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Electric Vehicle Test Report Cutler-Hammer Corvette

January 1981

Prepared by:
Jet Propulsion Laboratory
Pasadena, California
Under Contract No. A101-78CS54209

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Prepared for:
U.S. Department of Energy
Assistant Secretary for Conservation
and Solar Energy
Office of Transportation Programs
Washington, D.C. 20585

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The detailed contents of this report would not have been possible without the diligent efforts of several people. Ralph Esposito, Ray Freeman, Tom Shain, and Joe Toczylowski were major contributors to the track testing program at Edwards Test Station. During dynamometer testing, Bob Burleson, Ray Freeman, and Lou Johnson were responsible for the quality and quantity of data reported herein. The authors acknowledge these contributions and are thankful for them. Recognition is also due to Dan Griffin, who supplied the power measurements for the Corvette.

DEFINITION OF ABBREVIATIONS

A	ampere
Ah	ampere-hour
C	Celsius
cm	centimeter
F	Fahrenheit
h	hour
Hz	hertz
in	inch
in^2	square inch
kHz	kilohertz
km	kilometer
km/h	kilometer per hour
kW	kilowatt
kWh	kilowatt-hour
lb	pound
lbm	pound mass
lb/in^2	pound per square inch
m	meter
mi	mile
mi/h	mile per hour
min	minute
ms	millisecond
r/min	revolution per minute
s	second
us	microsecond
V	volt
W	watt
Wh	watt-hour
Wh/mi	watt-hour per mi
Wh/km	watt-hour per km

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SECTION I

INTRODUCTION

Public Law 94-413, passed by Congress on September 17, 1976, authorized funds to the Energy Research and Development Administration (ERDA), now the Department of Energy (DOE), to promote increased research and development of electric and hybrid vehicles. Vehicle system research and development and vehicle characterization testing to assist in determining the state-of-the-art were subsequently assigned by DOE, through NASA Headquarters, to the JPL Electric and Hybrid Vehicle System Research and Development Project. Program direction is provided by the Electric and Hybrid Vehicles Division in the Office of Transportation Programs of DOE. The work is performed under NASA Contract NAS7-100 and a NASA/DOE Interagency Agreement.

The work described in this report was part of the effort to characterize vehicles for the state-of-the-art assessment of electric vehicles. The vehicle evaluated was a Chevrolet Corvette converted to electric operation. The vehicle, leased from the AIL Division of the Cutler-Hammer Corp., was based on a standard production 1967 chassis and body. The original internal combustion engine was replaced by an electric traction motor manufactured by the General Electric Co. Eighteen batteries supplied the electrical energy. A controller, an onboard battery charger, and several dashboard instruments completed the conversion. The remainder of the vehicle, and in particular the remainder of the drive-train (clutch, driveshaft, and differential), was stock, except for the transmission.

SECTION II

OBJECTIVE AND SCOPE

The overall objective of the tests described here was to develop performance data at the system and subsystem level. The emphasis was on the electrical portion of the drive train, although some analysis and discussion of the mechanical elements are included. There was no evaluation of other aspects of the vehicle such as braking, ride, handling, passenger accomodations, etc.

This report includes a description of the vehicle, the tests performed and a discussion of the results. As noted above the emphasis in both the vehicle description and in the tests performed is on the "electric" portion of the Corvette. Tests were conducted both "on the road" (actually a mile long runway) and in a chassis dynamometer equipped laboratory. The majority of the tests performed were according to SAE Procedure J227a and included maximum effort accelerations, constant-speed range, and cyclic range. Some tests that are not a part of the SAE Procedure J227a are described and the analysis of the data from all tests is discussed.

Besides the presentation of electrical data based upon actual measurements, efficiency estimates are also made on some of the mechanical drive train subsystems. All observations regarding the Corvette, whether by the driver/operator, test conductor, or data analyst are limited to those of an objective nature. In other words, subjective observations, such as vehicle ride or handling, will not be discussed here. Finally, there are some observations and recommendations regarding refinements of electric vehicle test procedures.

SECTION III

SUMMARY

The Cutler-Hammer Corvette is a battery-powered electric vehicle based on a 1967 Chevrolet Corvette chassis. The vehicle is propelled by a separately excited d.c. traction motor rated at 15.7 kW (21 hp) that is powered by eighteen series-connected 6-V Exide EV-106 lead-acid batteries of nominally 108 V. The motor is controlled by pulse-width modulation of the power applied to the motor field. The traction motor drives the vehicle through a Borg-Warner heavy duty four-speed transmission and 4.11 rear axle. The conventional Chevrolet four-wheel disc brake system is used as a supplement to the automatic regenerative braking provided by the vehicle.

The Corvette was leased from the manufacturer and shipped to JPL in Pasadena, California, where test instrumentation was installed. Initial testing was conducted at the JPL Edwards Test Station near Lancaster, California. Later testing was performed on a chassis dynamometer at the JPL Automotive Test Facility in Pasadena, California. Test results are summarized in Tables 3-1 and 3-2.

Table 3-1. Summary of Corvette Range Test Results

Range Tests	Range, km (mi)	Battery Energy, Wh/km (Wh/mi)
40 km/h (25 mi/h)	101.8 (63.27)	137 (220)
56 km/h (35 mi/h)	81.49 (50.65)	147 (237)
72 km/h (45 mi/h)	55.85 (34.71)	172 (276)
Driving Schedule B	53.27 (33.11)	250 (402)
Driving Schedule C	34.06 (21.17)	287 (461)

Table 3-2. Summary of Corvette Acceleration Test Results

Acceleration Tests	Time to speed, s Battery Discharge Level 0%	 40%	 80%
0 to 32 km/h (20 mi/h)	7.6	6.9	8.2
0 to 48 km/h (30 mi/h)	18.3	16.0	19.2
0 to 64 km/h (40 mi/h)	36.1	30.4	-
0 to 80 km/h (50 mi/h)	74.8	55.9	-

SECTION IV

VEHICLE DESCRIPTION AND OPERATION

The electric Corvette (Figures 4-1 through 4-3) was leased from the AIL Division of the Cutler-Hammer Corporation, Farmingdale, New York. The vehicle design and modifications were the product of John Santini. Placement of the major components is shown in Figure 4-4, and the vehicle specifications are summarized in Table 4-1. The Corvette had a total curb weight of 1823 kg (4020 lbm) and a gross vehicle weight of 2005 kg (4420 lbm). The electric Corvette was based on a standard production 1967 chassis and body. The vehicle was 1.26 m (49.8 in) high, 4.45 m (175.1 in) long, 1.78 m (69.6 in) wide, and has a wheelbase of 2.49 m (98.0 in). Load capacity of the Corvette was two passengers and 45 kg (100 lbm) of baggage. Propulsion energy was derived from eighteen 6-V lead-acid batteries manufactured by Exide. The traction batteries were rated at approximately 147 Ah for a 3-h discharge time (49 A for 3 h), and the total battery weight was 514 kg (1134 lbm). The battery weight fraction of the Corvette as delivered to JPL was 0.29. The only knowledge of the previous battery history was that the batteries were used in New York City traffic while approximately 1770 km (1100 mi) were accumulated on the Corvette. The batteries were activitated in May 1977.

Batteries were carried in both the front and rear of the vehicle; ten in the front and eight in the rear (see Figure 4-4). Several modifications were made to the body and chassis to accommodate the storage batteries. A trunk lid was added by cutting into the rear deck to allow access to the rear mounted batteries. The frame rails were narrowed by 2 cm (3/4 in) to provide clearance for eight of the traction batteries located in the rear. A battery rack was fabricated and welded to the frame at this point. Modifications were made to the engine compartment to incorporate ten batteries in addition to the drive motor and controls. The batteries were supported by racks welded to the frame. Hood hinges were modified to provide clearance for the forward batteries. The suspension system was modified by replacing the stock 1967 springs with a set from a 1976 model to compensate for the additional weight added by "electrifying" the 1967 internal-combustion engine Corvette.

The vehicle was propelled by a separately excited shunt-wound, d.c. traction motor manufactured by the General Electric Co. (Model No. BT2376). The rated continuous power of the motor was 15.7 kW (21 hp). Rated motor voltage and current were 96 V and 220 A (1 h). Base (idle) speed of the motor was 1000 r/min at the manufacturers 96-V rating, however, with the 108-V battery system installed in the Corvette, base speed was observed to be about 1300 r/min. Maximum safe motor speed was 5200 r/min. The traction motor weighed 202 kg (445 lbm). Motor characteristics are shown in Figure 4-5.

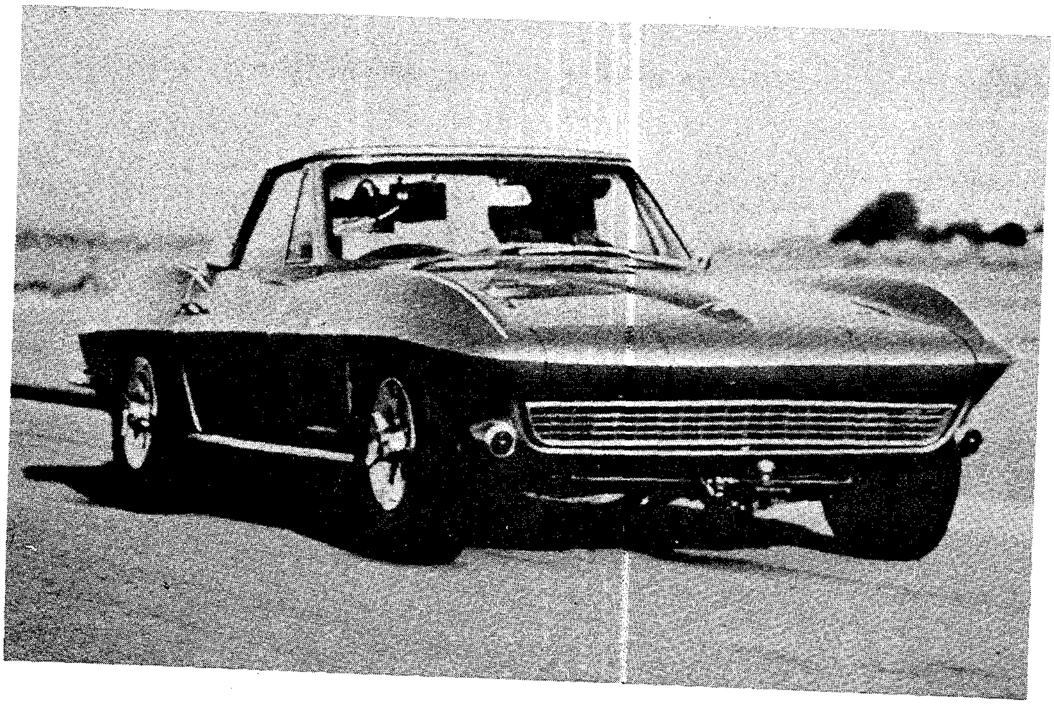


Figure 4-1. View of Corvette on ETS Runway

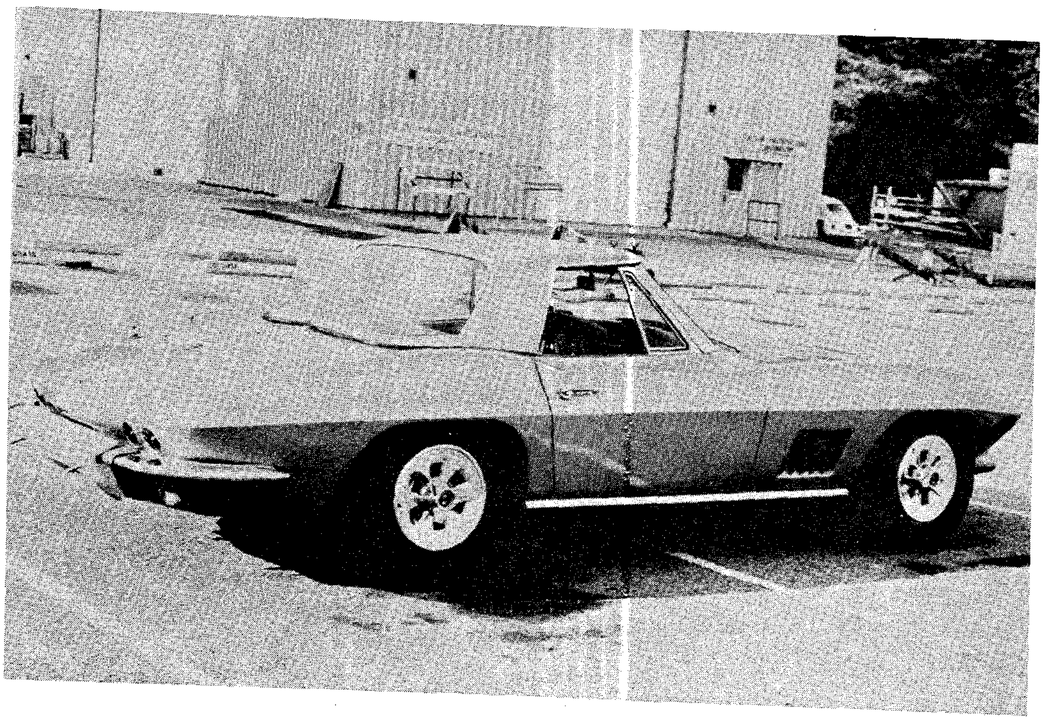


Figure 4-2. Side View of Corvette

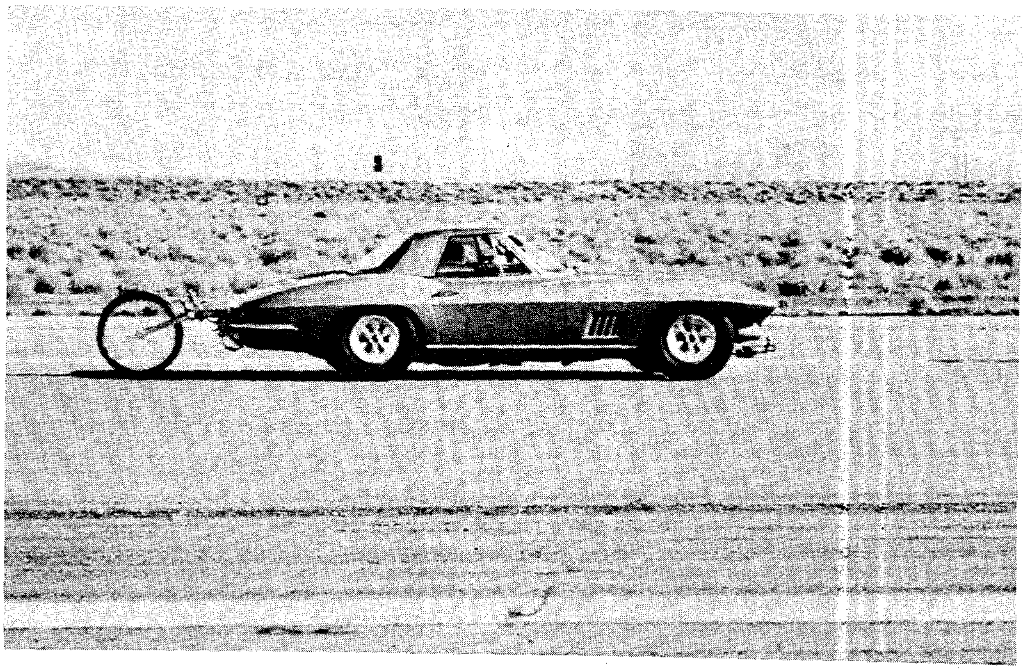


Figure 4-3. Side View of Corvette With Fifth Wheel Attached

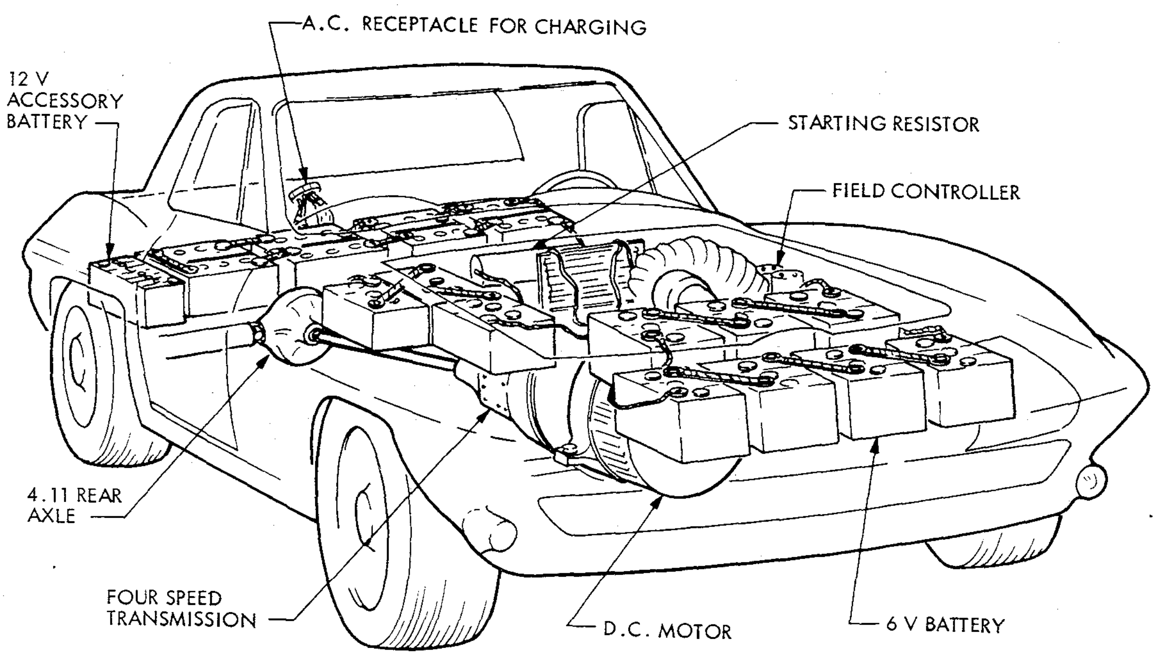


Figure 4-4. Cross-Sectional View of Corvette Showing Component Placement (Scale Not Exact)

Table 4-1. Cutler-Hammer Corvette Vehicle Specification Summary

Item		Specification
System	Vehicle	Electric
	Battery power source	Exide EV-106, lead-acid, 108 V
	Passengers	2
	Weight, curb	1832 kg (4020 lb) (rear axle = 966 kg, front axle = 857 kg)
	Weight, gross and ETS test	2005 kg (4420 lb)
	Weight, dynamometer test	1984 kg (4375 lb) dynamometer equivalent inertia weight
Electrical Components	Motor	General Electric 5BT2376, 28 kW (21 hp) at 1000 r/min, 96 V and 220 A[a]
		Maximum safe speed = 5200 r/min
	Controller	Controller maximum current = 375 A only when under base speed, otherwise 285 A
	Charger, onboard	Literature claims 15 A, sign on charger warns against exceeding 10 A. Takes 4 days for equalization recharge.
	Regeneration	Yes
	Chopper	
	• Armature	No
	• Field	Yes, 30-Hz rate, pulse-width modulated

[a]The base speed of the motor is actually 1380 r/min cold (21°C) and 1312 r/min warm (29°C) because of the higher motor voltage (108 V) and Corvette controls.

Table 4-1. (contd)

Item		Specification
Mechanical Components	Transmission	4-speed: first = 3.44:1, second = 2.28:1, third = 1.46:1, fourth = 1.00:1
	Differential	4.11:1
	Tires	Radial ply, 205 x 15
	Body	1967 Corvette
	Aero power at 80 km/h (50 mi/h)	6.38 kW (8.56 hp) dynamometer adjustment based on ETS data
		6.45 kW (8.65 hp) wind tunnel data, similar car
Performance (Manufacturer)	Range	128 km (80 mi) at 48 km/h (30 mi/h) 97 km (60 mi) at 64 km/h (40 mi/h)
	Acceleration	8 s, 0 to 48 km/h (30 mi/h) 30 s, 0 to 80 km/h (50 mi/h)

The traction motor drove the vehicle through a standard shift, heavy-duty Borg Warner (Model No. AS9T1OU) four-speed transmission with a 4.11 rear axle. The use of a heavy-duty transmission was not to satisfy the torque needs of the motor, but rather to obtain specific gear ratios. The gear ratios were: first, 3.44:1; second, 2.28:1; third, 1.46:1; and fourth, 1.00:1. The transmission characteristics are shown in Figure 4-6. A conventional clutch was used.

The Corvette was equipped with 205 x 15 size steel-belted radials inflated to a pressure of 2.76 bar (40 lb/in^2) cold. Dashboard instruments included: odometer, speedometer, tachometer (not operational during testing), battery voltage meter, armature current meter, starting resistor status lamp, high-current indicator lamp, and digital display for the current integrator. Additional features include hideaway head lamps, parking and tail lamps, brake lamps, turn signals, horn, windshield wipers, interior lamps, rearview and sideview mirrors, electric windows, and a removable hardtop.

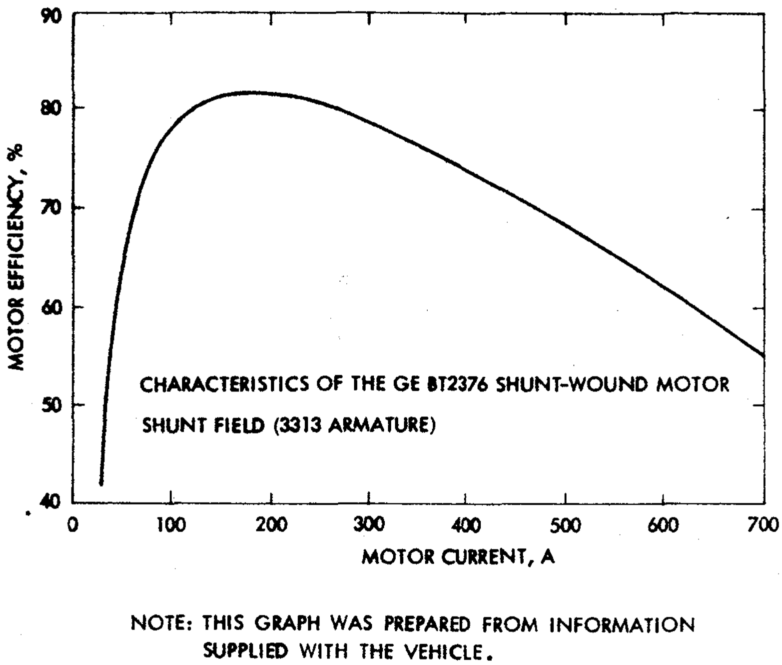


Figure 4-5. Corvette Motor Characteristics

Regenerative braking on the Corvette was available down to 14 km/h (9 mi/h) if downshifting was used. During decelerations, the inertial energy stored in the vehicle was partially returned to the propulsion batteries as the motor effectively became a generator. Care had to be exercised during downshifting to keep the motor (generator) below its maximum speed. Maximum utilization of regenerative braking was shown to have some range extending benefits, however the magnitudes were relatively small due to the high idle (base) speed of the motor. (See discussion in Section VII).

A block diagram of the Corvette propulsion system is shown in Figure 4-7. A schematic of the Corvette power system, including instrumentation sense points, is illustrated in Figure 4-8.

A. CORVETTE OPERATION

Operation of the Corvette was straightforward. Some minor differences between starting the electric Corvette and a conventional internal-combustion engine are required, but once the motor was operating the vehicle was driven in essentially the same manner as an internal-combustion engine equipped vehicle. The starting series of events are listed below:

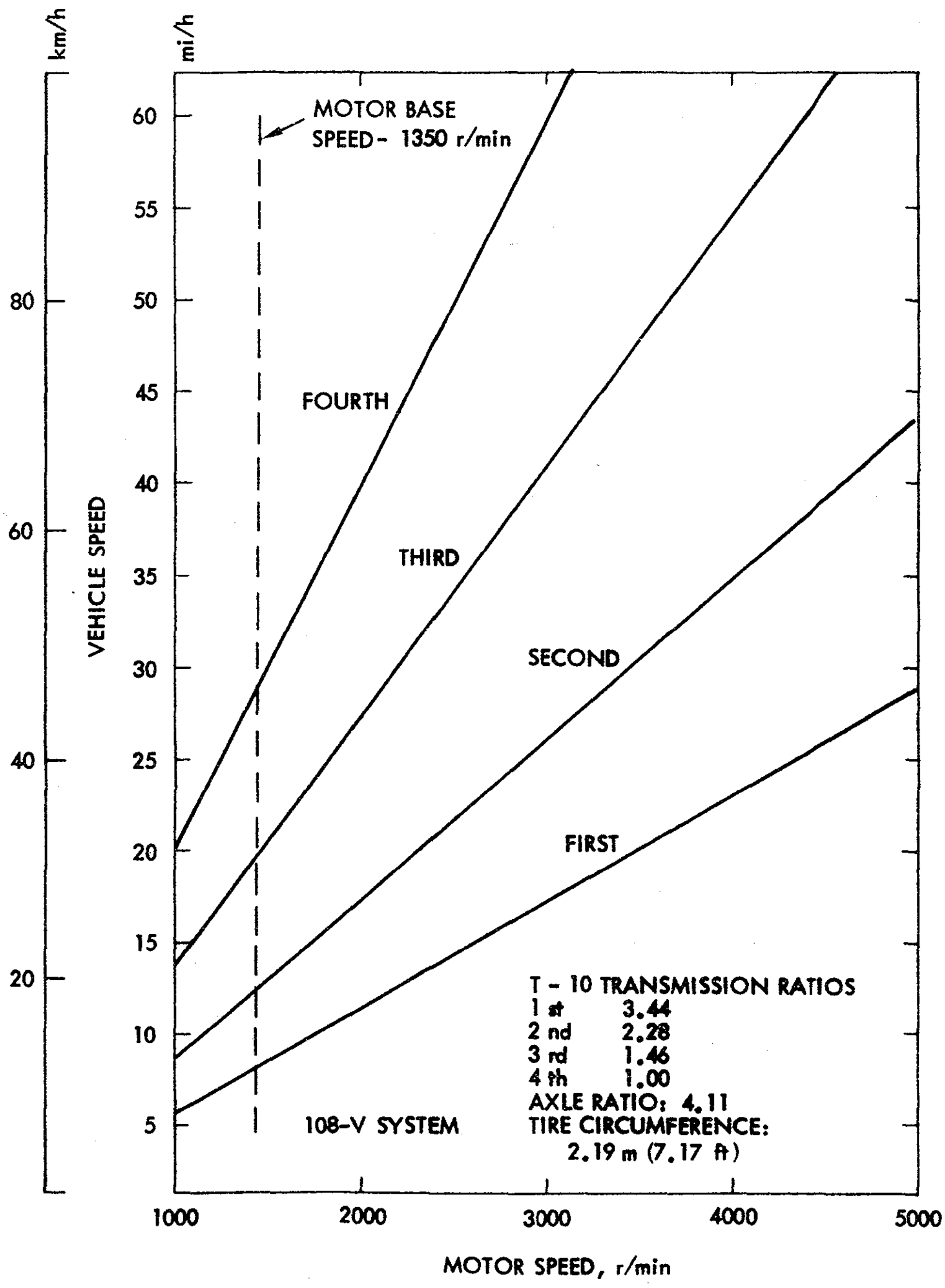


Figure 4-6. Corvette Transmission Characteristics

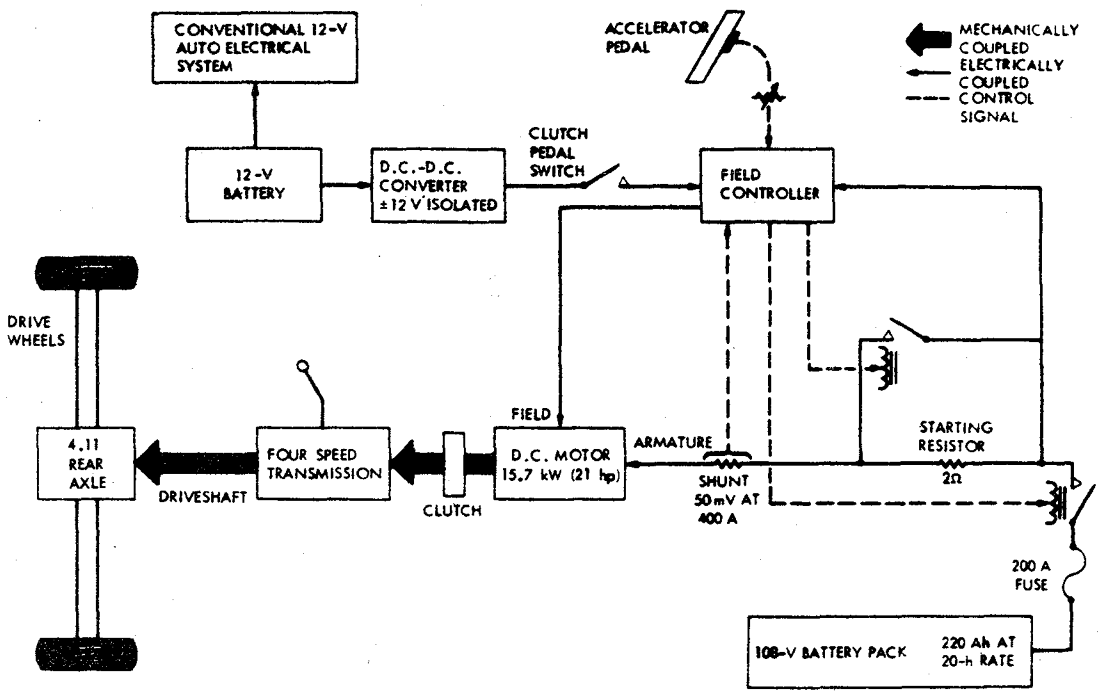
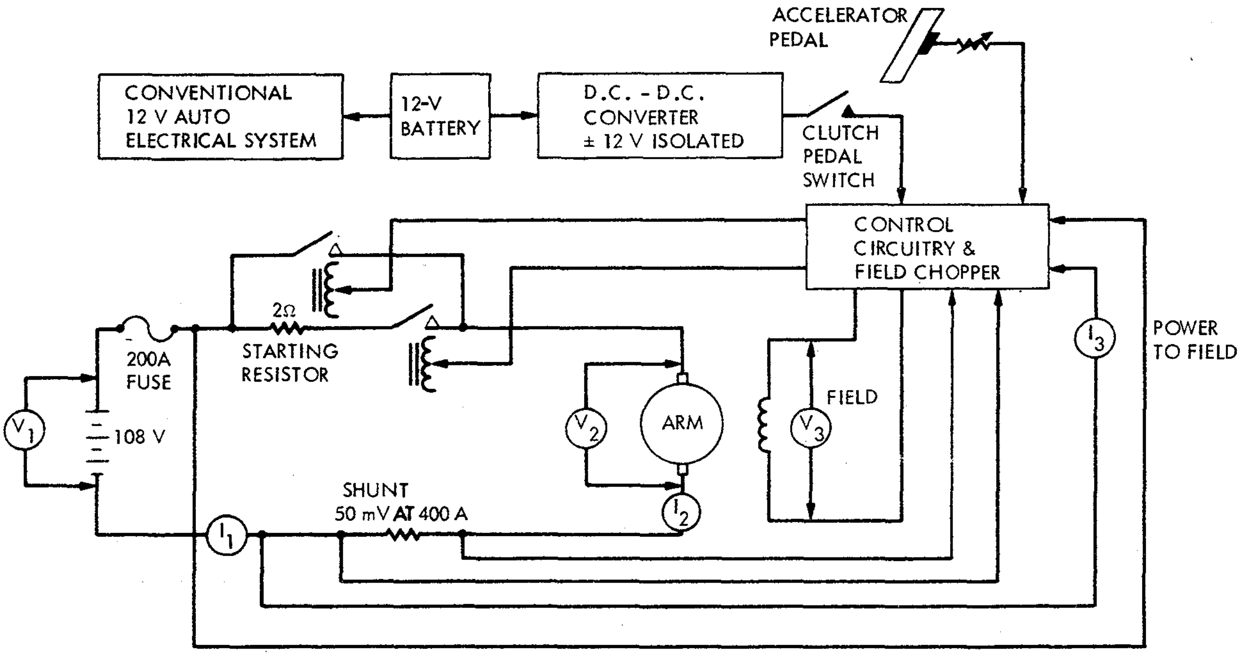


Figure 4-7. Corvette Propulsion System Block Diagram



NOTES

1. ALL CURRENTS WERE SENSED WITH CALIBRATED HALL EFFECT CURRENT TRANSDUCERS OR SHUNTS INSTALLED IN THE NEGATIVE LEG OF THE CIRCUIT
2. ALL CORVETTE CONTROL SIGNALS ARE NOT SHOWN HERE

JPL SENSORS

V_1 = BATTERY VOLTAGE
V_2 = ARMATURE VOLTAGE
V_3 = FIELD VOLTAGE
I_1 = BATTERY CURRENT (HALL EFFECT - 300 A)
I_2 = ARMATURE CURRENT (HALL EFFECT - 300 A)
I_3 = FIELD CURRENT (100 mV AT 100 A)

Figure 4-8. Corvette Power System Schematic

(1) Depress the clutch pedal completely to the floor. The car will not start unless the clutch pedal is fully depressed.

(2) Shift the transmission to neutral.

(3) Turn the keyswitch to the "start" position momentarily and then release it. The keyswitch will return to the "on" position and the motor starting sequence will occur automatically. In about 4 s, the motor speed will be raised to base speed (about 1350 r/min).

(4) Without depressing the accelerator pedal, shift the transmission into first gear or reverse. Slowly release the clutch pedal to start the car moving. Some caution must be exercised here as the motor has a large amount of torque at low vehicle speeds.

(5) Thereafter use the accelerator pedal, clutch pedal, and gearshift in a normal manner. The car drives very much like a conventional internal-combustion engine-powered car.

There were two features in this car to protect the traction motor: (1) an automatic circuit to protect against large current overloads and (2) a control logic that allowed a modest overcurrent to the motor for a limited time period. If the motor were overloaded (as when the clutch is released too quickly or when in the wrong gear) the main contactor opened up and a resistor was inserted in the armature circuit. To the driver, the motor felt as though it had stalled. Depressing the clutch pedal to the floor automatically reset the system, restoring full power. Failure to depress the clutch would overload the starting resistor and cause the vehicle to shut down completely. An indicator lamp on the instrument panel showed that the starting resistor was in the circuit.

The second feature was a digital current integrator. Whenever the motor was drawing more than its continuous current rating (nominally 220 A), a warning lamp went on (motor current high). This overcurrent was allowed for 1 min. If the driver commanded this high current for more than 1 min, the controller automatically lowered the maximum current to about 175 A, and a motor cooldown period was forced. A single-digit counter on the dash indicated the integrator count (0 = no previous high current, 8 = full count, current being lowered). An indicator lamp showed when the low current limit was in effect. The vehicle designer's objective was allow temporary motor overloads as an aid to acceleration onto freeways, for passing, etc.

As noted earlier, regenerative braking occured automatically when the driver removed his foot from the accelerator pedal. The car could be downshifted during a deceleration to maximuze the regenerative braking effect. If the deceleration from the regenerative braking were not enough, the conventional brakes had to be used. However, the operating instructions for the Corvette specified that the clutch pedal be depressed before the brake pedal. Applying the conventional brakes while the car was in gear resulted in an unnecessarily high motor current, whenever the motor was forced below its idle speed.

B. BATTERY CHARGING

The vehicle was equipped with an onboard battery charger. The charger operated on a standard 115-V a.c. outlet and consisted of a transformer and bridge rectifier which provided a pulsating direct current to charge the batteries. The charger had two modes of operation, but was always constrained to an upper limit of 10 A. A series resistor was used to limit the current (low mode) when first starting to charge a depleted set of batteries. As the battery voltage increased, the current rate was reduced. When the current was less than 5 A the high mode (series resistor shorted) could be selected manually to complete the charging cycle. The battery charger did not have an automatic shut-off feature. There was a separate 12-V onboard charger for charging the accessory battery that also operated on 115-V a.c. single-phase power.

C. MOTOR CONTROL STRATEGY

Field weakening was employed in the Corvette to control motor speed. The armature current assumed whatever value (up to the 300-A limit) was required until the motor (vehicle) achieved the speed commanded by the weakened field. Accelerator pedal position controlled the degree of field weakening by decreasing the amount of time a transistor switch was on during a 33-ms period. This control process occurred at a 30-Hz rate and was continually modified as dictated by throttle position and motor speed. Figure 4-9 demonstrates the field switching process which is frequently referred to as pulse-width modulation (PWM). Should the control logic sense a condition where armature current demand exceeded 285 A, it overrode the throttle signal and increased field current until armature current was regulated to about 285 A. Another control feature of the Corvette monitored how long armature current remained above the maximum motor rating of 220 A. This current integrator reduced maximum armature current to about 175 A when the 220-A rating was exceeded for 1 min. Allowing temporary motor overloads aided acceleration capability, while the current integrator ensured that excessive motor heating was not possible.

Maximum field current produced a minimum motor speed (base speed) of about 1350 r/min. If motor speed were forced sufficiently below the base speed that armature current exceeded 285 A, additional control was provided. Since control could not be achieved by means of

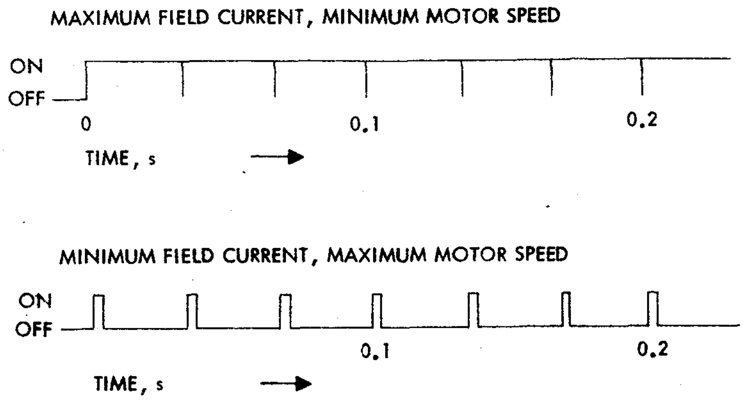


Figure 4-9. Field Chopper Pulse-Width Modulation

the field because it was already at its maximum level, the control circuitry inserted a 2-ohm resistor in series with the armature when 375 A was exceeded. During typical driving the motor is forced below base speed during each acceleration from a stop. To accomodate the brief 1-s current draw of about 350 A during initial clutch engagement, a 375-A maximum is allowed.

Voltage and current waveshapes are shown in Figures 4-10 through Figure 4-14. Each figure shows battery, motor armature, and motor field waveshapes under different operating conditions. In the case of the field, the voltage signal was recorded between the field chopper and the field itself, while the current signal was obtained between the propulsion batteries and the field chopper (See Figure 4-8). Operation of the field chopper is readily demonstrated in these figures. At the lowest motor speed (Figure 4-10) the field chopper conducted for the longest period within the 30-Hz repetition rate. At higher motor speeds, the field chopper conduction time can be seen to steadily decrease.

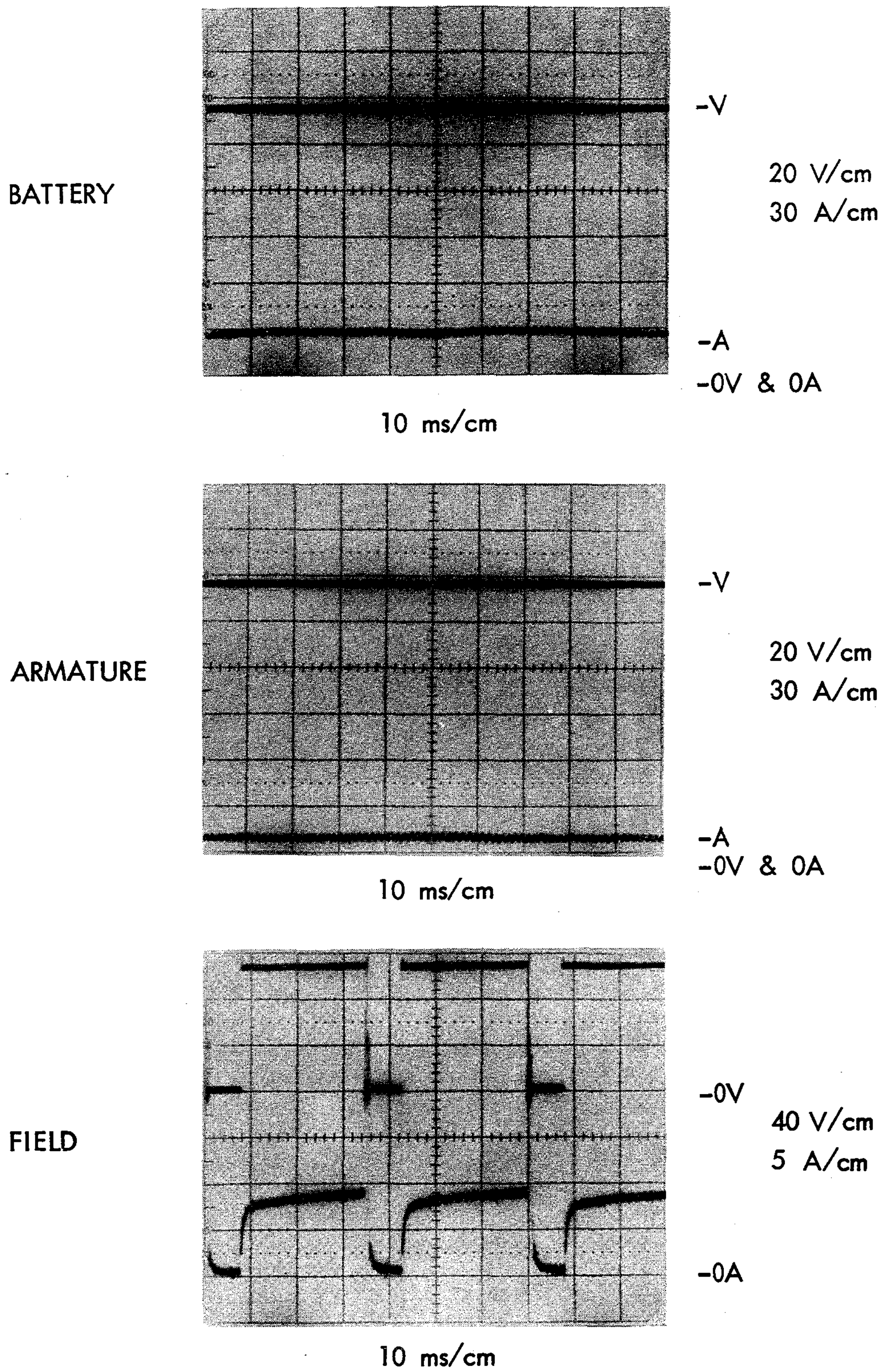


Figure 4-10. Corvette Voltage and Current Waveshapes at Idle

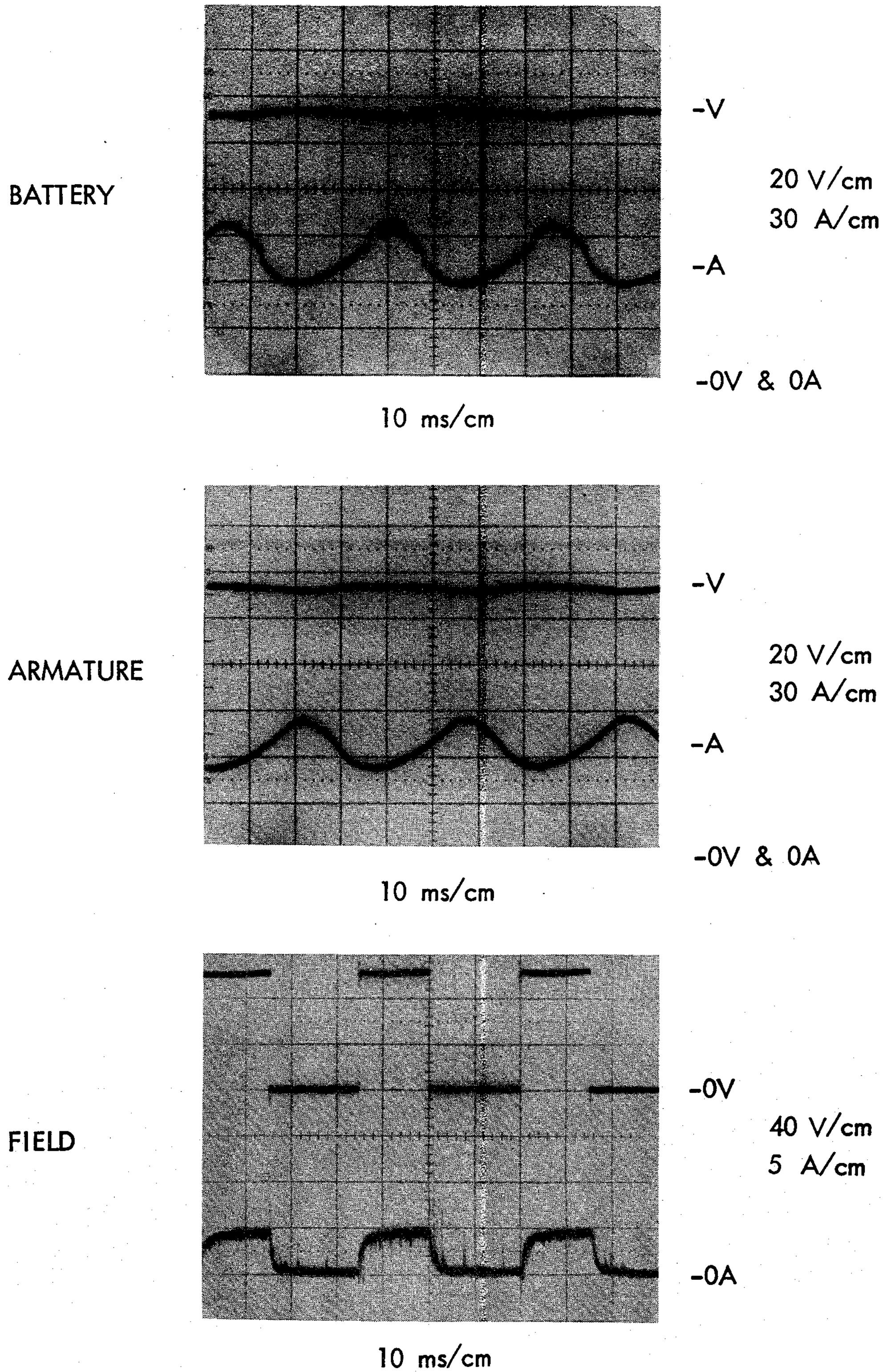


Figure 4-11. Corvette Voltage and Current Waveshapes at 25 mi/h in Third Gear

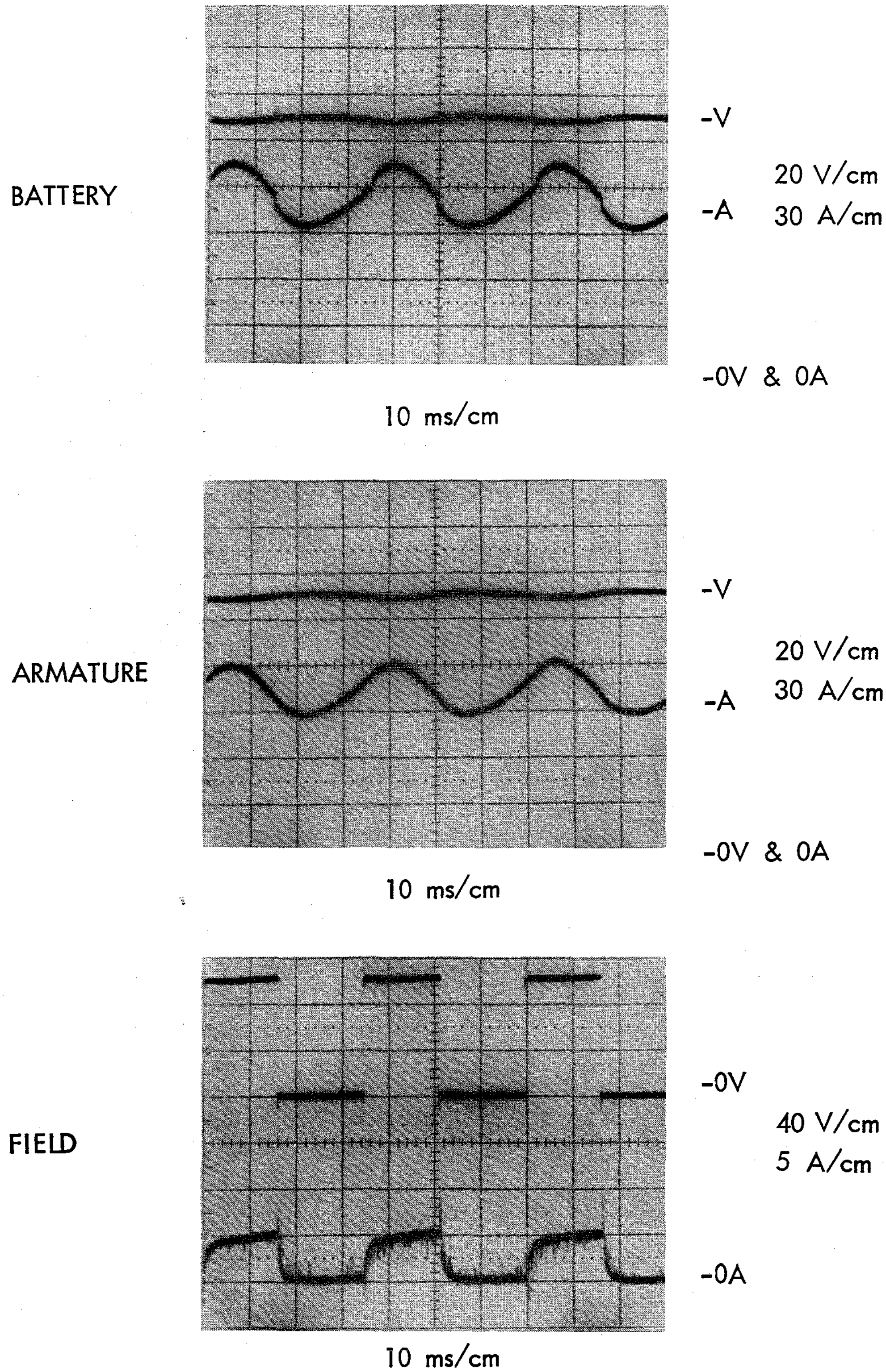


Figure 4-12. Corvette Voltage and Current Waveshapes at 35 mi/h in Fourth Gear

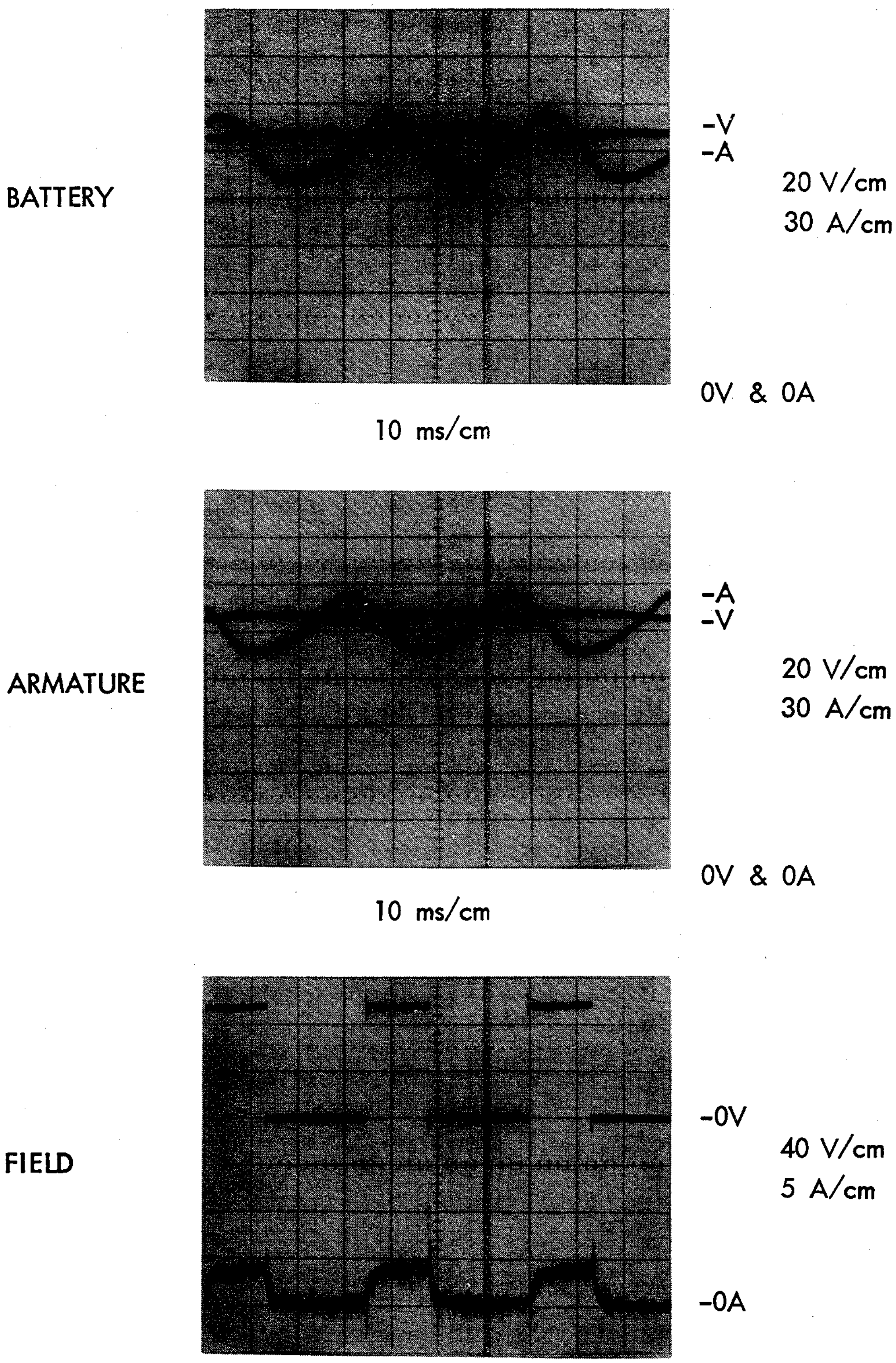
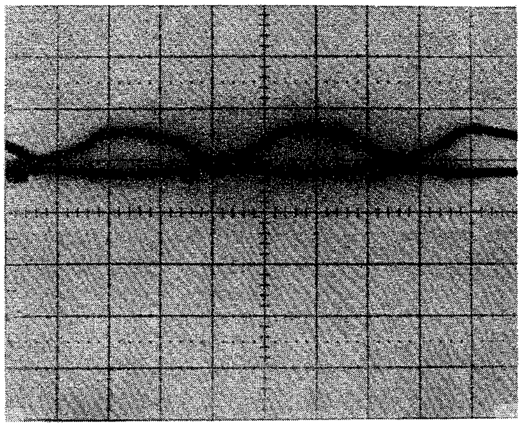
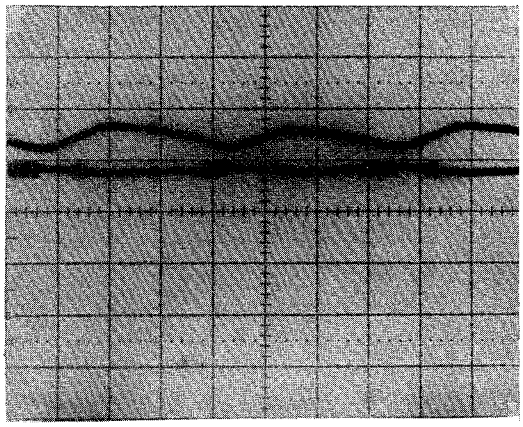


Figure 4-13. Corvette Voltage and Current Waveshapes at 45 mi/h in Fourth Gear

BATTERY



ARMATURE



FIELD

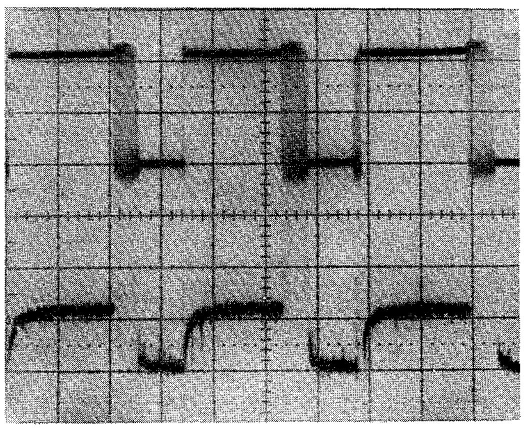


Figure 4-14. Corvette Voltage and Current Waveshapes at Maximum Acceleration in Fourth Gear

Effects of the relatively slow 30 Hz switching rate on battery and armature current can be seen in Figures 4-11 through 4-14. The armature inductance is insufficient to adequately smooth the armature current when the field operates at 30 Hz. In Figure 4-12 battery current fluctuations from 95 A to 135 A are seen. These represent a deviation of 17% about the nominal 115 A. Several references (4-1), (4-2), (4-3), and (4-4) indicate that a pulsing battery current degrades battery discharge capacity over that which could be obtained if only constant currents were required. Although there is considerable difference in the magnitude of the degradation reported by these sources, it is postulated that the Corvette would benefit from an increased field chopper repetition rate. For the conditions represented by Figure 4-12, a 300-Hz switching rate would reduce the fluctuations to about ± 2.5 A.

No specific tests were conducted to quantify susceptibility of the Corvette to radio-frequency or electromagnetic noise, but several observations were made which indicated some problems in this area. Walkie-talkies, used at the Edwards Test Station runway for communication between the test engineer and driver, caused interference in the Corvette control circuits. Each time the walkie-talkie was keyed on, vehicle speed increased. Viewing the location of many of the car sensors and control components one can readily understand this noise susceptibility. Many of the high impedance electrical components were not mounted in enclosures, nor was shielded wiring used for sensitive circuits.

Besides sensitivity to radio-frequency interference, the Corvette also appeared to be susceptible to electromagnetic interference (EMI). In Figure 4-14 it can be seen that the field chopper had a difficult time turning itself off. During the field on-to-off transition it induced sufficient electromagnetic noise back into its own control circuitry that it turned on again. These oscillations occurred 20 to 30 times before the field eventually stayed off. Further evidence of EMI susceptibility was observed in the overcurrent integrator. During many accelerations this integrator did not step sequentially from 0 through 8 before limiting motor power, but instead jumped from 0 to 8 and resulted in a premature current limit. The current integrator feature of the Corvette had to be inhibited to allow tests to be conducted according to SAE Procedure J227a Driving Schedule C.

SECTION V

TEST METHODOLOGY

Testing was divided into three general categories:

(1) Track testing on a aircraft runway at Edwards Air Force Base near Lancaster, California. This location will be referred to as Edwards Test Station (ETS).

(2) Chassis dynamometer tests conducted in the JPL Automotive Test Facility.

(3) Road load determination tests conducted at ETS solely for the purpose of establishing dynamometer adjustments.

All testing was conducted in accordance with the DOE procedure, "Electric Vehicle Test and Evaluation Procedure," (Ref. 5-1) which is based on the Society of Automotive Engineers (SAE) "Electric Vehicle Test Procedure", SAE J227a (Ref. 5-2). These procedures will not be discussed in detail here. Only those procedures that were different at the two test locations (JPL and ETS) or those which deviate from those specified by the DOE are discussed.

A. TRACK TESTING AT EDWARDS TEST STATION

Several runways exist at ETS. JPL has access to the North Base Runway which is located next to the JPL rocket test facilties on the Air Force Base. Figure 5-1 depicts the slope profile of this runway. In most cases the testing was performed on the relatively flat (0.18% slope) portion of the runway.

1. Battery Charging During Track Tests

The vehicle's on-board charger was employed at ETS. Propulsion battery charging had to be done in two stages to avoid exceeding the maximum 10-A current rating of the onboard charger. The first day of charge was done in the low mode and subsequent charging done in the high mode. Because of the low capacity of the Corvette's battery charger the equalization charge specified by the DOE procedures for range testing could not be accomplished in less than four days. Consequently, the equalization charge was not always performed. The Corvette accessory 12-V battery was charged with a commercial onboard 10-A charger. The 115-V power source for the two onboard chargers were separated from one another by JPL. All charging energy reported here excludes that required by the accessory battery. The fact that the propulsion batteries did not always receive an equalization

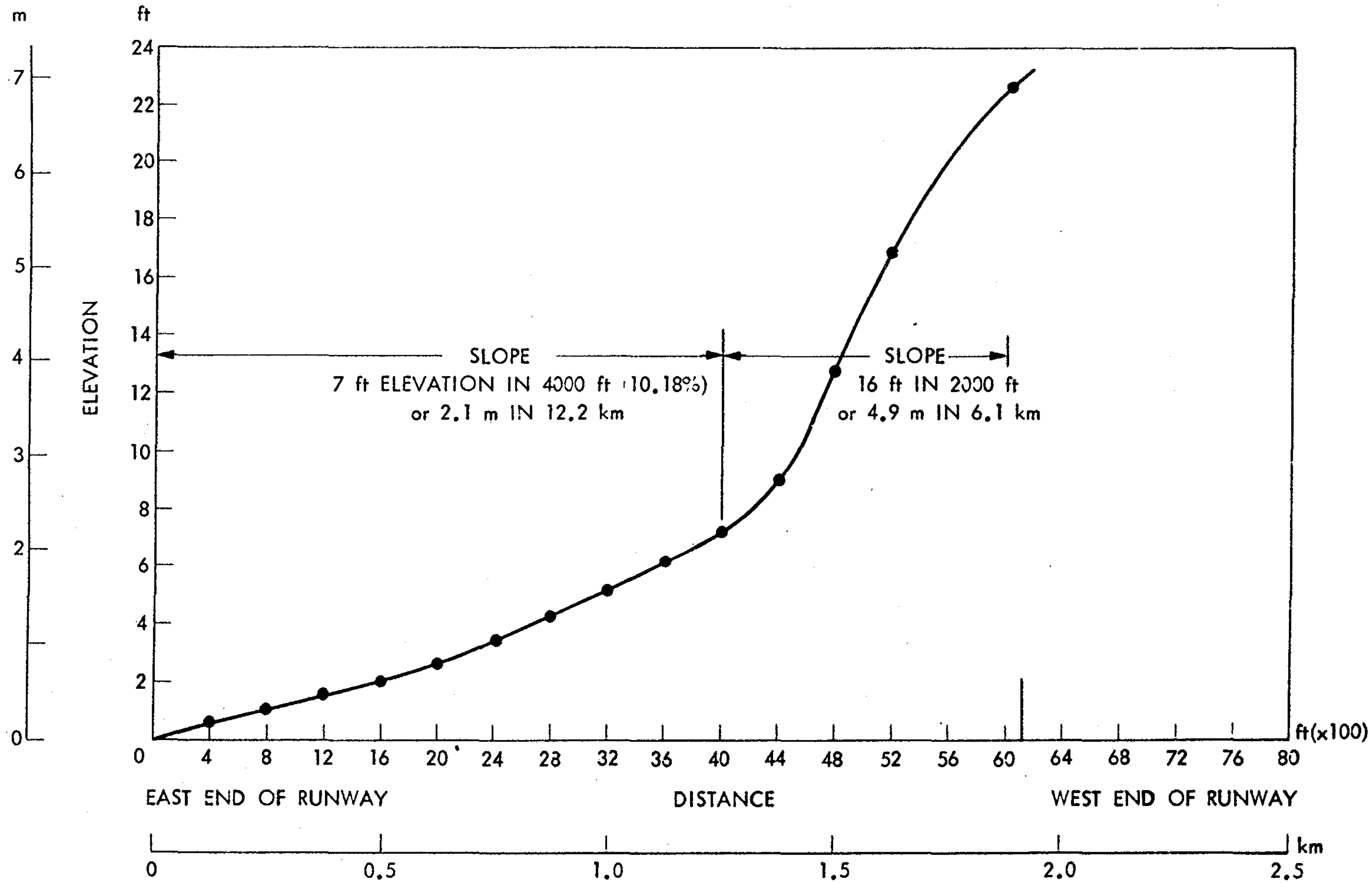


Figure 5-1. Edwards Test Station North Base Runway Profile

charge may be one of the factors contributing to the lack of consistent range performance during repeat tests conducted at ETS. This same slow charging rate also precluded the DOE specified postcharge 8-h soak before vehicle testing. However in all cases the battery electrolyte temperature was within the ambient test temperature limitations defined by the SAE procedure.

