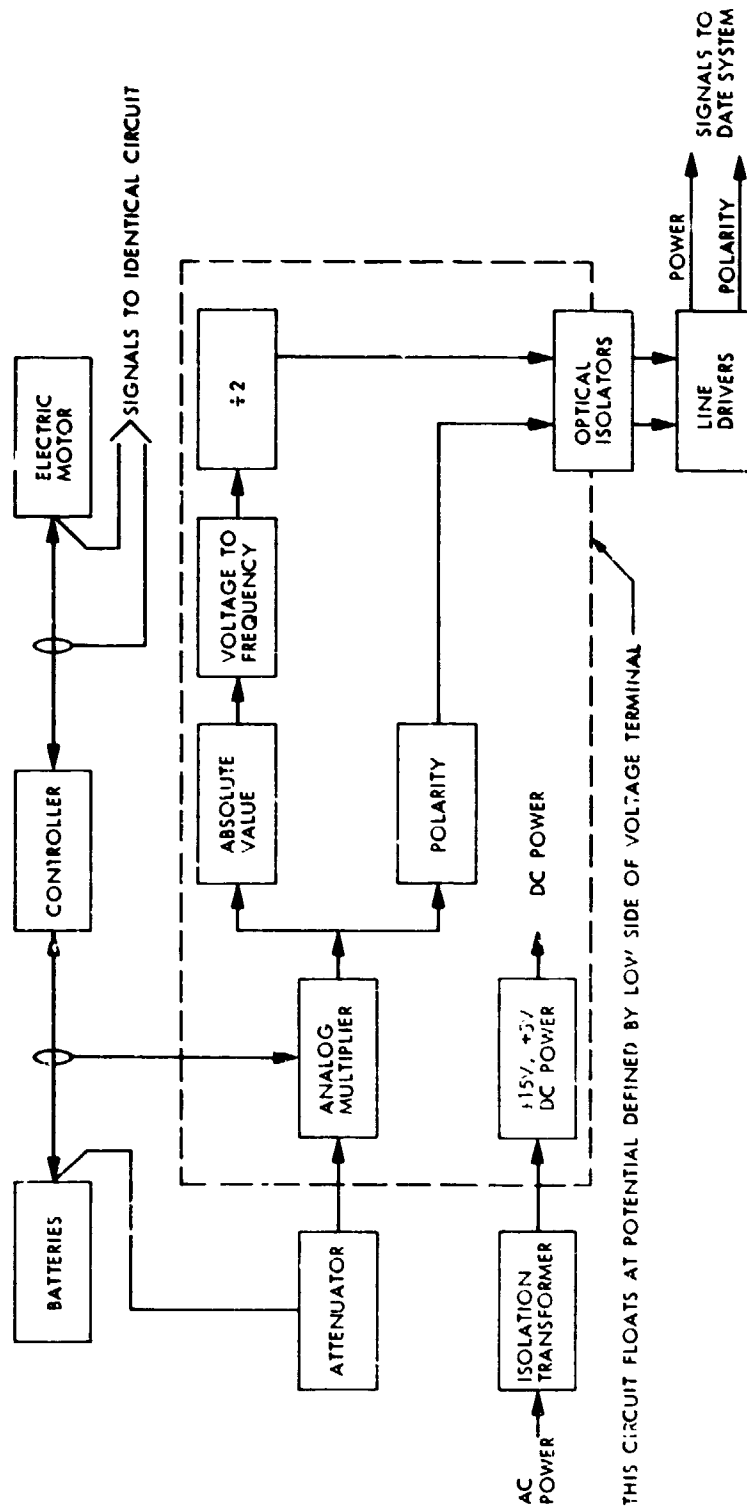


Figure 7-8. Power Measurement Block Diagram

measurements had considerable noise. Instrumentation amplifiers installed in a conventional rack mount case, with a 300V CMV capability, were then inserted into the voltage cabling before the power measurement circuits (Figure 7-7). These circuits could then be operated at the potential of the normal instrumentation ground. However, a design problem in the measurement circuit was later found to have caused, or at least contributed to, the apparent noise. The isolation amplifiers were left in the circuit since they provided good safety margins for checkout procedures during test operation.

