EPRI-SCE Testing and Evaluation of Electric Vehicles: Lucas Van and Jet 007, 750, and 1400

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ELECTRIC POWER RESEARCH INSTITUTE

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ABSTRACT

This report describes the second phase of the EPRI/SCE Electric Vehicle Project, in which four additional electric vehicles (EVs) were tested and evaluated: the Jet Industries Model 007 passenger car, Model 750 pickup truck, and Model 1400 passenger van; and the Lucas-Bedford Model CFE cargo van. During the first phase of this project (described in EPRI report number EM-1245), four EVs were also tested: Jet 500, Volkswagen Type 2, DAUG Type GM2, and Battronic Minivan. The project emphasizes road-testing of vehicles to acquire data on their useful driving range, performance, reliability, and driver acceptance in utility-fleet use. Each vehicle was driven more than 1000 miles along SCE-selected test routes to determine the effects of different terrains (level, slight grades, and steep grades), traffic conditions (one-, two-, three-, and four-stops/mile and freeway), and payload. The vehicle component failures that occurred during testing are itemized and described briefly, and assessments are made of expected field reliability. Other vehicle characteristics and measurements of interest are presented. The data base on these test vehicles is intended to provide the reader an overview of the "real world" performance that can be expected from present-day state-of-the-art EVs.

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EPRI PERSPECTIVE

PROJECT DESCRIPTION

This annual report under RP1136-1 describes the work accomplished in the second contract year of the project, June 1979 through April 1980. The project was initiated in March 1978 to develop information on performance and use characteristics for electric work vehicles that are available commercially or as preproduction prototypes and for which existing performance data are sufficiently promising to warrant more detailed tests. In these tests, information on vehicle physical characteristics, range, acceleration, payload capability, and field reliability is obtained under "real world" driving conditions that include various but well-defined traffic densities, terrains, and payloads.

EPRI is consolidating the testing information contained in this report with the objectives and electric vehicle (EV) selection criteria established for the EV pilot demonstration project being carried out by the Tennessee Valley Authority (TVA) with joint EPRI and TVA funding. Before procuring EVs for the pilot demonstration, data and information were required for EVs that were available. EPRI's need for an independent and objective assessment of candidate EVs for the EPRI-TVA project is provided by Southern California Edison Company.

PROJECT OBJECTIVE

The overall objective of this three-year project is to establish a data base on state-of-the-art EVs. This type of data base is required in selecting mission-compatible vehicles for the EPRI-TVA EV demonstration project; it also should be helpful to utilities contemplating use and involvement in the commercialization of EVs.

PROJECT RESULTS

The performance data obtained for the four vehicles tested during the second contract year showed that the useful ranges of all four vehicles depended significantly on the road test conditions used in the project. A vehicle's useful range with payload in average urban traffic was as much as 50 percent lower than the range on freeway routes without payload. Furthermore, during the various range tests on a specific vehicle, the lowest-to-highest energy-consumption-per-mile traveled varied as much as 260 percent. The fact that these vehicles differed significantly in payload capability, propulsion system design, vehicle costs, and condition (age) of the propulsion batteries accounts in large part for the differences in test results between the vehicles tested.

No incidents of electric propulsion system component failures were encountered during the more than 1000 miles of road testing. This indicates that EV reliability in field applications is considerably ahead of that experienced in the first contract year of this project. Minor problems with batteries, battery chargers, fuses, and fuel gauges indicate a need for improved quality control of components or assembly.

The project results confirm the importance of subjecting even basically sound, well-integrated vehicle designs to realistic road tests so as to ascertain their general usability before any vehicles are selected for experimental and commercial demonstration programs.

Since the EVs selected for testing differ considerably with respect to size, weight, payload capability, propulsion scheme, and vehicle cost, the reader is cautioned against attempting an absolute ranking of EVs on the basis of the project test data. Rather, the documented EV performance data should be used to determine which vehicles are most compatible with the user's own selection criteria, which necessarily depend on the missions to be accomplished by the EVs.

Ralph J. Ferraro, Project Manager
Energy Management and Utilization Division

ACKNOWLEDGMENTS

An important aspect of the vehicle evaluation program was an independent assessment by SCE fleet drivers, who volunteered to use the EVs on their regular work routes. This has involved some occasional inconvenience (e.g., because of breakdowns), and the cooperation and assistance of the many individuals is gratefully acknowledged. Mr. C.L. Herman of the SCE Whittier District Office is recognized for arranging this evaluation program with his drivers.

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TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

Section 1
SUMMARY

The purpose of the EPRI/SCE Electric Vehicle (EV) Project is to establish baseline data for contemporary EVs in order to assess EV technology as applied to utility fleet use. To accomplish this, SCE is conducting independent tests and evaluations of currently-available EVs. Based on SCE's extensive experience with EVs, the testing emphasizes "real world" conditions and data that will be meaningful to utility company fleet operations.

Four EVs were tested and evaluated during the second phase of the project: a Jet Electrica 007 passenger car, a Jet Model 750 pickup truck, a Jet Model 1400 passenger van, and a Lucas-Bedford cargo van. The design characteristics of these vehicles differed widely and are described in detail in Section 3 and are summarized in Table 1-1.

Each vehicle was subjected to a series of road tests over SCE-selected test routes to determine its performance under various conditions of traffic, terrain, and payload. Each vehicle was tested "as-received" from the manufacturer without any special preparation by SCE, and with only ordinary maintenance during the program.* The test and evaluation program is described in Section 4 and the detailed results are presented for the four test vehicles in Sections 5 through 8 and Appendix A. An overview of the road test results is presented in Table 1-2.

Five SCE fleet drivers made subjective evaluations after driving the test vehicle on their regular work routes for one day. Their responses were mixed regarding the vehicle characteristics (although there was a frequent concern for power and braking ability), and one to three of the drivers were willing to continue using each test vehicle in their regular work. Vehicle characteristics that were not related to the EV propulsion system (e.g., vehicle familiarity or driver comfort) appeared to be of equal or greater importance to driver acceptance.

Each vehicle was road tested more than 1000 miles. There were no propulsion system failures in any of the four test vehicles, and only minor problems with low specific gravity cells, fuse failures, sticking throttle, and fuel gauge. This is a significantly reduced incidence of component failures compared to the vehicles tested during Phase I of the program.

* Except repairs, as needed.

Table 1-1.
SUMMARY OF TEST VEHICLE CHARACTERISTICS.

MANUFACTURER	Jet Industries	Jet Industries	Jet Industries	Lucas Batteries Ltd
Location	Austin, Texas	Austin, Texas	Austin, Texas	Birmingham, ENGLAND
DESCRIPTION				
Model Designation	Electrica Model 007	Electra Van Model 750	Electra Van Model 1400	Lucas-Bedford CFE Van
GVW (lb)	3970	4600	6660	7716
Total Payload (lb)[a]	460	880	1200	2205
Cargo Volume (ft^3)	17	26[e]	38[f]	165
Number of Doors	3	2	5	4
Wheel Base (in.)	97	107	109	106
BATTERIES[b]				
Number-Voltage	20-6V	20-6V	24-6V	36-6V
System Voltage	120	120	144	216
Amp-hour Capacity	161[c]	161[c]	180[g]	180[g]
Manufacturer	Exide	Exide	SGL	Lucas
Weight (lb)[d]	1280	1280	1488	2205
MOTOR				
Type	Series	Series	Series	Series
Horse-Power Rating	23	23	37	50
Rated Speed (rpm)	3285	3285	2039	4500
Manufacturer	GE	GE	GE	Lucas
Weight (lb)	160	160	255	312
TRANSMISSION[h]				
Speeds Forward	4	4	3	1
Clutch	Yes	Yes	Yes	No
CONTROLLER				
Type	SCR	SCR	SCR	SCR
Manufacturer	GE	GE	GE	Lucas
Current Rating (A)	500	500	500	400
REGEN BRAKING	No	No	No	Yes
BODY				
Construction	Stamped Steel	Stamped Steel	Stamped Steel	Stamped Steel
Manufacturer	Dodge	Dodge	Dodge	Bedford
TIRES				
Size	P165/75R13	6.00 x 14LT	4L 78 x 15	205 x 14
Type	Radial	bias-ply	bias-ply	8-ply
Rolling Radius (in.)	10.8	12.5	13.8	12.9
BATTERY CHARGER				
Location	Off-board	Off-board	Off-board	Off-board
Type	Ferro-resonant	Ferro-resonant	SCR	3-step const. cur.
AC Voltage	240	240	240	240
Manufacturer	Lester	Lester	GE	Lucas

a. including driver
b. all batteries were lead-acid
c. at 75 amp discharge rate
d. approximate
e. enclosed space within truck bed
f. luggage space behind rear seat
g. 2-hr rating
h. all transmissions were manual shift

Table 1-2.
OVERVIEW OF ROAD-TEST RESULTS.

Test Result	Jet 007	Jet 750	Jet 1400	Lucas Bedford
Maximum range — on freeway route **without** payload (mi)	53	24	26	74
Range in average traffic* — **without** payload (mi)	30	21	17	61
Range in average traffic — **with** maximum payload (mi)	27	14	9	37
Minimum range — on steep hills route **with** maximum payload (mi)	17	10	9	15
Top speed — **without** payload (mph)	64	61	55	54
Fastest acceleration from 0 to 30 mph — **without** payload (sec)	8.6	10.2	10.5	11.2
Lowest and highest AC energy consumption (kWh/mi)	0.6 1.6	1.0 2.3	0.9 1.6	0.8 1.8

* The "average" traffic condition was 3 stops/mile on a level highway having occasional peak traffic speeds of between 40 and 50 mph and an average journey speed of 19 to 20 mph.Range is the useful driving distance between battery recharges. The "useful range" is usually less than the absolute range and was determined by the ability to meet the SCE vehicle performance criteria described in Figure 4-1.

NOTICE

Test data and information contained in this report, including that presented in the above overview of road-test results, was obtained through the application to each vehicle, as received, of an SCE-developed series of 21 specific performance tests relative to fleet-use of EVs, and the subsequent evaluation of test results. SCE used its best efforts in ensuring the scientific, objective, and otherwise proper conduct of each test and of subsequent reductions and interpretations of data and information collected therein. It is recognized that EV performance can be affected by variations in battery conditions such as age, production-lot quality, previous usage, and electrolyte temperature; vehicle conditions such as tire pressure, wheel alignment, and controller adjustments; external conditions such as air temperature, wind, variations in road-grade, driving technique, charger performance, and similar factors. It follows that the performance of these or similar EVs, as observed by others, could vary somewhat, depending on vehicle conditions, applications, or special circumstances which may differ from those experienced during the SCE testing.

Southern California Edison Company

This report documents the performance tests, driver evaluations, and other characteristics of the second set of four test vehicles in the EPRI/SCE Project. It is intended to provide the reader with an objective overview of the end-use performance characteristics of these contemporary EVs. The collected road-test information establishes a "real world" data base to assist potential utility users in selecting vehicles for their specific applications, and for assessing future improvements in commercially available EVs.

