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PERFORMANCE TESTING AND SYSTEM EVALUATION OF THE SOLEQ EVCORT ELECTRIC VEHICLE

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ABSTRACT

This report presents the results of tests performed on a direct current (dc) powertrain in a test bed vehicle (EVCORT) developed by the Soleq Corporation of Chicago, Illinois. The tests were performed by EG&G Idaho, Inc. at the Idaho National Engineering Laboratory (INEL). The purpose of the INEL testing was to provide test results from which an evaluation of the performance capabilities of the Soleq DC powertrain could be made and compared with other vehicle propulsion systems.

The propulsion system efficiency was found to be comparable to the Chrysler/GE ETV-1, which is considered to have one of the most efficient propulsion systems. On a power-to-weight basis, the acceleration performance of the Evcort is essentially equivalent to that of the highest performance electric vehicles tested at the INEL. The range of the Evcort compares favorably with the majority of the electric vehicles tested at the INEL, due to both its large battery mass fraction, and its low specific energy consumption (per unit vehicle mass).

The Evcort was equipped with air conditioner and heater/defroster systems, designed and manufactured by Soleq Corporation, which are powered from the main traction battery pack. The effect of operating the air conditioner on vehicle energy consumption and range was determined from dynamometer test data, and the effectiveness of the air conditioner and heater/defroster systems were assessed by conducting field tests of the vehicle under both summer and winter conditions.

SUMMARY

The Evcort electric vehicle, which is powered by a modified General Electric separately-excited DC electric motor (37 kW peak), Soleq controller, and 18/6-V Concorde GP 6250 batteries, was tested in the INEL Vehicle Dynamometer Laboratory. Tests were performed over a range of constant speeds up to 88 km/h and over various driving cycles, including the Federal Urban Driving Schedule (FUDS). The characteristics of the vehicle and powertrain are presented in Tables S-1 and S-2.

The GP 6250 sealed (absorbed electrolyte) lead-acid battery pack was tested in the INEL Battery Laboratory prior to and immediately after the dynamometer tests. The Ragone curve for the battery pack was found to be typical of sealed lead-acid batteries and very close to that of the Concorde GP 6180. Constant current discharges of the GP 6250 battery pack at the C/2 rate before and after it was used to power the Evcort vehicle in the dynamometer tests indicated that its capacity had declined from 159 Ah to 120 Ah or 25% in only 35 cycles. Part of this loss in capacity by the battery was due to improper charging of the battery by the on-board charger which was designed to charge sealed lead-acid batteries, but was not tailored specifically for the new GP 6250 batteries. Tests of a second GP 6250 pack in the INEL Battery Test Laboratory also showed a significant loss in capacity (10-15%) in 35 cycles even though that pack was charged with special care to minimize the overcharge factor. Further studies of the battery are underway to determine the reasons for its apparent short cycle life.

The Evcort vehicle was tested at the INEL on the dynamometer at constant speeds of 48 and 88 km/h and on the J227 C and FUDS driving cycles. The test results are summarized in Table S-3. For constant speed, the net DC energy consumption of the vehicle (with the air conditioner off) varied from 119 Wh/km at 48 km/h to 160 Wh/km at 88 km/h. For the driving cycles, the energy consumption was 201 Wh/km on the J227 C cycle and 212 Wh/km on the FUDS cycle. The wall-plug AC energy consumption using the Concorde GP 6250 batteries and the on-board battery charger varied significantly with driving schedule: 172 Wh/km at 48 km/h, to 313 Wh/km on the FUDS. The range of the Evcort at constant speed varied from 154 km at 48 km/h to 77 km at 88 km/h.

TABLE S-1 EVCORT VEHICLE CHARACTERISTICS

Test weight (kg)	1968
Tire Rolling Radius (m)	0.289 @ 35 psi
Aerodynamic Drag Coefficient	0.42
Frontal Area (m^2)	1.90
Rolling resistance (@ 80.5 km/h) CO	0.011
Battery System Weight (kg)	672
Peak Motor Power (kW)	32

TABLE S-2 EVCORT POWERTRAIN CHARACTERISTICS

Motor	
Type	Separately Excited dc
Peak Power(kW)	32 @ 98V, 400A, 1600 RPM
Maximum Speed (rpm)	6000
Maximum torque (N-M)	191
Corner Speed	1600
Manufacturer	General Electric Company
Controller	
Manufacturer	Soleq (U.S. Patent 4322667)
Maximum Current (A)	400
Transmission	
Type	5-speed manual
Manufacturer	Production Ford unit
Battery	
Type	Sealed lead-acid
Weight (kg)	
Individual module (6 V)	37.3
System	672
Voltage (nominal system)	108
Capacity (new)	
Ah at C/3	168
kWh at C/3	18
Capacity (after 34 cycles)	
Ah at C/3	119
kWh at C/3	13
Manufacturer	Concorde

TABLE S-3 EVCORT SUMMARY TEST RESULTS

	Energy Consumption (Wh/km) (without air conditioning)					Energy Consumption (Wh/km) (with air conditioning)				
Test Type	Range (km)	Wall AC	System DC	Gross DC	Net DC	Range (km)	Wall AC	System DC	Gross DC	Net DC
48 km/h (constant speed)	154.3	172	154	119	119	119.7	208	186	149	149
88 km/h (constant speed)	76.6	299[a]	269[a]	160	160	70.5	255	243	179	179
C-cycle	74.8	341[a]	306[a]	214	201	60.9	440	393	283	272
FUDS	67.6	313	278	226	212	60.2	408	364	281	270

Acceleration (seconds)

Battery State-of Charge	100% SOC	55% SOC	37% SOC	17% SOC
Speed				
0-48 km/h	8.3	8.7	9.2	12.5
0-80 km/h	25.6	26.1	28.1	48.5
0-88 km/h	32.5	32.8	36.0	--

Note: Tests with the air conditioner on, indicated acceleration performance of the Evcort was not affected by use of the air conditioner.

Energy Consumption Definitions

$$\text{AC} = \frac{\text{AC Energy to Charger for Recharge}}{\text{Distance Traveled}} \qquad \text{Veh. DC Gross} = \frac{\text{DC Energy from Battery While Driving (not including Regen Benefit)}}{\text{Distance Traveled}}$$

$$\text{System DC} = \frac{\text{DC Energy From Charger for Recharge}}{\text{Distance Traveled}} \qquad \text{Veh. DC Net} = \frac{\text{DC Energy from Battery While Driving (including Regen Benefit)}}{\text{Distance Traveled}}$$

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[a] These values are due to significant battery overcharge caused by an inappropriate charger cutoff criteria.

The range on the J227 C Cycle was 75 km and 68 km on the FUDS. Acceleration tests of the Evcort on the dynamometer resulted in acceleration times of 8.3 seconds for 0-48 km/h and 25.6 seconds for 0-80 km/h with a fully charged battery.

The Evcort is equipped with an air-conditioner and heater/defroster which are powered from the main traction battery pack. The effect of operating the air-conditioner on vehicle energy consumption and range was determined from dynamometer test data, and the effectiveness of the air-conditioner and heater/defroster were assessed by performing field tests of the Evcort under both summer and winter conditions. The performance of the air-conditioner and heater/defroster in the Evcort was compared to that of the factory packages in the ICE Escort by performing side-by-side tests of the two vehicles.

From dynamometer tests, it was found that the average power from the battery to operate the air-conditioner in the Evcort was about 1.5 kW and that its effect was to increase the energy consumption by 25% at 48 km/h, 11% at 88 km/h, and 27% on the FUDS driving cycle. The corresponding reductions in range were 22%, 10%, and 17%, respectively.

In field tests of the air conditioner in Phoenix, Arizona at an ambient temperature of 34^{O}C (94^{O}F), relative humidity of approximately 25%, the cool-down time to 26^{O}C (80^{O}F) from an initial temperature of 48^{O}C (118^{O}F) inside the vehicle was 24 minutes with the Evcort stationary and 20 minutes when the vehicle was moving at 56 km/h. The corresponding values for the ICE Escort were 17 minutes and 14 minutes, respectively. The 2kW heater/defroster in the Evcort was evaluated in an outdoor test in Idaho Falls, Idaho during the winter with an ambient temperature of -12^{O}C (15^{O}F). The heat-up time to 0^{O}C (32^{O}F) with the heater operating was 10-12 minutes in the Evcort and 5-6 minutes in the ICE Escort. The time required (starting with a thick layer of ice) to defrost 50% of the windshield was 27 minutes in the Evcort and 18 minutes in the ICE Escort.

The Evcort is compared in Table S-4 with other electric vehicles tested in the INEL Vehicle Dynamometer Laboratory. Energy consumption, range, and acceleration time data are given in the table, as well as vehicle and battery specifications for each vehicle.

TABLE S-4 INEL ELECTRIC VEHICLE TESTING SUMMARY

VEHICLE SPECIFICATIONS			
Vehicle Designation	Bedford Van	Eaton AC-3	Eaton DC
Weight (kg)			
Test	3490	1641	1723
Curb [a]	2658	1352	1588
Gross Veh.[b]	3500	c	c
Rolling Resistance Coeff. (kg/kg)	0.0104	0.0098	0.0098
Frontal Area (m^2)	3.35	1.84	1.84
Aero Drag Coeff. (C_D)	0.47	0.43	0.43
Drag Area Product- C_DA (m^2)	1.57	.79	.79
Power-to-weight ratio (W/kg)[d]	12	21	17
Motor	dc	ac	dc
Peak Power (kW)	40	33.6	29.8
Maximum Speed (rpm)	6000	12,500	4500
Transmission	single-speed	two-speed	three-speed
BATTERY SPECIFICATION			
Manufacturer	Lucas Chloride (EV5T)	Sears Die Hard	ALCO 2200
Type	Tubular Lead Acid (36 x 6 V)	Lead Acid (16 x 12 V)	Lead Acid (18 x 6 V)
Weight (kg)	1134	385	545
Battery Mass Fraction	0.32	0.23	0.32
VEHICLE PERFORMANCE DATA			
Acceleration (s)			
0-48 km/h	11.6	11.2	12.5
0-80 km/h	64.8	22.0	36.4
0-88 km/h	-	28.5	47.5
Energy Consumption (Wh/km)			
48 km/h (vehicle net dc)	183	* -	-
72 km/h (vehicle net dc)	233	159	145
C-Cycle (vehicle net dc)	299	179	-
D-Cycle (vehicle net dc)	311	188	241
FUD-Cycle (vehicle net dc)	313	192	-
Range (km)			
48 km/h	182	e -	-
72 km/h	109	e -	79
C-Cycle	97	e -	-
D-Cycle	82	55.5	41
FUD-Cycle	77[f]	e -	-
Gradeability (@ 32 km/h)	11%	18%	14%

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a. Based on weighing the vehicle.

b. Assigned by developer/manufacturer.

c. Means no weight assigned because vehicle was a test bed.

d. Propulsion System Peak Power-to-weight (vehicle ratio).

e. Only minimal range data taken because of the use of marine batteries in place of EV batteries.

f. Best Effort.

TABLE S-4 INEL ELECTRIC VEHICLE TESTING SUMMARY (Cont.)

VEHICLE SPECIFICATIONS			
Vehicle Designation	Chrysler/GE ETV-1	Ford/GE ETX-I	Evcort
Weight (kg)			
Test	1723	1705	1968
Curb [a]	1522	1566	1836
Gross Veh.[b]	1822	c	c
Rolling Resistance Coeff. (kg/kg)	0.0095	0.0097	0.011
Frontal Area (m^2)	1.84	1.78	1.90
Aero Drag Coeff. (C_D)	0.32	0.42	0.42
Drag Area Product- C_DA (m^2)	0.59	0.75	0.79
Power-to-weight ratio (W/kg)[d]	17	25	16
Motor	dc	ac	dc
Peak Power (kW)	30	43	32
Maximum Speed (rpm)	5000	9000	6000
Transmission	single-speed	two-speed	five-speed
BATTERY SPECIFICATION			
Manufacturer	JCI Phase 3 Gel/Cell	Lucas Chloride	Concorde
Type	Lead Acid (18 x 6 V)	Tubular Lead Acid (16 x 12 V)	Sealed Lead Acid (18 x 6 V)
Weight (kg)	539	520	672
Battery Mass Fraction	0.31	0.31	0.34
VEHICLE PERFORMANCE DATA			
Acceleration (s)			
0-48 km/h	10.4	7.4	8.3
0-80 km/h	23.6	21.3	25.6
0-88 km/h	28.8	29.8	32.5
Energy Consumption (Wh/km)			
48 km/h (vehicle net dc)	94	129	119
72 km/h (vehicle net dc)	108	140	144
C-Cycle (vehicle net dc)	163	201	201
D-Cycle (vehicle net dc)	154	181	-
FUD-Cycle (vehicle net dc)	174	208	212
Range (km)			
48 km/h	172	128	154
72 km/h	126	92	108
C-Cycle	85	65	75
D-Cycle	82	58	-
FUD-Cycle	75	60	68
Gradeability (@ 32 km/h)	18%	25%	17%

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a. Based on weighing the vehicle.

b. Assigned by developer/manufacturer.

c. Means no weight assigned because vehicle was a test bed.

d. Propulsion System Peak Power-to-weight (vehicle ratio).

e. Only minimal range data taken because of the use of marine batteries in place of EV batteries.

f. Best Effort.

It is concluded that the Evcort compares favorably with all the electric vehicles tested when one takes into account the relatively high test weight of the vehicle.

It is about 15% heavier than most of the other vehicles due primarily to the additional weight of the Concorde GP 6250 batteries. Calculation of the system efficiency (battery output to the wheels) from the constant speed energy consumption data indicate the efficiency of the Evcort is 84% at 88 km/h and 65% at 48 km/h. These efficiencies values are essentially equal to the corresponding values for the ETV-1, which is considered to have a very efficient driveline. The range of the Evcort is relatively long compared to most of the electric vehicles tested at the INEL due both to its high battery fraction of .34 and its low energy consumption per unit vehicle weight. The acceleration times of the Evcort are comparable to those of the highest performance electric vehicles tested, which is somewhat surprising when one considers that its weight is greater than those vehicles.

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CONTENTS

FIGURES

TABLES

ACRONYMS AND ABBREVIATIONS

A	Amperes, Unit of Current
AC	Alternating Current
AH	Ampere-hours
APS	Arizona Public Service
BMS	Battery Management System
C_dA	Drag-area product
DOD	Depth-of-Discharge
DOE	Department of Energy
DC	Direct Current
ETX-I	Electric Transaxle-I
ETV-1	Electric Test Vehicle-1
FUDS	Federal Urban Driving Schedule
I	Electric Current
INEL	Idaho National Engineering Laboratory
JCI	Johnson Controls, Inc.
JPL	Jet Propulsion Laboratory
LCEVS	Lucas Chloride Electric Vehicle System
RPM	Revolutions per Minute
SAE J227 C	Society of Automotive Engineers J227 Driving Cycles
SFUDS	Simplified Federal Urban Driving Schedule
SOC	State-of-Charge
V	Battery Voltage in Volts
W/kg	Battery Power Density on Watts per kg

1. INTRODUCTION

This report is concerned with the test and evaluation of the Soleq Evcort electric vehicle, which is a Ford Escort Wagon retrofitted with the DC electric powertrain developed by Soleq. The intent of the INEL tests of the Evcort was to determine its performance characteristics on various driving cycles under operationing conditions pertinent to electric vehicle applications and to compare the performance of the Soleq Evcort to other electric vehicles under equivalent conditions. In addition, the air-conditioning and heater systems of the Evcort were evaluated and their effect on vehicle energy consumption and range were determined.

2. PURPOSE AND OBJECTIVES

2.1 Battery Characterization Testing

The objective of the battery testing done in this program was to determine the characteristics of the Concorde GP 6250 battery used in the Evcort for comparison them with those of the Concorde GP 6180 and other lead-acid batteries available for use in electric vehicles. Characterization testing of the battery pack is done before the battery is used to power the test vehicle in order to determine its capacity in standardized discharges and to assess its condition relative to its rated capacity for the same standard discharges.

The battery characterization test results are used in planning the vehicle dynamometer tests and assessing whether the behavior of the battery in the vehicle tests is consistent with its known capacity and discharge characteristics. The initial testing of the battery pack also permits INEL personnel to become familiar with the charging characteristics of the battery and how the battery capacity varies from cycle to cycle. Good knowledge of the battery pack charging characteristics can help to minimize the variability between repeat tests during the vehicle test program.

After the vehicle tests are completed, additional standardized tests are performed on the battery to assess its change in capacity during the vehicle tests on the dynamometer.

This testing can give an early assessment of battery life and whether there are indications of premature capacity degradation.

2.2 Vehicle Dynamometer Testing

The objectives of the dynamometer testing of the Evcort vehicle are to determine its performance in terms of energy consumption, range, and acceleration in standardized tests for comparison with that of other electric vehicles of recent design. In the case of the Evcort, testing was done with and without the air-conditioner and heater operating to determine their effect on vehicle performance, energy consumption, and range.

3. VEHICLE/POWERTRAIN DESCRIPTION

3.1 Vehicle Description

The Evcort test vehicle is a production Ford Escort station wagon with the engine assembly replaced by the DC electric powertrain. The Concorde GP 6250 battery pack is split into two parts. Seven batteries are placed forward under the hood above the transaxle and eleven are placed in the rear in the luggage compartment behind the rear seat. A schematic drawing of the Evcort vehicle is provided in Figure 1. The characteristics of the vehicle are given in Table 1. The curb weight of the Evcort with the Concorde GP 6250 batteries installed is 1826 kg (4040 lbs). The test weight of 1968 kg (4340 lbs) was obtained by adding 136 kg (300 lbs) to the curb weight. The rolling resistance parameters and the aerodynamic drag coefficent were determined from the analysis of coastdown data for the Evcort taken at the Chrysler Proving Grounds in Phoenix, Arizona.

3.2 Powertrain Description

The component specifications for the powertrain are given in Table 2. The powertrain and vehicle operation are described in some detail in the Operating and Maintenance Manual (Reference 1) for the Evcort published by Soleq. Each of the components are discussed briefly in the following sections.

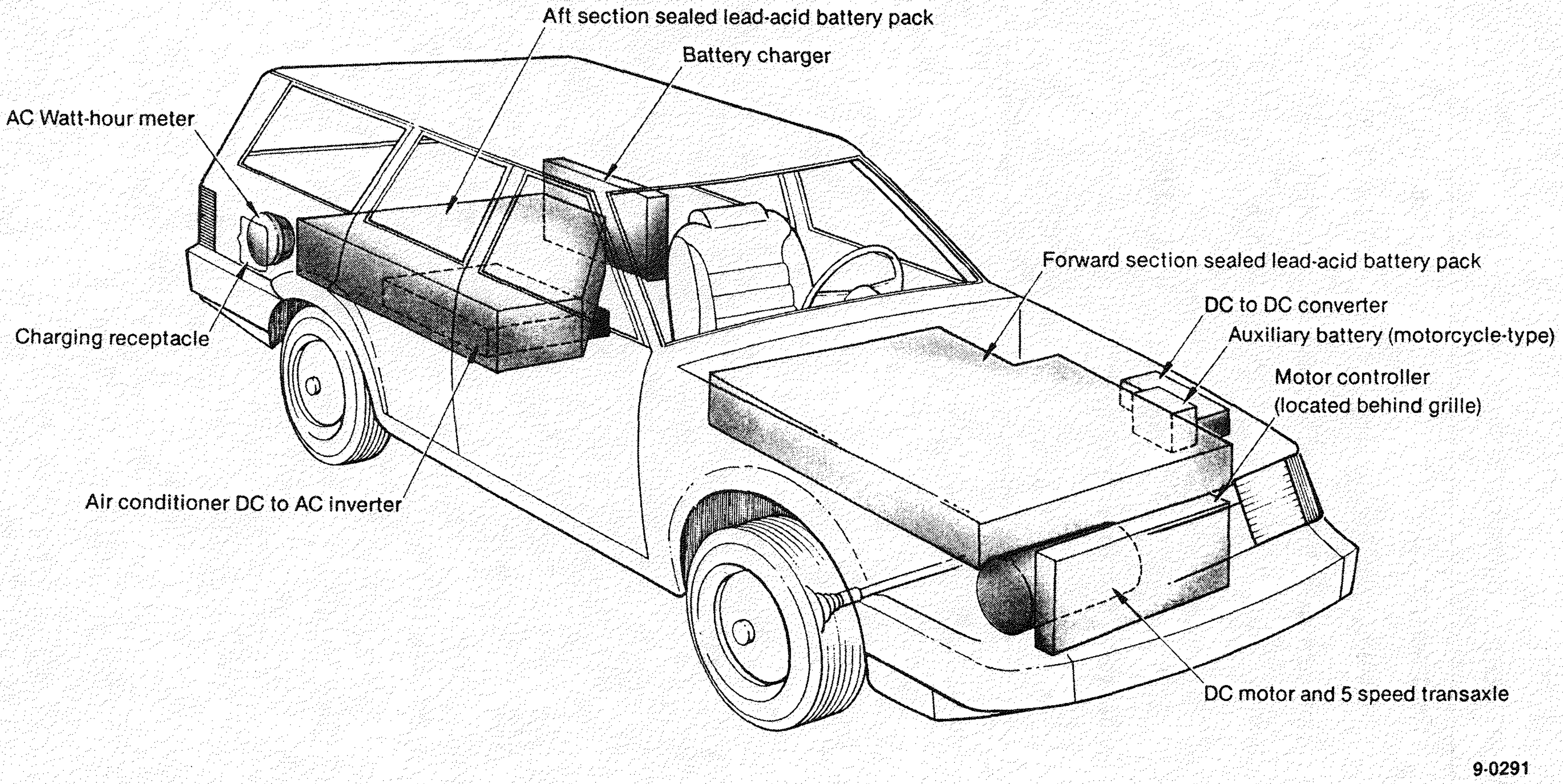

Figure 1. Schematic of the Evcort Test Vehicle

TABLE 1. EVCORT VEHICLE CHARACTERISTICS

Test weight (kg)	1968
Tire Rolling Radius (m)	0.289 @ 35 psi
Aerodynamic Drag Coefficient	0.42
Frontal Area (m^2)	1.90
Rolling resistance (@ 80.5 km/h) CO	0.011
Battery System Weight (kg)	672
Peak Motor Power (kW)	32

TABLE 2. EVCORT POWERTRAIN CHARACTERISTICS

Motor	
Type	Separately-Excited dc
Peak Power(kW)	32 @ 98 V, 400 A, 1600 RPM
Maximum Speed (rpm)	6000
Maximum torque (N-M)	191
Corner Speed	1600
Manufacturer	General Electric Company
Controller	
Manufacturer	Soleq (U.S. Patent 4322667)
Maximum Current (A)	400
Transmission	
Type	5-speed manual transaxle
Manufacturer	Production Ford unit
Battery	
Type	Sealed lead-acid
Weight (kg)	
Individual module (6 V)	37.3
System	672
Voltage (nominal system)	108
Capacity (new)	
Ah at C/3	168
kWh at C/3	18
Capacity (after 34 cycles)	
Ah at C/3	119
kWh at C/3	13
Manufacturer	Concorde

3.2.1 Traction Motor

The electric motor is an air-cooled, separately excited DC motor mounted to the transaxle. The maximum torque of the motor is 191 N-m (141 ft-lb) with the corner point at approximately 1600 RPM. The maximum motor power is 32 kW (at 98 volts and armature current of 400A). The maximum motor speed is 6000 RPM. The maximum field current is 20A and it is controlled over a range of about 10:1.

3.2.2 Motor Controller

The controller is the high power interface between the DC motor and the 108V battery pack. It controls the voltage to the motor armature and field circuits. Both the armature and field choppers in the Soleq controller are transistorized with chopping freqencies between 400 and 2000 Hz. Control of the armature and field currents is performed using high speed analog components utilizing inputs for accelerator position (i.e. driver power demand), motor output power, motor speed, and battery state-of-charge. The Soleq controller provides regenerative braking as well as coasting regeneration. The current limits are 400A in the motoring mode and 225A in regenerative braking mode. The combined efficiency of the motor/controller has been measured by Soleq to be 87% or above for most motor speeds and powers required for electric vehicle operation.

The Evcort utilizes a DC-DC converter to power the vehicle accessories from the 108V battery pack and to recharge the 12V accessory battery. The converter can deliver up to 40A at 13.7V for battery pack voltages down to about 90V. The motor controller limits the maximum motor power at low battery states-of-charge so that the battery voltage is never permitted to fall below 90V. This power limiting by the motor controller results in the vehicle not being able to closely follow variable power driving schedules, such as the FUDS, before such inability would occur due solely to battery voltage droop.

3.2.3 Transmission

The Evcort utilizes a Ford production front-wheel drive, 5-speed transaxle assembly. The transmission gear ratios are as follows: 1st 3.6, 2nd 2.12, 3rd 1.39, 4th 1.02, 5th .77 . The differential final drive ratio is 3.33:1. Shifting in the Evcort is done manually, but it is required infreqently. Most driving is done in 2nd gear, with 3rd gear being needed for speeds above 45 mph and 4th gear needed only at speeds above 70 mph. First gear is needed only for very low speeds on steep ramps. The driver is alerted that a shift is needed by a light on the instrument panel.

3.2.4 Concorde GP 6250 Battery

The lead-acid battery used in the Evcort is the Concorde GP 6250. This is a sealed battery, recently marketed by Concorde, which has a higher rated Ah capacity than their GP 6180 battery of similar design. Both the GP 6250 and the GP 6180 utilize an immobilized electrolyte which is absorbed into the glass mat separator and rely on internal recombination of gassing products to prevent pressure buildup in the sealed batteries during charging. The Evcort battery pack consists of eighteen 6V modules with seven of the modules being in the front under the hood and eleven of the modules being in the rear in the luggage compartment behind the rear seat. The average module weight of the GP 6250 is 38.2 kg (84 lbs) resulting in a pack weight of 687.6 kg (1512.7 lbs). The weight of a 108V pack of Concorde GP 6180 batteries would be 515 kg (1133 lbs), which is 173 kg (380 lbs) less than that of the new GP 6250 batteries. The capacity of the GP 6250 is 161 Ah at the 2-hr rate compared to 110 Ah for the GP 6180. Both of the capacities cited are for new batteries. Hence the GP 6250 battery is much heavier than the GP 6180 battery, but also has a much higher capacity in the same container. The two Concorde batteries will be compared in detail in a Section 5 of this report.

3.2.5 Battery Charging System

The Evcort has an on-board battery charger located at the rear of the vehicle. The charging is temperature compensated with the built-in algorithm intended for use with sealed lead-acid batteries. A maximum charging current of 16, 20, and 30A is user selectable. The charger is equipped with an AC Watt-hour meter for measurement of the wall-plug energy used for charging.

3.2.6 Air-conditioning and Heating System

The Evcort is equipped with both an air-conditioner and heater. The air-conditioner has a cooling capacity of 12000 Btu/hr with an electrical power requirement of about 1.6 kW. When the Evcort is being operated on the road or dynamometer, the compressor in the air-conditioning system is powered by an AC motor which derives energy from the 108V battery through 120V AC inverter. When the battery is being charged, the air-conditioning system is operated primarily off of wall-plug energy. The air conditioner system weight is approximately 136 kg (300 lbs). The development of the air-conditioning system for the Evcort is discussed in Reference 2. The heater is a 2kW resistance unit, which is operated directly off of the 108V battery. Air is heated by the unit and distributed in the vehicle for heating and defrosting as needed.

4. TEST EQUIPMENT, INSTRUMENTATION, AND PROCEDURES

4.1 Battery Characterization Tests

The battery characterization tests were performed in the INEL Battery Laboratory. They consisted of constant current, constant power, and variable power discharges of the battery. After each discharge, the battery was charged following the battery manufacturer's specifications.

The INEL Battery Laboratory consists of multiple workstations including a Normalizer, a Load Bank, and a Simulator (see Figure 2). Each station can be controlled manually from its front panel or externally through an IBM PC.

Figure 2. Photograph of the INEL Battery Test Laboratory

The Normalizer which is used to provide constant current and constant power discharges of batteries operates over the following ranges:

Discharge voltage	3 to 220 VDC
Discharge current	10 to 400 A
Charge current	0 to 50 A
Charge voltage	3 to 300 VDC

The Normalizer provides high battery currents and voltages over a long time period (minutes to hours) but has a relatively slow response time.

The Load Bank, which is used in pulsed, peak power tests of a battery is able to provide the following range of discharge conditions:

Voltage	3 to 34 VDC
Current	10 to 1000 A

The Load Bank can provide the high current pulses and has an extremely fast response time of less than 1 sec.

The Simulator can be programmed to perform variable power discharges consisting of repeated complex power profiles such as would be experienced by the battery in a vehicle on the FUDS or SFUDS driving schedule. The Simulator can provide conditions in the following ranges:

Charge voltage	3 to 300 VDC
Charge current	1 t0 150 A
Discharge voltage	3 to 220 VDC
Discharge current	10 to 400 A

and has a response time of 1 sec. The Simulator is used to perform the variable power discharges.

Battery charging is done using the Normalizer or a Hewlett Packard power supply (Model HP-64776) with a charge controller built by the EG&G Idaho Electronics group.

The chargers can handle complex charging algorithms with constant current and taper steps.