- 2) Buffer Amplifiers. The voltage divider provides a 10V full scale signal so this buffer amplifier has a gain of 1. The current channel has a gain of 2 to raise the 5 volt maximum current signal to 10V.
- 3) Multiplier. The analog multiplier multiplies essentially instantaneous values of voltage and current to provide power. The multiplier operates in 4 quadrants, so its output voltage can be positive or negative.
- 4) Absolute Value. This circuit converts either positive or negative voltages to a positive voltage that is fed to the V/F converter.
- 5) Polarity Circuit. The polarity circuit detects the polarity of the multiplier signal and sends an output signal that is at one of two fixed voltages, one for positive and the other for negative polarity. The polarity circuit is sensitive to less than 1 mv changes around zero.
- 6) Voltage to Frequency (V/F) Converter. This circuit provides an output frequency proportional to the input voltage. Since the absolute value circuit provides only positive voltages, the V/F will send an output frequency proportional to either the positive or negative power measurement from the multiplier.

At this point, the power measurement consists of a frequency proportional to the absolute value of the instantaneous power and a polarity signal that defines either a power out or power in condition.

- 7) Isolators. The isolators permit the output signal to the data system to be referenced to the data system ground.
- 8) Gating Circuits. These circuits use the polarity information to direct each pulse from the V/F converter to either the power out or the power in channels that are sent to the data system.

Two signals, power out and power in, are thus provided for both the battery and motor power measurements. The calibration of each channel is approximately 10 watts/Hz so excellent resolution is attained.

7.1.2 Real-Time Data Readout

The four output signals, two for the battery and two for the motor, are sent through short cables to a connector panel that is attached to the taxi body (Figure 7-9). In addition to the power measurements, other signals from the taxi transducers are also routed through this connector panel. This connector panel thus serves as a junction between the taxi measurements and the facility instrumentation system. Power measurements are sent through the instrumentation cabling system as a frequency with a relatively slow rise time and low voltage amplitude to minimize cross talk. The frequency data is then sent to the digital data system. Both hardware and software, which are a part of the standard data system capability, are used to convert the frequency data into real-time engineering units display of power and energy. Power readings are displayed as kilowatts with 0.01 kilowatts resolution; the power integral is displayed in watt-hour units with 0.1 watt hour resolution (Figure 7-10). Power integrals are reset at the start of each test. During a test, the kilowatt data thus defines the instantaneous power while the watt-hour data shows the power integral since the start of the test. In addition, the data system will display all four power measurements in a sequence on a single video display (Figure 7-11). The sequence for the video display of power and integrated power data, starting from the top, is:

<u>Channel ID</u>	<u>Measurement</u>
PBO	Power out of battery
PBI	Power into battery
PMI	Power into motor
PMO	Power out of motor