Section 2
INTRODUCTION

The emerging national effort to commercialize electric vehicles (EVs) has a potentially significant impact on electric utility system load-curves and distribution feeder-systems. With the implementation of national energy goals, utilities have recognized the need to identify the interactions between large-scale use of EVs and utility operations. Since utilities must provide the needed energy and "live with the impact," it is appropriate and desirable that utilities participate in the national effort to accelerate the evaluation and introduction of EVs into the U.S. transportation sector.

To acquire adequate, meaningful data on a wide range of EVs, EPRI selected Southern California Edison (SCE) to conduct independent, objective tests and evaluations of EVs that were available either commercially or as preproduction prototypes. For the past ten years, SCE has had an on-going EV program with the ultimate objectives of improving its system load factor, reducing fleet operating costs, reducing gasoline consumption, and improving ambient air quality in Southern California. During this time, SCE has fabricated two electric automobiles, fabricated one hybrid-electric automobile, purchased and field-tested five electric vans in participation with the Edison Electric Institute's Electric Vehicle Council evaluation program, independently tested six other makes of EVs, and is currently continuing various technical and cost-tradeoff studies related to EVs, including applications within the SCE fleet.

From SCE's previous EV test experience it became evident that prospective EV purchasers could not rely on manufacturers' advertised data, or on published track-test reports to accurately assess the performance of these vehicles in "real world" fleet operations. Accordingly, SCE developed its own test procedures and evaluation processes, which more accurately indicated the suitability of EVs to its fleet operations and which provided the basis of this report.

The EPRI/SCE Electric Vehicle Project differs from other EV test programs in both methods and objective. In general, the EPRI/SCE test and evaluation process is intended to indicate the performance that can be expected from the currently-available* electric work vehicles when in a utility fleet performing defined missions under "real-world" operating conditions. The SCE program emphasizes road testing with vehicles as-received from the manufacturer, in the actual terrains and traffic conditions found in SCE routes, and includes subjective assessments of vehicle acceptability by SCE-fleet drivers.

* "Currently available" means at the time the testing was conducted; vehicles are not necessarily in production as of the report publication date.

This interim report summarizes the testing and evaluation of the second set of four EVs selected by EPRI. The format of this second annual report has been slightly revised and expanded to include additional test data. This work was performed between June 1979 and April 1980 in accordance with the SCE proposal to EPRI October 21, 1977, and as authorized under EPRI Contract Number RP1136-1 of March 3, 1978, and as subsequently amended. Additional vehicles are being selected by EPRI and will be tested by SCE.

The EPRI project manager was Mr. R.J. Ferraro. The work was directed by Mr. R.K. McCluskey, the SCE project manager. The road testing was planned and conducted by Arias Research Associates, an independent consulting firm. Vehicle testing was conducted on the city streets of Whittier, California, a residential and commercial area located within the greater Los Angeles area.

Section 3
TEST VEHICLE DESCRIPTIONS

The four test vehicles were selected from two different manufacturers, representing different approaches to the propulsion system design, various body/chassis designs, and different gross-vehicle and payload weights. The test vehicles included two passenger vehicles (an automobile and van) and two cargo vehicles (a pickup and van). Brief vehicle descriptions are presented in this section, and more detailed information on each test vehicle is presented in Appendix A.

JET 007 PASSENGER CAR

The Electrica Model 007 shown in Figure 3-1 was a battery-powered passenger car manufactured by Jet Industries of Austin, Texas. The vehicle was a conversion of the standard Dodge "Omni" model automobile. It had bucket front seats and a fold-down rear bench seat and could accommodate four persons. The engine compartment contained the controller, motor, and five of the propulsion batteries and standard accessories (Figure 3-2). The remaining 15 propulsion batteries were housed in a compartment behind the rear seat. The vehicle was of steel construction and the conversion had a finished appearance.

Figure 3-1. View of Jet 007 Test Vehicle.

The propulsion system consisted of a 23-horsepower DC series-wound motor, a chopper controller without regenerative braking, and a standard four-speed transmission with clutch. The motor was adapted directly to the flywheel housing of the front-wheel drive assembly. The 120-volt battery

Figure 3-2. Additional Views of the Jet 007.

pack consisted of twenty 6-volt Exide XPV-23 batteries. The propulsion batteries and 12-volt accessories battery were recharged at the same time by an off-board charger operating on 240 VAC and which plugged into the front of the vehicle.

The gross vehicle weight was 3970 pounds, of which approximately 300 pounds was useful payload (i.e., in addition to a driver). The vehicle had a wheelbase of 97 inches, and a usable cargo volume of approximately 17 cubic feet.

JET 750 PICKUP TRUCK

The ElectraVan Model 750 (Figure 3-3) was a battery-powered light pickup truck manufactured by Jet Industries of Austin, Texas. The vehicle was a conversion of the standard Ford "Courier" model pickup. The cab had a bench seat that could comfortably accommodate two persons. The engine compartment contained the controller, motor, and five of the propulsion batteries and standard accessories. The remaining 15 propulsion batteries were housed in a metal compartment in the truck bed behind the cab (Figure 3-4). The vehicle was of all steel construction and the conversion had a finished appearance.

The propulsion system consisted of a 23-horsepower DC series-wound motor, a chopper controller without regenerative braking, and a standard four-speed transmission with clutch. The 120-volt battery pack consisted of twenty 6-volt Exide XPV-23 batteries. The propulsion and 12-volt accessories batteries were recharged at the same time by an off-board charger operating on 240 VAC and which plugged into the side of the vehicle.

The gross vehicle weight was 4600 pounds, of which approximately 700 pounds was useful payload (i.e., in addition to a driver). The vehicle had a wheelbase of 108 inches, and an enclosed cargo volume in the truck bed of approximately 26 cubic feet.

Figure 3-3. View of the Jet 750 Test Vehicle.

Figure 3-4. Additional Views of The Jet 750.

JET 1400 PASSENGER VAN

The ElectraVan Model 1400 (Figure 3-5) was a battery-powered van manufactured by Jet Industries of Austin, Texas. The vehicle was a conversion of a standard Dodge passenger van and could seat eight people (including driver) comfortably on two bench and two bucket-type seats. The electric motor was adapted to the standard flywheel housing and the vehicle transmission and drive train were standard Dodge components. The batteries were contained in two packs: A T-shaped configuration of 14 batteries under the front hood and ICE engine cover, and 10 batteries in a box under the rear floor. The vehicle had five doors (including the double side door for passenger loading) and room for small cargo (e.g., luggage) behind the rear seat (Figure 3-6). The vehicle was all steel construction, had a finished appearance, and had a comfortably appointed interior.

The propulsion system consisted of a 37-horsepower DC series-wound motor, a chopper controller without regenerative braking, and a standard 3-speed manual Dodge transmission. The 144-volt battery pack consisted of twenty-four 6-volt SGL batteries. The propulsion batteries and 12-volt accessories battery were recharged at the same time by an off-board charger operating on 240 VAC and which plugged into the battery pack in a receptacle under the hood.

The gross vehicle weight was 6660 pounds, of which approximately 1050 pounds was useful payload (sufficient for seven 150-pound passengers in addition to the driver). Passenger loading was convenient through the double side doors. The vehicle had a wheel base of 109 inches and approximately 38 cubic feet of cargo volume behind the rear seat.

Figure 3-5. View of the Jet 1400 Test Vehicle.

Figure 3-6. Additional Views of the Jet 1400.

LUCAS-BEDFORD CARGO VAN

The Lucas Bedford CFE Electric Van (Figure 3-7) was a battery-powered van manufactured by Lucas Batteries Ltd. of Birmingham, England. The vehicle was a conversion of a short wheelbase Bedford cargo van manufactured by Vauxhall Motors of Luton, England. The vehicle had bench seats for three persons, and right-hand-side steering. The controller was housed in the engine/transmission hump, and the battery pack was contained in a removable, rectangular metal tray mounted beneath the vehicle cargo floor. The motor was mounted in the rear and was connected to the rear axle through a chain drive. The vehicle had two side doors for passengers and two rear doors for loading and unloading cargo (Figure 3-8). There was no intrusion into cargo space by batteries or motor. The vehicle was of all steel construction and had a finished appearance.

The propulsion system consisted of a 50-horsepower DC series-wound motor, a chopper controller (shown removed in Figure 3-8) with regenerative braking, and a single-speed, Morse double-reduction chain drive between the motor and differential. The 216-volt battery pack consisted of thirty-six 6-volt Lucas EV5 batteries. The batteries were recharged by an off-board charger operating on 240 VAC, and the 12-volt accessories battery was recharged from the propulsion battery by a DC-DC converter.

The gross vehicle weight was 7716 pounds, of which approximately 2000 pounds was useful payload (in addition to the driver). The vehicle had a wheelbase of 106 inches, and a cargo volume of approximately 168 cubic feet.

Figure 3-7. View of Lucas-Bedford Van Test Vehicle.

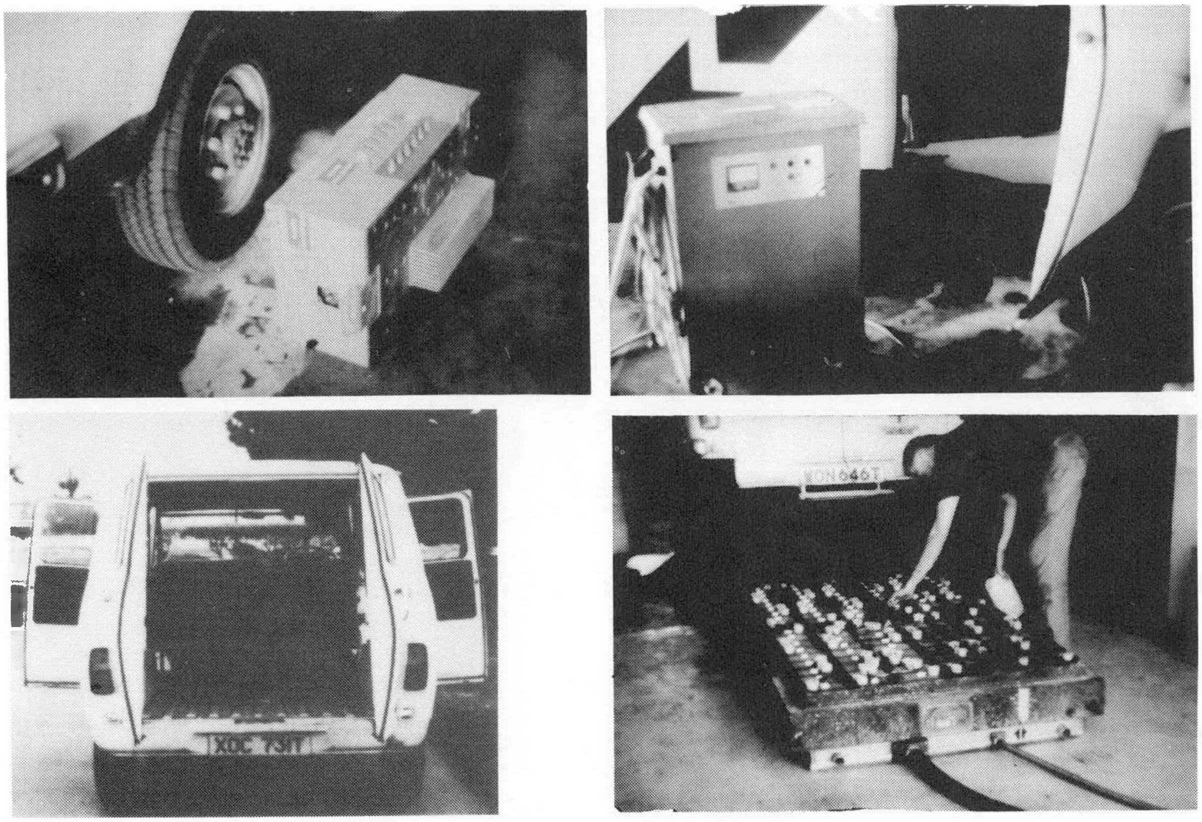


Figure 3-8. Additional Views of the Lucas-Bedford Van.