Each of the three workstations is controlled by a separate IBM PC XT, which performs the data acquistion, retrieval, reduction, and analysis functions. The workstations are linked to the Normalizer, Load Bank, and Simulator by Neff 470 NDAS data acquisition hardware and software. The Neff 470 permits measurements of pack voltage and current and module voltages and temperatures. The NDAS system is menu driven on the PC for both data acquisition and playback modes. Sampling times of 1 sec are used in most discharge tests, but sampling times as short as .1 sec are used for the peak power tests.

All battery characterization testing at the INEL is performed in accordance with detailed test procedures, which are can be found in Reference 3.

4.2 Vehicle Dynamometer Testing

4.2.1 Test Equipment and Instrumentation

Dynamometer tests of the Evcort test vehicle were performed in the INEL Vehicle Dynamometer Laboratory. A photograph of the laboratory with the Evcort on the dynamometer is shown in Figure 3. The key components of the laboratory are an electromechanical Clayton chassis dynamometer and a computer-automated data acquisition system (DAS). The DAS is a Standard Engineering Corporation MIK-11/73 microcomputer with a Digital Equipment Corporation (DEC) LSI-11/73 processor board housed in a CAMAC crate. The CAMAC provides a flexible system to handle a wide variety of input/output hardware. Details of the data acquisition system and related hardware are given in References 4. The instrumentation used in the Vehicle Dynamometer Laboratory is listed in Appendix A.

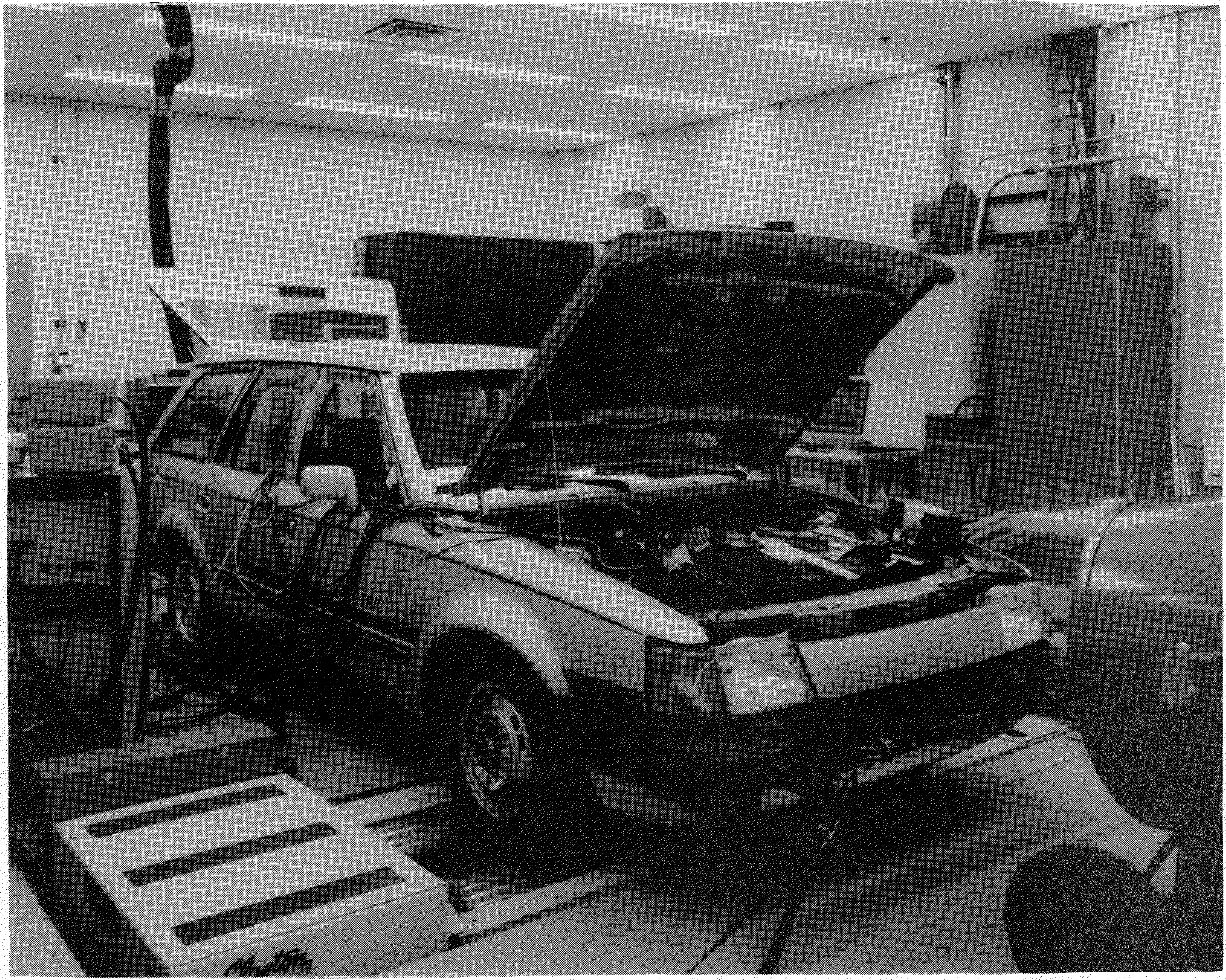

Figure 3. Photograph of the Evcort Test Vehicle in the INEL Vehicle Dynamometer Laboratory

The test vehicle, battery pack, and dynamometer were instrumented so that the following quantities could be recorded by the DAS:

(1) Traction battery voltage, current, and power

(2) Motor armature voltage and current

(3) Motor field voltage and current

(4) Air-conditioner Inverter voltage and current

(5) Air conditioner/heater fan voltage and current

(7) Auxiliary battery voltage and current

(8) Traction battery temperatures

(9) Motor temperature

(10) Transmission temperature

(11) Charger AC input energy.

(12) Dynamometer rpm (rolls)

(13) Dynamometer torque

The data can be recorded at either 0.1 or 1.0 second time increments. Second-by-second printouts of each of the measured variables can be obtained after the test from the DAS. Ampere-hours and energy (kWh) withdrawn from the battery during the test are determined by integrating the measured current and power values over time. Plots of the data versus time can easily be obtained using the DAS software.

4.2.2 Dynamometer Setup Procedures

The procedure for setting up the dynamometer for testing electric vehicles at INEL is well-established, based on past work on a number of vehicles. It involves obtaining good track coastdown data for the vehicle being tested and matching the dynamometer coastdown curve with that measured on the track.

Track coastdown tests of the Evcort vehicle were run by INEL in October 1988 at the Chrysler Proving Grounds in Phoenix, Arizona. Fifty-two coastdowns were performed (twenty-six in each direction).

The vehicle weight for the coastdown tests was 2067 kg. The data were corrected for weather conditions using information obtained from an on-site weather station. The coastdown tests were run in the early morning hours while the wind speed was below 4.8 km/h. The coastdown data were reduced and normalized to standard atmospheric conditions using an analytical technique developed at INEL (Reference 5). The average vehicle parameters obtained from the track coastdown tests are given below:

Coastdown Test Weight	2067 kg
Tire Rolling Radius (35 psi)	0.289 m
Aerodynamic Drag Coefficient	0.42
Frontal Area (projected)	1.90 m^2
Effective C_DA	0.79
Rolling Resistance (@ 80.5 km/h)	
CO	0.011

The procedure used to match the road load of the vehicle on the dynamometer with that on the track is given in detail in Appendix B. This is done by matching a computer-generated speed versus time coastdown curve, based on the track coastdown tests, with the speed versus time coastdown curve of the vehicle on the dynamometer. The INEL dynamometer is equipped with a programmable microprocessor controller through which the road load is changed by varying the input values of drag area product (C_DA) and the rolling resistance coefficients (C_0, C_1) for the vehicle being tested. The C_DA and rolling resistance values are varied until the dynamometer and target coastdown curves agree to the desired accuracy. A comparison of the track and dynamometer coastdown times are provided in the table below.

INEL Dyno		Track Coastdown	
Velocity (km/h)	Time (sec)	Velocity (km/h)	Time (sec)
88.5 - 72.4	20.47	88.5 - 72.4	20.49
32.2 - 16.1	43.18	32.2 - 16.1	43.15
96.5 - 16.1	148.47	96.5 - 16.1	147.88

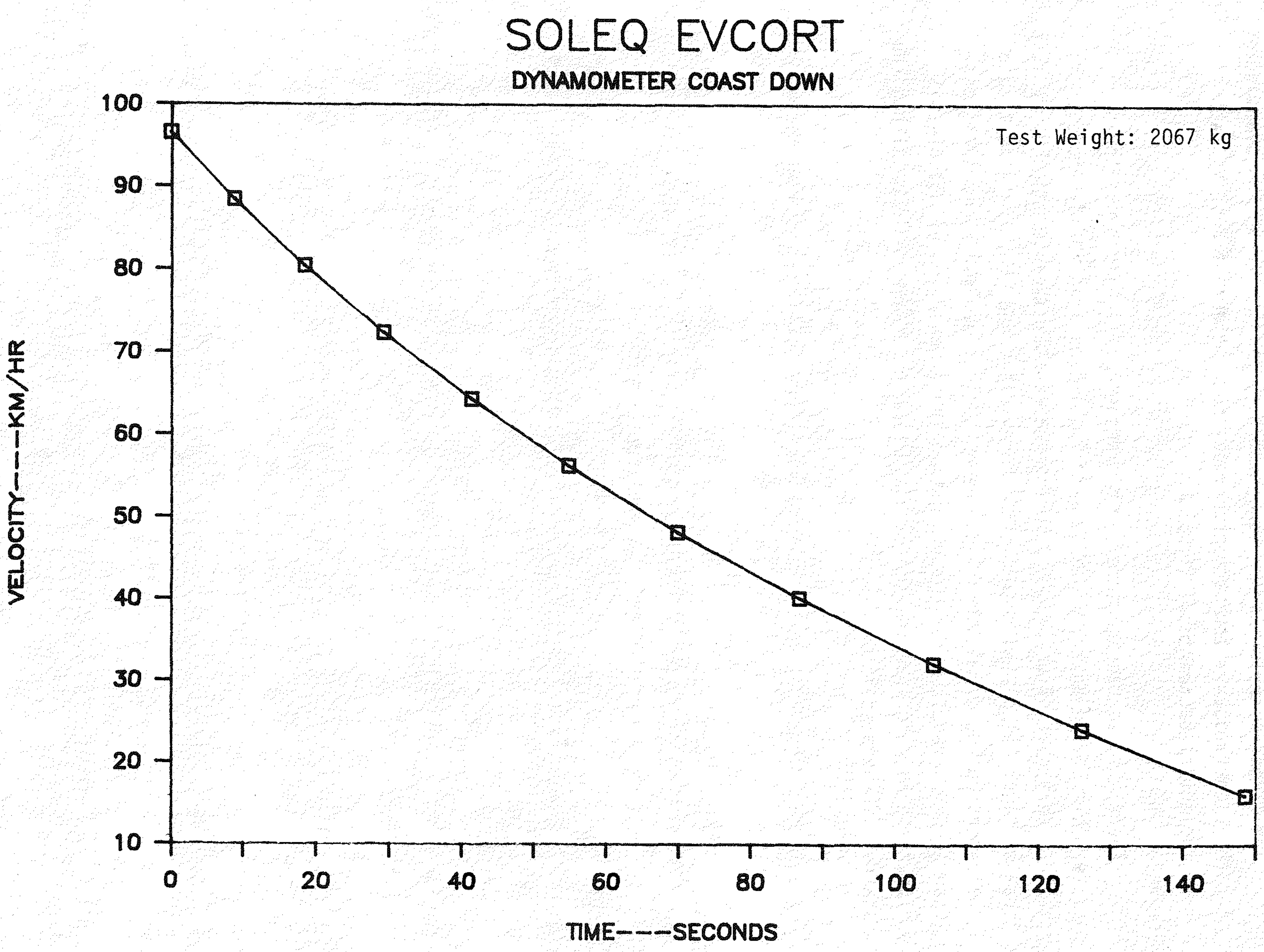

Figure 4. Evcort Dynamometer Coastdown Curve

The target coastdown curve (see Figure 4) used to setup the dynamometer for the Evcort tests was that for the coastdown weight of 2067 kg rather than the actual test weight of 1968 kg.

There are two consequences of this error in the target coastdown curve. First, the effective road load of the Evcort on the dynamometer is 5% less than that of the vehicle during the coastdown tests and thus 5% less than would be calculated from the coastdown data. Second, the road load of the Evcort on the dynamometer for the test weight of 1968 kg is 1-2% less than would be measured for that weight on the track. The effect of this difference in road load on energy consumption and range would be within the scatter of the present data.

5. BATTERY CHARACTERIZATION

Tests were performed at the INEL on two packs of Concorde GP 6250 batteries. One pack (No.35) was used only for characterization testing in the Battery Test Laboratory. The second pack (No.36) was in the Evcort when it was delivered to the INEL from Arizona Public Service (APS). Pack No.36 was used for all the Evcort dynamometer tests and was tested in the Battery Test Laboratory before and after the vehicle dynamometer tests to determine its capacity in standard discharge tests. All the tests of Pack No.36 were done with the pack in the vehicle (see Figure 5) and recharged with the on-board charger.

Test Summary Tables for both Pack No.35 and Pack No.36 are given in Appendix C. Data is shown for about 35 cycles for both battery packs. Pack No.36 had an additional 5-6 partial discharge cycles at Arizona Public Service before the Evcort was sent to INEL, but the initial tests at the INEL showed that both packs had essentially the same capacity at the outset of INEL tests. Data from both packs is utilized in the following sections to characterize the vehicle related performance of the Concorde GP 6250 in the "new" condition. More information on the INEL experience with Pack No.35 is given in Reference 6, which discusses in detail both the performance and post-mortem analysis of selected modules in the pack.

5.1 Constant Current Discharges

Constant current discharge tests of the Concorde GP 6250 battery were performed at 55, 77, and 135 A corresponding to the 3hr, 2hr, and 1hr rates, respectively. The results (Ah vs. I) are shown in Figure 6 for both pre-tests and post-tests of the battery. Also shown in the figure are Ah capacity results for the Concorde GP 6180 battery. The figure shows that the "new condition" capacity of the GP 6250 is about 40% greater than that of the GP 6180. However, the cycle life (capacity measurements over time) data for the two batteries indicates that the capacity of the GP 6180 is still slowly increasing after 80 cycles, while the capacity of the GP 6250 has decreased by 15-30% after only 35 cycles. The present version of the GP 6250 battery thus offers a significant capacity advantage over the GP 6180 only in the "new" condition.

Figure 5. Photograph of the Evcort Test Vehicle in the INEL Battery Test Laboratory

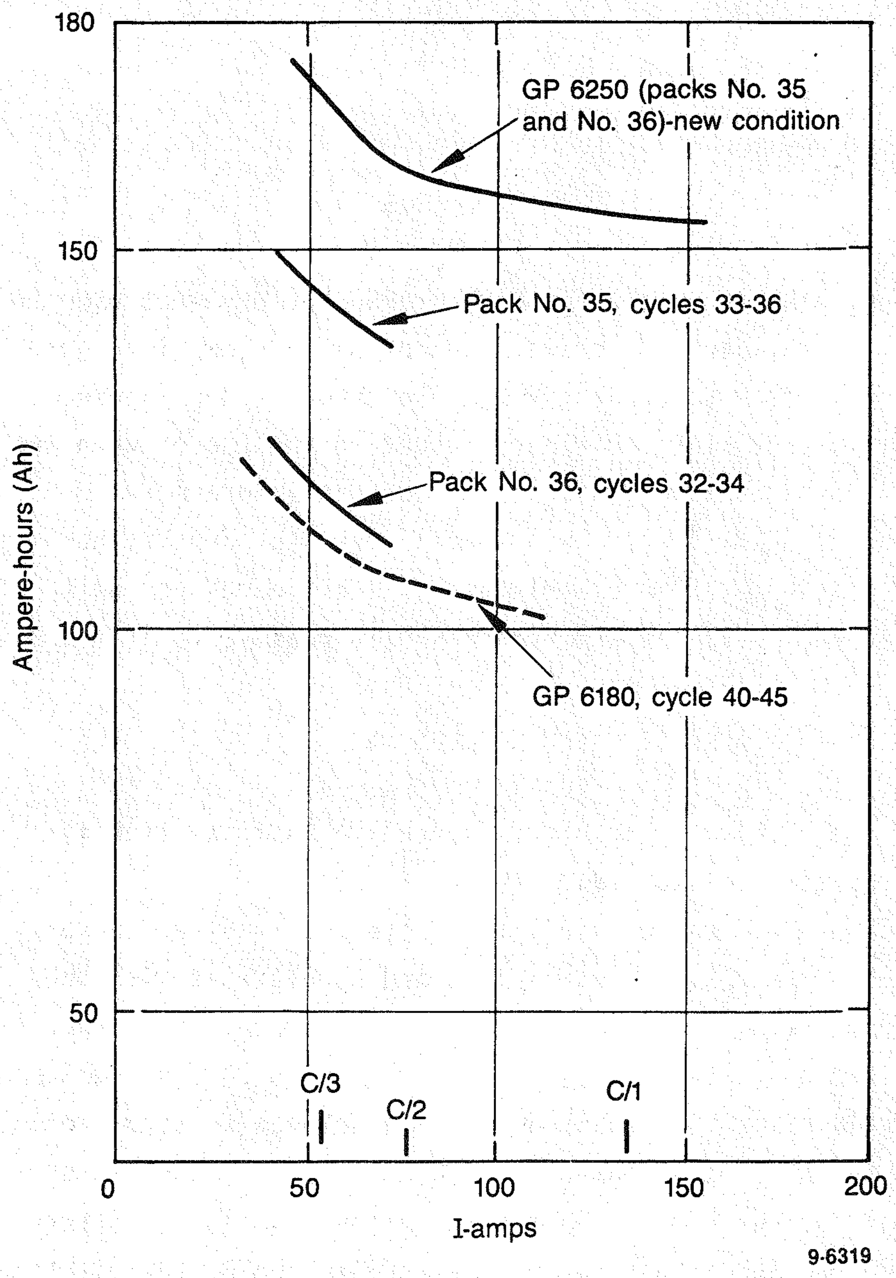

Figure 6. Peukert Curves for the Concorde GP6250 and GP6180 Batteries

5.2 Constant Power Discharges

Constant power tests of the Concorde GP 6250 were performed at power densities of 7, 21,42, and 60 W/kg based on module weight. The cut-off voltages used in the constant power tests are given in the table below:

Power Density (W/kg)	Cut-off Voltage (V/cell)
7	1.75
21	1.3
42	1.3
60	1.3

The constant power discharge data for the GP 6250 battery were used to plot the Ragone curve (energy density versus power density) shown in Figure 7. The Ragone curve for the GP 6180 battery is also shown in the figure. The two Ragone curves lie very close together indicating that, even when the GP 6250 battery is new, on a unit weight basis it does not store more electrical energy than the GP 6180 battery. Hence after its capacity has degraded in 30-40 cycles, the GP 6250 clearly stores less energy per unit weight than the GP 6180 and it is not an attractive alternative to it.

5.3 Variable Power Discharges

The response of the battery in an electric vehicle is most directly described in terms of battery voltage (V), current (I), and depth-of-discharge (DOD). In urban driving, the battery current and power vary rapidly with time as the vehicle accelerates and decelerates with the average discharge current being much less than the peak current. In order to determine the battery response for this type of discharge, data from variable power tests are required. Data from constant power discharge tests are of limited value because the pulse peak power is much greater than the battery can sustain for long periods of time. The most directly applicable battery data are that obtained from SFUDS tests of the battery in the Battery Test Laboratory or from dynamometer tests of the vehicle powered by the battery on the FUDS.

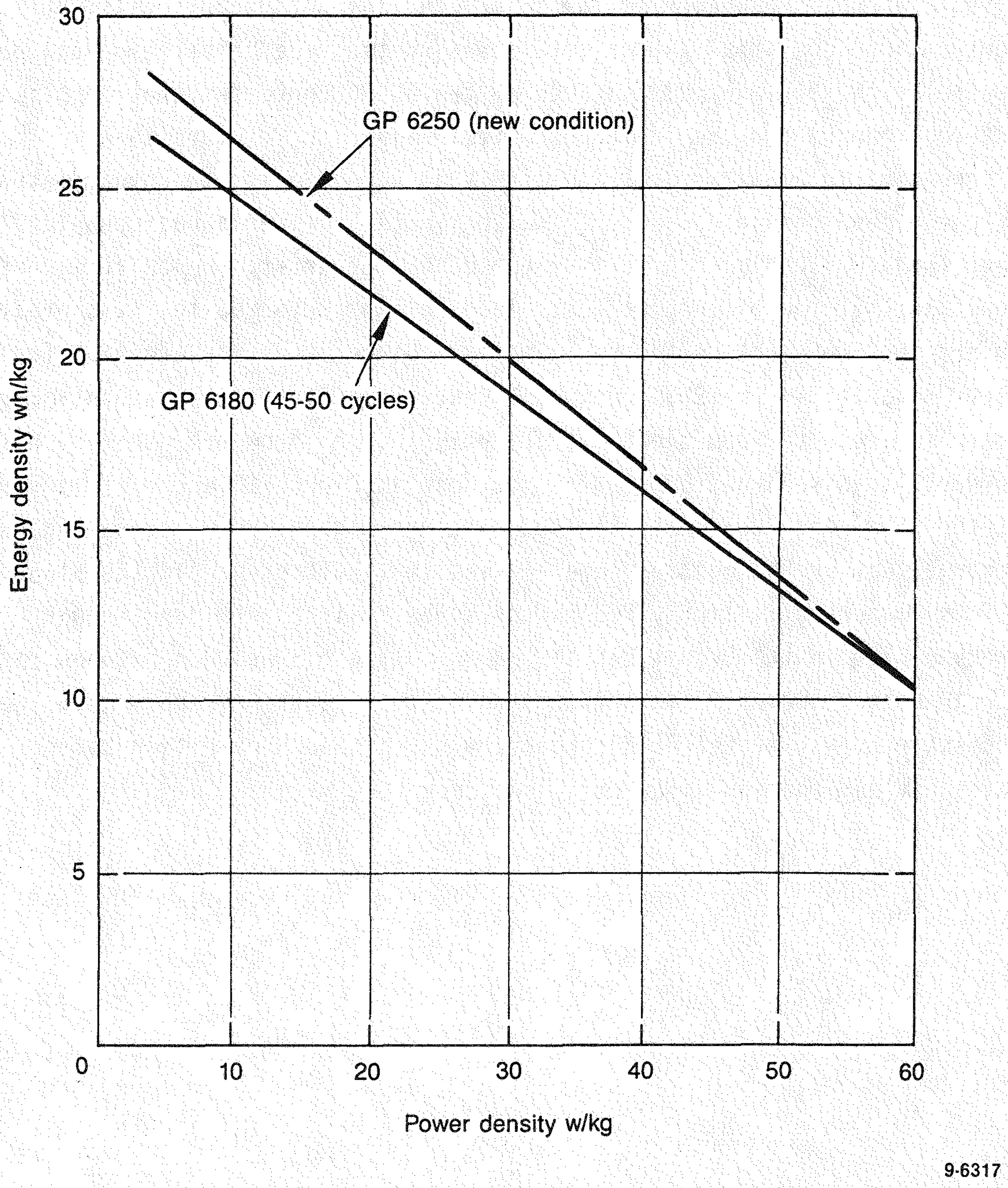

Figure 7. Ragone Curves for the Concorde GP6250 and GP6180 Lead-Acid Batteries

The voltage-current-DOD characteristics of the GP 6250 battery based on SFUDS and FUDS data are shown in Figures 8 and 9. The capacity of the GP 6250 battery in the SFUDS test was 162.8 Ah using a test termination voltage cut-off of 1.3V/cell. The capacity of the battery for the FUDS test of the Evcort on the dynamometer was 151.2 Ah with the test being terminated when the vehicle could no longer follow the cycle. As noted previously, the Evcort controller limits the battery power so that the battery voltage never drops below the 90V minimum required by the DC-DC converter that supplies electrical energy for the 12V accessories. Since the cell voltage corresponding to a battery voltage of 90V is 1.66 V/cell, the dynamometer test could have been continued if the termination criteria had been 1.3v/cell rather than the 90 V minimum set by the DC-DC converter. Hence it is not surprising that the battery capacity measured in the SFUDS test was greater than for the FUDS test on the dynamometer. Since it is not uncommon for the battery capacity in the SFUDS and FUDS tests to differ, it is advantageous to compare the results from the two tests using net Ah from the battery rather than depth-of-discharge (DOD). This is done in Figure 10 where it is seen that the SFUDS and FUDS tests yielded data for battery response during pulsed discharge that are in good agreement. The small difference in the slope of the V vs. I curves is likely due to the added resistance of the longer battery cables in the Evcort due to the splitting of the pack between forward and rear battery boxes. It should be noted that Figures 8 and 9 give the transient response of the GP 6250 battery in the "new" condition before significant degradation in capacity has occurred.