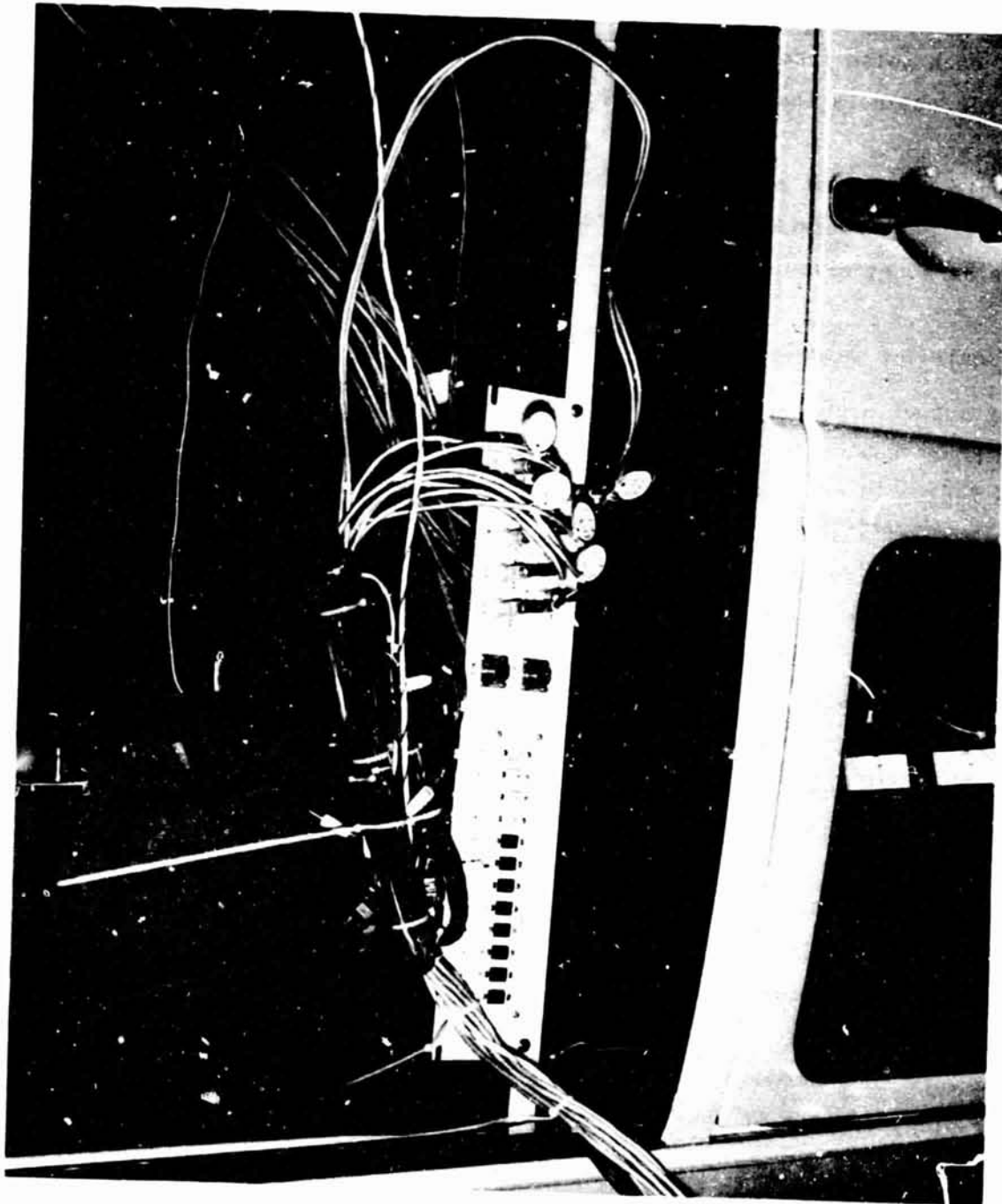


Figure 7-9. Connector Panel

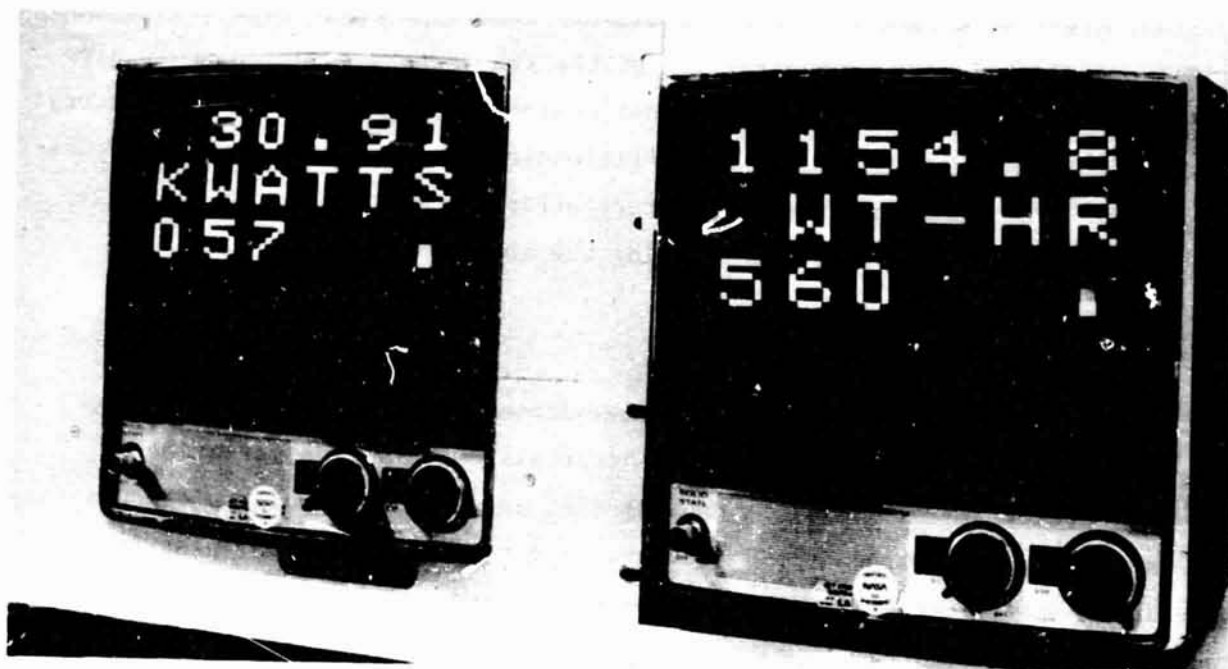


Figure 7-10. Kilowatt and Watt-hour Power Readings;
Single Channel Format

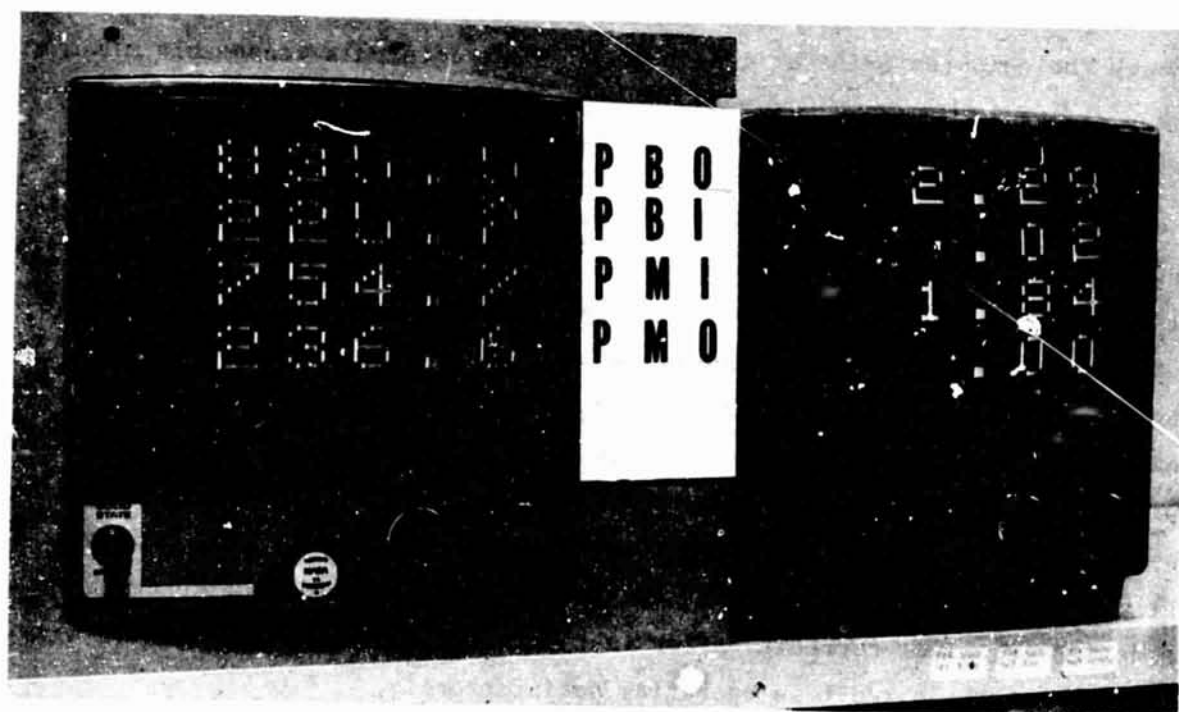


Figure 7-11. Four Channel Power Display

This display format was typically used during the tests since it provided an excellent means of determining the approximate real-time power flow in the taxi's various operational modes. Subtraction of the two battery power channels also provided a real-time indication of the net charge or discharge from the battery. For this information, nominal battery efficiencies were used to convert the displayed data, which does not include battery efficiencies, into an approximate indication of the net battery power during the test.