Section 4
PERFORMANCE TESTS AND EVALUATIONS

TEST METHOD AND RATIONALE

The test program was designed to determine the levels of performance that can be expected from EVs under "real world" conditions of traffic, terrain, and payload typical in utility company fleet use. Since there are a variety of possible missions and routes, selected tests were conducted to examine a range of conditions likely to be encountered by potential utility company EV users. The test conditions selected for the EPRI/SCE project were based on SCE's previous experience with EVs in their fleet, and used test criteria found to be meaningful in actual field operations.

Performance levels of the test vehicles were determined in a series of 21 well-defined road tests. SCE considered road testing preferable to track-testing because it yielded more realistic results and had acceptable reproducibility.* Tests were conducted by driving each vehicle on roads and highways that were typical of SCE service routes and that had been mapped and measured for distance, grades, and stops per mile. In each test, the vehicle was driven in both directions along the route, and only on days when the wind was less than 10 knots. The vehicle was driven continuously except for traffic signal stops (averaging about one minute), and a data stop every three miles (for approximately five minutes during which the battery voltage, electrolyte temperature, and specific gravity were measured).**

The maximum vehicle speed and acceleration were determined (on level terrain) at three-mile intervals immediately after each data stop, so that vehicle performance and battery condition could be plotted as a function of distance driven. The usefulness of this road-test data in evaluating EVs is twofold: (1) If the characteristics of the candidate ICE-replacement routes are known (i.e., route length, stops per mile, general grades, and payload), an examination of the data will indicate if an EV can be successfully substituted for an ICE vehicle; and (2) performance differences between various EVs can be seen for a broader range of driving conditions than would be indicated by any single test.

* Although both test profiles have approximately three-stops/mile, the useful driving range obtained in the SCE three-stops/mile road tests of the four EVs was 13% to 52% less (depending on the vehicle) than the ranges obtained from track-type tests using the standard SAE J227aC test profile. In reproducibility checks conducted during the SCE road-tests, the average range difference between pairs of identical tests was about 2%, and generally not more than 4%.

** The road test conditions are described by the average number of stops/mile, which is the **total** number of traffic and data stops, divided by the miles driven.

As it was specifically the **end-use** performance characteristics of the vehicle that were of interest, extensive subsystems performance data (e.g., motor power-draw and charger efficiencies) commonly acquired during track-test programs were unnecessary. Information necessary to identify subsystem design deficiencies was still acquired, however, from the incidence and diagnosis of component failures during the 1000 miles or more of road testing.

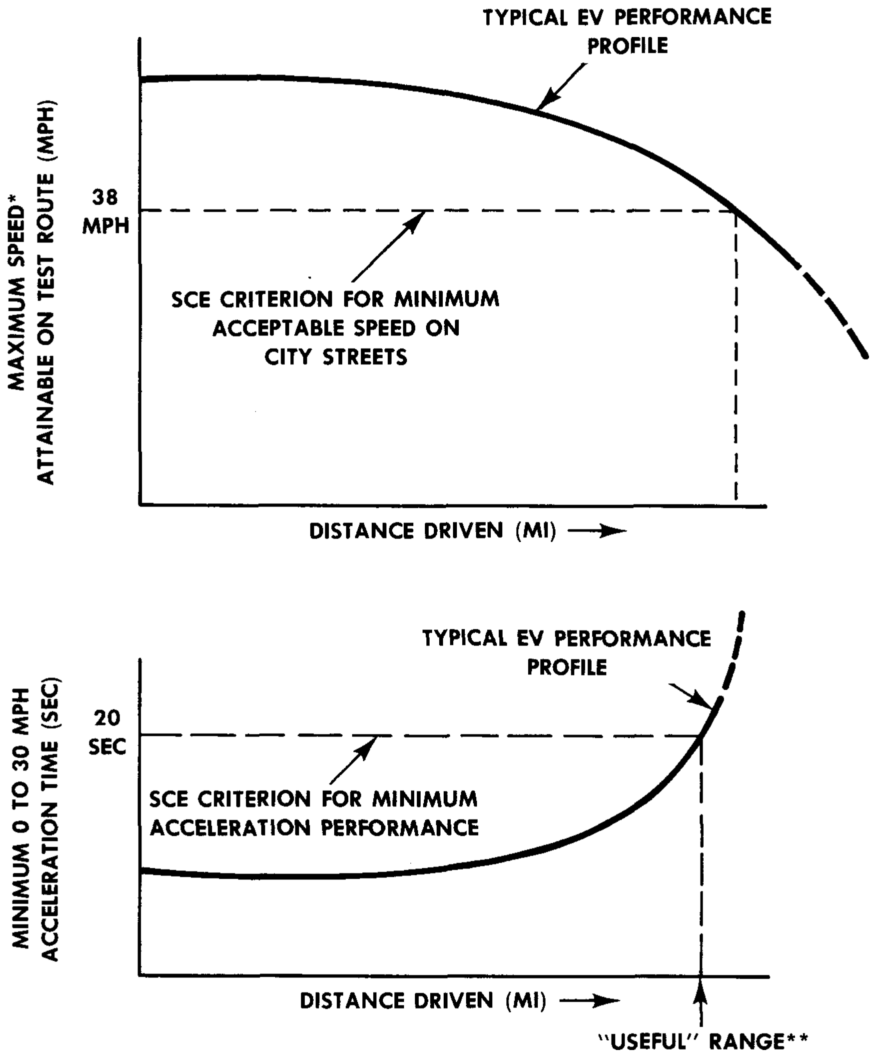
In general, the results of the road testing should provide a reasonable indication of the vehicle reliability and performance characteristics of these EVs for various traffic, load, and grade conditions likely to be encountered in field applications. Some caution must be used in literally extrapolating all test results to field application, however, because of the variations in useful range that could result from battery temperature differences or age. Battery temperatures can differ from day-to-day due to ambient temperature, charger operation, vehicle idle-time since last charge or last use, and other variable factors. In general, the useful driving range in the field can be expected to be less than indicated by the road-test results if (1) battery electrolyte temperatures are less than 90°F, or (2) as batteries become older.*

ACCELERATION AND TOP SPEED

Tests were conducted to determine the maximum acceleration and top speed that could be attained by each vehicle with batteries fully charged and 80% discharged, and with and without payload, on a level highway.

Although acceleration and top speed are standard measures of vehicle performance, they take on a special significance in testing EVs. Because the available battery power decreases with discharge, the top speed and acceleration performance tends to decrease with the distance driven. Instead of stopping abruptly (as when running out of gasoline), the EV speed and acceleration become progressively slower, until the vehicle will no longer move. This tapering-off of battery power usually occurs in the last one to eight miles of driving, depending on the age and type of battery and the design of the vehicle propulsion system. Before the vehicle becomes totally immobile, however, the performance deteriorates until it is unsafe and a nuisance to operate on the streets. Standardized criteria were therefore required by which to determine a meaningful "cutoff" during the road tests. For this, SCE developed the criteria for the "useful" driving range of an EV illustrated in Figure 4-1.

* Reductions in the useful driving range of 5% to 25% have been observed when allowing electrolyte temperatures to fall below 70°F (such as occurs during weekend storage, especially in colder climates). Reductions as much as 25% in vehicle range capability have been observed during this test program, apparently due to battery deterioration.



* MAXIMUM SPEED ATTAINABLE DURING A SPECIFIC ROAD TEST (MAY DIFFER SIGNIFICANTLY FROM TOP SPEED).
** BASED ON WHICHEVER LIMIT (38 MPH OR 20 SEC) IS REACHED FIRST (20 SEC LIMIT SHOWN, WHICH IS USUALLY THE CRITERION FAILED FIRST).

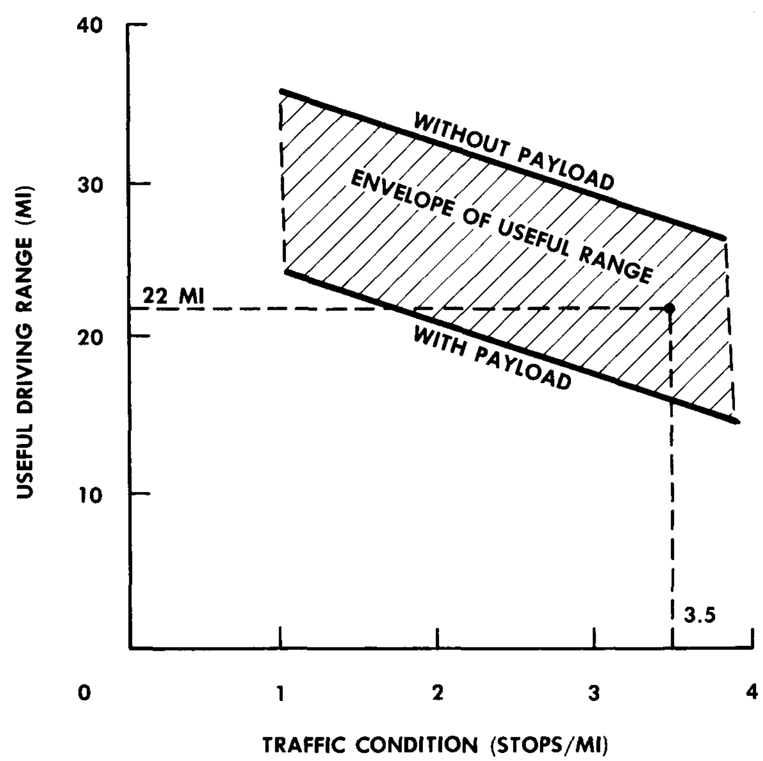
Figure 4-1. SCE Method for Determining the Useful Driving Range of an EV.

The limit of useful range on level terrain was defined as that range at which the attainable top speed of the vehicle during any road test became less than 38 mph, or the acceleration time from 0 to 30 mph required longer than 20 seconds.* These criteria were derived from previous SCE studies and driver experience with EVs on actual routes, which indicated that these are probably the lower limits for either, or both (1) driver acceptance of vehicle performance, and/or (2) tolerance of the motorists following the EVs on major surface streets in Southern California.

* EVs with new batteries usually fail both the minimum acceleration and minimum top-speed criteria at about the same range.