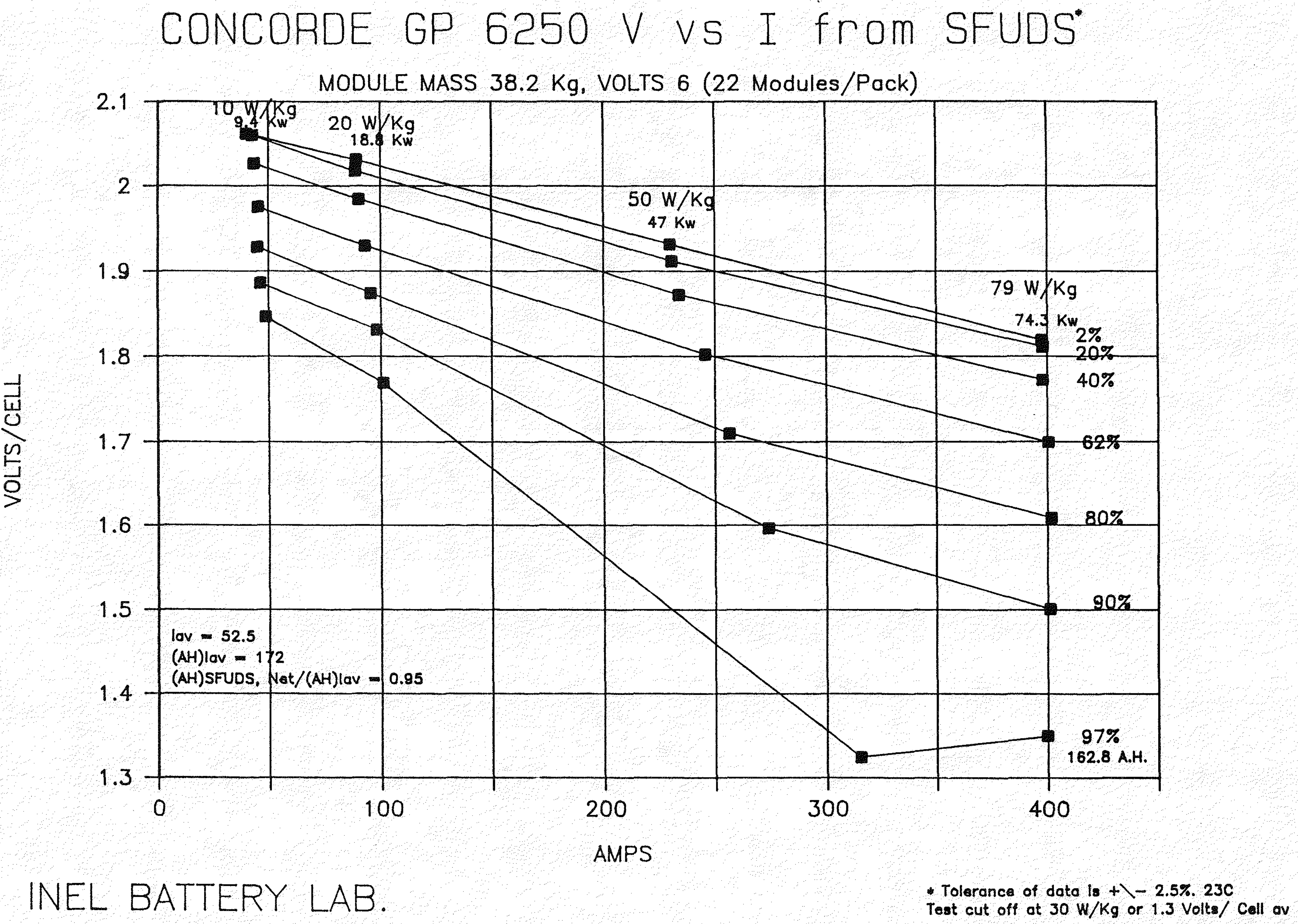

Figure 8. Voltage vs Current Characteristics of the Concorde GP6250 Battery Based on SFUDS Tests

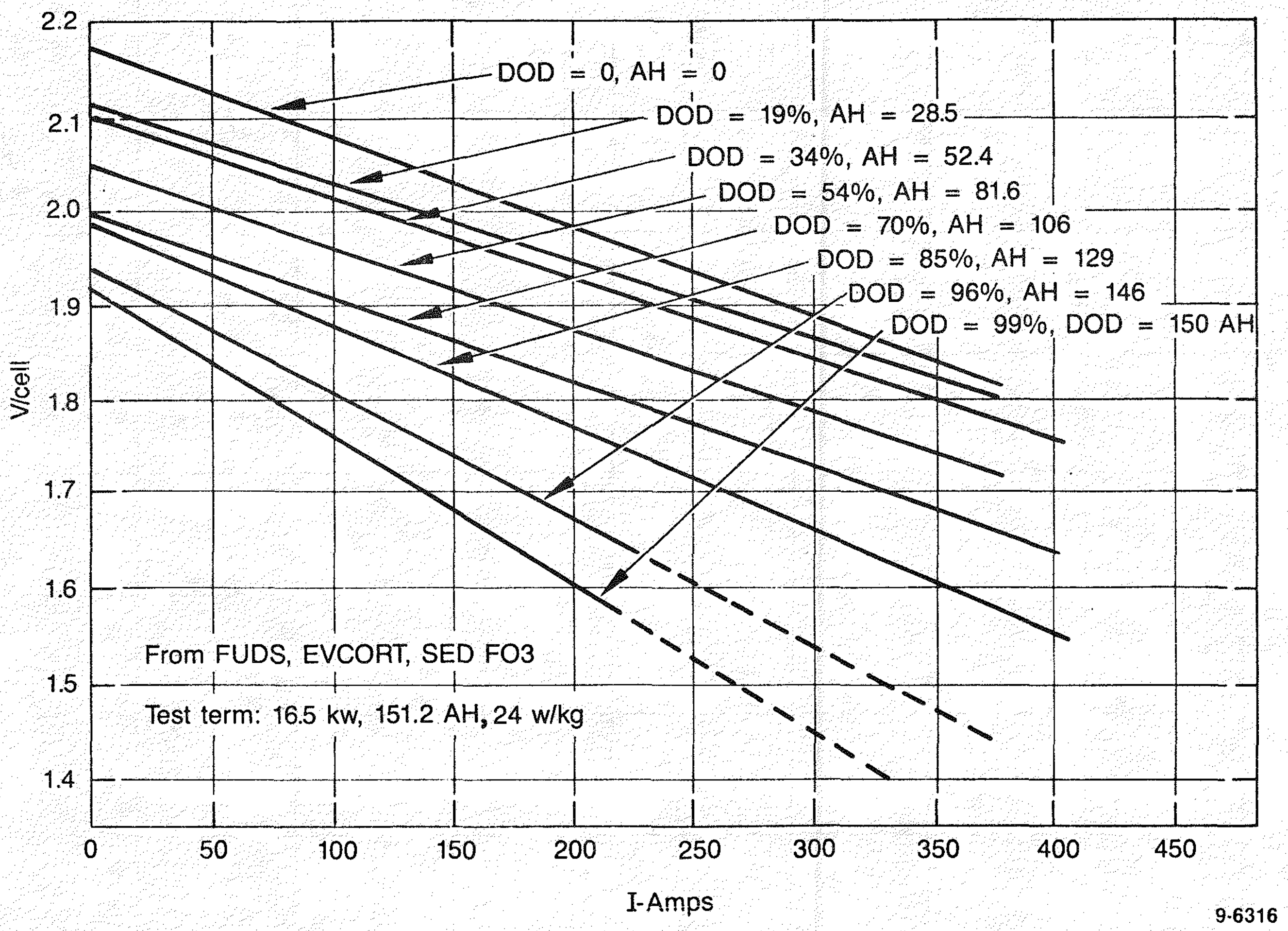

Figure 9. Voltage vs Current, DOD for the Concorde GP6250 from Vehicle FUDS Tests

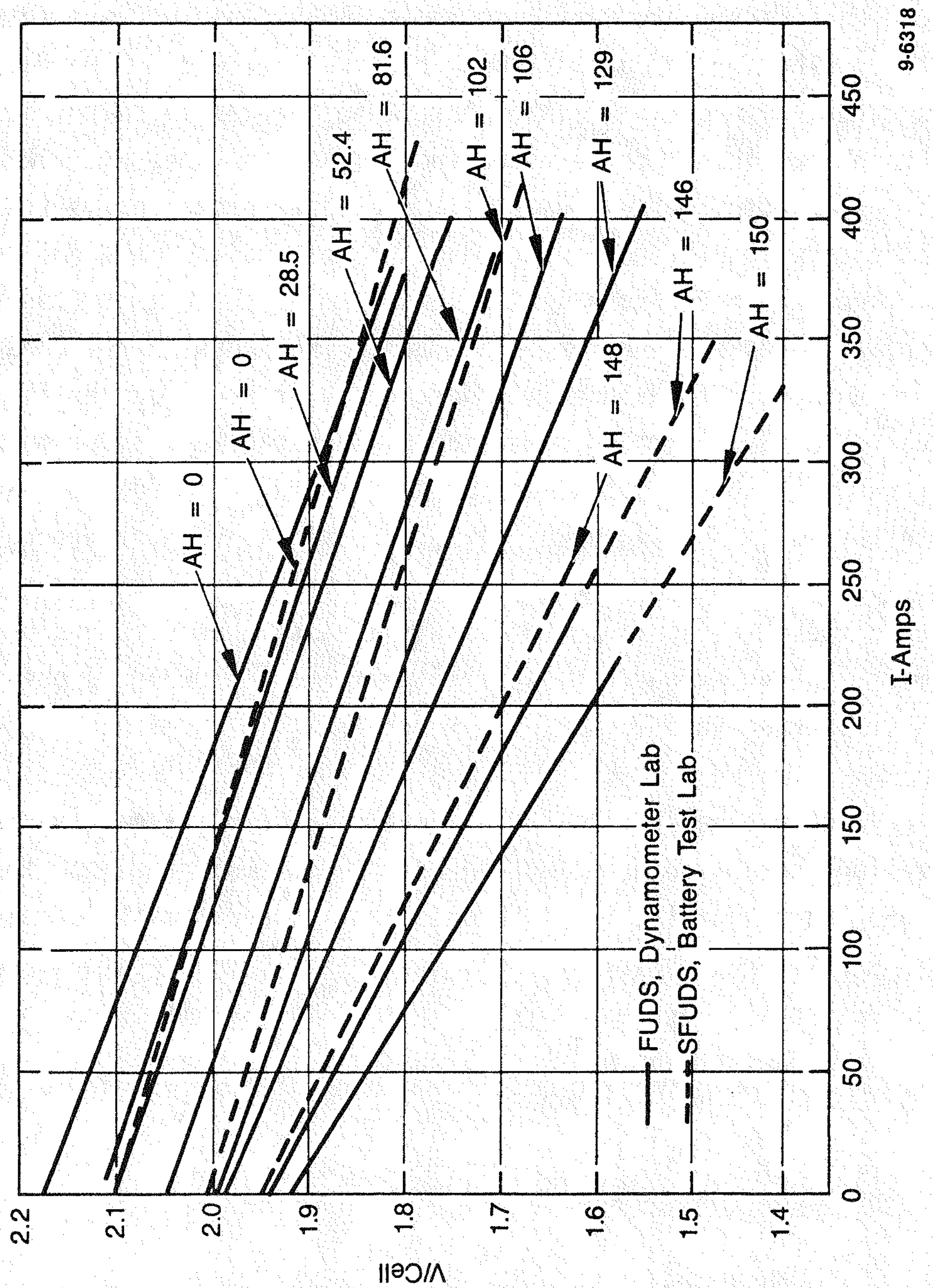

Figure 10. Comparison of the Voltage vs Current Characteristics of the GP6250 for Various AH Based on SFUDS and FUDS Test Data

6. EVCORT VEHICLE TEST RESULTS

6.1 Test Program and Procedures

A series of tests of the Evcort vehicle, powered by Concorde GP 6250 lead-acid batteries, were performed in the INEL Vehicle Dynamometer Laboratory. The test program is summarized in Table 3 . The data for each test is given in Appendix D. The procedures for testing electric vehicles at the INEL follow closely those recommended in the revised SAE J227 Electric Vehicle Test Procedure (Reference 7). A general exception is the number of tests of each type performed. At the INEL, two rules are used; (a) tests of the same type are never consecutive, and (b) only two tests (instead of the recommended three) are run for each type if the Gross Energy Consumption of the first two agree to within 3%. When the difference of the first two tests is greater than 3%, a procedure/equipment investigation is performed. If no clear reason for the variation can be determined, a third test is run and the three test results are averaged. If modifications to test procedure, equipment, or the vehicle are required, the third test result is averaged with the closest result from the first two tests. This method of operation sometimes requires a fourth test to be performed in order to obtain an acceptable average value.

The Electric Vehicle Test Procedure (SAE J227) allows the testing organization the option of selecting only those tests required to meet their needs. For this vehicle, the INEL chose not to perform the Deceleration Tests (SAE-J227 Section 12), Propulsion System Thermal Performance Tests (Section 13), or the Gradeability at Speed Test (Section 9).

6.2 Dynamometer Test Results

6.2.1 Energy Consumption

6.2.1.1 Definition of Terms. Energy consumption is the energy (Wh) required to operate the vehicle per unit distance (km) traveled during the test cycle. Hence, energy consumption is expressed as Wh/km. The energy consumption of most interest is the net energy supplied by the battery to power the vehicle.

TABLE 3. DYNAMOMETER TEST SUMMARY

	Test Type		Number of Tests Performed
48 km/h	Air conditioner off		2
48 km/h	Air conditioner on		1
88 km/h	Air conditioner off		3
88 km/h	Air conditioner on		1
C-Cycle	Air conditioner off		3
C-Cycle	Air conditioner on		1
C-Cycle	Heater on		1
FUDS	Air conditioner off		3
FUDS	Air conditioner on		1
Acceleration	Air conditioner off		2
Acceleration	Air conditioner on		1
		TOTAL	19

The net energy is the battery output energy (gross energy) minus the energy returned to the battery during periods of regenerative braking. The energy required to recharge the battery is also of interest. The AC recharge energy is the energy from the wall plug to the battery charger. The DC recharge energy is the energy from the battery charger into the battery. The ratio of the DC recharge energy to the AC recharge energy is the efficiency of the battery charger. The coulombic efficiency, which is a measure of battery gassing during recharge, is the ratio of the net ampere-hours withdrawn from the battery during the discharge (vehicle test) to the ampere-hours returned to the battery during recharge. The DC energy efficiency of the battery is the ratio of the kilowatt-hours withdrawn from the battery during discharge to the DC energy returned to the battery during recharge. (See the Acronyms and Abbreviations lists for the definitions of all the efficiency terms.)

6.2.1.2 <u>Energy Consumption with the Air-conditioner Off</u>. As indicated in Table 4, dynamometer tests of the Evcort were run with the air conditioner off and then with it operating. In this section the results of the tests with the air-conditioner off are discussed. The effect of air-conditioner operation on energy consumption is considered in the next section.

Tests were run at the constant speeds of 48 and 88 km/h and for the SAE J227 C and the FUDS driving cycles. At the start of the test series, there was some confusion as to the transmission gear that should be used for each of the tests. Consultation with Soleq clarified this situation. It was determined that the Evcort should be operated in 2nd gear at 48 km/h and for the C cycle test and most of the FUDS cycle and in 3rd gear at 88 km/h and during the 90 km/h excursions on the FUDS cycle. As a result of the early confusion, one 88 km/h test was run in 4th gear; one C-Cycle test was run in 3rd gear; and one FUDS test was run totally in 3rd gear. Table 5 shows the effect of gear selection on the net DC energy consumption of the Evcort and confirms that it is optimum to operate the vehicle in the lowest gear consistent with motor maximum speed considerations.

TABLE 4 EVCORT SUMMARY TEST RESULTS

	Energy Consumption (Wh/km) (without air conditioning)					Energy Consumption (Wh/km) (with air conditioning)				
Test Type	Range (km)	Wall AC	System DC	Gross DC	Net DC	Range (km)	Wall AC	System DC	Gross DC	Net DC
48 km/h (constant speed)	154.3	172	154	119	119	119.7	208	186	149	149
88 km/h (constant speed)	76.6	299[a]	269[a]	160	160	70.5	255	243	179	179
C-cycle	74.8	341[a]	306[a]	214	201	60.9	440	393	283	272
FUDS	67.6	313	278	226	212	60.2	408	364	281	270

Acceleration (seconds)

Battery State-of Charge	100% SOC	55% SOC	37% SOC	17% SOC
Speed				
0-48 km/h	8.3	8.7	9.2	12.5
0-80 km/h	25.6	26.1	28.1	48.5
0-88 km/h	32.5	32.8	36.0	--

Note: Tests with the air conditioner on, indicated acceleration performance of the Evcort was not affected by use of the air conditioner.

Energy Consumption Definitions

$$\text{AC} = \frac{\text{AC Energy to Charger for Recharge}}{\text{Distance Traveled}} \qquad \text{Veh. DC Gross} = \frac{\text{DC Energy from Battery While Driving (not including Regen Benefit)}}{\text{Distance Traveled}}$$

$$\text{System DC} = \frac{\text{DC Energy From Charger for Recharge}}{\text{Distance Traveled}} \qquad \text{Veh. DC Net} = \frac{\text{DC Energy from Battery While Driving (including Regen Benefit)}}{\text{Distance Traveled}}$$

---

[a] These values are due to significant battery overcharge caused by an inappropriate charger cutoff criteria.

TABLE 5: ENERGY CONSUMPTION DATA FOR SELECTED DRIVING CYCLE-GEAR COMBINATIONS

Test Type	Transmission Gear	Net DC Energy Consumption
88 km/h	3rd	159.5 Wh/km
	4th	166.7
C-Cycle	2nd	201.0
	3rd	235.7
FUDS	2nd[a]	211.5
	3rd	238.4

---

[a] Ran FUDS in second gear except during 90 km/h excursion--shifted to 3rd gear.

The energy consumption data of the Evcort (test weight 1968 kg) for the various driving schedules are shown graphically in Figure 11 and summarized in the following Table 6. Results are given for both the net battery DC energy consumption and the wall-plug AC energy consumption.

TABLE 6. ENERGY CONSUMPTION DATA FOR VARIOUS DRIVING SCHEDULES

Driving Schedule	Wh/km DC	Wh/km AC
48 km/h	119	172
88 km/h	160	227
J227 C	201	341[a]
FUDS	212	313

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[a] This value is due to significant battery overcharge caused by an inappropriate charger cutoff criteria.

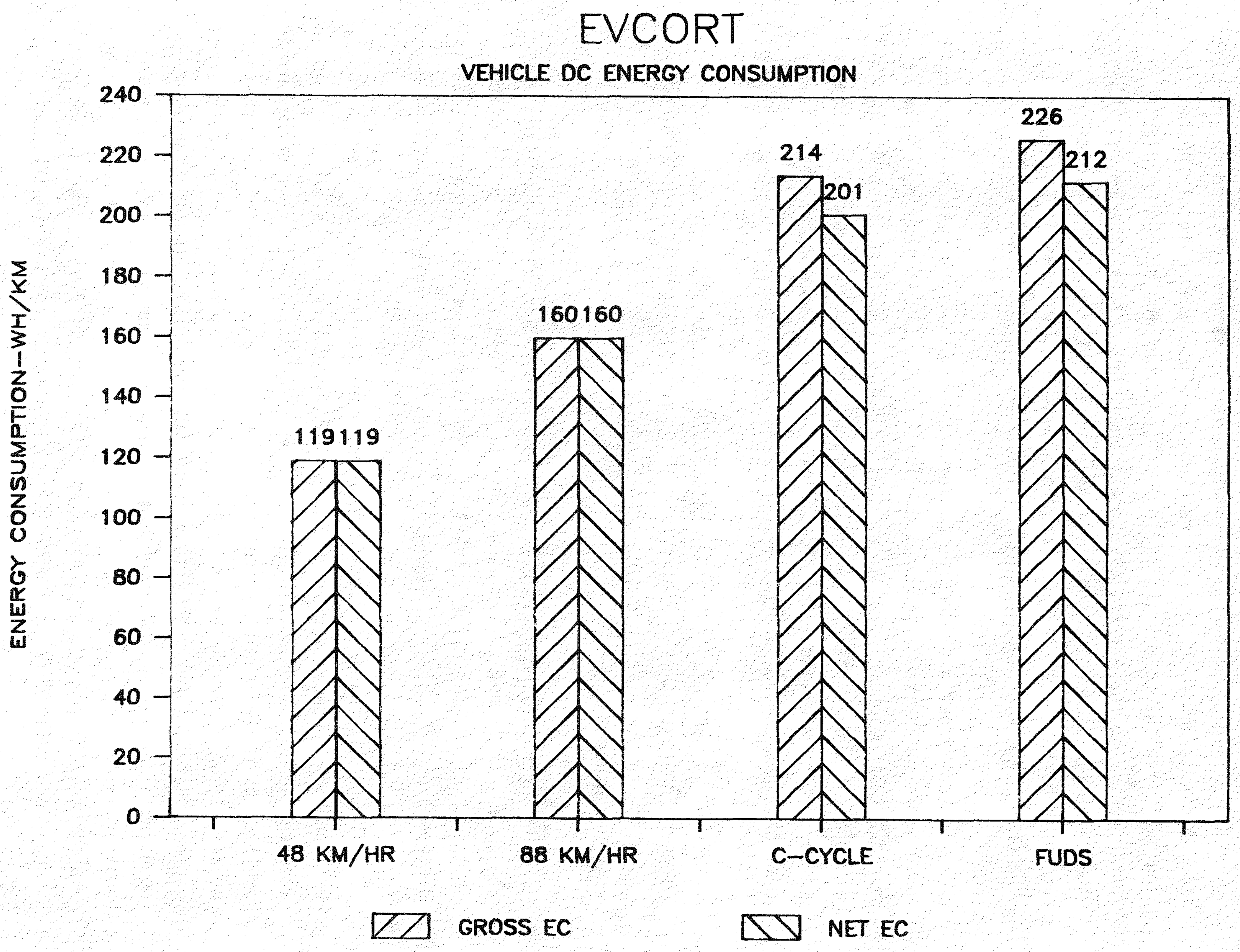


Figure 11. Net dc and Gross dc Energy Consumption for Selected Driving Schedules

The wall plug ac energy consumption values shown are based on the data given in Appendix D, but the ac recharge data was used only if the battery coulombic overcharge was 15% or less as is proper for sealed lead-acid batteries. The charger efficiency was about 90% for all the tests. When the battery was charged properly, the overall battery energy efficiency (that is battery output during discharge divided by ac wall plug input to the charger) was between 65-70%.

If the Evcort had used the Concorde GP 6180 battery rather than the GP 6250 battery, the battery weight would have been 173 kg less resulting in a vehicle test weight of 1795 kg which is 8.8% less than the test weight in the present Evcort tests. As a first approximation, this could be expected to reduce the energy consumption of the Evcort by about 8% compared to the data obtained in this program.

6.2.1.3 Energy Consumption with the Air-Conditioner Operating. Dynamometer tests of the Evcort were performed with the air-conditioner operating in order to determine the effect of its operation on vehicle energy consumption and range.

During an air-conditioner test, the air-conditioner is operating all the time. It is not cycled on and off to maintain a set cabin temperature. In this section, the effect of the air-conditioner on energy consumption is discussed.

The energy and power used by the air-conditioner were measured directly by mounting a coaxial shunt in the 108 DC input line to the air-conditioner inverter and monitoring voltage and current at that point. The energy used by the 12 V-DC fan during heater and air conditioner operation was obtained by installing a coaxial shunt at the blower motor and monitoring voltage and current there. Auxiliary battery power out and in was also monitored by mounting a coaxial shunt on the negative side of the auxiliary battery and monitoring current and voltage at that point. The energy and power used by the air-conditioner can also be determined indirectly by comparing the energy consumption of the vehicle with and without the air-conditioner operating.

This has been done for each of the driving schedules for which the Evcort was tested.

The data showing the effect of the air-conditioner on energy consumption are summarized in Table 8 and Figure 12 for the various driving schedules. The effect of the air-conditioner on energy consumption at constant speed varies from 11% at 88 km/h to 25% at 48 km/h. On the variable speed driving cycles, the effect is 25-35%. It should be noted that these effects are for the air-conditioner operating 100% of the time with no cycling.

It is of interest to determine from the data the power (kW) required to operate the air-conditioner and compare it to that required to power the vehicle without the air-conditioner. This has been done in two ways. In the first approach, the measured total DC energy to the air-conditioner inverter for each test was divided by the test time to obtain the average power. This is a direct method of determining the power. The average air-conditioner power can also be determined in an indirect manner from the battery output energy and vehicle range data for tests with and without the air-conditioner operating.

In this method the energy required to power the vehicle is calculated from the energy consumption (Wh/km) with the air-conditioner off and the vehicle range with the air-conditioner on. That energy is subtracted from the measured total battery energy for the test to determine the energy that was used to operate the air-conditioner. The average power used by the air-conditioner is then calculated by dividing the energy to the air-conditioner by the time during the test when the air-conditioner was operating. The results of these calculations are given in Table 7.

TABLE 7. AVERAGE AIR-CONDITIONER POWER

	Veh.	Direct Method		Indirect Method	
Test Type	Power	Power(kW)	%Diff.	Power(kW)	%Diff.
48 km/h	5.75	1.53	27	1.4	24
88 km/h	13.9	1.26	9	1.1	8
C cycle	5.25	1.51	29	1.82	35
FUDS	6.72	1.43	21	1.77	26

The two methods yielded air-conditioner values of average power which differ by an average of only .22kW. In most cases, the air-conditioner's average power was in the expected range of 1.1-1.6 kW given in Reference 2. Also shown in Table 6 are the average vehicle power for each driving schedule without the air-conditioner operating and the percent increase in power resulting from the operating the air-conditioner. The percent power increase should translate directly into increases in vehicle energy consumption due to the use of the air-conditioner. That this is the case is seen by comparing the results given Table 5 and 6 for the effect of the air-conditioner on vehicle power and energy requirements.

6.2.1.4 Energy Consumption with the Heater Operating. One C-cycle test was run with the heater on. The gross vehicle energy consumption was 287 Wh/km and the net energy consumption was 277 Wh/km. This was a 35% increase in energy consumption over that obtained on the C cycle when the heater was turned off and is comparable to the energy increase measured using air conditioning on the C-Cycle.

Both the air-conditioner and the heater use 1.5-2 kW of power so one would expect that their effect on vehicle energy consumption would be nearly the same.

TABLE 8. VEHICLE DC ENERGY CONSUMPTION WITH AND WITHOUT A/C

Test Type		Energy Consumption DC Gross (Wh/km)	Energy Consumption DC Net (Wh/km)	% Increase in Cons. due to Air Cond.
48 km/h	A/C on	149	149	25.2
	A/C off	119	119	
88 km/h	A/C on	179	179	11.3
	A/C off	160	160	
C-Cycle	A/C on	283	272	35.3
	A/C off	214	201	
FUDS	A/C on	281	270	27.4
	A/C off	226	212	

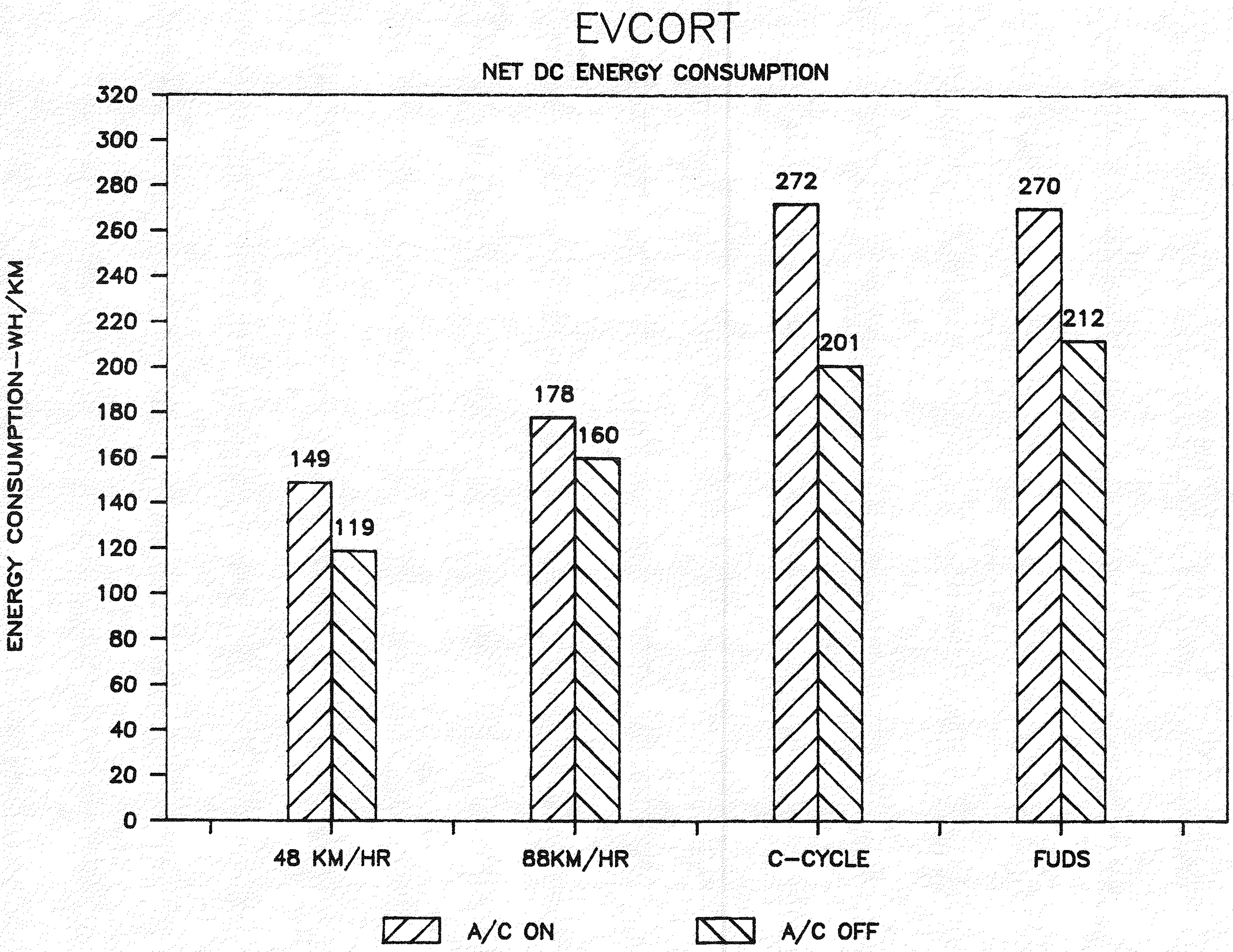


Figure 12. Evcort Net dc Energy Consumption with and without A/C

6.2.2 Range and Battery Capacity

6.2.2.1 Vehicle Range. The range of the Evcort for the various driving schedules with and without the air-conditioner operating is shown in Table 9. With the air-conditioner off, the range of the Evcort using the Concorde GP 6250 batteries in near new condition varied from 154 km at 48 km/h to 77 km at 88 km/h; for the C and FUDS cycles the ranges were 75 km and 68 km, respectively. With the air-conditioner operating, the ranges at constant speeds of 48 km/h and 88 km/h were reduced by factors of .78 and .92, respectively; for the C and FUDS cycles, the range reduction factors were .81 and .89, respectively. Note that the range reductions due to the operation of the air-conditioner are close to those expected based on the corresponding increase in energy consumption (see Table 5) .

TABLE 9. RANGE OF THE EVCORT WITH AND WITHOUT THE AIR-CONDITIONER OPERATING

	Range(km)		
Test Type	Without Air-conditioner	With Air-conditioner	Range Reduction
48 km/h	154	119.7	.78
88 km/h	76.6	70.5	.92
C cycle	74.8	60.9	.81
FUDS	67.6	60.2	.89

6.2.2.2 Battery Capacity during the Dynamometer Tests. As noted earlier in Section 5, the GP 6250 battery pack showed a 25% reduction in capacity at the 3hr rate from the pre to the post dynamometer characterization tests in the Battery Test Laboratory. Battery capacity data from the Evcort dynamometer tests are shown in Table 10 for the various types of driving schedules. It can be seen in the table that the battery began to lose capacity after about the 20th cycle and for the last cycles in the dynamometer test series the decline was quite rapid.

Hence range data for tests run after cycle 20 are subject to some uncertainty. Battery capacity degradation has a minimal effect on energy consumption results, so those data in the present program are considered to be valid with the minimum uncertainty.

TABLE 10. BATTERY CAPACITY DURING THE DYNAMOMETER TESTS

Test Type	Battery Cycle No.	Capacity (kWh)
48 km/h	11	18.13
	19	18.37
88 km/h	27	12.49
	28	12.04
C cycle	22	15.92
	26	14.15
	30	12.25
	31	11.34
FUDS	13	16.99
	23	15.43
	29	13.21

6.2.2.3 Battery Charging. The Concorde GP 6250 batteries are sealed lead-acid batteries. The life of this type of battery can be adversely affected if the batteries are consistently overcharged by too large a factor. Concorde did not specify to INEL personnel an overcharge factor for the GP 6250, but experience with other sealed batteries indicates the overcharge should not exceed 10-15% after the batteries have reached the rated capacity. Unfortunately, as can be seen from the data given in Appendix C, the GP 6250 battery pack used in the Evcort was often overcharged, by the on-board battery charger, by factors well in excess of 15%. This may have been a contributing factor to the observed decline in battery capacity. That the frequent excessive overcharges was not the sole reason for the short life of the batteries follows from the fact that Pack No.35, which was tested only in the INEL Battery Test Laboratory, experienced no excessive overcharge factors and its capacity degraded by 15% in only 35 cycles.