2. Vehicle Conditioning and Warm-up--Track

In an effort to minimize the effect of large ambient temperature variations on the electric vehicle's range performance, the Corvette was stored indoors up to test time. The storage room temperature was maintained between 15° and 24°C (60° and 75°F).

A vehicle warm-up was standard procedure before all ETS performance tests. This was accomplished by towing the vehicle up and down the runway at 24 to 48 km/h (15-20 mi/h) for about 4 km (2.5 mi). The intent of this warm-up period was to bring the vehicle lubricants and wheel bearings closer to their normal operating temperature. The Corvette power was never turned on during the pretest warm-up.

3. Test Termination Criteria--Track

All ETS tests were terminated when the vehicle could no longer satisfy the acceleration profiles for the SAE Test Procedure J227a driving schedules or, in the case of constant-speed tests, when the velocity fell below 95% of the required velocity. It should be noted here that constant-velocity tests at ETS were not truly conducted at a constant speed. The 1-mi runway was of insufficient width to permit the vehicle to negotiate a turn safely above about 20 km/h (16 mi/h). As a result of this limitation, all constant speed tests were interrupted once every mile by the need to slow for a turnaround. Then, of course, the vehicle had to be reaccelerated back to the specified speed. All constant velocity tests were terminated during this reacceleration phase of the turnaround. Turns during SAE J227a driving schedules were accomplished during the deceleration and acceleration phase of each driving cycle. Consequently, the track width limitation presented no particular problems for the driving cycle tests.

4. Environmental Conditions--Track

The relatively long calender time span over which Corvette testing took place at ETS exposed the vehicle to large ambient temperature extremes Ambient temperatures during the July and August testing were as high as 40°C (104°F). At the completion of the

ETS testing in December ambient temperatures during testing were as low as -2°C (28°F). Department of Energy test procedures specify ambient temperature limits of 5°C (41°F) to 35°C (95°F). As noted above, in order to minimize the ambient temperature effects on range data the Corvette was stored in a temperature-controlled garage until test initiation. Considering the relatively large thermal mass of the propulsion batteries it is believed that the temperature-controlled storage of the car compensated for any variances in performance which may have resulted from the ambient temperatures encountered during the actual tests.

5. Instrumentation--Track

For the purposes of the ETS tests an onboard data system, the Electric Vehicle Instrumentation System (EVIS), was used. Numerous hardware and data reduction problems resulted in almost all of the ETS testing being conducted before the data were reduced to a useful format. Once reduced data became available, it was apparent that relatively large errors existed in the power and energy measurements. Attempts to identify the source of these errors and to separate the errors from genuine experimental variabilities (such as environmental influences) proved to be difficult. It was especially difficult to justify expending much resources in such an effort, because dynamometer testing was already planned to circumvent the problem associated with the turns required for the constant-velocity tests. Therefore, no energy data from the ETS tests are reported herein. All energy data presented in this report were acquired during dynamometer tests. Range and velocity data were obtained with independent measurements using a precision fifth-wheel speedometer in conjunction with a distance totalizer.

B. JPL AUTOMOTIVE TEST FACILITY

Corvette testing was also conducted in the chassis dynamometer portion of the JPL Automotive Test Facility. The chassis dynamometer is the twin roll type specified by the Environmental Protection Agency (EPA) for exhaust emission certification testing.

1. Battery Charging--Dynamometer

As previously discussed, the Corvette battery charger required several days to complete an equalization type charge specified in the DOE/SAE procedures. Since this would have severely limited the quantity of range testing possible, a large, general-purpose charger was used for battery charging. The use of this charger was begun after consultation with the vehicle manufacturer. As a result of this change, charging time was reduced to about 18 h. Charging without equalization required only 10 to 12 h. Since equalization charging by nature is not energy efficient and since the Corvette onboard charger was not used, little recharge data was gathered. Rather the values for recharge energy developed later in this report are based upon 10% battery overcharge (ampere-hours) and a charger efficiency of 86%.

2. Battery Temperature Conditioning--Dynamometer

After battery charge termination the vehicle was allowed to soak in a temperature controlled room until the average battery electrolyte temperature stabilized at $21 \pm 2^{o}C$ ($70^{o}F$). An entire day was specifically set aside between each test day for temperature stabilization. Even with this extra "soak" day, forced convection cooling of the batteries had to be employed to safisfy the $21^{o}C$ ($70^{o}F$) test criterion within the allocated time. The final (equalization) portion of battery charging resulted in self-heating of the batteries to the point that they typically gained 10^{o} to $15^{o}C$ (18^{o} to $29^{o}F$). The final electrolyte temperature was then in excess of $38^{o}C$ ($100^{o}F$). Battery capacity, and hence range performance, is directly related to electrolyte temperature. The 1977 State-of-the-Art Assessment reported that battery capacity will vary by over 1% per degree Celsius (Ref. 5-3) over the temperature range allowed for vehicle testing. Using this rule of thumb a 30% variation in range will occur for a battery electrolyte temperature variation from $5^{o}C$ ($41^{o}F$) to $35^{o}C$ ($95^{o}F$). In order to reduce test-to-test variability from battery temperature, the extra day between tests was required.

3. Test Termination Criteria--Dynamometer

Except for the SAE J227a Driving Schedule B tests, all range tests were terminated when the battery pack voltage fell below 75 V. The 75-V limitation was prescribed by the owner of the vehicle. In the case of the driving cycle tests the 75-V limitation was allowed to be exceeded for about 10 s before the test was terminated.

This 75-V limit very nearly matched the other termination criteria established by the SAE procedure for Driving Schedule C tests. The Corvette just barely satisfied the Schedule C acceleration ramps when the battery voltage fell to 75 V. It is doubtful that the car could complete more than three additional Driving Schedule C cycles after the battery voltage dropped below 75 V.

One of the objectives of the dynamometer testing was to establish some correlation to the track testing conducted at ETS. For this reason, the 75-V limitation was not used during the Driving Schedule B tests on the dynamometer. As was done during the ETS track tests, termination of the test was defined as the point at which the car could no longer achieve the acceleration profile. On the dynamometer this corresponded to a battery voltage of about 50 V and resulted in only a 4% extension of range compared to the 75-V criterion.

All constant velocity range tests also used the 75 V termination criteria. Since all the constant velocity range tests on the track at ETS could not truly be conducted at a steady speed, there was no attempt to replicate the track test conditions.

4. Environmental Conditions--Dynamometer

An important advantage of dynamometer testing is the ability to provide a relatively stable set of environmental conditions to the vehicle and hence significantly reduce the effect of the environment on the test results. The chassis dynamometer room is maintained at a relatively constant 21° + 2°C (70°F) during all testing. Only during one test, VET-26 (Schedule B), was the above temperature tolerance exceeded. A NASA film crew had directed several 1000-W lamps at the Corvette during this test and as a result the ambient room temperature approached 27°C (80°F).

Although precise measurements of relative humidity and atmospheric pressure are routinely recorded in the JPL Automotive Test Facility, these values are not reported here. They are of little significance when pure electric vehicles are tested on a dynamometer within a closed building.

Simulation of the Corvette forced-convection cooling (airflow as a result of driving) was accomplished by the placement of a large fan in front of the car. While little heat is generated by electric vehicles it was felt that the batteries mounted in the front part of the vehicle would heat more on the dynamometer, as compared to the track tests, unless the fan was employed. During testing the front batteries (under the hood) were observed to be 3° to 4°C (5° to 8°F) cooler than those located in the trunk of the car.

5. Instrumentation--Dynamometer

A large, general-purpose Integrated Data Acquisition and Control (IDAC) data system is an integral part of the JPL Automotive Test Facility. Appendix A presents a further discussion of this data system, as it applies to the Corvette testing, as well as some of the facility components. What follows is a brief description of the pertinent measurements used during Corvette testing and how they were recorded.

a. Voltage, Battery and Motor Armature. Battery and motor voltages were divided by precision dividers and then conditioned with instrumentation amplifiers. The 20-kHz wideband output of the amplifiers is used by the power measurement circuits, while the 10-Hz, filtered output is recorded for trend information.

b. Current, Battery, Motor Armature and Motor Field. Bipolar measurements of battery and armature currents were done with Hall-effect current transducers. Although these current transducers have a considerable temperature sensitivity, the controlled environment of the dynamometer facility minimized any temperature-related errors to less than ±0.5% of full scale. These current signals were conditioned and distributed in the same manner as the voltage data. Field current was transduced with a standard bar shunt. It was conditioned and filtered (10 Hz) by an instrumentation amplifier before being recorded as trend data.

c. Power and Energy. Battery and motor armature power were calculated in real time (Figure 5-2). Conditioned, wideband voltage and current signals (described above) are applied to an analog multiplier circuit. The multiplier output is then converted to a frequency proportional to instantaneous power. The frequency is recorded directly as power and integrated to give energy. In the case of regenerative power, a polarity detector is used to switch counters so that any current returned to the battery could be accurately accounted for.

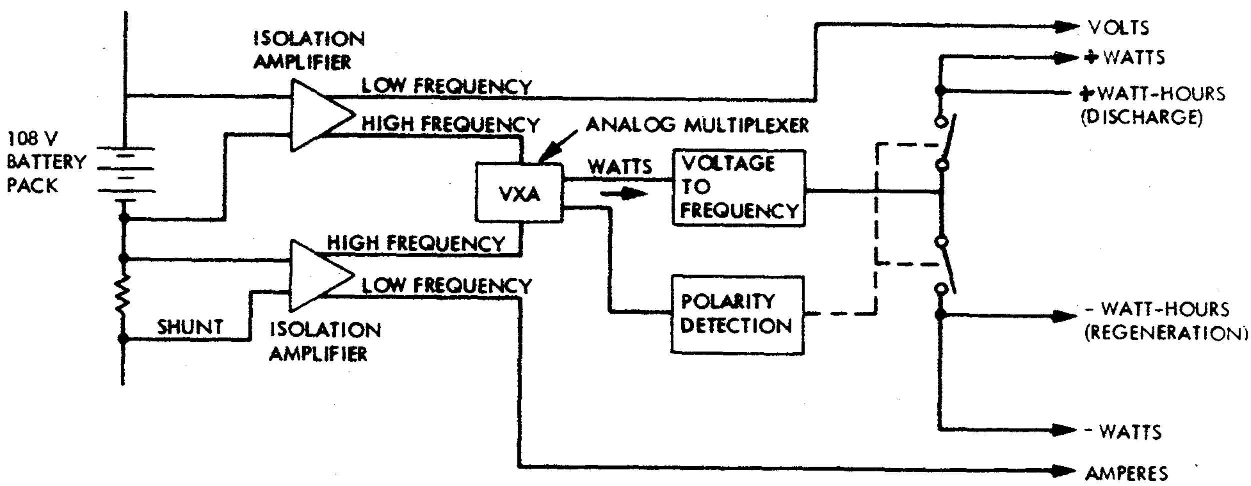


Figure 5-2. Typical Power Measurement Circuit

d. Motor and Drive Shaft Rate. Alternating strips of reflective and optically black tape were attached to the end of the motor shaft and to the drive shaft. Photooptical sensors were used to monitor the black-to-reflective transistions and provided a frequency signal proportional to rate in revolutions per minute.

e. Vehicle Velocity and Distance Traveled. Each of the two dynamometer rolls is equipped with a digital transducer which produces a pulse for each centimeter of distance traveled. These pulses are recorded as a rate (miles per hour) and integrated to give distance (miles). Although the pulse signals from both dynamometer rolls are recorded, only the data from the idle roll are used for reporting purposes. Data from the other dynamometer roll (absorption roll) are used for engineering information and to adjust the dynamometer aerodynamic horsepower simulation.

f. Torque and Aerodynamic Horsepower. Reactive torque as a result of power being dissipated in the dynamometer absorption unit is measured by a precision load cell.

Using torque and dynamometer revolutions per minute the IDAC data system calculates horsepower in near real time (within 0.1 s). This permits accurate adjustments of the dynamometer aerodynamic horsepower.

g. Miscellaneous Measurements. Additional recorded measurements include battery temperature, motor case temperature, atmospheric pressure, calibration voltages and several other parameters.

6. Data Recording--Dynamometer

Slices of data are acquired at various time intervals. The exact time within the test depends on the type of test. For instance, during constant-speed tests, data were recorded once every 30-s interval. During the driving schedule tests the 30-s interval data are supplemented by several continuous recordings of two complete repetitions of the driving cycle (Figure 5-3). These continuous recordings are intended to occur at 4 discrete levels of battery depth of discharge, however, the time at which these levels of depth of discharge occur must be estimated before test initiation. Because of the uncertainties associated with this estimating process, data indicated as occuring at 40%, 80% or 100% depth of discharge may actually have been recorded slightly before or after the specified depth of discharge. During several tests, the continuous recording at 100% depth of discharge was missed altogether because of the estimating process and the very rapid decay in battery voltage as 100% depth of discharge is approached.

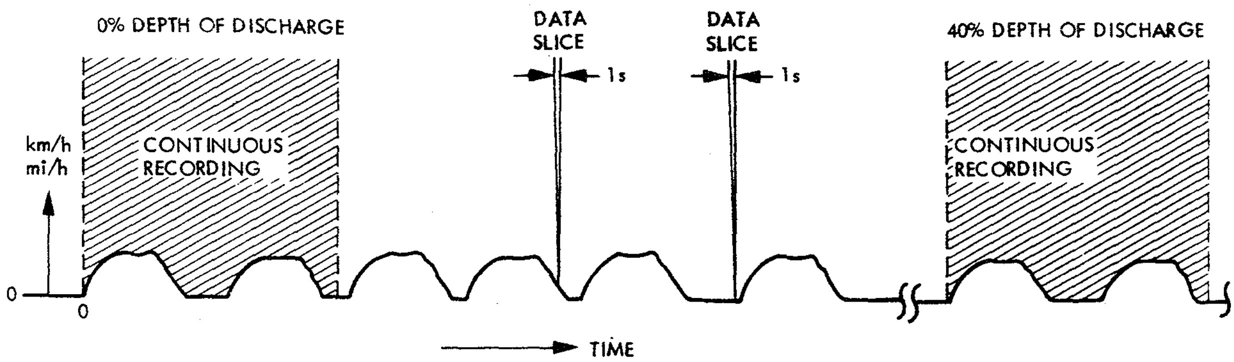


Figure 5-3. Typical Data Recording Format, Vehicle Velocity vs Recording Period

Data recording was accomplished in two ways: high-speed printer (on paper) and magnetic tape. The bulk of the recording was done with the magnetic tape while the direct printing was used for a "quick look" immediately after test completion. Subsequent data reduction of the magnetic tapes provided a detailed tabular printout of the data as well as plots of pertinent parameters. Appendix B contains a sample of the tabulated data.

In addition there is a significant amount of detailed information regarding electric vehicle performance that is available just from the plotted data. Vehicle efficiencies and power consumption during nonmotive portions of the driving schedule tests are readily gleaned from these plots along with a review of the appropriate tabular printouts. Because of the utilitarian nature of these plotted data, a typical set of plots for each type of test is included as Appendix C.

C. ROAD LOAD DETERMINATION

Determination of road load power requirements is a standard test specified in the SAE Test Procedure J227a. However, the intent of the procedure is to define road load for reporting purposes, while in the context of this report road load is established primarily for defining dynamometer adjustments. Without the initial determination of a given vehicle's actual road load (through track tests) the absolute value of any dynamometer test results would be suspect. Because of the important role of the road load data in all the dynamometer results it is included in this section and is discussed in considerable detail.

However, the road load data also bear on the characterization of the vehicle itself and hence there is additional discussion of the road load results in the Section VI, Test Results.

The Clayton twin-roll type of dynamometer used at JPL has only a single adjustment for the simulation of aerodynamic load. That is, the load can be set at only one value of vehicle speed. The loads at other speeds are fixed by the cubic variation of load as a function of vehicle velocity that is built into the dynamometer. In addition the tire pressure and/or the tire loading (vehicle weight on the drive wheels) can be manipulated, within limits, so as to vary the tire/roller losses. The steps necessary to adjust the dynamometer and tires are outlined below:

(1) Coastdown tests are performed on the vehicle at the ETS runway. During these tests the vehicle is towed to a speed of about 97 km/h (60 mi/h), released from the tow vehicle, and allowed to coast with the clutch disengaged to a speed of less than 16 km/h (10 mi/h). (Note that the vehicle could be accelerated under its own power and allowed to coast, but the length of the runway combined with the limited acceleration capability of the Corvette made this impractical.) The velocity of the vehicle as a function of time is recorded and represents the primary data from this test.

(2) The vehicle is moved to the dynamometer. The coastdown process is repeated, but the vehicle traction motor is used to turn the rear wheels. The time required to coast from 32 to 16 km/h (20 to 10 mi/h) is matched first by adjusting the tire pressure and/or tire loading. (This is probably the most difficult part of the dynamometer setup. Matching the tire/road interface with the tire/dynamometer interface sometimes presents problems.) At the nominal 24 km/h (15 mi/h) the aerodynamic portion of the total road load is small (Figure 5-4) and the necessary tire adjustments are not masked by the aerodynamic variable.

(3) Once the coastdown time is matched at about 24 km/h (15 mi/h) the aerodynamic load is adjusted by means of the water brake absorber portion of the dynamometer. This is generally done at 80 km/h (50 mi/h), but can, in principle, be done at any velocity. As high a speed as practical is used so that the aerodynamic load is as large a part of the total as possible. Again the time to coast between two speeds is matched to that obtained during the road test.

(4) Once the "road" coastdown times have been duplicated on the dynamometer, the resultant aerodynamic horsepower at 80 km/h (50 mi/h) is measured. (The specific value for the

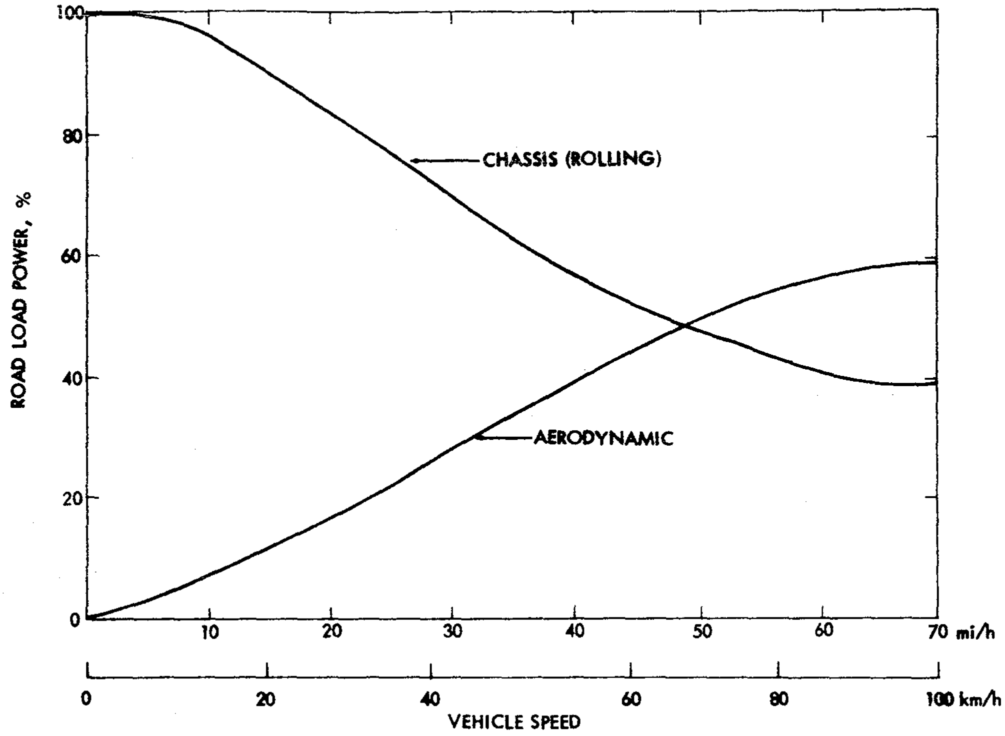


Figure 5-4. Distribution of Corvette Road Load

Corvette was 6.38 kW or 8.56 hp.) Note that this is the first time that an actual power value has been used even though road load is nominally being duplicated. The dynamometer was then adjusted to this specific horsepower value before each test of the Corvette.

An attempt was made to measure motor currents during periods of constant vehicle velocity at ETS as a second technique for matching road load on the dynamometer. Two vehicle characteristics and the short runway caused sufficient variability to this technique that it was not used in adjusting the dynamometer. Factors which attributed to the data scatter are:

(1) Short runway - making it almost impossible to achieve a truly constant velocity at the desired speeds.

(2) Poor acceleration capability of the Corvette which effectively reduced the length of the already short runway.

(3) Sensitive Corvette throttle which made it difficult to maintain constant current even though the velocity appeared constant to the driver.

(4) Time correlation of hand recorded data. All four parameters were manually recorded from a single digital voltmeter. Slight throttle variations between the recording intervals of each parameter made correlation between channels extremely difficult.

Despite the variability in these data, repeat tests were conducted on the dynamometer to further identify any other problems in this basic approach to establish road-to-dynamometer correlation. Dynomometer tests of constant-velocity currents only reinforced the observations made on the runway:

(1) Two miles were required to establish a constant-velocity, constant-throttle condition.

(2) Several parameters, at least six for the Corvette, must all be recorded within 0.1 s if the data are to be of any use.

The general conclusion was that this technique is potentially useful, but the practical problems noted above must be avoided. In particular, an onboard data system would be a necessity.

1. Environmental Effects on the Coastdown Data

The coastdown tests were conducted in December which is a relatively cold month at the ETS. Temperatures during the coastdown tests were between 5° and 13°C (41° and 55°F). The effects of temperature differences from the ETS runway to the temperature controlled dynamometer facility, nominally 21°C (70°F), are believed to be minimal. Tire losses and drive train lubricant losses are both a function of ambient temperature. However, based on coastdown tests conducted on another vehicle (Ref. 5-4), the ambient temperature coefficient of chassis rolling losses is less than 4% per 10°C. Applying this information to the two temperature conditions which existed between the ETS and the dynamometer facilities, a maximum difference of 3% would result in actual rolling losses. This percentage difference was further reduced by allowing the tires to cool for 5 min between each dynamometer coastdown. Based on the recorded hot tire pressures at ETS and JPL it is felt that temperature related differences between the two sites were less than 3%.

Winds have the largest environmental effect on road load data. For this reason wind velocity and direction were monitored at the midpoint of the ETS runway. Coastdown tests were limited to those times when average wind speed was less than 3 mi/h. Although several days may elapse before these near-zero wind conditions exist, it is the only way one can readily achieve a true picture of the vehicle road load losses.

2. Coastdown Data for Dynamometer Adjustments

Table 5-1 summarizes the coastdown data obtained on the ETS runway. Because of the slight slope of this runway, tests were conducted in opposite directions and then averaged to compensate for the differences in grade. These data are presented as the average value of that pair.

Table 5-1. Corvette Coastdown Tests on Track at ETS

Velocity, km/h (mi/h) From	To	Sample Pairs, No.	Coastdown Time, s	Standard Deviation, %	Total Road Load, kW (hp)
80 (50)	64 (40)	7	16.25	3	11.0 (14.7)
32 (20)	16 (10)	10	26.62	1	2.2 (3.0)

Tires at 2.76 bar (40 lb/in^2), cold

Dynamometer adjustments and tire pressures were varied until the 80 to 64 km/h (50 to 40 mi/h) and 32 to 16 km/h (20 to 10 mi/h) coastdown times, respectively, matched that which were observed for the track tests. Once good agreement was obtained, two dynamometer coastdowns were conducted. The results of the dynamometer coastdowns are given in Table 5-2.

Table 5-2. Corvette Coastdown Tests on Dynamometer at JPL

Velocity, km/h (mi/h) From	To	Samples, No.	Coastdown Time, s	Data Scatter, %	Total Road Load, kW (hp)
80 (50)	64 (40)	2	16.4	0	10.9 (14.6)
32 (20)	16 (10)	2	27.5	2	2.2 (3.0)

Tires at 2.41 bar (35 lb/in^2), cold

Figure 5-5 depicts the average data of just two of the ETS coastdowns. This same figure is presented in the Test Results Section. Because of the numerous coastdowns conducted at ETS only two were averaged over the entire velocity profile in the preparation of the road load figure. However, in the course of evaluating the 24 and 72 km/h road load data, all coastdown tests were analyzed. It is for this reason that there appears to be some discrepancy in the dynamometer and the total ETS averages superimposed on it. Table 5-3 better demonstrates the agreement between the dynamometer and track coastdown data. Wind tunnel data, obtained from a similar Corvette, is also given in this table. It is compared to the observed dynamometer aerodynamic loading at 80 km/h (50 mi/h) after the 24 and 72 km/h (15 mi/h and 45 mi/h) coast times on the dynamometer were matched to the track coast times. As can be seen, excellent agreement is shown between three different sources of road load data.

Table 5-3. Corvette Road Load Comparison Between Track and Dynamometer

Velocity, km/h (mi/h)	Test track power, kW (hp)	Dynamometer power, kW (hp)	Wind Tunnel power, kW (hp)
72 (45)	11.0 (14.7)	10.9 (14.6) [1%][a]	-
24 (15)	2.2 (3.0)	2.2 (3.0) [0%]	-
80 (50)[b]	-	6.4 (8.56)	6.5 (8.65) [1%]

[a]Numbers in brackets indicate percentage difference between columns
[b]Aerodynamic power only

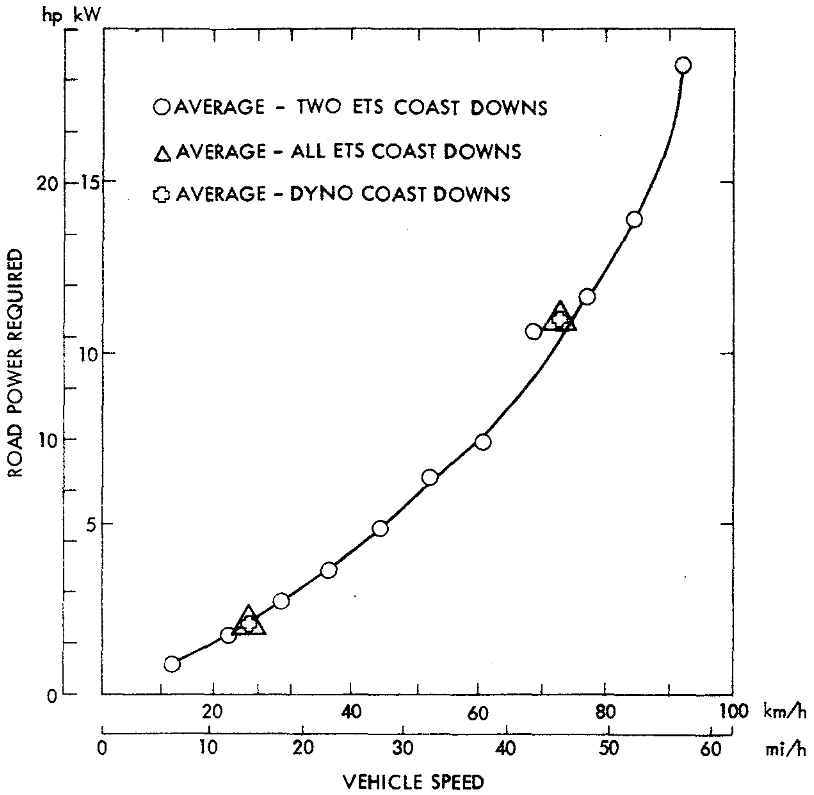


Figure 5-5. Corvette Road Power Coastdown Data

SECTION VI

TEST RESULTS

This section presents the results of both the track (ETS) and dynamometer testing. The results from each test location are presented in separate subsections and then compared in a third. As explained in Section V, very little energy data were obtained from the track tests due to instrumentation problems. As a result of this shortcoming, comparisons of the energy consumption between the track and dynamometer test locations are not attempted. Appendix C is a tabulation of all the dynamometer tests. Procedural differences in testing between the track and dynamometer location are discussed in Section V, Test Methodology.

A. RANGE AT CONSTANT SPEED

1. Track Tests

Lack of a continuous track at ETS precluded the possibility of truly constant speed tests. Because of this limitation only 40-km/h (25 mi/h) runs were attempted. (See Section V, Test Methodology). Table 6-1 gives the results of the 40 km/h (25 mi/h) road test data. Average range for the two complete tests was 80.37 km (49.95 mi).

Table 6-1. Range Tests at 40-km/h (25 mi/h)

Test No.	Electrolyte Temperature, °C (°F)		Range, km (mi)
	Before	After	
VET-13	27 (80)	44 (112)	89.30 (55.50)
VET-15	18 (64)	28 (82)	71.44 (44.40)
Average	-	-	80.37 (49.95)

The 20% difference in range between the two tests is primarily a result of the difference in battery temperature at the end of each test. The State-of-the-Art Electric Vehicle Report (Ref. 5-3) indicates that battery capacity is a strong function of electrolyte temperature. The rule of thumb derived from Reference 5-3 is a 1% change in capacity per each degree Celsius of temperature change. Using the value of 1% per degree Celsius, the 16°C (30°F) difference in battery temperature accounts for nearly all of the difference in ranges. In other words, 14.29 km of the 17.86 km difference may be attributed directly to differences in the end-of-test battery temperature.

2. Dynamometer Results

Two 40-km/h (25-mi/h) constant-speed range tests were completed on the dynamometer. These results are given in Table 6-2. Because of the excellent repeatability of these two tests and the need to save test time and resources, only one test was conducted at 56 km/h (35 mi/h) and 72 km/h (45 mi/h). The 56-km/h and 72-km/h data are shown in Tables 6-3 and 6-4, respectively. The variation in vehicle range shown in Figure 6-1 is simply a graphical display of the data from Tables 6-2, 6-3, and 6-4.

3. Track to Dynamometer Constant Speed Range Comparisons

As previously discussed, the ETS track precluded true constant velocity tests in as much as the vehicle had to reduce speed once each kilometer (0.6 mi) to negotiate turns. These frequent interruptions of the constant-velocity test for decelerations and reaccelerations during turns makes it impossible to make direct correlations between the results obtained from the two test locations. However, one obvious conclusion can be drawn. Tests containing accelerations and decelerations will show a shorter range than otherwise comparable tests conducted at a constant velocity. The average 40-km/h (25-mi/h) track range of 80.37 km is 21% less than the 101.8 km observed on the dynamometer.

B. DRIVING CYCLE RANGE

To simulate stop-and-go driving, the SAE has established four driving cycles for electric vehicles. The exact requirements of these cycles are presented in Reference 5-2, SAE J227a: "Electric Vehicle Test Procedure". Each cycle consists of five phases: (1) acceleration, (2) cruise, (3) coast, (4) brake, and (5) idle. The driving schedules of interest are characterized by cruise speeds of 32 km/h (20 mi/h), 48 km/h (30 mi/h), and 72 km/h (45 mi/h) for Driving Schedules B, C, and D, respectively. Due to the inability of the test vehicle to meet the Schedule D acceleration ramp, only Schedule B and C tests were performed.

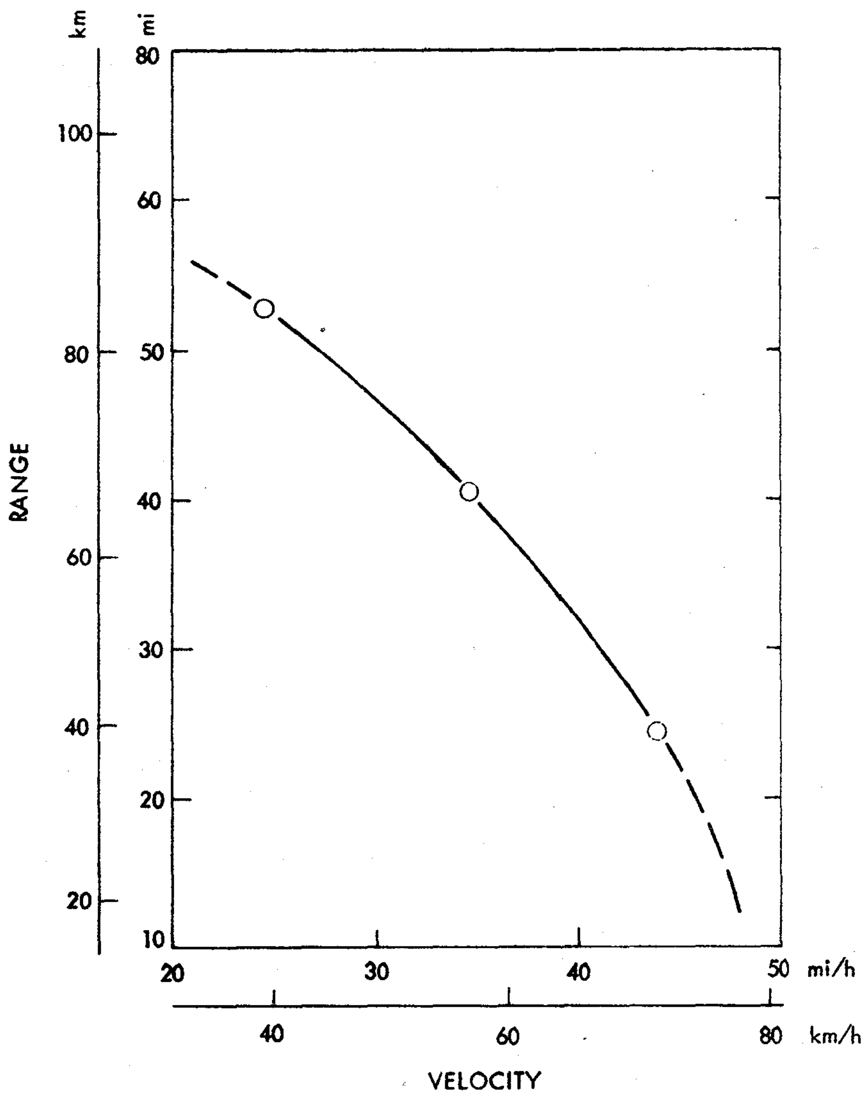


Figure 6-1. Corvette Range vs Speed Dynamometer Data

Table 6-2. Corvette Constant 40 km/h (25 mi/h) Range Tests on Dynamometer

Test No.	Range km (mi)	Battery Out Wh	Battery In Wh	Motor[a] In Wh	Motor[a] Out Wh	Battery Temp, °C (°F) Before	Battery Temp, °C (°F) After	Battery[b] km/kWh (mi/kWh)	Wall[c] km/kWh (mi/kWh)	Average Speed, km/h (mi/h)
VET-27	102.5 (63.691)	14185	27	13711	32	26 (78)	31 (88)	7.22 (4.490)	4.91 (3.053)	39.16 (24.341)
VET-28	101.1 (62.848)	13621	18	13190	21	24 (75)	29 (85)	7.42 (4.614)	5.05 (3.138)	39.66 (24.649)
Average	101.8 (63.270)	13903	23	13451	27	-	-	7.32 (4.552)	4.98 (3.095)	39.41 (24.495)

[a]Excludes field energy.
[b]Based on battery discharge only, excludes battery charging and charger efficiencies.
[c]Based on battery energy consumed divided by typical charging efficiency of 68%.

Table 6-3. Corvette Constant 56 km/h (35 mi/h) Range Tests on Dynamometer

Test No.	Range km (mi)	Battery Out Wh	Battery In Wh	Motor[a] In Wh	Motor[a] Out Wh	Battery Temp, °C (°F) Before	Battery Temp, °C (°F) After	Battery[b] km/kWh (mi/kWh)	Wall[c] km/kWh (mi/kWh)	Average Speed, km/h (mi/h)
VET-29	81.49 (50.646)	12001	0	11706	1	22 (72)	31 (87)	6.79 (4.220)	4.62 (2.870)	55.37 (34.414)

[a]Excludes field energy.
[b]Based on battery discharge only, excludes battery charging and charger efficiencies.
[c]Based on battery energy consumed divided by typical charging efficiency of 68%.

Table 6-4. Corvette Constant 72 km/h (45 mi/h) Range Tests on Dynamometer

Test No.	Range km (mi)	Battery Out Wh	Battery In Wh	Motor[a] In Wh	Motor[a] Out Wh	Battery Temp, oC (oF) Before	Battery Temp, oC (oF) After	Battery[b] km/kWh(mi/kWh)	Wall[c] km/kWh(mi/kWh)	Average Speed, km/h (mi/h)
VET-30	55.85(34.709)	9715	4	9594	4	21 (69)	31 (88)	5.82 (3.618)	3.96 (2.460)	70.00 (43.507)

[a]Excludes field energy.
[b]Based on battery discharge only, excludes battery charging and charger efficiencies.
[c]Based on battery energy consumed divided by typical charging efficiency of 68%.

1. Track Driving Cycle Test Results

Three of the five B schedule tests conducted at ETS were driven to battery depletion. The other two were terminated before battery depletion due to one problem or another and are not discussed in this report. Table 6-5 delineates the data obtained from the three valid Schedule B tests. Comparison of the ranges of these Schedule B tests is deceiving. It would appear that Test VET-20 was the only valid test and that Tests VET-23 and VET-24 suffered from some problems causing significantly shorter range (almost 20%), however both later tests show excellent agreement and were void of problems. The last two columns of Table 6-5 lend some insight to the apparently longer range of test VET-20. During the course of this test it was interrupted several times to allow aircraft landings. The test vehicle was pulled off the runway and stopped during each landing. These interruptions added more than 1 h to the test time. The large difference in total elapsed time probably accounts for the range differences because of battery recuperation. The vehicle sat still for more than an hour during VET-20, but only about 10 min during the other two tests.

If one makes the following simplifying assumptions, the longer range of Test VET-20 can be explained.

(1) Battery recuperation during the test interruption can be viewed as effectively being a lower average power drawn from the batteries. (See Section VII. Discussion.)

(2) The same amount of energy (watt-hours) was expended during each cycle of Test VET-20 as was expended during the equivalent tests on the dynamometer (91.7 Wh/cycle).

Extrapolating the driving cycle curve of Figure 6-9 (p. 6-24) to the reduced power rates of Test VET-20 results in a battery capacity of 16.3 kWh. Dividing this value by the assumed per-cycle energy requirements, 178 Schedule B cycles would be completed. This value agrees favorably with the 175 cycles actually completed during Test VET-20. Additional corrections of these data are needed to compensate for differences in end-of-test battery electrolyte temperatures. However, to add further corrections based upon additional rule-of-thumb relationships is not warranted. Two valid Driving Schedule B tests were completed in Tests VET-23 and VET-24. Corrections were only applied to VET-20 data to add credibility to the shorter range data of the later Schedule B tests.

Although test VET-20 may be considered a valid test within the definition of the SAE J227a test procedures and the discrepancies may be explained by the above, it is excluded from the average of Table 6-5 and from the dynamometer comparisons within this report.

Table 6-5. Corvette Driving Schedule B Track Tests

Test No.	Electrolyte Temperature, °C (°F) Before	Electrolyte Temperature, °C (°F) After	Cycles Driven, No.	Range, km (mi)	Range per Cycle, km (mi)	Test Duration, s	Driving Time, %
VET-20[a]	18 (64)	27 (80)	175	57.7 (35.84)	0.330 (0.205)	16820	74.9
VET-23	22 (71)	23 (74)	131	47.0 (29.2)	0.359 (0.223)	10140	93.0
VET-24	23 (73)	21 (70)	135	49.2 (30.6)	0.365 (0.227)	10400	94.8
Average	-	-	133	48.1 (29.9)	0.362 (0.225)	-	-

[a]Data from this test are not included in average values (see text).

Table 6-6. Corvette Driving Schedule C Track Tests

Test No.	Electrolyte Temperature, °C (°F) Before	Electrolyte Temperature, °C (°F) After	Cycles Driven, No.	Range, km (mi)	Range per Cycle, km (mi)	Test Duration, s	Driving Time, %
VET-07	28 (82)	43 (109)	62	38.99 (24.23)	0.629 (0.391)	-	-
VET-21	18 (64)	29 (85)	65	37.12 (23.07)	0.571 (0.355)	6400	81
Average	-	-	63.5	38.05 (23.65)	0.600 (0.373)	-	-

Of the three Schedule C tests attempted, two were carried to completion. Test VET-14 was aborted due to a recorder failure. Table 6-6 summarizes the two completed Schedule C tests. The differences in these two tests are interesting. Test VET-07 was conducted in the middle of July when ambient temperatures at ETS are well above 38°C (100°F), while Test VET-21 was conducted in the coolness of November. Even with the advantage of the hotter temperature, test VET-07 completed three less Schedule C cycles than did Test VET-21. Though Test VET-07 completed 5% less driving cycles, it went 5% further than Test VET-21. This is explained by the 10% difference in kilometers per cycle achieved for the two tests. Although it is obvious that the driving technique was considerably different for these Schedcule C tests, it does not explain the lack of range-extending benefits which the warmer (14°C) batteries of Test VET-07 should have demonstrated.

2. Dynamometer Driving Cycle Test Results

At the outset of dynamometer testing, two Schedule B tests were completed. An additional Schedule B test was performed at the completion of dynamometer testing to investigate the effects of reduced base (idle) speed on regeneration. The later test (VET-35) then was not intended to be a replicate of Tests VET-25 and VET-26. Table 6-7 gives the tabulated results for all three Schedule B cycles done on the dynamometer. The results of Test VET-35 are omitted from the average data and from the dynamometer to track comparisons as it was a unique test to observe changes in regeneration. Test VET-35 will be discussed in more detail in Section VII.

Both of the Schedule C dynamometer tests are summarized in Table 6-8. It can be seen that the overall results of these two tests are very close even though the magnitude of regenerative energy is different by over 30%. This difference is readily explained by the different driving technique used for each test:

(1) Test VET-31

(a) Accelerate using first, second, and third gears

(b) Cruise in fourth gear

(c) Downshift and coast in third gear

(2) Test VET-32

(a) Accelerate using first, second, and third gears

(b) Cruise in third gear

Table 6-7. Corvette Driving Schedule B Dynamometer Test Results

Test No.	Range km (mi)	Cycles Driven	Battery Out Wh	Battery In Wh	Motor[a] In Wh	Motor[a] Out Wh	Battery Temp, °C (°F) Before	Battery Temp, °C (°F) After	Battery[b] km (mi)/kWh	Wall[c] km (mi)/kWh	Range per Cycle, km (mi)
VET-25	52.64 (32.72)	143	13216	278	12492	326	21 (70)	33 (92)	3.98 (2.48)	2.70 (1.68)	0.368 (0.229)
VET-26	53.90 (33.50)	147	13383	200	12551	241	24 (75)	36 (96)	4.03 (2.50)	2.74 (1.70)	0.366 (0.227)
Average	53.27 (33.11)	145	13300	239	12522	284	-	-	4.01 (2.49)	2.72 (1.69)	0.367 (0.228)
VET-35[d]	47.41 (29.47)	138	12876	657	11272	770	19 (66)	31 (88)	3.68 (2.29)	2.50 (1.56)	0.344 (0.214)
Diff[e]	-11%	-4.8%	-3.2%	175%	-9.8%	171%	-	-	-8.1%	-8.1%	-6.4%

[a]Excludes field energy.
[b]Based on battery discharge only, excludes battery charging and charger efficiencies.
[c]Based on battery energy consumed divided by typical charging efficiency of 68%.
[d]Test VET-35 excluded from averaged data (see text).
[e]Percentage difference between averaged data and Test VET-35.

Table 6-8. Corvette Driving Schedule C Dynamometer Test Results

Test No.	Range km (mi)	Cycles Driven	Battery Out Wh	Battery In Wh	Motor[a] In Wh	Motor[a] Out Wh	Battery Temp, °C (°F) Before	Battery Temp, °C (°F) After	Battery[b] km (mi)/kWh	Wall[c] km (mi)/kWh	Range per Cycle, km (mi)
VET-31	34.56 (21.48)	60	9691	668	9388	719	21 (70)	38(100)	3.57 (2.22)	2.42 (1.51)	0.576 (0.358)
VET-32	33.55 (20.85)	59	9795	1062	9568	1123	21 (70)	38(101)	3.43 (2.13)	2.33 (1.45)	0.568 (0.353)
Average	34.06 (21.17	59.5	9743	865	9478	921	-	-	3.50 (2.17)	2.38 (1.48)	0.573 (0.356)

[a]Excludes field energy.
[b]Based on battery discharge only, excludes battery charging and charger efficiencies.
[c]Based on battery energy consumed divided by typical charging efficiency of 68%.

(c) Coast in third gear

The time saved during the coast phase of Test VET-32 by not having to downshift from fourth to third gear represented a significant portion of the time during which regeneration was possible. This is reflected in the larger values of regenerative energy observed in Test VET-32. Except for the lower distance driven per cycle, caused by the regeneration-induced higher deceleration rates during the coast phase of Test VET-32 and the aforementioned levels of regenerative energy, both Driving Schedule C tests were otherwise identical.

3. Track to Dynamometer Comparisons

Particular care was exercised during the last two track Schedule B tests with regard to driving technique and battery conditions. Of all the tests conducted on the track, it was felt that the Schedule B tests were least affected by the track limitations. Therefore Schedule B tests were the best candidates for comparison to the equivalent dynamometer tests. Schedule B dynamometer tests were carried out to the same conditions as was done on the track. The only exceptions were the pretest vehicle warm-up at the track and the end-of-test battery temperatures. Testing conditions are discussed in greater detail in Section V, Test Methodology. Table 6-9 lists the averages of the track and dynamometer Schedule B results for comparison purposes. It can be seen that the distance per cycle agrees within 1.5% and hence the driving techniques between the track and the dynamometer were apparently consistent. The remaining differences between the track and the dynamometer are range and

Table 6-9. Corvette Test Track to Dynamometer Comparison, SAE Procedure J227a Driving Schedule B

Test Location	Cycles Driven, No.	End-of-Test Electrolyte Temp, °C (°F)	Range, km (mi)	Range per Cycle, km (mi)
Track[a]	133	22 (72)	48.1 (29.90)	0.362 (0.255)
Dynamometer[b]	145	34.5 (94)	53.27 (33.11)	0.367 (0.228)
Difference	9%	12.5°C	10.7%	1.5%

[a]Average values from Table 6-5.
[b]Average values from Table 6-7.

electrolyte temperature at the end of test. Using the previously discussed capacity versus temperature correction of 1% per degree Celsius, the track range value is increased by 12.5% to compensate for the lower end-of-test electrolyte temperature observed during track testing. The application of battery temperature compensation gives a track range of 54.1 km (33.6 mi) and makes the results of dynamometer and track Schedule B tests agree within 2%.

Note that there is one other known difference between the track and dynamometer tests. That is the lack of vehicle warm-up during dynamometer tests. Section VII.A.5 discusses the effects of conducting tests without vehicle warm-up, however it is difficult to quantify these effects and no corrections have been attempted. However on a qualitative basis if there had been no vehicle warm-up before the track testing, the track range would have been reduced. This would partially negate the correction for battery temperature and could bring the results even closer together.

Comparisons of the Schedule C tests are less direct. The two track tests show considerable difference in the distance traveled per each cycle (see Table 6-6) and an unexplainable difference in range traveled, as discussed in Section VI.B.1. Since little information is available as to why the distance per cycle value of Test VET-07 is so high, this test is excluded from the dynamometer-to-track comparisons. Test VET-21 had sufficient hand-logged information, that its driving technique is well described and is identical to Test VET-32 that was conducted on the dynamometer. Table 6-10 compares test VET-21 to the average values obtained from dynamometer Tests VET-31 and 32. As demonstrated in Table 6-10, the driving technique

Table 6-10. Corvette Test Track to Dynamometer Comparison, SAE Procedure J227a Driving Schedule C

Test Location	Cycles Driven, No.	End-of-Test Electrolyte Temp, ^{o}C (^{o}F)	Range, km (mi)	Range per Cycle, km (mi)
Track[a]	65	29 (85)	37.12 (23.07)	0.571 (0.355)
Dynamometer[b]	60	38 (101)	34.06 (21.17)	0.573 (0.356)
Difference	-7.7%	$9^{o}C$	-8.2%	0.3%

[a]Track data from test VET-21 only.

[b]Average SAE J227a Driving Schedule C dynamometer data from Table 6-8.

between the track and dynamometer apparently agree very well, because the distance traveled per cycle agrees within 1%. Yet there is an 8% difference in the range achieved between test locations. This difference in range is further increased if the range data are corrected for the differences in the end-of-test electrolyte temperature. This correction increases the magnitude of track-to-dynamometer discrepancy from 8% to 16% as track range increases to 40.46 km (25.15 mi). However there are three additional factors that contribute to this discrepancy:

(1) Different test termination techniques were utilized between the two test locations (see Section V, Test Methodology). Had the same termination criteria been used for both sets of tests, the dynamometer range would have been extended by two to three additional cycles. This is based on an estimate of the difference in residual battery energy at the end of each of the test types.

(2) Battery electrolyte specific gravities for the track test (VET-21) started at the highest value observed during any other test (track or dynamometer) and the end-of-test specific gravities were the lowest recorded for all Schedule C tests. This would indicate that more battery energy was consumed during this particular track test, with a resultant extension in range. However there was no obvious reason why this should be so, and the magnitude of the additional energy available could not be quantified.

(3) Several aircraft landings interrupted the track test. This resulted in a total elapsed time of 6400 s for the track test as compared to the 5200 s required for the dynamometer tests. Considerable battery recuperation occurred during the track tests.

Using a similar argument to that which was used to attempt to rectify discrepancies in the Driving Schedule B track data, Figure 6-9 was again employed to estimate additional energy available at lower effective power rate as a result of test interruptions. Using dynamometer derived data summarized in Figure 6-9, it can be seen that the reduced power rate would allow 11.1 kWh to be removed from the batteries during Test VET-21. This is consistent with the specific gravity values recorded for this test. Assuming that the same amount of energy per cycle was expended during the track tests as was expended during the dynamometer tests, the 11.1 kwh leads to an excess of eight driving cycles for the track as compared to the dynamometer. Reducing the track range by 10 cycles (two for different termination criteria and eight for recuperation) yields a range of 34.8 km (21.7 mi). Although the corrected track range agrees favorably with the dynamometer 34.06 km (21.17 mi) range, the validity of the assumptions and corrections used to obtain this agreement are not necessarily verified.

C. ENERGY CONSUMPTION

Energy consumption and road power requirements were determined using the methods given in SAE Test Procedure J227a, Section 10, Vehicle Road Energy Consumption. For this procedure, three pairs of the coastdown tests are averaged for the full velocity profile, while over 20 pairs at two specific velocities were averaged in determining the dynamometer settings. Hence the results in the section will differ slightly from those of Section V.C. The results represent the energy required by the vehicle to overcome aerodynamic and rolling (including part of the transmission) losses. This is not the energy needed from the vehicle batteries to propel the vehicle at various speeds. The battery, controller, motor, and a portion of the transmission energy losses are excluded from the energy consumption values reported here. Table 6-11 presents the tabulation of the three pairs of coastdown tests, while Figure 6-2 gives the same data graphically. From the velocity-vs-time data, road load and energy consumption were calculated using the appropriate equations from SAE Procedure J227a. The results of these calculations are given in Table 6-12 and are plotted in Figures 6-3 and 6-4.

Table 6-11. Track Coastdown Data

Velocity		Time, s		
mi/h	km/h	E-W	W-E	Average
60	96.5	0.0	0.0	0.0
55	88.5	6.3	6.1	6.2
50	80.5	12.8	14.5	13.5
45	72.4	20.1	23.2	21.5
40	64.4	28.0	31.3	29.5
35	56.3	36.7	42.6	39.5
30	48.3	46.2	53.5	49.7
25	40.2	56.3	65.7	60.9
20	32.2	67.2	78.4	72.7
15	24.1	78.4	91.9	85.1
10	16.1	90.8	107.3	99.0
5	8.0	104.8	124.5	114.6

Table 6-12. Vehicle Energy Consumption and Power as a Function of Velocity from Coastdown Tests

Velocity, mi/h (km/h)	Power, kW (hp)	Energy Consumption, kWh/km (kWh/mi)
57.5 (92.5)	18.40 (24.67)	0.199 (0.320)
52.5 (84.5)	13.88 (18.62)	0.165 (0.265)
47.5 (76.4)	11.77 (15.79)	0.154 (0.248)
42.5 (68.4)	10.54 (14.13)	0.142 (0.228)
37.5 (60.3)	7.44 (9.98)	0.123 (0.198)
32.5 (52.3)	6.32 (8.48)	0.121 (0.195)
27.5 (44.2)	4.87 (6.53)	0.110 (0.177)
22.5 (36.2)	3.78 (5.07)	0.104 (0.168)
17.5 (28.2)	2.80 (3.75)	0.099 (0.160)
12.5 (20.1)	1.78 (2.39)	0.089 (0.143)
7.5 (12.1)	0.95 (1.28)	0.079 (0.127)

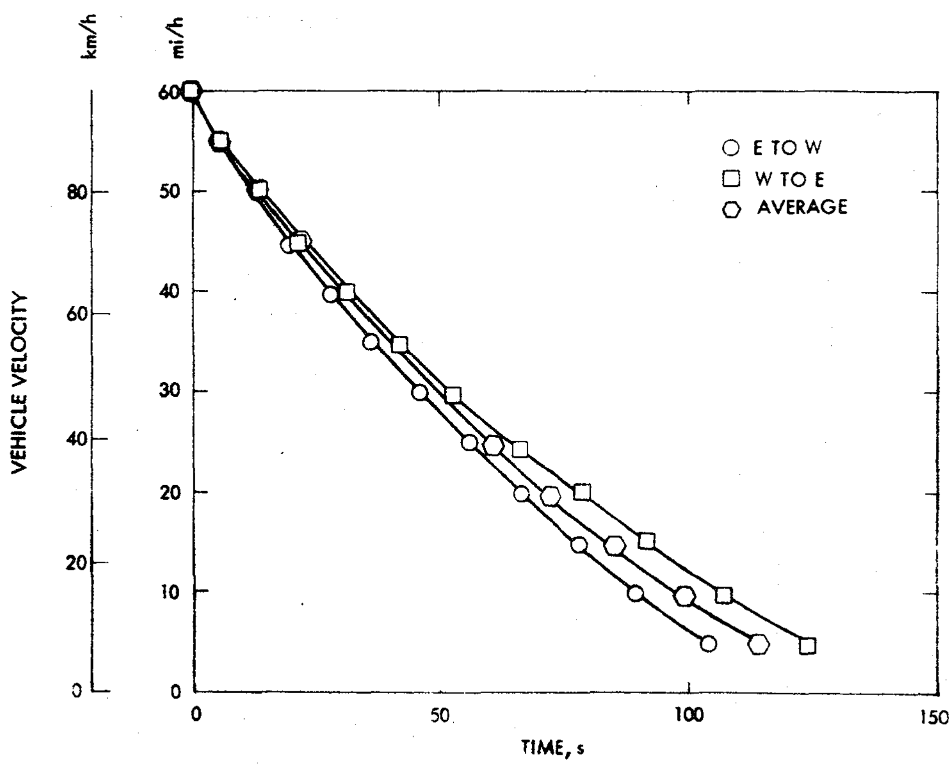


Figure 6-2. Corvette Track Coastdowns, Average of Three Tests

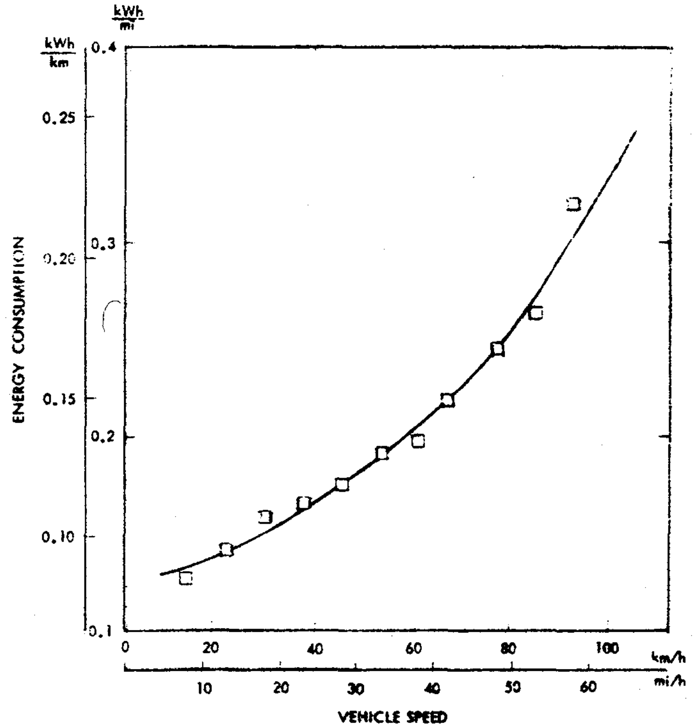


Figure 6-3. Corvette Road Energy Consumption

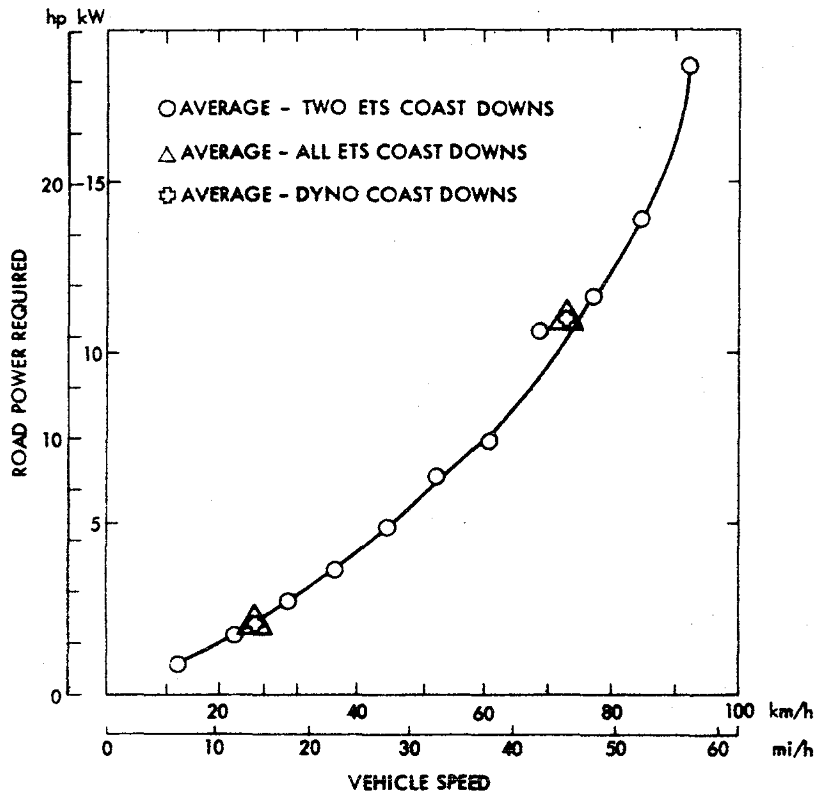


Figure 6-4. Corvette Road Power

D. ENERGY ECONOMY

Direct measurements of energy economy (i.e. range divided by wall energy required for the battery recharge) were precluded by two factors. First, as discussed earlier in this report, instrumentation problems voided the electrical energy data recorded during the ETS tests except for measurements of wall energy. Second, the battery charging done as part of the dynamometer tests included the large overcharge specified in SAE Procedure J227a and did not use the onboard charger supplied with the Corvette. Consequently there was no single test for which both wall and battery energy were measured. However, by using data from the two test sites a reasonable estimate of the energy economy can be made.

During the ETS tests simultaneous measurements of energy into the Corvette onboard battery charger and into the battery were made. From this data the charger efficiency was determined to be 86%. From the dynamometer tests the battery charge/discharge efficiency was determined in the following manner. During a vehicle test both the energy and the ampere-hours drawn from the battery were measured directly. During the subsequent recharge both ampere-hours and energy into the battery were again measured. The point in the recharge where the ampere-hours returned were 10% greater than the ampere-hours drawn during the test was defined as 100% charge, and the energy returned at that point likewise defined as 100% charge. The DOE/SAE test procedures call for a large overcharge (to ensure fully and equally charged batteries) which results in an unrealistically low charge-discharge energy efficiency. For the purposes of the energy economy values given here, the energy corresponding to a 10% ampere-hour overcharge was used and resulted in a battery charge-discharge energy efficiency of 80%. This leads to a net charger-battery efficiency of 68% (0.80 x 0.86 x 100). Thus the estimated energy economies of Table 6-13 and Figure 6-5 were obtained by dividing the experimentally measured battery output energy by 0.68.

E. MAXIMUM ACCELERATION

Tests of maximum acceleration capability were conducted at the ETS track and on the dynamometer. The tests at the two locations differed significantly in two areas. At the track the vehicle was warmed-up by towing before the first test, while on the dynamometer there was no vehicle warm-up. Shift speeds were also different. The track acceleration data are not discussed here because of the inability to obtain reduced data from the magnetic tapes.

Discharging the batteries between accelerations according to the DOE/SAE procedures presented a problem when the tests were terminated according to the minimum voltage criteria discussed in Section V.B.3.

Table 6-13. Corvette Energy Economy

Test No.	Test Type	Battery Output, Wh	A.c. Wall Power, Wh	Range, km (mi)	Wall Energy Economy, kWh/km (kWh/mi)	Average[a] Velocity, km/h (mi/h)
VET-27	40 km/h (25 mi/h)	14185	20860	102.48 (63.691)	0.204 (0.328)	39.16 (24.341)
VET-28	40 km/h (25 mi/h)	13621	20031	101.12 (62.848)	0.198 (0.319)	39.66 (24.649)
VET-29	56 km/h (35 mi/h)	12001	17649	81.49 (50.646)	0.216 (0.348)	55.37 (34.414)
VET-30	72 km/h (45 mi/h)	9715	14287	55.85 (34.709)	0.256 (0.412)	70.00 (43.507)
VET-25	Schedule B	13216	19435	52.64 (32.719)	0.369 (0.594)	17.49 (10.868)
VET-26	Schedule B	13383	19681	53.90 (33.497)	0.365 (0.588)	17.12 (10.640)
VET-35	Schedule B	12876	18935	47.41 (29.468)	0.400 (0.643)	16.93 (10.520)
VET-31	Schedule C	9691	14251	34.56 (21.480)	0.412 (0.663)	24.80 (15.416)
VET-32	Schedule C	9795)	14404	33.55 (20.854)	0.429 (0.691)	24.65 (15.318)

[a]Average velocity is obtained by dividing the total distance traveled (range) by the measured elapsed time ET required to achieve that range.