TRAFFIC CONDITIONS AND PAYLOAD EFFECTS ON RANGE

The useful driving range of EVs is sensitive to the traffic conditions, which can be described by the number of starts and stops per mile and the peak speed over the route. These conditions can vary widely, from freeway driving to heavy downtown traffic. Based on SCE's survey of vehicle use in its own fleet, the following five traffic conditions were selected for the road test program to represent the spectrum of typical EV service routes: One-, two-, three-, and four-stops/mile on streets with a 45-mph top speed, and a simulated freeway mission with a 55-mph top speed. SCE considered the average driving conditions for most of its service area to be about three-stops/mile. A stop was defined as coming to a complete, or nearly complete (i.e., less than 5 mph) stop, but did not include the other slowdowns and speed variations normally encountered in street driving. These tests were conducted both with and without payload to assess the range sensitivity to payload and to derive an envelope of the useful driving range. This envelope of useful driving range and an example of its use is shown in Figure 4-2 for a hypothetical EV.



EXAMPLES OF USE:

1. ASSUME AVERAGE TRAFFIC CONDITIONS ARE 3.5 STOPS/MI
2. ASSUME VEHICLE CARRIES 1/2 OF MAXIMUM PAYLOAD
3. ESTIMATED USEFUL DRIVING RANGE IS 22 MI

Figure 4-2. Use of Range Envelope for Hypothetical Vehicle.

The freeway test was conducted to estimate the maximum useful driving range on a route involving mostly freeway or expressway driving. The freeway route consisted of approximately 90% travel on the freeway, and the remaining 10% on surface streets (to get to and from the freeway). The vehicles were tested on a level stretch of California freeway in highest gear, in light, brisk traffic averaging about 55 mph. The vehicle exitted the freeway at approximately five-mile intervals for data measurements (electrolyte specific gravity, etc.).

TERRAIN AND PAYLOAD EFFECTS ON RANGE

The useful driving range of EVs varies with payload and grade conditions. To assess these effects, driving range tests were conducted with and without payload on level terrain (3 stops/mile) "slightly hilly," and "steep-hill" test routes.

The "with payload" test was conducted at gross vehicle weight (with sandbag payload), and "without payload" with driver only. The level-terrain route was a three-stops/mile test, and the "slightly hilly" (up to 8% grade) and "steep hill" (up to 23% grade) routes were in a commercial section of the central city and a residential area, respectively, and are described in Figure 4-3. The vehicles were run in both directions on the hill routes so there was no net gain in altitude during the test. The reader is therefore cautioned not to interpret the test results as representative of continuous climb on a specific grade, but representative of a service route similar to the test — i.e., with both uphill and downhill travel on those grades shown in Figure 4-3, and the vehicle ultimately ending its daily route where it began, with no net gain in altitude.

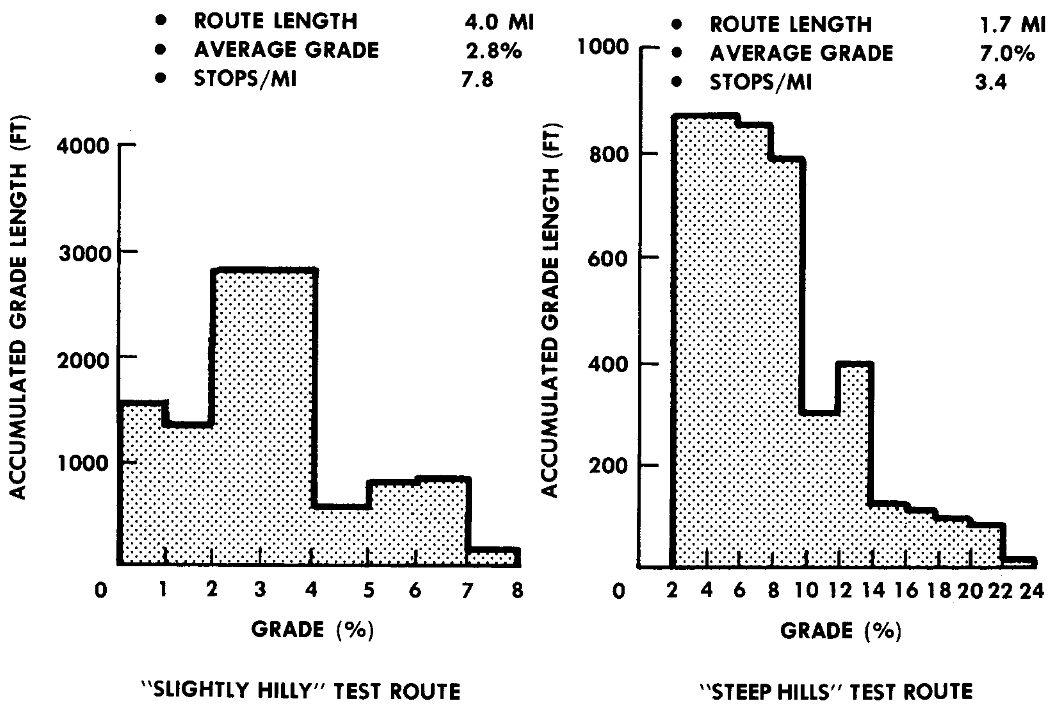


Figure 4-3. Hill-Test Route Characteristics.

FIELD RELIABILITY

One of the most important results of the road-test program was the incidence and cause of component failures. Each test vehicle was driven over 1000 miles in the test program, during which failures occurred on some vehicles. For purposes of the test program a "failure" was defined as any component malfunction or breakage that prevented completion of the test or acquisition of the test data, or could result in unsafe operation of the vehicle. After each failure, the cause was diagnosed as completely as possible. An assessment was made of the vehicle reliability that could be expected in actual field use from the nature of the failure, its frequency, likelihood of reoccurrence, and methods of correction.

ENERGY CONSUMPTION

The AC energy consumption per mile was determined for each road test by recording the AC kWh required for recharge on a standard utility meter and divided by the total number of miles driven in each test (which is slightly more than the useful range). The envelope of energy consumption for the various conditions should provide a reasonable expectation of AC energy consumption in field use.

DRIVER EVALUATIONS

Five SCE employees, after a briefing and instruction-drive, drove each test vehicle for a full day on their regular work routes. The employees included both those who had previously driven a test EV and those who had no previous experience. At the conclusion of the test drive each employee filled out the questionnaire presented in Appendix B. In addition to the five SCE drivers, the test driver contracted for the road-performance tests responded to the same questionnaire, and his experience represented more than one month of driving experience with each vehicle. The compiled results for the six drivers are summarized under "Results" for each vehicle. While these results are not statistically significant because of the limited number of test participants, they do indicate the nature of the drivers' concerns and attitudes regarding these vehicles.

Section 5
JET 007 RESULTS

The test and evaluation results for the Jet Industries Electrica Model 007 were derived from 1100 miles of road testing using Exide XPV-23 batteries.

PERFORMANCE TESTS

Top Speed

Top speed varied slightly with range and the maximum attained was 64 mph driving on the freeway without payload and with fully-charged batteries. Top-speed performance as a function of range can be seen in the speed profiles from selected road tests shown in Figure 5-1.

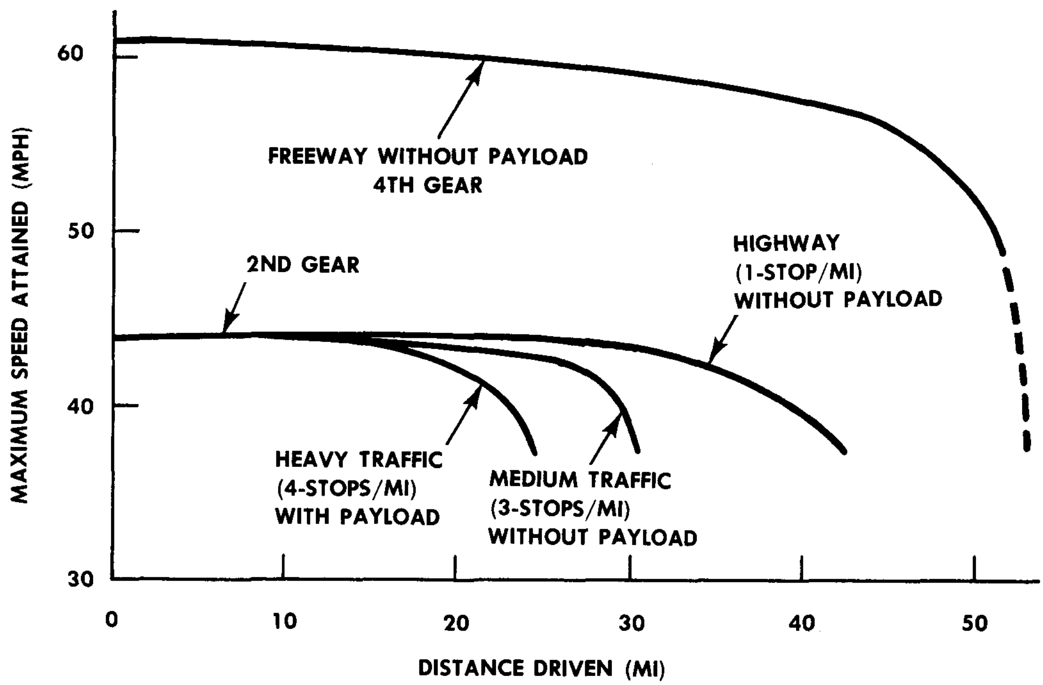


Figure 5-1. Jet 007 Maximum Speed Versus Distance Driven.

Acceleration

Acceleration performance profiles are shown in Figures 5-2 and 5-3, and the elapsed times to achieve selected speeds with fully-charged batteries are summarized in Table 5-1.

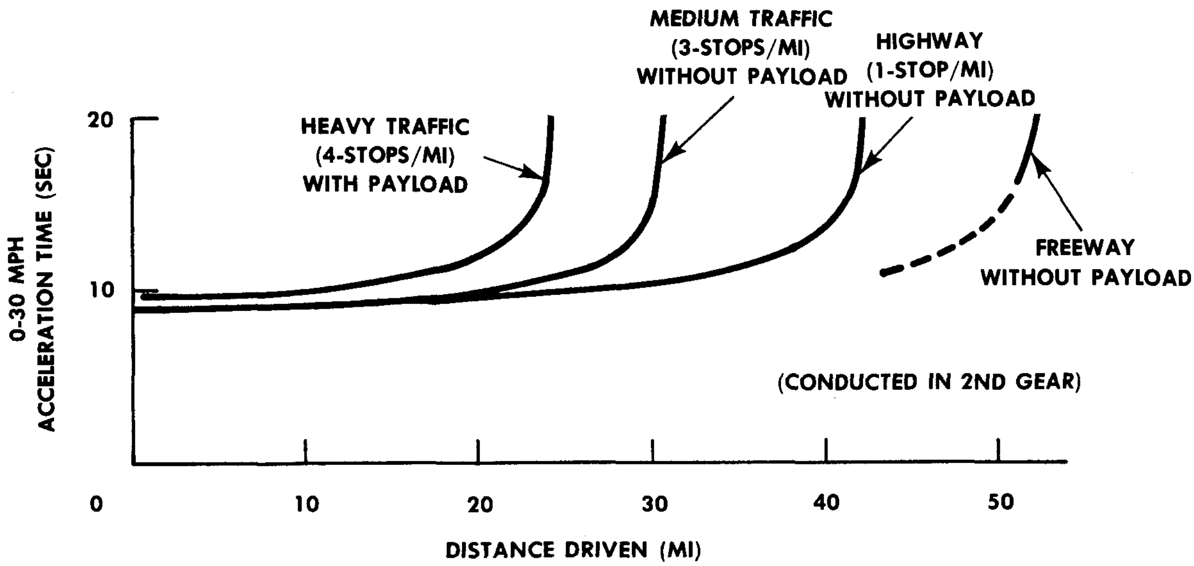


Figure 5-2. Effect of Distance Driven on Jet 007 Acceleration Performance.