7.1.3 Computer Plots of Power Data

The data system also logs all the power measurements on digital magnetic tape. Data are transferred to tape at 0.1 sec intervals, with a time variation of approximately 50 microseconds. A program that produced a computer plot from this data was developed for the hybrid testing. A portion of a typical plot for equivalent parts of the FTP cycle for the hybrid and on/off modes is shown in Figures 7-12 and 7-13. These figures quickly display the difference in the utilization of electric power for the two taxi operating modes.

The electrical power data can also be printed at specified intervals to investigate the power flow during a test cycle. The minimum interval is 0.1 sec although the computer printout length makes 1 sec intervals reasonable minimum.

7.1.4 Circuit Design Problems

The early checkout activities indicated that the power measurements had considerable noise, as discussed in Paragraph 7.1.1 (1). However, later checkout and analysis activities indicated that the rapid change of current, shown in Figure 5-13, was causing the polarity signal from the power measurement circuit to change rapidly. At this time, the design of the gating circuits (para 7.1.1 (8)) permitted a polarity change to provide an output pulse in the same manner as that of a frequency pulse that was proportional to the instantaneous power. This had the effect of generating false additional pulses so both the output and input power measurements were too great. The error was on the order of 10 percent. This design error was corrected after test no. 7. Checks after this time have indicated that the circuit is operating satisfactorily.

900-851

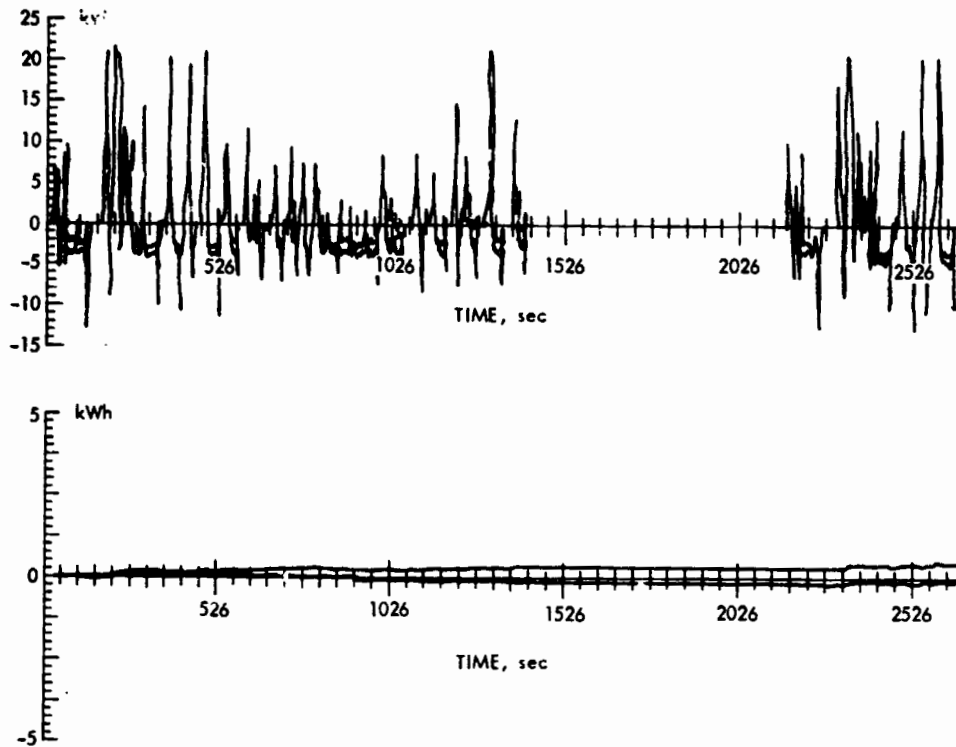


Figure 7-12. Plot of Battery and Motor Power From Test 13, The Baseline Hybrid Configuration