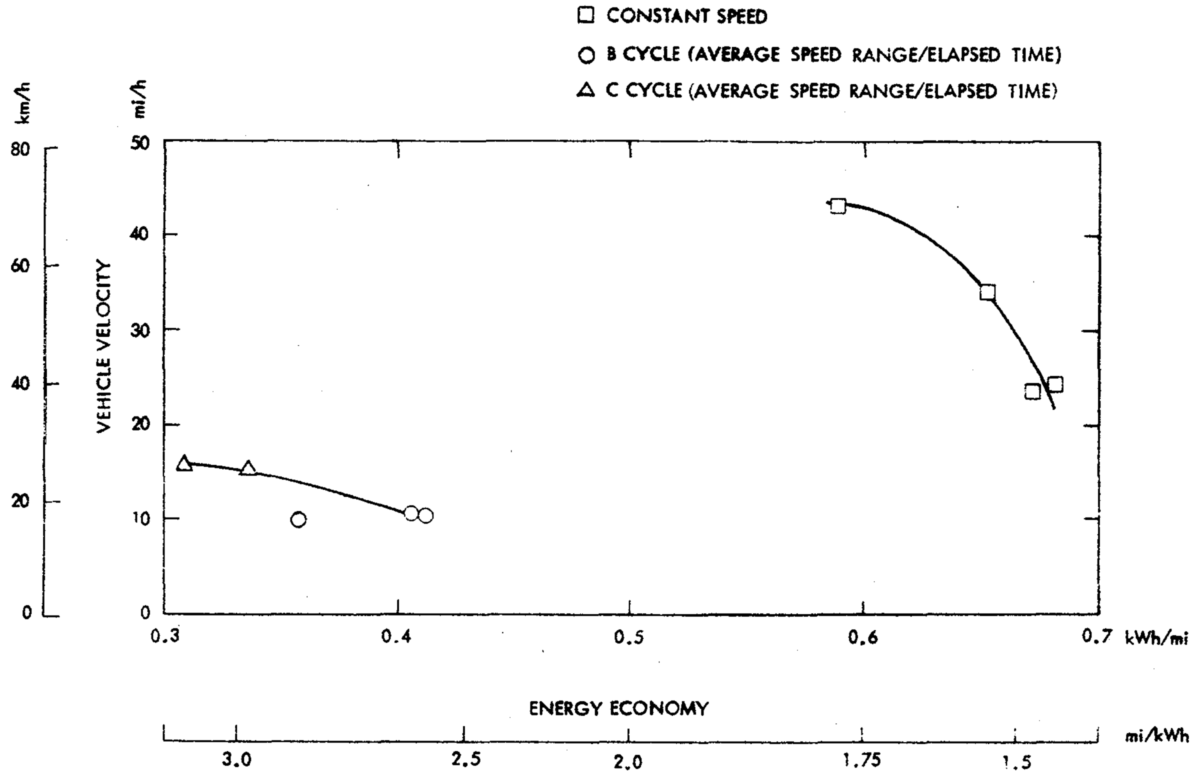


Figure 6-5. Corvette Wall Energy Economy

The higher power rates during acceleration quickly reduced the battery voltage below the minimum limit, even though the voltage observed when discharging the batteries to the 80% depth of discharge at a reduced power was well above the termination criteria. The data in Table 6-14 give the average of two dynamometer accelerations at different levels of depth of discharge. Figure 6-6 shows dynamometer accelerations. Rate of acceleration from the dynamometer tests is presented in Figure 6-7. Detailed plots of battery voltage, currents, and other vehicle parameters are given in Appendix C for the dynamometer accelerations.

Also included in Figure 6-7 are best-effort acceleration data points derived from the maximum gradeability dynamometer tests discussed in Section VI.F.2. It is quite evident, from both sources of data presented in Figure 6-7, that gear shifts should have been done at lower velocities during the acceleration tests. Acceleration rates were greater just after an upshift compared to that observed during the later portion of the preceeding gear. This was especially true of the first and second gear shift points. Although a strip chart recorder was used as a tool to aid in the determination of optimum shift points for maximum acceleration, it was difficult to resolve small changes in acceleration rates. This was equivalent to using Figure 6-6 to determine shift points. This problem, combined with the natural instinct to shift gears as if the Corvette had a

Table 6-14. Maximum Dynamometer Accelerations

Velocity, km/h (mi/h)	Depth of Discharge, % 0	40	80
	Time, s		
0.0 (0)	0.0	0.0	0.0
8.0 (5)	0.8	0.8	0.9
16.1 (10)	2.2	1.7	2.0
24.1 (15)	4.2	3.6	4.3
32.2 (20)	7.6	6.9	8.2
40.2 (25)	12.1	10.7	12.3
48.3 (30)	18.3	16.0	19.2
56.3 (35)	25.4	22.1	27.7
64.4 (40)	36.1	30.4	-
72.4 (45)	52.7	40.8	-
80.5 (50)	74.8	55.9	-

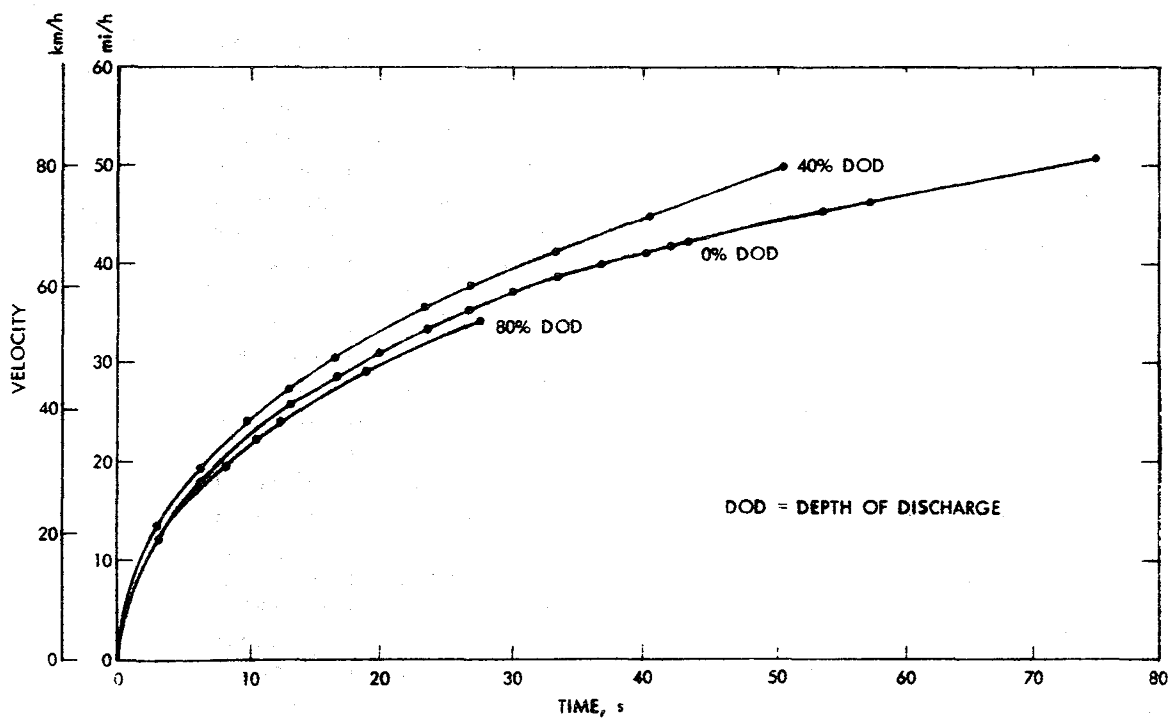


Figure 6-6. Corvette Maximum Acceleration, Velocity vs Time

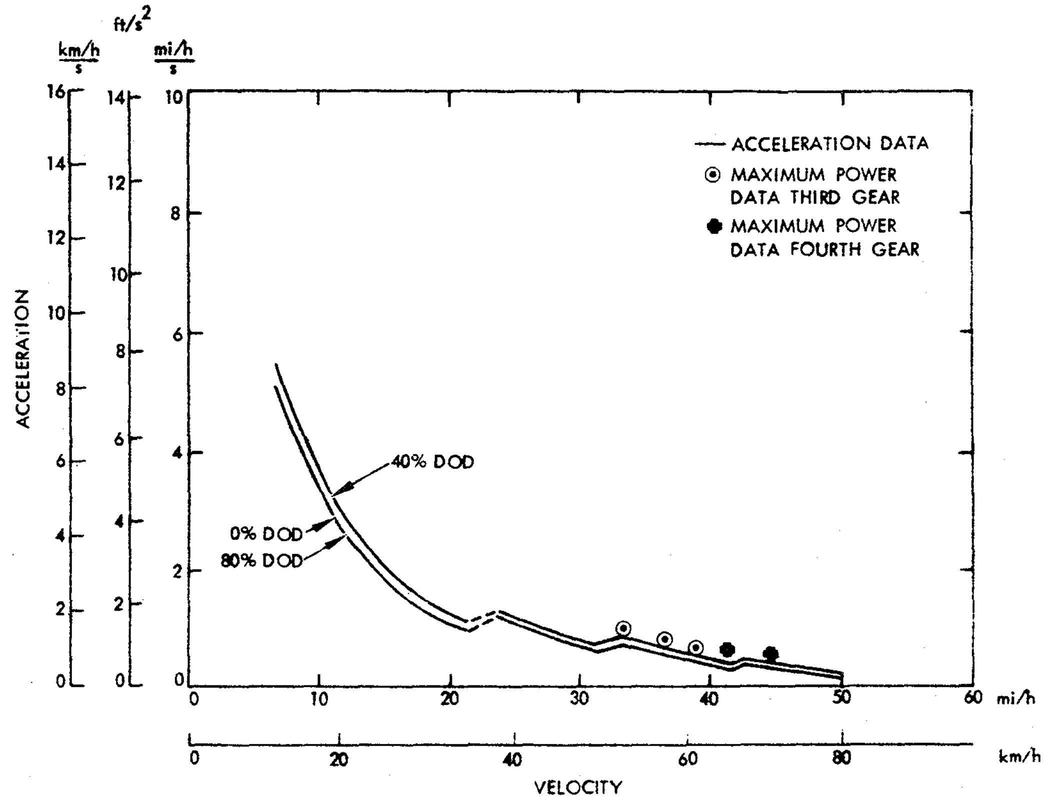


Figure 6-7. Corvette Maximum Acceleration Rate vs Velocity

gasoline engine, resulted in late gear shifts. Even had improved shift points been used, the Corvette acceleration would have improved only slightly (about 5 to 10%).

F. MAXIMUM GRADEABILITY

The DOE and SAE procedures provide two methods of determining vehicle gradeability as a function of speed. Either maximum acceleration rates or a variation of dynamometer-absorbed power can be used to derive gradeability.

1. Maximum Gradeability from Dynamometer Acceleration Data

Utilization of the dynamometer acceleration rates defined in Figure 6-7 and Equation (6-1) provides gradeability information.

$$\%\ \text{gradeability at velocity } v = 100 \tan(\sin^{-1} 0.0455\ a) \qquad (6\text{-}1)$$

where a = maximum acceleration in mi/h/s at velocity v

Figure 6-8 shows the result of applying Equation (1) to the acceleration data of Figure 6-7. As in the acceleration data, the gradeability of the Corvette can be improved by about 5 to 10% by shifting gears at lower speeds.

2. Maximum Gradeability from Dynamometer Tractive Force Data

To verify the gradeability results of the acceleration tests and to obtain some insight into the Corvette propulsion system efficiency, a second technique was used. Dynamometer absorption power was increased while holding vehicle velocity constant until the vehicle was forced to operate at maximum throttle. The dynamometer absorption power was then further increased in steps and a new lower constant vehicle velocity achieved. Data were recorded at each of the constant velocities. Five data points were recorded at different velocities before the main battery fuse failed. At this point the test was terminated rather than risk any damage to the vehicle.

In order to deduce maximum gradeability from the tractive force data a modified version of the relationship specified in Reference 5-2 was used. The relationship of Reference 5-2 is reproduced here as Equation (6-2).

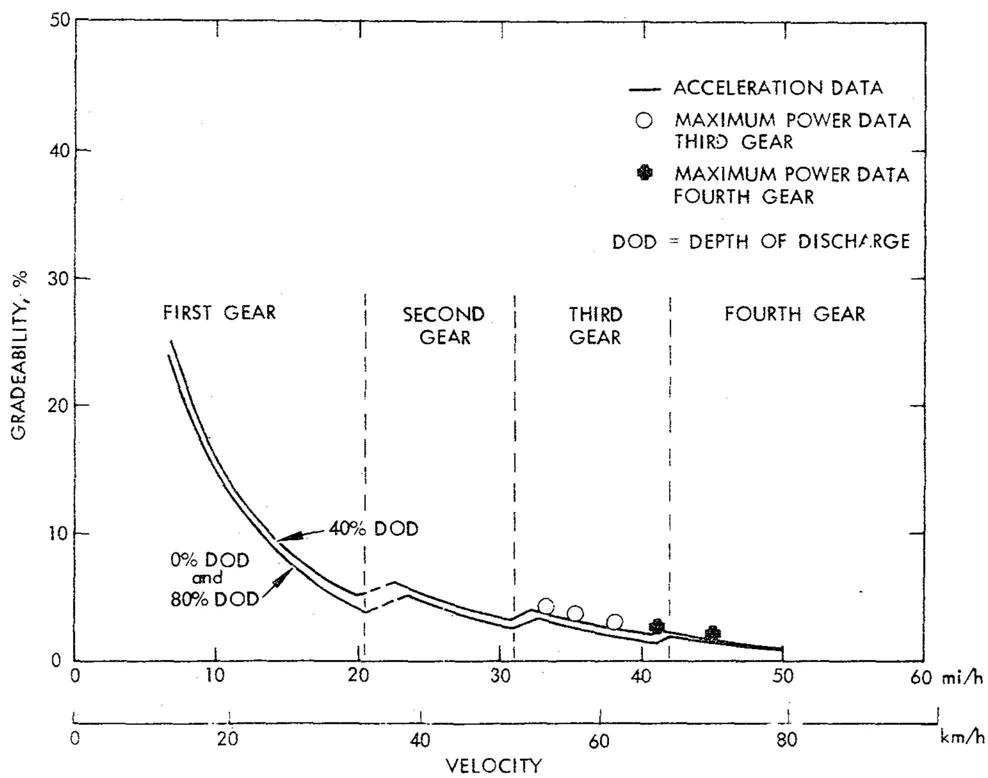


Figure 6-8. Corvette Maximum Gradeability vs Velocity

$$\% \text{ gradeability} = 100 \tan\left[\sin^{-1}\left(\frac{375\ (p-p_o)}{Wv}\right)\right] \qquad (6\text{-}2)$$

where p = power absorbed by the dynamometer, hp

p_o = road load power, hp (from coastdowns)

v = vehicle speed, mi/h

W = gross vehicle weight, lb

The intent of Equation (6-2) appears to be the subtraction of the normal (level) road load power from the total power absorbed by the dynamometer. The balance is the power available for climbing grades. The problem here is that chassis dynamometers of the type used at JPL do not absorb all of the road load. Rather only that portion of the road load that leaves the drive wheels of the vehicle is absorbed; i.e., the aerodynamic power. The rolling losses of the vehicle are dissipated internally, just as on the road, and are not absorbed by the dynamometer. To subtract all components of road load power from the total dynamometer power will cause a considerable understatement, especially at low speed, of power available for hill climbing. Equation (6-3) rectifies this problem:

$$\% \text{ gradeability} = 100 \tan\left[\sin^{-1}\left(\frac{375\ (p-p_a)}{Wv}\right)\right] \qquad (6\text{-}3)$$

where p_a = aerodynamic component of road load at velocity v and all other terms are defined as for Equation (6-2).

The results of this test are included in Figure 6-8.

It should be noted here that Equation (6-3) is not a universal relationship. Those chassis dynamometers which also provide partial tire loss simulation need a different equation.

G. BATTERY CAPACITY

One of the results of the dynamometer testing was a concern that some factor other than the basic vehicle design had affected the test results. This concern was primarily the result of the vehicle range being less than claimed by the manufacturer and less than predicted by the Project vehicle simulation programs. The condition of the motive batteries was one of the factors suspected of causing the reduced range. The batteries were suspect for several reasons:

ontactor failures during the initial stages of the ETS testing resulted in complete battery pack discharge (less than 0.2 V/cell). This may have resulted in some degradation in capacity.

(2) Charge-discharge self-heating was relatively high. This is consistent with the increased internal resistance commonly seen in batteries past their peak capacity.

(3) Voltage roll-off near the end of discharge was smoother than the sharp knee produced by new batteries. This is typical of older batteries, where the cells having lower capacity go through the voltage knee at varying times before the balance of the good cells. The shape of the voltage knee is readily seen in the battery voltage plots from the steady state tests. (See Appendix C).

Because of this concern a separate battery pack capacity test was performed by discharging the pack through a constant load. This resulted in an average current of 50 A. Other than temperature, all other conditions were similar to independent laboratory tests of Exide EV-106 batteries performed at JPL. This permitted a direct comparison of capacity. The results of this test are tabulated in Table 6-15. Figure 6-9 shows battery capacity versus discharge rate from all of the dynamometer tests as well as from the special capacity test.

Table 6-15. Battery Capacity Test

Elapsed Time, min	Battery Voltage, V	Battery Capacity, Ah	Battery Energy, Wh	Battery Current, A
0	107.7	0	0	49.2
174	85.0	144.42	13900	-
183	80.0	151.34	14350	-
191	75.0	157.16	14790	44.0
198	70.0	161.74	15068	-

During the light bank discharge tests, 157.16 Ah were removed at the 75-V level. This corresponds to 151 Ah obtained in the battery laboratory. However, the latter tests were true constant-current discharges, not constant load. It is the conclusion of JPL battery personnel that had both tests been identical, the Corvette batteries would display a 3% reduced capacity compared to new batteries. It can then be said that the Corvette range might be extended by about 3% by installing fresh batteries. This does not explain all of the discrepancy between expected and actual performance.

As a sidelight, Figure 6-9 can be used to explain the range results of the ETS Tests VET-20 and VET-21. The results of those two tests are included here, but with the power consumed reduced to account for the long interruptions of those Driving Schedule B and C tests. On that basis, the total energy required correlates well with the total energy from the uninterrupted driving schedule tests, after adjustments are made to account for the different discharge rates.

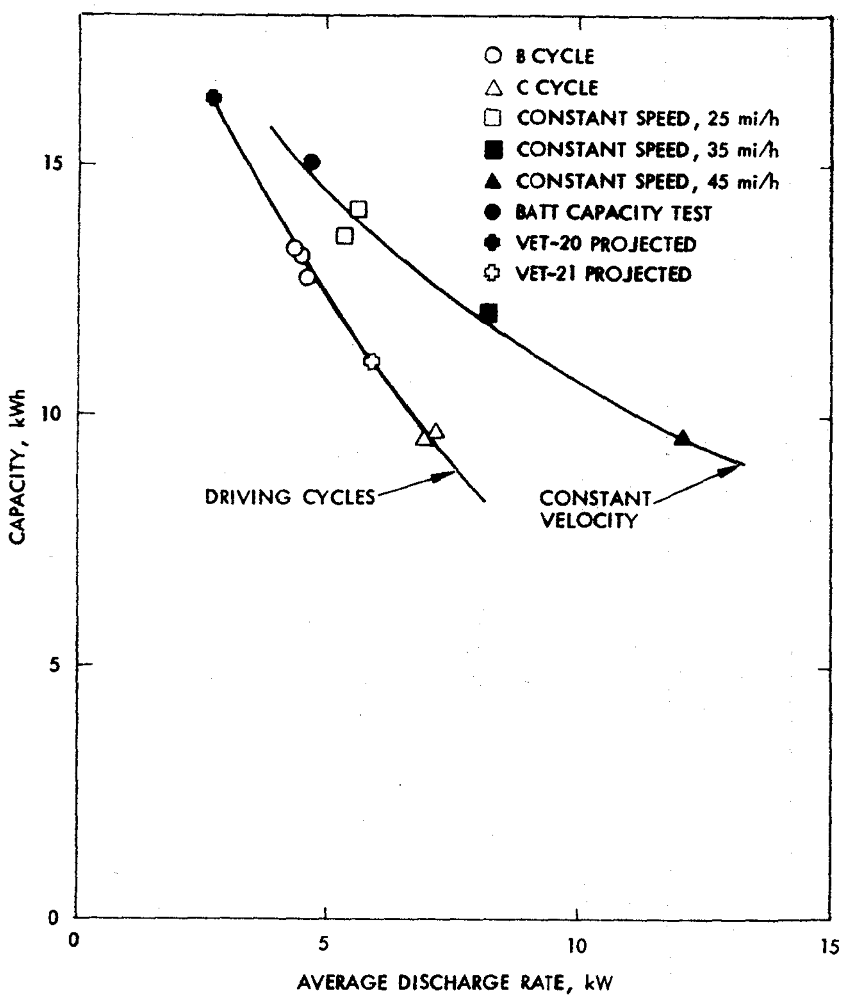


Figure 6-9. Corvette Battery Capacity vs Discharge Rate

SECTION VII

DISCUSSION

This section presents observations regarding the performance, characteristics, advantages and disadvantages of the Corvette. Some of the discussion is not necessarily unique to the Corvette, but will be inclusive of any electric vehicle having generically similar motor control features.

A. CHARACTERISTICS OF THE CORVETTE MOTOR CONTROLS UNDER VARIOUS DRIVING CONDITIONS

The Corvette used a shunt-wound d.c. motor with a separately excited field. Two advantages of the use of such a motor with field weakening are:

(1) Simplicity of control: only small current carrying components are needed for field weakening. The armature is connected directly to the propulsion batteries.

(2) Regeneration is automatic: There is no control required other than the field.

The major benefit of this relatively simple control approach is the lack of energy dissipated as heat in the controller itself. Under the worst conditions observed during the tests by JPL, the field controller dissipated only 50 W of power as heat. For all types of tests reported here, the minimum efficiency of the controller itself was 98%. This is referenced to the total motor input power. During constant-speed driving, maximum benefits of this type control will be realized. However, during stop-and-go driving, the Corvette motor idles at a relatively high rate (about 1350 r/min). This results in a disadvantage for the Corvette control technique because battery energy is consumed without providing any propulsion power to the wheels. Another disadvantage is the inability to achieve regeneration below the motor base (idle) speed. (Note that these disadvantages are neither fatal flaws nor are they necessarily inherent in a separately excited motor using field weakening, but rather result from the implementation strategy used by the Corvette designer.)

B. ENERGY USAGE

To better appreciate the characteristics of the Corvette controls during stop-and-go driving, energy usage is analyzed as a function of the five phases of the SAE Procedure J227a Driving Schedules.

1. Driving Schedule B Energy Usage

Regardless of the type of motor control, the magnitudes of energy used during the acceleration and cruise portions of the driving schedules will be about the same for a given type of vehicle chassis. However, this is not true for the coasting portion of the driving cycle and the energy consumed there is a strong function of the hardware and control strategy. As can be seen in Figure 7-1, a full 15% of the Corvette battery energy was expended during nonmotive (coast, brake and idle) portions of Driving Schedule B. Almost 9% of the energy was used while the car was completely stopped. Regeneration benefits were also small. Only 1.8% of the energy consumed during each cycle was returned to the batteries. This was a direct result of the base speed of the motor. The majority of regeneration was achieved during the first second of the coast phase. At the end of one second of coast, the Corvette speed was 30.6 km/h (19 mi/h) in third gear. This corresponds to the motor base speed and since the cruise speed in Driving Schedule B is 32.2 km/h (20 mi/h), little regeneration was realized. For the balance of the coast phase power was again drawn from the batteries. Downshifting could have been used to increase regeneration, however, since the duration of the coast segment is just 4 s, only a small benefit would have been gained after the downshift.

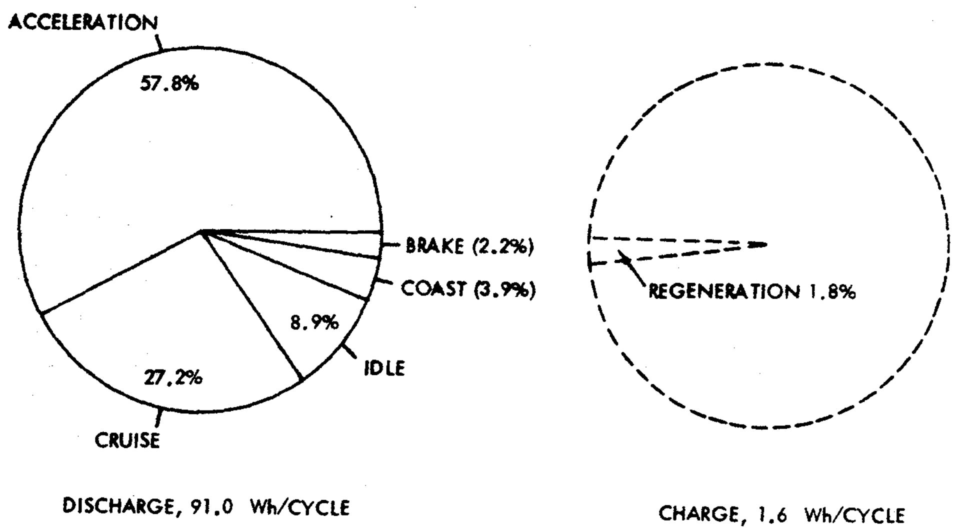


Figure 7-1. Corvette Driving Schedule B Battery Energy Usage, Average of Two Driving Cycles at 40% Depth of Discharge, Test VET-26, Base Speed 1350 r/min

A control technique which completely turned off the motor during the idle portion of Driving Schedule B would substantially reduce the energy consumed for nonmotive conditions. Although driveability may suffer as a result of motor shut-down, it is estimated that Driving Schedule B range would be extended by 7%. The amount of the extension was determined by comparing the reduced power consumption rate to the battery capacity data shown in Figure 6-9.

The effects of lowering motor base (idle) speed were experimentally investigated. Base speed was reduced to about 1200 r/min by increasing field strength and a Schedule B test was conducted at the reduced idle speed. Energy usage for the reduced base speed conditions is shown in Figure 7-2. Figure 7-2 should be compared to Figure 7-1 which corresponds to the normal base speed. The results for the two tests are also directly compared in Figure 7-3. From these figures and the data in Table 6-7, there were three noteworthy results from lowering base speed:

(1) The amount of regenerative energy was tripled.

(2) The total energy consumed per cycle was increased.

(3) The range traveled per cycle decreased.

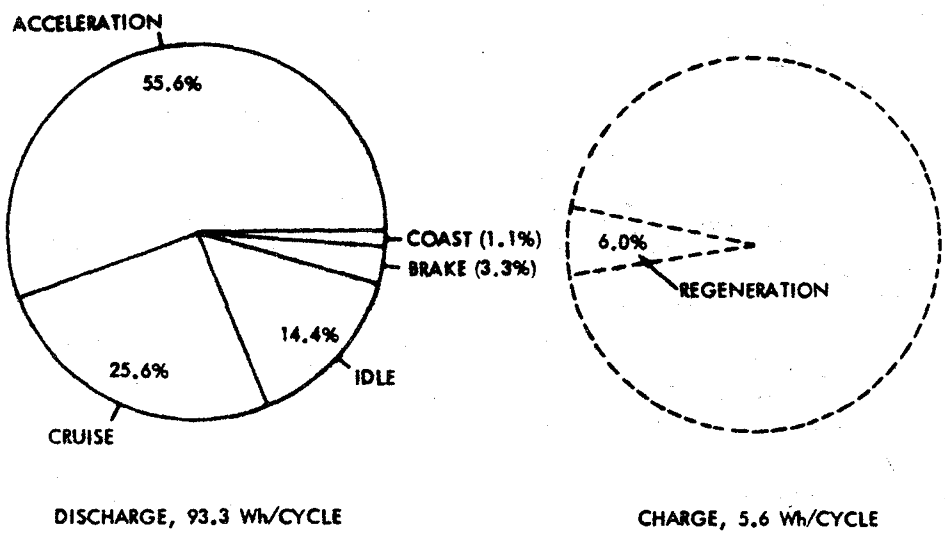


Figure 7-2. Corvette Driving Schedule B Battery Energy Usage, Average of Two Driving Cycles at 40% Depth of Discharge, Test VET-35, Base Speed 1200 r/min

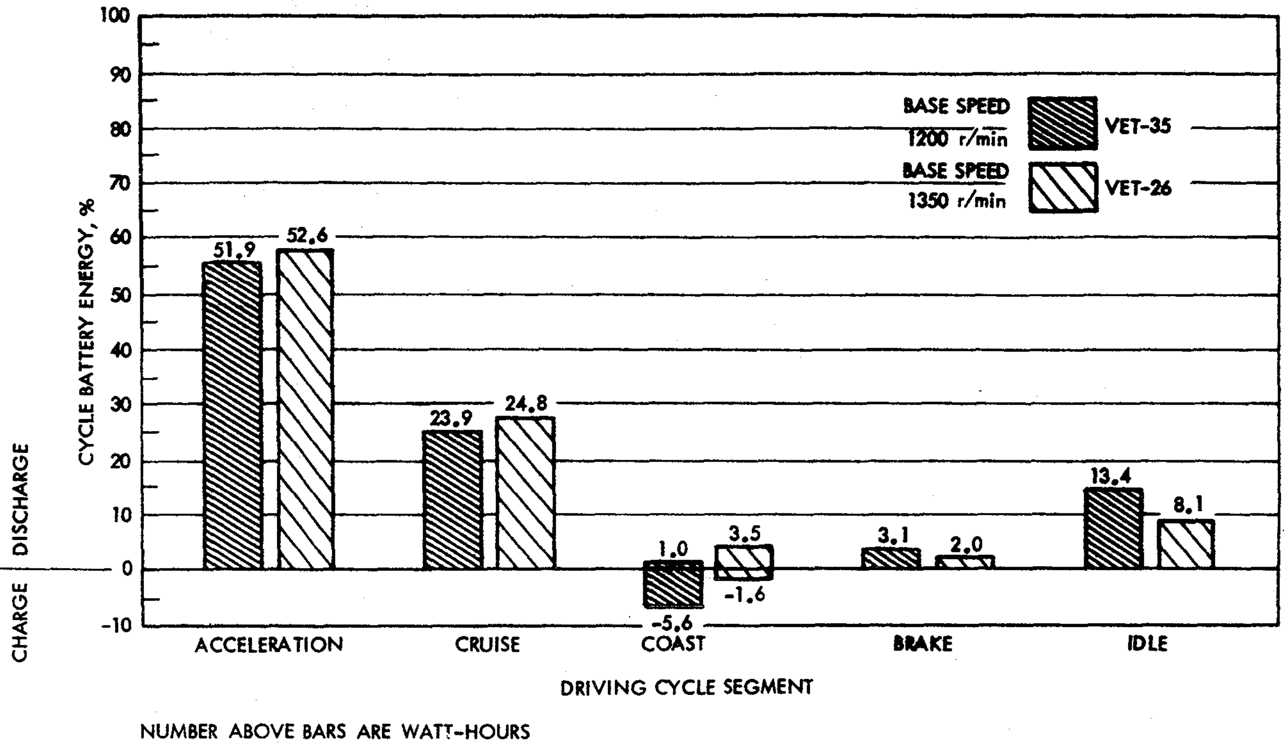


Figure 7-3. Corvette Driving Schedule B Battery Energy Usage Comparison, Different Motor Base Speeds

Clearly the amount of regeneration possible was a direct function of base speed. However, this was not without penalty. To reduce base speed, field energy had to be increased, which more than offset any benefits of increased regeneration. Furthermore, the higher regenerative braking caused a much faster deceleration rate during the "coast" portion of the driving cycle. This caused an appreciable reduction (6.4%) in the distance traveled for each driving cycle, even though both tests met the letter of the DOE/SAE test procedures. So while the difference in number of cycles driven was only 4.8%, the range was reduced by 11%. Details of these percentage differences are tabulated in Table 6-7 (p. 6-9).

2. Driving Schedule C Energy Usage

As indicated earlier, each of the two Driving Schedule C tests were driven slightly differently. Only data from Schedule C Test VET-32 are presented graphically. This test had a higher level of regeneration because of the difference in driving techniques and is therefore a more interesting test for analysis. Figure 7-4 displays the relative energy split for this Schedule C test. The motive portion of the cycle (acceleration and cruise) consumed almost 93% of the battery energy compared to the total cycle. Nonmotive energy was slightly over 7%, while regenerative energy approached 11% when referenced to the battery discharge energy. Again a substantial portion of the nonmotive energy consumption could be eliminated by different or modified motor control techniques.

By driving the car in third gear during the cruise portion of the cycle, regeneration began immediately at the initiation of the "coast". The minimum Corvette velocity in third gear was about 28 km/h (20 mi/h), so regenerative braking could take place from 42 km/h (30 mi/h) down to the minimum speed. To achieve maximum regeneration in Test VET-32 the Corvette was driven in third gear during "cruise" as compared to fourth gear in the previous test. In both tests, "coast" was done in third gear. Inspection of the Schedule C data indicates that the benefits of added regeneration were offset by lower motor drive train efficiency when operating in third, rather than fourth gear during the cruise portion of the test. Compared to the initial dynamometer test using Driving Schedule C (VET-31), the added regenerative energy had no range-extending benefits.

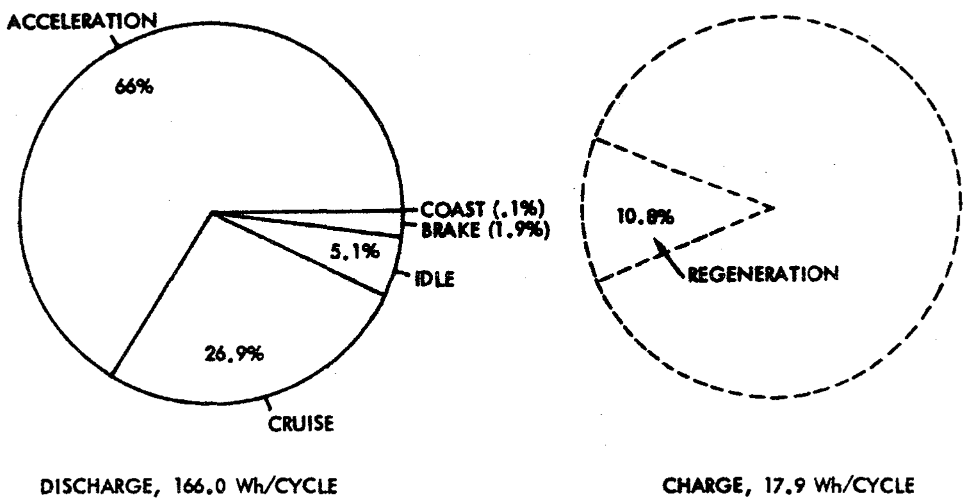


Figure 7-4. Corvette Driving Schedule C Battery Energy Usage at 40% Depth of Discharge, Test VET-32

3. Comparison of Driving Schedules B and C Energy Usage

Figures 7-5 and 7-6 compare the energy usage for the B and C driving schedules. On a percentage basis, both driving schedules appear quite similar (see Figure 7-5). The only large difference is in the "coast" phase of these cycles. Had the Corvette gear ratios been slightly different, the percentage of regeneration energy would have also been similar. The combination of the various gear ratios and the base speed of the Corvette motor provided nearly optimum regeneration capability during Driving Schedule C cycles and almost totally precluded it during Schedule B cycles. Although the relative percentages of battery energy are very close for these cycles, the absolute levels are appreciably different. As reflected in Figure 7-6, the acceleration energy during a Schedule C cycle is twice that of Driving Schedule B. Cruise energy during the Schedule C cycle is also considerably greater than that of Driving Schedule B.

4. Effects of Starting Tests With Cold Vehicles (No Warm-Up)

Each of the dynamometer tests was started only after the Corvette had been soaked at room temperature (22oC) for a minimum of 12 h. The vehicle was towed onto the dynamometer without the use of its own

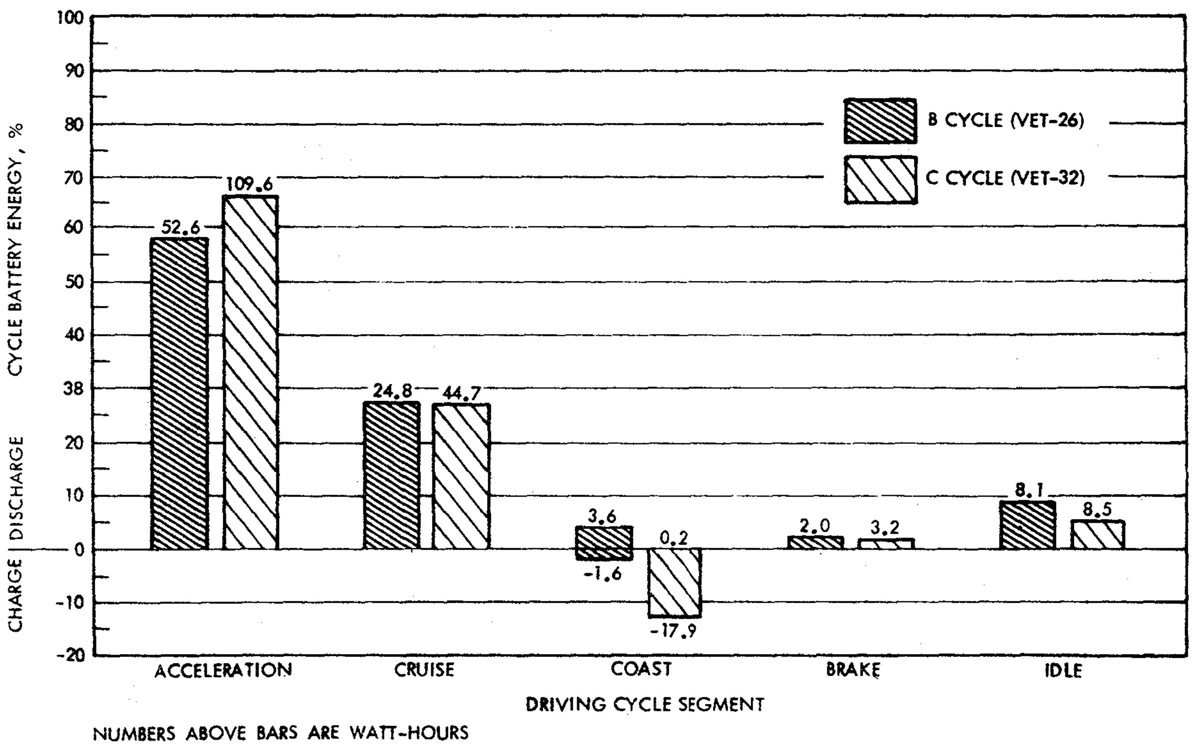


Figure 7-5. Comparison of Corvette Driving Schedules B and C Energy Usage, Test VET-26 vs Test VET-32

propulsion system. The main objective of this procedure was to achieve consistant, easily attainable conditions at the beginning of each test and, in particular, to ensure consistent battery conditions. Towing a vehicle to achieve a stabilized warmed-up condition would require a minimum towing distance of 28 km (20 mi) which was not practical. Furthermore, this stabilized condition would be unique to the weather conditions during the warm-up.

Due to the lack of vehicle warm-up, the propulsion energy requirements at test initiation were significantly larger than needed after 10 to 15 min of test time. A comparison of the Schedule C energy split at 0% depth of discharge and 40% depth of discharge is given in Figure 7-7. The higher drive train and tire losses in the cold (0% depth of discharge) cycles are readily seen in the "cruise" portion of the cycle. The cold "cruise" required over 20% more energy than did the warmed-up portion (40% depth of discharge). Acceleration during cold cycle required a relatively smaller percentage of the total cycle energy due to the larger amount going to cruise and because of slight differences in driving technique during the initial cycles of the test. Regardless of how familiar a driver was with the vehicle, the first few cycles always reflected human adjustments as the "feel" of the car was reestablished. This is especially true when performing "cold-start" tests as the vehicle driving characteristics change during the initial stages of the test.

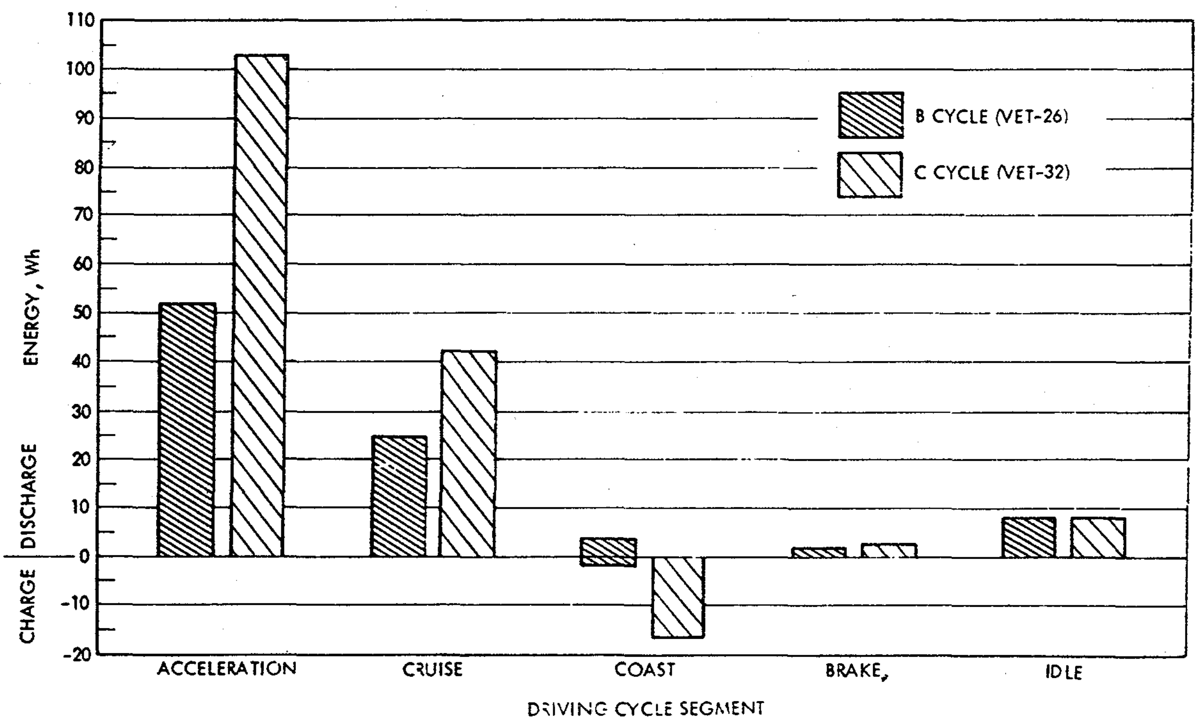


Figure 7-6. Comparison of Corvette Driving Schedules B and C Battery Energy Usage, Test VET-26 vs Test VET-32

Further evidence of the higher rolling resistance losses during cold operation can be observed in the energy split data for Driving Schedule B presented in Figure 7-8. As is the case in the previous figure, the 0% depth of discharge "cruise" energy is about 20% greater than the warmed-up (40% or 80% depth of discharge) equivalent and the relative part of cycle energy attributable to acceleration is smaller.

Another electric vehicle characteristic is reflected in the data of Figure 7-8. During the last two accelerations of the Schedule B test (100% depth of discharge), the batteries and motor were operating at their minimum efficiencies. Battery voltage during acceleration dropped below 60 V, compared to the initial 105 V at maximum current. These lower efficiencies, combined with the slightly longer acceleration time during the final cycles, resulted in a 6% higher energy consumption compared to the 40% and 80% depth of discharge accelerations.

Graphs of battery or motor currents and power as a function of time during steady state tests also show the effects of no vehicle warm-up. These data are enclosed in Appendix C. Details of the Corvette warm-up rates are best seen in the constant velocity data available in this appendix.

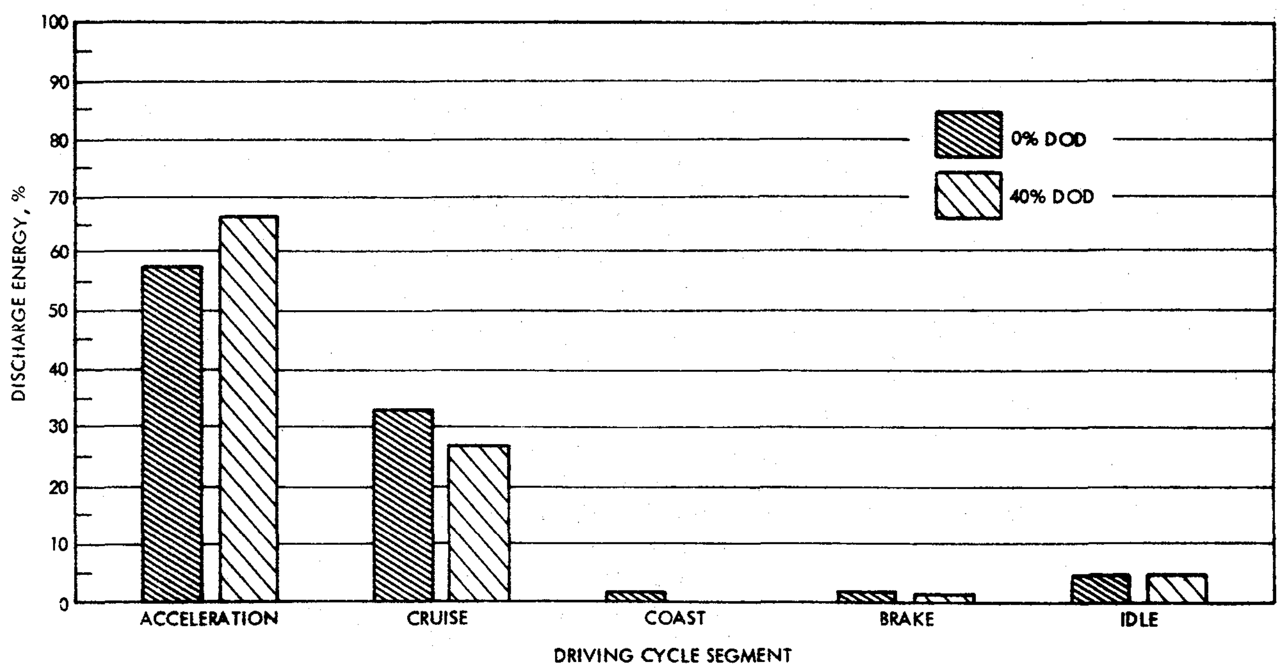


Figure 7-7. Corvette Driving Schedule C Battery Energy Usage vs Depth of Discharge, Test VET-32

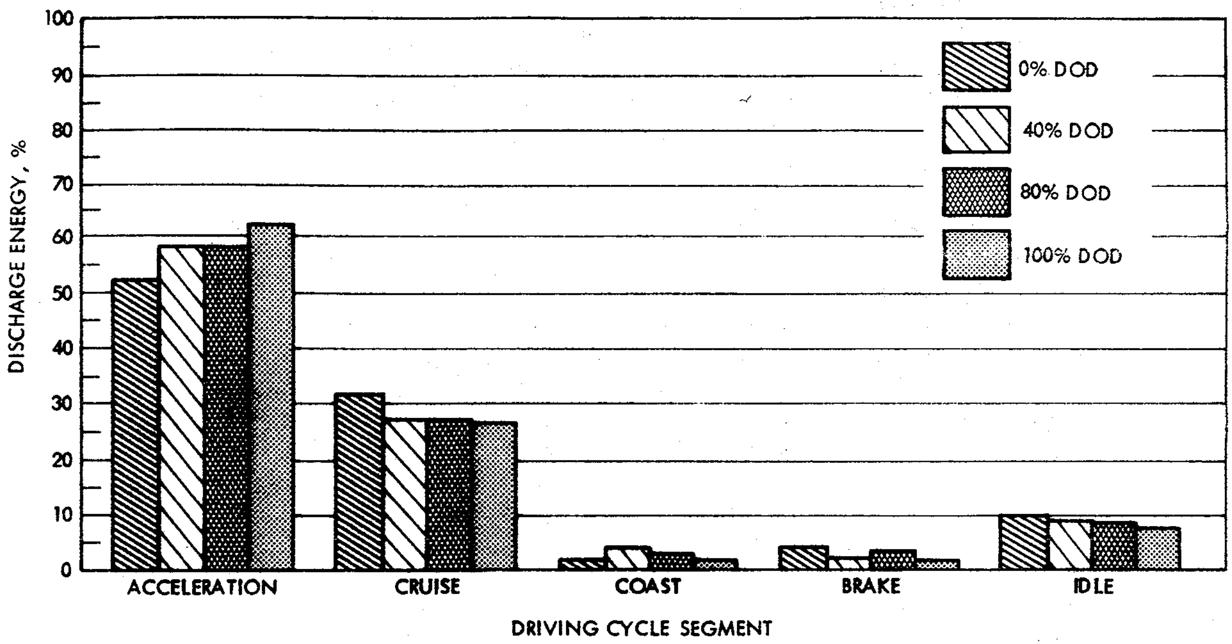


Figure 7-8. Corvette Driving Schedule B Battery Energy Usage vs Depth of Discharge, Test VET-26

5. Effects of Test Interruptions

As noted in Section VI (p. 6-6) during track testing at the Edwards Test Station runway unscheduled aircraft landings caused several interruptions during Corvette range tests. In the case of one of the Schedule B tests and one of the Schedule C tests, the duration of these interruptions were of sufficient length to affect the range of the vehicle, compared to an uninterrupted test. Two battery characteristics are believed to play an important role in changing the vehicle range capability during tests that had interruptions of any kind: (1) battery recuperation and (2) battery electrolyte temperature at end of test.

In the context of this report, the effects of battery recuperation is considered the same as would result from power being drawn from the batteries at reduced levels. In other words, during test interruptions, no power was being withdrawn from the batteries, effectively increasing the duration of the test without using more battery energy. The average rate of power drain on the batteries is then reduced. It is a well established fact that lower rates of battery power consumption allow greater overall levels of energy to be withdrawn. This is born out by Corvette test results in Section VI and can be best seen in Figure 6-9. Under standardized environmental conditions, battery recuperation cannot be directly equated to battery capacity as a function of the reduced power levels. Self-heating during discharges with pauses will not induce as high an end-of-test battery temperature as would be the case in a continuous discharge because of battery cooling during periods of inactivity. Since battery end-of-test temperature also has a significant effect on battery capacity, it also must be considered when quantifying the effects of recuperation. Although other small factors influence battery capacity as a function of test interruptions, it is these two major characteristics which have been used in adjusting the track range data to compensate for test interruptions.

Separate studies of recuperation have been conducted in JPL's battery laboratories. Preliminary results of these data show that battery capacity, and hence vehicle range, can be related to the equivalent reduced power rates during an interrupted test (Ref. 7-2). Utilization of the above factors to understand the driving cycle data of the Corvette at the track is one thing, however, to apply them directly to constant velocity range data is extremely difficult. The effects of decelerating and reaccelerating can easily offset any benefits of recuperation occuring during interruptions of steady-state speed tests. As shown earlier in this Section, accelerations consume a relatively large proportion of energy compared to constant-velocity driving.

In general, any test interruption during a cyclic test will effectively increase the range of the vehicle because of battery recuperation. Only optimistic range results can be obtained from such tests. On the other hand, constant-velocity tests may benefit from recuperation during interruption or they may be penalized due to the need to reaccelerate the vehicle after each test pause. Unless sufficient information is available to quantify each characteristic of the vehicle under test, it is believed that numerous interruptions of constant-velocity tests will most likely result in an invalid test.

Examples of interrupted steady state speed tests are seen in the two 40-km/h (25-mi/h) track tests (VET-13 and VET-15). Both tests were hampered by two types of interruptions:

(1) Test stoppage to permit aircraft landings.

(2) Velocity reductions to allow the car to negotiate turns at each end of the runway.

Each of these tests required a minimum of 50% more time to complete than would be expected from the desired test velocity of the car and the range it traversed. Only a small percentage of this excess time can be attributed to the speed reduction for a car turnaround. Therefore, at least 40% of the test time for each of these tests expired without any milage being accumulated. Despite these extensive opportunities to realize battery recuperation, track tests showed 20% less range than was observed on the dynamometer tests. Acceleration after each test interruption and after each slowdown for vehicle turnarounds apparently more than offset the range extending benefits of extensive recuperation time.

6. Transmission and Motor Efficiency

Reasonable estimates of the combined motor-transmission efficiencies can be obtained by analysis of the following tests:

(1) Coastdowns for road load power requirements

(2) Maximum accelerations

(3) Maximum gradeability as function of dynamometer load and speed

(4) Constant-velocity tests

During coastdown testing, the power requirements for the Corvette were characterized as a function of vehicle velocity. The aerodynamic portion of road load power was quantified only after the dynamometer adjustments matched the track coast times of the Corvette (See Section V).

Knowing aerodynamic power consumption at one velocity (80 km/h or 50 mi/h) and total road load requirements at two speeds (80 and 24 km/h), fairly accurate estimates of road load power can be easily calculated for any vehicle velocity.

As previously indicated in Section V, the road load values were obtained from coastdown tests. Since coast conditions included all of the normal drive train components from the rear wheels back through the output shaft of the transmission, all of the losses associated with them are reflected in the road load power values. At coast initiation the Corvette transmission was placed in neutral and the clutch was disengaged. Thus, the gearing connecting the motor to the tranmission output shaft were not engaged during the coastdowns, so their losses are not included in the road load power data.

Adding the calculated road load power values to the measured power absorbed by the dynamometer during vehicle acceleration, or to the excess dynamometer loads (loads above road load) in the case of the maximum speed versus dynamometer load gradeability tests, gives a measure of power levels entering the final output gear of the transmission. Dividing this sum by the measured motor input power provides a measure of the combined motor-transmission efficiency, excluding the last output stage of the transmission. It is these data which are presented in Figure 7-9 as a function of motor speed.

As is typical of shunt-wound d.c. motors, the maximum efficiency is observed around its base speed and then decays as motor speed increases. However, there are four distinct efficiency curves in Figure 7-9, indicating different sets of motor-transmission efficiencies as a function of gearing. Almost all of the data presented in this figure are from tests in which the motor was operated at the maximum armature current allowed by the Corvette controller. Consequently, motor efficiency will primarily be a function of motor speed rather than armature current. With motor efficiency being constant for a given motor speed, the differences in combined motor-transmission efficiency for each gear reflect differences in gear efficiencies. If it is assumed that the motor efficiency is 79% (from Figure 4-4) at 2500 r/min, then the following gear efficiencies result:

(1) Fourth gear = 93.7%

(2) Third Gear = 91.1%

(3) Second Gear = 86.1%

(4) First Gear = 73.4%

Transmission losses, especially in the lower gears, are greater than anticipated. However, these losses are consistant with the heavy duty type of transmission selected by the vehicle assembler. The standard Corvette transmission was capable of accommodating a 200- to 300-hp engine to begin with. Changing to a heavier duty type would imply the capability of handling a more powerful motor. In terms of these powerful engines, transmission losses would be a relatively small percentage. For instance, the 4.7 hp (3.5 kW) that is dissipated as heat in second gear is only 2.4% of the power of a 200-hp engine, while it is 13.9% of the electric Corvette input power. Although the manufacturer's desired gear ratios were satisfied through the selection of a heavy duty transmission, an appreciable penalty was realized because of the higher throughput losses.

Figure 7-9 also supports the observation presented in Section VI regarding gearshift speeds during the acceleration tests. Maximum acceleration is achieved when the maximum battery power is delivered to the rear wheels. To obtain maximum power at the rear wheels the optimum motor-transmission efficiencies must be realized. During the performance of the acceleration tests, shift points were implemented at too high a motor speed, which resulted in less than optimum motor-transmission efficiency. For example, at 45 km/h (31 mi/h) in second gear the motor is turning at 3500 r/min and the combined efficiency is 64%. Had the vehicle been at the same velocity in third gear, the motor speed would be 2241 r/min and would display a combined efficiency of 74%. With motor input power being the same for both conditions, wheel power for the higher gear, lower motor speed, would have resulted in a 10% improvement in wheel power compared to lower gear, higher motor speed condition actually used.

The reader is cautioned that the in situ measurements of motor-transmission efficiencies described here are difficult and the results are subject to relatively large errors (10%). The data were derived by subtracting two relatively large numbers to obtain a small resultant. One of these large values is vehicle rolling losses, which have been assummed to be a function only of velocity and are based upon the near steady-state coastdown test data. However vehicle rolling losses are different under various driving conditions. For instance, it has recently been reported that tire losses during average accelerations can be 25% greater than that during steady-state driving (Ref. 7-1). This type of rolling loss change would obviously lead to errors in the analyses presented here.

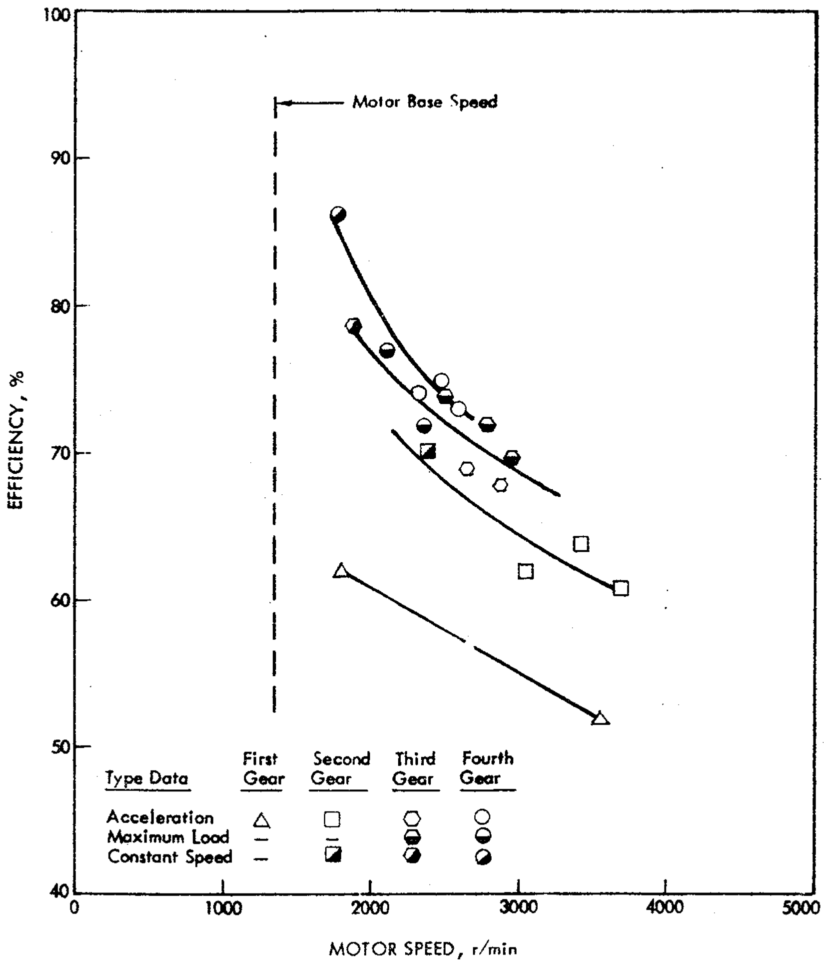


Figure 7-9. Corvette Combined Motor-Transmission Efficiency vs Motor Speed

C. COMPARISON TO OTHER ELECTRIFIED VEHICLES

A qualitative evaluation of the Corvette has been made by comparing the performance described in this report with the results reported in Reference 5-3. Reference 5-3 contains test results for 22 electric vehicles that were tested specifically for the purpose of assessing the state-of-the-art in 1977. Figures 7-10 through 7-13 have data from this report superimposed on figures from the referenced material.

Figure 7-10 is a plot of vehicle range for constant-speed operation versus vehicle speed. The vehicles from Reference 5-3 fell into two broad categories. The average of these two categories is denoted by light dashed lines. Superimposed on Figure 7-11 is a dashed line that represents the performance of the Corvette as derived from Table E-1. The Corvette range is well above the average of the lower group of vehicles, but also it is clearly well below the range of the best vehicles reported in the state-of-the-art assessments in Reference 5-3.

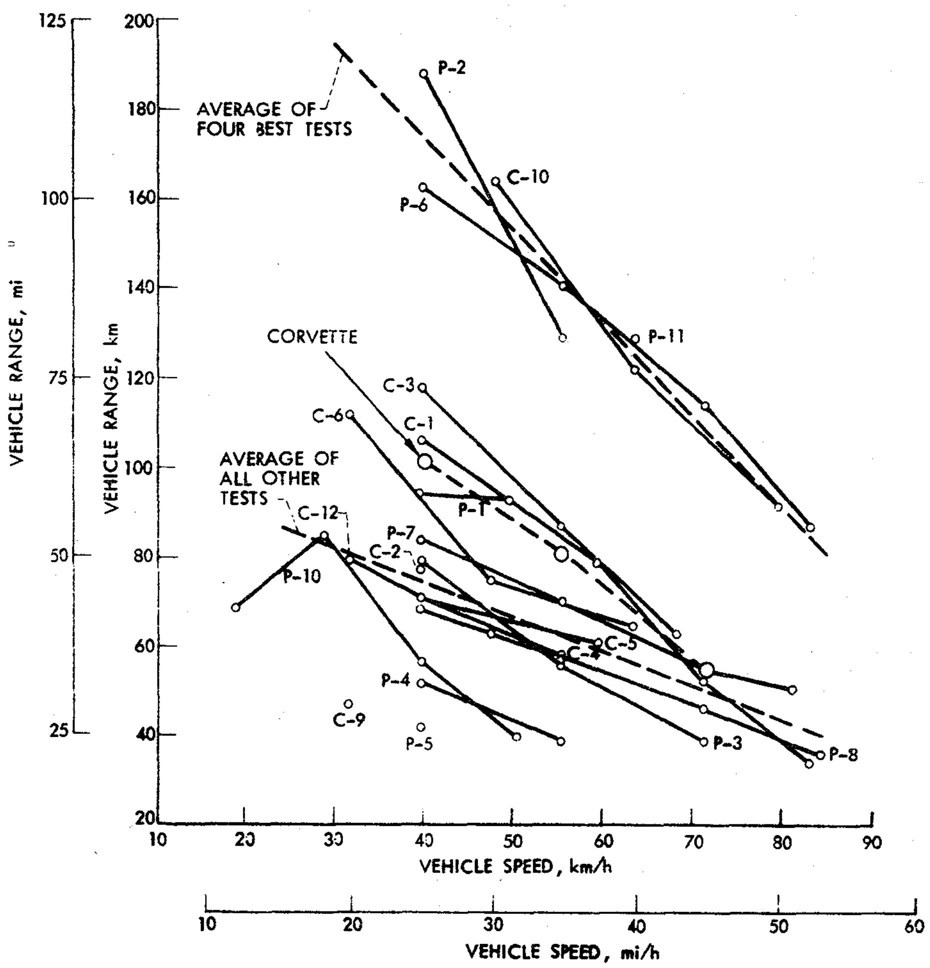


Figure 7-10. Vehicle Range as a Function of Speed

Figure 7-11 from Reference 5-3 shows wall energy consumption as a function of vehicle speed. The wall energy data from Reference 5-3 and from Table E-1 have been corrected to correspond to a 10% coulombic overcharge. The Corvette compares very favorably in terms of wall energy consumption and, in particular, with the vehicle labeled C-1. The Corvette and vehicle C-1 have very nearly equivalent ranges and yet, the energy consumption of the Corvette is about half that of vehicle C-1. Because of the inherent difficulties in comparing data from two different test sites and because the energy data have been corrected, one should view with caution the size of the difference between the two vehicles. However, it does seem clear that the Corvette performed very well in terms of wall energy consumption. Whether the good performance of the Corvette relative to the vehicles in Reference 5-3 should be attributed to efficient vehicle operation, efficient battery charging, or some other source, would require additional details about the test results from vehicle C-1.