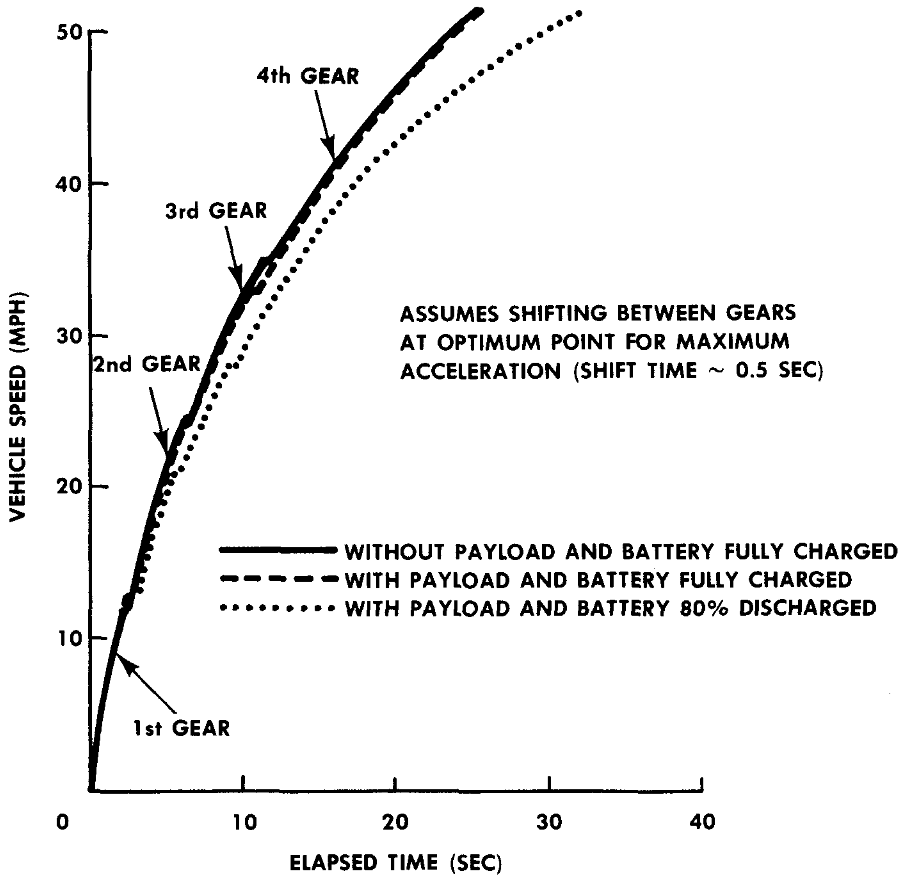


Figure 5-3. Jet 007 Acceleration Profiles.

Table 5-1.
JET 007 ACCELERATION TIMES.

Speed (mph)	Elapsed Time (sec) Without Payload Optimum*	Without Payload 2nd Gear	With Max Payload Optimum*	With Max Payload 2nd Gear
20	4.7	5.0	4.9	5.1
30	8.6	8.9	8.8	9.8
40	15.2	16.6	15.5	17.0
50	23.7	—	24.1	—

* The "Optimum shift" accelerations were not actually conducted. The acceleration times shown were extrapolated from the individual acceleration curves obtained in each gear. It was assumed that shifting occurred between gears at the optimum point for maximum acceleration and within 0.5 seconds. In actual experience with drivers performing the shifting, the 0 to 30 mph acceleration times were usually one to two seconds longer than the "optimum-shift" time.

Traffic Conditions and Payload Effects on Range

The effect of traffic conditions (expressed in stops/mile) and payload on the useful driving range of the vehicle is shown in Figure 5-4.

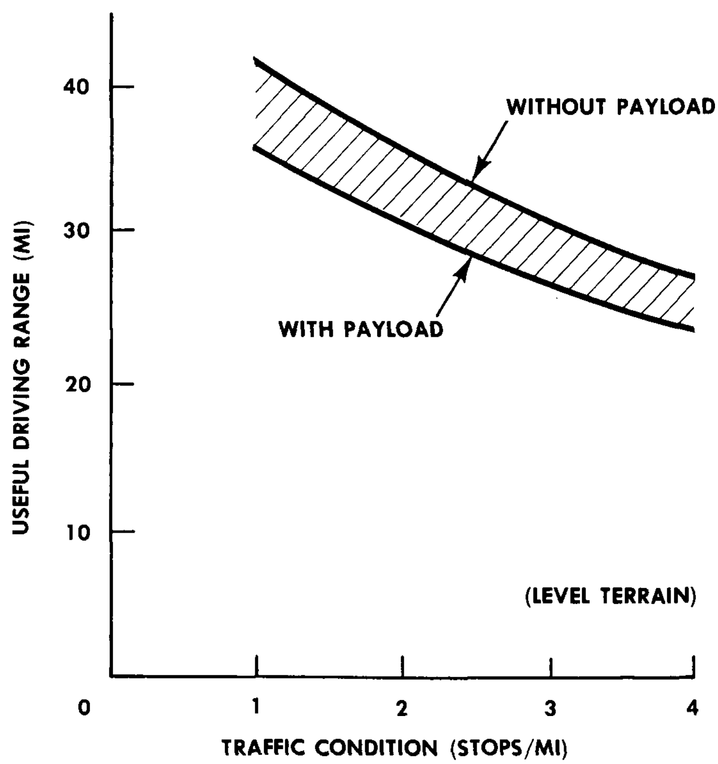


Figure 5-4. Effect of Traffic Conditions on Jet 007 Range.

The useful ranges in the freeway driving tests were 52.5 miles total without payload (49.1 miles freeway and 3.4 miles surface streets), and 37.0 miles total with payload (33.4 miles freeway and 3.6 miles surface streets).

Terrain and Payload Effects on Range

The effect of terrain and payload on useful vehicle range is shown in Figure 5-5.

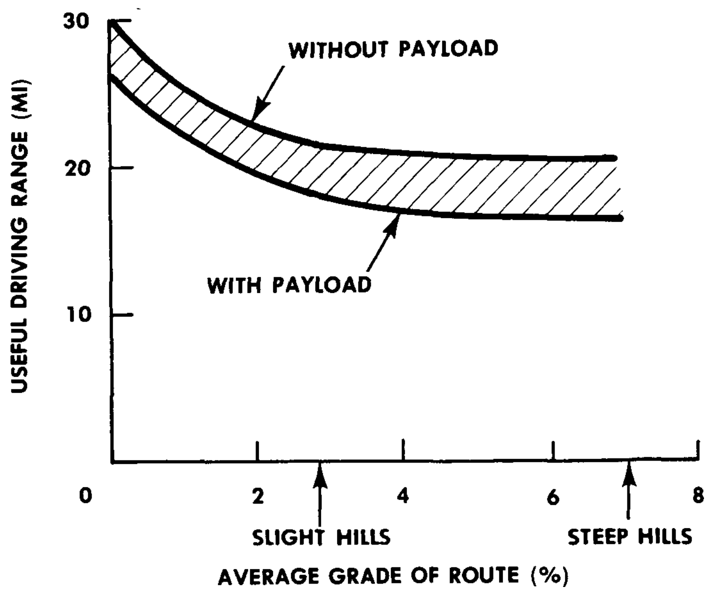


Figure 5-5. Effect of Terrain and Payload on Jet 007 Range.

Summary of Range Tests

Results of the individual range tests and test conditions are summarized in Table 5-2.

FIELD RELIABILITY

There was one minor component "failure" in the propulsion system during the 1100 miles of road testing. A sticking accelerator throttle caused the electric motor to continue to run after the driver's foot was removed from the pedal, and the test was discontinued. It was found that the cable moved to where it was binding against the chassis. The cable was repositioned and tied down with a wire clamp, and the problem did not reoccur.

Other problems that occurred during the road testing were with the fuel gauge and batteries. The "fuel" gauge (i.e., battery capacity gauge) became inoperative and the control circuit (card) was replaced. This did not correct the problem, which was apparently a mechanical sticking of the gauge within the dash. As repair required replacement of the dash panel, the problem was not corrected.

Table 5-2
SUMMARY OF JET 007 RANGE TEST DATA.

Test No.[a]	Description	With Maximum Payload[b]	Stops/ Mile[c]	Average Speed[d] (mph)	Ambient Temperature (°F)	Battery Temp (°F) Initial	Battery Temp (°F) Final	AC Energy Consumption (kWh/mi)	Range (mi)
4	Heavy traffic	No	4	17.3	60	100	130	1.21	27.1
3	Medium traffic	No	3	19.5	61	100	126	1.02	30.7
3A	Repeatability	No	3	19.8	54	99	128	1.03	29.6
2	Light traffic	No	2	23.3	57	100	124	0.90	36.5
7	Highway	No	1	26.0	68	93	122	0.74	41.7
16	Freeway	No	0.2	55[e]	81	89	130	0.63	52.5
8	Slight hills	No	7.8	15.8	60	100	132	1.36	21.4
9	Steep hills	No	3.4	19.2	75	90	126	1.52	20.8
4A	Heavy traffic	Yes	4	18.2	85	104	144	n.a.	23.8
10	Medium traffic	Yes	3	22.2	69	94	139	1.14	26.7
2A	Light traffic	Yes	2	23.5	70	100	138	0.96	31.2
7A	Highway driving	Yes	1	27.9	60	102	136	0.98	35.9
16A	Freeway	Yes	0.2	55[e]	60	82	148	0.69	37.0
11	Slight hills	Yes	7.8	15.7	60	100	151	n.a.	18.9
12	Steep hills	Yes	3.4	20.4	65	80	146	n.a.	16.5
17A	Weekend effect[f]	No	3	21.4	52	70	114	0.98	24.2
13B	Range repeatability	No	3	22.0	60	97	145	1.12	21.2
13BB	Range repeatability	No	3	19.9	63	97	152	n.a.	21.0
13A	J227ac	Yes	2.6	16.8	65	79	142	0.86	30.8

[a] SCE test identification number. Data are presented out of sequence for clarity.
[b] With maximum payload = tests at gross vehicle weight of 3970 lb (approximately 260-lb payload + 200-lb driver)
[c] Approximate average
[d] Average speed over route, including traffic signal stops
[e] Average cruise speed; actual speeds varied from 50 to 64 mph
[f] Lower initial electrolyte temperature due to vehicle standing idle for a weekend
n.a. Valid data not available (charger problem)

Two batteries were replaced near the end of the test program because of "weak" cells (low specific gravity). This was prompted by a 25% reduction in range observed during the range-repeatability check conducted near the end of the test program, but the battery replacements did not improve vehicle performance.