Special care was taken in the Battery Test Laboratory in charging Pack No.35 to insure it was charged properly. The charging voltage was maintained at 2.4V/cell and the overcharge factor was usually less than 10%. A detailed study of Pack No.35 has been made in the Battery Test Laboratory to determine the reasons for its short life.

6.2.3 Vehicle Acceleration and Gradeability

Three acceleration tests were run on the Evcort--two with the air conditioning off and one with it operating. No measurable difference in the vehicle acceleration was observed with the air-conditioner operating. All accelerations were started in 2nd gear and shifted to 3rd gear at 72 km/h. Figure 13 shows speed versus time for the various battery states-of-charge. The acceleration rate versus time for the same states-of-charge are given in Figure 14. The times required to accelerate to 48, 80, and 88 km/h are listed in Table 11. The Evcort accelerated to 48 km/h (30 mi/h) in 8-9 s, to 80 km/h (50 mi/h) in 25-26 s, and to 88 km/h (55 mi/h) in 32-35 s at battery states-of-charge greater than 35%. At lower states-of-charge, the acceleration times are somewhat greater. In general, the acceleration of the Evcort is comparable to other high performance electric vehicles,such as the ETV-1 and the ETX-I. This is particularly impressive in that the weight of the Evcort is 1968 kg compared to about 1700 kg for the ETV-1 and ETX-I.

The percent gradeability at speed (G@S) may be analytically derived from acceleration rate vs speed data using the equation

$$(\%)\ \text{Gradeability at Speed} = 100 \tan(\sin^{-1} 0.0283A)$$

Where A = Acceleration in km/h/sec

The results of the calculations at various battery SOC are provided in Figure 15. A maximum gradeability of about 30% is achieved in first gear at approximately 15 km/h.

Vehicle gradeability limit tests were conducted at the Chrysler Arizona Proving Grounds in October of 1988.

TABLE 11. EVCORT ACCELERATION

Battery SOC (%) (Base 169.5 AH)		Acceleration Time (seconds) 0-48 km/h	0-80 km/h	0-88 km/h
100	Test 1 No A/C	8.5	26.2	33.2
100	Test 2 A/C on	8.0	24.7	31.1
100	Test 3 No A/C	8.1	25.1	31.9
65	Test 1	8.9	26.6	33.4
58	Test 2	8.7	26.3	33.2
55	Test 3	8.6	25.6	32.3
47	Test 1	9.0	27.5	34.9
37	Test 2	9.0	27.9	35.7
33	Test 3	9.4	28.8	37.1
29	Test 1	--	--	--
17	Test 2	11.9	43.6	--
11	Test 3[a]	13.2	53.4	--

---

[a] Single acceleration.

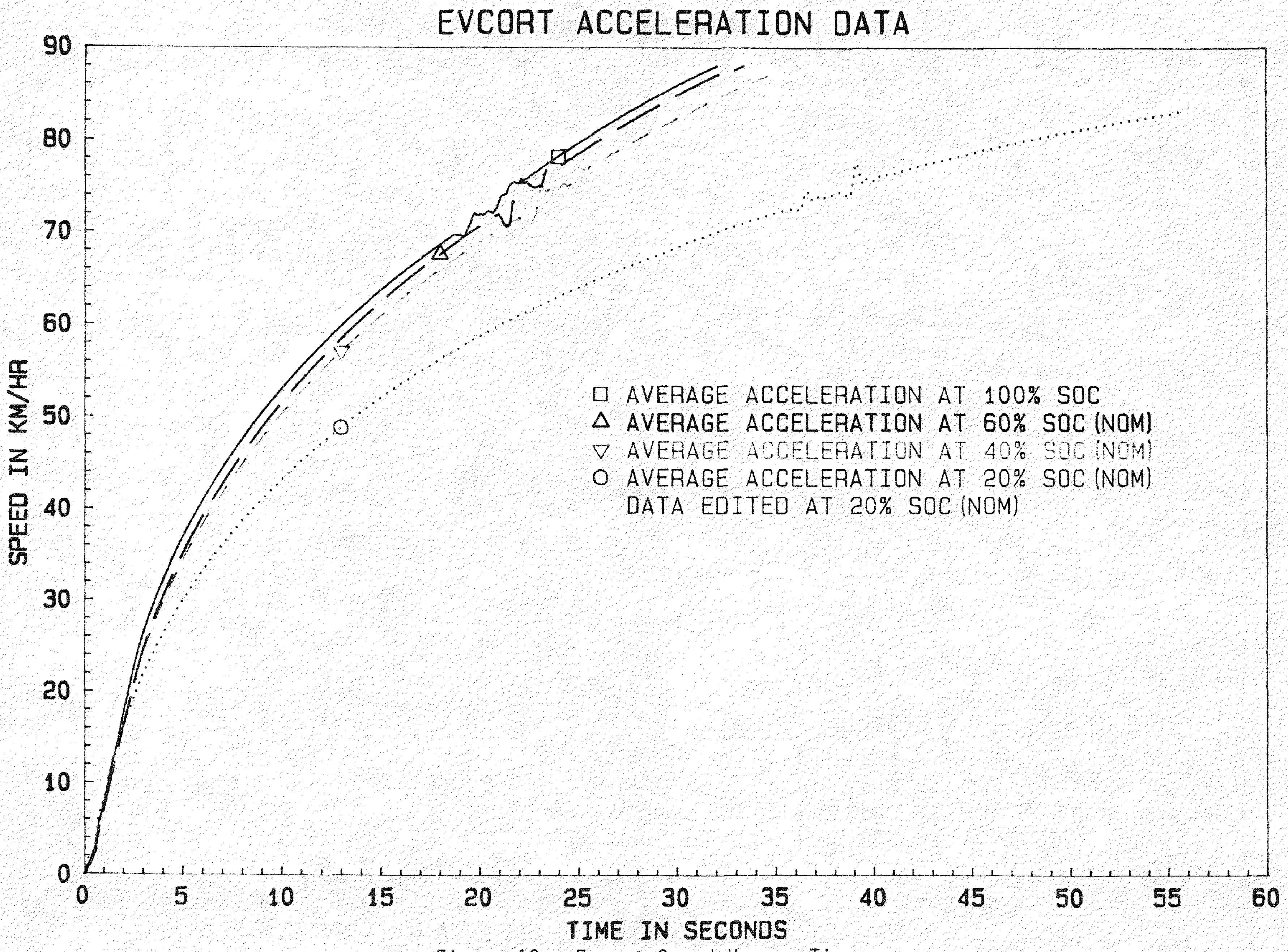


Figure 13. Evcort Speed Versus Time

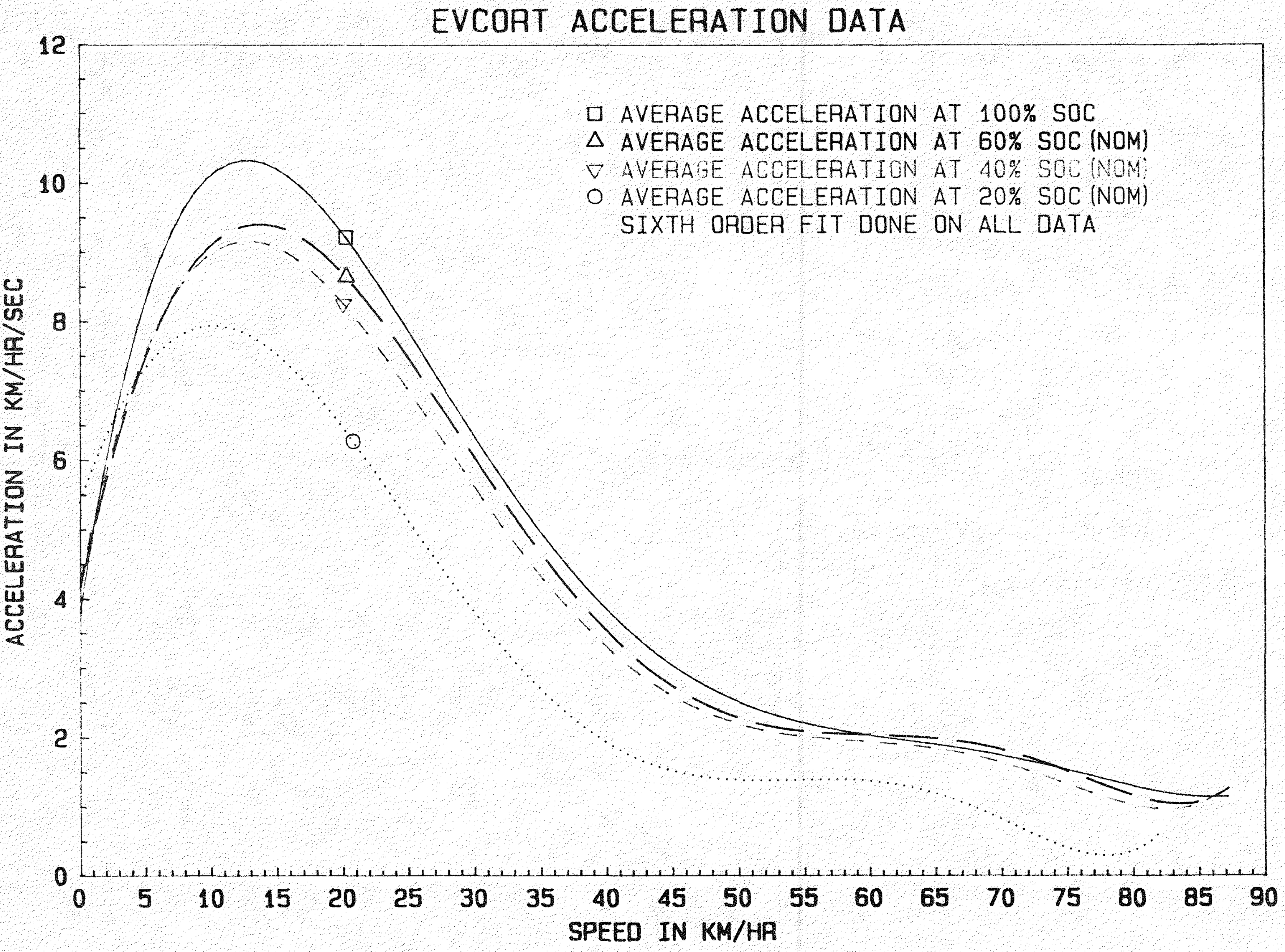


Figure 14. Evcort Acceleration vs Time

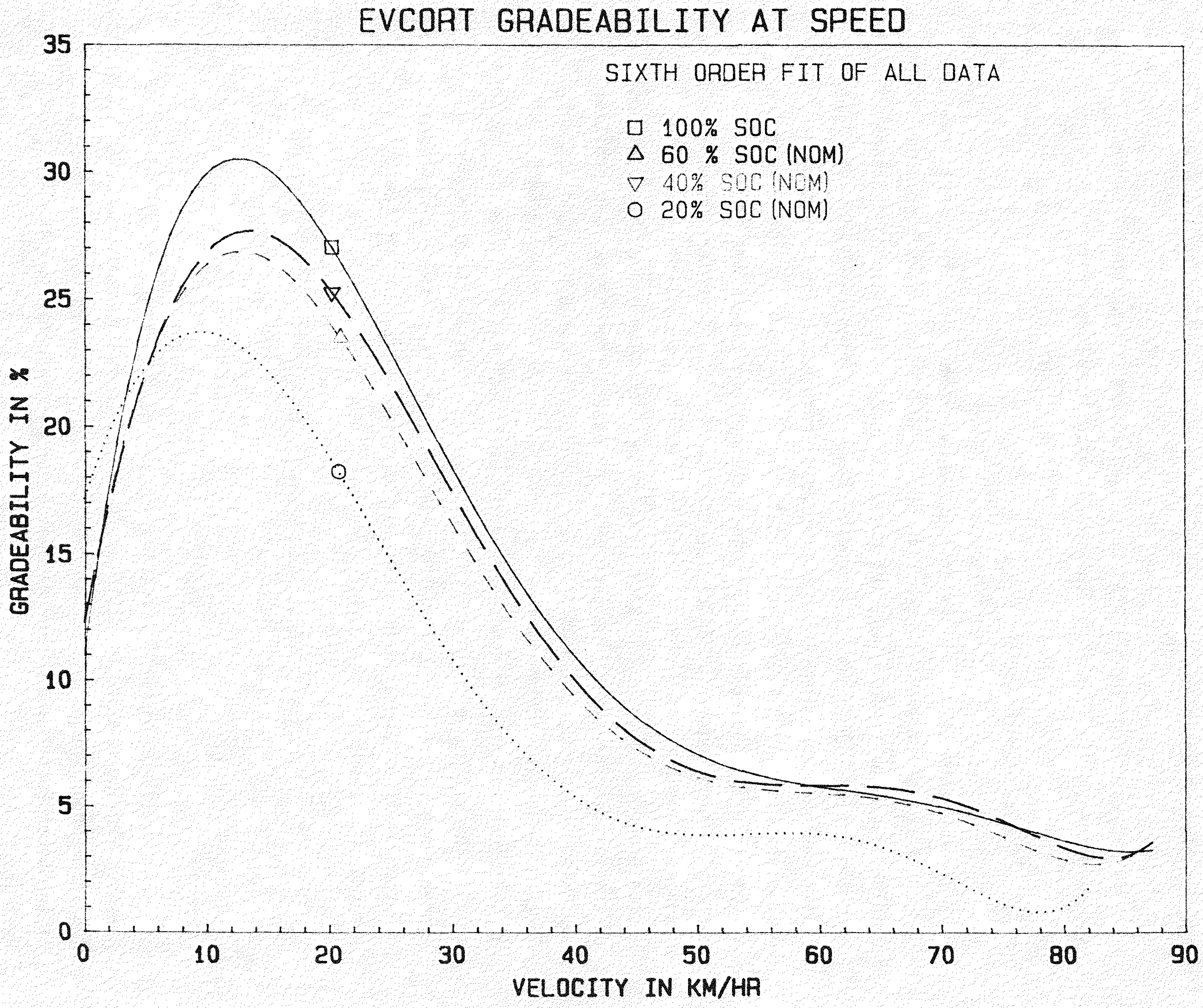


Figure 15. Evcort Gradeability at Speed vs DOD

At 100% traction battery SOC with the vehicle in first gear, the Evcort was able to negotiate the 30% gradeability limit event, stop at the midpoint and continue up the grade.

As expected, gradeability at speed decreases to less than 2.5% for speeds greater than 75 km/h at low (20% nominal) traction battery SOC.

6.2.4 Vehicle Driveability

The driveability of the Evcort on the dynamometer was in general quite good. The constant speed tests at 48 and 88 km/h were run with no difficulty as the vehicle held the constant speed with minimum attention from the driver. The Evcort also performed well during the FUDS test. The driver was able to follow the rapid velocity changes in the FUDS cycle without great difficulty. Most limitations in the power available from the driveline during periods of high accelerations were due to the the minimum battery voltage constraint (90V) set to maintain 13.7V from the DC-DC converter. When driving the C Cycle, some velocity oscillations were encountered during the transition from the acceleration and cruise portions of the velocity profile. The Evcort has a coasting regeneration capability and Soleq feels that those oscillations can be eliminated by an adjustment in the regeneration circuit. As indicated in Figure 13, some speed oscillations were also encountered during and after shifting from 2nd to 3rd gear in the maximum effort acceleration tests. These oscillations are probably due to the difficulty in precisely controlling the motor after it is decoupled from the driveline during the shift without torque feedback in the control scheme for the motor.

6.3 Track Air Conditioner Testing

6.3.1 Introduction

Air conditioning performance testing of the Evcort was conducted at the Chrysler Proving Grounds in Wittmann, Arizona, in early October of 1988. Testing methodology called for side-by-side cabin temperature measurements of the Soleq Evcort and a conventional internal combustion engine (ICE) vehicle.

An ICE Ford Escort was rented from the Hertz Corporation in Phoenix, Arizona. The rented vehicle was the closest match to the Evcort that could be located in the Phoenix area. The notable differences in appearance between the vehicles were:

Soleq Evcort	Light silver exterior paint
	Dark blue interior
	No luggage rack
	No front bumper
Ford Escort	White exterior paint
	Dark gray interior
	Luggage rack

Four tests were conducted to evaluate the differences in cabin temperature. The first two tests (SEAIR1 and SEAIR2) were run with the vehicles stationary. They were situated eight feet apart on a blacktop driveway (see Figure 16). Ambient starting temperature was $33^{\circ}\mathrm{C} \pm 1^{\circ}\mathrm{C}$. The vehicles were soaked in sunlight (windows up) until the cabin temperatures stabilized. At that time both vehicles were simultaneously started and the air conditioners turned on. The air conditioner systems were set to maximum A/C and the blower switches set to high. Test SEAIR2 was run on the day following. The last two tests (SEAIR3 and SEAIR4) were run on the track at 56 km/h. Ambient air temperature for both of these tests was $31^{\circ}\mathrm{C} \pm 1^{\circ}\mathrm{C}$. The vehicles were again allowed to stabilize in the sun. Both vehicles were started simultaneously, the A/C units turned on and driven immediately onto the track. Each test consisted of seven full laps around the 6.8 km track, which is a distance of 47.6 km. Elapsed time for these tests was approximately 1.1 h.

6.3.2 Instrumentation

The Evcort and the Escort were instrumented for five temperature measurements each. The transducers were placed (as closely as possible) in identical locations in both vehicles.

Figure 16. Ford ICE Escrot and Soleq Evcort During Side-by-side A/C Testing in Phoenix, Arizona

1. Driver's face
2. Left A/C vent
3. Right A/C vent
4. Passenger's face--center rear seat
5. Passenger's external front door handle--shaded by the handle.

6.3.3 Soleq Evcort Instrumentation

The Evcort temperature instrumentation consisted of five thermistors connected to the prototype Versatile Data Acquisition System (VDAS). This equipment is a new time-based data acquisition system which in the future, will be the replacement of the event-based VDAS equipment presently used in several vehicles by site operators.

6.3.4 Ford Escort Instrumentation

The Escort instrumentation consisted of five Type E thermocouples connected to a Campbell scientific Model 21 X data acquisition system. Data from the 21 X was stored in a Toshiba (Model T1000) lap top computer.

6.3.5 Test Results

The data for the stationary and moving vehicle tests will be discussed separately. The stationary vehicle case will considered first. The temperatures at various locations inside the passenger compartment are given in Figures 17 and 18 as a function of time after the air-conditioner is turned on for the Evcort and Escort. The temperature-time histories during the cool-down period for the two vehicles are compared in Figures 19 and 20 for the driver's head and rear seat locations. The corresponding data for the case in which the vehicles are moving at 56 km/h on the track are given in Figures 21-23.

In all respects the performance of the air-conditioner in the ICE Escort is significantly better than the electrically driven air-conditioner in the Evcort. The performance of the two systems are compared quantitatively in Table 12 for both the stationary and moving vehicles and for both the front and rear seat locations.