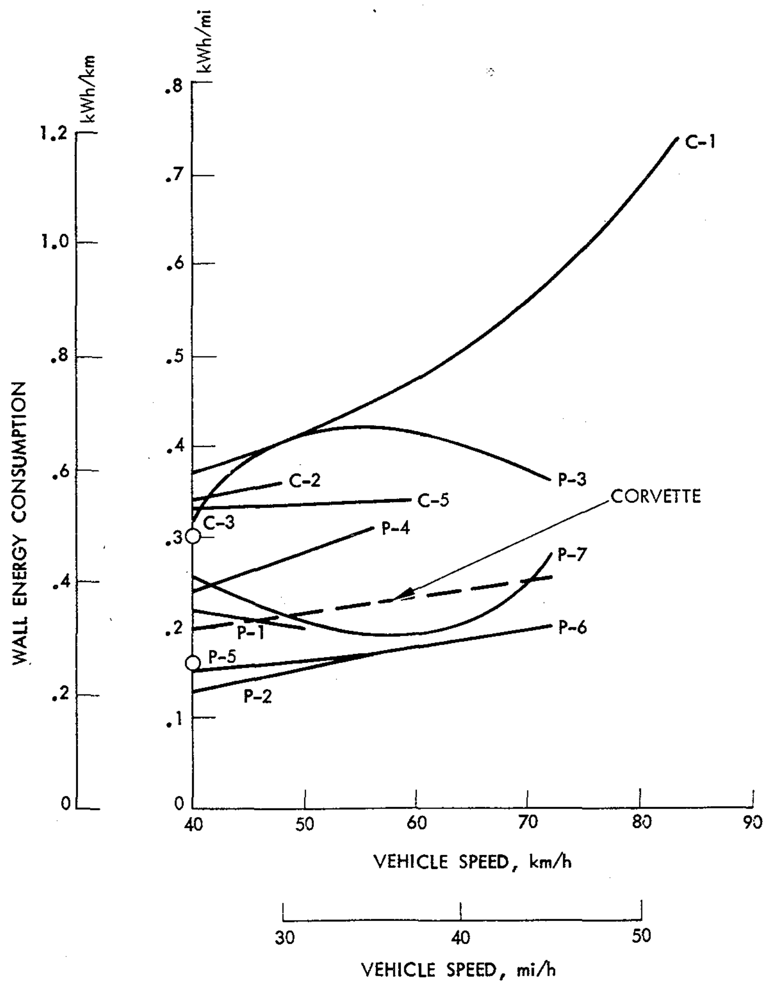


Figure 7-11. Wall Energy Consumption as a Function of Vehicle Speed for Electric Test Vehicles

Figures 7-12 and 7-13, again based on Reference 5-3, show vehicle range and wall energy consumption for the SAE J227a B and C driving schedules. The Corvette comparison for the cyclic tests is very similar to that for the constant-speed tests. In terms of range, the Corvette again is only as good as the majority of the vehicles, but its wall energy consumption falls among the best of the vehicle cited in Reference 5-3

The qualitative comparison with the 1977 state-of-the-art vehicles shows that the Corvette is as good as or better than most of the 1977 vehicles. However, at the same time, it fell well short of the best vehicles evaluated in 1977. It is therefore concluded, from an overall vehicle viewpoint, that the Corvette represents no particular advance in technology.

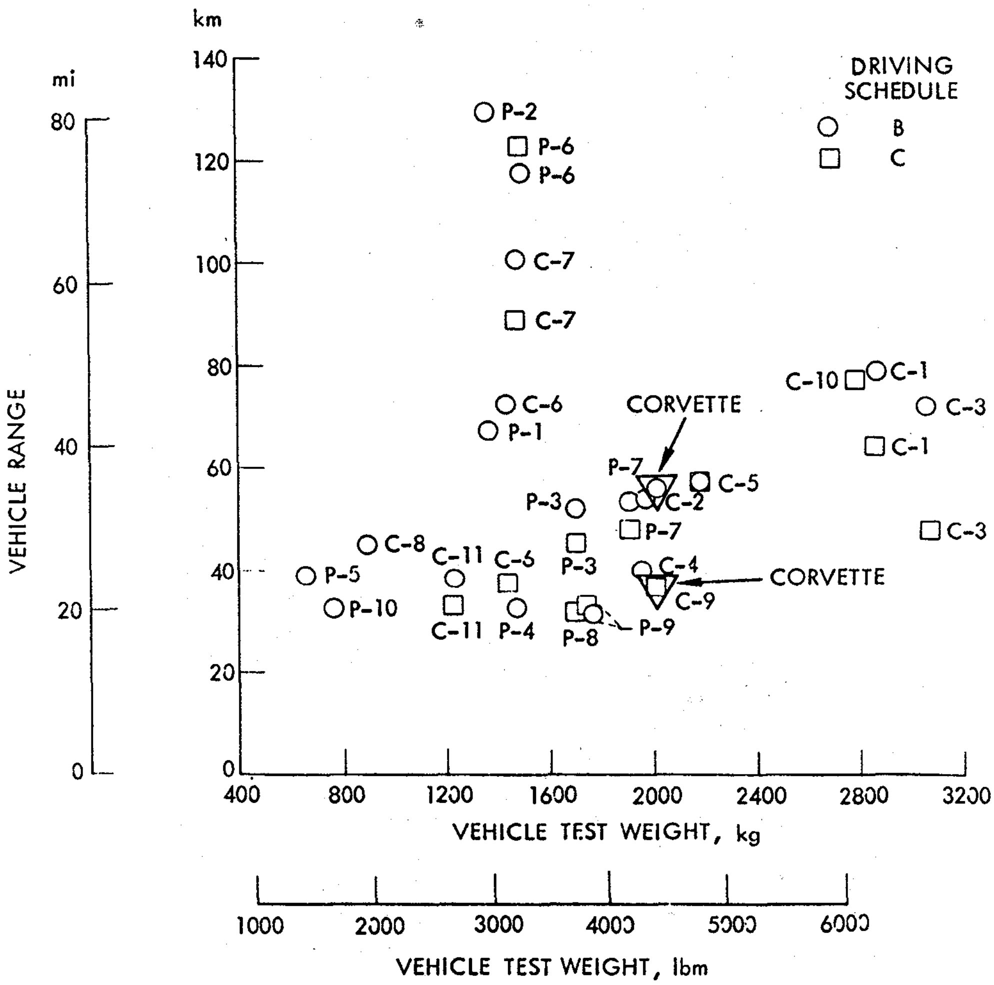


Figure 7-12. Variation of Cycle Range with Weight

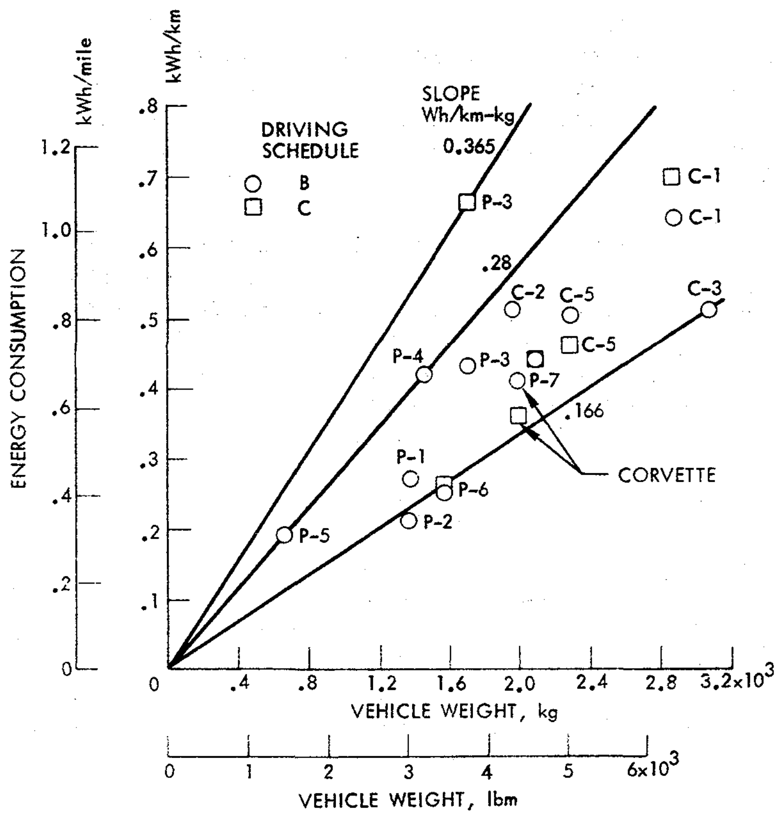


Figure 7-13. Effect of Weight on Wall Energy Consumption

SECTION VIII

OBSERVATIONS AND RECOMMENDATIONS RELATIVE TO TESTING

Since the technology of electric vehicles in general is young and evolving, it is understandable that test techniques and procedures associated with electric vehicles are also still in their infancy. During testing of the Corvette, several problem areas were noted where procedural refinements would enhance the test process, either by improving test precision or by reducing the test time. Several of the observations presented here were also discussed in some detail in previous sections. Also, several of the recommendations (relative to battery temperature, test interruptions, and driving schedule variability) are now in the process of being implemented at JPL.

A. BATTERY END-OF-TEST TEMPERATURES

Lead-acid battery temperature has a strong influence on battery discharge capacity, which, in turn, can be translated directly to vehicle range. This large temperature sensitivity is not likely to be reduced significantly as advanced batteries are developed. Existing DOE/SAE procedures specify that batteries be "soaked" for a minimum of 8 h between charge termination and initiation of vehicle test. The "soak" is to take place within ambient temperature limits between 16 and 32°C. A larger temperature range, 5° to 32°C, is allowed for performance of the vehicle test. If it is assumed that the batteries reach the same temperature as the soak area, then tests will be initiated with batteries anywhere from 16° to 32°C. Given nominal battery self-heating characteristics and the effects of ambient cooling or heating over the broader temperature limits in effect during testing, it is postulated that end-of-test temperatures can range from 12° to 42°C. As previously discussed in Section VI, each degree Celsius equates to a 1% change in battery capacity or vehicle range. Therefore, the allowable 12° to 42°C end-of-test battery temperature can easily result in range differences of up to 30%. This magnitude of difference in vehicle range precludes comparisons of data from a given vehicle let alone comparisons of data from other vehicles. It is recommended that pretest battery temperature be limited from 18° to 24°C and that ambient temperature during testing be restricted to between 10° and 32°C.

B. EFFECTS OF TEST INTERRUPTION

Recuperation of the batteries during test interruptions also has a significant effect on battery capacity and consequently on vehicle range. Cyclic tests of the Corvette which were subjected to interruptions for aircraft landings exhibit extended range capability. The magnitude of this effect for a specific Schedule B test was in excess of 30% as presented in the test results of Section VI.

Effects of interruptions on steady-state tests are difficult to generalize because the frequent reaccelerations of the vehicle can easily offset the benefits of recuperation. It is impractical to totally deny test interruptions, expecially with the longer test times associated with improved vehicles. Future JPL testing will use criteria that invalidate any test which has interruptions greater than 1 minute for each hour of test time.

C. DRIVING SCHEDULE VARIABILITY

The cyclic tests specified in DOE/SAE procedures are comprised of five discrete segments: (1) acceleration, (2) cruise, (3) coast, (4) brake, and (5) idle. Only the cruise and idle segments have unique time versus velocity specifications. The manner in which the acceleration, coast, and brake segments are achieved is left up to the subjectivity of individual drivers as each cycle is performed. As a result of this ambiguity a large variability can exist in the amount of energy consumed per cycle and the distance traveled per cycle. Acceleration techniques can also have a significant effect on the number of cycles completed. This is especially true for Schedule D tests.

To alleviate the cause of the variability it is recommended that specific velocity versus time profiles be established as is now being done for JPL test procedures. One of the constraints being included in the JPL "standardization" is that these profiles be constructed such that vehicles possessing regenerative braking are not penalized by the design of the profiles.

D. TEST DURATION

One of the results of improvements in batteries and electric vehicles in general is range extension. The better the range, the longer the test. Testing of the vehicles recently procured by DOE is taking almost 6 h to complete a Schedule B cycle. By the time pretest and post-test operations are complete, a full work day has been expended to test only one vehicle. If the Schedule B test were representative of how vehicles are actually driven, it would still remain a worthwhile procedure. However, this is not the case for passenger vehicles.

To expedite the rigorous test schedule delineated by existing procedures it is recommended that only delivery type vehicles be tested for the B cycle. It is also suggested that any test which requires more than 3 h to complete be done only once while the shorter tests be repeated at least once.

E. RECOMMENDATION SUMMARY

While there may be other procedural areas in need of improvement, it is the authors' opinion that the first three items discussed in this section are the major contributors to test variability of electric vehicles. Without even attempting to maximize each individual effect to one extreme or another, the authors postulate that the combined variability of these items can routinely cause 20% differences in the range of a given vehicle.

REFERENCES

4-1. Cataldo, R. L., Response of Lead-Acid Batteries to Chopper-Controlled Discharge, NASA TM-73834, August 1978.

4-2. Amato, C. J., Latent Losses in 'Lectric Lizzies, IEEE Transactions, September 1969, pp. 558-565.

4-3. Demerdash, N., et al., Effects of Complex Forms on Copper Losses in Large DC Motors, IEEE Conference Record, 1970, pp. 78-81.

4-4. Triner, J. and Hansen, I., Electric Vehicle Power Train Instrumentation--Some Constraints and Considerations, NASA TM X-73629, April 1977.

5-1. Electric Vehicle Test and Evaluation Procedure (EVTEP), ERDA-EHV-TEP, 1977.

5-2. Electric Vehicle Test Procedure--SAE J227a, Society of Automotive Engineers--Recommended Practice, February 1976.

5-3. State-of-the-Art Assessment of Electric and Hybrid Vehicles, NASA TM-73756, September 1977.

5-4. Shain, T. W., Baseline Vehicle Test Report: South Coast Technology Rabbit, Document 5030-428, Jet Propulsion Laboratory, Pasadena, California, September 1979 (JPL internal document).

7-1. Schuring, D. J., Transient Versus Steady-State Tire Rolling Loss Testing, SAE-790116, 1979.

7-2. Rowlette, J. J., and Leising, C. J., Battery Test Report, Document 5030-286, Jet Propulsion Laboratory, Pasadena, California, May 1979 (JPL internal document).

APPENDIX A

FACILITY AND INSTRUMENTATION

APPENDIX A

FACILITY AND INSTRUMENTATION

The JPL chassis dynamometer test facility includes the normal complement of equipment needed to conduct Federal Test Procedures (FTP) of internal combustion engine vehicles as well as purely electric vehicle tests. The instrumentation for the Corvette tests includes both analog and digital equipment. Digital data were 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. A photograph of the central instrumentation area is shown in Figure A-1.

1. POWER MEASUREMENT CIRCUITS

In addition to the normal facility equipment, electric power measurements were basic to the Corvette testing program. A photograph and a block diagram of the battery and motor power measurement circuits are shown in Figures A-2 and A-3. Identical circuits, within normal construction technology, were used for these battery and motor power measurements. The functions of the blocks shown in Figure A-3 are as follows:

(1) Isolation Amplifiers. Instrumentation amplifiers installed in a conventional rack mount case with a 300-V common mode voltage capability were inserted into the voltage cabling before the power measurement circuits (Figure A-2). These circuits could be operated at the potential of the normal instrumentation ground.

(2) Buffer Amplifiers. The voltage divider provides a 10-V full scale signal so the buffer amplifier has a gain of 1. The current channel has a gain of 2 to raise the 5-V maximum current signal to 10 V.

(3) Multiplier. The analog multiplier multiples 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 voltage-to-frequency 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.

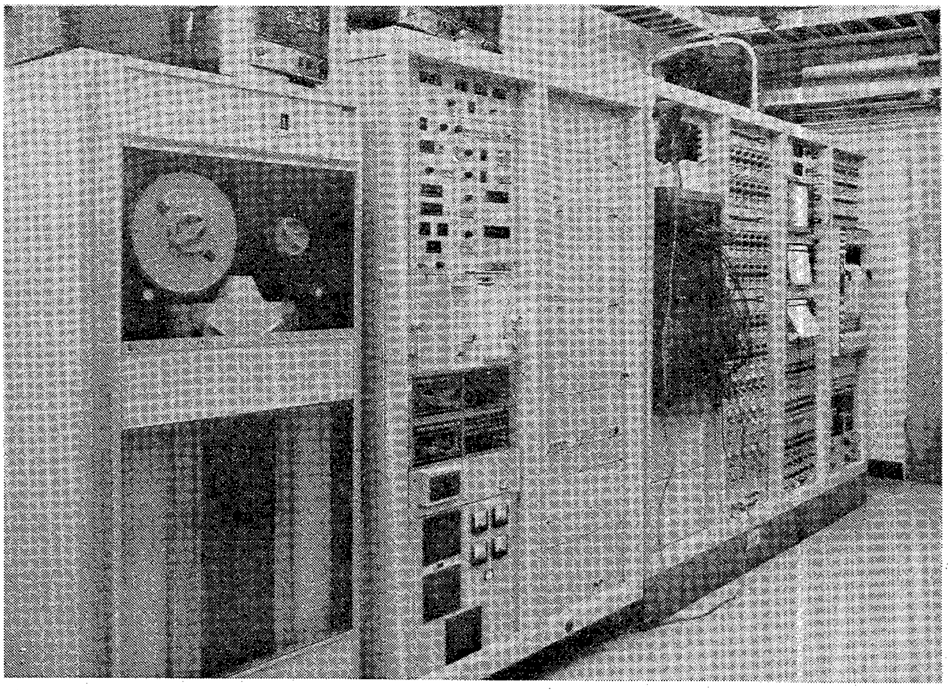


Figure A-1. Central Instrumentation Area

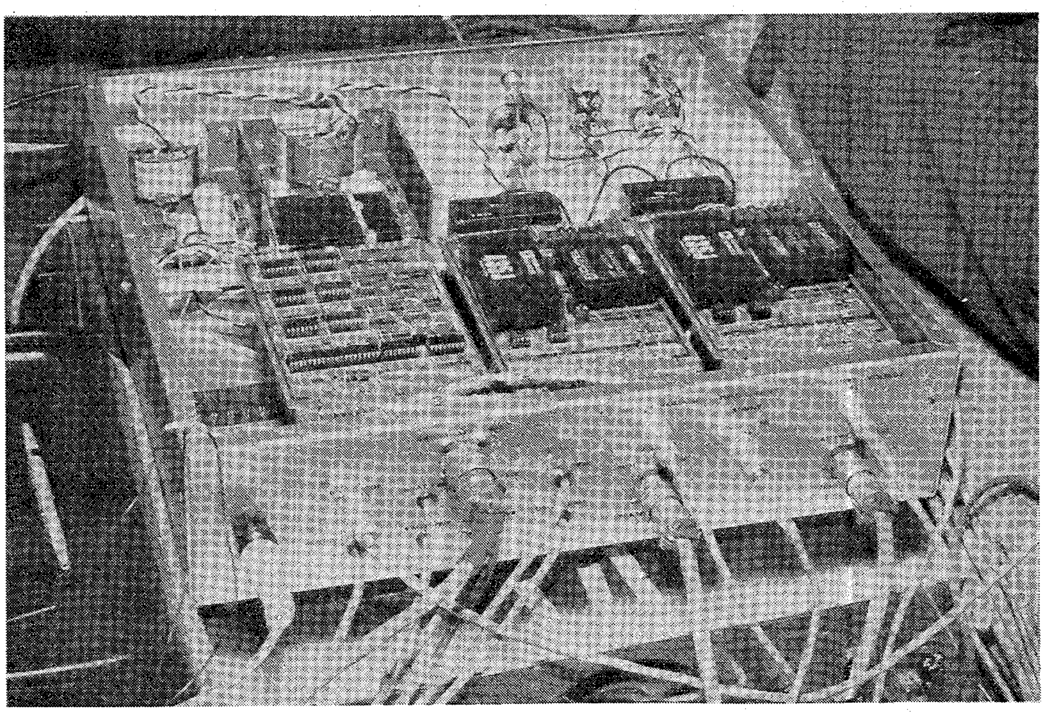


Figure A-2. Electrical Power Measurement Chassis

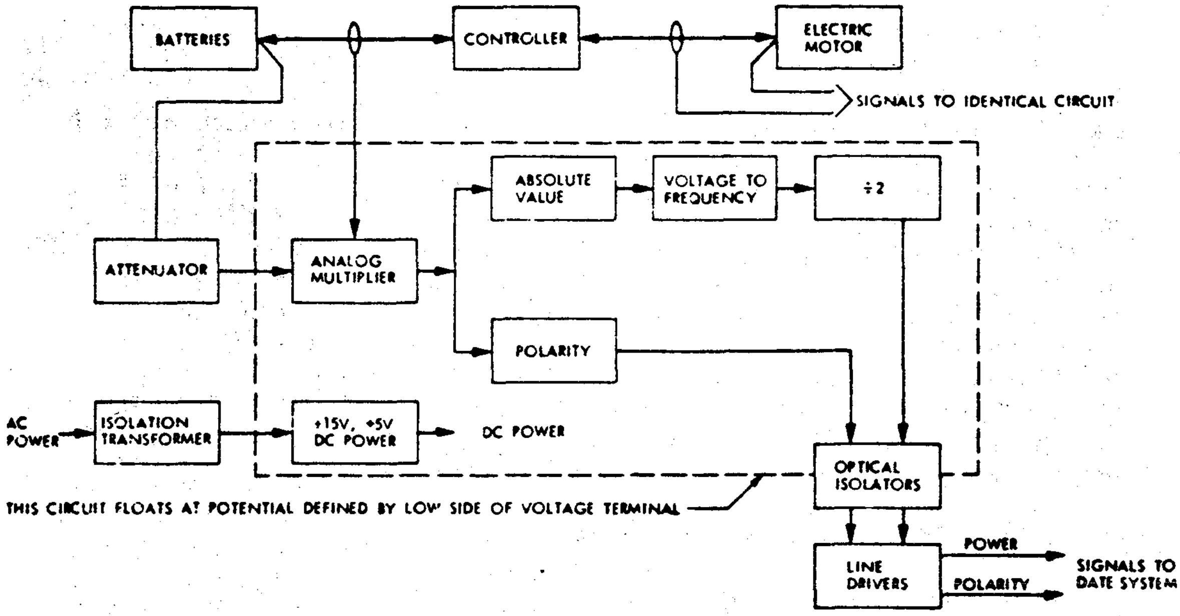


Figure A-3. Power Measurement Block Diagram

(6) Voltage-to-Frequency Converter. This circuit provides an output frequency proportional to the input voltage. Since the absolute value circuit provides only positive voltages, the voltage-to-frequency converter will send an output frequency proportional to either the postive 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 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 voltage-to-frequency 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 about 10 W-s/Hz, so excellent resolution is attained.

2. REAL-TIME DATA READOUT

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 are 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 for display of power and energy. Power readings are displayed as kilowatts with 0.01-kW resolution; the power integral is displayed in watt-hours with 0.1-Wh resolution. 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 from 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 A-4). The channel identifiers and sequence for the video display of power and integrated power data, starting from the top, are:

(1) PBO = power out of battery

(2) PBI = power into battery

(3) PMI = power into motor

(4) PMO = power out of motor

This display format was typically used during the tests since it provided an excellent means of determining the approximate real-time power flow during the various Corvette operational modes. Subtraction of the two battery power channels also provided a real-time indication of the net charge or discharge from the battery.

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-s intervals, with a time variation of about 50 us. A program that produced a computer plot from this data was developed for the electric vehicle testing. Computer plots for each type of test are in Appendix C.

The electrical power data is also printed at specified intervals to investigate the power flow during a test cycle, the minimum interval being 0.1 s. Areas of technical interest are located from these plots, after which detailed analysis of the tabular data takes place.

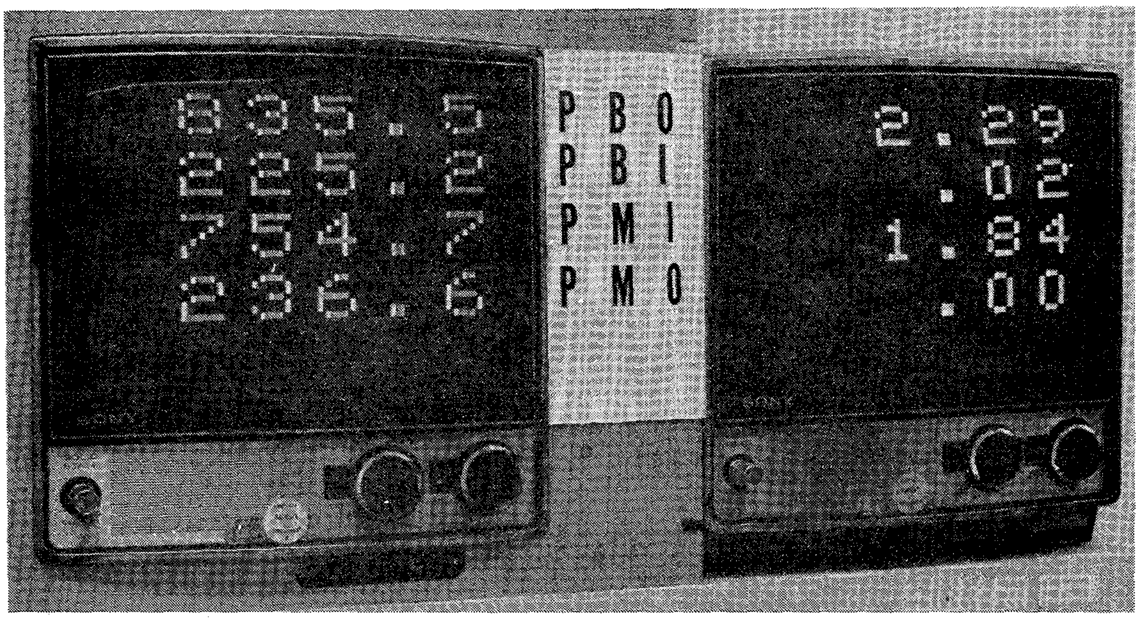


Figure A-4. Four-Channel Power Display

APPENDIX B

SAMPLE OF TABULATED DATA

APPENDIX B

SAMPLE OF TABULATED DATA

The following data covers a time span of 84 s, which includes the start-up of the Corvette and the completion of the first cycle of a Schedule C test.

IDAC TAPE W660R TEST NO. 31 DAY 52 09:56:13 SITE NO.=4.0 IDAC SITE= 6
TAMB = 666.011 DEG F PAMB = 14.057 PSIA TEST DATA START 09:56:18

RUN	TIME	MPH	ERO	ERI	EMI	EMO	BAMP	BVOLT	MFLDI	MAMP	MVOLT	PRO	PRI	PMI	PMO	MRPM	DSS	ATEMP	MTEMP	DIST
													KW							
1	482.0	.00	1.	0.	0.	0.	7.9	114.6	5.56	-.3	.1	.77	-.02	-.01	-.01	-0.	1.	70.	64.	.000
1	482.2	.00	1.	0.	0.	0.	7.9	114.5	5.52	-.2	.0	.73	-.02	-.00	-.01	-0.	0.	70.	64.	.000
1	482.3	.00	1.	0.	0.	0.	7.8	114.6	5.49	-.3	.0	.72	-.02	-.01	-.01	0.	1.	70.	64.	.000
1	482.4	.00	1.	0.	0.	0.	7.9	114.6	5.54	-.2	.1	.78	-.02	-.01	-.02	0.	0.	70.	64.	.000
1	482.6	.00	1.	0.	0.	0.	7.9	114.6	5.55	-.2	.1	.75	-.02	-.01	-.02	-0.	0.	70.	64.	.000
1	482.7	.00	1.	0.	0.	0.	7.8	114.6	5.52	-.2	.1	.72	-.02	-.00	-.01	0.	0.	70.	64.	.000
1	482.8	.00	1.	0.	0.	0.	7.9	114.3	5.55	-.3	.1	.71	-.02	-.01	-.02	-0.	1.	70.	64.	.000
1	483.0	.00	1.	0.	0.	0.	7.9	114.5	5.56	-.2	.0	.77	-.02	-.01	-.01	-1.	1.	70.	64.	.000
1	496.2	.00	7.	0.	2.	0.	14.5	113.1	5.08	6.9	113.1	1.65	.08	1.03	.14	1347.	100.	70.	64.	.000
1	496.3	.00	7.	0.	2.	0.	14.4	113.1	5.08	6.8	113.1	1.50	.13	.96	.18	1346.	200.	70.	64.	.000
1	496.5	.00	7.	0.	3.	0.	14.5	113.4	5.10	6.9	113.1	1.56	.09	.87	.25	1347.	168.	70.	64.	.000
1	496.6	.00	7.	0.	3.	0.	14.5	113.1	5.10	6.9	113.1	1.64	.09	.96	.21	1347.	149.	70.	64.	.000
1	496.7	.00	8.	0.	3.	0.	14.4	113.1	5.07	6.8	113.1	1.64	.07	.97	.19	1347.	238.	70.	64.	.000
1	496.9	.00	8.	0.	3.	0.	14.5	113.1	5.07	6.9	113.1	1.54	.09	.94	.18	1347.	231.	70.	64.	.000
1	497.0	.00	8.	0.	3.	0.	14.4	113.1	5.10	6.9	112.4	1.56	.10	.90	.21	1347.	172.	70.	64.	.000
1	497.1	.00	8.	0.	3.	0.	14.4	113.1	5.11	6.8	113.1	1.61	.11	1.00	.16	1347.	160.	70.	64.	.000
1	506.3	.00	12.	0.	5.	1.	14.2	112.8	5.07	6.7	112.7	1.63	.02	.95	.15	1345.	153.	70.	64.	.000
1	506.5	.00	12.	0.	5.	1.	14.2	112.8	5.04	6.6	112.8	1.67	.02	.98	.16	1345.	263.	70.	64.	.000
1	506.6	.00	12.	0.	5.	1.	14.0	112.8	5.02	6.5	112.7	1.56	.03	.95	.15	1345.	227.	70.	64.	.000
1	506.7	.00	12.	0.	5.	1.	14.1	112.8	5.04	6.6	112.7	1.47	.10	.91	.15	1345.	233.	70.	64.	.000
1	506.9	.00	12.	0.	5.	1.	14.2	112.8	5.06	6.7	112.7	1.59	.09	.94	.18	1345.	240.	70.	64.	.000
1	507.0	.00	12.	0.	5.	1.	14.0	112.8	5.03	6.5	112.7	1.60	.08	.96	.17	1345.	287.	70.	64.	.000
1	507.1	.00	12.	0.	5.	1.	14.0	112.7	5.02	6.5	112.7	1.45	.13	.93	.16	1345.	344.	70.	64.	.000
1	507.3	.00	12.	0.	5.	1.	14.2	112.7	5.04	6.7	112.7	1.45	.13	.92	.16	1345.	296.	70.	64.	.000
1	507.4	.00	12.	0.	5.	1.	14.1	112.8	5.04	6.6	112.7	1.57	.10	.96	.17	1344.	204.	70.	64.	.000
1	507.5	.00	12.	0.	5.	1.	14.2	112.7	5.02	6.7	112.7	1.53	.13	.93	.19	1345.	229.	70.	64.	.000
1	507.7	.00	12.	0.	5.	1.	14.3	112.8	4.98	7.0	112.6	1.54	.06	.87	.23	1346.	178.	70.	64.	.000
1	507.8	.00	12.	0.	5.	1.	14.2	112.7	4.98	6.8	112.6	1.58	.01	.91	.18	1346.	139.	70.	64.	.000
1	507.9	.00	12.	0.	6.	1.	14.0	112.8	4.97	6.6	112.7	1.65	.04	.94	.18	1346.	222.	70.	64.	.000
1	508.1	.00	12.	0.	6.	1.	14.1	112.4	4.93	6.7	112.7	1.54	.08	.97	.15	1347.	241.	70.	64.	.000
1	508.2	.00	13.	0.	6.	1.	14.2	112.7	4.89	6.9	112.6	1.47	.09	.87	.24	1347.	204.	70.	64.	.000
1	508.4	.00	13.	0.	6.	1.	14.0	112.7	4.94	6.7	112.6	1.56	.06	.88	.22	1348.	184.	70.	64.	.000
1	508.5	.00	13.	0.	6.	1.	14.0	112.7	4.94	6.6	112.7	1.60	.06	.94	.19	1349.	169.	70.	64.	.000
1	508.6	.00	13.	0.	6.	1.	14.1	112.7	4.89	6.7	112.7	1.53	.08	.97	.16	1349.	161.	70.	64.	.000
1	508.8	.00	13.	0.	6.	1.	13.8	112.7	4.89	6.6	112.6	1.48	.07	.93	.16	1349.	138.	70.	64.	.000
1	508.9	.00	13.	0.	6.	1.	13.7	112.8	4.92	6.4	112.7	1.54	.07	.93	.16	1350.	159.	70.	64.	.000
1	509.0	.00	13.	0.	6.	1.	13.9	112.7	4.90	6.6	112.7	1.54	.11	.97	.15	1350.	170.	70.	64.	.000
1	509.2	.00	13.	0.	6.	1.	14.0	112.7	4.89	6.7	112.6	1.59	.05	.89	.24	1350.	151.	70.	64.	.000
1	509.3	.00	13.	0.	6.	1.	13.6	112.7	4.88	6.4	112.6	1.47	.05	.81	.27	1350.	150.	70.	64.	.000
1	509.4	.00	13.	0.	6.	1.	14.5	112.7	4.84	7.2	112.6	1.62	.03	.90	.21	1350.	149.	70.	64.	.000
1	509.6	.00	13.	0.	6.	1.	19.2	112.3	4.35	12.7	112.2	1.96	.02	1.37	.07	1352.	186.	70.	64.	.000
1	509.7	.00	13.	0.	6.	1.	25.2	111.8	3.63	19.5	111.7	2.41	.02	1.91	.02	1364.	215.	70.	64.	.000
1	509.8	.00	13.	0.	6.	1.	40.0	110.7	3.28	34.8	110.3	3.67	-.00	3.19	.00	1382.	236.	70.	64.	.000
1	510.0	.00	14.	0.	7.	1.	72.3	108.4	3.60	66.7	108.1	6.63	-.01	6.07	-.01	1377.	173.	70.	64.	.000
1	510.1	.00	14.	0.	7.	1.	94.0	106.7	3.60	88.7	106.4	9.25	-.02	8.77	-.01	1357.	353.	70.	64.	.000
1	510.2	1.14	15.	0.	7.	1.	97.7	106.4	3.58	92.4	106.1	9.81	-.01	9.28	-.01	1357.	302.	70.	64.	.000
1	510.4	1.48	15.	0.	8.	1.	103.4	105.6	3.58	98.1	105.6	10.44	-.02	9.90	-.01	1357.	295.	70.	64.	.000
1	510.5	1.91	15.	0.	8.	1.	111.7	105.2	3.64	106.4	104.9	11.14	-.02	10.64	-.01	1354.	236.	70.	64.	.000
1	510.6	2.86	16.	0.	9.	1.	139.1	103.5	4.10	133.1	103.1	13.21	-.01	12.66	-.01	1337.	292.	70.	64.	.000
1	510.8	4.18	17.	0.	9.	1.	167.9	101.8	4.83	161.2	101.3	15.78	-.01	15.09	-.02	1304.	350.	70.	64.	.000
1	510.9	5.80	17.	0.	10.	1.	187.7	100.4	5.42	180.4	100.1	17.69	-.02	16.95	-.01	1267.	398.	70.	64.	.001

Figure B-1. Sample of Tabulated Data

IDAC TAPE M660R TEST NO. 31 DAY 52 09:56:13 SITE NO.=4.0 IDAC SITE= 4
TAMB = 668.355 DEG F PAMB = 14.059 PSIA TEST DATA START 09:56:18

RUN	TIME	MPH	ERO	ERI	EMI	EMO	BAMP	BVOLT	MFLDI	MAMP	MVOLT	PRO	PRI	PMI	PMO	MRPM	USS	MTEMP	MTEMP	DIST
				KWH									KA							
1	511.1	6.60	18.	0.	11.	1.	179.3	100.7	5.32	172.2	100.6	17.55	-.02	16.86	-.00	1244.	370.	70.	64.	.001
1	511.2	6.85	19.	0.	11.	1.	161.0	101.7	4.76	154.6	101.6	16.27	-.02	15.64	-.00	1248.	446.	70.	64.	.001
1	511.3	6.95	19.	0.	12.	1.	155.5	102.0	4.51	149.3	101.8	15.73	-.01	15.09	-.01	1263.	454.	70.	64.	.001
1	511.5	7.02	20.	0.	12.	1.	160.0	102.0	4.58	153.7	101.5	15.90	-.01	15.28	-.01	1270.	413.	70.	64.	.002
1	511.6	7.11	20.	0.	13.	1.	161.0	101.6	4.59	154.6	101.4	15.91	-.01	15.31	-.02	1272.	447.	70.	64.	.002
1	511.7	7.25	21.	0.	13.	1.	151.9	102.1	4.41	145.8	102.0	15.29	-.02	14.69	-.01	1277.	441.	70.	64.	.002
1	511.9	7.44	21.	0.	14.	1.	125.4	103.6	3.86	119.9	103.6	13.37	-.03	12.81	-.01	1299.	407.	70.	64.	.003
1	512.0	7.62	22.	0.	14.	1.	103.9	105.0	3.26	99.1	104.9	11.37	-.02	10.90	-.01	1337.	498.	70.	64.	.003
1	512.1	7.79	22.	0.	14.	1.	89.2	106.0	2.84	84.7	105.8	9.72	-.01	9.35	-.01	1377.	540.	70.	64.	.003
1	512.3	7.95	23.	0.	15.	1.	84.4	106.2	2.69	80.1	106.1	9.03	-.02	8.60	-.02	1412.	529.	70.	64.	.003
1	512.4	8.09	23.	0.	15.	1.	80.0	106.6	2.57	75.8	106.5	8.55	-.02	8.14	-.01	1442.	486.	70.	64.	.004
1	512.5	8.21	23.	0.	15.	1.	75.6	106.9	2.40	71.6	106.8	8.08	-.01	7.72	-.00	1469.	454.	70.	64.	.004
1	512.7	8.32	23.	0.	16.	1.	71.3	107.2	2.26	67.4	107.0	7.53	-.02	7.23	-.01	1494.	444.	70.	64.	.004
1	512.8	8.44	24.	0.	16.	1.	71.7	107.1	2.18	67.9	107.0	7.46	-.02	7.13	-.02	1516.	446.	70.	64.	.005
1	512.9	8.55	24.	0.	16.	1.	70.9	107.1	2.08	67.3	107.1	7.45	-.02	7.12	-.02	1537.	490.	70.	64.	.005
1	513.1	8.64	24.	0.	17.	1.	71.4	107.2	1.99	67.8	107.0	7.44	-.02	7.15	-.02	1557.	490.	70.	64.	.005
1	513.2	8.73	24.	0.	17.	1.	70.4	107.2	1.91	66.9	107.0	7.27	-.02	7.01	-.01	1576.	478.	70.	64.	.006
1	513.3	8.84	25.	0.	17.	1.	71.7	107.2	1.87	68.2	107.0	7.39	-.02	7.10	-.01	1595.	514.	70.	64.	.006
1	513.5	8.95	25.	0.	17.	1.	73.2	106.9	1.79	69.9	106.8	7.59	-.02	7.30	-.02	1613.	493.	70.	64.	.006
1	513.6	9.06	25.	0.	18.	1.	81.3	106.5	1.69	78.2	106.2	8.17	-.02	7.93	-.02	1633.	463.	70.	64.	.007
1	513.8	9.21	26.	0.	18.	1.	93.6	105.6	1.62	90.6	105.4	9.18	-.02	8.94	-.01	1657.	487.	70.	64.	.007
1	513.9	9.39	26.	0.	18.	1.	111.4	104.5	1.63	108.4	104.2	10.78	-.02	10.50	-.01	1685.	513.	70.	64.	.007
1	514.0	9.62	26.	0.	19.	1.	128.4	103.4	1.58	125.6	103.0	12.41	-.01	12.13	-.01	1717.	536.	70.	64.	.008
1	514.2	9.86	27.	0.	20.	1.	153.3	101.9	1.55	150.7	101.4	14.45	-.02	14.20	-.02	1755.	549.	70.	64.	.008
1	514.3	10.18	28.	0.	20.	1.	179.9	100.2	1.58	177.4	99.7	16.72	-.02	16.43	-.01	1802.	562.	70.	64.	.008
1	514.4	10.51	28.	0.	21.	1.	203.7	98.7	1.64	201.1	98.3	18.88	-.02	18.56	-.02	1852.	570.	70.	64.	.009
1	514.6	10.82	29.	0.	22.	1.	217.6	97.7	1.66	215.1	97.4	20.28	-.02	19.98	-.01	1906.	599.	70.	64.	.009
1	514.7	11.14	30.	0.	22.	1.	224.5	97.2	1.62	222.2	96.8	20.96	-.02	20.70	-.01	1961.	595.	70.	64.	.010
1	514.8	11.45	31.	0.	23.	1.	232.0	96.7	1.55	229.8	96.4	21.59	-.01	21.31	-.01	2015.	596.	70.	64.	.010
1	515.0	11.75	32.	0.	24.	1.	231.5	96.6	1.55	229.4	96.3	21.81	-.02	21.52	-.01	2072.	607.	70.	64.	.011
1	515.1	12.03	32.	0.	25.	1.	230.2	96.6	1.50	228.1	96.4	21.81	-.02	21.54	-.01	2126.	630.	70.	64.	.011
1	515.2	12.30	33.	0.	25.	1.	228.7	96.7	1.44	226.6	96.4	21.65	-.01	21.42	-.01	2176.	635.	70.	64.	.011
1	515.4	12.56	34.	0.	26.	1.	225.7	96.8	1.38	223.7	96.5	21.40	-.01	21.16	-.00	2227.	693.	70.	64.	.012
1	515.5	12.81	35.	0.	27.	1.	223.8	96.9	1.36	221.7	96.6	21.28	-.02	21.02	-.02	2276.	727.	70.	64.	.012
1	515.6	13.05	36.	0.	28.	1.	220.0	97.2	1.33	218.1	96.9	21.07	-.02	20.82	-.01	2321.	743.	70.	64.	.013
1	515.8	13.26	37.	0.	29.	1.	206.0	97.9	1.27	204.0	97.7	20.07	-.01	19.85	-.01	2364.	735.	70.	64.	.013
1	515.9	13.44	37.	0.	29.	1.	190.9	98.8	1.20	188.9	98.5	18.61	-.02	18.62	-.02	2402.	724.	70.	64.	.014
1	516.0	13.58	38.	0.	30.	1.	173.0	99.8	1.14	171.0	99.6	17.41	-.02	17.21	-.01	2436.	721.	70.	64.	.014
1	516.2	13.73	38.	0.	31.	1.	163.2	100.5	1.07	161.2	100.2	16.47	-.02	16.27	-.01	2468.	747.	70.	64.	.015
1	516.3	13.88	39.	0.	31.	1.	159.3	100.6	1.04	157.2	100.4	15.89	-.02	15.72	-.01	2497.	761.	70.	64.	.015
1	516.5	14.03	40.	0.	32.	1.	155.1	100.9	1.00	153.1	100.7	15.42	-.01	15.25	-.01	2525.	749.	70.	64.	.016
1	516.6	14.15	40.	0.	32.	1.	154.3	101.0	.99	152.3	100.7	15.33	-.02	15.15	-.01	2551.	770.	70.	64.	.016
1	516.7	14.26	41.	0.	33.	1.	155.6	100.9	.96	153.6	100.6	15.42	-.01	15.23	-.02	2575.	764.	70.	64.	.017
1	516.9	14.41	42.	0.	34.	1.	162.0	100.5	.95	160.0	100.2	15.76	-.02	15.60	-.01	2601.	763.	70.	64.	.018
1	517.0	14.57	42.	0.	34.	1.	168.5	100.1	.97	166.6	99.8	16.26	-.02	16.09	-.02	2620.	766.	70.	64.	.018
1	517.1	14.71	42.	0.	34.	1.	170.6	100.0	.97	168.7	99.6	16.60	-.02	16.39	-.01	2652.	773.	70.	64.	.018
1	517.3	14.84	43.	0.	35.	1.	175.3	99.6	.96	173.4	99.3	16.98	-.02	16.79	-.02	2678.	801.	70.	64.	.019
1	517.4	14.99	44.	0.	36.	1.	180.0	99.3	.95	178.3	98.9	17.50	-.02	17.14	-.01	2703.	796.	70.	64.	.020
1	517.5	15.16	44.	0.	36.	1.	192.9	98.5	.95	191.2	98.0	18.23	-.02	18.04	-.01	2731.	798.	70.	64.	.020
1	517.7	15.32	45.	0.	37.	1.	209.4	97.4	.99	207.6	97.1	19.56	-.02	19.34	-.01	2760.	806.	70.	64.	.021
1	517.8	15.52	46.	0.	38.	1.	222.9	96.6	1.01	221.3	96.2	20.68	-.02	20.49	-.01	2792.	844.	70.	64.	.021

Figure B-1. (contd)

IDAC TAPE W660R   TEST NO. 31   DAY 52   09:56:13   SITE NO.=4.0   IDAC SITE= 4
TAMB = 668.852 DEG F   PAMB = 14.060 PSIA   TEST DATA START 09:56:18

RUN	TIME	MPH	EBO	EBI	EMI	EMO	BAMP	BVOLT	MFLDI	MAMP	MVOLT	PBO	PBI	PMI	PMO	MRPM	USS	ATEMP	MTEMP	DIST
				W-H									KW							
1	517.9	15.69	47.	0.	39.	1.	233.3	96.0	1.02	231.7	95.6	21.52	-.01	21.33	-.01	2623.	854.	70.	64.	.022
1	518.1	15.88	48.	0.	40.	1.	238.7	95.6	1.04	237.2	95.2	22.11	-.01	21.90	-.01	2856.	847.	70.	64.	.023
1	518.2	16.06	48.	0.	40.	1.	243.0	95.3	1.05	241.5	95.0	22.57	-.01	22.34	-.01	2888.	864.	70.	64.	.023
1	518.3	16.24	50.	0.	42.	1.	245.6	95.1	1.02	244.1	94.8	22.77	-.02	22.58	-.01	2921.	819.	70.	64.	.024
1	518.5	16.41	50.	0.	42.	1.	247.4	95.0	1.02	245.9	94.7	22.89	-.02	22.69	-.01	2953.	795.	70.	64.	.024
1	518.6	16.58	51.	0.	43.	1.	246.0	95.1	1.01	244.5	94.7	22.69	-.02	22.67	-.01	2984.	763.	70.	64.	.025
1	518.7	16.71	52.	0.	44.	1.	246.0	95.1	1.01	244.5	94.8	22.95	-.02	22.72	-.01	3015.	766.	70.	64.	.026
1	518.9	16.46	53.	0.	45.	1.	197.8	97.7	.94	196.1	98.0	19.95	-.02	19.76	-.02	3062.	701.	70.	64.	.026
1	519.0	16.34	53.	0.	45.	1.	108.8	103.0	.69	107.3	103.2	13.09	-.02	13.00	-.02	3142.	756.	70.	64.	.027
1	519.2	16.24	54.	0.	46.	1.	51.3	106.9	.56	49.5	107.0	7.32	-.02	7.28	-.02	3218.	822.	70.	64.	.028
1	519.3	16.13	54.	0.	46.	1.	21.7	109.2	.50	19.6	109.3	3.69	-.02	3.64	-.01	3268.	846.	70.	64.	.028
1	519.4	16.00	54.	0.	46.	1.	25.5	109.4	.47	23.5	109.1	3.06	-.02	2.99	-.01	3297.	850.	70.	64.	.029
1	519.6	16.24	54.	0.	46.	1.	44.2	108.1	.50	42.3	107.7	4.25	-.02	4.17	-.02	3308.	867.	70.	64.	.029
1	519.7	16.47	54.	0.	46.	1.	77.3	105.7	.61	75.2	105.4	7.06	-.02	6.92	-.02	3266.	874.	70.	64.	.030
1	519.8	16.85	54.	0.	46.	1.	113.6	103.4	.73	111.7	102.9	10.38	-.02	10.20	-.01	3174.	882.	70.	64.	.030
1	520.0	17.66	55.	0.	47.	1.	166.5	100.1	1.01	164.4	99.5	14.71	-.02	14.51	-.02	3012.	909.	70.	64.	.031
1	520.1	18.80	56.	0.	48.	1.	223.9	96.7	1.49	221.5	96.0	19.36	-.02	19.09	-.01	2770.	956.	70.	64.	.032
1	520.2	18.71	56.	0.	48.	1.	246.3	95.1	1.81	243.8	94.8	21.98	-.01	21.64	-.01	2507.	971.	70.	64.	.032
1	520.4	18.42	58.	0.	50.	1.	228.7	96.1	1.64	226.6	95.8	21.54	-.02	21.25	-.01	2344.	963.	70.	64.	.033
1	520.5	18.43	58.	0.	50.	1.	216.6	96.7	1.46	214.5	96.6	20.65	-.02	20.43	-.00	2282.	972.	70.	64.	.033
1	520.6	18.78	59.	0.	51.	1.	218.8	96.7	1.37	216.7	96.2	20.58	-.02	20.35	-.00	2274.	1046.	70.	64.	.035
1	520.8	18.92	60.	0.	52.	1.	228.2	96.0	1.47	226.0	95.7	21.26	-.01	21.00	-.02	2275.	975.	70.	64.	.036
1	520.9	18.96	61.	0.	52.	1.	227.1	96.1	1.45	224.9	95.8	21.37	-.02	21.11	-.02	2281.	961.	70.	64.	.036
1	521.0	19.20	62.	0.	54.	1.	223.6	96.3	1.38	221.7	95.9	21.12	-.02	20.90	-.01	2299.	1003.	70.	64.	.037
1	521.2	19.41	62.	0.	54.	1.	233.5	95.7	1.39	231.5	95.3	21.64	-.02	21.41	-.02	2318.	1010.	70.	64.	.038
1	521.3	19.51	63.	0.	55.	1.	241.0	95.3	1.41	239.0	94.8	22.27	-.02	22.00	-.01	2335.	1024.	70.	64.	.038
1	521.4	19.70	64.	0.	56.	1.	244.5	95.0	1.40	242.4	94.6	22.65	-.02	22.40	-.02	2355.	1035.	70.	64.	.039
1	521.6	19.91	65.	0.	57.	1.	247.1	94.6	1.38	245.2	94.4	22.64	-.01	22.61	-.02	2377.	1016.	70.	64.	.040
1	521.7	20.06	66.	0.	57.	1.	247.6	94.7	1.38	245.8	94.4	22.90	-.02	22.66	-.01	2396.	1006.	70.	64.	.040
1	521.9	20.22	67.	0.	59.	1.	245.6	94.9	1.37	243.7	94.5	22.85	-.02	22.60	-.01	2416.	1018.	70.	64.	.042
1	522.0	20.39	67.	0.	59.	1.	244.3	95.0	1.35	242.4	94.6	22.81	-.01	22.57	-.01	2437.	1032.	70.	64.	.042
1	522.1	20.54	68.	0.	60.	1.	244.3	94.9	1.32	242.5	94.6	22.73	-.02	22.51	-.01	2455.	1038.	70.	64.	.043
1	522.3	20.68	69.	0.	61.	1.	241.7	95.1	1.30	240.0	94.7	22.54	-.02	22.32	-.01	2475.	1076.	70.	64.	.044
1	522.4	20.85	70.	0.	62.	1.	241.5	95.2	1.30	239.7	94.9	22.53	-.02	22.29	-.01	2493.	1094.	70.	64.	.044
1	522.5	21.01	71.	0.	62.	1.	241.5	95.1	1.28	239.7	94.8	22.56	-.01	22.32	-.01	2512.	1092.	70.	64.	.045
1	522.7	21.14	72.	0.	64.	1.	241.8	95.1	1.25	240.0	94.8	22.52	-.02	22.31	-.01	2529.	1074.	70.	64.	.046
1	522.8	21.29	72.	0.	64.	1.	243.1	95.0	1.24	241.3	94.6	22.56	-.02	22.35	-.00	2547.	1105.	70.	64.	.047
1	522.9	21.45	73.	0.	65.	1.	244.3	94.9	1.24	242.5	94.6	22.71	-.02	22.47	-.01	2566.	1106.	70.	64.	.047
1	523.1	21.59	74.	0.	66.	1.	245.0	94.8	1.23	243.2	94.6	22.81	-.02	22.57	-.01	2583.	1099.	70.	64.	.049
1	523.2	21.59	75.	0.	67.	1.	245.0	94.8	1.23	243.2	94.6	22.81	-.02	22.57	-.01	2583.	1099.	70.	64.	.049
1	523.3	21.87	76.	0.	67.	1.	244.5	94.9	1.20	242.8	94.6	22.71	-.02	22.50	-.01	2618.	1125.	70.	64.	.050
1	523.5	22.01	77.	0.	69.	1.	245.2	94.9	1.21	243.4	94.6	22.80	-.02	22.57	-.01	2635.	1110.	70.	64.	.051
1	523.6	22.16	78.	0.	69.	1.	243.7	95.0	1.19	241.9	94.7	22.75	-.01	22.53	-.01	2652.	1147.	70.	64.	.052
1	523.7	22.27	79.	0.	70.	1.	242.7	95.0	1.16	241.0	94.7	22.62	-.02	22.42	-.01	2668.	1118.	70.	64.	.053
1	523.9	22.40	79.	0.	71.	1.	243.1	95.0	1.16	241.4	94.7	22.60	-.02	22.39	-.01	2684.	1073.	70.	64.	.053
1	524.0	22.54	80.	0.	72.	1.	242.6	95.1	1.15	240.9	94.7	22.62	-.02	22.40	-.01	2701.	1146.	70.	64.	.054
1	524.1	22.67	81.	0.	73.	1.	242.0	95.1	1.14	240.2	94.8	22.63	-.02	22.41	-.02	2716.	1161.	70.	64.	.055
1	524.3	22.80	82.	0.	74.	1.	241.1	95.1	1.12	239.5	94.8	22.50	-.02	22.30	-.01	2732.	1195.	70.	64.	.056
1	524.4	22.93	83.	0.	74.	1.	239.7	95.3	1.11	238.0	94.9	22.37	-.02	22.17	-.01	2748.	1169.	70.	64.	.057
1	524.6	23.05	84.	0.	75.	1.	240.0	95.3	1.12	238.3	95.0	22.44	-.02	22.20	-.00	2762.	1076.	70.	64.	.058
1	524.7	23.15	84.	0.	76.	1.	238.6	95.3	1.10	236.9	95.0	22.39	-.01	22.17	-.00	2777.	1108.	70.	64.	.059

Figure B-1. (contd)

IDAC TAPE M660R TEST NO. 31 DAY 52 09:56:13 SITE NO.=4.0 IDAC SITE= 4

TAMB = 669.349 DEG F PAMB = 14.059 PSIA TEST DATA START 09:56:18

RUN	TIME	MPH	EBO	EBI	EMI	EMO	BAMP	BVOLT	MFLDI	MAMP	MVOLT	PBO	PBI	PMI	PMO	MRPM	USS	HTEMP	MTEMP	DIST
				MPH									KW							
1	524.8	23.28	85.	0.	77.	1.	236.7	95.5	1.07	235.1	95.2	22.18	-.02	22.00	-.02	2792.	1193.	70.	64.	.059
1	525.0	23.40	86.	0.	78.	1.	236.1	95.5	1.07	234.6	95.2	22.10	-.02	21.90	-.01	2807.	1137.	70.	64.	.060
1	525.1	23.52	87.	0.	78.	1.	235.9	95.6	1.08	234.2	95.2	22.13	-.02	21.90	-.02	2820.	1134.	70.	64.	.061
1	525.2	23.63	87.	0.	79.	1.	234.8	95.7	1.06	233.2	95.3	22.10	-.01	21.87	-.01	2835.	1087.	70.	64.	.062
1	525.4	23.73	89.	0.	80.	1.	234.5	95.7	1.05	232.8	95.3	21.99	-.02	21.81	-.01	2846.	1079.	70.	64.	.063
1	525.5	23.85	89.	0.	81.	1.	234.2	95.7	1.04	232.6	95.3	21.93	-.02	21.74	-.01	2862.	1116.	70.	64.	.064
1	525.6	23.96	90.	0.	81.	1.	232.5	95.8	1.03	231.0	95.5	21.88	-.02	21.67	-.01	2875.	1117.	70.	64.	.064
1	525.8	24.06	91.	0.	83.	1.	231.3	95.9	1.02	229.8	95.6	21.84	-.02	21.63	-.01	2888.	1163.	70.	64.	.066
1	525.9	24.17	92.	0.	83.	1.	231.2	95.9	1.01	229.6	95.6	21.75	-.02	21.56	-.01	2901.	1207.	70.	64.	.066
1	526.0	24.28	92.	0.	84.	1.	230.2	96.0	1.00	228.7	95.6	21.64	-.02	21.45	-.01	2914.	1163.	70.	64.	.067
1	526.2	24.37	94.	0.	85.	1.	228.3	96.1	1.00	226.7	95.8	21.56	-.02	21.35	-.01	2926.	1172.	70.	64.	.068
1	526.3	24.48	94.	0.	86.	1.	228.1	96.1	.99	226.5	95.8	21.57	-.02	21.36	-.01	2939.	1146.	70.	64.	.069
1	526.4	24.58	95.	0.	87.	1.	227.8	96.2	.98	226.2	95.8	21.50	-.02	21.31	-.02	2951.	1123.	70.	64.	.070
1	526.6	24.67	96.	0.	87.	1.	226.1	96.3	.97	224.5	95.9	21.32	-.02	21.14	-.02	2962.	1137.	70.	64.	.071
1	526.7	24.72	97.	0.	88.	1.	221.5	96.6	.99	219.7	96.4	21.05	-.02	20.84	-.01	2974.	1115.	70.	64.	.072
1	526.8	24.35	98.	0.	89.	1.	165.8	99.7	.87	164.2	99.9	17.47	-.02	17.29	-.01	3002.	1154.	70.	64.	.073
1	527.0	24.20	98.	0.	89.	1.	100.9	103.7	.67	99.2	103.9	12.04	-.02	11.95	-.02	3067.	1237.	70.	64.	.074
1	527.1	24.18	98.	0.	89.	1.	60.7	106.4	.58	58.9	106.5	7.77	-.02	7.71	-.02	3135.	1206.	70.	64.	.075
1	527.3	24.07	98.	0.	90.	1.	41.2	107.9	.54	39.3	107.9	5.29	-.02	5.22	-.02	3189.	1214.	70.	64.	.076
1	527.4	23.89	98.	0.	90.	1.	30.5	108.9	.51	28.4	108.8	3.85	-.02	3.76	-.02	3228.	1249.	70.	64.	.077
1	527.5	23.84	98.	0.	90.	1.	32.0	108.9	.50	30.0	108.7	3.55	-.02	3.48	-.03	3257.	1261.	70.	64.	.077
1	527.7	23.85	99.	0.	90.	1.	46.9	108.0	.51	44.9	107.7	4.57	-.02	4.47	-.02	3276.	1271.	70.	64.	.079
1	527.8	24.06	99.	0.	90.	1.	69.1	106.5	.57	67.2	106.1	6.54	-.03	6.39	-.02	3267.	1274.	70.	64.	.079
1	527.9	24.37	99.	0.	91.	1.	99.4	104.5	.71	97.5	104.1	9.26	-.02	9.10	-.02	3190.	1286.	70.	64.	.080
1	528.1	24.69	100.	0.	91.	1.	133.4	102.4	.90	131.3	101.9	12.21	-.02	12.04	-.02	3031.	1295.	70.	64.	.081
1	528.2	25.13	100.	0.	92.	1.	177.0	99.7	1.25	174.7	99.1	15.87	-.02	15.63	-.02	2807.	1294.	70.	64.	.082
1	528.3	25.65	101.	0.	92.	1.	228.5	96.6	1.82	225.8	96.0	20.12	-.02	19.78	-.02	2533.	1279.	70.	64.	.083
1	528.5	25.63	102.	0.	93.	1.	250.5	95.2	2.24	247.3	95.1	22.42	-.02	22.06	-.01	2263.	1273.	70.	64.	.084
1	528.6	25.50	103.	0.	94.	1.	219.2	96.9	1.88	216.8	96.6	20.98	-.02	20.70	-.01	2109.	1266.	69.	64.	.085
1	528.7	25.57	103.	0.	95.	1.	208.8	97.6	1.72	206.3	97.3	20.17	-.01	19.89	-.01	2042.	1306.	70.	64.	.086
1	528.9	25.79	104.	0.	96.	1.	212.3	97.4	1.76	209.6	97.1	20.27	-.02	19.97	-.01	2018.	1342.	70.	64.	.087
1	529.0	25.82	105.	0.	96.	1.	217.8	97.1	1.74	215.3	96.8	20.59	-.02	20.31	-.01	2007.	1313.	70.	64.	.088
1	529.1	25.92	106.	0.	97.	1.	220.8	96.9	1.71	218.3	96.5	20.80	-.02	20.53	-.01	2006.	1297.	70.	64.	.089
1	529.3	26.10	107.	0.	98.	1.	228.3	96.5	1.74	225.8	96.0	21.34	-.02	21.06	-.02	2011.	1305.	69.	64.	.090
1	529.4	26.20	107.	0.	99.	1.	237.4	95.9	1.79	234.7	95.6	22.08	-.02	21.76	-.02	2017.	1343.	70.	64.	.091
1	529.5	26.31	109.	0.	100.	1.	240.2	96.1	1.75	237.8	95.4	22.42	-.02	22.12	-.01	2024.	1374.	70.	64.	.092
1	529.7	26.46	109.	0.	100.	1.	241.7	95.6	1.74	239.3	95.2	22.52	-.02	22.26	-.02	2034.	1346.	70.	64.	.093
1	529.8	26.58	110.	0.	101.	1.	243.6	95.5	1.75	241.3	95.1	22.69	-.02	22.40	-.01	2042.	1334.	70.	64.	.093
1	530.0	26.67	111.	0.	102.	1.	245.8	95.3	1.76	243.4	95.0	22.92	-.02	22.62	-.02	2051.	1358.	70.	64.	.095
1	530.1	26.81	112.	0.	103.	1.	247.6	95.3	1.76	245.2	94.9	23.11	-.01	22.81	-.01	2061.	1368.	70.	64.	.096
1	530.2	26.94	112.	0.	104.	1.	248.2	95.2	1.75	245.9	94.9	23.12	-.01	22.86	-.02	2070.	1363.	70.	64.	.096
1	530.4	27.05	114.	0.	105.	1.	248.3	95.2	1.74	245.9	94.9	23.11	-.01	22.83	-.02	2079.	1385.	70.	64.	.098
1	530.5	27.18	114.	0.	106.	1.	248.8	95.2	1.74	246.5	94.9	23.21	-.02	22.91	-.02	2088.	1374.	70.	64.	.099
1	530.6	27.30	115.	0.	106.	1.	249.3	95.2	1.70	246.9	94.9	23.29	-.02	22.99	-.02	2097.	1446.	70.	64.	.099
1	530.8	27.40	116.	0.	107.	1.	249.1	95.2	1.70	246.7	94.9	23.22	-.01	22.95	-.01	2106.	1469.	70.	64.	.101
1	530.9	27.52	117.	0.	108.	1.	248.7	95.2	1.66	246.4	94.8	23.16	-.01	22.69	-.02	2115.	1486.	70.	64.	.102
1	531.0	27.63	118.	0.	109.	1.	247.4	95.3	1.69	245.2	95.0	23.13	-.01	22.84	-.01	2123.	1448.	70.	64.	.103
1	531.2	27.75	119.	0.	110.	1.	246.8	95.3	1.67	244.5	95.0	23.14	-.02	22.85	-.02	2132.	1402.	70.	64.	.104
1	531.3	27.86	119.	0.	111.	1.	246.4	95.3	1.65	244.1	95.1	23.06	-.02	22.80	-.02	2141.	1426.	70.	64.	.105
1	531.4	27.96	120.	0.	111.	1.	245.0	95.4	1.63	242.7	95.1	22.91	-.01	22.65	-.02	2149.	1392.	70.	64.	.106
1	531.6	28.07	121.	0.	113.	1.	243.7	95.5	1.62	241.5	95.2	22.87	-.02	22.59	-.01	2156.	1393.	70.	64.	.107