Reliability Assessment

The absence of any major propulsion system failures during the rigors of the test program suggests that reliable performance can be expected in the field. The sticking accelerator cable and fuel gauge indicates minor problems with assembly details/procedures that may reoccur. The significant reduction in useful driving range during the test program suggests that degradation in range performance and a short battery life may occur in field use.

ENERGY CONSUMPTION

The AC energy consumption is shown for the various conditions of traffic, terrain, and payload in Figure 5-6. The charger had an automatic shut-off feature (designed to sense the rate of voltage change) that occasionally failed to function, causing high readings of AC energy consumption*.

DRIVER EVALUATIONS

The results of the driver evaluations are summarized as follows:

a. All drivers felt vehicle performance was satisfactory at least most of the time, and that job performance would be acceptable.
b. Drivers generally felt as safe in the vehicle as their regular car, although half expressed some concern about ability to panic stop.
c. Most drivers felt comfort was satisfactory and most felt that the vehicle was quieter than their regular ICE vehicle.
d. Drivers most liked the smooth ride, gas-independence, easy handling, and vehicle appearance.
e. Drivers most disliked the brakes and bucket seats.

Drivers generally found the test vehicle acceptable. Of the five SCE test drivers, two stated they would be willing to use it on a permanent basis, and three with changes to the vehicle (better brakes and more power).

* Although grossly high readings were deleted from the data base, AC energy consumption figures **may** be slightly high because of the uncertainty over charger operation. While it is also recognized that overcharge can shorten battery life, it is not believed to be the cause of the observed reduction in vehicle range because there was no significant rise in battery temperature observed during the occasions of charger shut-off failure.

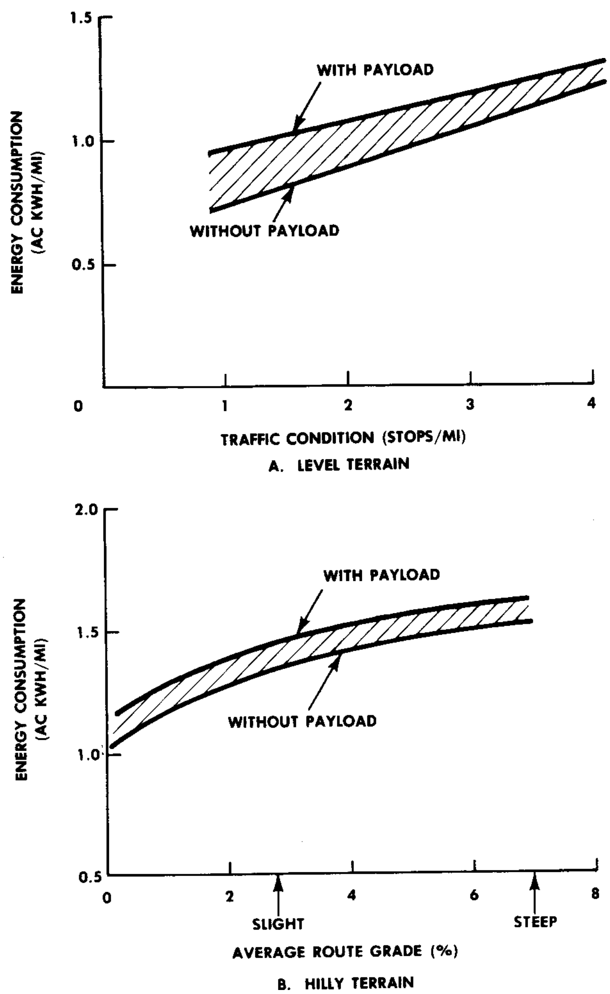


Figure 5-6. Jet 007 Energy Consumption.

CONCLUSIONS

The Jet 007 appears suited for roles involving personnel transport or lightweight cargos (up to 300 pounds) on all work routes including freeways and steep hills. Driver acceptance of the vehicle is expected to be generally good.

The useful range of the vehicle, as tested, is between 53 miles (on level freeway with no payload) and 17 miles (with payload on a steep-hill route), with AC energy consumptions between 0.6 and 1.6 kWh/mile, respectively.

It is expected that the vehicle propulsion system will perform reliably in the field, although there may be some minor problems with accessory components, and significant range degradation may occur early in battery life.

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Section 6
JET 750 RESULTS

The test and evaluation results for the Jet Industries Model 750 Pickup Truck were derived from 1000 miles of road testing with XPV-23 batteries.

PERFORMANCE TESTS

Top Speed

Top speed varied significantly with range and the maximum attained was 61 mph driving on the freeway without payload and with fully-charged batteries. Top-speed performance as a function of range can be seen in the speed profiles from selected road tests shown in Figure 6-1.

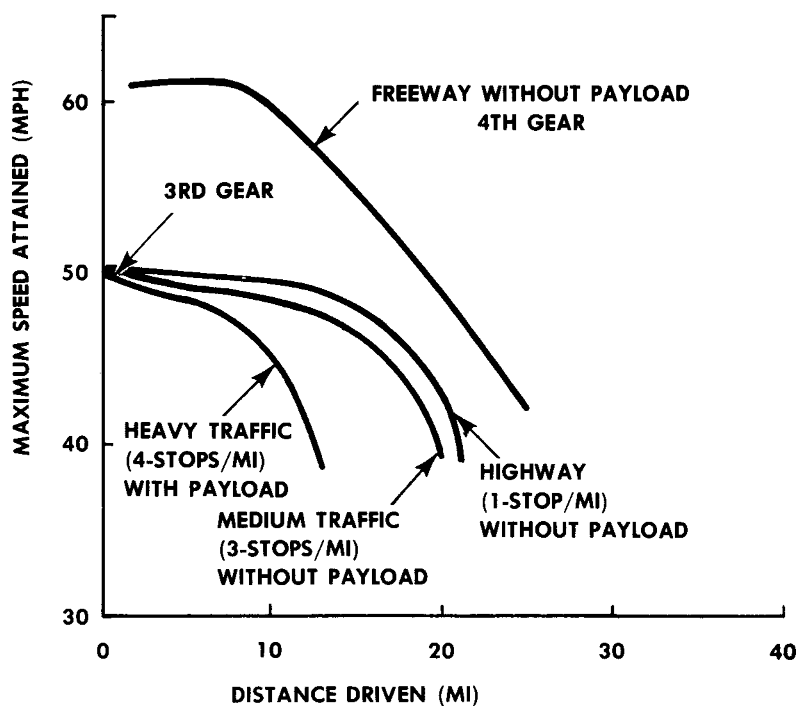

Figure 6-1. Jet 750 Maximum Speed Versus Distance Driven.

Acceleration

Acceleration performance profiles are shown in Figures 6-2 and 6-3, and the elapsed times to achieve selected speeds with fully-charged batteries are summarized in Table 6-1.

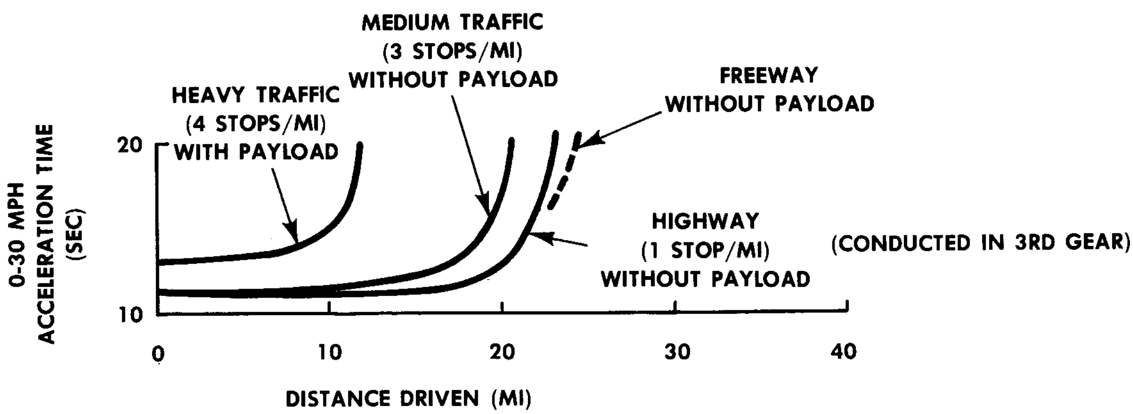

Figure 6-2. Effect of Distance Driven on Jet 750 Acceleration Performance.

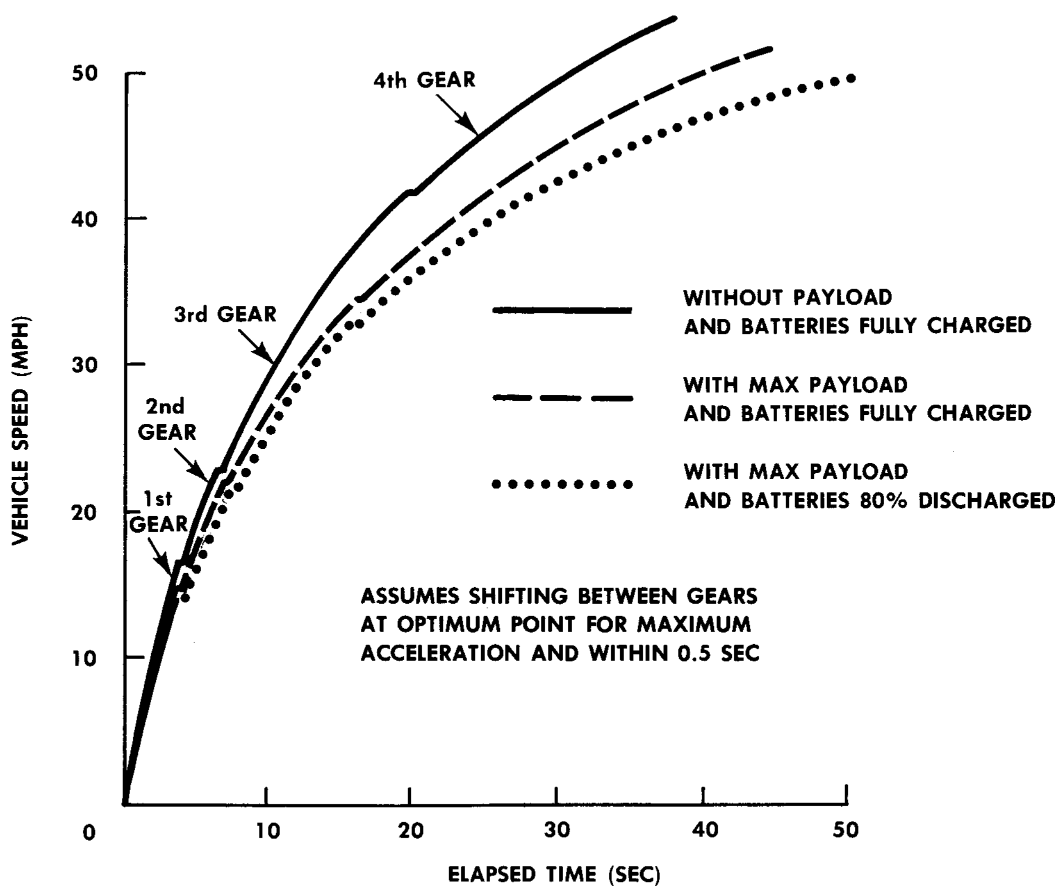

Figure 6-3. Jet 750 Acceleration Profiles.