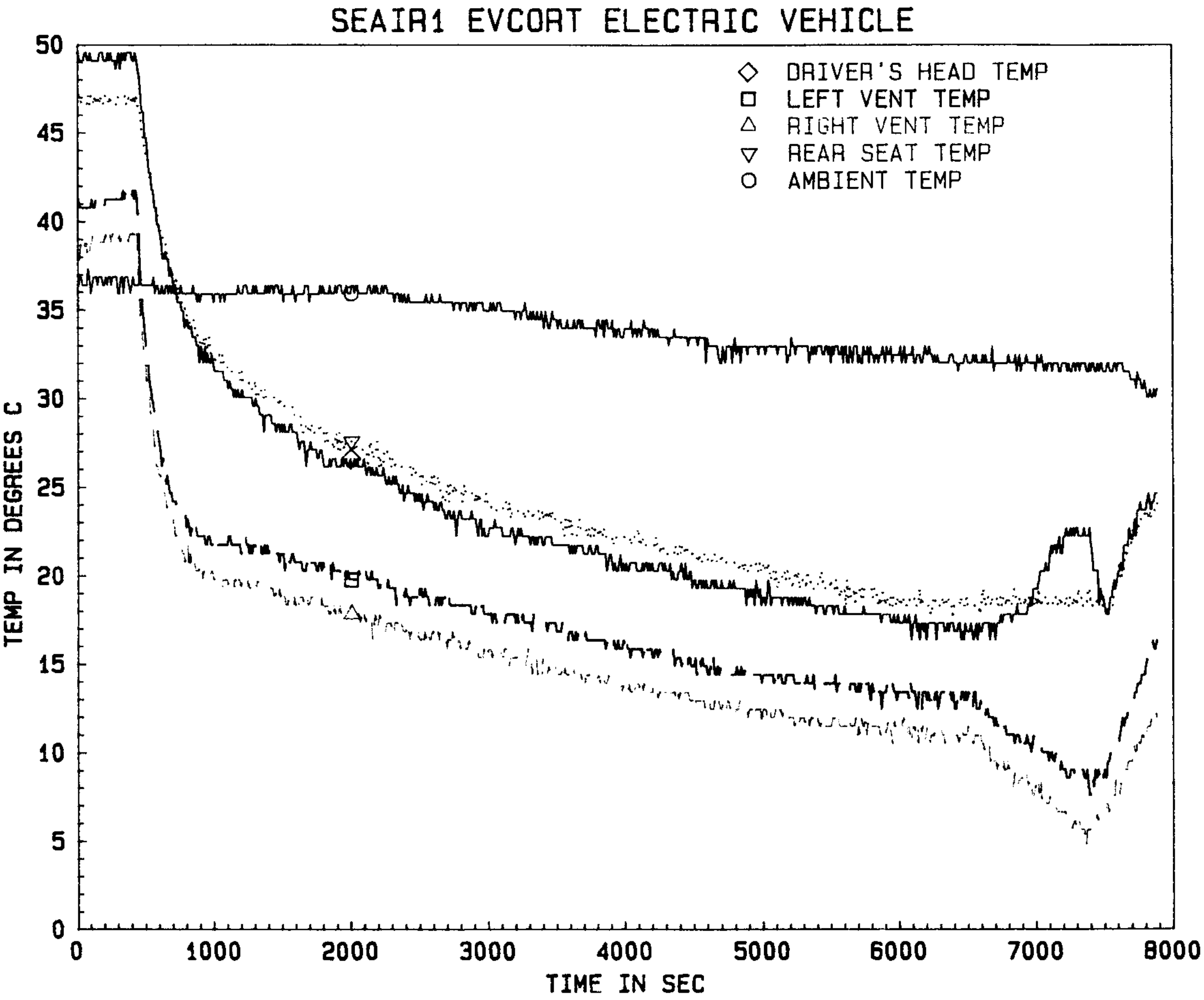


Figure 17. Evcort Air Conditioning Test

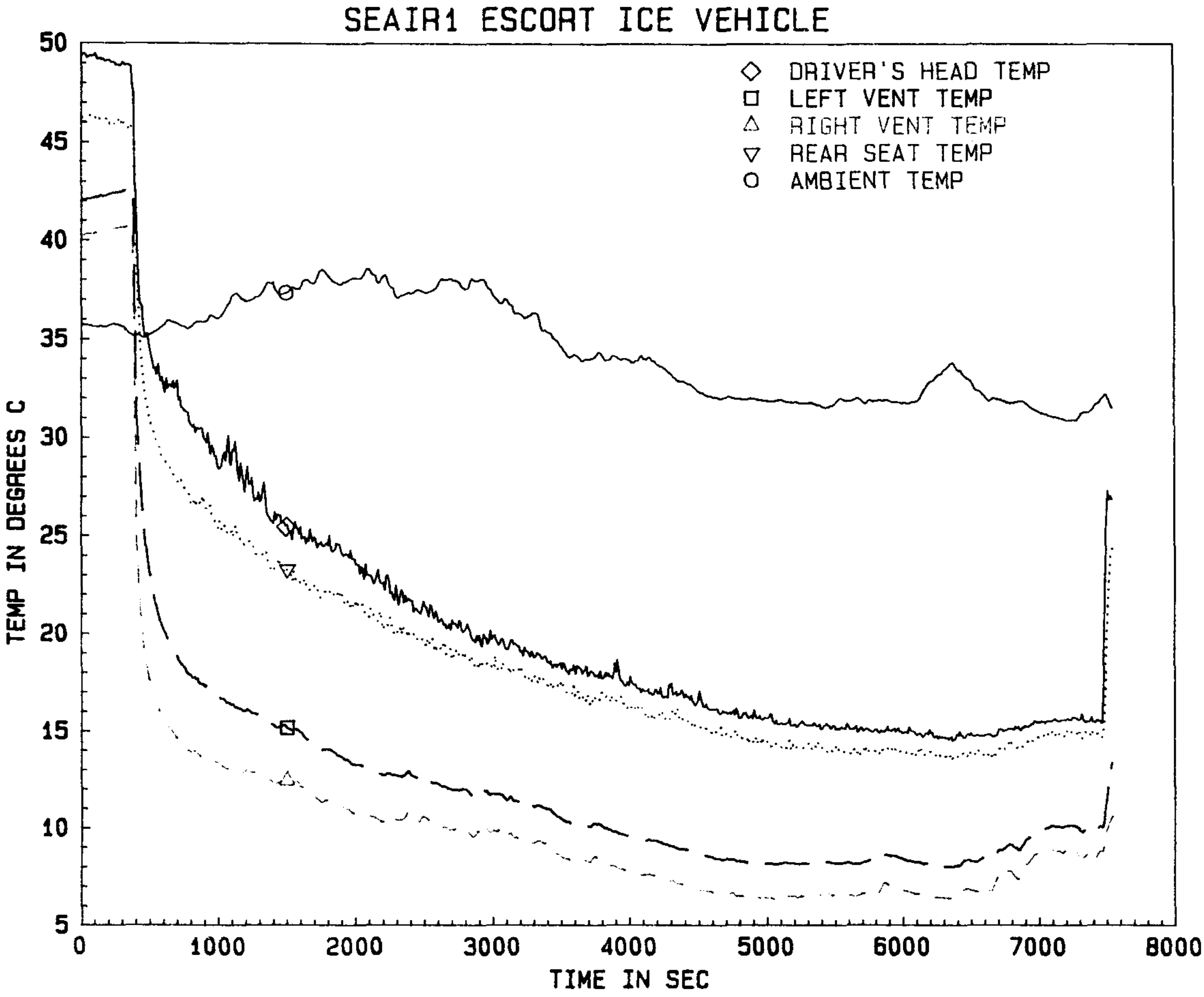


Figure 18. Internal Combustion Engine Ford Escort Air Conditioner Test

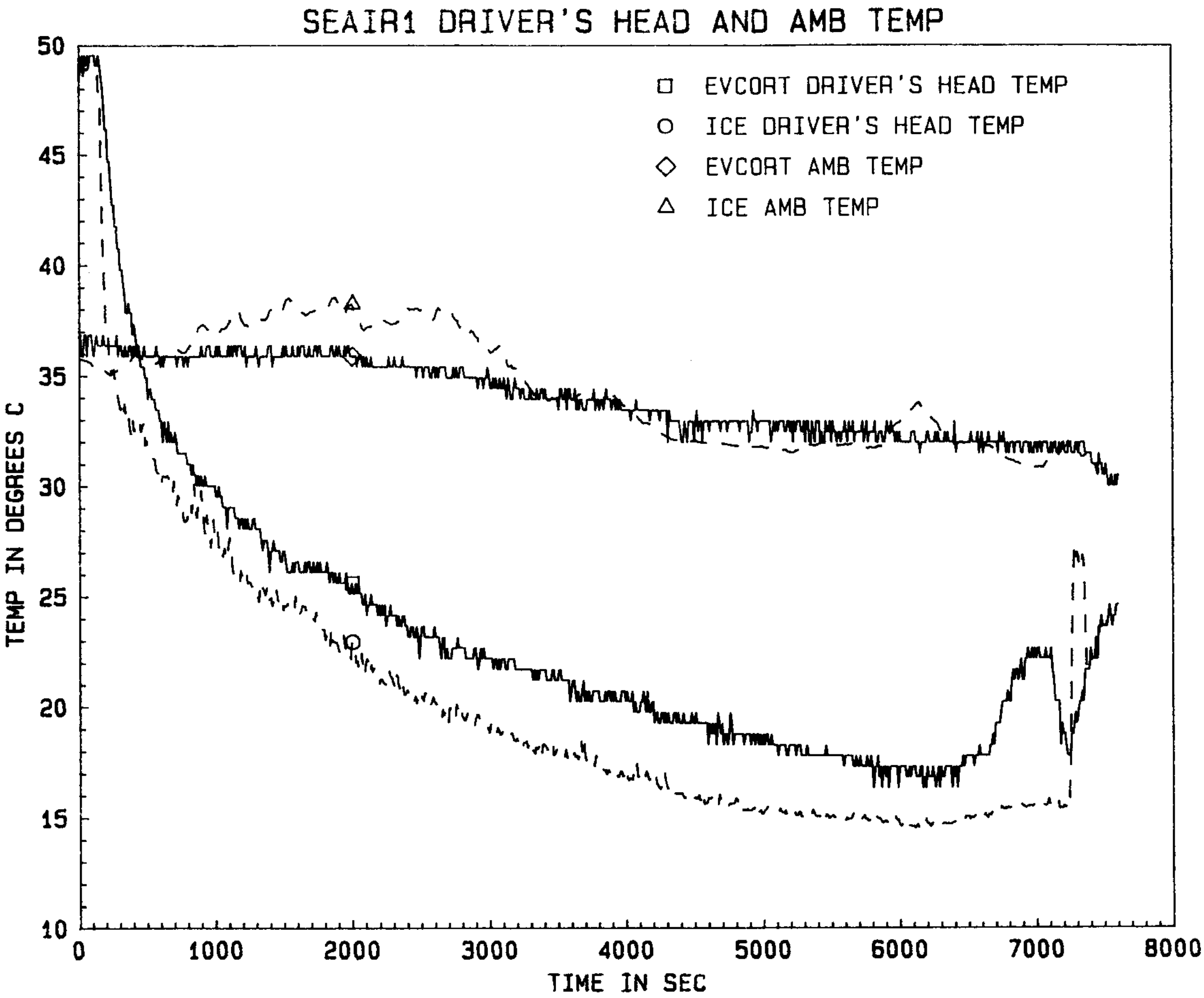


Figure 19. Evcort vs Escort Air conditioner Test

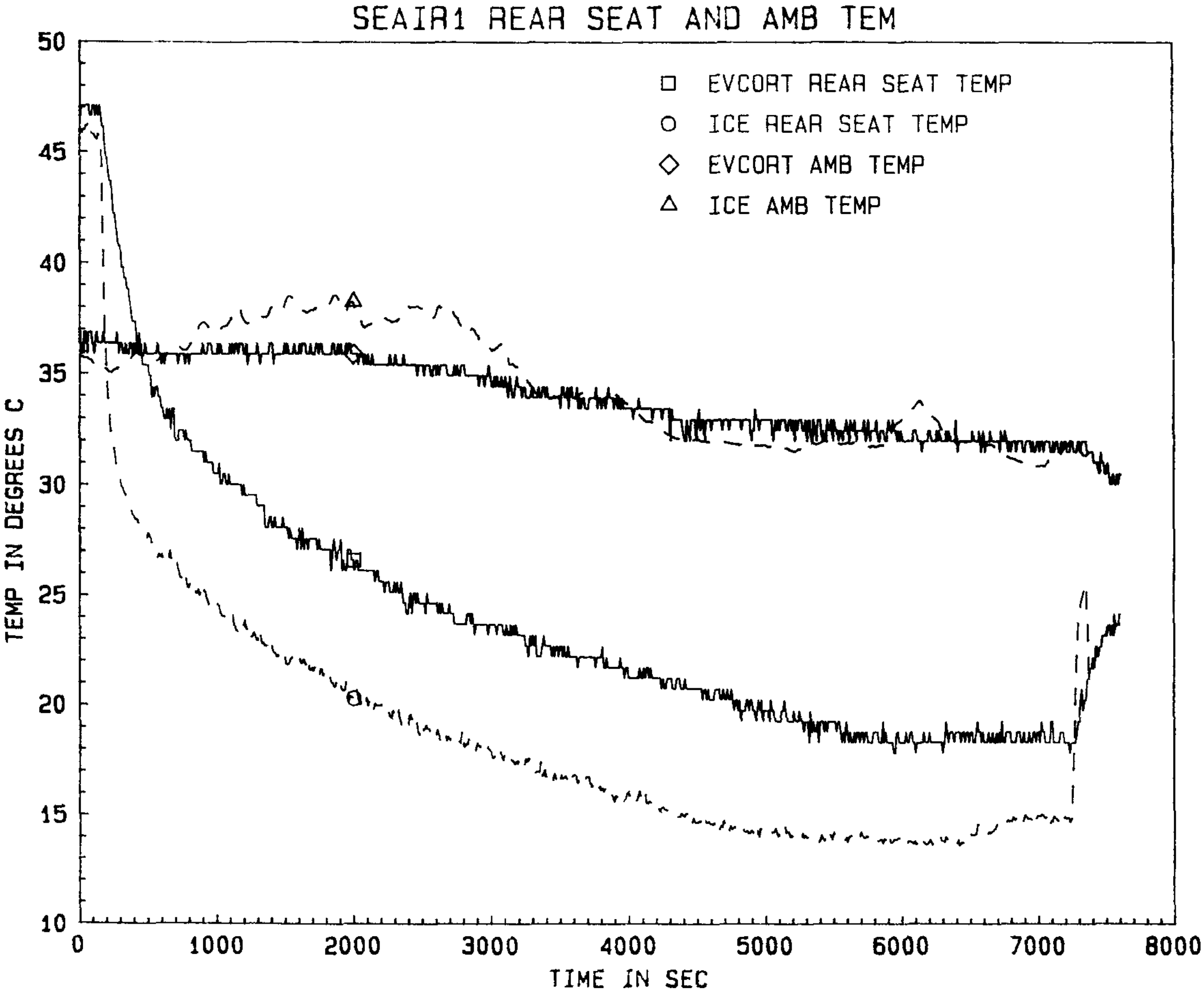


Figure 20. Air Conditioner Test Rear Seat Temperatures Escort (ICE) vs Evcort

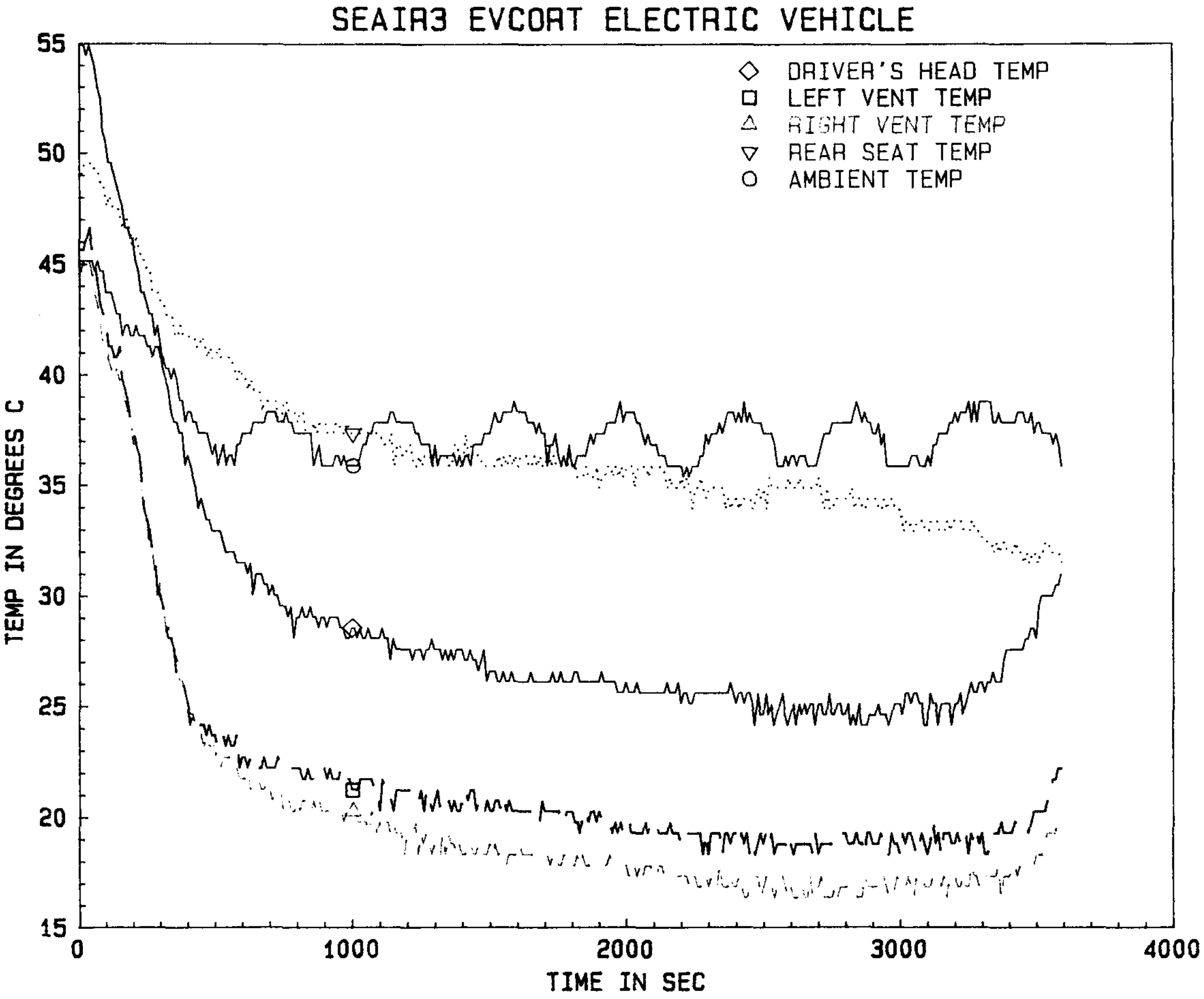


Figure 21. Air Conditioner Test Evcort Internal Temperature Profile

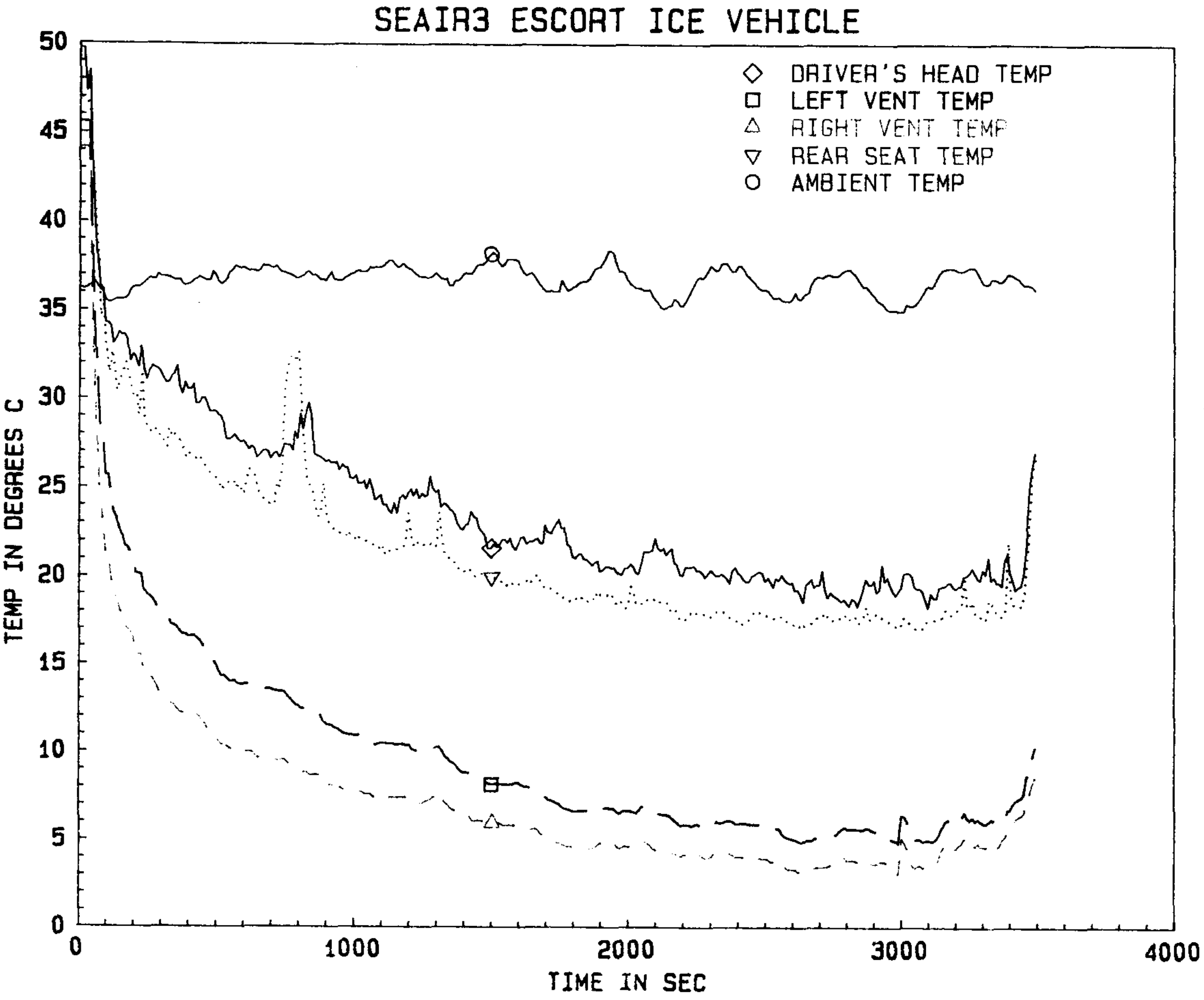


Figure 22. Air Conditioner Test Escort (ICE) Internal Temperature Profile

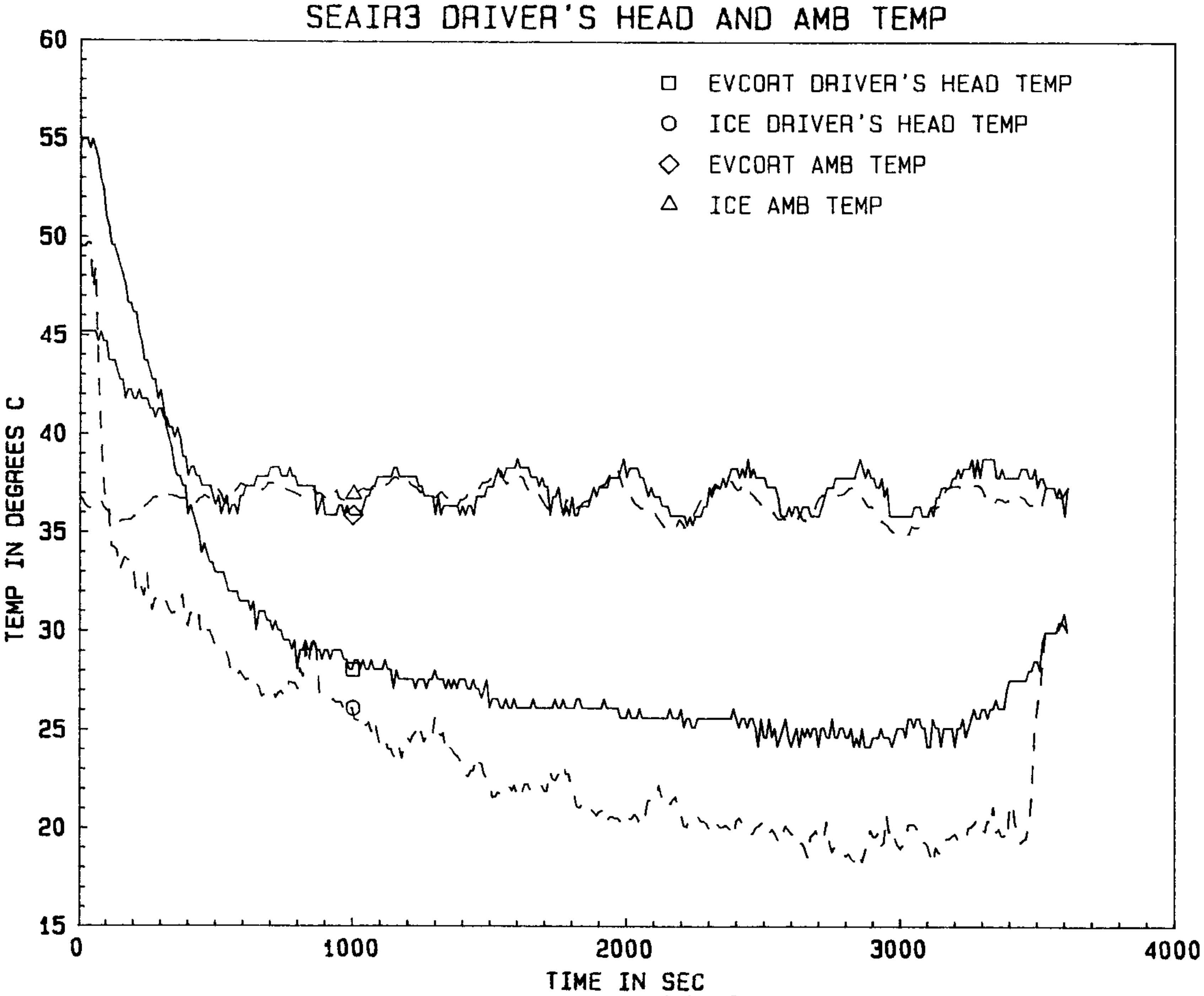


Figure 23. Evcort vs ICE Escort Driver Position Temperature Profile Comparison

The figure of merit used in the comparisons is the time required to cool the temperature to 26.6°C (80°F) from the initial soak temperature of about 48°C (118°F). For the front seat, the cool-down time for the Evcort was 20 minutes when the vehicle was stationary and 16 minutes when the vehicle was moving at 56 km/h. The corresponding values for the ICE Escort are 16.6 minutes and 13.8 minutes. For both vehicles, the cool-down times are shorter when the vehicle is moving. The data showed that, as expected, the minimum temperatures achieved during the cool-downs were higher when the vehicles were moving than when stationary. For the Evcort, the minimum cool-down temperatures were 18°C (64°F) when the vehicle was stationary and 25°C (77°F) when the vehicle was moving at 56 km/h. The corresponding values in the front seat (driver's side) for the ICE Escort are 15°C (59°F) and 19°C (66°F). The air-conditioner in the ICE Escort adequately cooled the rear seat location for both the stationary and moving situations, but the air-conditioner in the Evcort cooled the rear seat location for the stationary case only.

TABLE 12. SUMMARY OF AIR-CONDITIONER TEST RESULTS FOR THE EVCORT AND ICE ESCORT

	Cool-down Time (min.)to 26.6 C	
	Front	Rear
Evcort (electric)		
Vehicle stationary	24	30
Vehicle Moving (56 km/h)	20	no cooling
Minimum Temperature in front seat		
vehicle stationary	18°C (64°F)	
vehicle moving	25°C (77°F)	
	Front	Rear
Escort (ICE)		
Vehicle stationary	16.6	8.7
Vehicle moving	13.8	5.8
Minimum Temperature in front seat		
vehicle stationary	15°C (59°F)	
vehicle moving	19°C (66°F)	

6.4 Heater/Defroster Testing

Four tests were performed under winter conditions in Idaho Falls, Idaho to compare the 2 kilowatt resistance heater system in the Evcort with a conventional heater/defroster system in a conventional ICE vehicle. A 1988 Ford Escort station wagon was rented from a local dealer. The Escort was gray in color with a dark gray interior. Seven thermocouples were mounted in each vehicle in the following locations:

1. Driver's feet
2. Driver's head
3. Front passenger's feet
4. Front passenger's head
5. Left rear passenger's feet
6. Right rear passenger's feet
7. Outside left rear door (ambient).

All floor thermocouples were mounted three inches above the floor and centered at each position. The "head" thermocouples protruded out and down from the sun visors to the face position. The temperature measured by the six internal thermocouples were averaged and reported as vehicle cabin temperature.

The Evcort and the Escort were parked adjacent to the laboratory, pointed into the direction of the prevailing wind (see Figure 24). The ambient temperature for the tests ranged from -12°C to 0°C (10°F to 32°F). The wind speeds varied from 12 to 40 km/h (8 to 27 mi/h). The vehicles were parked outside during the night prior to the test, so that they had soaked at low temperature for more than 12 hr. For the defroster test, there was a thick coating of ice on the windshield.

In addition to the temperature measurements, the Evcort was monitored for heater fan power, heater element power, and traction battery power. The heater control positions for the four tests performed were as follows:

Test 1	Fan motor-high; heater control position--floor
Test 2	Fan motor-high; heater control position--floor
Test 3	Fan motor-high; heater control--defrost
Test 4	Fan motor-high; heater control--mix.

During the tests, it was determined that the heater fan uses an average of 0.17 kW of power from the traction battery and the heater element uses an average of 1.8 kW.

The data from the heater/defroster tests are shown in Figures 25-28 for both the Evcort and the ICE Escort. For the heater tests, the average temperature inside the vehicle is given as a function of time after the heater was turned on. For the defroster tests, contours of defrosted area on the windshield are shown. The figures show that the heater/defroster in the ICE Escort performed significantly better than the one in the Evcort. Quantitative comparisons of the two heater/defroster systems are given in Table 11. The primary figure of merit used for the heater is the time required for the vehicle to heat up to 0°C (32°F) from the ambient temperature of about -12°C (10°F).

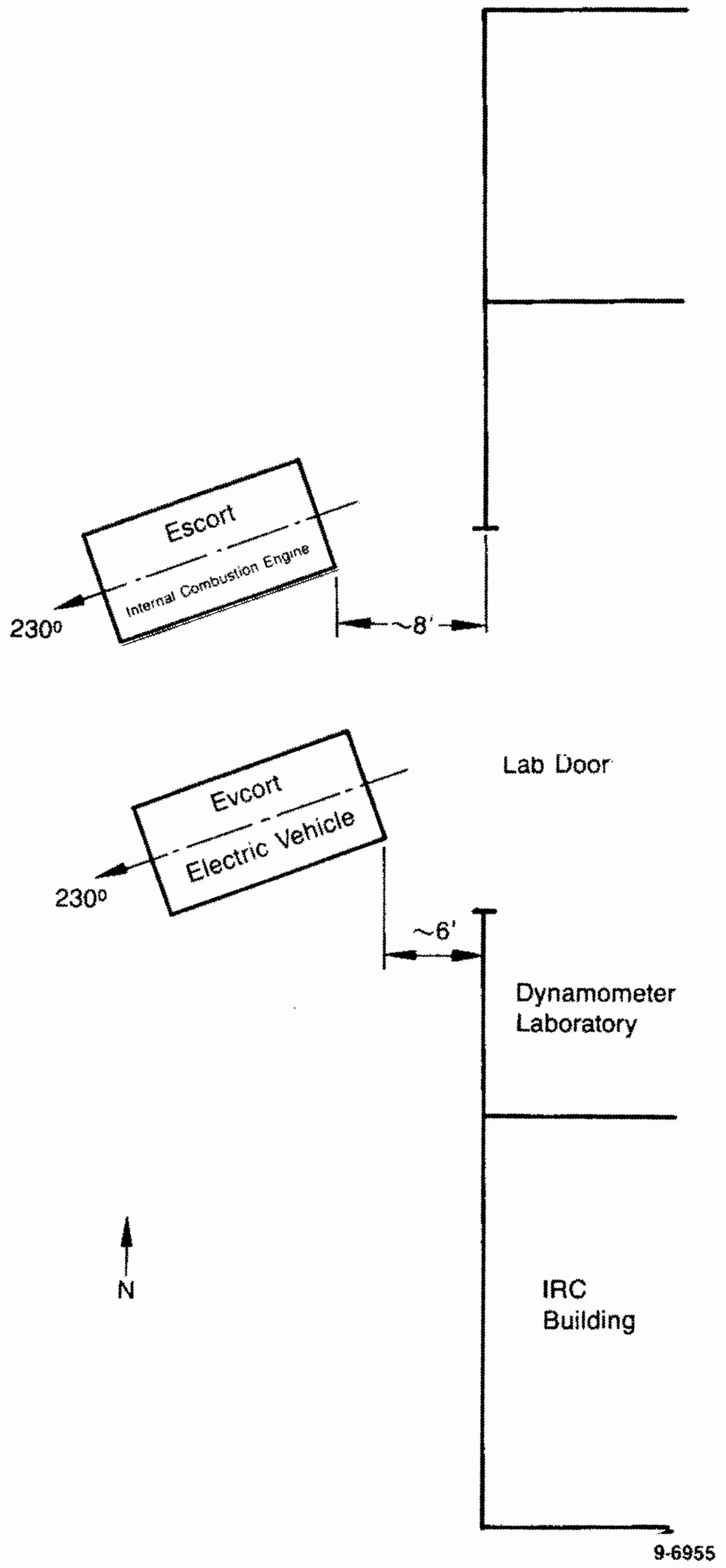


Figure 24. Evcort/Escort Heater Test Setup.

The figure of merit used for the defroster is the time require to defrost 50% of the windshield area. The heat-up times are 10-12 minutes for the Evcort and 5-6 minutes for the Escort. The windshield defrost times are 27 minutes for the Evcort and 18 minutes for the ICE Escort. It took 58 minutes to completely defrost the windshield in the Evcort and 28 minutes in the ICE Escort. In general, it took about twice as long in the Evcort to accomplish a given heater/defroster function as in the ICE Escort.

The data indicate that the 2 kW heater/defroster unit in the Evcort is not adequate for use in cold, northern winter weather and a larger unit or more direct means of using the energy for heating/defrosting is needed for electric vehicles used in northern climates.