Figure B-1. (contd)

IDAC TAPE W660R   TEST NO. 31   DAY 52   09:56:13   SITE NO.=4.0   IDAC SITE= 4
TAMB = 670.060 DEG F   PAMB = 14.057 PSIA   TEST DATA START 09:56:16

RUN	TIME	MPH	EHU	EHI	EMI	EMO	BAMP	BVOLT	MFLDI	MAMP	MVOLT	PRO	PRI	PMI	PMO	RPM	DSS	ATEMP	MTEMP	DIST
				MPH									KW							
1	531.7	28.17	122.	0.	113.	1.	243.4	95.6	1.62	241.2	95.3	22.88	-.02	22.60	-.02	2166.	1433.	70.	64.	.108
1	531.8	28.28	123.	0.	114.	1.	244.0	95.5	1.60	241.6	95.2	22.87	-.02	22.61	-.01	2174.	1411.	70.	64.	.110
1	532.0	28.38	124.	0.	115.	1.	243.2	95.6	1.58	241.0	95.2	22.75	-.02	22.50	-.02	2181.	1430.	70.	64.	.110
1	532.1	28.47	125.	0.	116.	1.	243.3	95.6	1.58	241.0	95.3	22.77	-.02	22.50	-.02	2189.	1424.	70.	64.	.111
1	532.2	28.57	126.	0.	117.	1.	243.0	95.6	1.58	240.7	95.3	22.82	-.02	22.53	-.02	2197.	1446.	70.	64.	.113
1	532.4	28.68	126.	0.	118.	1.	242.2	95.6	1.56	240.6	95.3	22.77	-.02	22.51	-.02	2205.	1450.	70.	64.	.113
1	532.5	28.78	127.	0.	118.	1.	241.7	95.7	1.54	239.5	95.4	22.66	-.02	22.42	-.01	2213.	1464.	70.	64.	.114
1	532.7	28.87	128.	0.	119.	1.	241.9	95.7	1.54	239.7	95.3	22.67	-.02	22.40	-.01	2220.	1504.	70.	64.	.116
1	532.8	28.97	129.	0.	120.	1.	242.0	95.7	1.55	239.8	95.4	22.74	-.02	22.45	-.01	2228.	1411.	70.	64.	.117
1	532.9	29.07	130.	0.	121.	1.	241.5	95.8	1.53	239.2	95.4	22.71	-.02	22.44	-.01	2236.	1452.	70.	64.	.118
1	533.1	29.16	131.	0.	122.	1.	241.1	95.8	1.50	238.9	95.4	22.61	-.02	22.37	-.02	2243.	1393.	70.	64.	.119
1	533.2	29.25	131.	0.	123.	1.	241.4	95.7	1.51	239.3	95.4	22.63	-.02	22.37	-.02	2250.	1459.	70.	64.	.120
1	533.3	29.36	132.	0.	123.	1.	241.8	95.8	1.51	239.6	95.4	22.72	-.02	22.44	-.02	2257.	1479.	70.	64.	.121
1	533.5	29.44	133.	0.	124.	1.	243.7	95.9	1.49	241.5	95.3	22.67	-.02	22.60	-.01	2264.	1434.	70.	64.	.122
1	533.6	29.54	134.	0.	125.	1.	244.1	95.6	1.49	242.0	95.3	22.63	-.02	22.59	-.01	2272.	1395.	70.	64.	.123
1	533.7	29.63	135.	0.	126.	1.	244.5	95.5	1.49	242.4	95.2	22.67	-.02	22.61	-.01	2279.	1416.	70.	64.	.124
1	533.9	29.72	136.	0.	127.	1.	245.2	95.6	1.49	243.1	95.2	22.99	-.02	22.71	-.01	2286.	1458.	70.	64.	.126
1	534.0	29.82	137.	0.	128.	1.	246.3	95.5	1.47	244.2	95.1	23.08	-.02	22.82	-.01	2293.	1424.	70.	64.	.127
1	534.1	29.90	137.	0.	128.	1.	247.1	95.4	1.46	245.0	95.1	23.07	-.01	22.84	-.01	2301.	1435.	70.	64.	.127
1	534.3	30.00	139.	0.	129.	1.	248.1	95.4	1.47	245.9	95.0	23.14	-.01	22.89	-.02	2308.	1455.	70.	64.	.129
1	534.4	30.09	139.	0.	130.	1.	249.2	95.4	1.48	247.1	95.0	23.31	-.02	23.02	-.02	2315.	1435.	70.	64.	.130
1	534.5	30.19	140.	0.	131.	1.	249.3	95.4	1.47	247.3	95.0	23.32	-.02	23.07	-.01	2322.	1480.	70.	64.	.132
1	534.7	30.27	141.	0.	132.	1.	249.0	95.4	1.45	247.0	95.0	23.23	-.02	22.99	-.02	2328.	1530.	70.	64.	.132
1	534.8	30.35	142.	0.	133.	1.	246.0	95.4	1.45	246.0	95.0	23.19	-.02	22.93	-.01	2335.	1569.	70.	64.	.133
1	534.9	30.45	143.	0.	134.	1.	247.7	95.5	1.44	245.7	95.1	23.23	-.01	22.96	-.02	2342.	1522.	70.	64.	.135
1	535.1	30.54	144.	0.	135.	1.	247.3	95.4	1.43	245.3	95.1	23.20	-.02	22.95	-.02	2350.	1495.	70.	64.	.136
1	535.2	30.62	144.	0.	135.	1.	247.3	95.5	1.43	245.3	95.1	23.11	-.02	22.88	-.02	2356.	1440.	70.	64.	.137
1	535.4	30.43	146.	0.	136.	1.	236.5	96.1	1.46	234.1	96.2	22.46	-.02	22.18	-.01	2365.	1339.	70.	64.	.138
1	535.5	30.08	146.	0.	137.	1.	136.1	101.7	1.08	136.3	102.1	15.90	-.02	15.73	-.01	2427.	1377.	70.	64.	.139
1	535.6	29.97	146.	0.	137.	1.	71.5	106.0	.81	69.6	106.2	9.60	-.02	9.51	-.02	2510.	1522.	70.	64.	.140
1	535.8	29.93	146.	0.	137.	1.	36.1	108.6	.71	33.9	108.7	5.34	-.02	5.29	-.02	2592.	1528.	70.	64.	.142
1	535.9	29.76	147.	0.	137.	1.	19.2	110.1	.67	17.0	110.1	2.95	-.02	2.88	-.02	2640.	1548.	70.	64.	.142
1	536.0	29.62	147.	0.	137.	1.	11.3	110.9	.65	9.0	110.8	1.76	-.03	1.69	-.02	2667.	1521.	70.	64.	.143
1	536.2	29.55	147.	0.	137.	1.	13.2	111.0	.62	10.9	110.8	1.50	-.02	1.48	-.02	2681.	1535.	70.	64.	.145
1	536.3	29.43	147.	0.	138.	1.	19.8	110.6	.62	17.0	110.3	1.96	-.02	1.86	-.02	2691.	1461.	70.	64.	.146
1	536.4	29.43	147.	0.	138.	1.	19.8	110.6	.62	17.0	110.3	1.96	-.02	1.85	-.02	2691.	1401.	70.	64.	.147
1	536.6	29.73	147.	0.	138.	1.	57.1	106.0	.80	54.8	107.6	5.19	-.02	5.03	-.02	2601.	1461.	70.	64.	.148
1	536.7	29.99	147.	0.	138.	1.	101.0	105.1	1.11	96.5	104.5	8.98	-.02	8.80	-.01	2531.	1424.	70.	64.	.149
1	536.8	30.27	148.	0.	138.	1.	155.0	101.7	1.65	152.2	101.0	13.63	-.02	13.35	-.02	2324.	1466.	70.	64.	.150
1	537.0	30.58	149.	0.	139.	1.	219.4	97.7	2.54	215.6	97.1	19.06	-.02	18.63	-.02	2075.	1450.	70.	64.	.152
1	537.1	30.57	149.	0.	140.	1.	234.1	96.7	2.96	230.0	96.5	21.27	-.02	20.80	-.01	1852.	1507.	70.	64.	.152
1	537.2	30.51	150.	0.	141.	1.	210.9	97.9	2.69	207.5	97.7	20.27	-.02	19.90	-.02	1730.	1540.	70.	64.	.154
1	537.4	30.56	151.	0.	142.	1.	196.2	98.8	2.61	192.5	98.6	19.23	-.02	18.85	-.02	1675.	1500.	70.	64.	.155
1	537.5	30.63	151.	0.	142.	1.	179.7	99.6	2.55	176.1	99.6	18.01	-.02	17.62	-.01	1650.	1520.	70.	64.	.156
1	537.6	30.60	152.	0.	143.	1.	163.2	100.7	2.47	159.5	100.6	16.56	-.01	16.22	-.02	1630.	1533.	70.	64.	.157
1	537.8	30.60	153.	0.	143.	1.	141.4	102.0	2.38	137.8	101.9	14.67	-.02	14.35	-.02	1631.	1520.	70.	64.	.158
1	537.9	30.60	153.	0.	144.	1.	124.1	103.1	2.30	120.4	103.0	13.08	-.02	12.75	-.01	1627.	1555.	70.	64.	.159
1	538.1	30.55	154.	0.	144.	1.	114.1	103.9	2.25	110.4	103.7	12.03	-.01	11.71	-.01	1624.	1552.	70.	64.	.161
1	538.2	30.54	154.	0.	145.	1.	103.1	104.5	2.18	99.4	104.4	10.69	-.02	10.60	-.01	1622.	1565.	70.	64.	.162
1	538.3	30.48	154.	0.	145.	1.	93.6	105.2	2.16	90.1	105.0	9.91	-.02	9.62	-.02	1622.	1563.	70.	64.	.163
1	538.5	30.42	155.	0.	146.	1.	85.7	105.6	2.15	82.0	105.5	9.15	-.02	8.83	-.02	1610.	1557.	70.	64.	.164

Figure B-1. (contd)

IDAC TAPE #660R TEST NO. 31 DAY 52 09:56:13 SITE NO.=4.0 IDAC SITE= 4
TAMB = 670.557 DEG F PAMB = 14.059 PSIA TEST DATA START 09:56:18

RUN	TIME	MPH	EBO	EHI	EMI	EMO	BAMP	BVOLT	MFLDI	MAMP	MVOLT	PRO	PRI	PMI	PMO	MRPM	USS	ATEMP	MTEMP	MIST
1	538.6	30.42	155.	0.	146.	1.	78.2	106.2	2.09	74.7	106.1	8.44	-.02	8.13	-.02	1616.	1573.	70.	64.	.165
1	538.7	30.37	155.	0.	146.	1.	75.7	106.4	2.06	72.0	106.3	7.95	-.02	7.69	-.01	1615.	1597.	70.	64.	.166
1	538.9	30.34	156.	0.	146.	1.	73.3	106.6	2.06	69.7	106.4	7.65	-.03	7.37	-.01	1613.	1559.	70.	64.	.168
1	539.0	30.29	156.	0.	147.	1.	71.5	106.9	2.09	67.9	106.6	7.54	-.02	7.22	-.02	1611.	1515.	70.	64.	.168
1	539.1	30.25	156.	0.	147.	1.	69.0	106.9	2.08	65.3	106.8	7.30	-.02	7.06	-.02	1609.	1526.	70.	64.	.169
1	539.3	30.21	157.	0.	147.	1.	66.5	107.1	2.08	62.8	107.0	6.95	-.02	6.67	-.02	1606.	1571.	70.	64.	.171
1	539.4	30.15	157.	0.	147.	1.	62.6	107.4	2.13	56.7	107.3	6.60	-.02	6.29	-.01	1604.	1590.	70.	64.	.172
1	539.5	30.06	157.	0.	147.	1.	51.0	108.2	2.18	47.1	108.1	5.71	-.02	5.38	-.01	1601.	1593.	70.	64.	.173
1	539.7	29.97	157.	0.	148.	1.	39.0	109.1	2.17	35.1	109.0	4.52	-.02	4.23	-.01	1597.	1590.	70.	64.	.174
1	539.8	29.88	157.	0.	148.	1.	31.6	109.6	2.17	27.7	109.6	3.55	-.02	3.27	-.02	1591.	1587.	70.	64.	.175
1	539.9	29.78	157.	0.	148.	1.	27.2	110.1	2.19	23.2	109.9	3.03	-.02	2.71	-.02	1587.	1560.	70.	64.	.177
1	540.1	29.69	157.	0.	148.	1.	25.3	110.3	2.21	21.4	110.2	2.83	-.02	2.49	-.01	1582.	1544.	70.	64.	.178
1	540.2	29.59	158.	0.	148.	1.	28.4	110.1	2.12	24.5	109.9	2.93	-.02	2.64	-.02	1577.	1516.	70.	64.	.179
1	540.3	29.57	158.	0.	148.	1.	39.6	109.3	2.03	35.9	109.0	3.79	-.02	3.51	-.02	1576.	1543.	70.	64.	.180
1	540.5	29.56	158.	0.	148.	1.	60.9	107.9	2.01	57.4	107.5	5.73	-.02	5.40	-.02	1574.	1486.	70.	64.	.161
1	540.6	29.62	158.	0.	149.	1.	85.6	106.2	2.04	82.0	105.8	8.08	-.02	7.75	-.01	1573.	1485.	70.	64.	.182
1	540.8	29.69	159.	0.	149.	1.	110.4	104.6	2.08	106.9	104.1	10.34	-.01	10.04	-.01	1574.	1550.	70.	64.	.183
1	540.9	29.78	159.	0.	150.	1.	135.9	102.9	2.18	132.5	102.5	12.71	-.02	12.37	-.01	1577.	1532.	70.	64.	.184
1	541.0	29.82	160.	0.	150.	1.	158.2	101.6	2.31	154.6	101.2	14.69	-.02	14.51	-.02	1579.	1509.	70.	64.	.185
1	541.2	29.91	160.	0.	151.	1.	172.7	100.6	2.37	169.3	100.3	16.39	-.01	16.02	-.01	1582.	1534.	70.	64.	.187
1	541.3	29.99	161.	0.	151.	1.	180.8	100.0	2.43	177.3	99.7	17.21	-.02	16.86	-.01	1585.	1534.	70.	64.	.188
1	541.4	30.06	161.	0.	152.	1.	185.3	99.8	2.49	181.7	99.4	17.77	-.01	17.40	-.01	1588.	1531.	70.	64.	.188
1	541.6	30.14	162.	0.	153.	1.	186.3	99.7	2.51	182.7	99.3	18.07	-.02	17.69	-.01	1592.	1505.	70.	64.	.190
1	541.7	30.20	163.	0.	153.	1.	186.1	99.6	2.47	182.5	99.3	18.07	-.02	17.72	-.01	1595.	1539.	70.	64.	.191
1	541.8	30.28	163.	0.	154.	1.	187.0	99.5	2.44	183.5	99.2	18.09	-.02	17.75	-.02	1599.	1578.	70.	64.	.192
1	542.0	30.35	164.	0.	155.	1.	187.9	99.4	2.45	184.3	99.1	18.23	-.02	17.87	-.01	1602.	1590.	70.	64.	.193
1	542.1	30.41	165.	0.	155.	1.	186.7	99.4	2.44	185.2	99.1	18.36	-.01	18.00	-.01	1606.	1521.	70.	64.	.194
1	542.2	30.47	165.	0.	156.	1.	188.2	99.4	2.43	184.6	99.1	18.28	-.01	17.95	-.01	1609.	1566.	70.	64.	.195
1	542.4	30.54	167.	0.	157.	1.	184.7	99.6	2.44	181.2	99.3	18.00	-.01	17.65	-.01	1613.	1558.	70.	64.	.197
1	542.5	30.59	167.	0.	157.	1.	178.7	100.0	2.45	175.1	99.6	17.64	-.01	17.26	-.02	1617.	1561.	70.	64.	.198
1	542.6	30.63	168.	0.	158.	1.	170.1	100.5	2.41	166.5	100.3	17.00	-.02	16.65	-.01	1619.	1571.	70.	64.	.199
1	542.8	30.65	168.	0.	159.	1.	161.5	101.0	2.36	157.9	100.8	16.18	-.02	15.86	-.01	1620.	1527.	70.	64.	.200
1	542.9	30.68	169.	0.	159.	1.	147.6	101.8	2.35	144.0	101.7	15.04	-.02	14.72	-.01	1622.	1541.	70.	64.	.201
1	543.0	30.67	170.	0.	160.	1.	130.2	103.0	2.28	126.6	102.8	13.06	-.01	13.31	-.02	1623.	1591.	70.	64.	.203
1	543.2	30.65	170.	0.	160.	1.	116.3	103.8	2.19	112.8	103.7	12.33	-.02	12.01	-.01	1623.	1611.	70.	64.	.204
1	543.3	30.62	170.	0.	160.	1.	106.3	104.5	2.12	102.7	104.3	11.18	-.02	10.92	-.01	1624.	1589.	70.	64.	.204
1	543.5	30.58	171.	0.	161.	1.	99.3	104.9	2.09	95.7	104.8	10.42	-.01	10.12	-.01	1622.	1572.	70.	64.	.206
1	543.6	30.56	171.	0.	161.	1.	95.0	105.2	2.08	91.5	105.1	10.00	-.02	9.67	-.01	1621.	1557.	70.	64.	.207
1	543.7	30.53	171.	0.	161.	1.	91.9	105.5	2.07	88.3	105.3	9.61	-.02	9.32	-.01	1621.	1540.	70.	64.	.208
1	543.9	30.53	172.	0.	162.	1.	89.9	105.7	2.06	86.3	105.5	9.28	-.02	9.01	-.02	1619.	1538.	70.	64.	.210
1	544.0	30.52	172.	0.	162.	1.	87.4	105.8	2.06	83.9	105.6	9.09	-.03	8.78	-.02	1619.	1536.	70.	64.	.210
1	544.1	30.49	172.	0.	162.	1.	87.0	105.8	2.06	83.4	105.7	9.07	-.02	8.75	-.01	1616.	1522.	70.	64.	.211
1	544.3	30.46	173.	0.	163.	1.	86.8	105.8	2.05	83.3	105.7	8.97	-.02	8.68	-.02	1617.	1496.	70.	64.	.213
1	544.4	30.45	173.	0.	163.	1.	86.3	106.0	2.05	82.8	105.7	8.87	-.02	8.58	-.02	1616.	1483.	70.	64.	.214
1	544.5	30.44	173.	0.	163.	1.	85.6	106.0	2.06	82.1	105.8	8.67	-.02	8.55	-.01	1615.	1466.	70.	64.	.215
1	544.7	30.41	174.	0.	164.	1.	85.7	106.0	2.06	82.1	105.8	8.89	-.02	8.56	-.01	1613.	1431.	70.	64.	.216
1	544.8	30.38	174.	0.	164.	1.	84.5	106.1	2.04	80.9	105.9	8.71	-.01	8.44	-.01	1613.	1469.	70.	64.	.217
1	544.9	30.36	174.	0.	164.	1.	81.9	106.2	2.05	78.3	106.1	8.47	-.01	8.19	-.01	1612.	1500.	70.	64.	.218
1	545.1	30.32	175.	0.	165.	1.	79.2	106.5	2.07	75.6	106.3	8.31	-.02	7.98	-.01	1611.	1509.	70.	64.	.220
1	545.2	30.30	175.	0.	165.	1.	76.4	106.6	2.07	72.6	106.5	8.06	-.02	7.75	-.02	1609.	1594.	70.	64.	.221
1	545.3	30.27	175.	0.	165.	1.	74.7	106.8	2.06	71.0	106.6	7.75	-.02	7.48	-.02	1607.	1558.	70.	64.	.222

Figure B-1. (contd)

IDAC TAPE W660R TEST NO. 31 DAY 52 09:56:13 SITE NO.84.0 IDAC SITE# 4
TAMB = 671.054 DEG F PAMB = 14.059 PSIA TEST DATA START 09:56:18

RUN	TIME	MPH	EAU	EAI KWH	EMI	EMO	BAMP	BVOLT	MFLDI	MAMP	MVOLT	PBO	PAI KW	PMI	PMO	MRPM	JSS	ETEMP	MTEMP	DIST
1	545.5	30.22	176.	0.	166.	1.	73.3	106.9	2.06	69.7	106.7	7.62	-.02	7.31	-.01	1605.	1586.	70.	64.	.223
1	545.6	30.20	176.	0.	166.	1.	73.0	106.9	2.07	69.4	106.7	7.63	-.02	7.31	-.01	1603.	1569.	70.	64.	.224
1	545.7	30.16	176.	0.	166.	1.	73.6	106.9	2.06	69.9	106.7	7.65	-.02	7.35	-.02	1602.	1561.	70.	64.	.226
1	545.9	30.14	176.	0.	166.	1.	73.6	106.8	2.05	70.1	106.7	7.57	-.02	7.29	-.02	1601.	1590.	70.	64.	.226
1	546.0	30.11	177.	0.	167.	1.	74.2	106.8	2.07	70.5	106.5	7.63	-.02	7.32	-.01	1599.	1556.	70.	64.	.227
1	546.2	30.08	177.	0.	167.	1.	74.1	106.9	2.09	70.5	106.7	7.74	-.01	7.41	-.01	1597.	1540.	70.	64.	.229
1	546.3	30.05	177.	0.	167.	1.	74.1	106.8	2.09	70.4	106.6	7.69	-.02	7.39	-.02	1596.	1537.	70.	64.	.230
1	546.4	30.03	178.	0.	167.	1.	73.9	107.0	2.10	70.2	106.7	7.60	-.02	7.36	-.02	1595.	1502.	70.	64.	.231
1	546.6	29.99	178.	0.	166.	1.	74.2	106.9	2.11	70.4	106.7	7.66	-.02	7.34	-.02	1593.	1505.	70.	64.	.232
1	546.7	29.96	178.	0.	168.	1.	75.1	106.8	2.11	71.3	106.6	7.80	-.02	7.47	-.02	1590.	1512.	70.	64.	.233
1	546.8	29.94	178.	0.	168.	1.	75.9	106.6	2.10	72.3	106.6	7.81	-.02	7.51	-.02	1590.	1517.	70.	64.	.234
1	547.0	29.91	179.	0.	169.	1.	76.2	106.6	2.11	72.6	106.5	7.89	-.02	7.56	-.02	1586.	1553.	70.	64.	.236
1	547.1	29.88	179.	0.	169.	1.	76.5	106.7	2.15	72.7	106.5	7.92	-.01	7.56	-.02	1587.	1530.	70.	64.	.236
1	547.2	29.87	179.	0.	169.	1.	76.0	106.7	2.14	72.3	106.6	7.94	-.02	7.60	-.01	1585.	1513.	70.	64.	.237
1	547.4	29.83	180.	0.	170.	1.	76.2	106.7	2.12	72.5	106.5	7.84	-.01	7.56	-.01	1584.	1550.	70.	64.	.239
1	547.5	29.82	180.	0.	170.	1.	76.9	106.7	2.12	73.2	106.5	7.88	-.02	7.58	-.02	1582.	1570.	70.	64.	.240
1	547.6	29.79	180.	0.	170.	1.	79.0	106.6	2.14	75.3	106.4	6.14	-.01	7.80	-.01	1581.	1474.	70.	64.	.241
1	547.8	29.78	181.	0.	170.	1.	84.2	106.3	2.13	80.5	106.0	8.56	-.02	8.26	-.02	1581.	1561.	70.	64.	.242
1	547.9	29.80	181.	0.	171.	1.	93.5	105.7	2.11	89.7	105.4	9.24	-.02	8.94	-.02	1581.	1551.	70.	64.	.243
1	548.0	29.85	181.	0.	171.	1.	105.2	105.0	2.12	101.7	104.6	10.33	-.02	10.09	-.02	1582.	1565.	70.	64.	.245
1	548.2	29.88	182.	0.	172.	1.	117.1	104.2	2.19	113.6	103.9	11.52	-.02	11.17	-.01	1582.	1521.	70.	64.	.246
1	548.3	29.91	182.	0.	172.	1.	124.0	103.7	2.20	120.5	103.4	12.26	-.02	11.94	-.01	1584.	1520.	70.	64.	.246
1	548.4	29.94	183.	0.	173.	1.	129.8	103.3	2.24	126.3	103.1	12.76	-.02	12.46	-.02	1585.	1558.	70.	64.	.248
1	548.6	29.98	183.	0.	173.	1.	131.2	103.2	2.29	127.6	103.0	13.07	-.02	12.72	-.02	1586.	1570.	70.	64.	.249
1	548.7	29.95	184.	0.	173.	1.	115.3	104.1	2.50	111.3	104.2	12.09	-.01	11.71	-.01	1580.	1539.	70.	64.	.250
1	548.9	29.76	184.	0.	174.	1.	63.0	107.4	2.52	59.0	107.6	7.86	-.02	7.55	-.01	1582.	1559.	70.	64.	.251
1	549.0	29.60	184.	0.	174.	1.	24.0	110.2	2.49	19.8	110.3	3.87	-.02	3.57	-.01	1574.	1542.	70.	64.	.252
1	549.1	29.44	184.	0.	174.	1.	5.2	112.0	2.56	.7	112.0	1.81	.29	1.54	.47	1564.	1504.	70.	64.	.253
1	549.3	29.29	184.	1.	174.	1.	-8.3	113.4	2.54	-12.7	113.3	.79	.88	.60	1.23	1559.	1509.	70.	64.	.255
1	549.4	29.12	184.	1.	174.	1.	-11.1	113.8	2.59	-15.7	113.8	.38	1.27	.27	1.62	1554.	1534.	70.	64.	.255
1	549.5	29.00	184.	1.	174.	1.	-12.6	114.1	2.62	-17.2	113.9	.27	1.47	.15	1.90	1549.	1539.	70.	64.	.256
1	549.7	29.00	184.	1.	174.	1.	-12.6	114.1	2.62	-17.2	113.9	.27	1.47	.15	1.90	1549.	1539.	70.	64.	.256
1	549.8	28.74	184.	1.	174.	1.	-10.9	114.1	2.73	-15.7	114.0	.24	1.36	.07	1.70	1535.	1535.	70.	64.	.259
1	549.9	28.61	184.	1.	174.	1.	-10.1	114.1	2.75	-14.9	114.0	.23	1.36	.10	1.70	1529.	1546.	70.	64.	.259
1	550.1	28.48	184.	1.	174.	1.	-9.1	114.0	2.81	-13.9	113.9	.23	1.31	.06	1.71	1522.	1548.	70.	64.	.261
1	550.2	28.36	184.	1.	174.	1.	-7.3	113.9	2.87	-12.1	113.8	.33	1.12	.12	1.40	1515.	1499.	70.	64.	.262
1	550.3	28.24	184.	1.	174.	2.	-5.2	113.8	2.90	-10.1	113.6	.36	1.02	.12	1.30	1509.	1490.	70.	64.	.263
1	550.5	28.14	184.	1.	174.	2.	-3.7	113.6	2.93	-8.6	113.5	.39	.94	.10	1.20	1503.	1451.	70.	64.	.264
1	550.6	28.03	184.	1.	174.	2.	-1.7	113.6	3.00	-6.7	113.3	.50	.82	.23	1.10	1497.	1431.	70.	64.	.265
1	550.7	27.91	184.	1.	174.	2.	.1	113.4	3.04	-5.0	113.3	.64	.64	.31	.92	1491.	1453.	70.	64.	.266
1	550.9	27.80	184.	1.	174.	2.	2.2	113.1	3.06	-2.9	113.0	.73	.56	.45	.73	1484.	1476.	70.	64.	.267
1	551.0	27.72	184.	1.	174.	2.	3.9	113.0	3.09	-1.2	112.9	.79	.45	.46	.05	1479.	1509.	70.	64.	.267
1	551.1	27.60	184.	1.	174.	2.	5.2	112.8	3.10	.1	112.7	.87	.45	.48	.05	1473.	1503.	70.	64.	.270
1	551.3	27.51	184.	1.	174.	2.	7.1	112.7	3.21	1.8	112.7	1.02	.34	.60	.49	1466.	1457.	70.	64.	.270
1	551.4	27.41	184.	1.	174.	2.	8.5	112.6	3.23	3.3	112.5	1.11	.28	.68	.46	1463.	1479.	70.	64.	.271
1	551.6	27.31	184.	1.	174.	2.	9.7	112.5	3.26	4.4	112.4	1.10	.26	.76	.35	1456.	1455.	70.	64.	.273
1	551.7	27.22	185.	1.	174.	2.	11.2	112.4	3.32	5.7	112.3	1.32	.18	.89	.27	1453.	1450.	70.	64.	.273
1	551.8	27.13	185.	1.	174.	2.	13.1	112.1	3.37	7.6	112.1	1.47	.15	1.01	.22	1448.	1417.	70.	64.	.274
1	552.0	27.04	185.	1.	174.	2.	14.2	112.2	3.38	8.8	112.0	1.47	.13	1.09	.17	1442.	1386.	70.	64.	.276
1	552.1	26.95	185.	1.	174.	2.	15.4	112.0	3.43	9.9	111.9	1.59	.03	1.03	.16	1436.	1412.	70.	64.	.276
1	552.2	26.87	185.	1.	174.	2.	17.4	111.9	3.49	11.7	111.7	1.76	.02	1.24	.13	1433.	1423.	70.	64.	.277

Figure B-1. (contd)

IDAC TAPE #660R TEST NO. 31 DAY 52 09:56:13 SITE NO.=4.0 IDAC SITE= 4
TAMB = 671.479 DEG F PAMB = 14.059 PSIA TEST DATA START 09:56:16

RUN	TIME	MPH	ERO	ERI	EMI	EMO	BAMP	BVOLT	MFLDI	MAMP	MVOLT	PRO	PRI	PMI	PMO	MRPM	USS	ATEMP	MTEMP	IST
1	552.4	26.79	185.	1.	174.	2.	19.1	111.7	3.52	13.4	111.6	1.99	-.02	1.44	.06	1426.	1380.	70.	64.	.279
1	552.5	26.72	185.	1.	174.	2.	20.5	111.7	3.53	14.0	111.4	2.02	-.00	1.49	.06	1423.	1427.	70.	64.	.279
1	552.6	26.64	185.	1.	174.	2.	22.0	111.4	3.56	16.2	111.3	2.15	-.01	1.63	.03	1420.	1460.	70.	64.	.280
1	552.8	26.56	185.	1.	174.	2.	23.6	111.3	3.63	17.8	111.2	2.43	-.01	1.87	.00	1416.	1451.	70.	64.	.282
1	552.9	26.48	185.	1.	174.	2.	24.6	111.2	3.63	19.0	111.1	2.56	-.01	2.04	-.00	1411.	1462.	70.	64.	.282
1	553.0	26.41	185.	1.	175.	2.	25.9	111.1	3.63	20.1	110.9	2.58	-.01	2.09	-.01	1409.	1463.	70.	64.	.283
1	553.2	26.34	165.	1.	175.	2.	27.3	111.2	3.67	21.5	110.8	2.73	-.02	2.20	-.01	1405.	1459.	70.	64.	.284
1	553.3	26.28	165.	1.	175.	2.	29.5	110.8	3.77	23.5	110.7	3.05	-.02	2.47	-.02	1401.	1419.	70.	64.	.285
1	553.4	26.21	166.	1.	175.	2.	31.0	110.7	3.77	25.0	110.5	3.19	-.02	2.66	-.01	1397.	1450.	70.	64.	.287
1	553.6	26.13	186.	1.	175.	2.	31.6	110.6	3.75	25.7	110.4	3.19	-.02	2.69	-.01	1392.	1481.	70.	64.	.287
1	553.7	26.09	186.	1.	175.	2.	33.3	110.5	3.79	27.2	110.4	3.40	-.02	2.83	-.02	1389.	1563.	70.	64.	.288
1	553.8	26.03	186.	1.	175.	2.	34.8	110.3	3.89	28.7	110.2	3.65	-.02	3.05	-.02	1386.	1502.	70.	64.	.290
1	554.0	25.97	186.	1.	175.	2.	35.8	110.2	3.90	29.7	110.1	3.66	-.02	3.15	-.01	1382.	1436.	70.	64.	.290
1	554.1	25.90	186.	1.	175.	2.	36.9	110.1	3.92	30.8	110.0	3.73	-.02	3.21	-.01	1379.	1359.	70.	64.	.291
1	554.3	25.86	186.	1.	175.	2.	38.0	110.0	3.96	31.9	109.9	3.93	-.01	3.34	-.01	1376.	1352.	70.	64.	.292
1	554.4	25.79	187.	1.	176.	2.	39.4	110.0	4.00	33.2	109.8	4.14	-.01	3.55	-.01	1373.	1420.	70.	64.	.293
1	554.5	25.76	187.	1.	176.	2.	40.2	110.0	3.99	34.0	109.7	4.12	-.02	3.58	-.01	1370.	1410.	70.	64.	.294
1	554.7	25.70	187.	1.	176.	2.	41.3	109.8	4.03	35.1	109.6	4.21	-.02	3.65	-.02	1367.	1386.	70.	64.	.295
1	554.8	25.66	187.	1.	176.	2.	42.3	109.8	4.08	35.9	109.6	4.39	-.02	3.79	-.01	1364.	1408.	70.	64.	.296
1	554.9	25.60	187.	1.	176.	2.	43.7	109.6	4.09	37.3	109.5	4.57	-.02	3.94	-.01	1361.	1401.	70.	64.	.297
1	555.1	25.55	187.	1.	176.	2.	44.1	109.5	4.07	37.8	109.4	4.53	-.02	3.96	-.01	1359.	1399.	70.	64.	.298
1	555.2	25.50	186.	1.	177.	2.	44.7	109.4	4.09	38.3	109.3	4.60	-.02	4.01	-.02	1356.	1372.	70.	64.	.299
1	555.3	25.47	186.	1.	177.	2.	46.0	109.4	4.12	39.6	109.3	4.60	-.02	4.18	-.01	1354.	1358.	70.	64.	.300
1	555.5	25.41	188.	1.	177.	2.	47.2	109.3	4.14	40.8	109.2	4.93	-.02	4.35	-.01	1351.	1351.	70.	64.	.301
1	555.6	25.36	188.	1.	177.	2.	47.8	109.2	4.16	41.4	109.1	4.90	-.01	4.33	-.01	1350.	1348.	70.	64.	.302
1	555.7	25.25	188.	1.	177.	2.	52.9	109.0	4.27	44.5	108.8	5.22	-.02	4.60	-.02	1346.	1343.	70.	64.	.302
1	555.9	24.81	189.	1.	177.	2.	41.6	109.7	4.12	35.2	109.7	4.64	-.02	4.01	-.02	1347.	1324.	70.	64.	.304
1	556.0	24.29	189.	1.	177.	2.	24.6	111.1	3.66	18.8	110.9	3.07	-.02	2.56	-.01	1366.	1304.	70.	64.	.304
1	556.1	23.86	189.	1.	178.	2.	18.1	111.5	3.48	12.4	111.4	2.16	-.02	1.66	.03	1391.	1285.	70.	64.	.306
1	556.3	23.57	189.	1.	178.	2.	14.8	112.0	3.40	9.2	111.7	1.70	.07	1.30	.09	1409.	1267.	70.	64.	.306
1	556.4	23.58	189.	1.	178.	2.	13.4	112.0	3.36	7.8	112.0	1.63	.07	1.18	.13	1422.	1259.	70.	64.	.307
1	556.5	23.51	189.	1.	178.	2.	12.4	112.0	3.30	7.0	112.1	1.54	.06	1.05	.21	1431.	1254.	70.	64.	.308
1	556.7	23.31	189.	1.	178.	2.	11.8	112.1	3.27	6.4	112.1	1.38	.10	.90	.28	1435.	1240.	70.	64.	.309
1	556.8	23.07	189.	1.	178.	2.	11.5	112.3	3.30	6.0	112.2	1.35	.14	.65	.33	1430.	1230.	70.	64.	.310
1	557.0	22.79	189.	1.	178.	2.	11.5	112.3	3.26	6.0	112.2	1.42	.13	1.00	.20	1441.	1223.	70.	64.	.311
1	557.1	22.51	189.	1.	178.	2.	11.4	112.3	3.27	5.9	112.3	1.36	.14	.99	.21	1442.	1208.	70.	64.	.312
1	557.2	22.26	189.	1.	178.	2.	11.4	112.4	3.27	5.9	112.2	1.26	.17	.63	.30	1444.	1194.	70.	64.	.312
1	557.4	21.97	189.	1.	178.	2.	11.3	112.4	3.29	5.8	112.3	1.32	.16	.62	.32	1445.	1179.	70.	64.	.313
1	557.5	21.67	189.	1.	178.	2.	11.3	112.4	3.29	5.8	112.3	1.40	.13	.95	.23	1443.	1165.	70.	64.	.314
1	557.6	21.37	189.	1.	178.	2.	11.2	112.4	3.27	5.6	112.3	1.32	.15	1.00	.18	1444.	1150.	70.	64.	.315
1	557.8	21.05	189.	1.	178.	2.	11.1	112.6	3.27	5.7	112.3	1.27	.16	.64	.28	1445.	1133.	70.	65.	.316
1	557.9	20.69	189.	1.	178.	2.	11.1	112.4	3.29	5.7	112.3	1.32	.17	.64	.32	1445.	1116.	70.	64.	.316
1	558.0	20.33	189.	1.	178.	2.	11.3	112.5	3.29	5.8	112.3	1.36	.15	.97	.21	1444.	1097.	70.	64.	.317
1	558.2	19.99	189.	1.	178.	2.	11.2	112.5	3.27	5.8	112.3	1.30	.15	.99	.18	1445.	1079.	70.	64.	.318
1	558.3	19.66	190.	1.	178.	2.	11.2	112.5	3.26	5.8	112.3	1.26	.18	.85	.27	1444.	1061.	70.	64.	.319
1	558.4	19.29	190.	1.	178.	2.	11.0	112.1	3.30	5.6	112.4	1.35	.16	.86	.31	1446.	1042.	70.	64.	.319
1	558.6	18.94	190.	1.	178.	2.	11.4	112.4	3.29	5.9	112.4	1.39	.14	.97	.21	1446.	1024.	70.	64.	.320
1	558.7	18.56	190.	1.	178.	2.	11.1	112.5	3.26	5.7	112.4	1.29	.14	.90	.25	1445.	1004.	70.	64.	.321
1	558.8	18.17	190.	1.	178.	2.	11.2	112.5	3.29	5.8	112.4	1.26	.18	.84	.30	1446.	984.	70.	64.	.322
1	559.0	17.79	190.	1.	178.	2.	11.1	112.6	3.29	5.7	112.4	1.36	.15	.88	.31	1445.	963.	70.	64.	.322
1	559.1	17.44	190.	1.	178.	2.	11.4	112.3	3.26	5.9	112.4	1.38	.14	.95	.24	1445.	945.	70.	64.	.323

Figure B-1. (contd)

IDAC TAPE #660R TEST NO. 31 DAY 52 09:56:13 SITE NO.#4.0 IDAC SITE# 4
TAMB = 672.116 DEG F PAMB = 14.057 PSIA TEST DATA START 09:56:18

RUN	TIME	MPH	EBG	EAI	EMI	EMO	BAMP	BVOLT	MFLDI	MAMP	MVOLT	PAO	PAI	PMI	PMO	MRPM	DSS	ATEMP	ITEMP	ISI
1	559.2	17.07	190.	1.	178.	2.	11.0	112.6	3.26	5.6	112.4	1.27	.15	.85	.29	1446.	924.	70.	64.	.324
1	559.4	16.72	190.	1.	178.	2.	11.2	112.6	3.29	5.8	112.4	1.29	.16	.87	.26	1446.	906.	70.	64.	.324
1	559.5	16.35	190.	1.	178.	2.	11.2	112.5	3.28	5.7	112.5	1.35	.15	.92	.25	1446.	886.	70.	64.	.325
1	559.7	16.01	190.	1.	178.	2.	11.3	112.5	3.28	5.9	112.4	1.37	.14	.91	.26	1446.	866.	70.	64.	.325
1	559.8	15.63	190.	1.	178.	2.	11.0	112.6	3.27	5.7	112.4	1.26	.14	.83	.30	1446.	848.	70.	64.	.326
1	559.9	15.26	190.	1.	178.	2.	11.2	112.6	3.29	5.8	112.4	1.29	.15	.85	.30	1446.	829.	70.	64.	.326
1	560.1	14.86	190.	1.	179.	2.	11.2	112.6	3.30	5.7	112.5	1.36	.15	.91	.25	1446.	807.	70.	64.	.327
1	560.2	14.49	190.	1.	179.	2.	11.3	112.6	3.28	5.9	112.5	1.33	.16	.89	.29	1446.	787.	70.	64.	.328
1	560.3	14.07	190.	1.	179.	2.	11.1	112.6	3.26	5.6	112.4	1.25	.16	.82	.30	1446.	767.	70.	64.	.328
1	560.5	13.72	190.	1.	179.	2.	11.2	112.6	3.31	5.8	112.5	1.30	.18	.84	.27	1446.	746.	70.	64.	.329
1	560.6	13.32	190.	1.	179.	2.	11.4	112.5	3.29	5.9	112.5	1.38	.15	.86	.29	1446.	725.	70.	64.	.329
1	560.7	12.91	190.	1.	179.	2.	11.0	112.5	3.27	6.2	112.4	1.34	.14	.96	.23	1445.	704.	70.	64.	.329
1	560.9	12.57	191.	1.	179.	2.	11.3	112.6	3.26	5.9	112.4	1.26	.19	.62	.31	1445.	685.	70.	64.	.330
1	561.0	12.25	191.	1.	179.	2.	11.6	112.6	3.29	6.1	112.4	1.35	.17	.87	.29	1445.	667.	70.	64.	.330
1	561.1	12.02	191.	1.	179.	2.	11.7	112.6	3.29	6.3	112.5	1.40	.14	.92	.26	1446.	651.	70.	64.	.331
1	561.3	11.70	191.	1.	179.	2.	11.8	112.6	3.28	6.5	112.4	1.34	.14	.93	.25	1444.	636.	70.	64.	.331
1	561.4	11.34	191.	1.	179.	2.	11.6	112.6	3.30	6.2	112.4	1.31	.13	.81	.31	1445.	618.	70.	64.	.332
1	561.5	10.99	191.	1.	179.	2.	11.9	112.6	3.31	6.4	112.5	1.43	.10	.93	.25	1445.	598.	70.	64.	.332
1	561.7	10.64	191.	1.	179.	2.	11.8	112.6	3.31	6.4	112.5	1.46	.08	.90	.26	1444.	581.	70.	64.	.333
1	561.8	10.26	191.	1.	179.	2.	11.9	112.6	3.28	6.5	112.4	1.35	.15	.93	.25	1444.	562.	70.	64.	.333
1	561.9	9.92	191.	1.	179.	2.	11.6	112.6	3.30	6.3	112.4	1.34	.11	.93	.19	1444.	542.	70.	64.	.334
1	562.1	9.59	191.	1.	179.	2.	11.9	112.6	3.30	6.5	112.5	1.42	.12	.98	.23	1445.	523.	70.	64.	.334
1	562.2	9.24	191.	1.	179.	2.	11.7	112.6	3.29	6.2	112.5	1.47	.13	1.00	.20	1445.	508.	70.	64.	.334
1	562.4	8.86	191.	1.	179.	2.	11.4	112.6	3.28	6.1	112.5	1.30	.15	.87	.29	1445.	486.	70.	64.	.335
1	562.5	8.51	191.	1.	179.	2.	11.2	112.7	3.30	5.8	112.5	1.28	.15	.92	.19	1446.	466.	70.	64.	.335
1	562.6	8.17	191.	1.	179.	2.	11.6	112.6	3.32	6.2	112.5	1.39	.15	.95	.24	1446.	448.	70.	64.	.335
1	562.8	7.83	191.	1.	179.	2.	11.5	112.6	3.31	6.0	112.6	1.35	.14	.99	.19	1446.	430.	70.	64.	.335
1	562.9	7.83	191.	1.	179.	2.	11.5	112.6	3.31	6.0	112.6	1.36	.14	.99	.19	1446.	430.	70.	64.	.336
1	563.0	7.10	191.	1.	179.	2.	11.2	112.7	3.30	5.7	112.5	1.30	.15	.84	.29	1447.	391.	70.	64.	.336
1	563.2	6.79	191.	1.	179.	2.	11.2	112.7	3.28	5.8	112.6	1.39	.14	.91	.29	1447.	375.	70.	64.	.336
1	563.3	6.45	191.	1.	179.	2.	11.1	112.7	3.29	5.7	112.6	1.35	.14	.93	.24	1447.	357.	70.	65.	.336
1	563.4	6.12	191.	1.	179.	2.	10.9	112.7	3.27	5.6	112.6	1.26	.16	.88	.25	1447.	339.	70.	64.	.337
1	563.6	5.79	192.	1.	179.	2.	11.2	112.7	3.30	5.5	112.6	1.24	.21	.83	.31	1448.	320.	70.	64.	.337
1	563.7	5.45	192.	1.	179.	2.	10.9	112.7	3.29	5.5	112.7	1.34	.17	.90	.27	1448.	305.	70.	64.	.337
1	563.8	5.13	192.	1.	179.	2.	10.9	112.7	3.29	5.6	112.6	1.32	.15	.91	.26	1448.	285.	70.	64.	.337
1	564.0	4.80	192.	1.	179.	2.	10.9	112.8	3.27	5.5	112.6	1.24	.15	.91	.31	1446.	270.	70.	64.	.337
1	564.1	4.46	192.	1.	180.	2.	10.9	112.8	3.28	5.5	112.6	1.30	.16	.87	.24	1446.	250.	70.	64.	.338
1	564.2	4.12	192.	1.	180.	2.	10.9	112.8	3.30	5.5	112.7	1.33	.17	.88	.24	1446.	232.	70.	64.	.338
1	564.4	3.77	192.	1.	180.	2.	11.0	112.8	3.27	5.6	112.6	1.30	.15	.86	.30	1448.	212.	70.	64.	.338
1	564.5	3.42	192.	2.	180.	2.	10.8	112.8	3.27	5.5	112.6	1.21	.19	.67	.24	1448.	195.	70.	64.	.338
1	564.6	3.08	192.	2.	180.	2.	11.1	112.7	3.29	5.7	112.7	1.33	.10	.85	.31	1448.	173.	70.	64.	.338
1	564.8	2.73	192.	2.	180.	2.	10.9	112.8	3.28	5.5	112.7	1.32	.18	.96	.21	1448.	160.	70.	64.	.338
1	564.9	2.38	192.	2.	180.	3.	11.0	112.8	3.27	5.5	112.7	1.29	.16	.92	.24	1448.	142.	70.	64.	.338
1	565.1	2.05	192.	2.	180.	3.	10.6	112.8	3.27	5.3	112.6	1.17	.24	[illegible]	.31	1448.	119.	70.	64.	.338
1	565.2	1.71	192.	2.	180.	3.	10.9	112.8	3.32	5.5	112.7	1.31	.18	.91	.25	1449.	102.	70.	64.	.339
1	565.3	1.37	192.	2.	180.	3.	10.9	112.8	3.28	5.4	112.7	1.29	.19	.91	.25	1449.	85.	70.	64.	.339
1	565.5	1.02	192.	2.	180.	3.	11.2	112.8	3.28	5.8	112.6	1.26	.15	.89	.26	1449.	70.	70.	64.	.339
1	565.6	.00	192.	2.	180.	3.	10.7	112.8	3.27	5.6	112.7	1.24	.17	.81	.30	1449.	52.	70.	64.	.339
1	565.7	.00	192.	2.	180.	3.	11.0	112.8	3.31	5.7	112.7	1.35	.19	.89	.29	1449.	25.	70.	65.	.339
1	565.9	.00	192.	2.	180.	3.	10.9	112.9	3.28	5.5	112.7	1.34	.14	.95	.20	1449.	9.	70.	65.	.339
1	566.0	.00	192.	2.	180.	3.	11.0	112.8	3.28	5.6	112.7	1.28	.15	[illegible]	.25	1449.	4.	70.	64.	.339

Figure B-1. (contd)

APPENDIX C

PLOTS OF DYNAMOMETER DATA

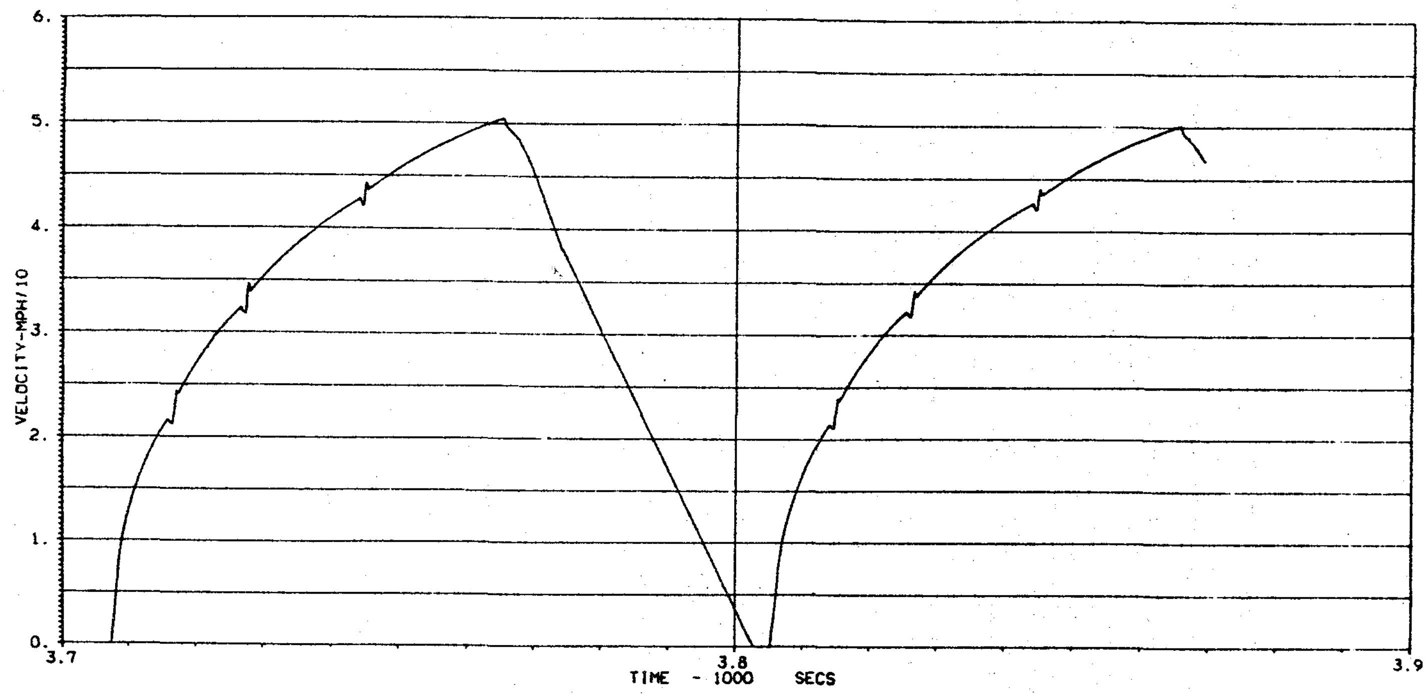


Figure C-1. Vehicle Velocity, Test VET-33: Maximum Acceleration at 40% Battery Depth of Discharge

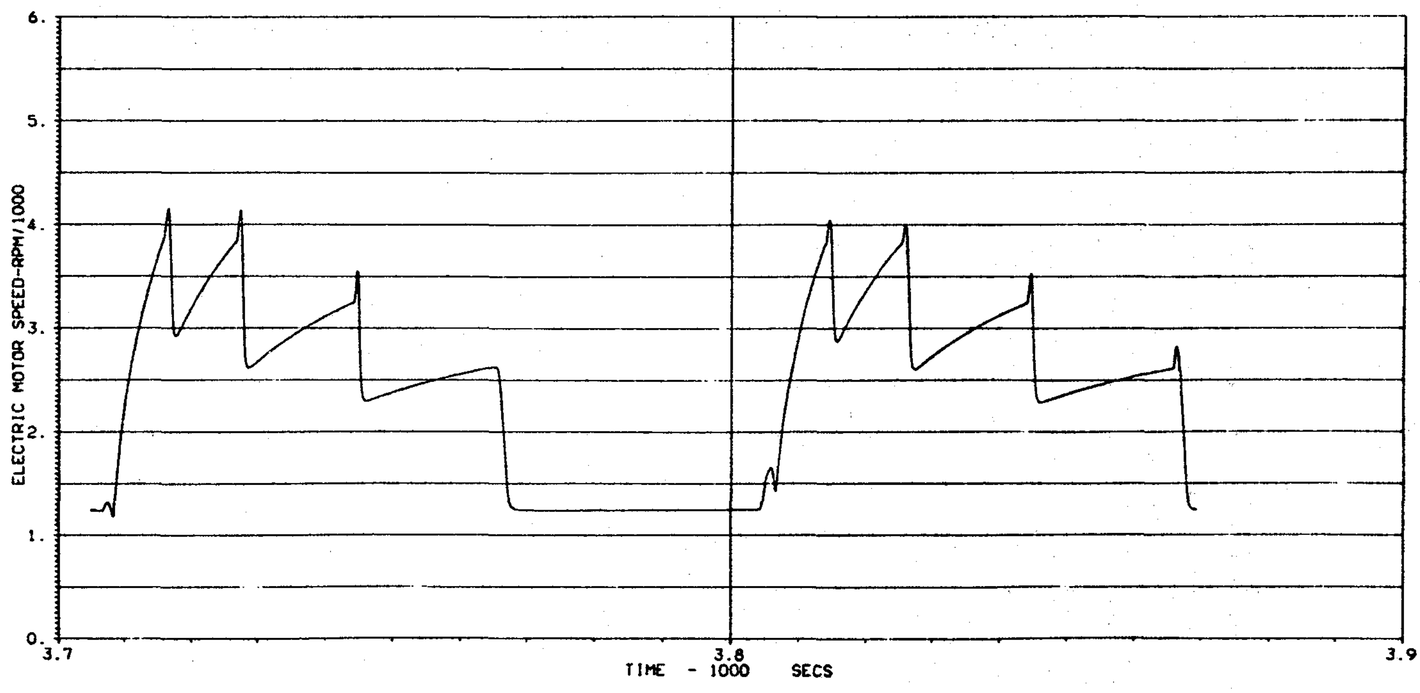


Figure C-2. Motor Speed, Test VET-33: Maximum Acceleration at 40% Battery Depth of Discharge

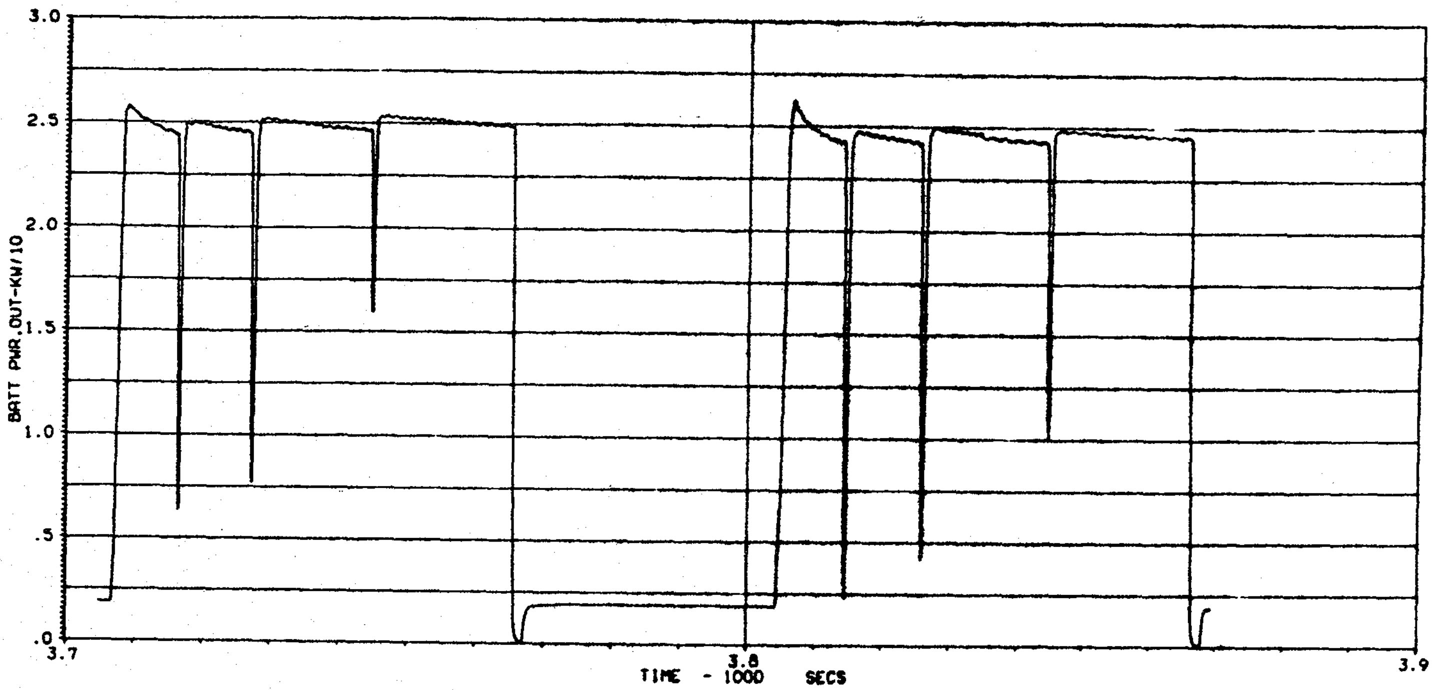


Figure C-3. Battery Output Power, Test VET-33: Maximum Acceleration at 40% Battery Depth of Discharge

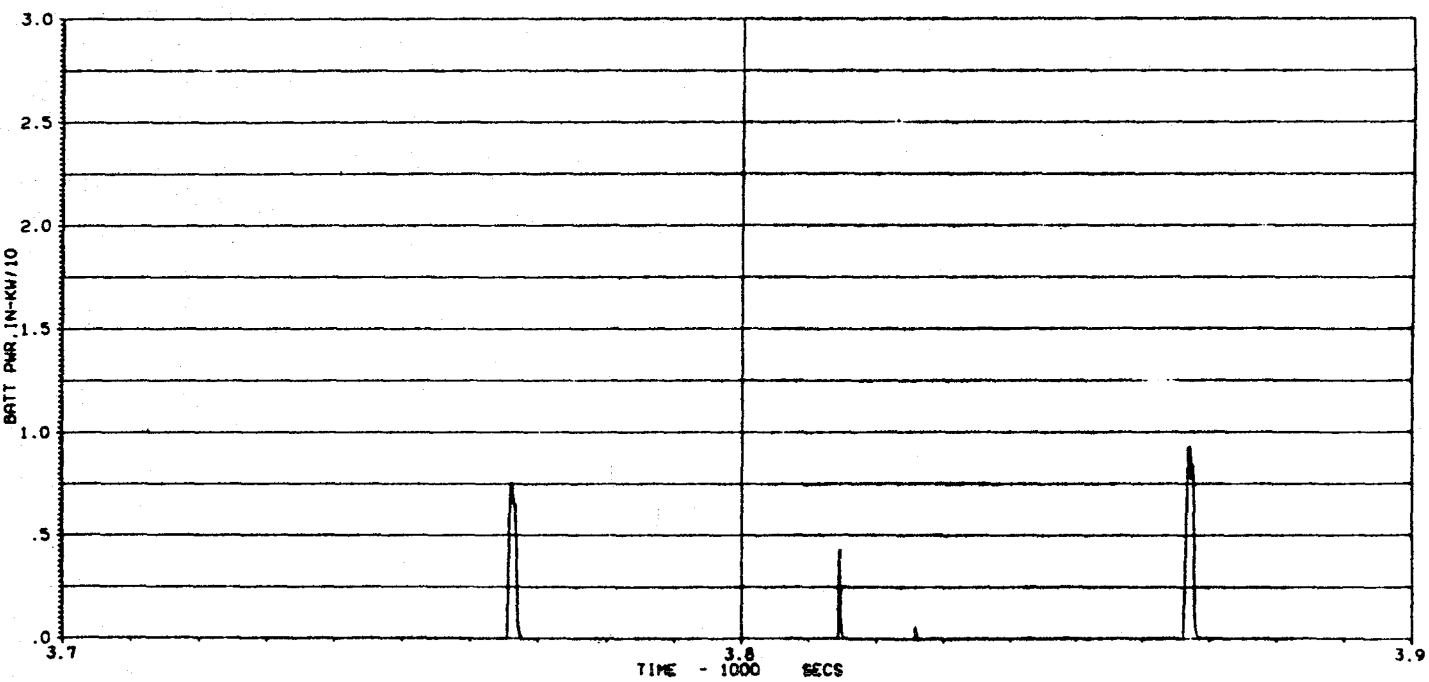


Figure C-4. Battery Input Power (Regeneration), Test VET-33: Maximum Acceleration at 40% Battery Depth of Discharge