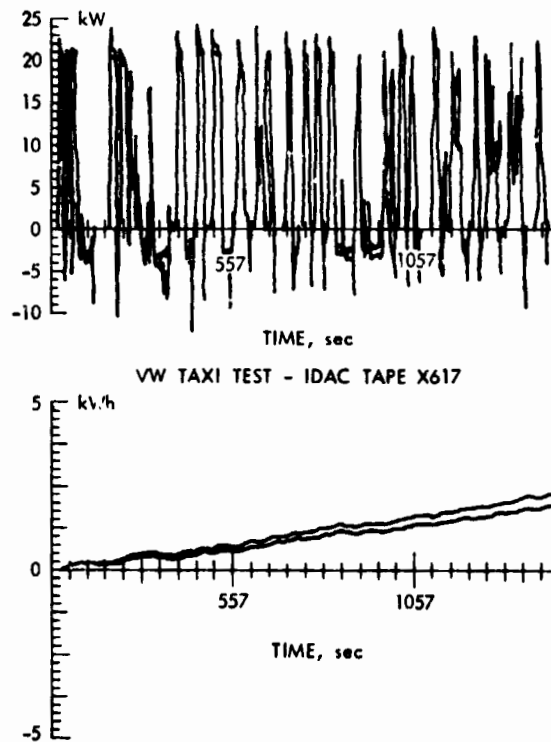


Figure 7-13. Plot of Battery and Motor Power From Test 22, an On/Off Configuration. Test was Terminated at End of The Stabilized Phase Because of Battery Discharge

7.2 GASOLINE FLOW MEASUREMENTS

A recurring problem with emission testing is the possibility of very minor malfunctions inserting undetected errors in the emission measurements. This is especially true of leaks in any part of the exhaust gas measurement system. Since a leak in any part of the piping from the engine head-to-exhaust manifold connection through to the internal parts of the emission instruments may effect the measurement, many potential leak sources are involved in both the vehicle and facility. JPL uses a gasoline weighing system both as a check against these errors and to provide an accurate and easily checked method of determining the actual fuel economy of an emissions test.

The FTP specifies that emission measurements of exhaust gasses be used to define the fuel economy of vehicles. However, this procedure depends on the proper functioning of many electromechanical components and highly sensitive emission measuring instruments. As a check of the entire emission measurement system, JPL weighs the gasoline that is used during each test. The weigh system is shown in Figure 7-14. It consists of a small specially fabricated tank that is reasonably light (2 pounds) yet meets safety standards for gasoline, a load cell and related plumbing. The load cell range is 10 pounds so about 7 pounds of gasoline can be used during a test; this is adequate for tests where the vehicle gets 10 mpg. The tank is pressurized with dry nitrogen to approximately 3 psi to force gasoline from the weigh tank to the test vehicle.

A set of calibration weights (Figure 7-15) calibrated to 0.001 grams each is used to define the linearity and hysteresis characteristics of this system. The 20 small weights permit linearity performance and hysteresis to be carefully investigated at intervals of several months. The larger weights are used for more frequent single point checks of the calibrations. The calibrations are done end-to-end with the physical weights being suspended from the weigh tank (Figure 7-16) while the data system shows the value in grams. Linearity, taken in the decreasing direction associated with gasoline flow during a test, is better than 0.1 percent. Hysteresis, which is not normally an error with the technique used, is about 0.1 percent. Combined effects with the procedure used during a test is less than 0.3 percent.