TABLE 13. SUMMARY OF TEST RESULTS FOR THE HEATER/DEFROSTER SYSTEMS IN THE EVCORT AND ICE ESCORT

Ambient Temperature	-12°C (15°F)
Vehicle Parked	
Heater Results	
Time to heat-up to 0°C (32°F)	
Evcort	10-12 minutes
Escort	5-6 minutes
Temperature after 30 minutes	
Evcort	3.5°C (38°F)
Escort	22.5°C (72°F)
Defroster Results	
Time to defrost 50% of the windshield	
Evcort	27 minutes
Escort	18 minutes
Time to defrost 100% of the Windshield	
Evcort	58 minutes
Escort	28 minutes

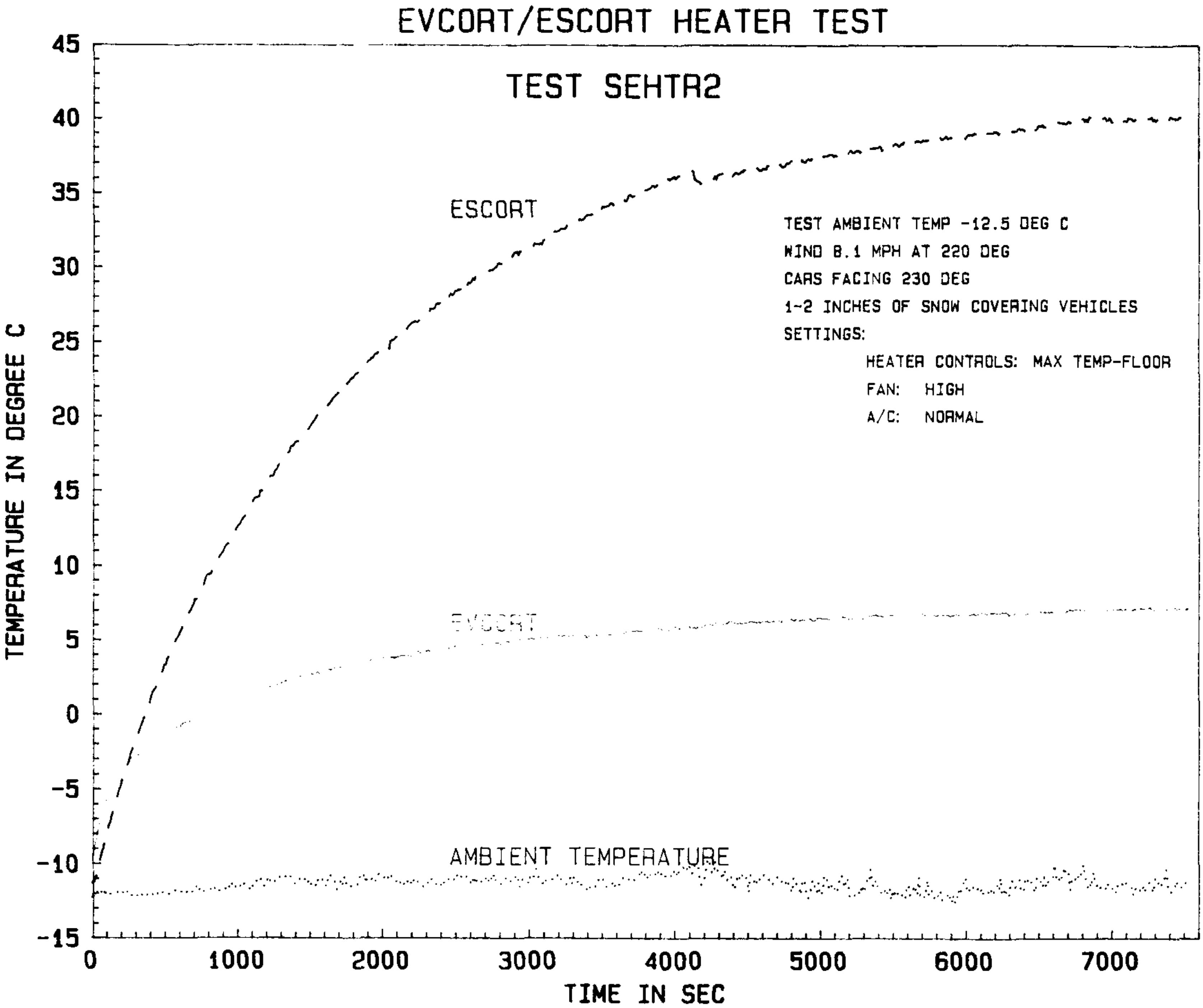
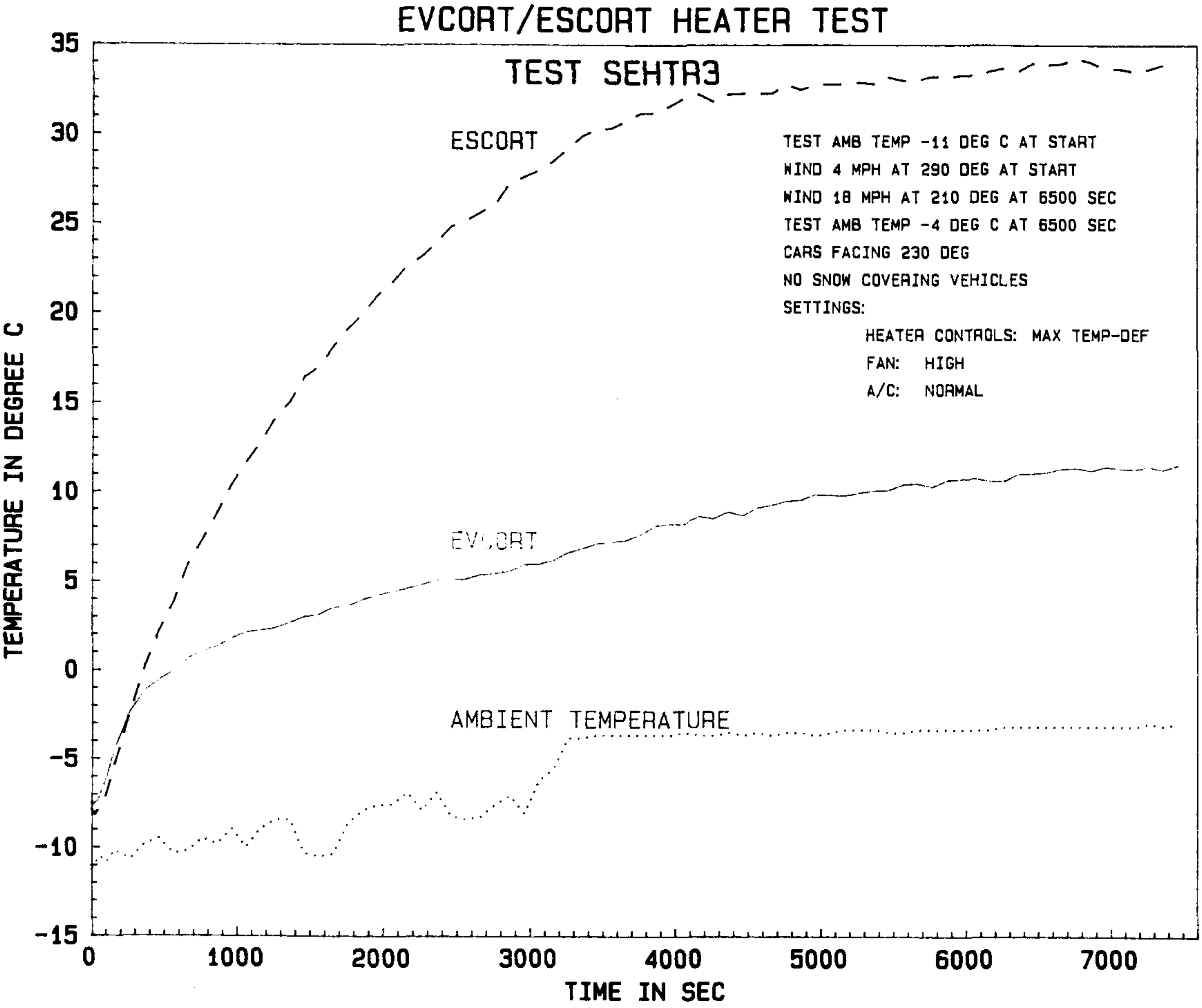
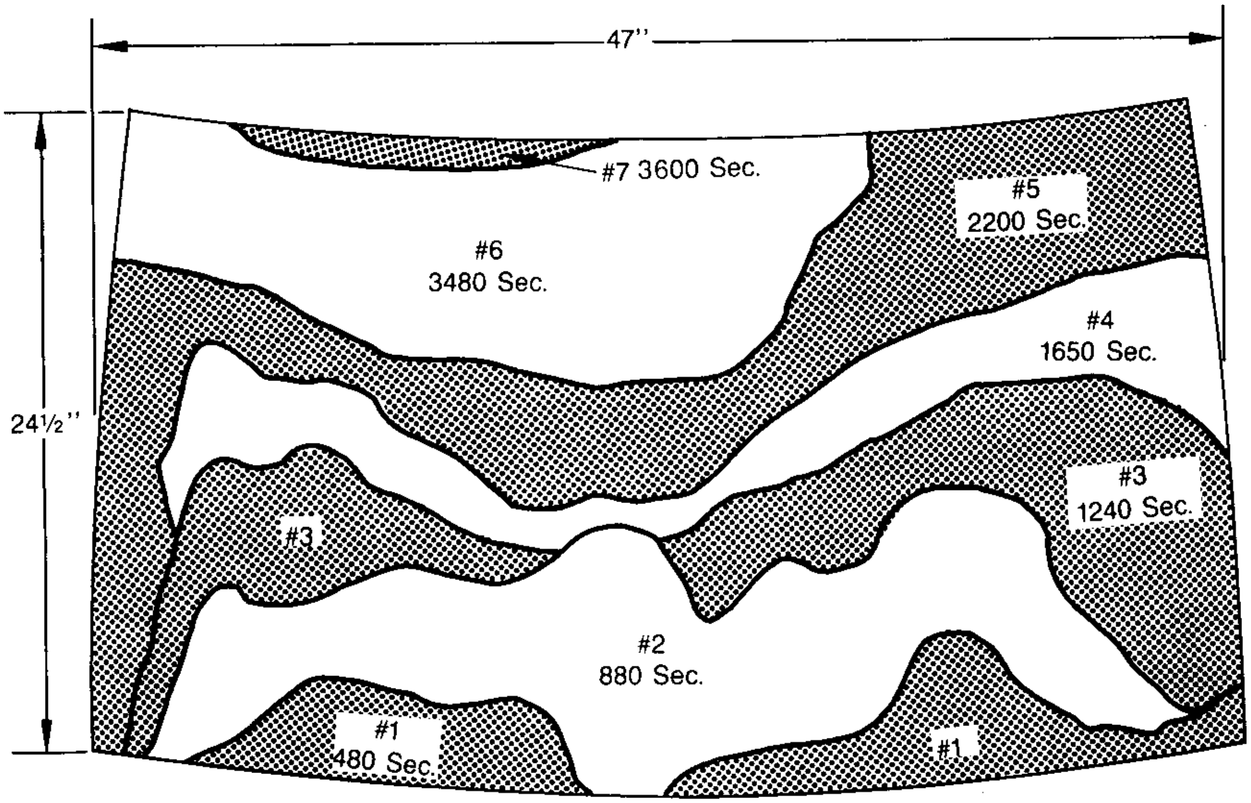


Figure 25. Evcort/Escort Heater Test (SEHTR2)



TEST AMB TEMP -11 DEG C AT START
WIND 4 MPH AT 290 DEG AT START
WIND 18 MPH AT 210 DEG AT 6500 SEC
TEST AMB TEMP -4 DEG C AT 6500 SEC
CARS FACING 230 DEG
NO SNOW COVERING VEHICLES
SETTINGS:
HEATER CONTROLS: MAX TEMP-DEF
FAN: HIGH
A/C: NORMAL

Figure 26. Evcort/Escort Heater Test (SEHTR3)



WINDSHIELD DEFROSTING PROFILE

Date 1-9-89
SOLEQ EVCORT Electric Vehicle
Heater/defroster test (SEHTR3)

9-6698

Figure 27. Electric Vehicle Windshield Defrosting Profile.

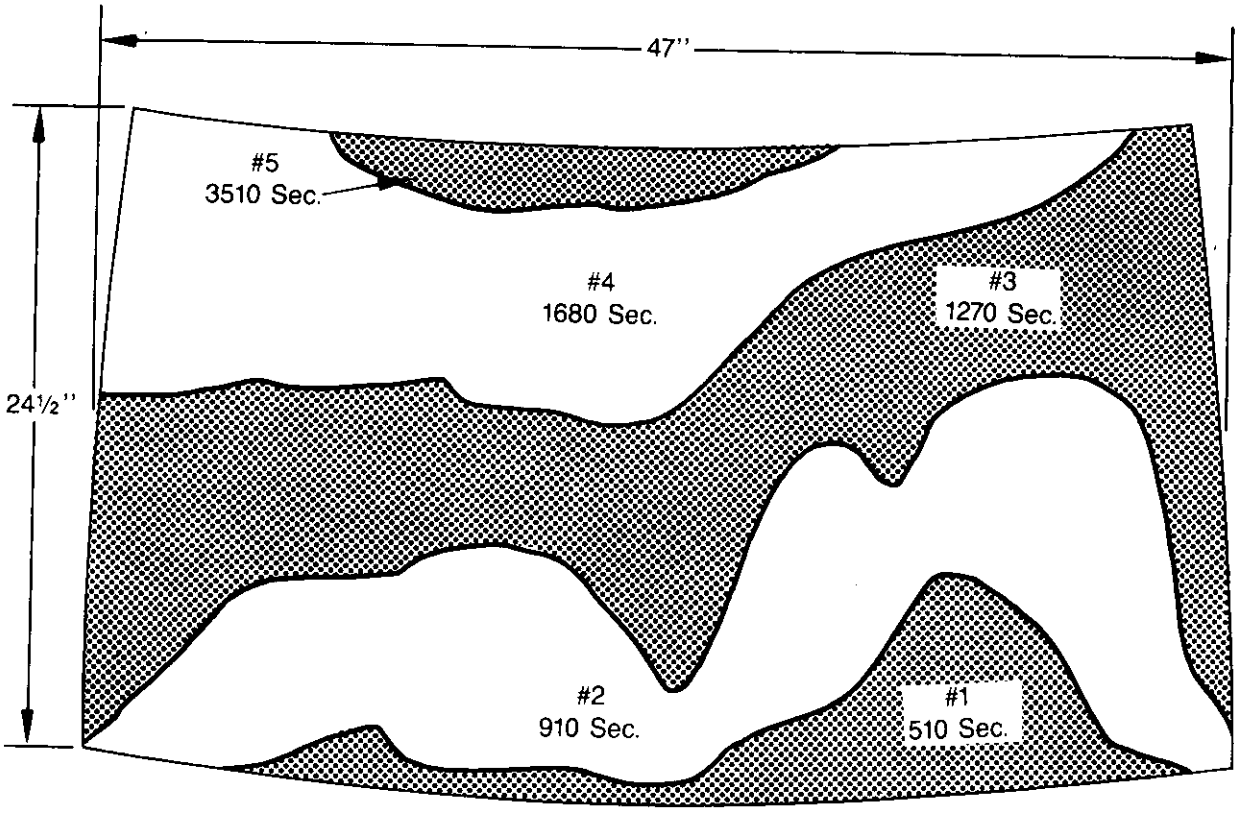


Figure 28. Internal Combustion Engine Vehicle Windshield Defrosting Profile.

7. COMPARISONS WITH OTHER VEHICLES AND BATTERIES

7.1 Introduction

The previous sections of this report were concerned with the characteristics and performance of the Soleq Evcort and the Concorde GP 6250 batteries. In this section, the Evcort and GP 6250 battery are compared with other vehicles and batteries tested in the Dynamometer and Battery Test Laboratories at the INEL in the last several years.

7.2 Comparison with Other Lead-acid Batteries

A number of lead-acid batteries have been tested in the INEL Battery Test Laboratory. These include the three Johnson Control Gel/Cell batteries-Phase 3, Phase 4, and the GC2, the ALCO 2200, the Chloride EV5T and HED85 (ETX-I), and the Concorde GP 6180. The Ragone curves of those batteries are compared with the Ragone curve of the Concorde GP 6250 battery in Figure 29. The Ragone Curve shown for the GP 6250 is that for the battery in the "new" condition. On a per unit mass basis, Figure 29 indicates that the capacities of the Concorde GP 6250 and Gp 6180 batteries are essentially the same and that the Concorde batteries in their "new" condition have the best performance of the sealed batteries available. The ETX-I battery has the best capacity performance of the lead-acid batteries tested at INEL, but that battery is a flooded plate design and hence, is not maintenance free. All the lead-acid batteries have comparable capacity performance, so battery selection is likely to be based primarily on battery life and initial cost. Unfortunately none of the sealed batteries tested to date at the INEL have exhibited long life potential.

The voltage-current characteristics of several lead-acid batteries are shown in Figure 30. The discharge current has been normalized by the discharge current at the 2hr rate in order to compare the characteristics of batteries with significantly different cell Ah capacities.

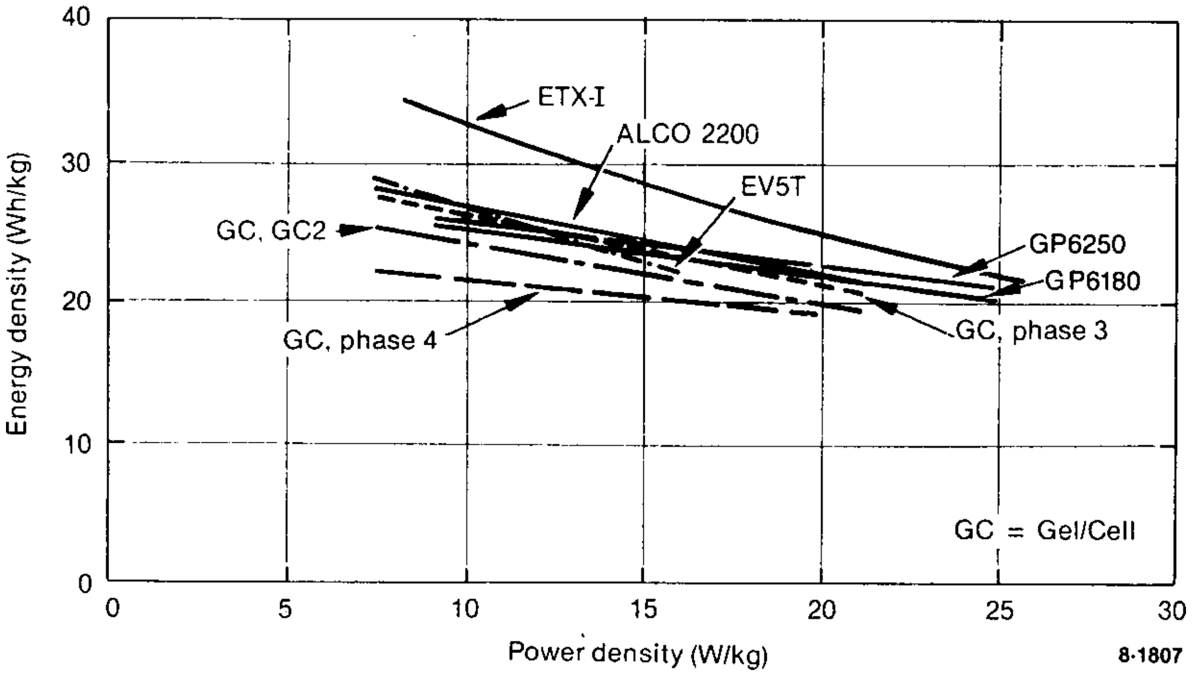


Figure 29. Ragone curves for various lead-acid batteries.

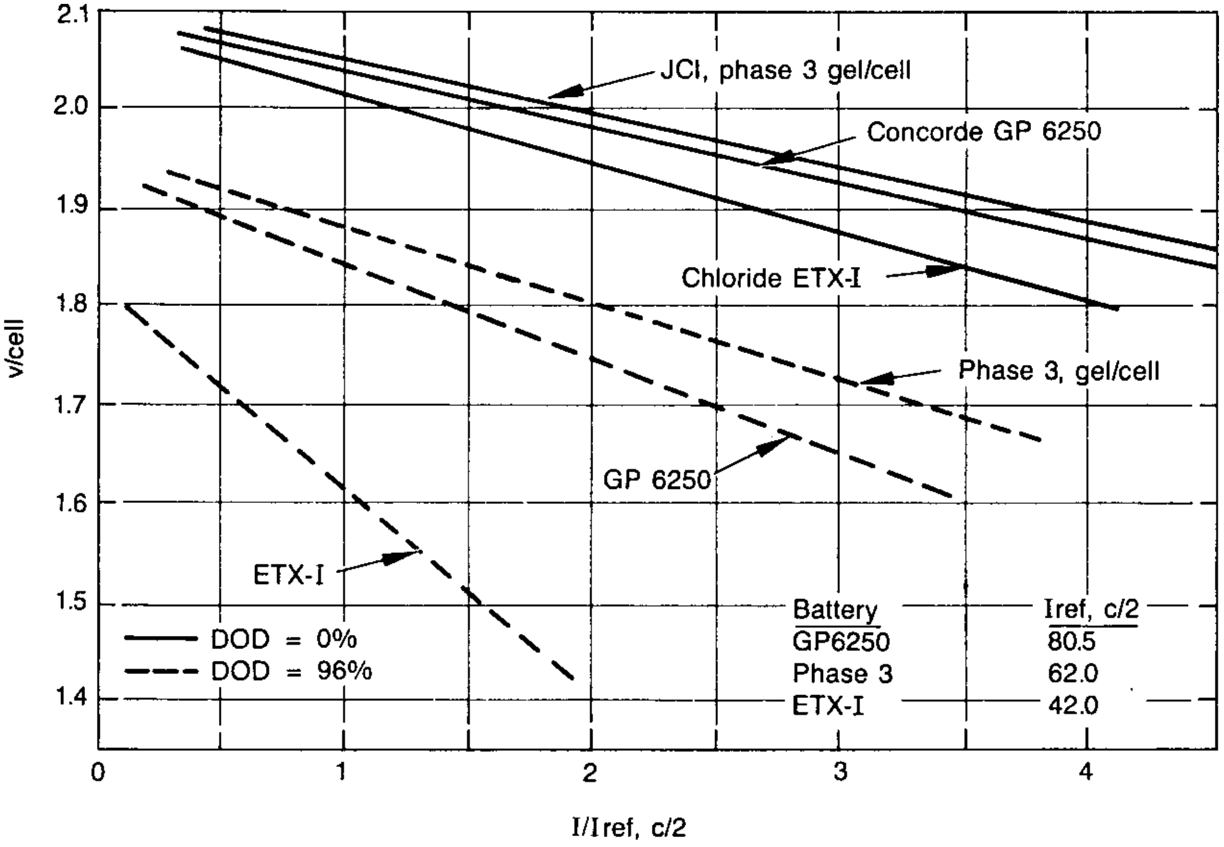


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Figure 30. Comparison of the V vs I Charateristics of Several Lead-Acid Batteries

Figure 30 indicates that at 100% SOC, the effective internal resistance of the GP 6250, Phase 3 Gel/cell, and ETX-I batteries are essentially equal; however, at near complete discharge, the sealed batteries have much lower resistance than the ETX-I battery. The flooded batteries, such as the ALCO 2200 and the Chloride EV5T and ETX-I batteries, show higher capacity than the sealed batteries at low discharge rates (W/kg<10), but their capacity decreases more rapidly at the higher discharge rates (W/kg>15).

7.3 Comparison with Other Vehicles

The Evcort is compared with other electric vehicles tested at the INEL in Table 14. The table shows the physical characteristics of the vehicles as well as various performance parameters,including energy consumption, range and acceleration times. The data given in Table 14 show that the performance of the Evcort compares favorably with all the electric vehicles tested at the INEL when one takes into account the relatively the high test weight of the vehicle. Calculation of the system efficiency (battery output to the wheels) from the constant speed energy consumption data indicate the efficiency of the Evcort is 84% at 88 km/h and 65% at 48 km/h. As shown in Figure 31, these efficiencies are very close to those measured at INEL and JPL for the ETV-1, which is often used as the benchmark for driveline efficiency comparisons. The range of the Evcort is relatively long compared to most of the other electric vehicles tested at the INEL due both to its high battery fraction of .34 and its low energy consumption per unit vehicle weight. The acceleration times for the Evcort are comparable to those of the highest performance electric vehicles tested, which is somewhat surprising when one considers that its weight is about 15% greater than most of the other vehicles.

TABLE 14 INEL ELECTRIC VEHICLE TESTING SUMMARY

VEHICLE SPECIFICATIONS			
Vehicle Designation	Bedford Van	Eaton AC-3	Eaton DC
Weight (kg)			
Test	3490	1641	1723
Curb [a]	2658	1352	1588
Gross Veh. [b]	3500	c	c
Rolling Resistance Coeff. (kg/kg)	0.0104	0.0098	0.0098
Frontal Area (m^2)	3.35	1.84	1.84
Aero Drag Coeff. (C_D)	0.47	0.43	0.43
Drag Area Product- C_DA (m^2)	1.57	.79	.79
Power-to-weight ratio (W/kg) [d]	12	21	17
Motor	dc	ac	dc
Peak Power (kW)	40	33.6	29.8
Maximum Speed (rpm)	6000	12,500	4500
Transmission	single-speed	two-speed	three-speed
BATTERY SPECIFICATION			
Manufacturer	Lucas Chloride (EV5T)	Sears Die Hard	ALCO 2200
Type	Tubular Lead Acid (36 x 6 V)	Lead Acid (16 x 12 V)	Lead Acid (18 x 6 V)
Weight (kg)	1134	385	545
Battery Mass Fraction	0.32	0.23	0.32
VEHICLE PERFORMANCE DATA			
Acceleration (s)			
0-48 km/h	11.6	11.2	12.5
0-80 km/h	64.8	22.0	36.4
0-88 km/h	-	28.5	47.5
Energy Consumption (Wh/km)			
48 km/h (vehicle net dc)	183	* -	-
72 km/h (vehicle net dc)	233	159	145
C-Cycle (vehicle net dc)	299	179	-
D-Cycle (vehicle net dc)	311	188	241
FUD-Cycle (vehicle net dc)	313	192	-
Range (km)			
48 km/h	182	[e] -	-
72 km/h	109	[e] -	79
C-Cycle	97	[e] -	-
D-Cycle	82	55.5	41
FUD-Cycle	77 [f]	[e] -	-
Gradeability (@ 32 km/h)	11%	18%	14%

---

a. Based on weighing the vehicle.

b. Assigned by developer/manufacturer.

c. Means no weight assigned because vehicle was a test bed.

d. Propulsion System Peak Power-to-weight (vehicle ratio).

e. Only minimal range data taken because of the use of marine batteries in place of EV batteries.

f. Best Effort.

TABLE 14 INEL ELECTRIC VEHICLE TESTING SUMMARY (Cont.)

VEHICLE SPECIFICATIONS			
Vehicle Designation	Chrysler/GE ETV-1	Ford/GE ETX-I	Evcort
Weight (kg)			
Test	1723	1705	1968
Curb [a]	1522	1566	1836
Gross Veh.[b]	1822	c	c
Rolling Resistance Coeff. (kg/kg)	0.0095	0.0097	0.011
Frontal Area (m^2)	1.84	1.78	1.90
Aero Drag Coeff. (C_D)	0.32	0.42	0.42
Drag Area Product- C_DA (m^2)	0.59	0.75	0.79
Power-to-weight ratio (W/kg)[d]	17	25	16
Motor	dc	ac	dc
Peak Power (kW)	30	43	32
Maximum Speed (rpm)	5000	9000	6000
Transmission	single-speed	two-speed	five-speed
BATTERY SPECIFICATION			
Manufacturer	JCI Phase 3 Gel/Cell	Lucas Chloride	Concorde
Type	Lead Acid (18 x 6 V)	Tubular Lead Acid (16 x 12 V)	Sealed Lead Acid (18 x 6 V)
Weight (kg)	539	520	672
Battery Mass Fraction	0.31	0.31	0.34
VEHICLE PERFORMANCE DATA			
Acceleration (s)			
0-48 km/h	10.4	7.4	8.3
0-80 km/h	23.6	21.3	25.6
0-88 km/h	28.8	29.8	32.5
Energy Consumption (Wh/km)			
48 km/h (vehicle net dc)	94	129	119
72 km/h (vehicle net dc)	108	140	144
C-Cycle (vehicle net dc)	163	201	201
D-Cycle (vehicle net dc)	154	181	-
FUD-Cycle (vehicle net dc)	174	208	212
Range (km)			
48 km/h	172	128	154
72 km/h	126	92	108
C-Cycle	85	65	75
D-Cycle	82	58	-
FUD-Cycle	75	60	68
Gradeability (@ 32 km/h)	18%	25%	17%

---

a. Based on weighing the vehicle.

b. Assigned by developer/manufacturer.

c. Means no weight assigned because vehicle was a test bed.

d. Propulsion System Peak Power-to-weight (vehicle ratio).

e. Only minimal range data taken because of the use of marine batteries in place of EV batteries.

f. Best Effort.

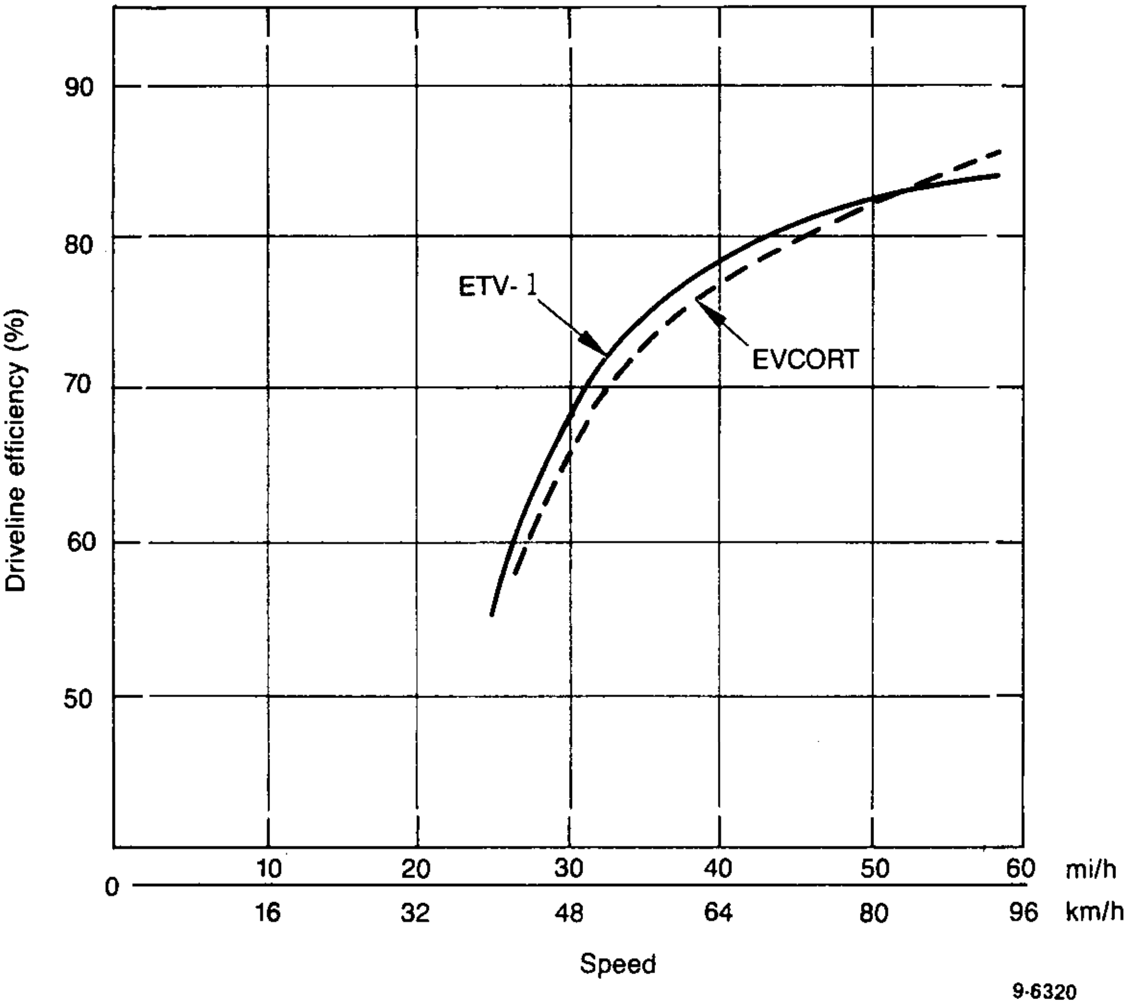

Figure 31. Driveline Efficiency of the Soleq Evcort and ETV-1 at Various Constant Speed Conditions

8. CONCLUSIONS

The following statements concerning the Evcort and its air-conditioner and heater/defroster systems and the Concorde GP 6250 battery summarize the test results discussed in the previous sections:

(1) The driveability of the Evcort is in general excellent in that it functioned smoothly and reliably at constant speeds up to 88 km/h (55 mi/h) and on the FUDS driving cycle; some oscillations in vehicle speed can be experienced during periods of coasting regeneration and gear shifting at high power demand.