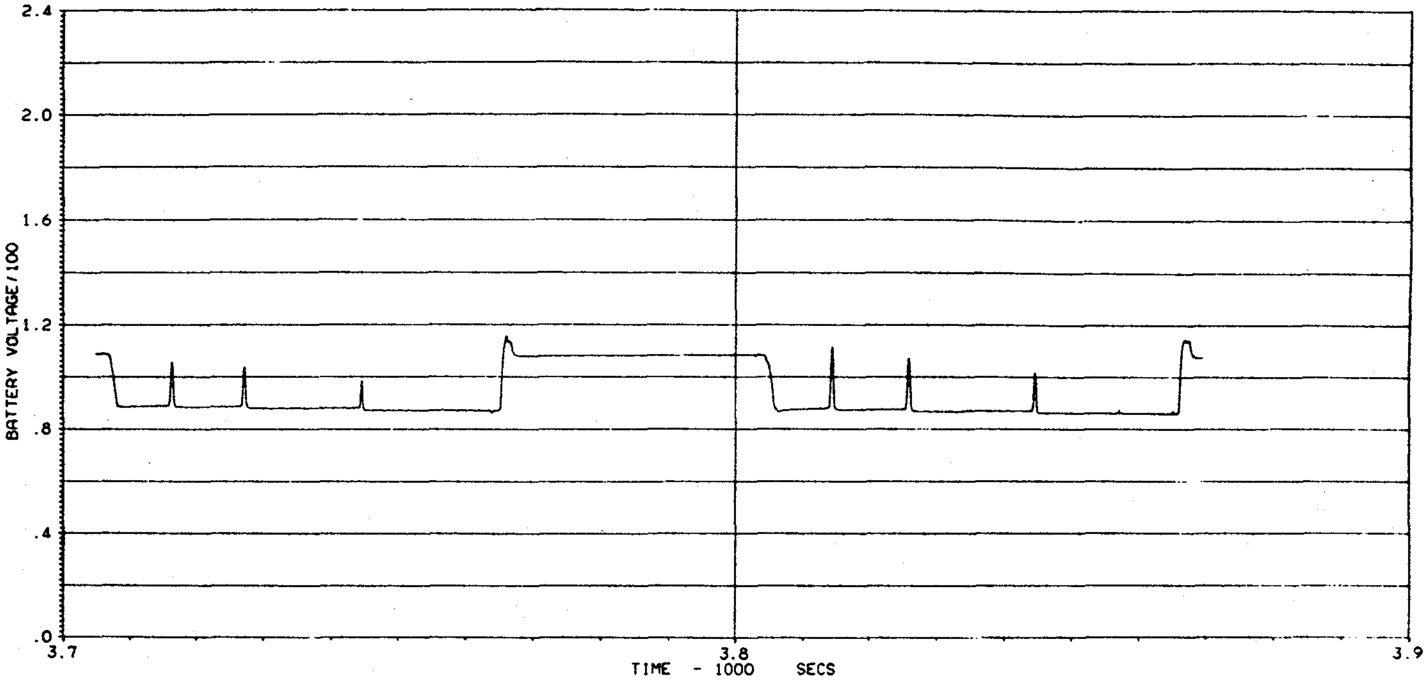


Figure C-5. Battery Voltage, Test VET-33: Maximum Acceleration at 40% Battery Depth of Discharge

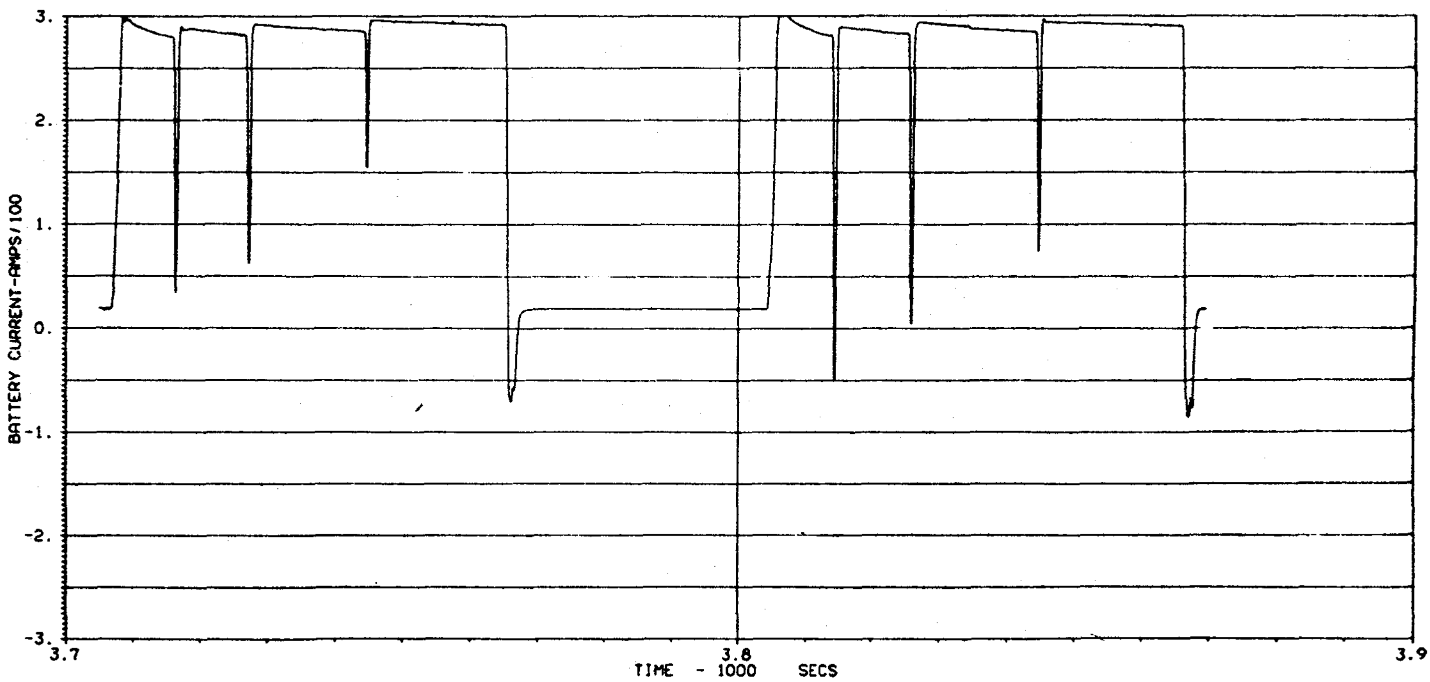


Figure C-6. Battery Current, Test VET-33: Maximum Acceleration at 40% Battery Depth of Discharge

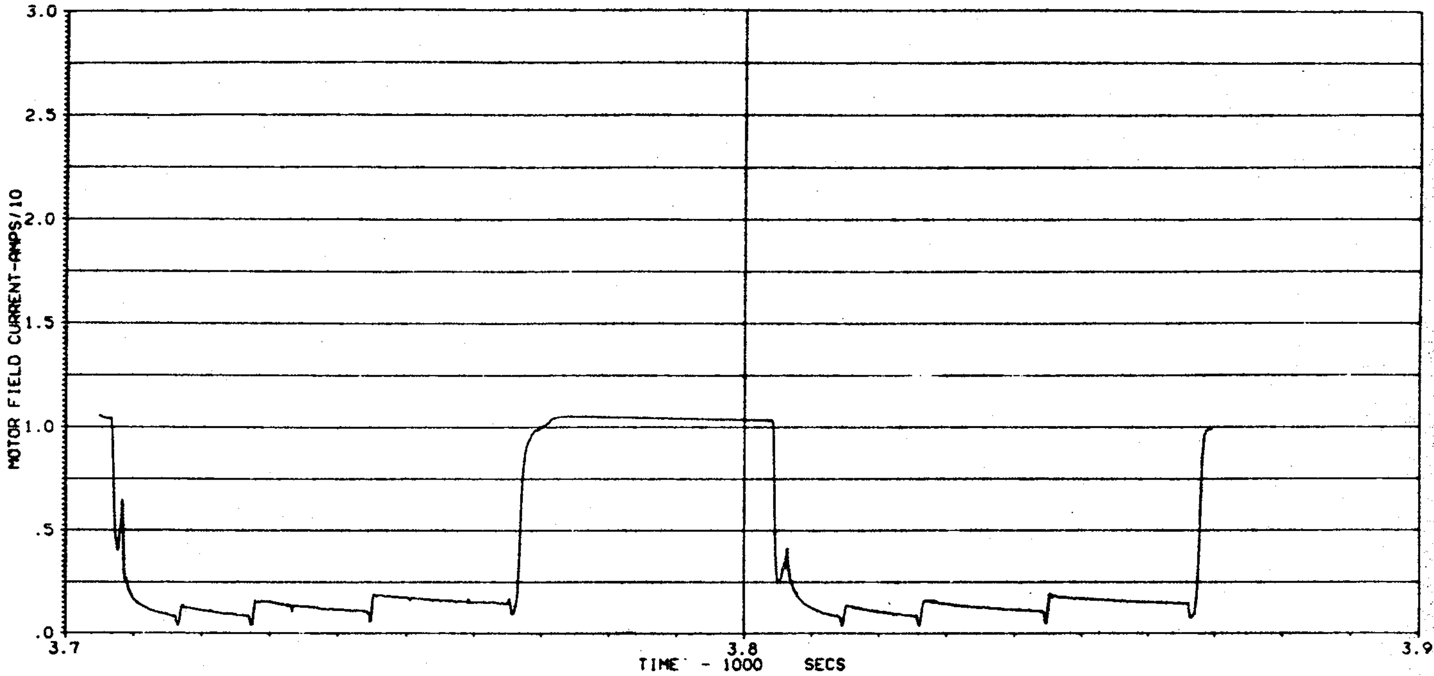


Figure C-7. Motor Field Current, Test VET-33: Maximum Acceleration at 40% Battery Depth of Discharge

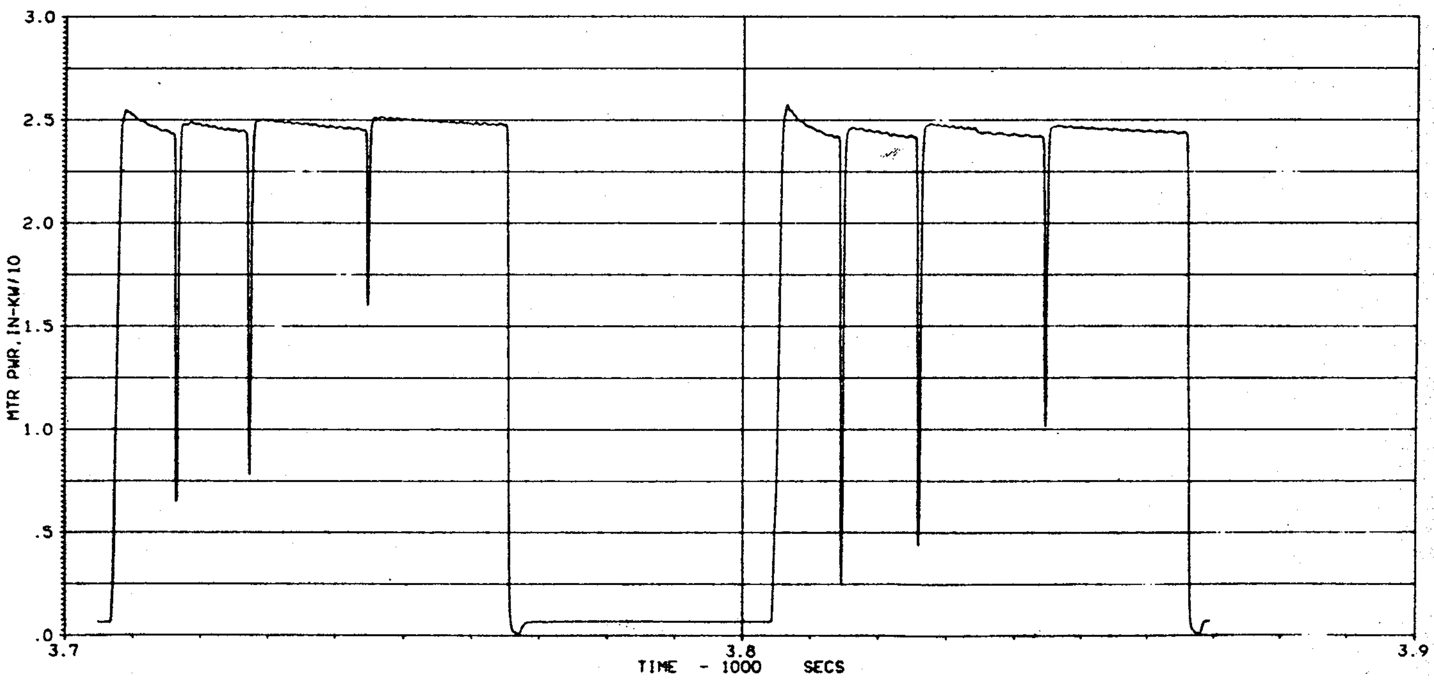


Figure C-8. Motor Input Power, Test VET-33: Maximum Acceleration at 40% Battery Depth of Discharge

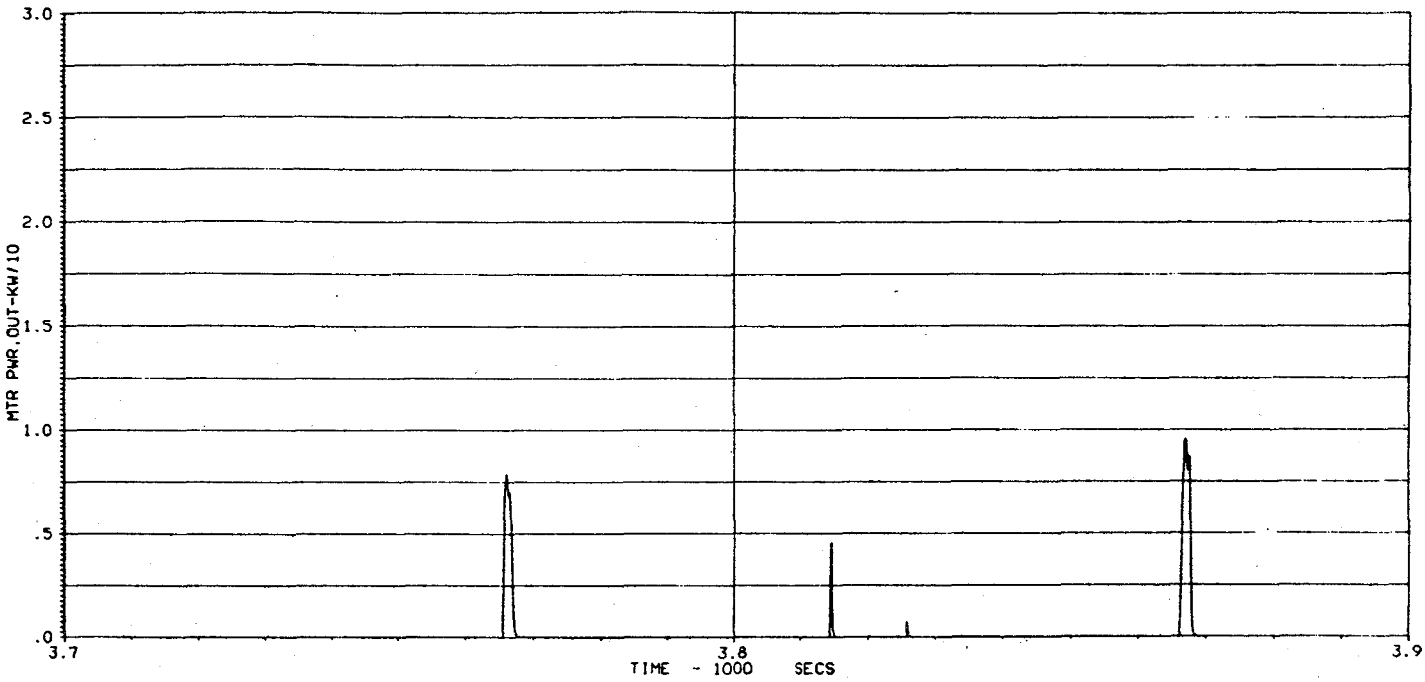


Figure C-9. Motor Output Power (Regeneration), Test VET-33: Maximum Acceleration at 40% Battery Depth of Discharge

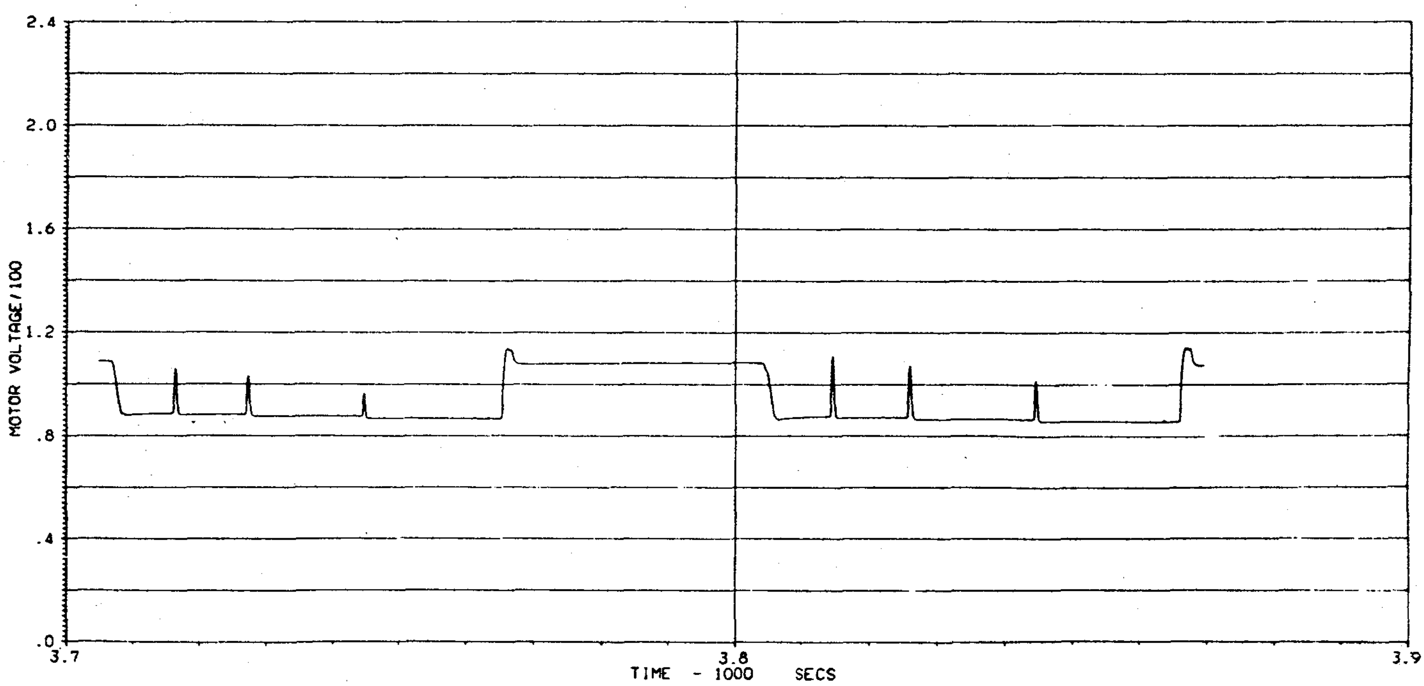


Figure C-10. Motor Voltage, Test VET-33: Maximum Acceleration at 40% Battery Depth of Discharge

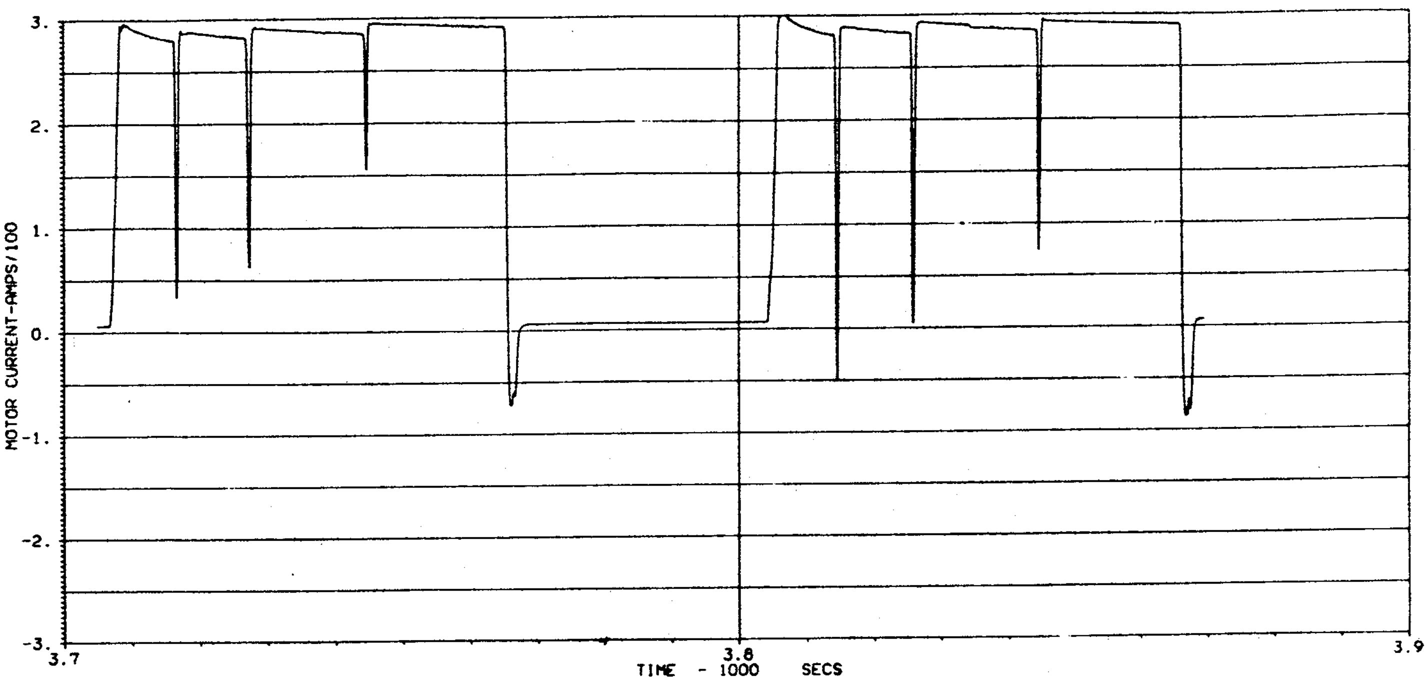


Figure C-11. Motor Current, Test VET-33: Maximum Acceleration at 40% Battery Depth of Discharge

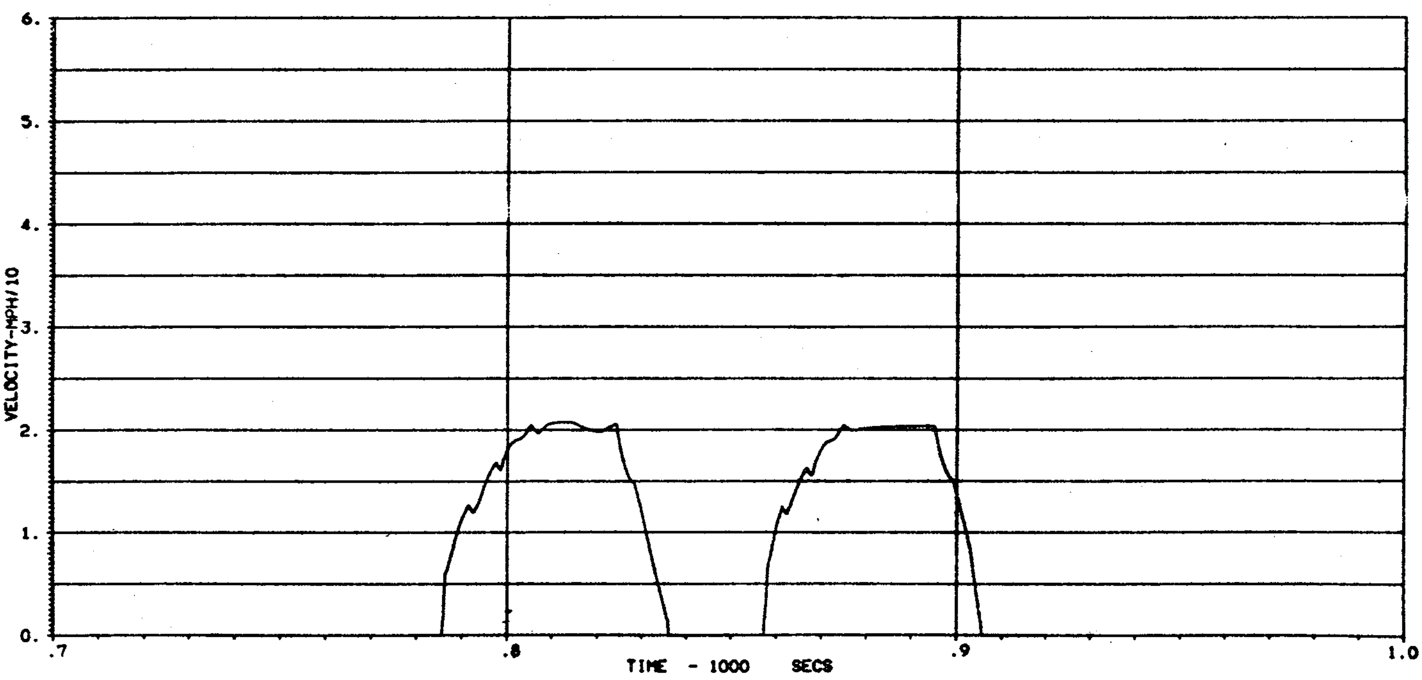


Figure C-12. Vehicle Velocity, Test VET-35: Driving Schedule B Range at 0% Battery Depth of Discharge

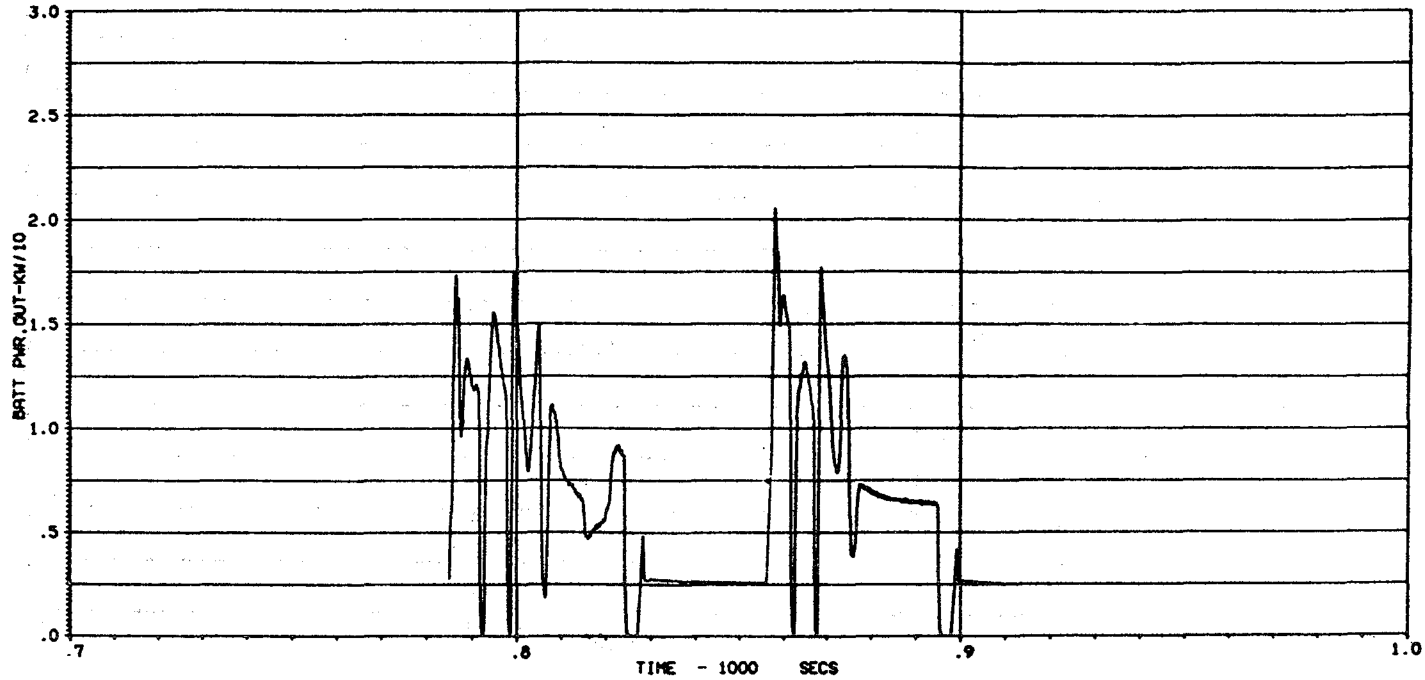


Figure C-13. Battery Output Power, Test VET-35: Driving Schedule B Range at 0% Battery Depth of Discharge

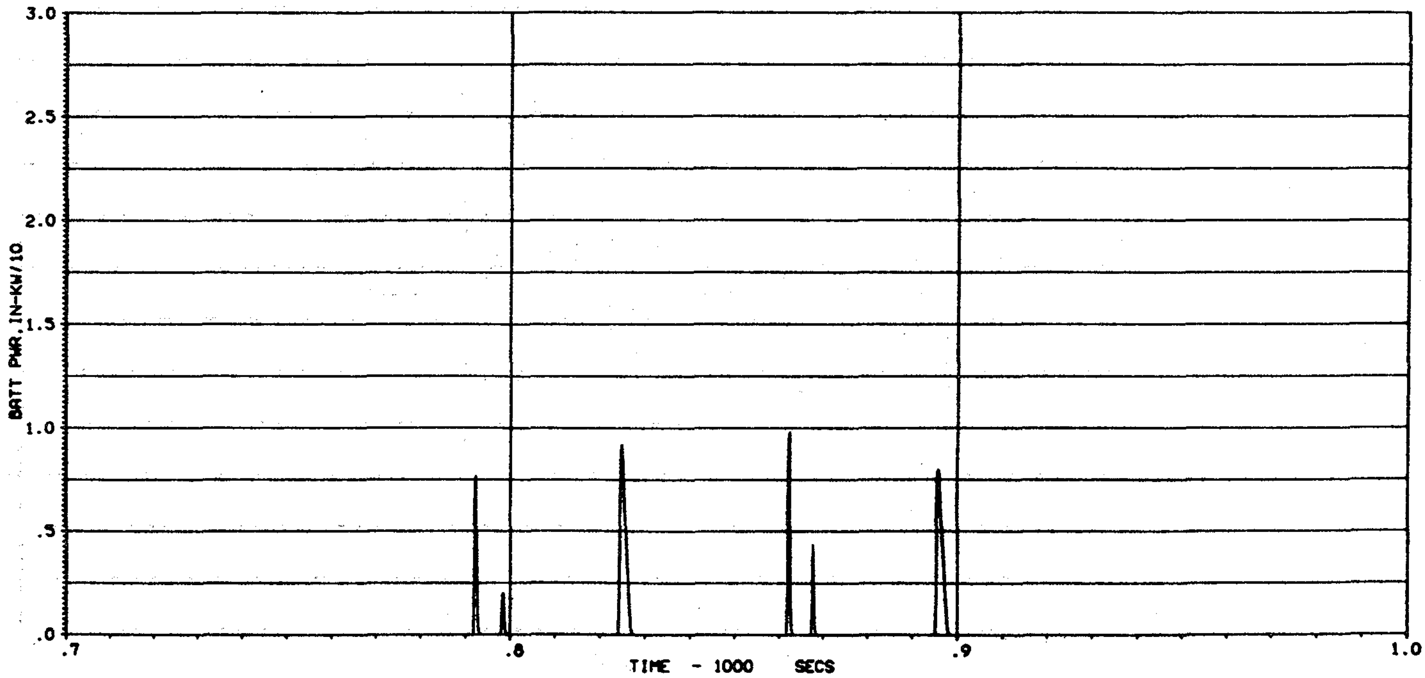


Figure C-14. Battery Input Power (Regeneration), Test VET-35: Driving Schedule B Range at 0% Battery Depth of Discharge

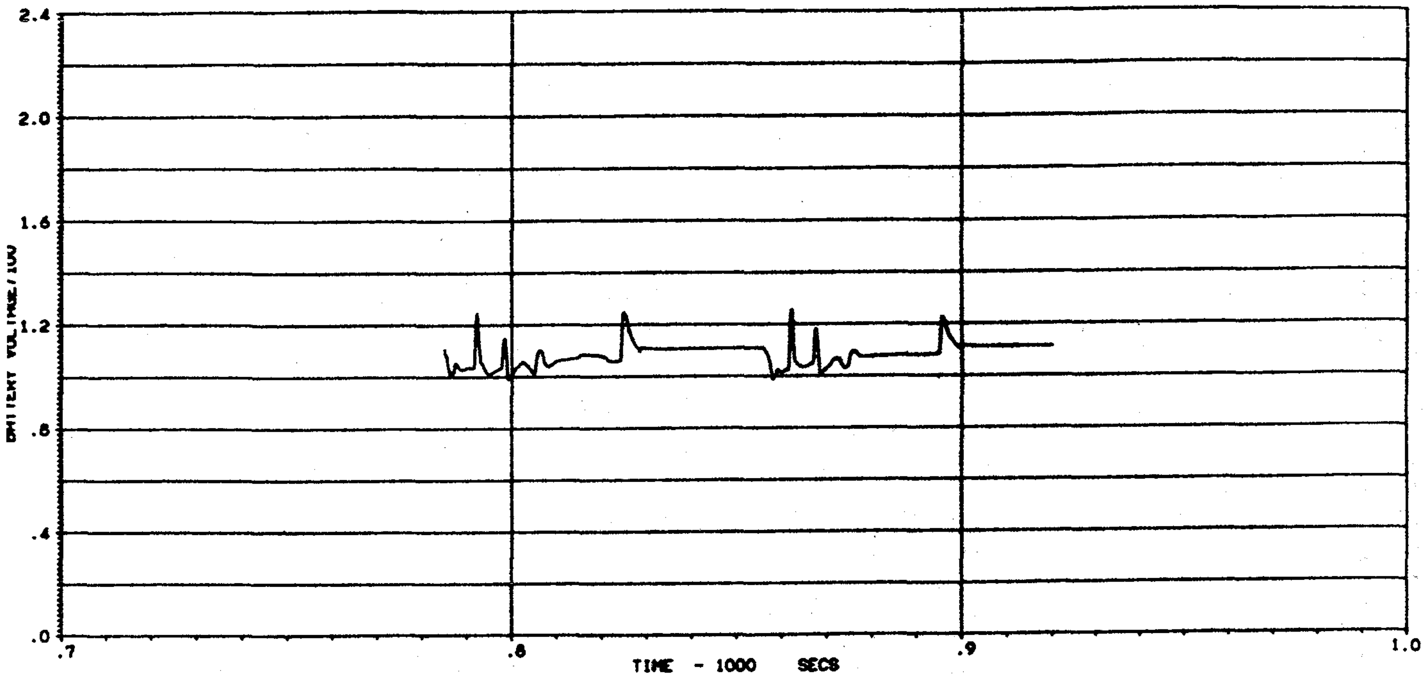


Figure C-15. Battery Voltage, Test VET-35: Driving Schedule B Range at 0% Battery Depth of Discharge

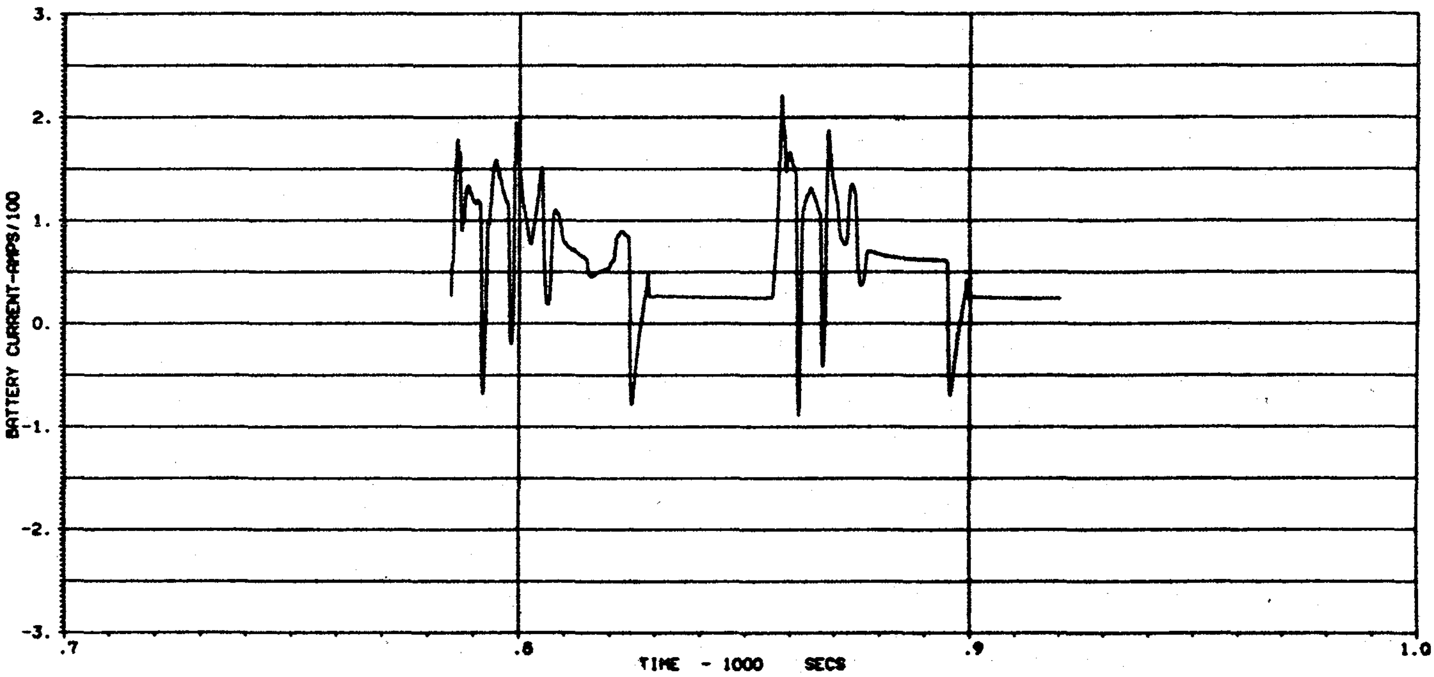


Figure C-16. Battery Current, Test VET-35: Driving Scedule B Range at 0% Battery Depth of Discharge

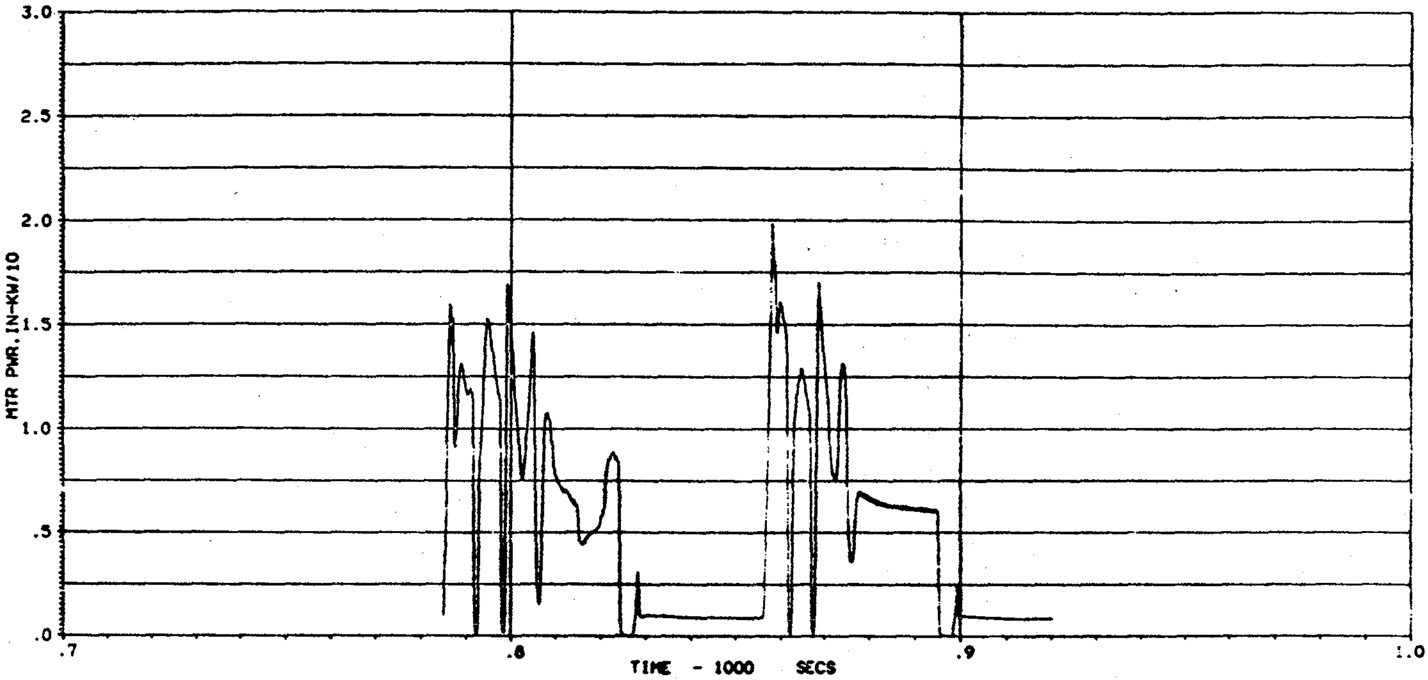


Figure C-17. Motor Input Power, Test VET-35: Driving Schedule B Range at 0% Battery Depth of Discharge

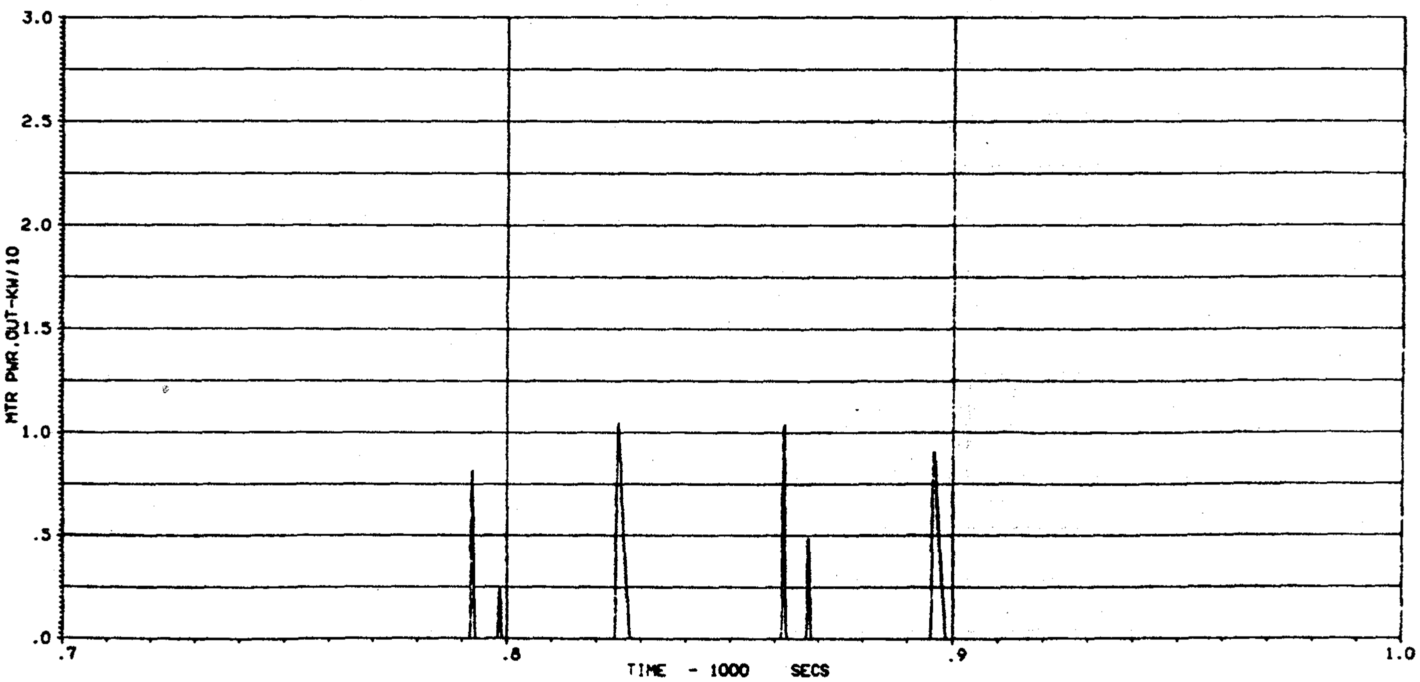


Figure C-18. Motor Output Power (Regeneration), Test VET-35: Driving Schedule B Range at 0% Battery Depth of Discharge

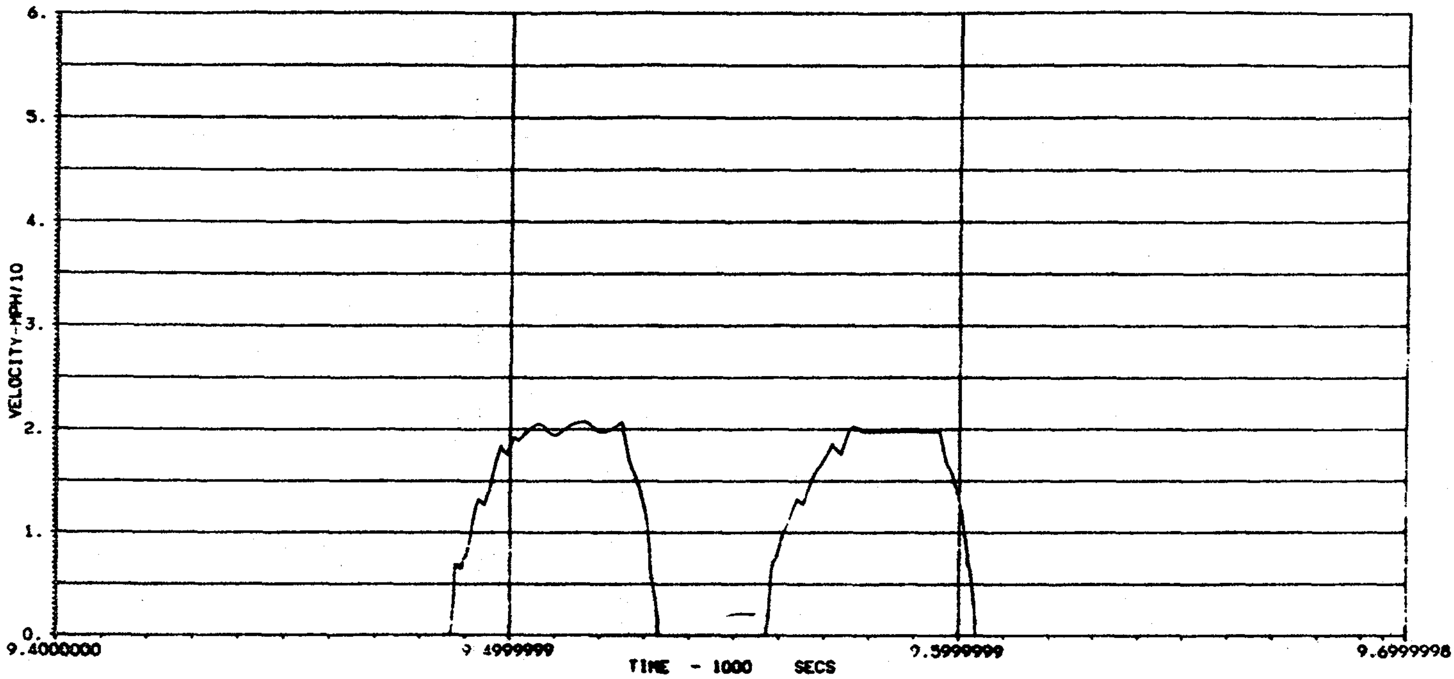


Figure C-19. Vehicle Velocity, Test VET-35: Driving Schedule B Range at 80% Battery Depth of Discharge

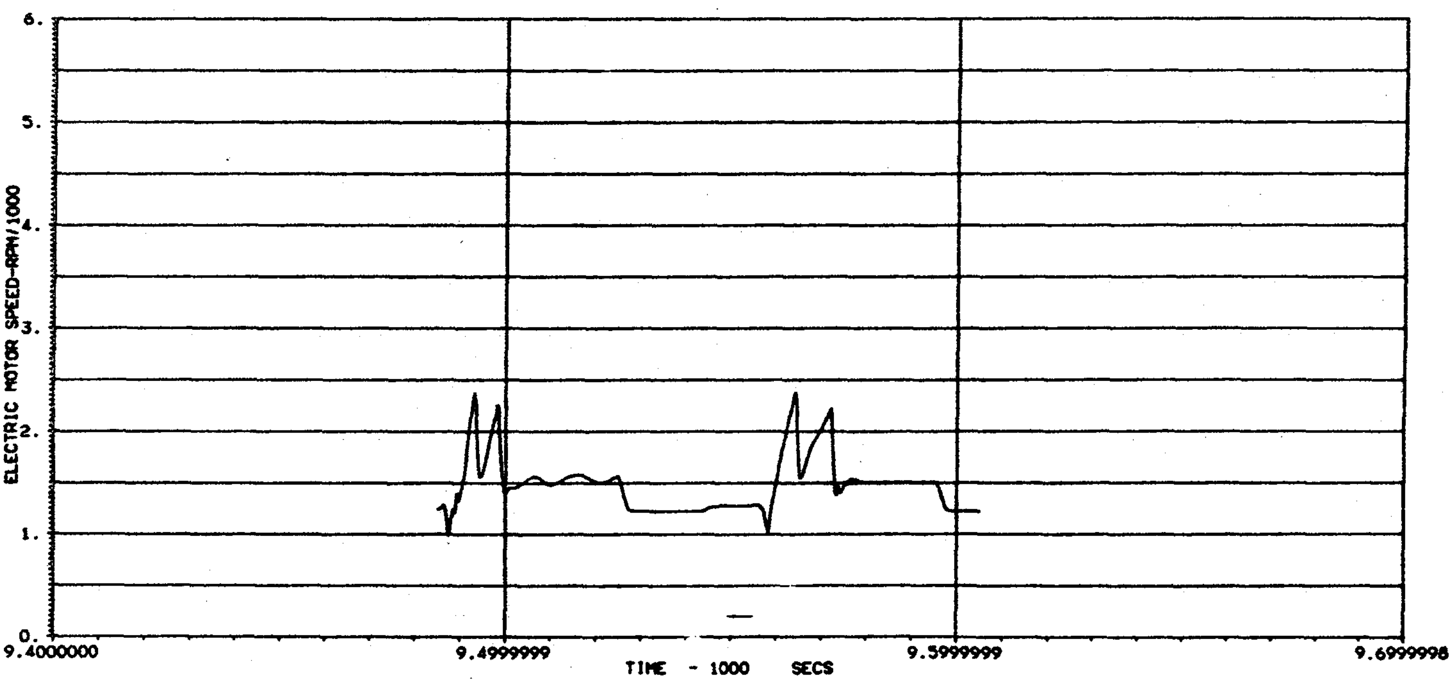


Figure C-20. Motor Speed, Test VET-35: Driving Schedule B Range at 80% Battery Depth of Discharge

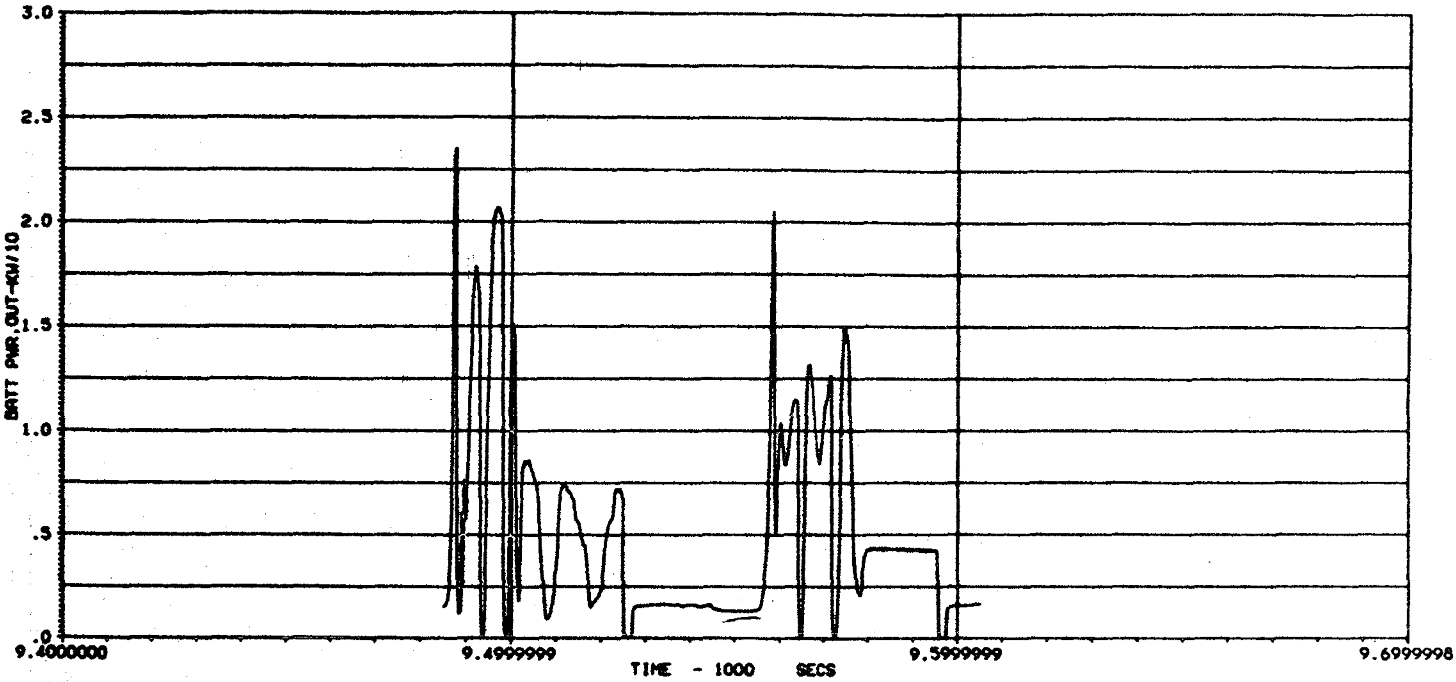


Figure C-21. Battery Output Power, Test VET-35: Driving Schedule B Range at 80% Battery Depth of Discharge

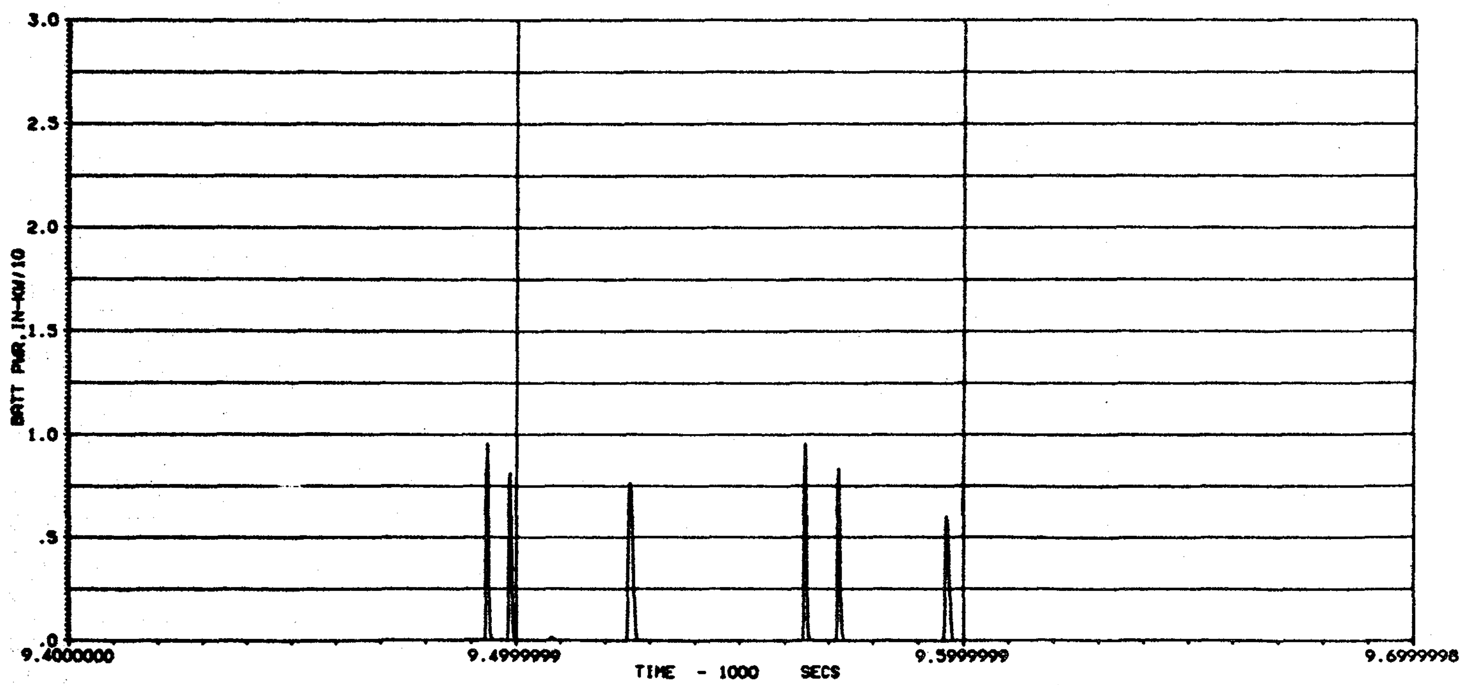


Figure C-22. Battery Input Power (Regeneration), Test VET-35: Driving Schedule B Range at 80% Battery Depth of Discharge

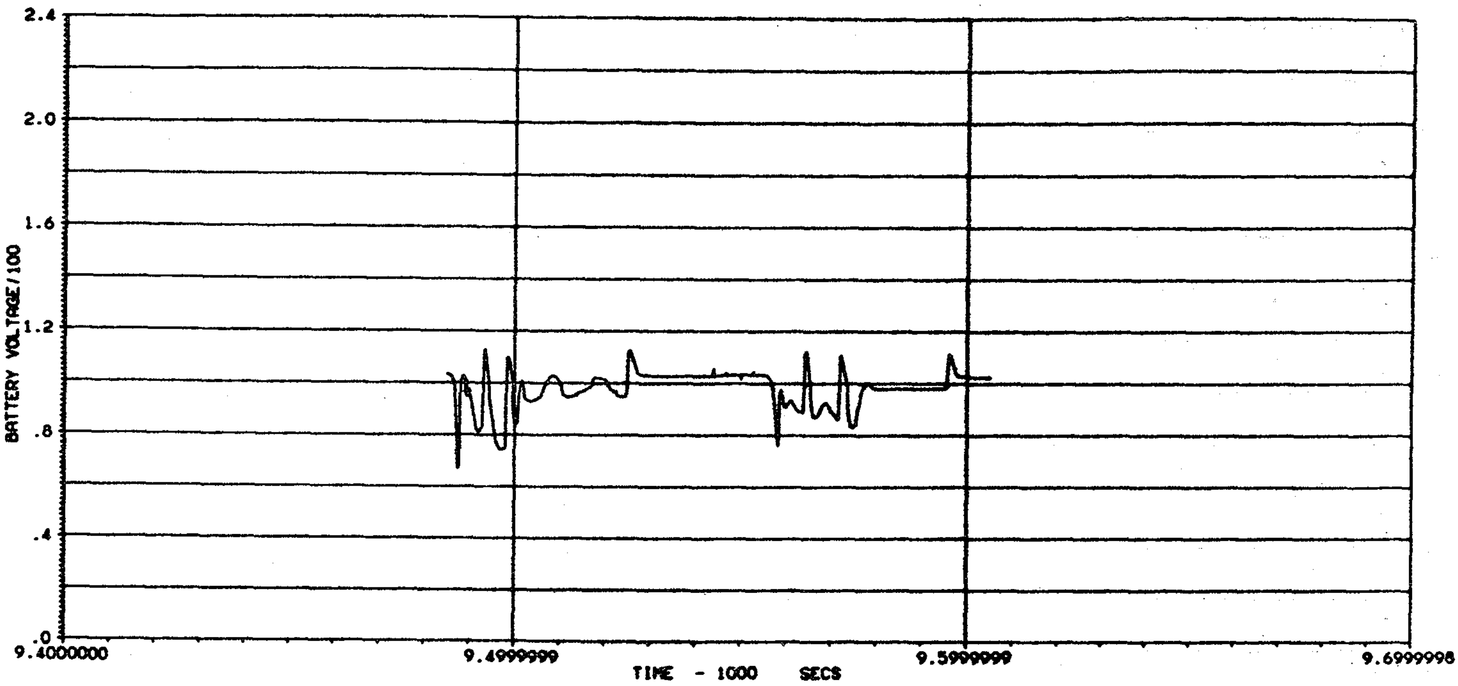


Figure C-23. Battery Voltage, Test VET-35: Driving Schedule B Range at 80% Battery Depth of Discharge

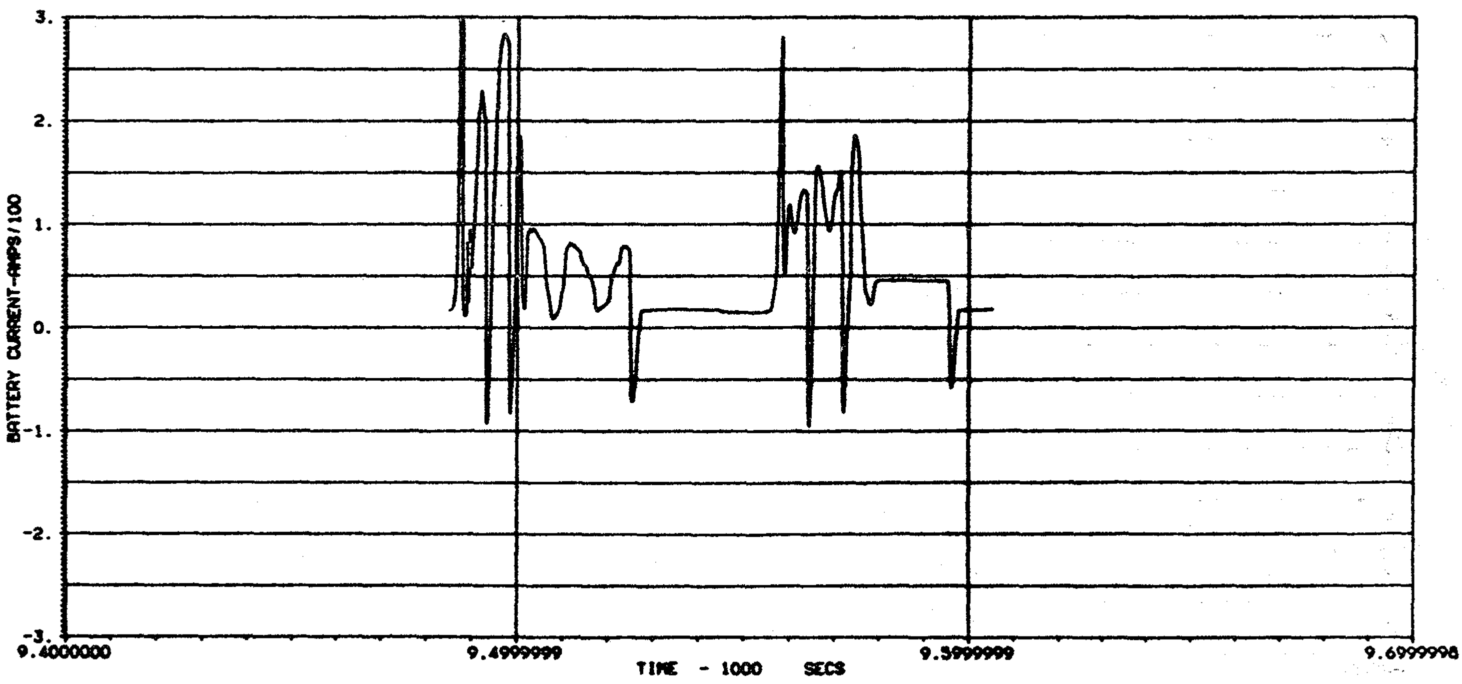


Figure C-24. Battery Current, Test VET-35: Driving Schedule B Range at 80% Battery Depth of Discharge