Table 6-1.
JET 750 ACCELERATION TIMES.

Speed (mph)	Elapsed Time (sec) — Without Payload: Optimum	Without Payload: 3rd Gear	With Max Payload: Optimum	With Max Payload: 3rd Gear
20	5.2	6.9	5.8	8.2
30	10.2	11.5	11.9	13.8
40	17.5	18.8	22.5	24.4
50	30.6	—	39.3	—

Traffic Conditions and Payload Effects on Range

The effect of traffic conditions (expressed in stops/mile) and payload on the useful driving range of the vehicle is shown in Figure 6-4.

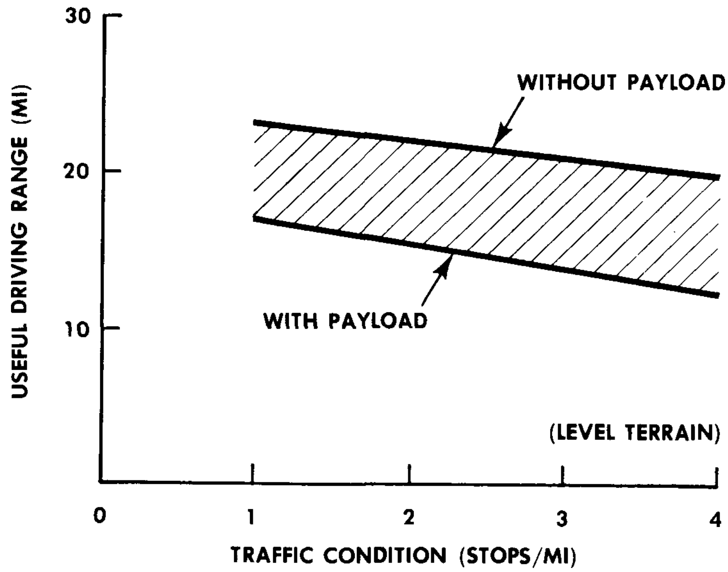

Figure 6-4. Effect of Traffic Conditions on Jet 750 Range.

The useful ranges in the freeway driving tests were 24.3 total miles without payload (19.7 miles freeway and 4.6 miles surface streets), and 20.6 total miles with payload (18.3 miles freeway and 2.3 miles surface streets).

Terrain and Payload Effect on Range

The effect of terrain and payload on useful vehicle range is shown in Figure 6-5.

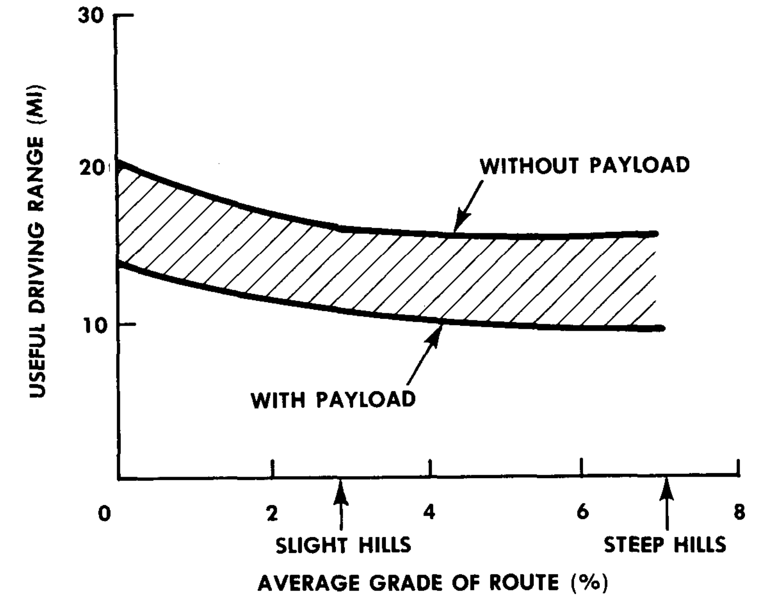

Figure 6-5. Effect of Terrain and Payload on Jet 750 Range.

Summary of Range Tests

Results of the individual range tests and test conditions are summarized in Table 6-2.

FIELD RELIABILITY

There were no component failures in 1000 miles of road testing. However, two batteries were replaced toward the end of the program because of "weak" cells (low specific gravity). This was prompted by a 24% reduction in range observed during the range-repeatability checks conducted near the end of the test program, but battery replacement did not improve vehicle performance.

Reliability Assessment

The absence of any component failures during the rigors of the test program suggests that reliable vehicle performance can be expected in the field. The significant reduction in useful driving range during the test program suggests degradation in range performance and short battery life may occur in field use.

Table 6-2
SUMMARY OF JET 750 RANGE TEST DATA

Test No.[a]	Description	With Maximum Payload[b]	Stops/ Mile[c]	Average Speed[d] (mph)	Ambient Temperature (°F)	Battery Temp (°F) Initial	Battery Temp (°F) Final	AC Energy Consumption (kWh/mi)	Range (mi)
4	Heavy traffic	No	4	16.6	60	94	120	1.48	19.5
3	Medium traffic	No	3	19.3	60	94	122	n.a.	20.5
3A	Repeatability	No	3	19.4	66	92	120	1.35	20.5
2	Light traffic	No	2	23.4	58	104	123	1.27	21.8
7	Highway	No	1	23.5	64	82	108	1.11	23.1
16	Freeway	No	0.2	55[e]	61	82	105	n.a.	24.3
8	Slight hills	No	7.8	13.9	70	94	118	1.52	16.0
9	Steep hills	No	3.4	19.0	70	88	112	1.65	15.5
4A	Heavy traffic	Yes	4	16.3	78	91	120	n.a.	11.7
10	Medium traffic	Yes	3	19.0	71	97	122	1.83	13.5
2A	Light traffic	Yes	2	24.7	70	106	138	1.62	16.5
7A	Highway driving	Yes	1	23.0	70	102	127	n.a.	17.0
16A	Freeway	Yes	0.2	53[e]	72	96	121	1.35	19.3
11	Slight hills	Yes	7.8	14.9	63	86	112	n.a.	11.0
12	Steep hills	Yes	3.4	18.8	70	90	115	2.30	9.7
17A	Weekend effect[f]	No	3	18.6	67	74	110	1.45	18.1
13B	Range repeatability	No	3	20.3	58	96	115	n.a.	15.5
13BB	Range repeatability	No	3	21.9	67	95	113	1.72	15.4
13A	J227ac	Yes	2.6	16.1	72	98	118	1.56	17.5

[a] SCE test identification number. Data are presented out of sequence for clarity.

[b] With maximum payload = tests at gross vehicle weight of 4600 lb (approximately 680-lb payload + 200-lb driver)

[c] Approximate average

[d] Average speed over route, including traffic signal stops

[e] Average cruise speed; actual speeds varied from 50 to 60 mph

[f] Lower initial electrolyte temperature due to standing idle for a weekend

n.a. Valid data not available (charger failed to turn off)

ENERGY CONSUMPTION

The AC energy consumption is shown for the various conditions of traffic, terrain, and payload in Figure 6-6. The charger had an automatic shut-off feature (designed to sense the rate of voltage change) that occasionally failed to function, causing high readings of AC energy consumption*.

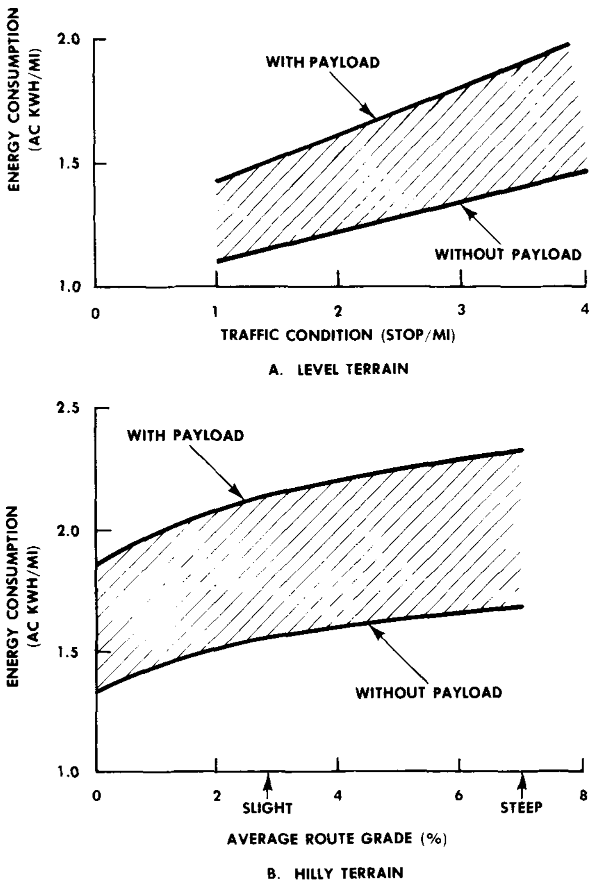

Figure 6-6. Jet 750 Energy Consumption.

* Although grossly high readings were deleted from the data base, AC energy consumption figures **may** be slightly high because of the uncertainty over charger operation. While it is also recognized that overcharge can shorten battery life, it is not believed to be the cause of the observed reduction in vehicle range because there was no significant rise in battery temperature observed during the occasions of charger shut-off failure.

DRIVER EVALUATIONS

The driver evaluations are summarized as follows:

a. Driving performance on city streets (acceleration, speed, hill climbing, and steering) was satisfactory for most drivers, at least most of the time, except for two opinions that the EV had insufficient power.
b. Although all drivers rated overall safety acceptable, the braking ability was of concern to half the drivers — especially at high speeds or with payload. Power reduction with range was also considered unsafe by one driver.
c. All but one driver felt job performance would be acceptable using the test vehicle.
d. Most drivers felt comfort features were adequate. Drivers most like the quiet ride, the gasoline-independence of the vehicle, and handling.
e. Drivers most disliked the limited range, power reduction with range, manual shift, and braking ability from high speeds.

Of the five SCE test drivers, one was willing to continue driving the vehicle and three were willing to continue only if changes were made. Since these three drivers disliked the power reduction with range, the vehicle might be acceptable to them for shorter missions.

CONCLUSIONS

The Jet 750 appears suited for limited transport roles involving large volume or lightweight cargos (up to 700 pounds) on all work routes including freeway travel and steep hills. Driver acceptance is expected to be generally fair. Driver acceptance for vehicle missions with a short driving range and light payloads (so that performance reductions are not noticeable) is expected to be better.

The useful driving range of the vehicle, as tested, is between 24 miles (level freeway with no payload) and 10 miles (in steep hills carrying maximum payload), with AC energy consumption between 0.7 and 2.3 kWh/mile, respectively.