(2) The energy consumption (DC battery out) of the Evcort is good for a vehicle of its weight being 119 Wh/km at 48 km/h, 160 Wh/km at 88 km/h, and 212 Wh/km on the FUDS driving cycle; the corresponding wall-plug AC energy consumptions using the Concorde GP 6250 battery and the on-board battery charger are 172 Wh/km, 227 Wh/km, and 313 Wh/km, respectively.

(3) The range of the Evcort is 154 km at 48 km/h, 77 km at 88 km/h, and 68 km on the FUDS driving cycle.

(4) The acceleration times of the Evcort with a fully charged battery are 8.3 s for 0-48 km/h, 25.6 s for 0-80 km/h, and 32.5 s for 0-88 km/h; these are good acceleration times for vehicle having a test weight of 1968 kg.

(5) The Ragone curve for the Concorde GP 6250 battery in its "new" condition was very close to that of the GP 6180 battery previously tested at the INEL; the capacity of the GP 6250 declined by 15-30% over the 35 cycles of the present test program; there seems to be no reason to select the new, heavier GP 6250 battery in place of the GP 6180 battery in that the older model has the same capacity per unit weight and longer demonstrated life.

(6) The effect of operating the air-conditioner in the Evcort is to increase the energy consumption by 25% at 48 km/h, 11% at 88 km/h, and 27% on the FUDS driving cycle; the corresponding reductions in vehicle range are 22%,10%, and 17%, respectively.

(7) The power consumption of the air-conditioner was about 1.5 kW in the dynamometer tests; in outdoor tests of the air-conditioner in Phoenix, Arizona at an ambient temperature of 34^{o}C (94^{o}F), the cool-down time to 26^{o}C (80^{o}F) from an initial temperature of 48^{o}C (118^{o}F) inside the vehicle was 24 minutes with the Evcort stationary and 20 minutes when the vehicle was moving at 56 km/h; the corresponding values for an ICE Escort were 17 minutes and 14 minutes, respectively.

(8) The 2kW heater/defroster in the Evcort was evaluated in outdoor tests in Idaho Falls, Idaho during the winter with an ambient temperature of -12^{o}C (15^{o}F); the heat-up time to 0^{o}C (32^{o}F) with the heater operating was 10-12 minutes in the Evcort and 5-6 minutes in the ICE Escort; the time require to defrost 50% of the windshield was 27 minutes in the Evcort and 18 minutes in the ICE Escort.

(9) The Evcort compared favorably with other electric vehicles tested at the INEL in terms of energy consumption, range, and acceleration; the performance characteristics of the Concorde GP 6250 battery on a unit weight basis were comparable to other sealed lead-acid batteries tested at INEL, but its cycle life was extremely short (less than 50 cycles).

9. REFERENCES

1. Soleq Evcort Operating and Maintenance Manual.

2. S. Ohba, The Development of an EV Air Conditioner and Controls, Soleq Corporation 1988.

3. Idaho National Engineering Laboratory (INEL) Electric and Hybrid Vehicle Program Test Procedures.

4. R. L. Crumley, INEL Electric Vehicle Laboratory Qualification: Transition Test Results and Comparisons with JPL ETV-1 Data, EGG-SE-6743, November 1984.

5. J. R. Venhuizen, Techniques to Analyze Vehicle Coastdown Data, EGG-ED-6725, April 1985 (Revision 1).

6. Society of Automotive Engineers Electric Vehicle Test Procedure-SAE J227; Recommended Practice, May 8, 1986.

APPENDIX A
DYNAMOMETER INSTRUMENTATION LIST

APPENDIX A. Soleq Evcort Instrumentation List

Measurement	Symbol	Range	Estimated Accuracy	Upper Cut-Off Frequency	Sensor Location	Description
Battery Temperature	TBAT1	0-100	±1C°	0.5 Hz (Computer)	Battery Module	24-30 gauge ungrounded TC, ice point reference junction (Type E)
Battery Temperature	TBAT2	0-150	±1C°	0.5 Hz (Computer)	Battery Module	24-30 gauge ungrounded TC, ice point reference junction (Type E)
Battery Temperature	TBAT3	0-150	±1C°	0.5 Hz (Computer)	Battery Module	24-30 gauge ungrounded TC, ice point reference junction (Type E)
Battery Temperature	TBAT4	0-150	±1C°	0.5 Hz (Computer)	Battery Module	24-30 gauge ungrounded TC, ice point reference junction (Type E)
Electric Motor Temperature	TEM1	0-100	±1C°	0.5 Hz (Computer)	Electric Motor	24-30 gauge ungrounded TC, ice point reference junction (Type E)
Transaxle Temperature	TRCS	0-100	±1C°	0.5 Hz (Computer)	Transmission	24-30 gauge ungrounded TC, ice point reference junction (Type E)
Ambient Temperature	TAMB	0-100	±1C°	0.5 Hz (Computer)	Dyno Room	24-30 gauge ungrounded TC, ice point reference junction (Type E)
Battery Voltage	BV	0-300V	±1/2% FS	5 Hz (PMI Box)	Vehicle	JPL PMI Box Card #1
Battery Amps	BA	0-500A	±1/2% FS	5 Hz (PMI Box)	Vehicle	500 Amp shunt, JPL PMI Box Card #1
Dyno Torque	DT	0-3580 n	±1/2% FS	5 Hz (Computer)	Dyno	Daytronics Power Supply and Signal Conditioning
Dyno Idle Roll	DIR	0-3000 rpm	±0.5 rpm	--	Dyno	Digital Encoder Accumulator
Dyno Load Roll	LDSPD	0-150 km/h	±0.161 km/h	5 Hz (Computer)	Dyno	Clayton System Controller

Measurement	Symbol	Range	Estimated Accuracy	Upper Cut-Off Frequency	Sensor Location	Description
Auxillary Battery Voltage	AUXBV	0 - 20 V	±0.5%	5 Hz (PMI)	Vehicle	JPL PMI: CARD 5
Auxillary Battery Current	AUXBI	0 - 50 A	±0.5%	5 Hz (PMI)	Vehicle	JPL PMI: CARD 5
Energy Out of Battery Power Out of Battery	EBOD PBOD	0 - 50 kWh 0 - 150 kWh	±0.5 kWh ±1.6 kWh	50 kHz (PMI Box)	Vehicle	500-A Shunt, JPL PMI Card #1
Energy Into Battery Power Into Battery	EBI PBI	0 - 50 kWh 0 - 90 kWh	±1/2 kWh ±1.6 kW	50 kHz (PMI Box)	Vehicle	500-A Shunt, JPL PMI Card #1, Energy is a function of total pulse count
Total Ah out Battery	ABO	0 - 500 kWh	±1/2% FS	50 kHz (PMI Box)	Vehicle	500-A Shunt, JPL PMI Card #2 Voltage input set at 10 V. Charge is a function of total pulse count.
Total Ah into Battery (Regenerative)	ABI	0 - 500 kAh	±1.0% FS	50 kHz (PMI Box)	Vehicle	500-A Shunt, JPL PMI Card #2, Voltage input set at 10 V. Charge is function of total pulse count.
Power out of Battery	PBO	0 - 100 kW	±1% FS	50 kHz (PMI Box)	Vehicle	500-A shunt, JPL PMI Card #1. Average power is software calculate
Power Into Battery	PBI	0 - 100 kW	±1/0% FS	50 kHz (PMI Box)	Vehicle	500-A shunt, JPL PMI Card #1. Average power is software calculate

APPENDIX A. Soleq Evcort Instrumentation List (Cont.)

Measurement	Symbol	Range	Accuracy	Upper Cut-Off Frequency	Sensor Location	Description
Energy out of Auxillary Battery	EAUXB	0 - 10 kW	±1.0% FS	50 kHz (PMI Box)	Vehicle	50-A shunt, JPL PMI Card #5. Energy Function of total puls
Power out of Auxillary Battery	PAUXB	0 - 1 kW	±1.0% FS	50 kHz (PMI Box)	Vehicle	50-A shunt, JPL PMI Card #5. Average power software calcul
Distance	DIST	0 - 322 km	±1/2% FS	--	Idle Roll	Digital encoder
Cycles Driven	--	--	--	--	--	Computer calculated
Elapsed Time	--	--	--	--	--	Computer generated
kph	--	--	--	--	--	Computer calculated
Battery Recharge Amps	BAR	0 - 50A	±1/2% FS	5 kHz	Vehicle	JPL PMI Card
Battery Recharge Energy	EBIR	0 - 500 kWh	±1.0% FS	50 kHz	Vehicle	JPL PMI Card
Battery Recharge Power	PBIR	0 - 15 kW	±1.0% FS	--	Vehicle	JPL PMI Card
Battery Recharge Ah	ABIR	0 - 500 Ah	±1.0% FS	50 kHz	Vehicle	JPL PMI Card
Energy Battery Recharge (ac wall power)	EBCI	0 - 500 Ah	TBD	50 kHz	Charger	JPL PMI Card
Battery Recharge Volts	BVR	0 - 300V	±1.0% FS	5 Hz	Vehicle	JPL PMI Card

Measurement	Symbol	Range	Estimated Accuracy	Upper Cut-Off Frequency	Sensor Location	Description
Inverter Input Voltage	IV	200 V	±0.5%	5 Hz	Inverter Input	
Inverter Input Current	IA	50 A	±0.5%	5 Hz	Inverter Input	50 Amp Coaxial Shunt
Inverter Input Power	PII	10 kW	±0.5%	50 kHz		
Inverter Input Energy	EII	50 kW	±0.5%	50 kHz		
Fan Motor Voltage	FMV	20 V	±0.5%	5 Hz	Fan Motor Input	
Fan Motor Current	FMA	25 A	±0.5%	5 Hz	Fan Motor Input	50 Amp Cooxial Shunt
Fan Motor Power	PFMI	500 W	±1.0%	50 kHz		
Fan Motor Energy	EFMI	5 kWh	±1.0%	50 kHz		
Motor Arm. Voltage	MAV	200 V	±0.5%	5 Hz	Controller Output	
Motor Arm. Current	MAI	500 A	±0.5%	5 Hz	Controller Output	500 Amp Cooxial Shunt
Motor Arm. Power Input	PMAI	100 kW	±1.0%	50 kHz		
Motor Arm. Power Out	PMAO	100 kW	±1.0%	50 kHz		
Motor Arm. Energy Input	EMAI	150 kWh	±1.0%	50 kHz		
Motor Arm. Energy Out	EMAO	150 kWh	±1.0%	50 kHz		
Motor Field Voltage	MFV	200 V	±0.5%	5 Hz	Controller Output	
Motor Field Current	MFA	25 A	±0.5%	5 Hz	Controller Output	50 Amp Cooxial Shunt
Motor Field Power Input	PMFI	5 kW	±1.0%	50 kHz		
Motor Field Power Out	PMFO	5 kW	±1.0%	50 kHz		
Motor Field Energy Input	EMFI	50 kWh	±1.0%	50 kHz		
Motor Field Energy Out	EMFO	50 kWh	±1.0%	50 kHz		

APPENDIX B
DYNAMOMETER COASTDOWN METHODS

ROAD LOAD FORCE RELATIONS

Laboratory vehicle performance testing utilizing a chassis dynamometer requires that the dynamometer be set up to accurately reproduce the road load characteristics of the vehicle obtained from track coastdown tests. A computerized method of analyzing road coastdown data and extracting the rolling resistance and aerodynamic drag coefficients to be used for matching the road load to the dynamometer load on vehicles has been developed at the INEL.[a] The INEL technique uses a least-squares parameter estimation technique to determine the rolling resistance and aerodynamic drag coefficients from velocity versus time data taken during the track coastdown. The technique also normalizes the data to standard conditions and compensates for track elevation variations.

The simplified force equation describing the coastdown motion (assuming no wind, grade, or aerodynamic lift) is given by

$$\text{Force} = M \frac{dV}{dt} = -C_{RR} W - \frac{1}{2} A{*}c_d{*}\rho V^2 = -(C_0 + C_1 V) W - \frac{1}{2} A{*}c_d{*}\rho V^2 \qquad \text{(A-1)}$$

where

M = effective vehicle mass (includes rotating mass)
C_{RR} = tire rolling resistance
W = vehicle weight
A = vehicle frontal area
C_D = aerodynamic drag coefficient
V = vehicle speed
ρ = air density.

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[a] Techniques to Analyze Vehicle Coastdown Data by J. R. Venhuizen, EGG-ED-6725, April 1985

Values for C_0, C_1, and C_D can be determined from the track coastdown data using a least-squares fitting technique. The vehicle mass, air density, and vehicle frontal area are determined separately and are input data to the estimation program.

Experience has shown that the fitting process converges most rapidly and reliably if C_1 is set equal to zero. This is not necessary, but otherwise one can experience an interaction between C_1 and C_D, which results in an unrealistically low value for C_D.

In Equation (A-1), the rolling resistance C_{RR} W is broken into two parts, namely C_0W and C_1VW where C_0W is the frictional force independent of velocity and C_1VW is the frictional force dependent on velocity. The aerodynamic force is given by 1/2 CD*A*ρ V2. Once the coefficients are determined, the rolling resistance horsepower and the aerodynamic horsepower are easily evaluated at any desired velocity and environmental condition.

DYNAMOMETER ROAD LOAD MATCHING

At the INEL, a twin roll Clayton Model DC-80 chassis dynamometer is used for vehicle testing. The dynamometer consists of several components including a fixed "trim" flywheel and a number of declutchable rotating disks which allow the operator to set a rotational inertia equivalent to the linear inertia of a test vehicle to within 56.7 kg (125 lb). The power absorption unit is a direct current motor capable of providing a wide range of motoring or absorbing torques at various speeds. The microprocessor controlled system controller has the capability of electrically compensating the rotational inertia to match the exact weight of the test vehicle and to set up the dc-80 system to simulate the road load of the vehicle by inputting the rolling resistance and aerodynamic coefficients from the computer terminal.

To perform the vehicle road load simulation, the dynamometer is designed to solve the force equation and is written

$$F = A + BV + CV^{n} \qquad \text{(A-2)}$$

where

F = force at the surface of the rolls
V = velocity at the surface of the rolls
A = tire frictional force coefficient independent of velocity
B = tire frictional force dependent on velocity
C = windage(aerodynamic) force coefficient of velocity
n = velocity exponent (adjustable from 1.0 to 3.0).

This form of the equation has combined the constants from the coastdown analysis with the input constants

$A = C0\ W$
$B = C1\ W$
$C = C_D\ (1/2\ A\rho)$.

SET UP STEPS

This procedure uses a similar technique to that used to calculate the vehicle road loads during coastdown testing. It is based on the assumption that the velocity/time profile desired for coastdown of the vehicle mounted on the dynamometer is known. The coastdown program used to calculate the vehicle loads on the dynamometer is the same program used to calculate the road loads on the track.

Step 1

Remove vehicle half axles and disk brakes

Step 2

Warm-up the dyno and vehicle for 30 min at 80 km/h (50 mph). The A, B, and C coefficients in the force equation are set equal zero during warmup. The road load horsepower required to maintain 80 km/h (50 mph) is recorded(this is the roll and tire friction).

Step 3

The aerodynamic drag coefficient (C_D) from the road coastdown is set into the force equation ($C=C_D$) along with the exponential velocity value of 2.0.

Step 4

The vehicle is coasted down from 96 to 16 km/h (60 to 10 mph) with the velocity/time data being recorded on the laboratory data acquisition system.

Step 5

Data from Step 4 is analyzed to get the "effective" vehicle road load on the dyno. This procedure yields the effective coefficients in the following equation:

$$F = (A_D - A_E) + (B_D - B_E) V + C_D V^2$$

where the subscript D represents the desired coefficient and the subscript E the effective coefficient. The difference between the desired and effective coefficients becomes the settings for the dynamometer

$A = AD - AE$

$B = BD - BE$

$C = CD = 1/2\ (C_DA)$

Step 6

The coastdown is repeated with the dynamometer coefficients set equal to A, B, and C of Step 5.

(NOTE: Before each coastdown, the vehicle is warmed up to match the original friction load horsepower readings recorded in Step 2.)

Step 7

The difference between the new set of effective coefficients and the desired coefficients is added to the dyno coefficients and the process repeated. Usually three to four iterations are sufficient to determine the A and B coefficients such that the coastdown time from 96.5 to 16 km/h (60 to 10 mph), 88 to 72 km/h (55 to 45 mph), and 32 to 16 km/h (20 to 10 mph) match the track (target) coastdown times to within one second or less. If the systematic iterative procedure cited to determine A and B does not converge in 4 to 5 interations, a trial-and-error approach is used in which small changes are made in A, B, and C to affect final convergence to the desired accuracy in matching the coast-down curve.

The above matching technique results in a dynamometer coastdown curve for which the sum of squares of the differences in the velocities between the track and dynamometer curves is less than 1.00 using 100 to 150 time points in the coastdown.

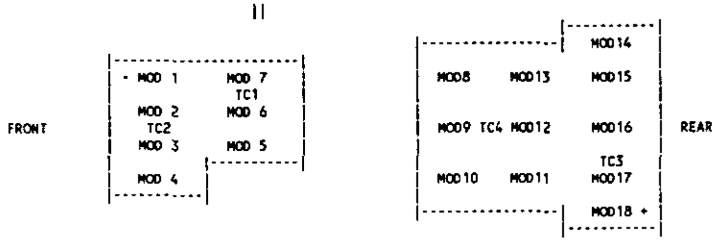
APPENDIX C
BATTERY TEST DATA
SUMMARY TABLES

TOTAL SUMMARY BATTERY DATA SHEET PACK NO.36 APS EVA CONCORDE 6250

	DISCHARGE									CHARGE									
	DATE	DR (A,P,F)	ABOD (Ah)	EBOD (KWH)	DCV* (VOLTS)	EDT (AVG.)	MAX.TEMP. (C)	TTD	X SPGR (g/cc)	DATE	ABIR (Ah)	EBIR (KWH)	CC (amps)	% CHARGE	ECT (AVG.)	MAX.TEMP. (°C)	TTOC	X SPGR (g/cc)	NOTES
Cycle 1	10/20/88	55.00	110.08	11.85	94.5	25.72	26.54	1H 57M	SEALED	10/20/88	122.40	14.90	2.45	111	28.43	30.71	10H 35M	SEALED	MOD.3 TO 3.2 V AT 120 MIN. REPLACED AFTER CH
Cycle 2	10/21/88	55.10	143.28	15.32	94.5	26.45	27.79	2H 36M	---	10/21/88	159.00	19.32	2.49	111	24.97	28.12	13H 30M	---	CHG #' ARE APPROX. DUE TO POWER OUTAGE
Cycle 3	10/22/88	55.50	166.51	17.68	94.5	26.68	27.91	3H 00M	---	10/22/88	182.17	22.01	2.72	109	25.46	28.53	15H 10M	---	DIS #2 MOD.16 TO 4.3 AT 156 MIN.REPLACED AFT
Cycle 4	10/23/88	55.26	168.55	17.95	94.5	26.08	27.48	3H 03M	---	10/23/88	186.99	22.66	2.76	111	25.66	28.80	15H 40M	---	
Cycle 5	10/24/88	77.16	159.47	16.90	94.5	27.38	28.85	2H 04M	---	10/24/88	176.73	21.38	2.79	111	28.16	31.70	14H 35M	---	
Cycle 6	10/25/88	76.98	159.09	16.84	94.5	25.93	26.68	2H 04M	---	10/25/88	173.35	20.98	2.68	109	27.35	30.66	13H 50M	---	
Cycle 7	10/26/88	134.59	157.02	16.04	70.2	29.85	30.88	1H 10M	---	10/26/88	167.63	20.33	2.58	107	24.47	25.56	13H 45M	---	
Cycle 8	10/27/88	135.52	155.85	16.03	70.2	30.40	32.10	1H 09M	---	10/27/88	169.14	20.51	2.59	108	26.04	27.49	13H 45M	---	
Cycle 9	10/28/88	54.99	170.46	18.26	94.5	22.25	26.12	3H 06M	---	10/28/88	184.96	22.28	2.70	109	27.10	28.86	14H 35M	---	
Cycle 10	10/31/88	54.69	169.52	18.07	94.5	23.04	23.80	3H 03M	---	10/31/88	185.10	22.34	2.73	109	26.12	27.92	14H 40M	---	
Cycle 11	11/16/88		162.62	18.12	94.5	28.70	28.70	3H 09M	---	11/17/88	190.27	22.94	2.78	117	31.30	31.30	14H 00M	---	
Cycle 12	11/21/88		132.02	13.58	94.5	29.10	29.10	56M	---	11/22/88	175.02	21.67	2.88	133	31.90	31.90	15H 40M	---	
Cycle 13	11/22/88		154.76	16.99	87.0	34.20	34.20	3H 07M	---	11/23/88	233.72	28.80	3.00	151	33.40	33.40	19H 35M	---	
Cycle 14	11/28/88		162.28	16.41	87.0	33.30	33.30	2H 42M	---	11/29/88	221.42	27.35	1.58	136	31.40	31.40	17H 39M	---	
Cycle 15	11/29/88		189.65	18.21	94.5	22.40	22.40	2H 45M	---	11/30/88	NO DATA	21.53	NO DATA	NO DATA	NO DATA	NO DATA	NO DATA	---	ALL RECHARGE DATA FROM COUNTERS. NO LOAS DA
Cycle 16	11/30/88		182.89	17.84	94.5	28.70	28.70	2H 30M	---	12/01/88	184.35	22.30	1.45	101	28.70	28.70	13H 45M	---	
Cycle 17	12/01/88		158.92	16.56	94.5	32.00	32.00	2H 21M	---	12/02/88	193.95	23.90	3.00	122	31.60	31.60	14H 10M	---	
Cycle 18	12/02/88		167.94	16.25	87.0	33.80	33.80	2H 35M	---	12/03/88	181.35	21.96	3.15	108	34.10	34.10	13H 55M	---	
Cycle 19	12/05/88		189.46	18.35	94.5	27.50	27.50	3H 18M	---	12/06/88	198.33	24.40	2.30	105	30.70	30.70	15H 10M	---	ABOD DATA IS QUESTIONABLE
Cycle 20	12/06/88		101.22	10.86	N/A	N/A	N/A	1H 42M	---	12/07/88	151.36	19.01	2.28	150	34.30	34.30	13H 50M	---	ABORTED TEST
Cycle 21	12/07/88		159.72	16.76	94.5	32.00	32.00	2H 31M	---	12/08/88	184.58	22.30	2.98	116	29.90	29.90	14H 20M	---	
Cycle 22	12/08/88		154.41	15.92	94.5	32.80	32.80	3H 02M	---	12/09/88	177.32	21.45	2.85	115	30.60	30.60	14H 00M	---	
Cycle 23	12/09/88		151.23	15.43	87.0	33.60	33.60	3H 08M	---	12/10/88	168.57	20.29	2.45	111	31.90	31.90	13H 05M	---	
Cycle 24	12/12/88		149.82	16.01	94.5	28.80	28.80	2H 25M	---	12/13/88	182.82	22.16	3.35	122	34.00	34.00	15H 45M	---	
Cycle 25	12/13/88		120.70	12.52	94.5	33.40	33.40	50M	---	12/14/88	141.01	17.15	3.33	117	28.60	28.60	11H 35M	---	
Cycle 26	12/14/88		137.24	14.15	87.0	30.70	30.70	2H 43M	---	12/15/88	196.07	24.01	5.43	143	37.30	37.30	18H 18M	---	
Cycle 27	12/15/88		119.47	12.45	94.5	31.50	31.50	54M	---	12/16/88	175.76	21.60	5.48	147	36.70	36.70	16H 12M	---	
Cycle 28	12/16/88		116.60	12.02	94.5	30.80	30.80	52M	---	12/17/88	160.91	19.67	3.45	138	35.00	35.00	17H 30M	---	
Cycle 29	12/19/88		131.88	13.21	87.0	28.20	28.20	2H 50M	---	12/20/88	144.41	17.39	1.93	109	29.00	29.00	11H 25M	---	
Cycle 30	01/12/89		119.68	12.25	87.0	30.90	30.90	2H 18M	---	01/12/89	134.16	16.09	2.10	112	29.20	29.20	10H 42M	---	
Cycle 31	01/13/89		110.49	11.34	87.0	28.80	28.80	1H 38M	---	01/13/89	123.99	14.95	2.08	112	29.60	29.60	10H 06M	---	
Cycle 32	01/18/89	54.16	121.86	12.84	94.5	25.46	26.31	2H 15M	---	01/18/89	136.02	16.19	3.22	112	31.46	34.14	11H 15M	---	
Cycle 33	01/19/89	54.03	118.88	12.54	94.5	24.52	25.60	2H 12M	---	01/19/89	154.20	18.52	3.26	130	32.40	34.74	16H 00M	---	
Cycle 34	01/20/89	53.95	115.99	12.24	94.5	24.60	25.36	2H 09M	---	01/20/89	131.56	15.69	2.89	113	32.83	34.12	11H 05M	---	
Cycle 35																			
Cycle 36																			
Cycle 37																			
Cycle 38																			
Cycle 39																			
Cycle 40																			
Cycle 41																			
Cycle 42																			

TOTAL SUMMARY BATTERY DATA SHEET PACK NO.36 APS EVA CONCORDE 6250

	DISCHARGE									CHARGE									
	DATE	DR (A,P,F)	ABOD (Ah)	EBOD (KWH)	DCV* (VOLTS)	EDT (AVG.)	MAX.TEMP. (C)	TTD	X SPGR (g/cc)	DATE	ABIR (Ah)	EBIR (KWH)	CC (amps)	% CHARGE	ECT (AVG.)	MAX.TEMP. (°C)	TTOC	X SPGR (g/cc)	NOTES
Cycle 43																			
Cycle 44																			
Cycle 45																			
Cycle 46																			
Cycle 47																			
Cycle 48																			
Cycle 49																			
Cycle 50																			
Cycle 51																			
Cycle 52																			
Cycle 53																			
Cycle 54																			
Cycle 55																			
Cycle 56																			



NOTES. 1. ALL CHARGES WERE DONE WITH THE ON BOARD CHARGER.