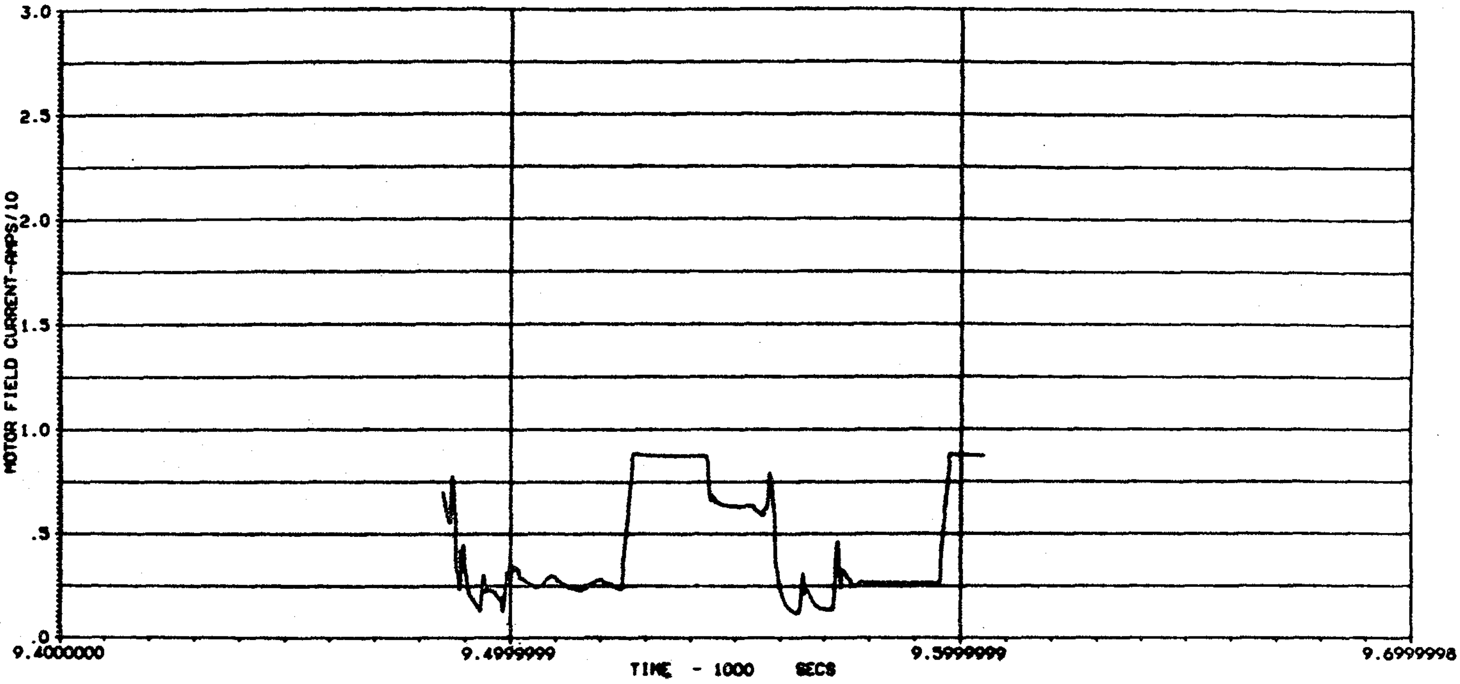


Figure C-25. Motor Field Current, Test VET-35: Driving Schedule B Range at 80% Battery Depth of Discharge

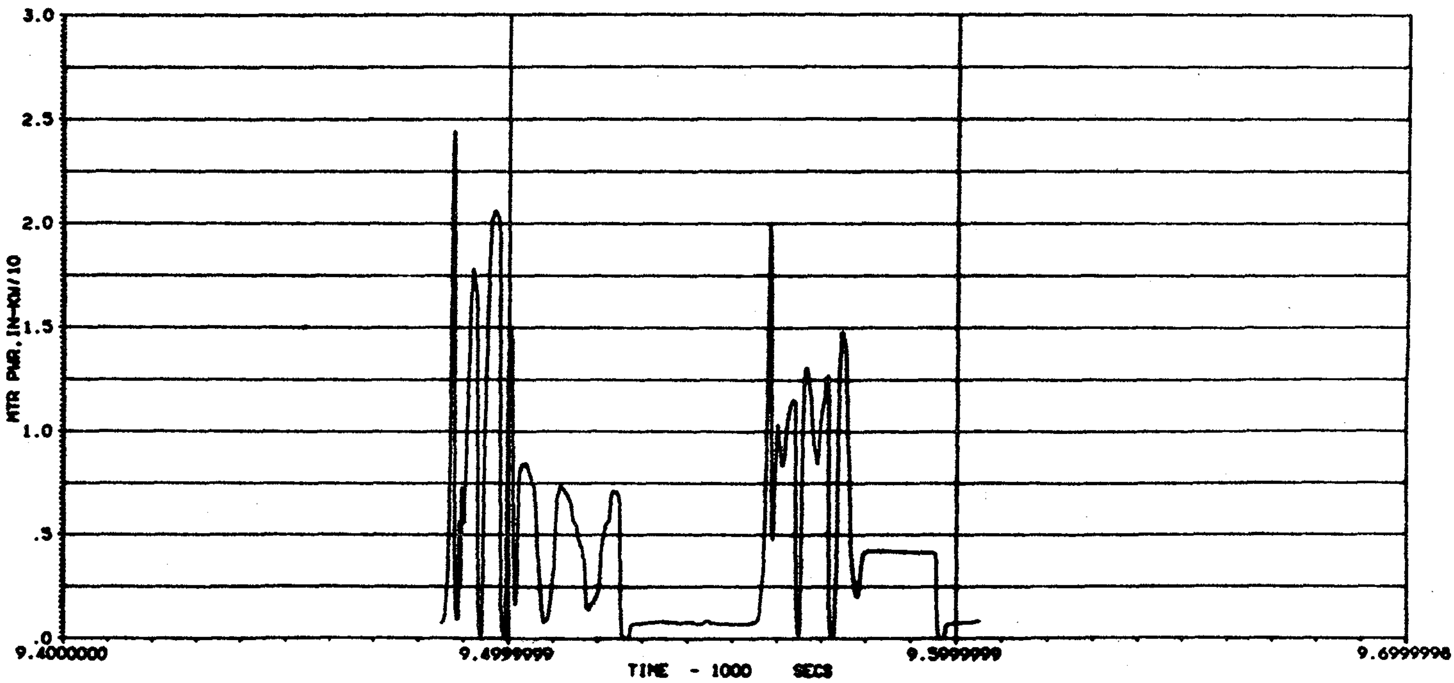


Figure C-26. Motor Input Power, Test VET-35: Driving Schedule B Range at 80% Battery Depth of Discharge

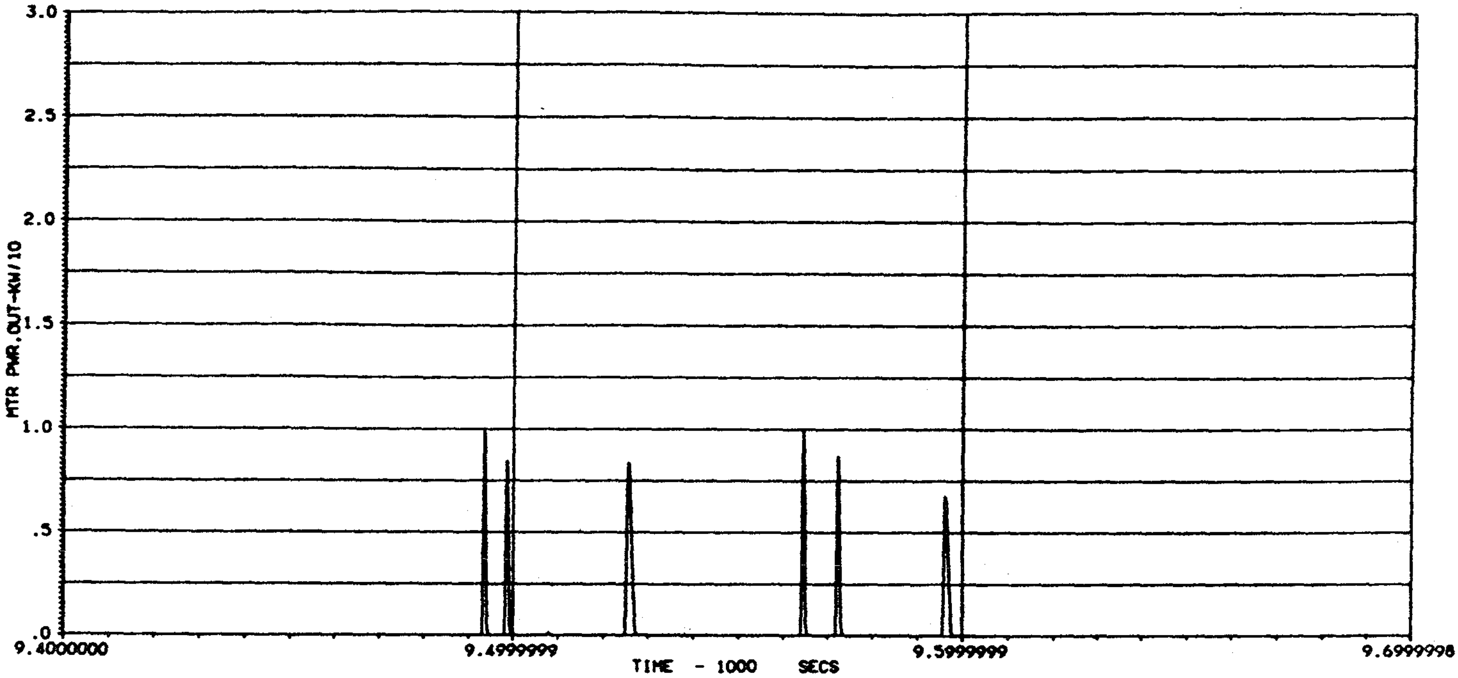


Figure C-27. Motor Output Power (Regeneration), Test VET-35: Driving Schedule B Range at 80% Battery Depth of Discharge

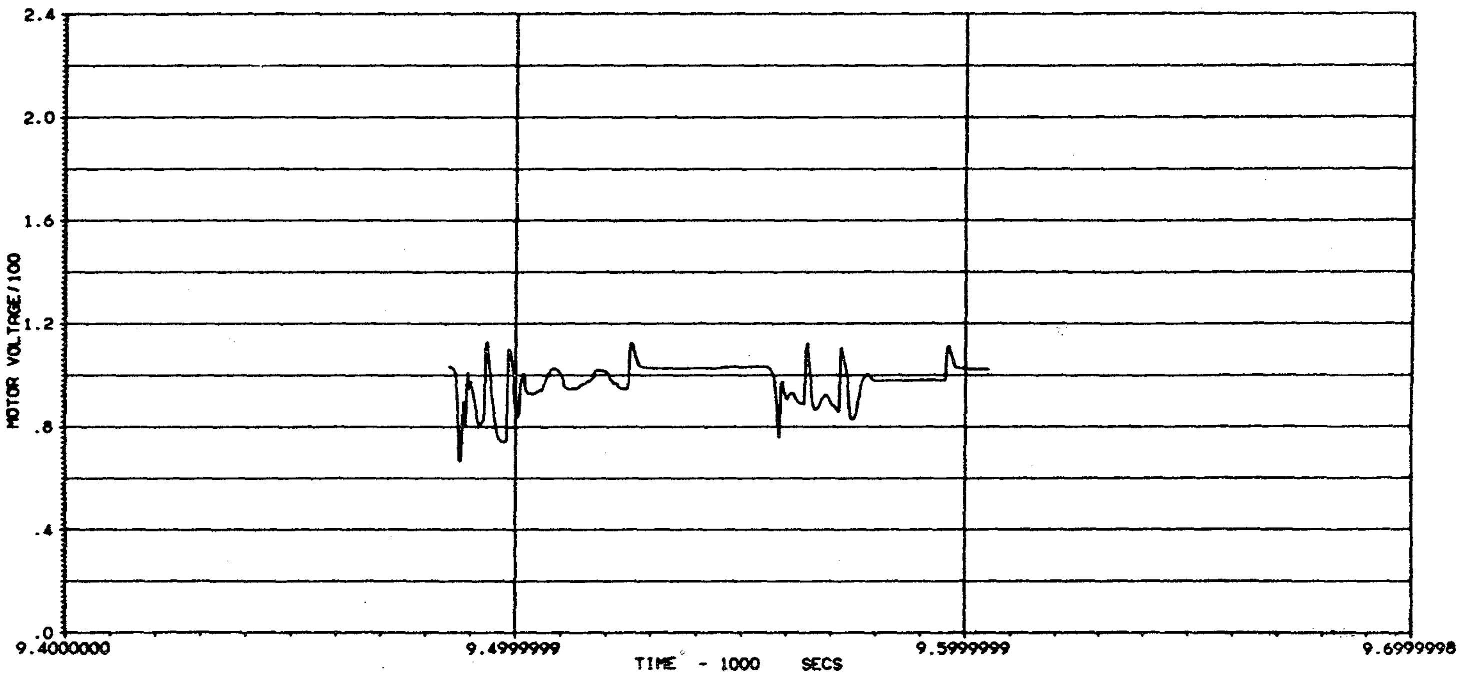


Figure C-28. Motor Voltage, Test VET-35: Driving Schedule B Range at 80% Battery Depth of Discharge

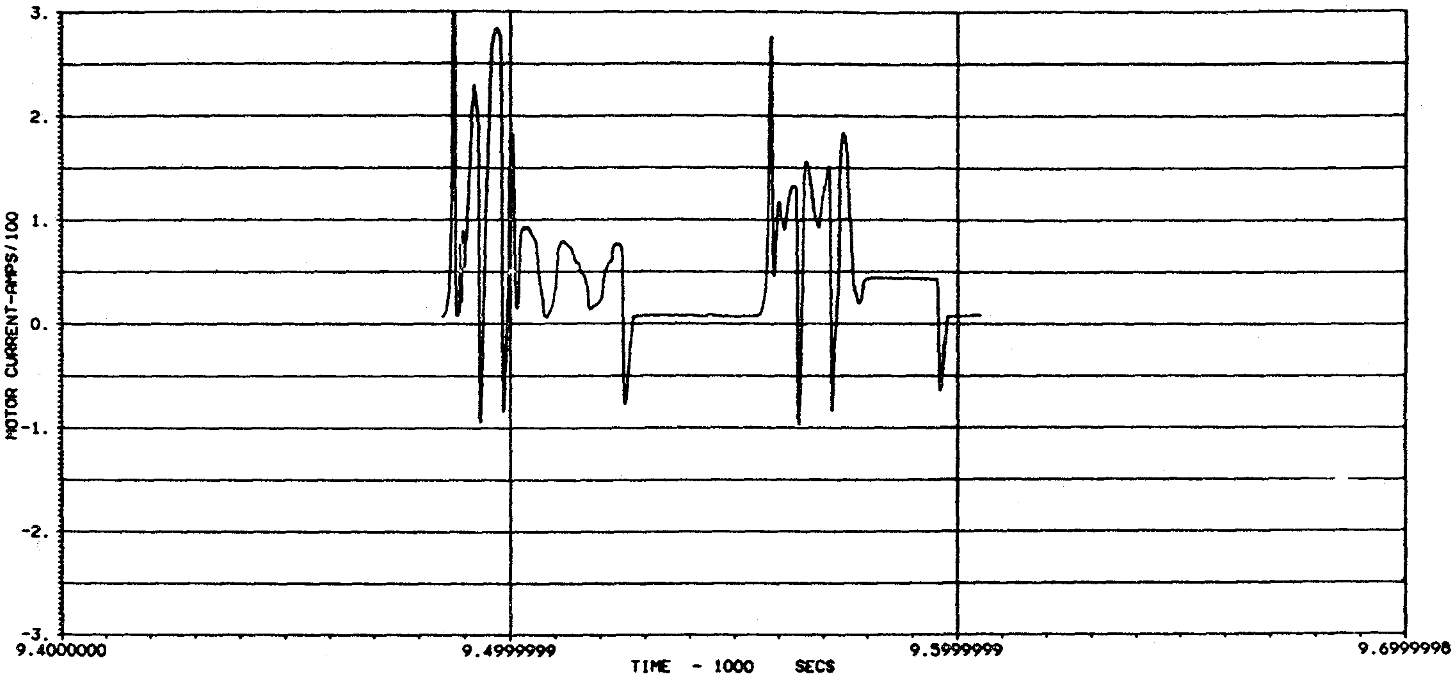


Figure C-29. Motor Current, Test VET-35: Driving Schedule B Range at 80% Battery Depth of Discharge

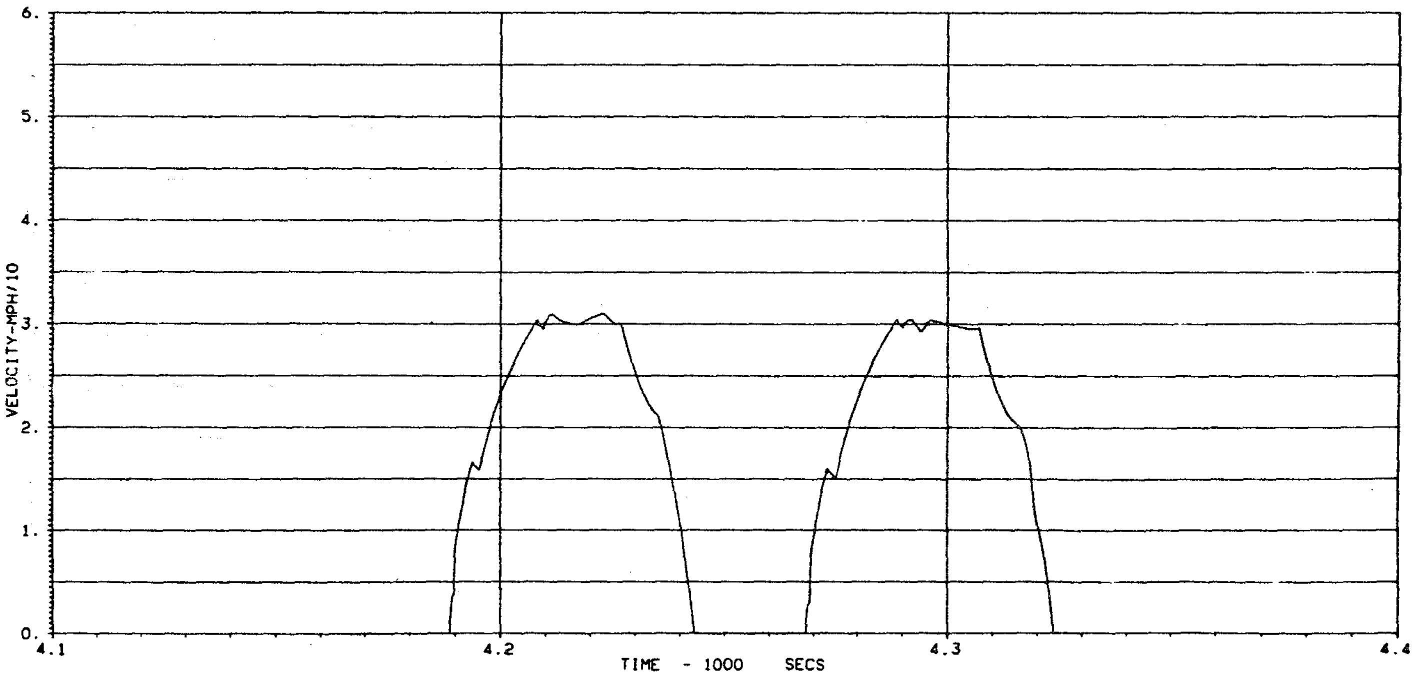


Figure C-30. Vehicle Velocity, Test VET-32: Driving Schedule C Range at 80% Battery Depth of Discharge

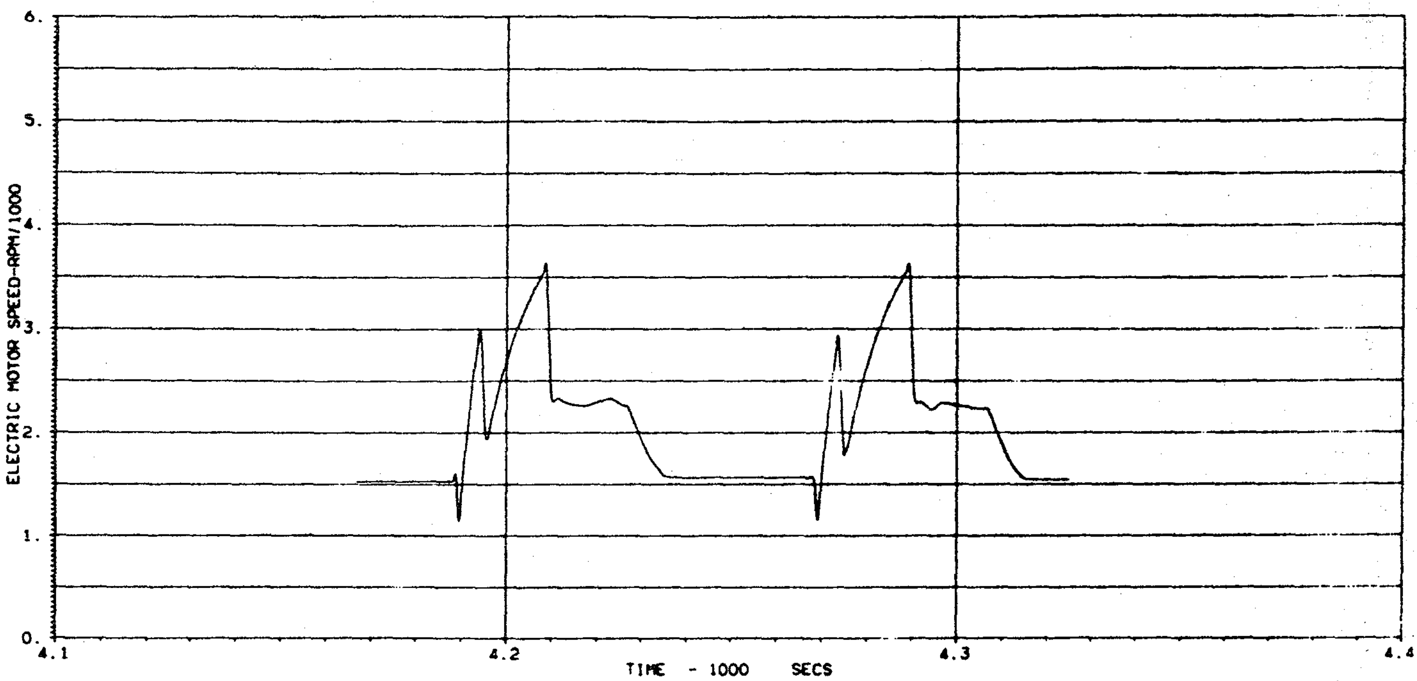


Figure C-31. Motor Speed, Test VET-32: Driving Schedule C
Range at 80% Battery Depth of Discharge

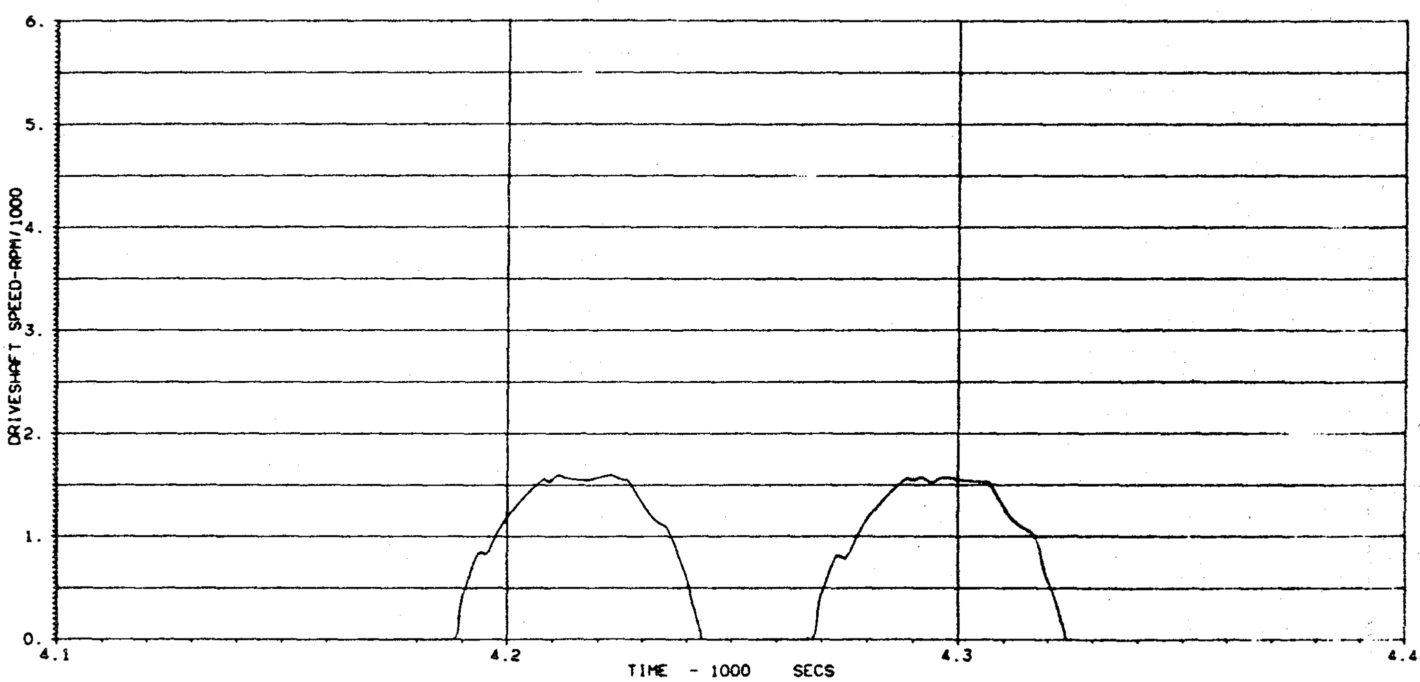


Figure C-32. Drive Shaft Speed, Test VET-32: Driving Schedule C
Range at 80% Battery Depth of Discharge

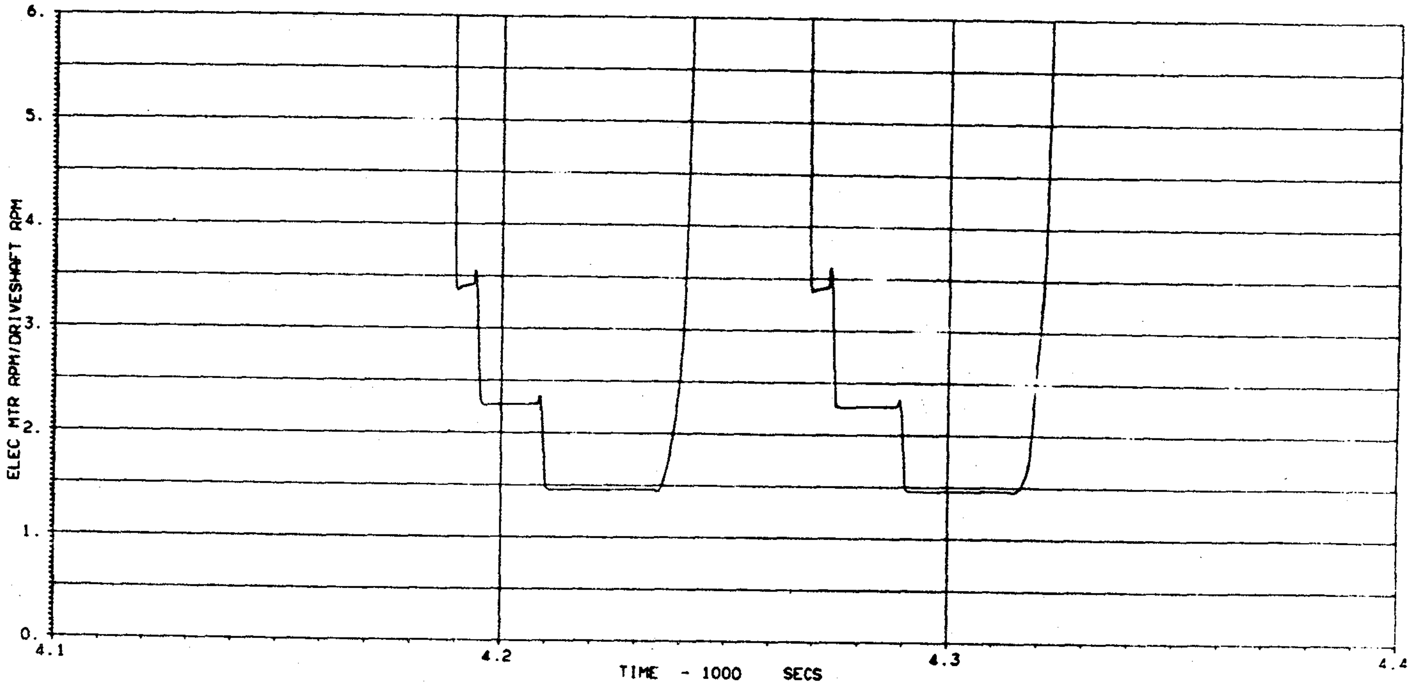


Figure C-33. Gear Ratios (Motor Speed/Drive Shaft Speed), Test VET-32: Driving Schedule C Range at 80% Depth of Discharge

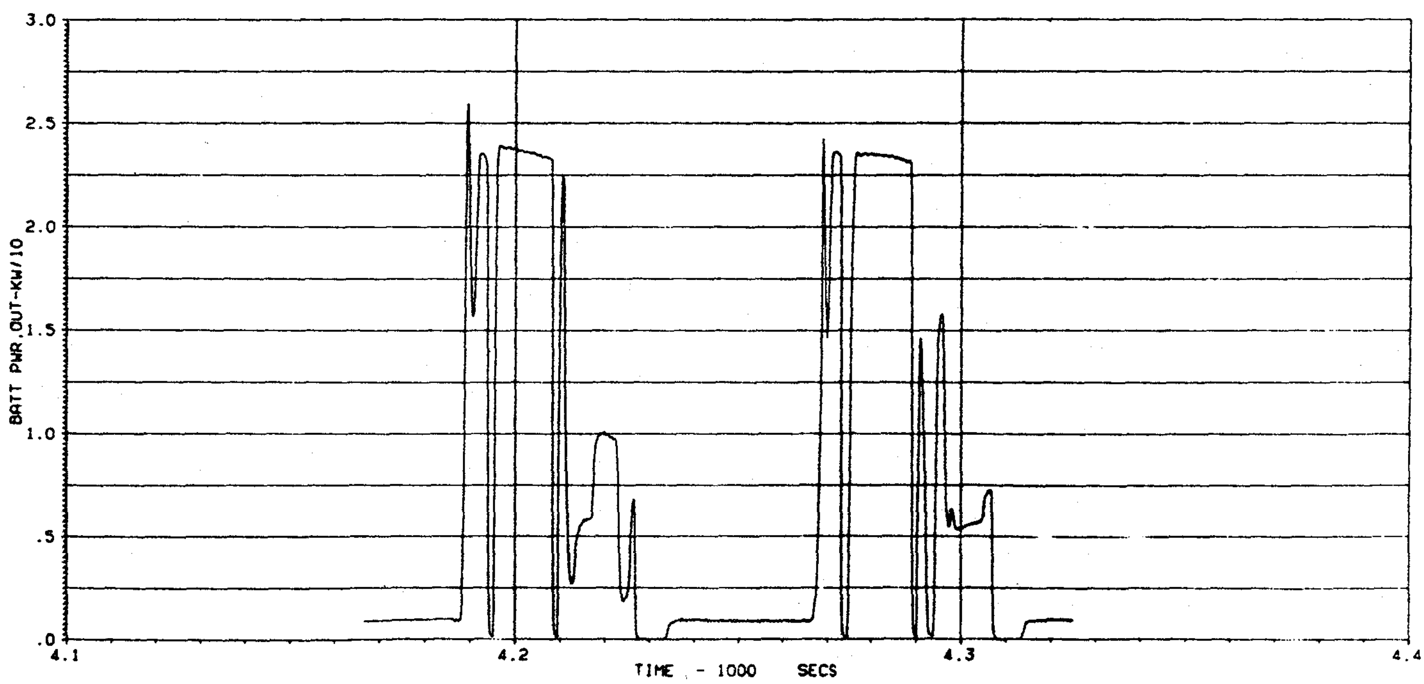


Figure C-34. Battery Output Power, Test VET-32: Driving Schedule C Range at 80% Battery Depth of Discharge

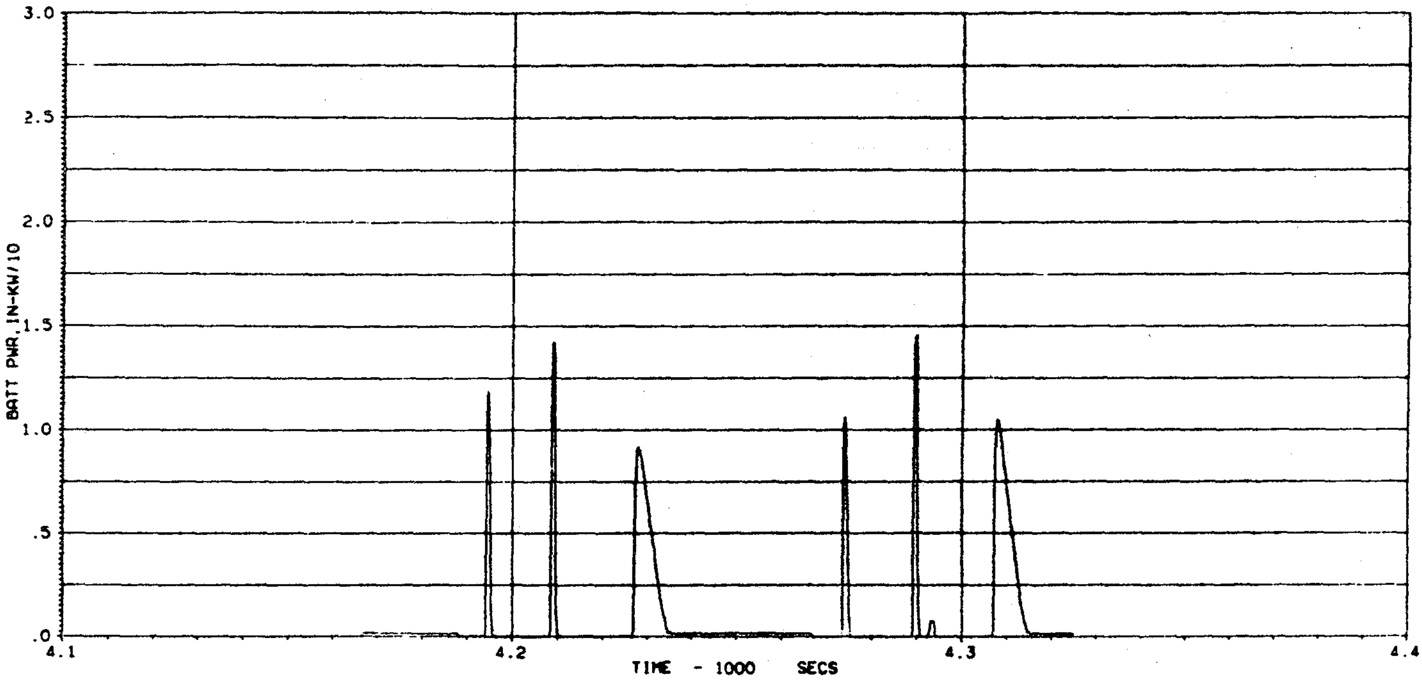


Figure C-35. Battery Input Power (Regeneration), Test VET-32: Driving Schedule C Range at 80% Battery Depth of Discharge

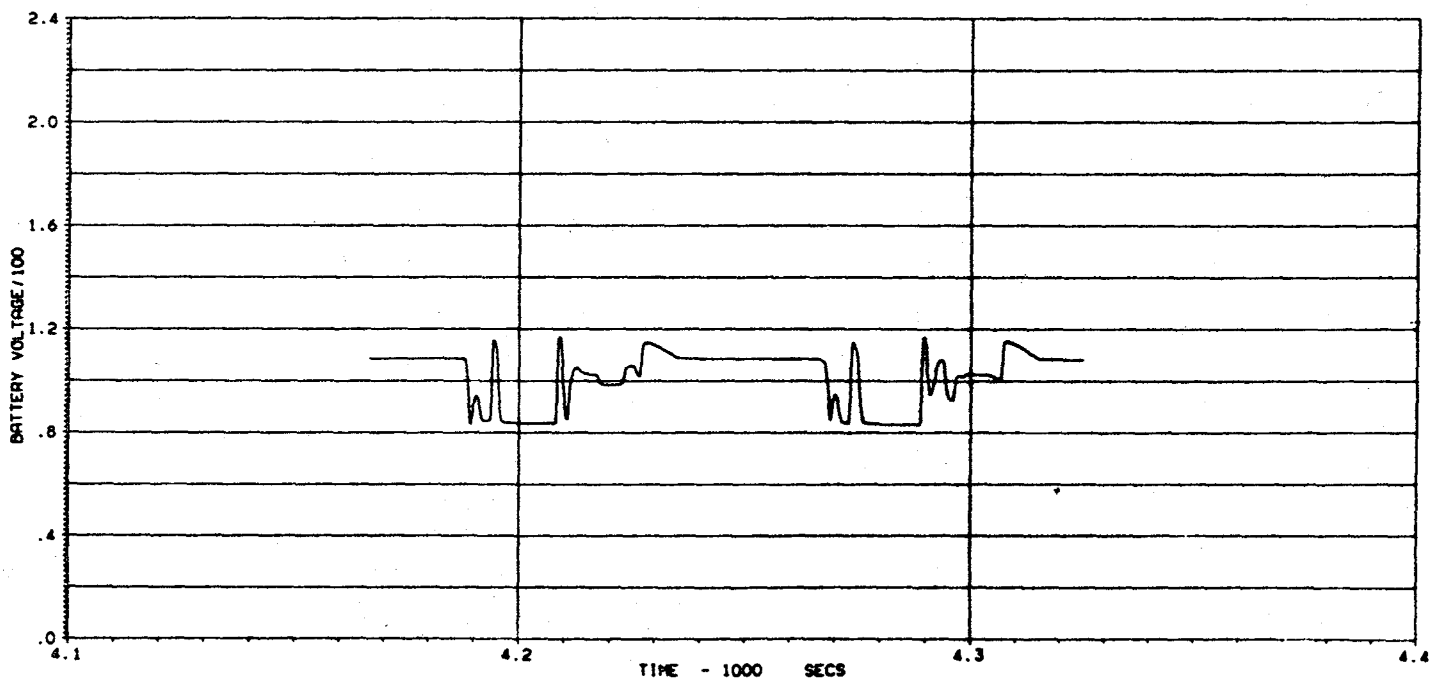


Figure C-36. Battery Voltage, Test VET-32: Driving Schedule C Range at 80% Battery Depth of Discharge

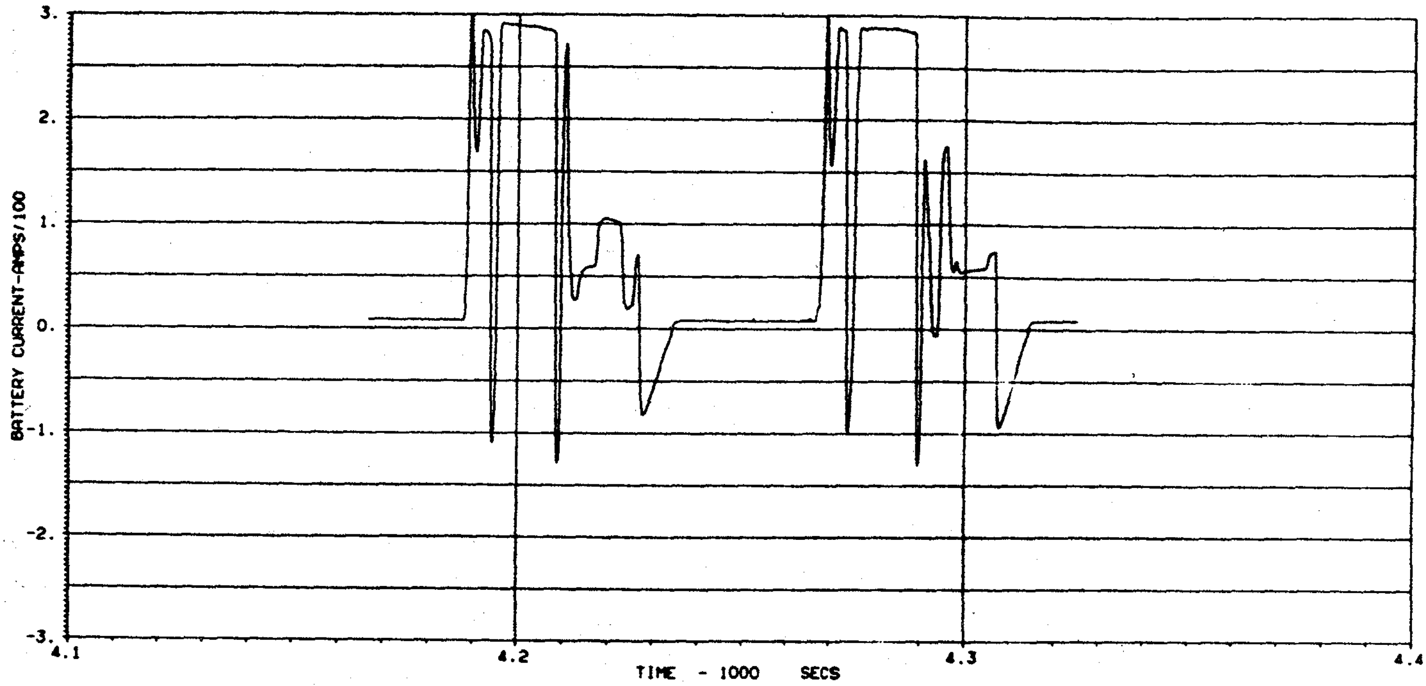


Figure C-37. Battery Current, Test VET-32: Driving Schedule C Range at 80% Battery Depth of Discharge

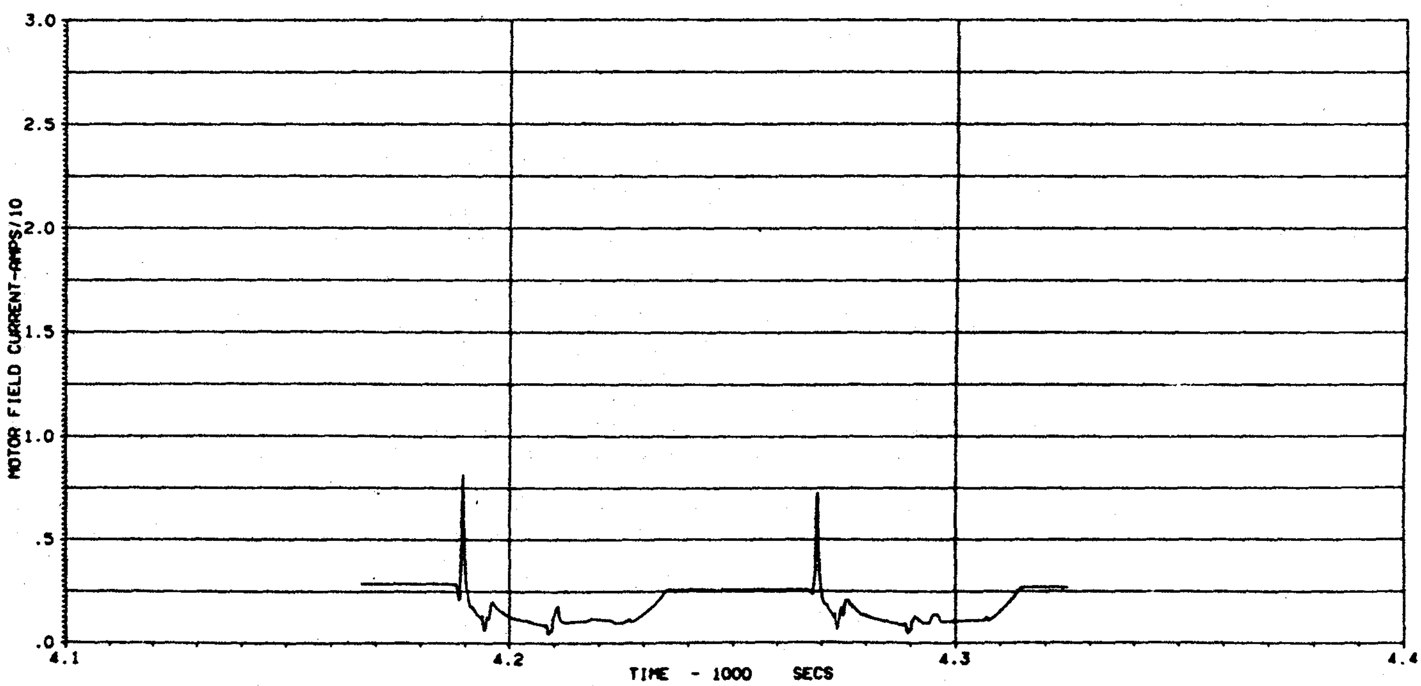


Figure C-38. Motor Field Current, Test VET-32: Driving Schedule C Range at 80% Battery Depth of Discharge

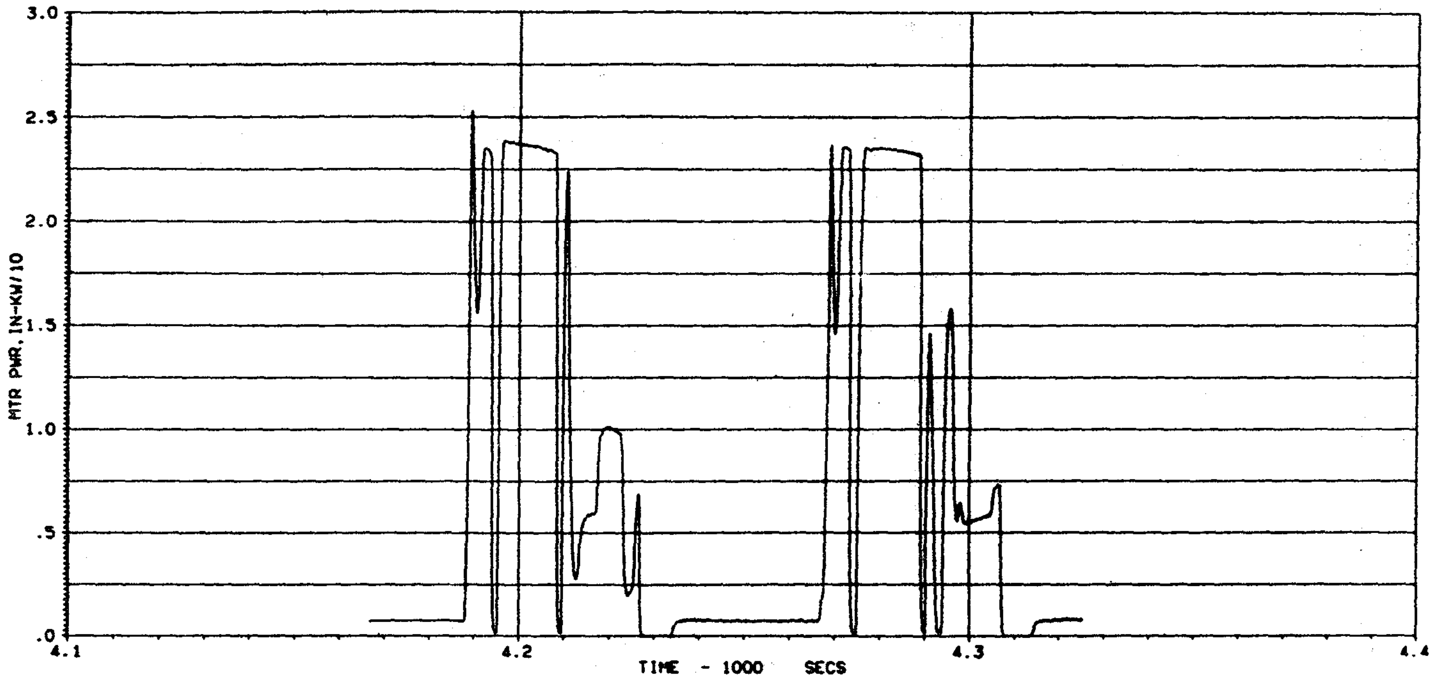


Figure C-39. Motor Input Power, Test VET-32: Driving Schedule C Range at 80% Battery Depth of Discharge

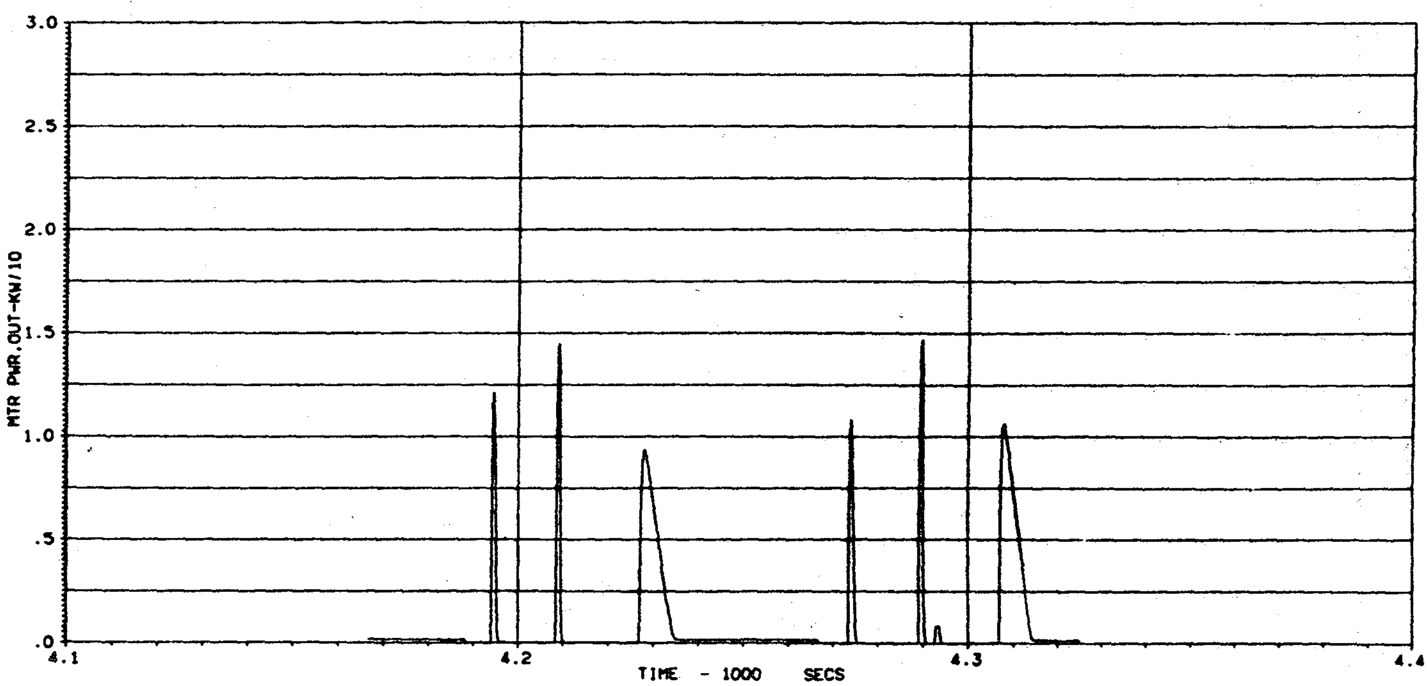


Figure C-40. Motor Output Power (Regeneration), Test VET-32: Driving Schedule C Range at 80% Battery Depth of Discharge

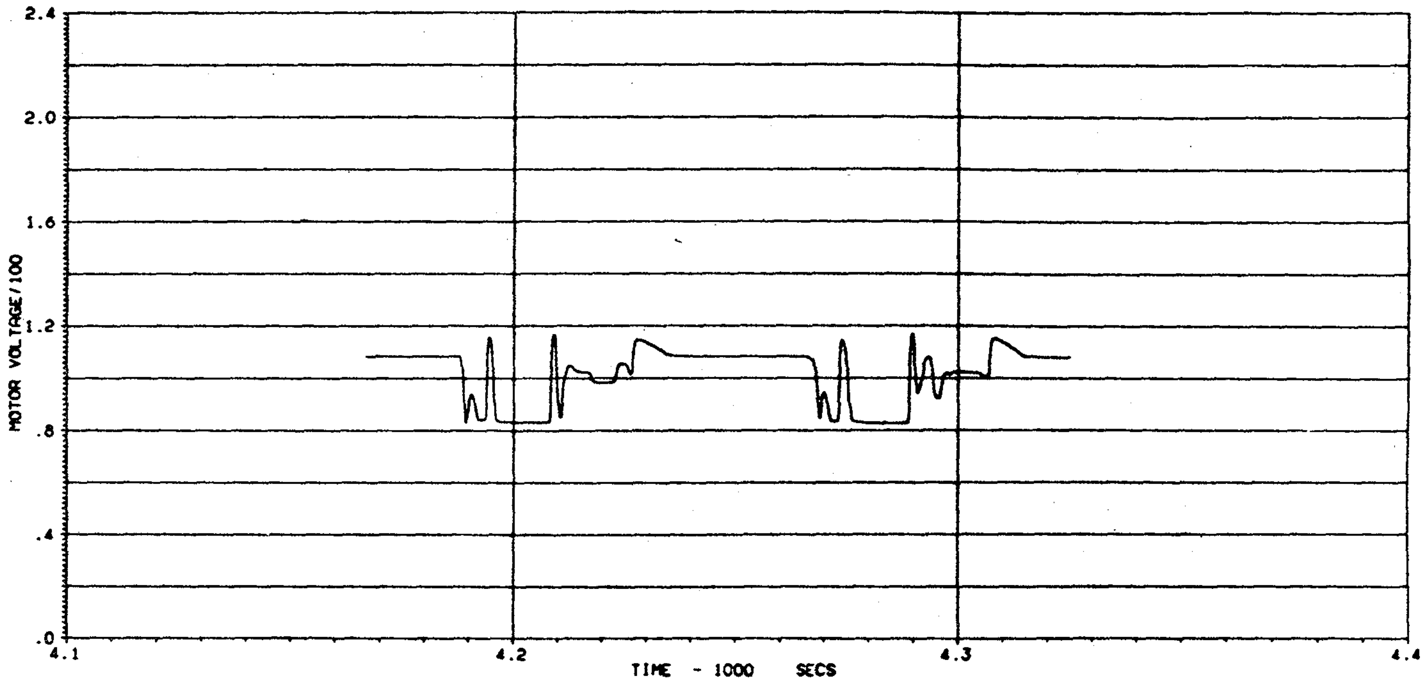


Figure C-41. Motor Voltage, Test VET-32: Driving Schedule C Range at 80% Battery Depth of Discharge

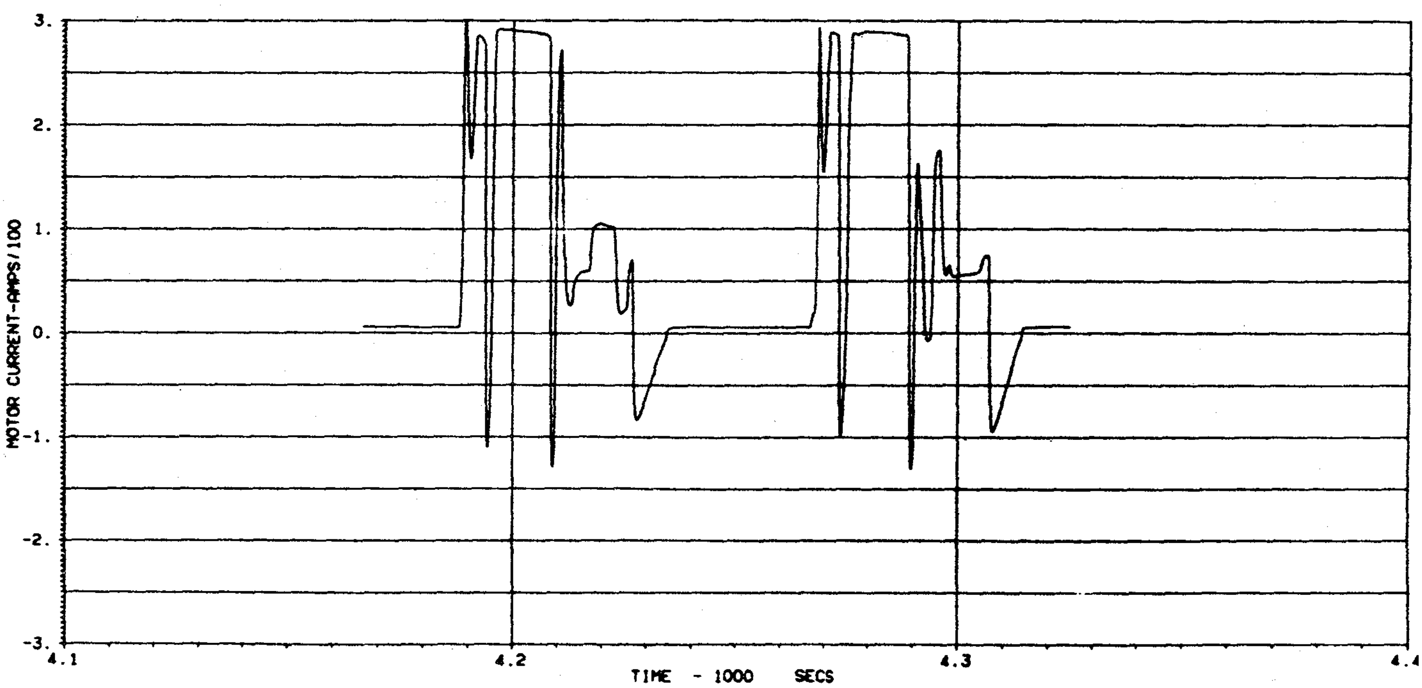


Figure C-42. Motor Current, Test VET-32: Driving Schedule C Range at 80% Battery Depth of Discharge