900-851

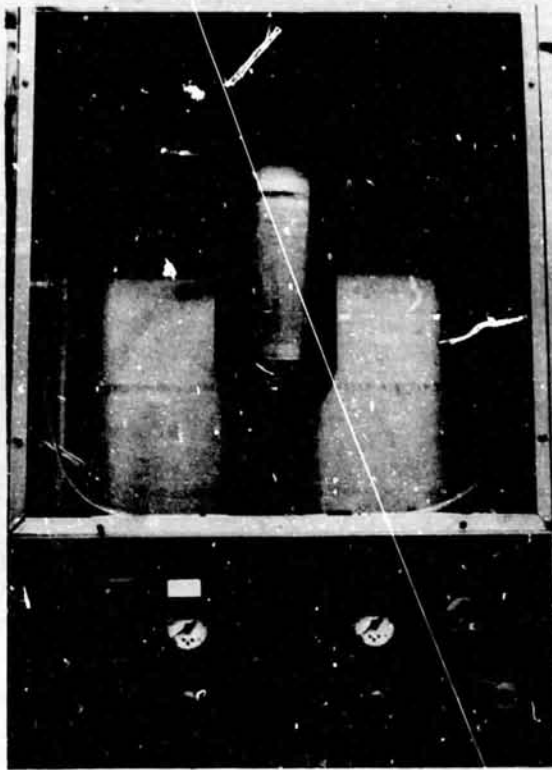


Figure 7-14. Gasoline Weighing System

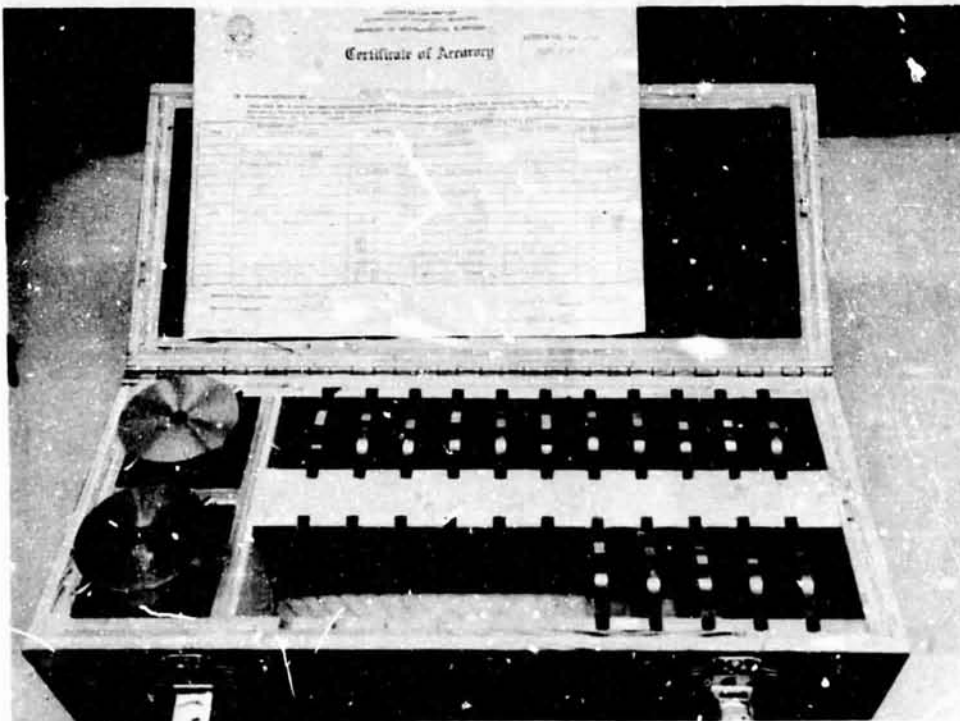


Figure 7-15. Calibration Weights for the Gasoline Weighing System

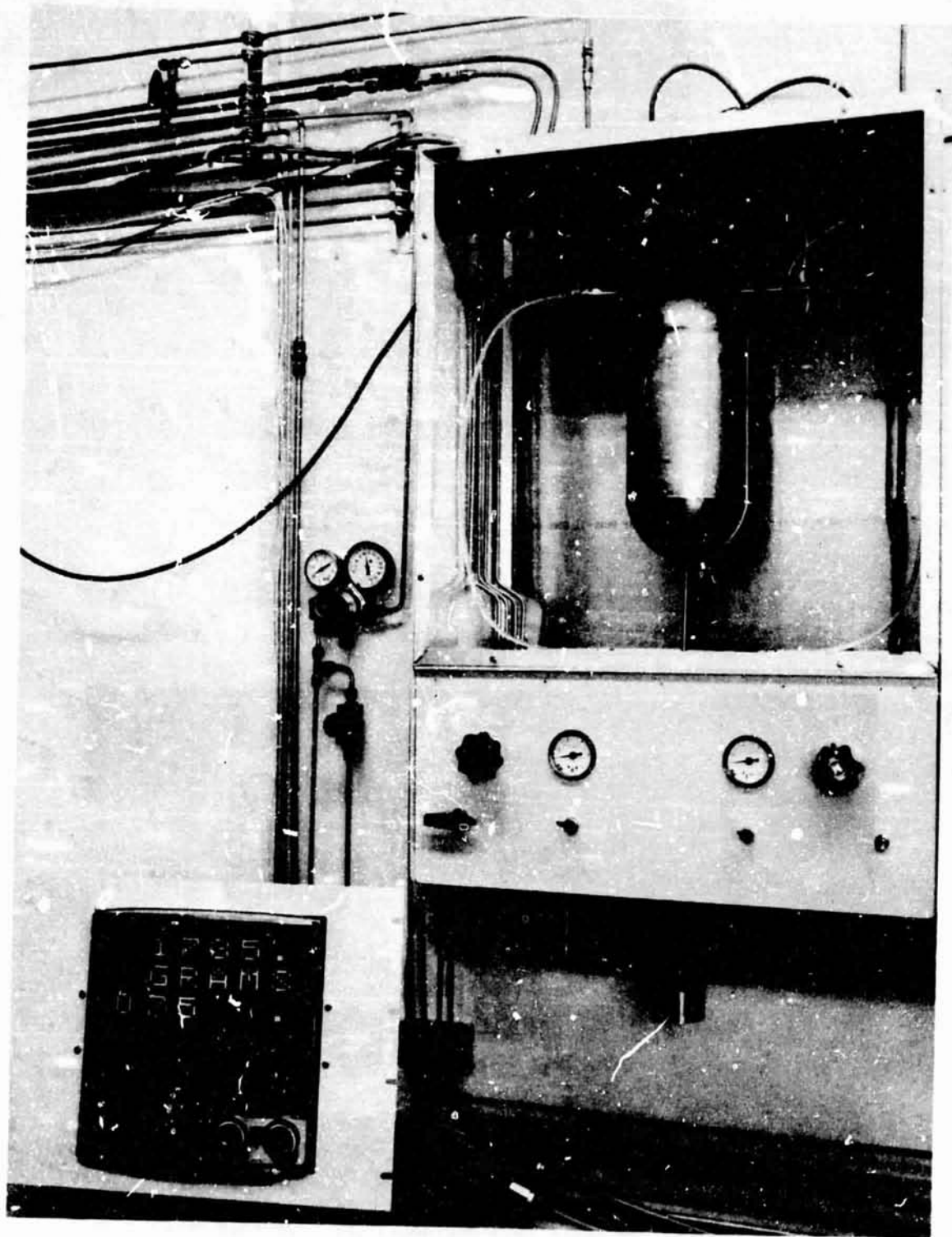


Figure 7-16. Calibration of the Gasoline Weighing System

In addition, temperature and pressure errors will add to the linearly and hysteresis errors. Investigations of temperature effects show this error to be less than 0.05 percent even when a severe gradient is imposed across the weighing system. The effects due to pressure forces on the connecting lines are less than 0.02 percent in the pressure range used for tests.

The overall system error is thus less than 0.3 percent and probably on the order of 0.2 percent. Further calibrations over an extended period will be required to be certain of the lower value.

REFERENCES

- Ref. 1 Milks, D. & Matula, R. A.; "Emissions and Fuel Economy Test Methods and Procedures for Light Duty Motor Vehicles - A Critique"; SAE paper 760141.

- Ref. 2 Blumberg, Paul N. "Powertrain Simulation: A Tool for the Design and Evaluation of Engine Control Strategies in Vehicles; SAE Paper 76012.

- Ref. 3 Unnewehr, L. E., et. al; "Hybrid Vehicle for Fuel Economy"; SAE Paper 760121.

- Ref. 4 "The Taxi Project: Realistic Solutions for Today"; The Museum of Modern Art, New York.

- Ref. 5 Frank, H. A. and Rippel, W.; "Evaluation of W. Rippel's Electric Datsun 1200"; JPL Report 900-759; October 1976.

- Ref. 6 "Chassis Dyno Problems as Related to the Electric Car; Internal JPL communication.