Acronyms:	
ABOD	Amps Battery Out Discharge
EBOD	Energy Battery Out Discharge
EDT	Avg. Ending Discharge Temperature
DR	Discharge (A-Amps, P-Power Kw, F-FUDS Cycle)
DCV	Discharge Cutoff Voltage (* varies due to time interval spacing)
TTD	Total Time of Discharge
ABIR	Amps Battery In Recharge
EBIR	Energy Battery In Recharge
CC	End of Charge Current
ECT	Avg. Ending Charge Temperature
TTOC	Total Time of Charge

TOTAL SUMMARY BATTERY DATA SHEET PACK NO. 35 CONCORDE GP6250

	DISCHARGE									CHARGE								
	DATE	DR (A,P,F)	ABOD (Ah)	EBOD (KWH)	DCV* (VOLTS)	EDT (AVG.)	MAX.TEMP. (C)	TTD	% RATED CAPACITY	DATE	ABIR (Ah)	EBIR (KWH)	CC (amps)	% CHARGE	ECT (AVG.)	MAX.TEMP. (°C)	TTOC	NOTES
Cycle 1	10/13/88	73.38	143.08	19.82	126.0	23.65	25.90	1H 57M	---	10/13/88	176.69	28.80	1.81	123	22.95	24.50	16H 35M	
Cycle 2	10/17/88	47.06	171.89	24.00	126.0	22.34	24.31	3H 46M	---	10/17/88	201.27	32.59	1.81	117	24.16	25.67	16H 20M	
Cycle 3	10/18/88	55.01	171.41	24.21	126.0	23.77	25.81	3H 08M	---	10/18/88	197.09	31.94	1.65	115	23.00	24.69	16H 25M	
Cycle 4	10/19/88	54.96	170.38	24.24	126.0	22.94	24.70	3H 06M	---	10/19/88	189.85	30.67	1.45	111	22.98	24.63	15H 35M	
Cycle 5	10/20/88	55.27	171.35	24.42	126.0	22.88	23.99	3H 06M	---	10/20/88	191.13	30.88	1.45	112	22.84	24.63	16H 10M	MODS. 23 & 24 WERE REMOVED FROM PACK AFTER CYCLE 5 CHARG
Cycle 6	10/26/88	54.90	167.46	21.72	115.5	23.52	23.98	3H 03M	---	10/26/88	199.09	29.60	1.39	118	23.05	26.22	16H 40M	
Cycle 7	10/27/88	77.88	161.61	20.92	115.5	24.24	25.41	2H 06M	---	10/27/88	186.51	27.83	1.35	115	23.08	26.32	15H 35M	
Cycle 8	10/28/88	77.95	161.09	20.92	115.5	24.04	25.07	2H 06M	---	10/28/88	176.91	26.34	1.74	110	22.99	26.19	11H 05M	
Cycle 9	10/31/88	78.12	158.83	20.53	115.5	24.07	25.08	2H 02M	---	10/31/88	177.00	26.37	1.77	111	23.08	26.77	10H 50M	AVG. CAP. AT 2 HR. RATE (78A) 160.51 AH
Cycle 10	11/01/88	136.13	156.55	19.62	85.8	25.07	26.53	1H 09M	---	11/01/88	173.48	25.96	1.52	111	23.10	25.55	12H 05M	
Cycle 11	11/02/88	141.88	153.71	19.35	85.8	24.89	26.45	1H 05M	---	11/02/88	168.48	25.20	1.97	110	22.86	25.42	10H 05M	
Cycle 12	11/03/88	141.82	153.64	19.37	85.8	25.10	26.38	1H 05M	---	11/03/88	168.52	25.21	1.85	110	22.80	25.32	9H 50M	AVG. CAP. AT 1 HR. RATE (142A) 154.63 AH
Cycle 13	11/08/88	53.74	171.98	22.44	115.5	23.52	24.40	3H 12M	---	11/08/88	187.06	28.87	2.00	109	23.83	25.96	10H 00M	
Cycle 14	11/09/88	55.14	173.68	22.68	115.5	23.57	24.31	3H 09M	---	11/09/88	188.52	27.90	2.17	109	22.93	26.10	9H 40M	
Cycle 15	11/10/88	55.03	173.35	22.67	115.5	23.53	24.03	3H 09M	---	11/10/88	NO DATA -- COMPUTER FAILURE							AVG. CAP. AT 3 HR. RATE (55A) 173 AH
Cycle 16	11/14/88	6.74W/KG	175.14	22.94	115.5	23.36	23.84	4H 03M	---	11/14/88	194.17	28.78	2.13	111	23.15	26.73	11H 30M	CYCLES 16 THRU 21 CONSTANT POWER DISCHARGES WERE RUN
Cycle 17	11/15/88	6.76W/KG	177.14	23.28	115.5	23.32	23.80	4H 06M	---	11/15/88	193.14	28.65	2.15	109	23.10	26.36	11H 00M	WITH NORMALIZER, IT WAS NOT FAST ENOUGH TO KEEP UP
Cycle 18	11/16/88	19.60W/KG	141.59	18.13	115.5	24.44	25.83	1H 06M	---	11/16/88	155.80	23.33	1.76	110	23.16	26.39	9H 15M	WITH POWER DEMANDS.
Cycle 19	11/17/88	19.49W/KG	151.23	19.10	85.8	24.74	25.98	1H 10M	---	11/17/88	166.22	24.82	2.16	110	23.23	26.80	10H 00M	
Cycle 20	11/18/88	19.48W/KG	150.99	19.11	85.8	24.81	26.16	1H 10M	---	11/18/88	166.05	24.80	2.09	110	22.96	25.25	9H 35M	
Cycle 21	11/21/88	38.19W/KG	124.02	14.75	85.8	25.78	27.59	27M	---	11/21/88	136.18	20.44	2.76	110	23.55	26.23	6H 40M	
Cycle 22	11/28/88	42W/KG	116.46	13.80	85.8	26.03	27.96	23.5M	---	11/28/88	126.20	18.91	2.92	108	23.64	25.76	5H 45M	
Cycle 23	11/29/88	42W/KG	115.41	13.79	85.8	27.18	28.77	23.5M	---	11/29/88	126.62	18.96	2.79	110	23.61	25.58	5H 55M	AVG. CAP. AT 42 W/KG CONSTANT POWER, 115.935 AH
Cycle 24	11/30/88	21W/KG	138.94	17.45	85.8	24.64	25.65	59M	---	11/30/88	154.02	22.98	2.75	111	23.63	26.35	7H 40M	
Cycle 25	12/01/88	21W/KG	143.73	18.03	85.8	24.65	25.76	61M	---	12/01/88	153.36	22.82	3.57	107	23.84	27.19	6H 15M	AVG. CAP. AT 21 W/KG CONSTANT POWER, 141.335 AH
Cycle 26	12/05/88	SFUD 79	147.40	---	94.2	24.53	25.42	2H 21M	---	12/05/88	166.84	24.81	2.98	113	23.91	27.30	8H 45M	ON DISCHG.WRONG PWR LEVELS WERE USED
Cycle 27	12/14/88	SFUD 79	162.21	20.02	85.8	24.55	25.43	3H 16M	---	12/14/88	166.66	24.69	3.50	103	24.15	27.10	7H 35M	SIMULATOR EPROM PROBLEM, LOST SOME DATA DUE TO DISC FULL
Cycle 28	12/16/88	SFUD 79	167.25	20.71	85.8	23.94	26.33	3H 06M	---	12/16/88	186.79	28.00	3.12	111	24.33	27.65	14H 50M	ESTIMATED RANGE ON IDSEP 72.96 KM
Cycle 29	12/20/88	SFUD 79	162.84	20.21	85.8	25.00	27.09	2H 58M	---	12/20/88	184.09	27.56	2.85	113	22.88	27.20	15H 35M	ESTIMATED RANGE ON IDSEP 70.67 KM
Cycle 30	01/04/89	60W/KG	90.87	0.92	7.8	29.48	30.39	11M 55S	---	01/04/89	99.95	---	---	110	28.34	28.35	---	MODS. 1 & 2 ONLY - LOST END OF CHARGE DATA
Cycle 31	01/09/89	60W/KG	88.52	0.90	7.8	30.71	31.93	11M 53S	---	01/11/89	CHARGED MODS. 1 & 2 WITH MODS. 3 THRU 7							DISCHARGE MODS. 1 & 2 ONLY
Cycle 31	01/10/89	60W/KG	85.24	2.12	19.5	29.87	34.99	11M 24S	---	01/11/89	103.39	4.99	4.58	118	26.13	28.63	5H 24M	DISCHARGE MODS. 3 THRU 7, CHARGE MODS. 1 THRU 7
Cycle 32	01/12/89	60W/KG	85.45	2.15	19.5	31.87	36.67	11M 36S	---	01/12/89	92.24	3.14	4.74	108	25.62	27.15	3H 45M	THIS CYCLE MODULES 3 THRU 7 ONLY
Cycle 33	01/13/89	53.88	142.79	18.51	115.5	24.72	25.91	2H 39M	---	01/13/89	158.62	23.43	4.37	111	25.19	27.27	6H 35M	
Cycle 34	01/16/89	55.00	147.26	18.98	105.0	24.48	25.80	2H 46M	---	01/16/89	163.90	24.19	4.69	111	24.22	26.65	6H 40M	MODS 21 & 22 REMOVED AT 162 MINUTES
Cycle 35	01/23/89	53.75	142.42	15.94	99.7	24.39	25.33	2H 39M	---	01/23/89	166.21	21.27	4.66	117	24.93	26.71	7H 30M	MODS 7, 21 & 22 REMOVED FOR LOW CAPACITY
Cycle 36	01/24/89	53.81	142.60	15.98	99.7	24.59	25.24	2H 39M	---	01/24/89	158.52	20.26	5.21	111	24.94	26.40	6H 25M	
Cycle 37																		
Cycle 38																		
Cycle 39																		
Cycle 40																		
Cycle 41																		
Cycle 42																		
Cycle 43																		
Cycle 44																		
Cycle 45																		
Cycle 46																		
Cycle 47																		
Cycle 48																		
Cycle 49																		

APPENDIX D
DYNAMOMETER TEST
SUMMARY TABLES

Equations used to calculate vehicle and battery performance as provided in the dynamometer test summary tables (Appendix D):

$$\text{AC Energy Consumption} = \frac{\text{AC Energy into Charger}}{\text{Distance Traveled}}$$

$$\text{Vehicle DC Energy Cons. (Gross)} = \frac{\text{TB Energy Out} + \text{Aux Bat Energy Out}}{\text{Distance Traveled}}$$

$$\text{Vehicle DC Energy Cons. (Net)} = \frac{\text{TB Energy Out} - \text{TB Energy Regen} + \text{Aux Bat Energy Out}}{\text{Distance Traveled}}$$

$${}^{*}\text{TB Energy Recharge Efficiency} = \frac{\text{TB Energy Out} - \text{TB Energy Regen}}{\text{Charger Output Energy}}\ (100\%)$$

$$\text{TB Coulombic Recharge Efficiency} = \frac{\text{TB Amp h Out} - \text{TB Amp h Regen}}{\text{Recharge Amp Hours}}\ (100\%)$$

$$\text{Wall AC Efficiency} = \frac{\text{TB Energy Out} - \text{TB Energy Regen} + \text{Aux Bat Energy Out}}{\text{Charger AC Energy Input}}\ (100\%)$$

$$\text{Air Conditioner Energy} = \text{Energy into Inverter} + \text{Blower Fan Energy}$$

$$\text{Charger Efficiency} = \frac{\text{DC Energy Out of Charger}}{\text{AC Energy into Charger}}\ (100\%)$$

$$\text{Auxiliary Battery Energy Consumption} = \frac{\text{Aux Battery Energy}}{\text{Distance Traveled}}$$

$$\text{TB Specific Energy Gross} = \frac{\text{TB Energy Out}}{672\ \text{kg}}$$

$$\text{TB Specific Energy Net} = \frac{\text{TB Energy Out} - \text{TB Energy In}}{672\ \text{kg}}$$

$$\text{TB Spec Power Gross} = \frac{\text{TB Energy Out}}{\text{Time (h)} \times 672\ \text{kg}}$$

$$\text{TB Spec Power Net} = \frac{\text{TB Energy Out} - \text{TB Energy In}}{\text{Time (h)} \times 672\ \text{kg}}$$

$$\text{Controller Efficiency} = \frac{{}^{**}\text{En Motor Field} + \text{En Motor Arm} + \text{En into DC/DC Conv.}}{\text{Traction Batt Energy Out} - \text{Invert Energy Input}}\ (100\%)$$

*TB is traction battery
**En is energy

INEL SOLEQ EVCORT TESTING

	C-CYCLE A/C OFF	C-CYCLE A/C ON	C-CYCLE HEATER ON	CON SPD 48KM/HR A/C OFF	CON SPD 48KM/HR A/C ON	CON SPD 88KM/HR A/C OFF
RANGE KILOMETERS						
RANGE-KM	74.8	60.9	40.9	154.3	119.7	76.6
SYS ENGY CONS WH/KM						
AC EN CONS. Wh/Km	341.3	439.6	412.8	171.6	207.5	299.3
SYS DC EN CONS Wh/Km	306.0	392.6	365.9	153.6	186.2	269.1
VEH DC EN CONS WH/KM						
VEH DC EN CONS GROSS	213.7	283.0	286.9	118.5	149.0	159.9
VEH DC EN CON NET WH/KM	200.9	272.2	277.1	118.5	148.9	159.4
BAT EFFICIENCY PERCENT						
BAT ENER RECH. EFF %	66.5	69.2	75.7	77.1	79.9	59.3
BAT COUL. RECH EFF %	78.4	81.8	88.9	90.4	99.1	69.8
COMPONENT EFF PERCENT						
CONTRLR EFF-RUN %	96.3	95.1	96.8	95.3	95.7	97.4
CHARGER EFF. %	89.6	89.3	88.6	89.4	89.7	89.9
WALL-AC-EFF. %	59.6	61.9	67.1	68.9	71.7	53.3
BAT SPEC ENERGY WH/KG						
BAT SPEC. EN. GR.-WH/KG	23.8	25.6	17.4	27.1	26.5	18.2
BAT SPEC. EN. NET-WH/KG	22.3	24.6	16.8	27.1	26.5	18.2
BAT SPEC POWER W/KG						
BAT SPEC. POWR GR.-W/KG	8.2	10.9	11.0	8.4	10.6	20.7
BAT SPEC. PWR-NET W/KG	7.7	10.4	10.6	8.4	10.6	20.6

INEL SOLEQ EVCORT TESTING

	CON SPD 88KM/HR A/C ON	FUDS A/C OFF	FUDS A/C ON
RANGE KILOMETERS			
RANGE-KM	70.5	67.6	60.2
SYS ENGY CONS WH/KM			
AC EN CONS. Wh/Km	254.7	312.8	407.5
SYS DC EN CONS Wh/Km	243.1	278.3	364.3
VEH DC EN CONS WH/KM			
VEH DC EN CONS GROSS	178.7	225.8	281.4
VEH DC EN CON NET WH/KM	177.6	211.5	269.7
BAT EFFICIENCY PERCENT			
BAT ENER RECH. EFF %	73.0	75.9	74.0
BAT COUL. RECH EFF %	85.6	90.4	92.5
COMPONENT EFF PERCENT			
CONTRLR EFF-RUN %	97.4	NO AVG.	NO AVG.
CHARGER EFF. %	95.4	88.9	89.4
WALL-AC-EFF. %	69.7	67.6	66.2
BAT SPEC ENERGY WH/KG			
BAT SPEC. EN. GR.-WH/KG	18.7	22.7	25.2
BAT SPEC. EN. NET-WH/KG	18.6	21.3	24.1
BAT SPEC POWER W/KG			
BAT SPEC. POWR GR.-W/KG	22.4	7.6	9.7
BAT SPEC. PWR-NET W/KG	22.2	7.1	9.3

TEST DATA SUMMARY

FOR VEHICLE ID: EVCORT

TEST NUMBER	SED481	SED482	SED483	SED881	SED882
VALID TEST	Y	Y	Y	N	Y
TEST TYPE	CON SPD 48KM/HR A/C OFF	CON SPD 46KM/HR A/C ON	CON SPD 48KM/HR A/C OFF	CON SPD 88KM/HR A/C OFF	CON SPD 88KM/HR A/C ON
TEST DATE	11/16/88	11/30/88	12/05/88	11/21/88	12/13/88
BATTERY CYCLE NO.	11.00	16.00	19.00	12.00	25.00
TERMINAL VOLTAGE	94.00	94.00	94.00	94.00	94.00
RANGE-KM	150.41	119.78	158.18	81.47	70.54
TEST TIME-MIN	188.86	149.84	198.06	56.13	50.17
NUMBER OF CYCLES	0.00	1.00	1.00	1.00	1.00
AC EN CONS. Wh/Km	171.00	207.55	172.34	296.67	254.75
SYS DC EN CONS Wh/Km	153.00	186.26	154.32	266.23	243.12
VEH DC EN CONS GROSS	121.00	149.02	116.13	166.69	178.76
VEH DC EN CON NET WH/KM	121.00	148.94	116.07	166.69	177.63
BATT DISCH. EN. Kwh	18.13	17.85	18.37	13.58	12.60
BATT REGEN. EN. Kwh	0.01	0.01	0.01	0.00	0.08
BAT DISCH AMP HRS.	162.75	183.02	189.69	132.03	121.36
BATT REGEN. AMP HRS.	0.13	0.12	0.23	0.01	0.66
AVE BAT TMP TST-STRT-C	24.30	23.25	22.63	21.60	26.20
AVE BAT TMP TST-END C	28.70	28.69	27.55	29.06	33.37
RECH. ENERGY DC Kwh	22.94	22.31	24.41	21.69	17.15
RECH. ENERGY AC Kwh	25.69	24.86	27.26	24.17	17.97
RECH. AMPERAGE Ah	190.27	184.51	198.43	175.33	141.01
BAT ENER RECH. EFF %	79.00	79.96	75.22	62.61	73.00
BAT COUL. RECH EFF %	85.50	99.13	95.48	75.30	85.60
RECHARGE TIME Min.	840.00	825.00	910.00	950.00	695.00
AVE BAT TMP RECH-STRT C	28.70	28.86	27.39	29.10	32.52
AVE BAT TMP RECH-END C	31.30	25.79	30.23	28.65	23.17
WALL-AC-EFF. %	70.50	71.76	67.35	56.19	69.73
AUX BAT EN. DISCH. KWH	0.00	0.00	0.00	0.00	0.01
AUX BAT EN. CHG. KWH	0.00	0.01	0.01	0.01	0.00
AIR COND ENERGY KWH	0.01	3.81	0.02	0.00	1.05
NOT USED	0.00	0.00	0.00	0.00	0.00
NOT USED	0.00	0.00	0.00	0.00	0.00
CHARGER EFF. %	89.30	89.74	89.55	89.74	95.44
AUX BAT CONS. Wh/KM	0.00	0.00	0.00	0.00	0.14
BAT SPEC. EN. GR.-WH/KG	26.98	26.56	27.34	20.21	18.75
BAT SPEC. EN. NET-WH/KG	26.97	26.55	27.32	20.21	18.63
BAT SPEC. POWR GR.-W/KG	8.57	10.64	8.28	21.60	22.42
BAT SPEC. PWR-NET W/KG	8.57	10.63	8.28	21.60	22.28
CONTRLR EFF-RUN %	96.60	95.70	94.10	97.80	97.40
NOT USED	0.00	0.00	0.00	0.00	0.00
NOT USED	0.00	0.00	0.00	0.00	0.00

*** NOTES ***

SED481 : DATA HAND ENTERED FROM RAW TEST DATA RESULTS. 2ND GEAR
SED482 : 2ND GEAR AIR COND ON
SED483 : 2ND GEAR---- AMP HRS DISCHARGED FROM BAT QUESTIONABLE--LOOSE CONNECTON
SED881 : 4TH GEAR
SED882 : 3 RD GEAR A/C ON

TEST DATA SUMMARY

FOR VEHICLE ID: EVCORT

TEST NUMBER	SED883	SED884	SEDAC1	SEDAC2	SEDAC3
VALID TEST	Y	Y	Y	Y	Y
TEST TYPE	CON SPD 88KM/HR A/C OFF	CON SPD 88KM/HR A/C OFF	ACCEL A/C OFF	ACCEL A/C ON	ACCEL A/C OFF
TEST DATE	12/15/88	12/16/88	11/29/88	12/07/88	12/12/88
BATTERY CYCLE NO.	27.00	28.00	15.00	21.00	24.00
TERMINAL VOLTAGE	94.00	94.00	88.00	94.00	94.00
RANGE-KM	78.09	75.29	138.47	128.27	125.92
TEST TIME-MIN	53.93	51.88	164.69	150.53	144.83
NUMBER OF CYCLES	1.00	1.00	1.00	1.00	1.00
AC EN CONS. Wh/Km	308.23	290.48	0.00	194.51	196.71
SYS DC EN CONS Wh/Km	276.86	261.52	0.00	173.93	175.98
VEH DC EN CONS GROSS	159.94	159.91	131.65	133.23	127.14
VEH DC EN CON NET WH/KM	159.30	159.65	129.70	130.66	125.40
BATT DISCH. EN. Kwh	12.49	12.04	18.23	17.09	16.01
BATT REGEN. EN. Kwh	0.05	0.02	0.27	0.33	0.22
BAT DISCH AMP HRS.	119.90	115.79	191.40	162.50	151.69
BATT REGEN. AMP HRS.	0.42	0.19	1.75	2.78	1.86
AVE BAT TMP TST-STRT-C	24.72	24.19	23.70	23.66	21.93
AVE BAT TMP TST-END C	31.46	30.81	30.65	31.95	28.90
RECH. ENERGY DC Kwh	21.62	19.69	0.00	22.31	22.16
RECH. ENERGY AC Kwh	24.07	21.87	0.00	24.95	24.77
RECH. AMPERAGE Ah	175.90	161.09	0.00	184.69	182.82
BAT ENER RECH. EFF %	57.54	61.05	0.00	75.12	71.25
BAT COUL. RECH EFF %	67.92	71.76	0.00	86.48	81.95
RECHARGE TIME Min.	984.20	1055.00	0.00	865.00	945.00
AVE BAT TMP RECH-STRT C	32.07	29.86	0.00	31.26	25.37
AVE BAT TMP RECH-END C	37.27	34.67	0.00	29.30	30.64
WALL-AC-EFF. %	51.68	54.96	0.00	67.17	63.75
AUX BAT EN. DISCH. KWH	0.00	0.00	0.00	0.00	0.00
AUX BAT EN. CHG. KWH	0.01	0.01	0.00	0.01	0.01
AIR COND ENERGY KWH	0.00	0.00	0.00	0.44	0.00
NOT USED	0.00	0.00	0.00	0.00	0.00
NOT USED	0.00	0.00	0.00	0.00	0.00
CHARGER EFF. %	89.82	90.03	0.00	89.42	89.46
AUX BAT CONS. Wh/KM	0.00	0.00	0.00	0.00	0.00
BAT SPEC. EN. GR.-WH/KG	18.59	17.92	27.13	25.43	23.82
BAT SPEC. EN. NET-WH/KG	18.51	17.89	26.73	24.94	23.50
BAT SPEC. POWR GR.-W/KG	20.68	20.72	9.88	10.14	9.87
BAT SPEC. PWR-NET W/KG	20.60	20.69	9.74	9.94	9.73
CONTRLR EFF-RUN %	97.80	97.00	96.90	95.80	96.60
NOT USED	0.00	0.00	0.00	0.00	0.00
NOT USED	0.00	0.00	0.00	0.00	0.00

*** NOTES ***

SED883 : 3RD GEAR
SED884 : 3RD GEAR
SEDAC1 : NO RECHARGE DATA-POWER FAILED NO 20% SOC DATA SHIFT 2-3 DURING ACCEL
SEDAC2 : 2ND-3RD GEAR A/C ON DURING ACCELERATIONS
SEDAC3 : SHIFT 2-3RD AT 72 KM/HR

TEST DATA SUMMARY

FOR VEHICLE ID: EVCORT

TEST NUMBER	SEDC01	SEDC02	SEDC03	SEDC04	SEDC05
VALID TEST	N	Y	Y	Y	N
TEST TYPE	C-CYCLE A/C OFF	C-CYCLE A/C ON	C-CYCLE A/C OFF	C-CYCLE A/C OFF	C-CYCLE A/C OFF
TEST DATE	11/28/88	12/01/88	12/08/88	12/14/88	01/12/89
BATTERY CYCLE NO.	14.00	17.00	22.00	26.00	30.00
TERMINAL VOLTAGE	88.00	88.00	88.00	88.00	88.00
RANGE-KM	69.59	60.94	78.84	70.76	59.80
TEST TIME-MIN	161.92	140.98	181.97	163.22	138.11
NUMBER OF CYCLES	122.00	106.00	137.00	123.00	104.00
AC EN CONS. Wh/Km	439.14	439.61	304.41	378.18	304.18
SYS DC EN CONS Wh/Km	393.02	392.68	272.07	340.02	269.23
VEH DC EN CONS GROSS	235.81	283.07	214.99	212.55	217.39
VEH DC EN CON NET WH/KM	235.67	272.23	201.93	199.97	205.02
BATT DISCH. EN. Kwh	16.41	17.22	16.95	15.04	13.00
BATT REGEN. EN. Kwh	0.01	0.66	1.03	0.89	0.74
BAT DISCH AMP HRS.	162.32	164.65	163.31	144.88	126.16
BATT REGEN. AMP HRS.	0.04	5.72	8.90	7.65	6.48
AVE BAT TMP TST-STRT-C	23.04	23.21	23.78	22.79	23.41
AVE BAT TMP TST-END C	33.28	31.83	31.83	30.69	30.85
RECH. ENERGY DC Kwh	27.35	23.93	21.45	24.06	16.10
RECH. ENERGY AC Kwh	30.56	26.79	24.00	26.76	18.19
RECH. AMPERAGE Ah	221.42	194.17	177.37	196.48	134.29
BAT ENER RECH. EFF %	59.96	69.20	74.22	58.81	76.15
BAT COUL. RECH EFF %	73.29	81.85	87.06	69.84	89.12
RECHARGE TIME Min.	1059.10	850.00	935.03	1107.83	640.00
AVE BAT TMP RECH-STRT C	31.46	31.05	30.36	0.00	29.55
AVE BAT TMP RECH-END C	31.37	30.03	28.28	37.83	22.63
WALL-AC-EFF. %	53.66	61.93	66.33	52.88	67.40
AUX BAT EN. DISCH. KWH	0.00	0.03	0.00	0.00	0.00
AUX BAT EN. CHG. KWH	0.01	0.01	0.01	0.01	0.01
AIR COND ENERGY KWH	0.00	3.54	0.00	0.00	0.00
NOT USED	0.00	0.00	0.00	0.00	0.00
NOT USED	0.00	0.00	0.00	0.00	0.00
CHARGER EFF. %	89.50	89.32	89.38	89.91	88.51
AUX BAT CONS. Wh/KM	0.00	0.49	0.00	0.00	0.00
BAT SPEC. EN. GR.-WH/KG	24.42	25.63	25.22	22.38	19.35
BAT SPEC. EN. NET-WH/KG	24.40	24.64	23.69	21.06	18.24
BAT SPEC. POWR GR.-W/KG	9.05	10.91	8.32	8.23	8.40
BAT SPEC. PWR-NET W/KG	9.04	10.49	7.81	7.74	7.93
CONTRLR EFF-RUN %	93.90	95.10	96.40	96.20	96.60
NOT USED	0.00	0.00	0.00	0.00	0.00
NOT USED	0.00	0.00	0.00	0.00	0.00

*** NOTES ***

SEDC01 : RAN IN 3RD GEAR VEHICLE OPERATON ERRATIC AFTER WARM UP
SEDC02 : 2ND GEAR VEHICLE ERRATIC AFTER WARMUP A/C ON
SEDC03 : 2ND GEAR CAR RUNNING ROUGH DURING MIDDLE PORTION OF TEST
SEDC04 : 2ND GEAR VEHICLE OPERATION STILL ERRATIC AFTER FIRST 1000 SEC
SEDC05 : NEW CONTROLLER S/N 1265 RAN IN 2ND GEAR

TEST DATA SUMMARY

FOR VEHICLE ID: EVCORT

TEST NUMBER	SEDC06	SEDF01	SEDF02	SEDF03	SEDF04
VALID TEST	Y	N	Y	Y	Y
TEST TYPE	C-CYCLE HEATER ON	FUDS A/C OFF	FUDS A/C ON	FUDS A/C OFF	FUDS A/C OFF
TEST DATE	01/13/89	11/22/88	12/02/88	12/09/88	12/19/88
BATTERY CYCLE NO.	31.00	13.00	18.00	23.00	29.00
TERMINAL VOLTAGE	88.00	87.00	88.00	88.00	88.00
RANGE-KM	40.91	71.27	60.27	72.15	63.15
TEST TIME-MIN	94.69	187.38	154.84	187.45	169.53
NUMBER OF CYCLES	71.00	6.00	5.00	6.00	5.20
AC EN CONS. Wh/Km	412.86	447.31	407.50	316.42	309.26
SYS DC EN CONS Wh/Km	365.93	404.10	364.36	281.36	275.38
VEH DC EN CONS GROSS	286.97	242.74	281.40	227.58	224.07
VEH DC EN CON NET WH/KM	277.19	238.39	269.79	213.86	209.18
BATT DISCH. EN. Kwh	11.74	17.30	16.95	16.42	14.15
BATT REGEN. EN. Kwh	0.40	0.31	0.70	0.99	0.94
BAT DISCH AMP HRS.	113.96	200.59	178.80	160.14	140.44
BATT REGEN. AMP HRS.	3.48	45.83	10.85	8.91	8.57
AVE BAT TMP TST-STRT-C	22.14	22.83	22.79	24.81	16.31
AVE BAT TMP TST-END C	28.77	34.17	33.81	33.61	28.16
RECH. ENERGY DC Kwh	14.97	28.80	21.96	20.30	17.39
RECH. ENERGY AC Kwh	16.89	31.88	24.56	22.83	19.53
RECH. AMPERAGE Ah	124.15	233.72	181.40	168.72	144.41
BAT ENER RECH. EFF %	75.75	58.99	74.00	76.01	75.96
BAT COUL. RECH EFF %	88.99	66.22	92.59	89.63	91.32
RECHARGE TIME Min.	1052.20	1174.00	835.00	785.00	685.00
AVE BAT TMP RECH-STRT C	25.87	35.15	33.24	30.93	25.92
AVE BAT TMP RECH-END C	22.59	36.45	31.16	26.65	25.42
WALL-AC-EFF. %	67.14	53.29	66.21	67.59	67.64
AUX BAT EN. DISCH. KWH	0.00	0.00	0.01	0.00	0.00
AUX BAT EN. CHG. KWH	0.01	0.01	0.01	0.01	0.01
AIR COND ENERGY KWH	0.00	0.00	2.72	0.00	0.00
NOT USED	0.00	0.00	0.00	0.00	0.00
NOT USED	0.00	0.00	0.00	0.00	0.00
CHARGER EFF. %	88.63	90.34	89.41	88.92	89.04
AUX BAT CONS. Wh/KM	0.00	0.00	0.17	0.00	0.00
BAT SPEC. EN. GR.-WH/KG	17.47	25.74	25.22	24.43	21.06
BAT SPEC. EN. NET-WH/KG	16.88	25.28	24.18	22.96	19.66
BAT SPEC. POWR GR.-W/KG	11.07	8.24	9.77	7.82	7.45
BAT SPEC. PWR-NET W/KG	10.69	8.10	9.37	7.35	6.96
CONTRLR EFF-RUN %	96.80	0.00	0.00	0.00	0.00
NOT USED	0.00	0.00	0.00	0.00	0.00
NOT USED	0.00	0.00	0.00	0.00	0.00

*** NOTES ***

SEDC06 : HEATER TEST-NEW CONTROLLER
SEDF01 : AMP HRS RETURNED TO BAT MEASUREMENT BAD RAN IN 3RD GEAR
SEDF02 : A/C ON 2ND-3RD GEAR
SEDF03 : 2ND-3RD GEAR A/C OFF
SEDF04 : 2ND-3RD GEAR