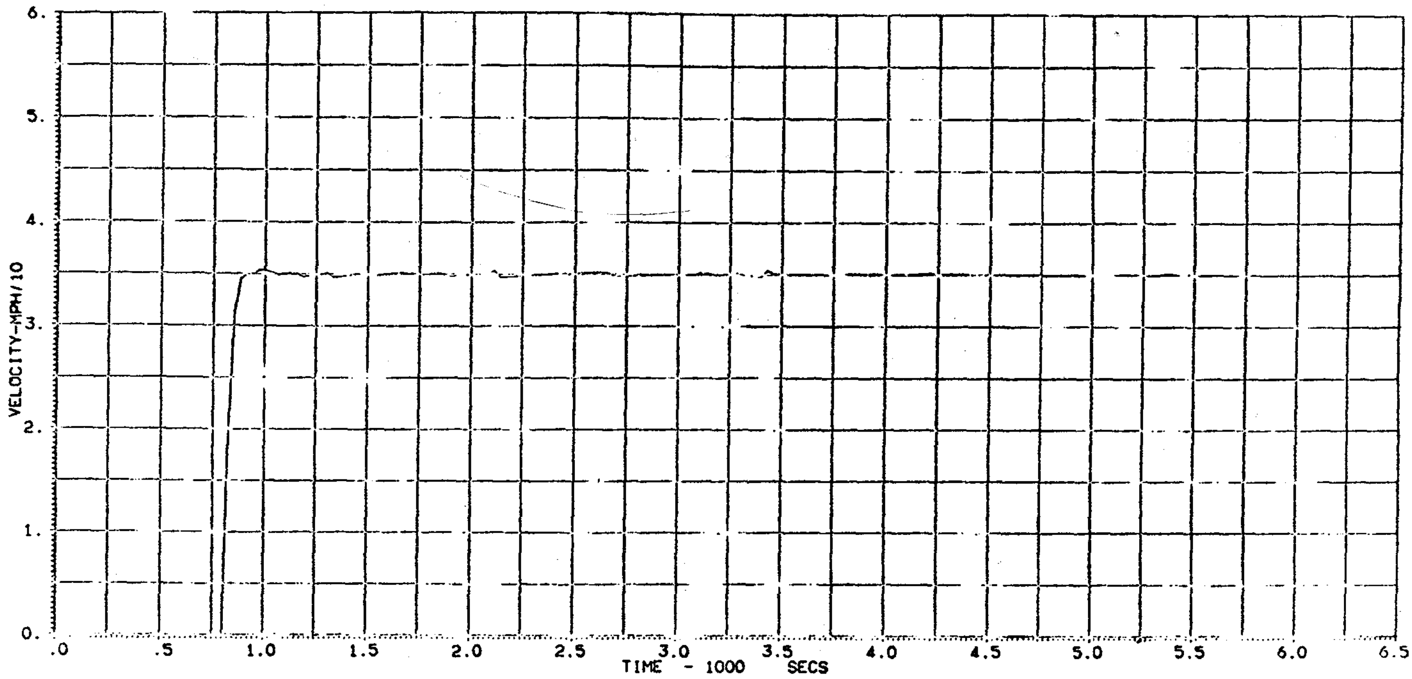


Figure C-43. Vehicle Velocity, Test VET-29: Range at 35 mi/h

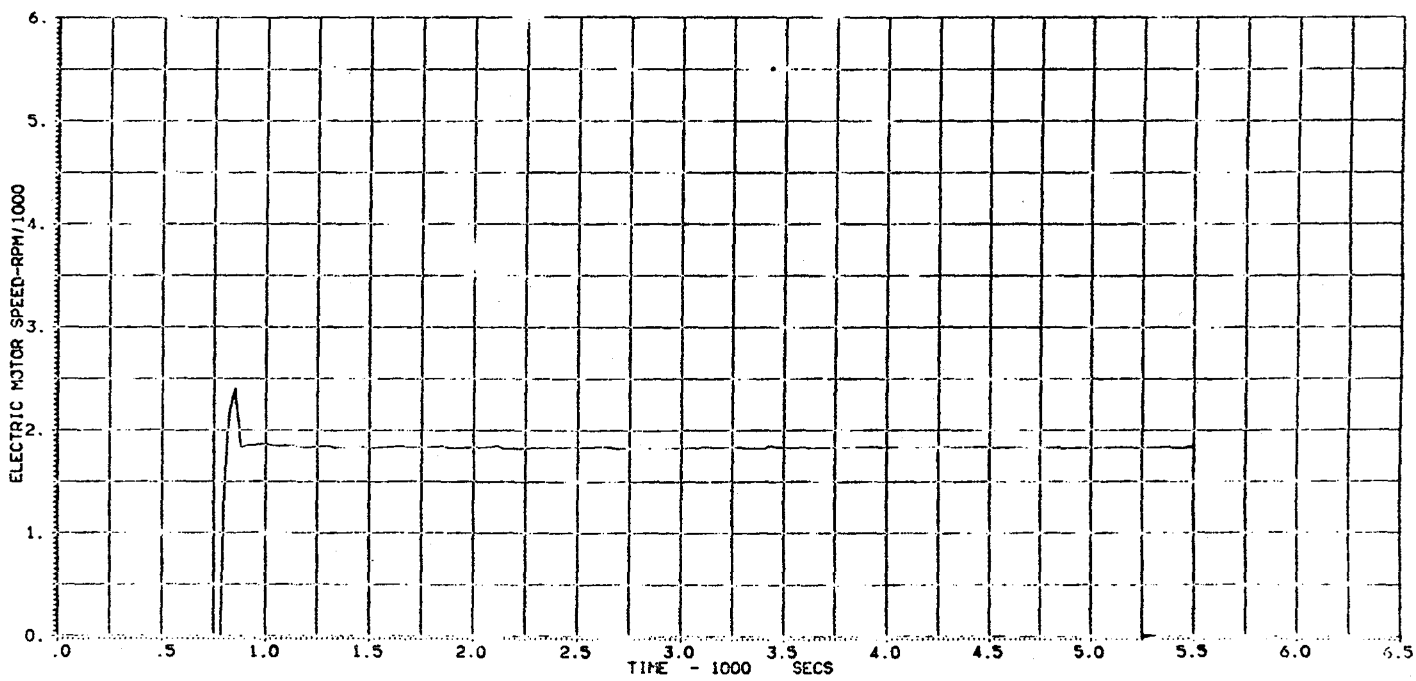


Figure C-44. Motor Speed, Test VET-29: Range at 35 mi/h

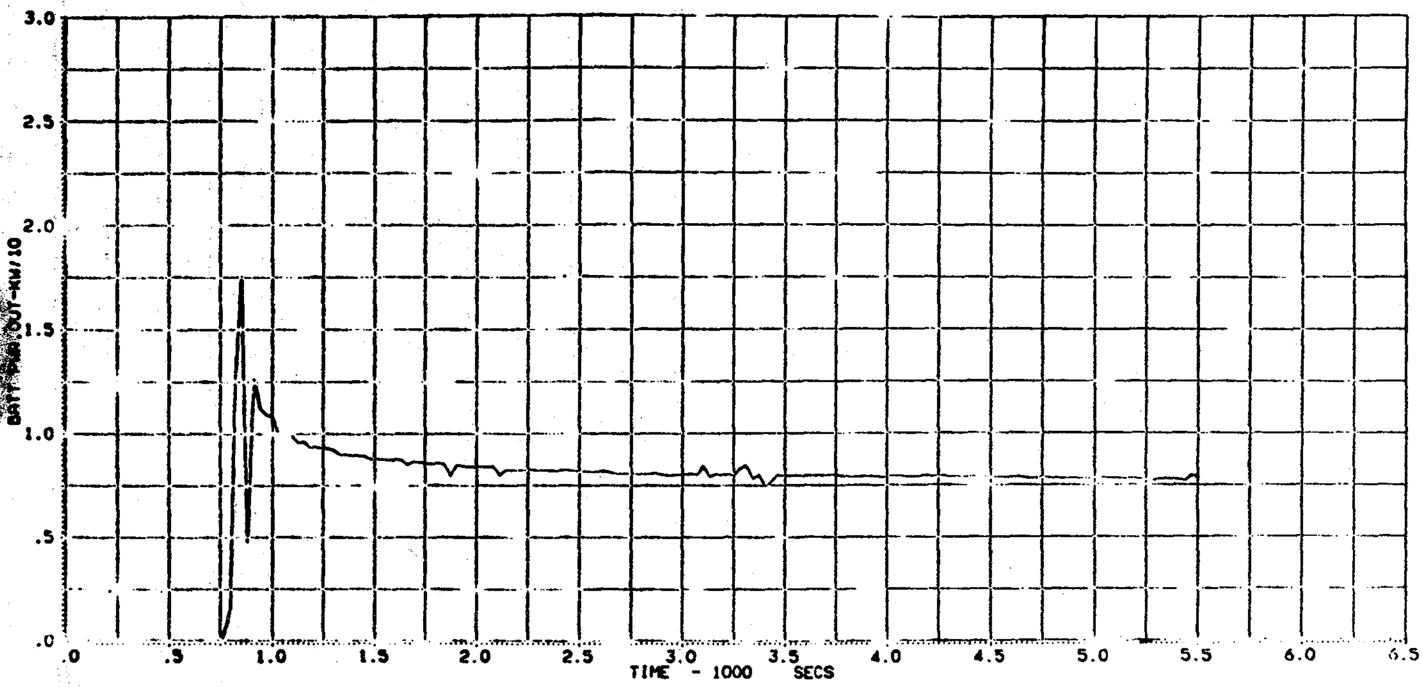


Figure C-45. **Battery Output Power, Test VET-29:** Range at 35 mi/h

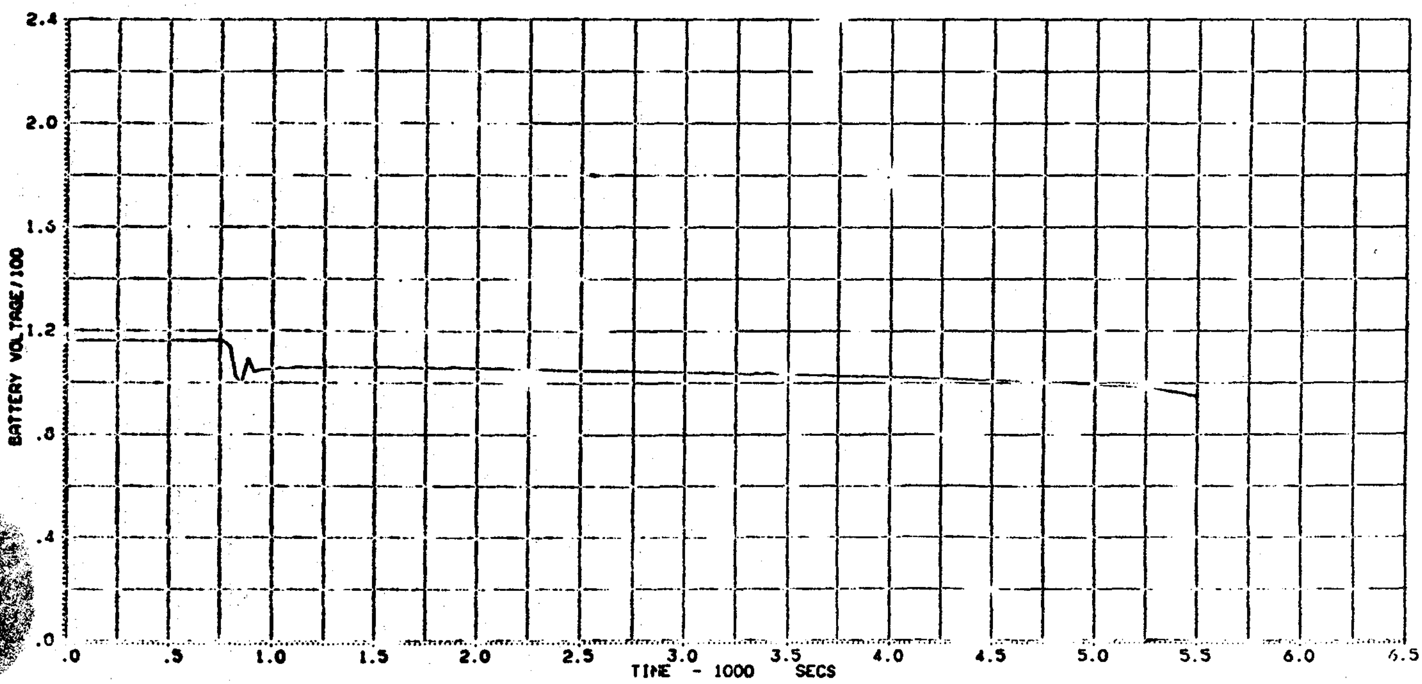


Figure C-46. **Battery Voltage, Test VET-29:** Range at 35 mi/h

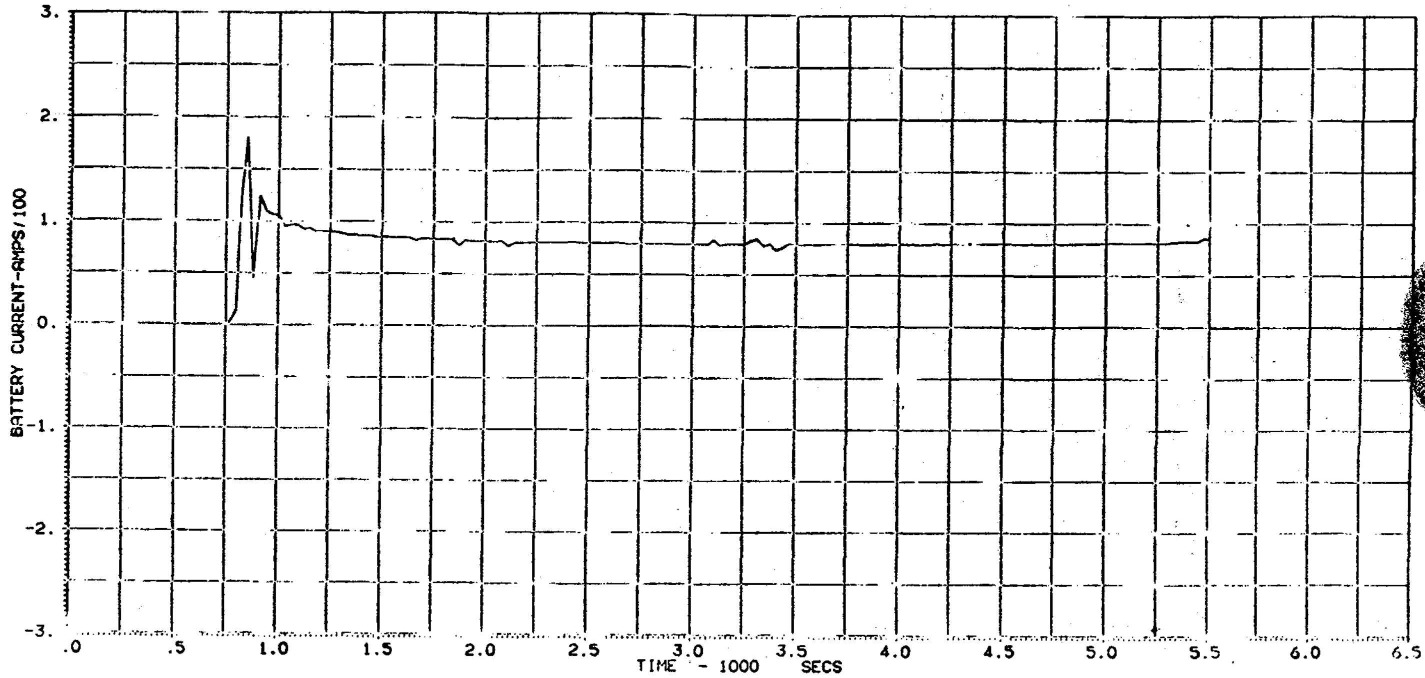


Figure C-47. Battery Current, Test VET-29: Range at 35 mi/h

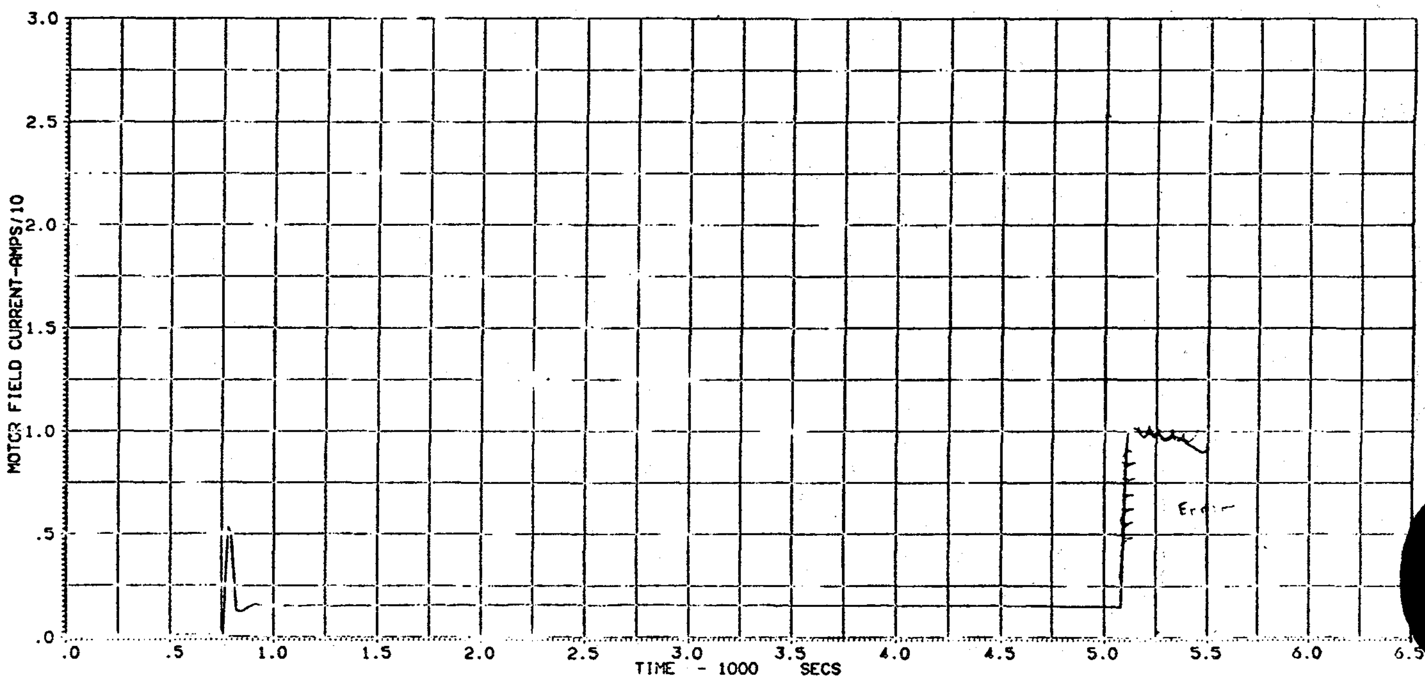


Figure C-48. Motor Field Current, Test VET-29: Range at 35 mi/h

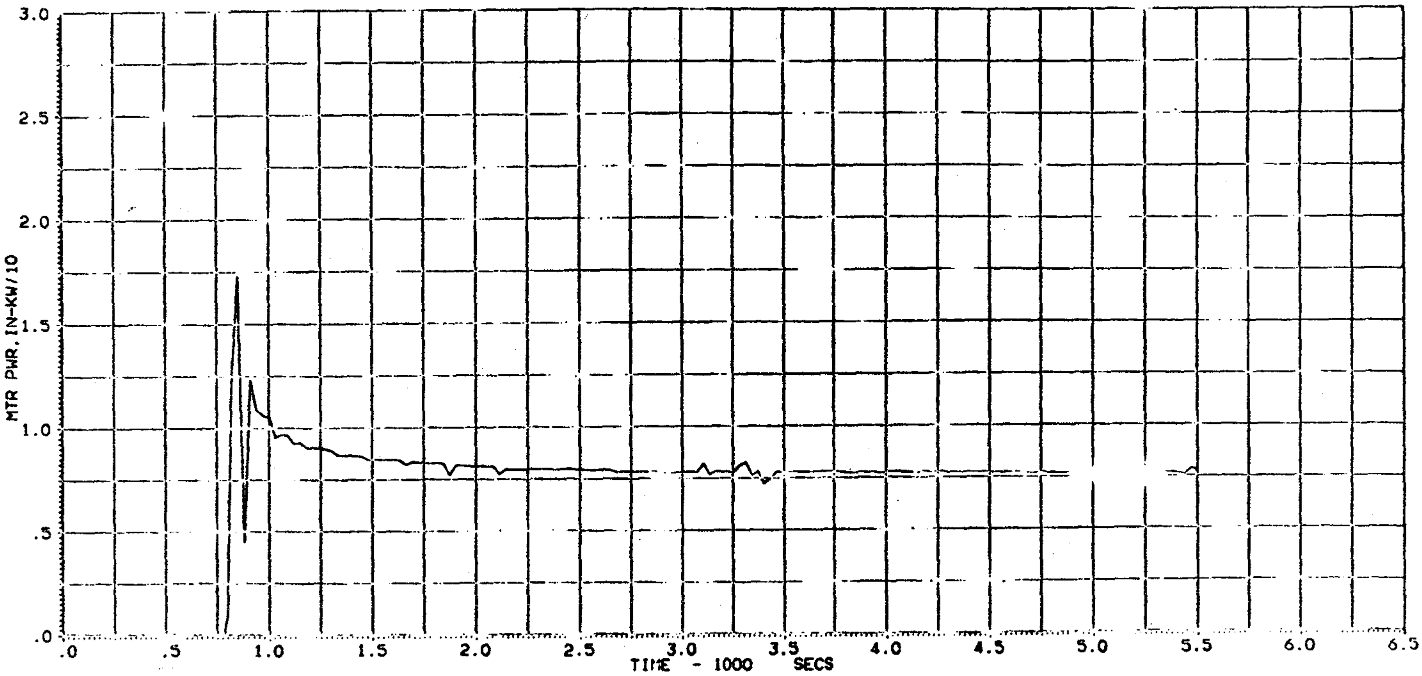


Figure C-49. Motor Input Power, Test VET-29: Range at 35 mi/h

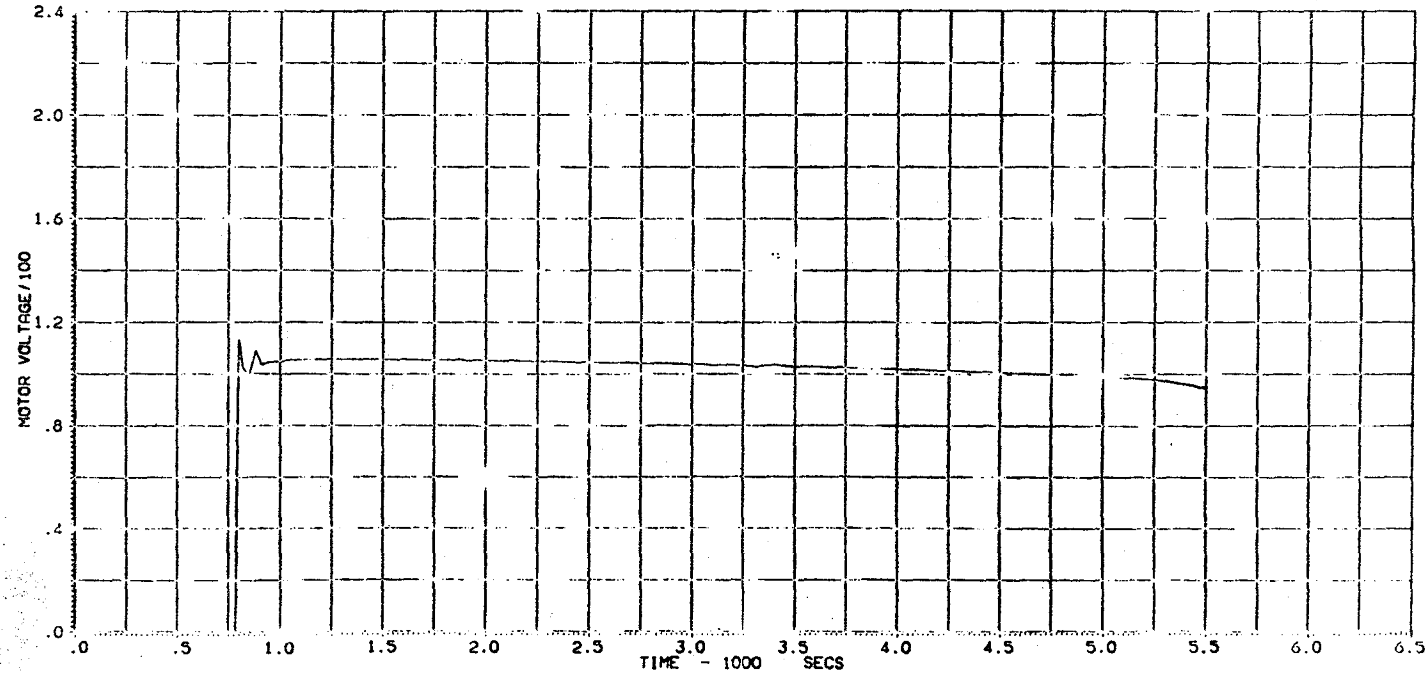


Figure C-50. Motor Voltage, Test VET-29: Range at 35 mi/h

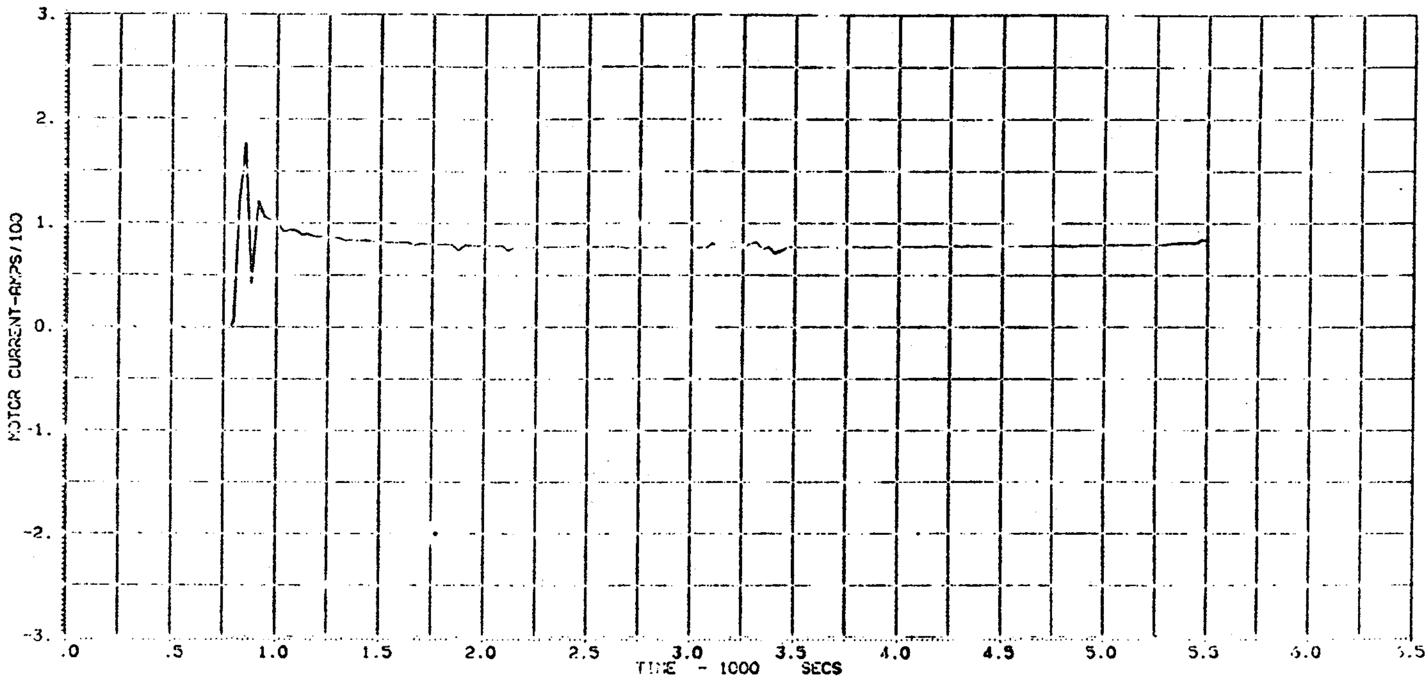


Figure C-51. Motor Current, Test VET-29: Range at 35 mi/h

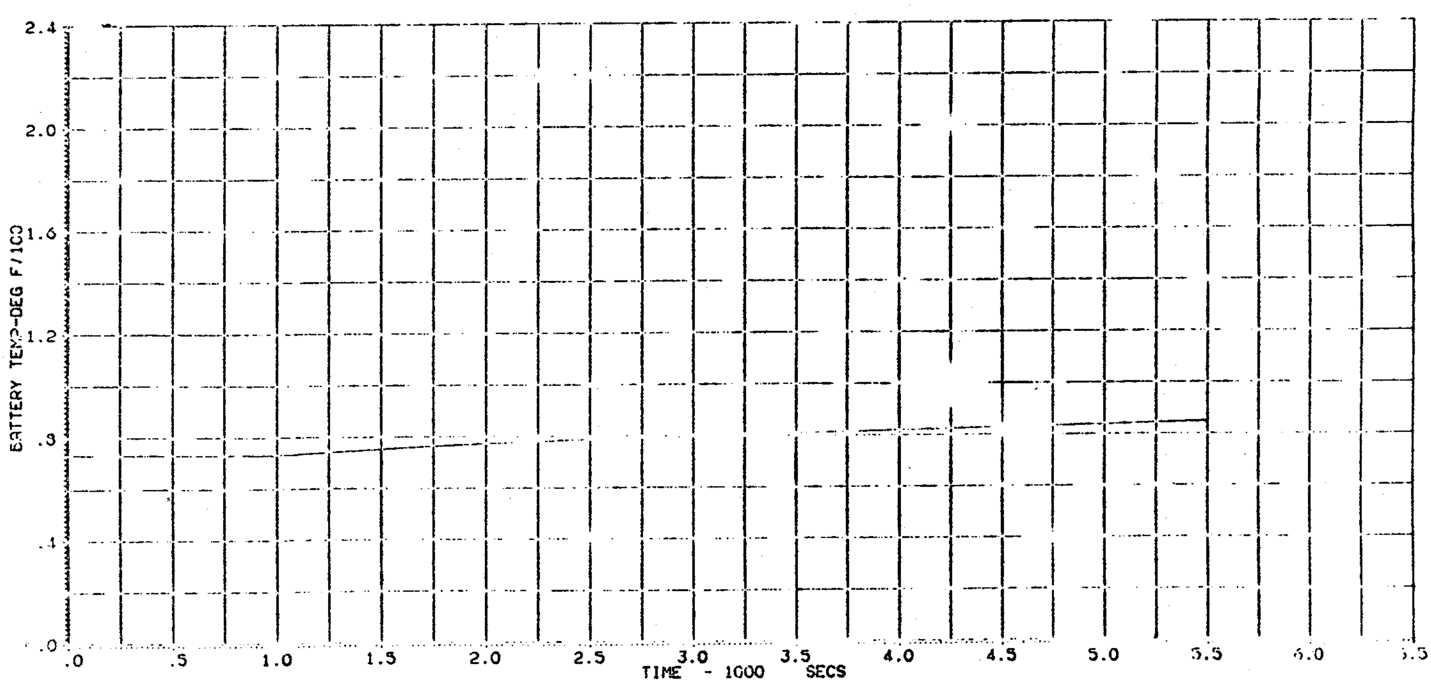


Figure C-52. Battery Pack Temperature, Test VET-29: Range at 35 mi/h

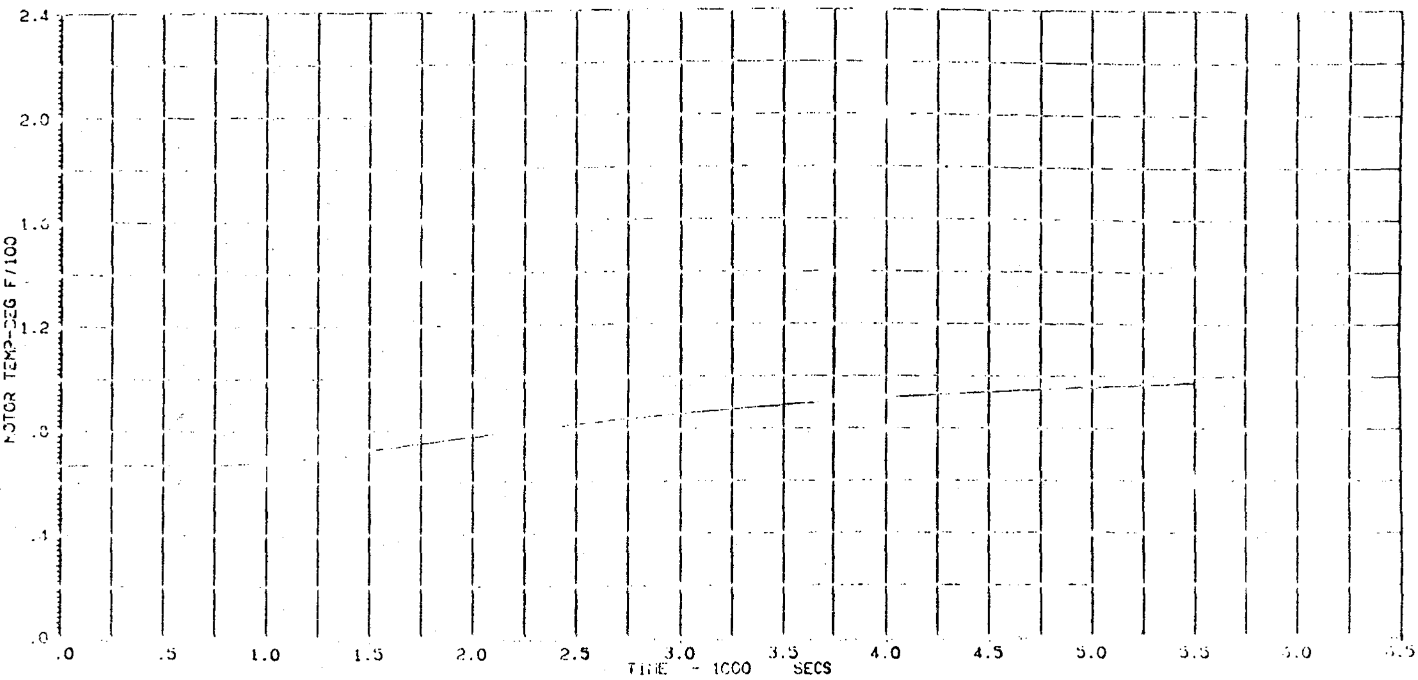


Figure C-53. Motor Case Temperature, Test VET-29: Range at 35 mi/h

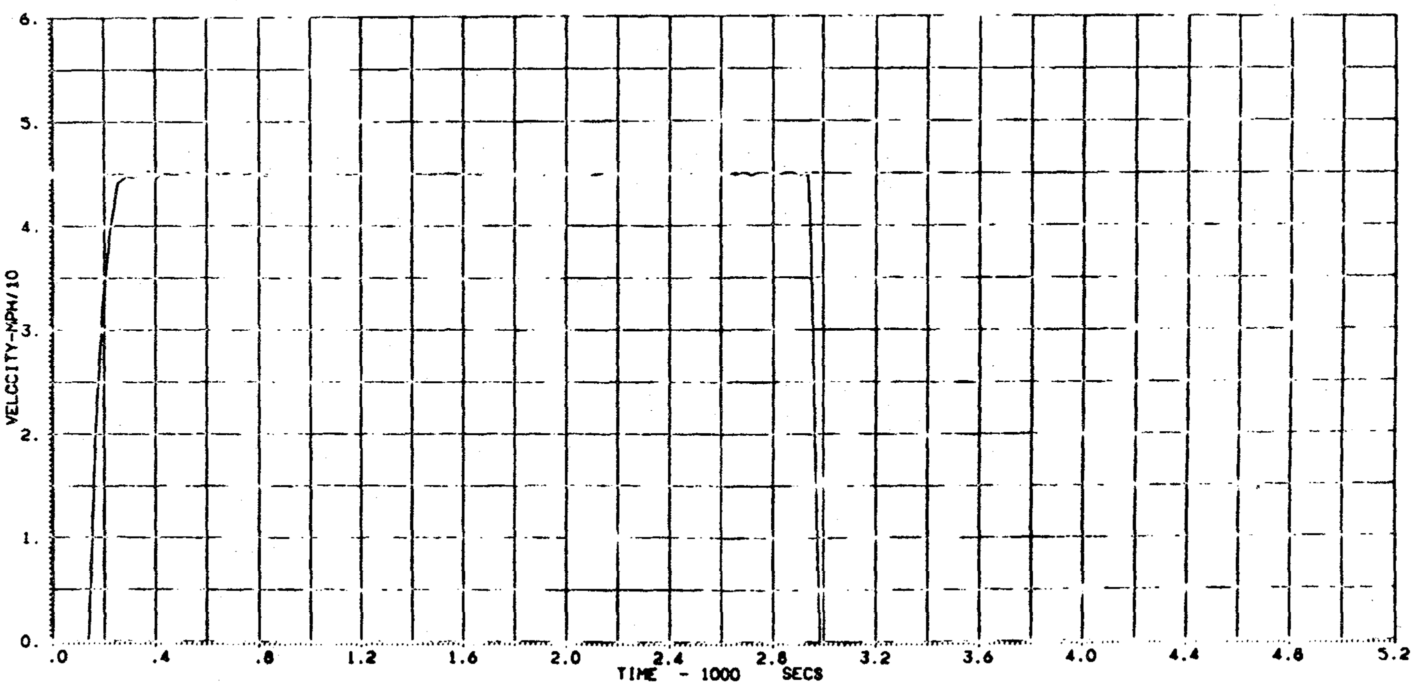


Figure C-54. Vehicle Velocity, Test VET-30: Range at 45 mi/h

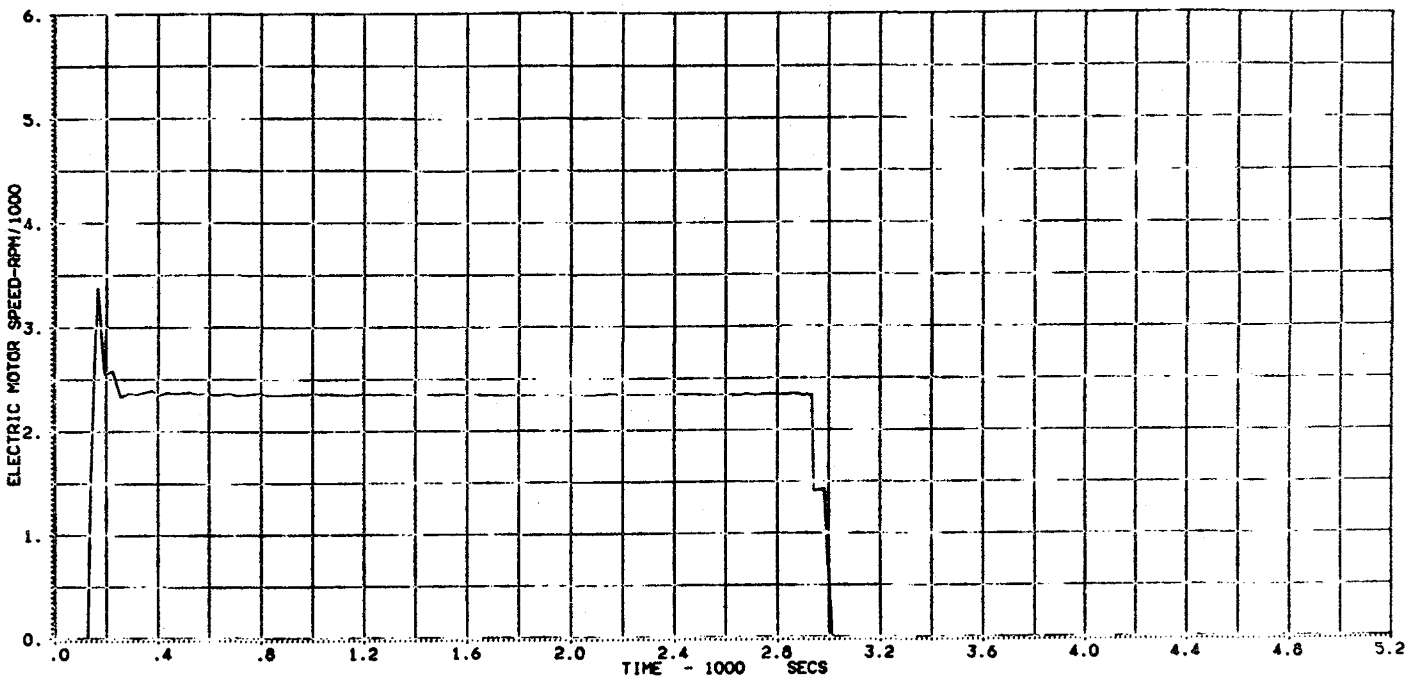


Figure C-55. Motor Speed, Test VET-30: Range at 45 mi/h

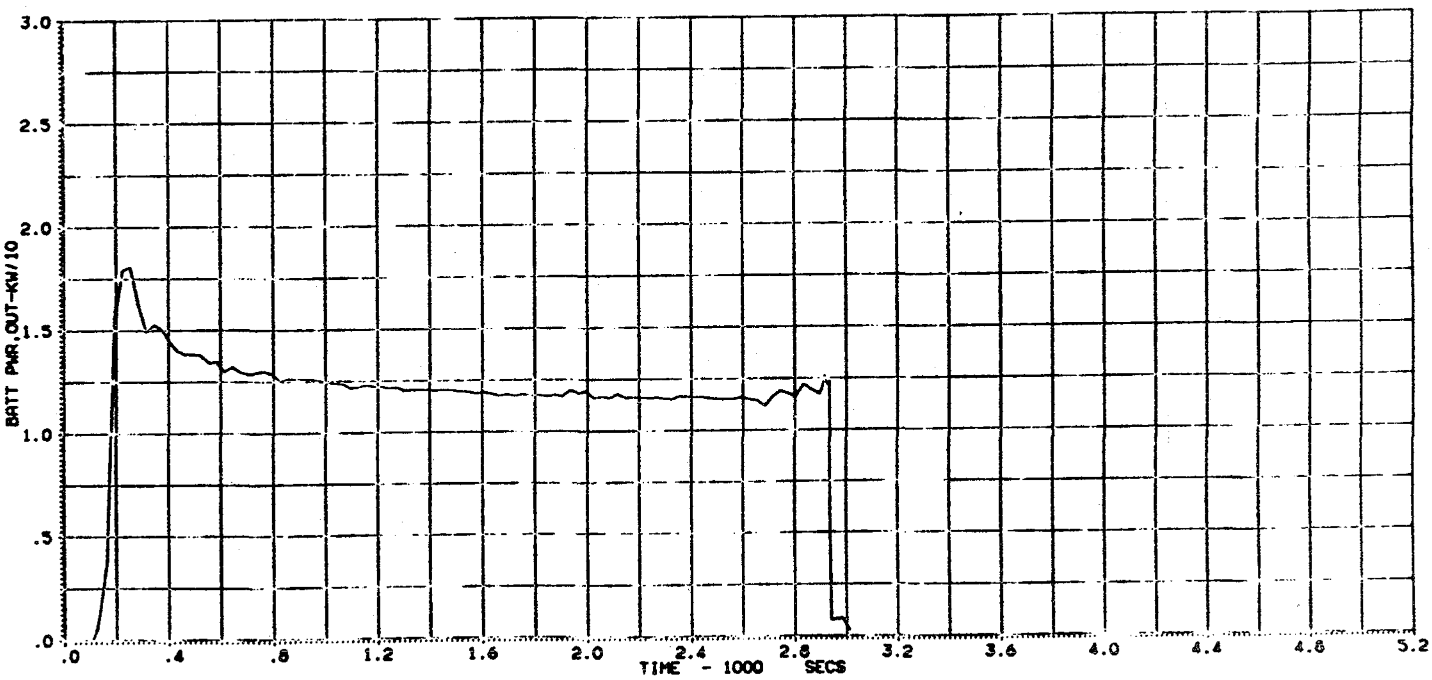


Figure C-56. Battery Output Power, Test VET-30: Range at 45 mi/h

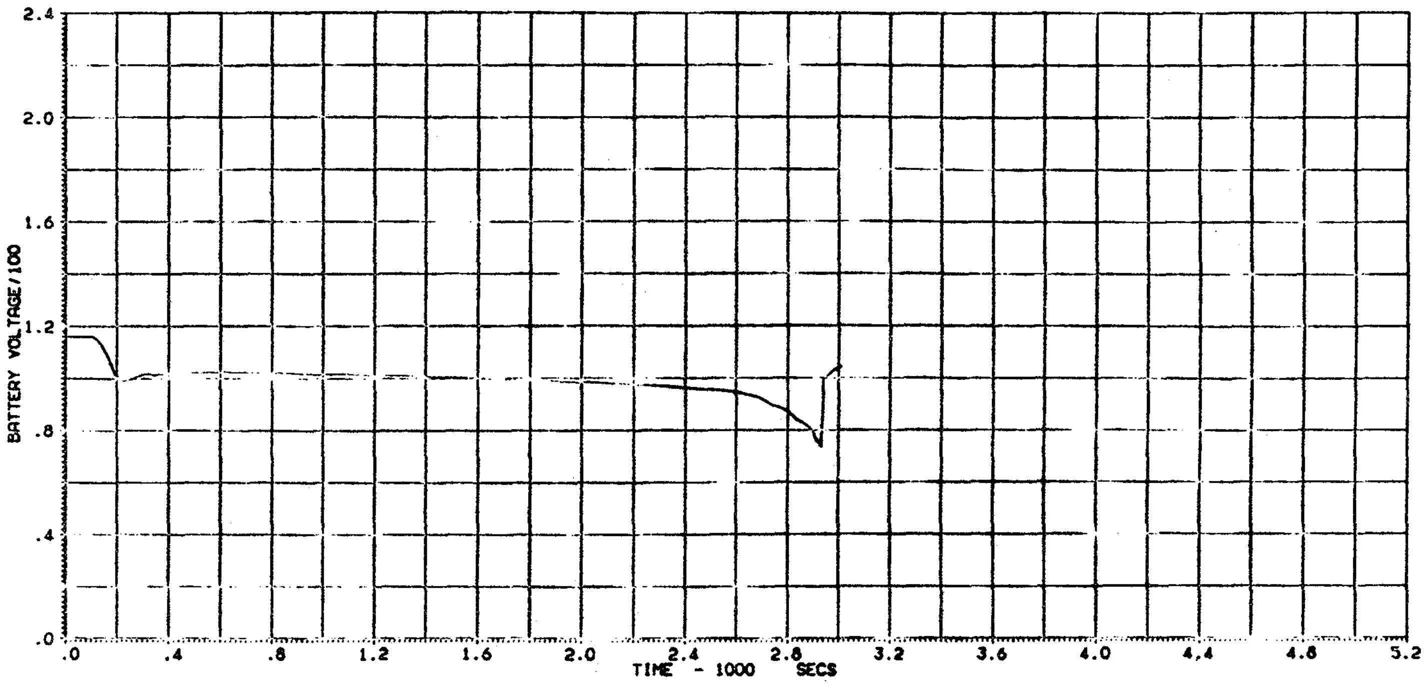


Figure C-57. Battery Voltage, Test VET-30: Range at 45 mi/h

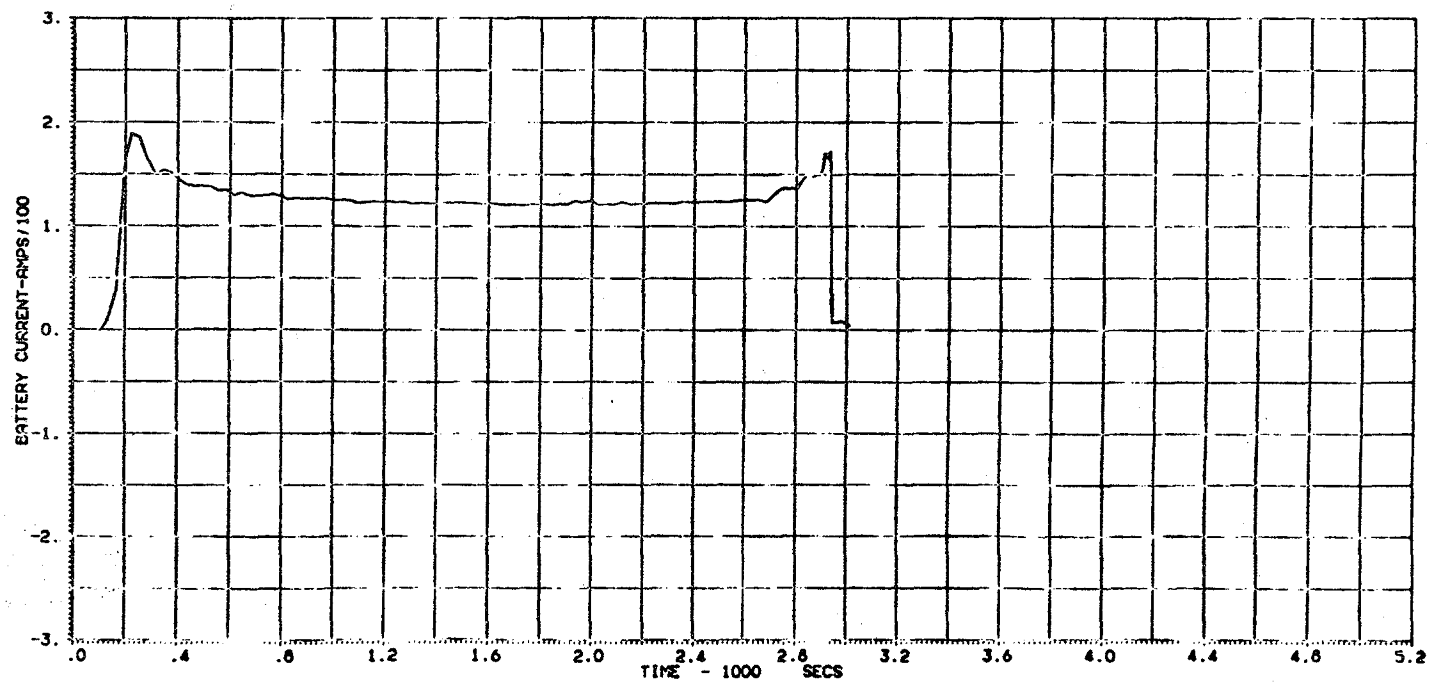


Figure C-58. Battery Current, Test VET-30: Range at 45 mi/h

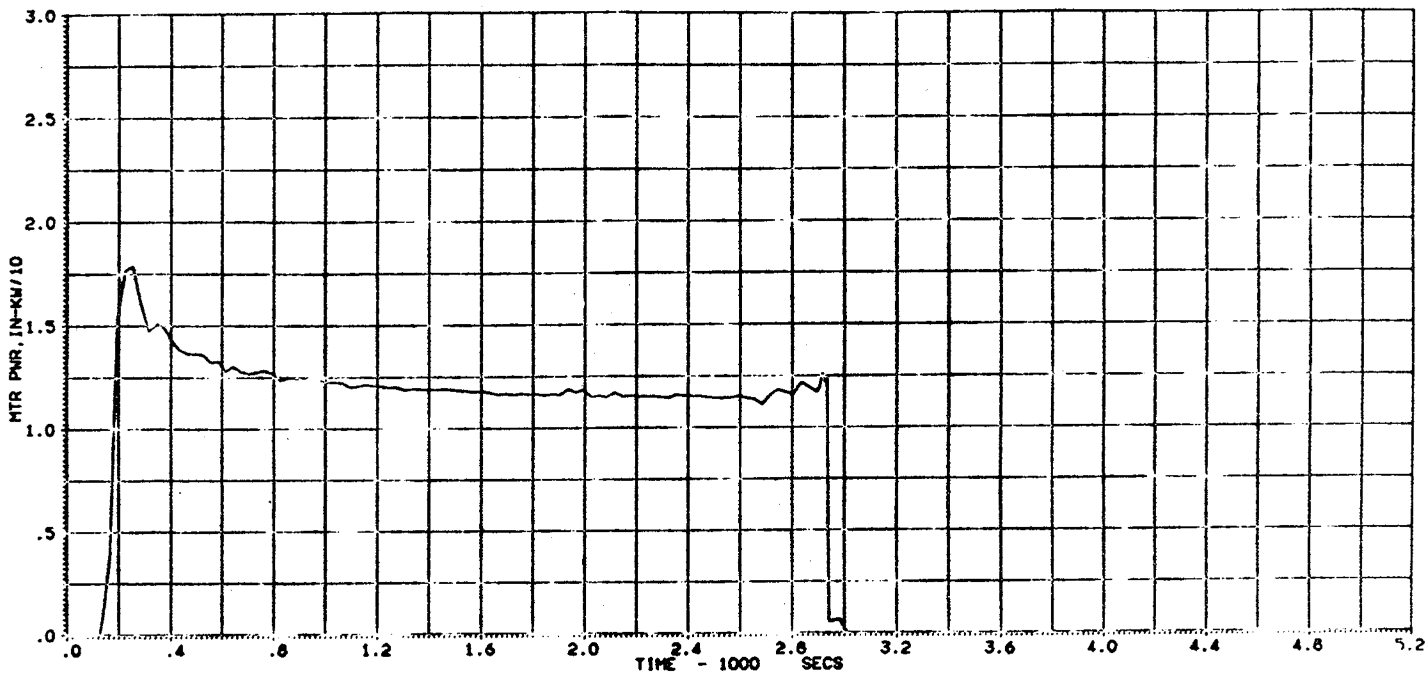


Figure C-59. Motor Input Power, Test VET-30: Range at 45 mi/h

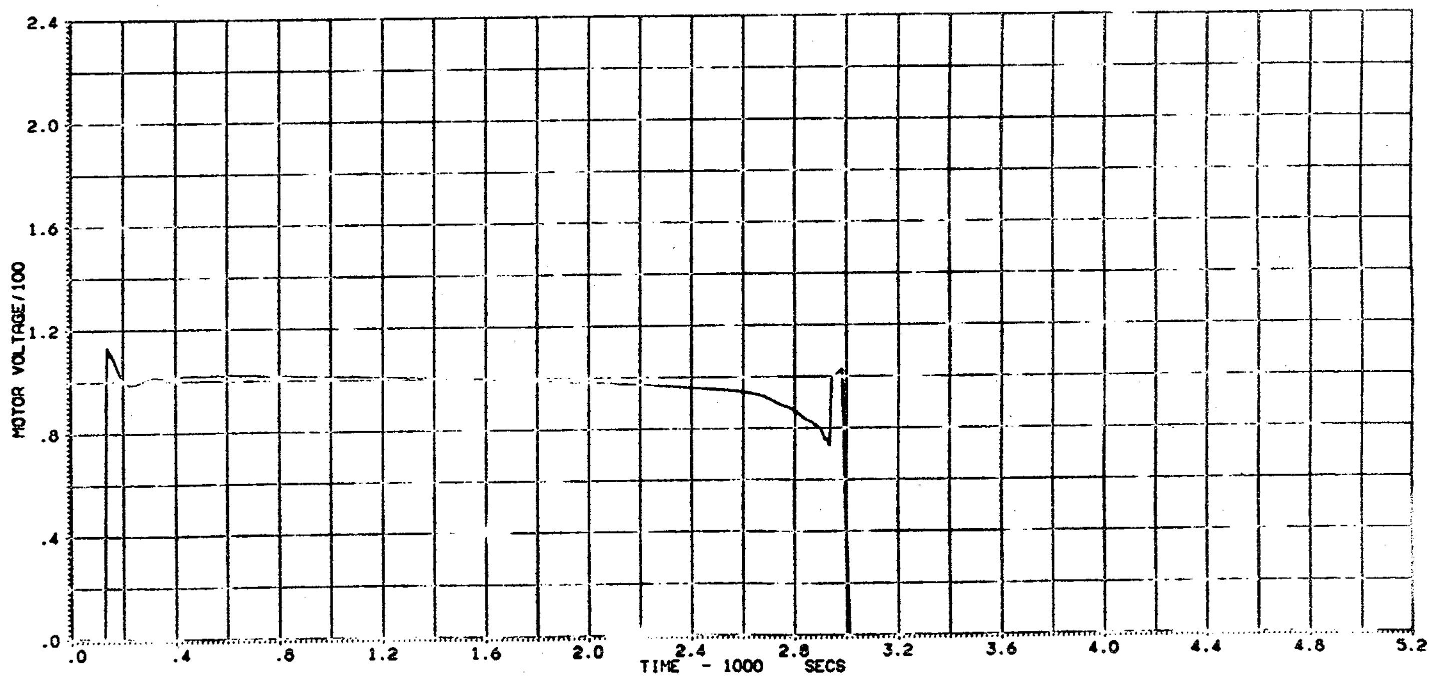


Figure C-60. Motor Voltage, Test VET-30: Range at 45 mi/h

Figure C-61. Motor Current, Test VET-30: Range at 45 mi/h

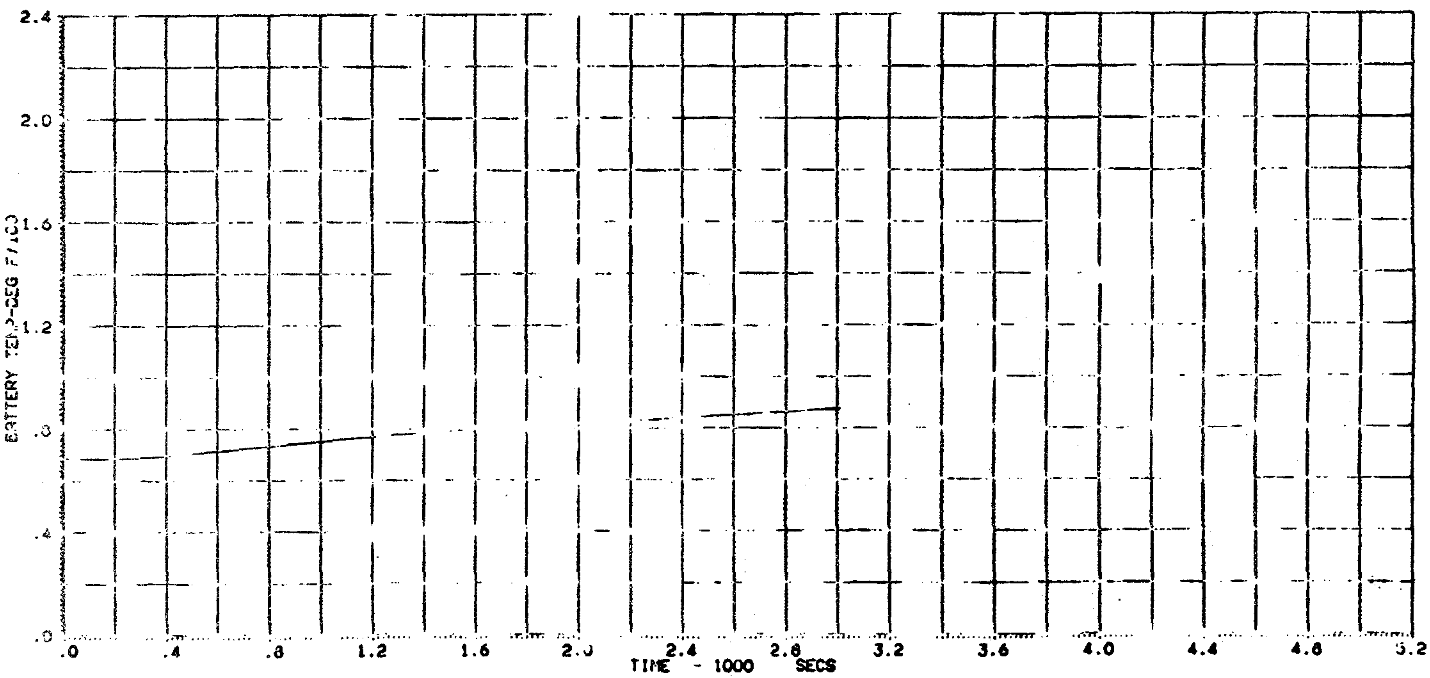


Figure C-62. Battery Pack Temperature, Test VET-30: Range at 45 mi/h

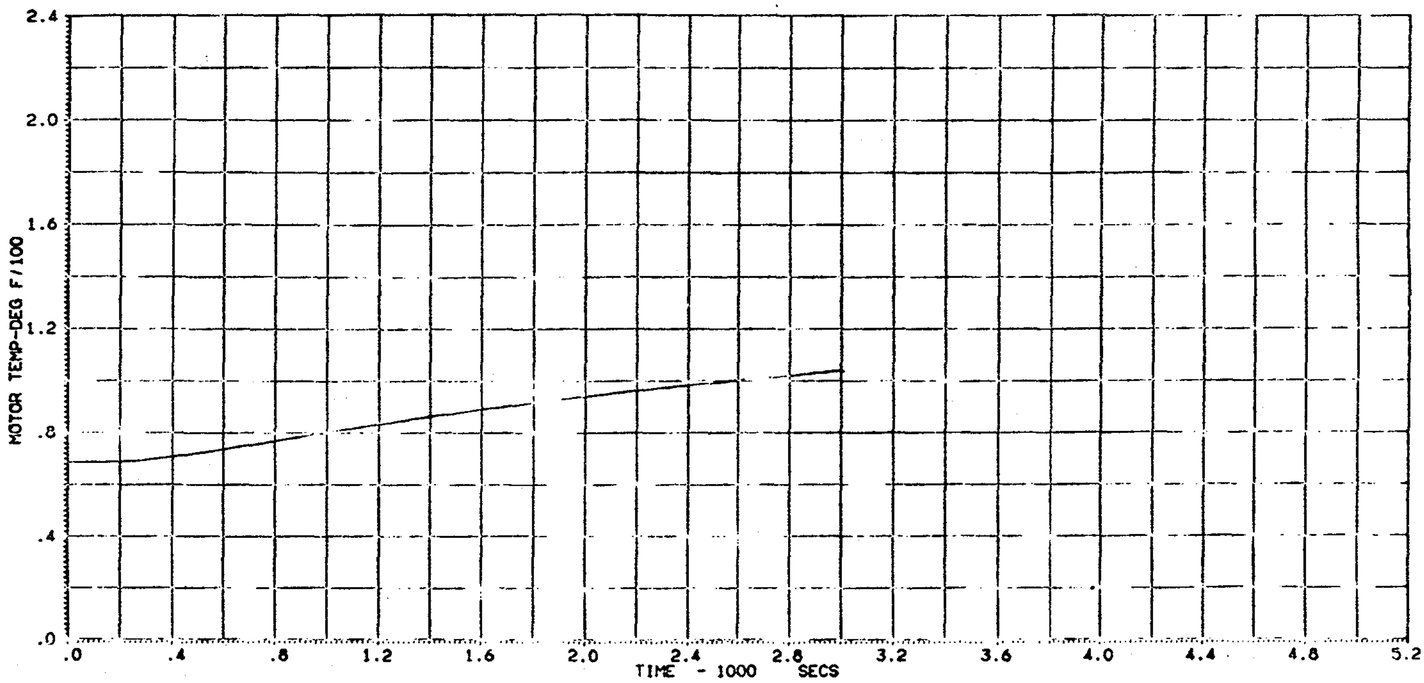


Figure C-63. Motor Case Temperature, Test VET-30: Range at 45 mi/h

APPENDIX D

TRACK TEST DATA

Table D-1. Track Test Data

Tape No.	Date	Test Description	Miles per Cycle	Miles Driven	Cycles Completed	Length of Test, h
VET04 HEX	28 Jun 78	Constant Speed at 15, 25, 35, 45, max (mi/h)	-	17.96	-	0.85
VET05 HEX	7 Jul 78	Constant Speed at 15, 25, 35, 45, max (mi/h)	-	18.88	-	0.88
VET06 HEX	12 Jul 78	Driving Cycle Schedule B	0.234	11.46	49	1.15
VET07 HEX	13 Jul 78	Driving Cycle Schedule C	0.391	24.23	62	1.57
VET08 HEX	14 Jul 78	Acceleration	-	29.15	-	2.22
VET09 HEX	18 Jul 78	Constant Speed at 15, 25, 35, 45, max (mi/h)	-	20.14	-	0.95
VET10 HEX	20 Jul 78	Range at 25 mi/h (incomplete)	-	16.97	-	0.75
VET11 HEX	4 Aug 78	Constant Speed at 15, 25, 35, 45, max (mi/h)	-	18.40	-	1.17
VET12 HEX	7 Aug 78	Driving Cycle Schedule B	0.229	17.65	77	2.28
VET13 HEX	9 Aug 78	Range at 25 mi/h	-	55.50	-	2.40
VET14 HEX	15 Aug 78	Driving Cycle Schedule C	0.383	14.93	39	1.40
VET15 HEX	18 Aug 78	Range at 25 mi/h	-	44.40	-	2.03
VET16 HEX	5 Sep 78	Acceleration	-	27.26	-	2.02
VET17 HEX	16 Oct 78	Coastdowns (incomplete)	-	-	-	-
VET18 HEX	18 Oct 78	Coastdowns (EVIS IIA- Brakes removed)	-	-	-	-
VET19 HEX	19 Oct 78	Coastdowns	-	-	-	-
VET20 HEX	3 Nov 78	Driving Cycle Schedule B	0.205	35.84	175	-
VET21 HEX	15 Nov 78	Driving Cycle Schedule C	0.355	23.07	65	1.78
VET22 HEX		Driving Cycle Schedule B (incomplete)	-	-	-	-
VET23 HEX	13 Dec 78	Driving Cycle Schedule B	0.223	29.2	131	2.81
VET24 HEX	15 Dec 78	Driving Cycle Schedule B	0.227	30.6	135	2.89

APPENDIX E

DYNAMOMETER TEST DATA

Table E-1. Dynamometer Test Data

Test No.	Description	Electrolyte Temp, °F Before/After	Cycle Range, mi	Distance Traveled, mi	Cycles, No.	Wh From Battery	Wh to Armature	Wh From Arm (Regen)	Wh to Battery (Regen)	Recharge Wh from Wall	Recharge Wh to Battery	Regenerative Fraction, %	Wall to Battery Eff., %	Battery Efficiency, %	Wall Economy, mi/kWh	Battery Economy, mi/kWh	Test Duration, s
VET-25	Schedule B Range	70/92	0.2288	32.719	143	13216	12492	326	278	19435	16520	2.5	86	80	1.684	2.476	10838
VET-26	Schedule B Range	76/96	0.2276	33.497	147	13383	12551	241	200	19681	16729	1.8	86	80	1.702	2.503	11334
VET-27	Range at 25 mi/h	77/88	-	63.691	-	14185	13711	32	27	20860	17731	0.2	86	80	3.053	4.490	9420
VET-28	Range at 25 mi/h	75/85	-	62.848	-	13621	13191	21	18	20031	17026	0.2	86	80	3.138	4.614	9179
VET-29	Range at 35 mi/h	72/87	-	50.646	-	12001	11706	1	0	17649	15002	0.0	86	80	2.870	4.220	5298
VET-30	Range at 45 mi/h	69/88	-	34.709	-	9715	9594	4	4	14287	12144	0.0	86	80	2.460	3.618	2872
VET-31	Schedule C Range	70/100	0.3580	21.480	60	9691	9388	719	668	14251	12114	6.9	86	80	1.507	2.216	5016
VET-32	Schedule C Range	70/101	0.3535	20.854	59	9795	9568	1123	1062	14404	12244	10.8	86	80	1.448	2.129	4901
VET-33	Maximum Acceleration	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
VET-34	Gradeability at Speed	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
VET-35	Schedule B Range	66/88	0.2135	33.108	138	12876	11292	770	657	18935	16095	5.1	86	80	1.557	2.289	10084

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