It is expected that the vehicle will perform reliably in field service, although a significant degradation of range capability may occur early in battery life.

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Section 7
JET 1400 RESULTS

The test and evaluation results for the Jet Industries ElectraVan Model 1400 were derived from 1000 miles of road testing with SGL batteries.

PERFORMANCE TESTS

Top Speed

Top speed varied slightly with range and the maximum attained was 55 mph driving on the freeway without payload and with fully-charged batteries. Top-speed performance as a function of range can be seen in the speed profiles from selected road tests as shown in Figure 7-1.

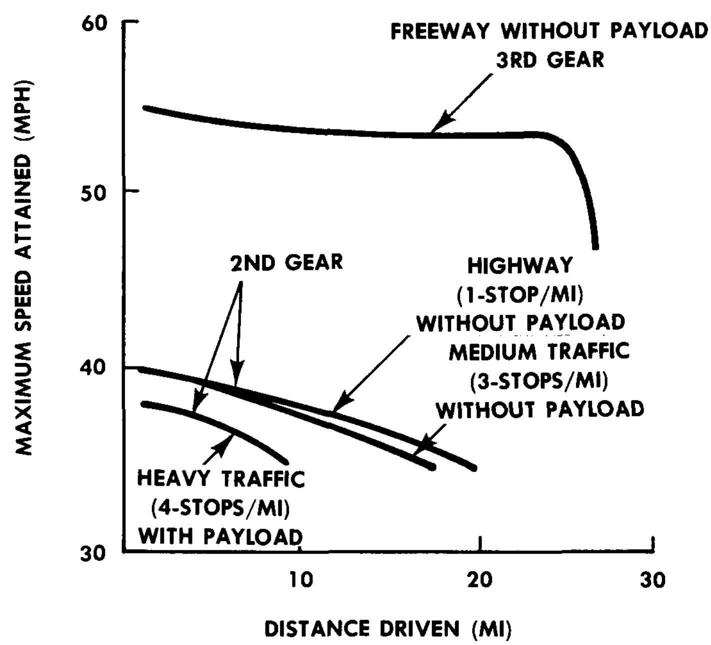

Figure 7-1. Jet 1400 Maximum Speed Versus Distance Driven.

Acceleration

Acceleration performance profiles are shown in Figures 7-2 and 7-3, and the elapsed times to achieve selected speeds with fully charged batteries are summarized in Table 7-1.

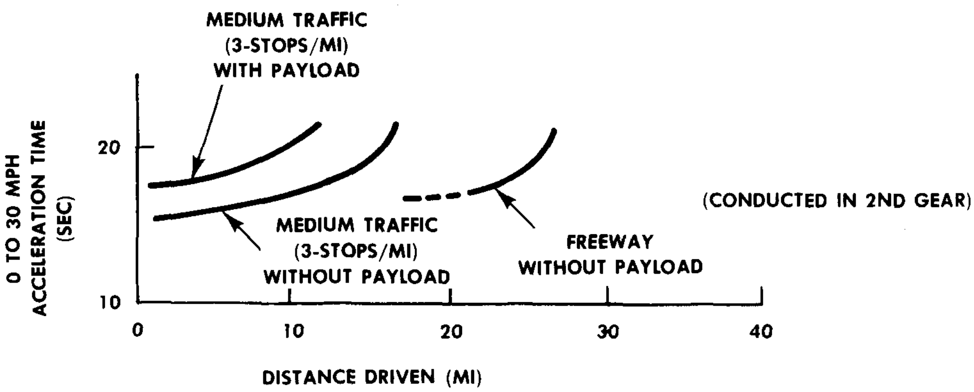

Figure 7-2. Effect of Distance Driven on Jet 1400 Acceleration Performance.

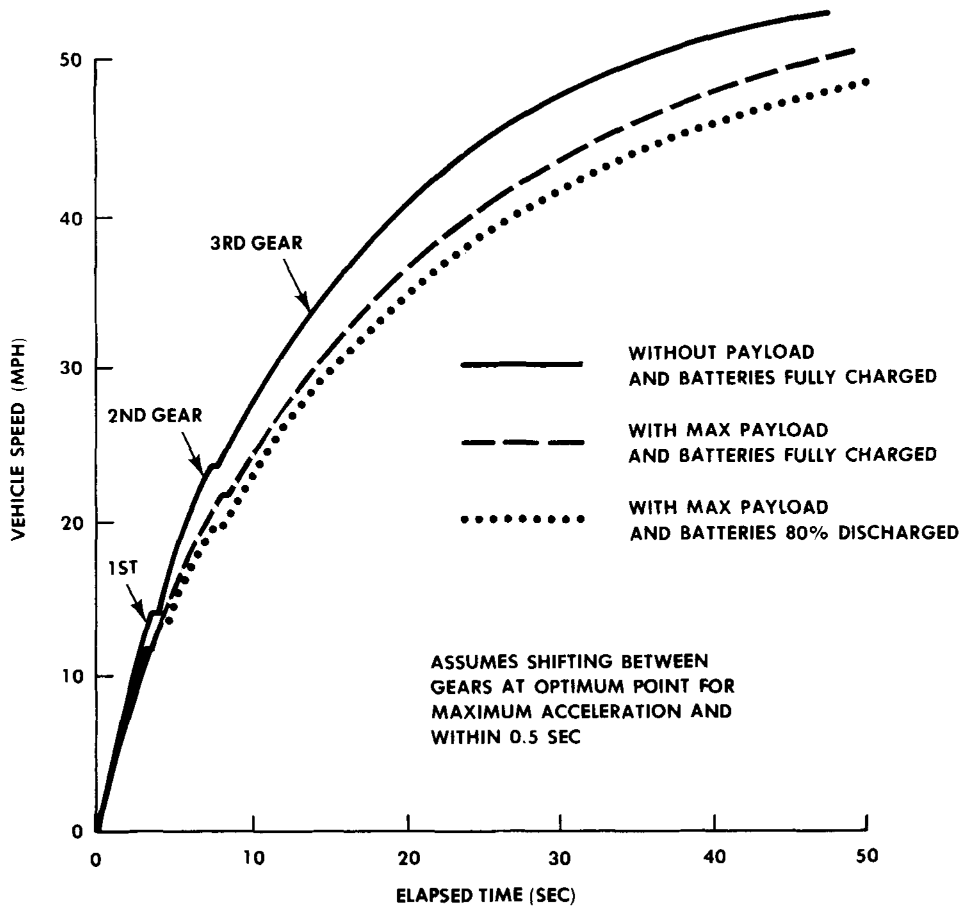

Figure 7-3. Jet 1400 Acceleration Profiles.

Table 7-1.
JET 1400 ACCELERATION TIMES.

Speed (mph)	Elapsed Time (sec) Without Payload Optimum	Without Payload 2nd Gear	With Max Payload Optimum	With Max Payload 2nd Gear
20	5.4	6.3	6.9	7.6
30	10.5	13.6	14.3	17.5
40	19.6	32.5	24.2	44.4
50	35.4	—	46.8	—

Traffic Conditions and Payload Effects on Range

The effect of traffic conditions (expressed in stops/mile) on the useful driving range of the vehicle is shown in Figure 7-4.

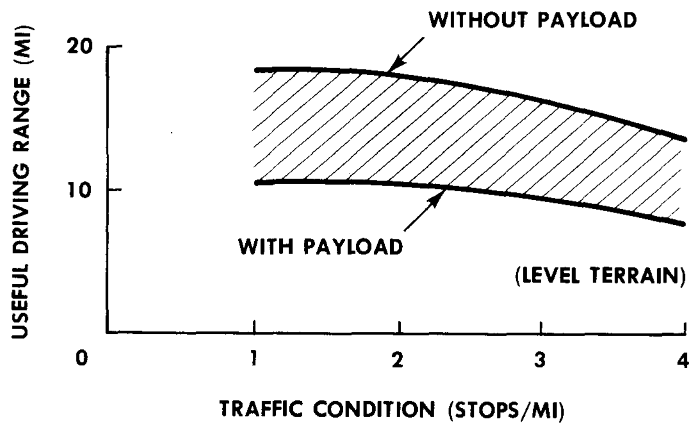

Figure 7-4. Effect of Traffic Conditions on Jet 1400 Range.

The useful ranges in the freeway driving tests were 25.8 total miles without payload (23.5 miles freeway and 2.3 miles surface streets), and 23.0 total miles with payload (20.3 miles freeway and 2.7 miles surface streets).

Terrain and Payload Effects on Range

The effect of terrain and payload on useful vehicle range is shown in Figure 7-5.

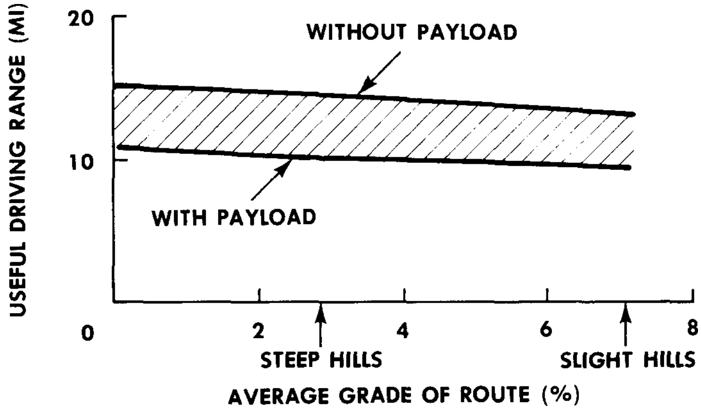

Figure 7-5. Effect of Terrain and Payload on Jet 1400 Range.

Summary of Range Tests

Results of the individual range tests and test conditions are summarized in Table 7-2.

FIELD RELIABILITY

There were no component failures in 1000 miles of road testing.

Reliability Assessments

The absence of any component failures during the rigors of the test program suggests that reliable vehicle performance can be expected in the field.

ENERGY CONSUMPTION

The AC energy consumption is shown in Figure 7-6 for various conditions of traffic, terrain, and payload.

DRIVER EVALUATIONS

The results of the driver evaluations are summarized as follows:

a. Driving performance on city streets (acceleration, speed, hill climbing, and steering) was satisfactory, at least most of the time, except for one opinion that the EV had insufficient power to mix with traffic.
b. Opinions on vehicle safety were divided. Although most drivers felt safety was acceptable, they felt the vehicle was not as safe overall as their regular vehicle, and particularly regarding power and braking.

Table 7-2.
SUMMARY OF JET 1400 RANGE TEST DATA

Test No.[a]	Description	With Maximum Payload[b]	Stops/ Mile[c]	Average Speed[d] (mph)	Ambient Temperature (°F)	Battery Temp (°F) Initial	Battery Temp (°F) Final	AC Energy Consumption (kWh/mi)	Range (mi)
4	Heavy traffic	No	4	13.0	78	92	112	1.58	13.6
3	Medium traffic	No	3	16.4	97	90	120	1.26	15.2
6	Driving Style	No	3	15.0	84	n.a.	114	1.20	19.8
2	Light traffic	No	2	21.2	84	81	112	1.10	18.4
7	Highway	No	1	25.1	95	88	117	0.93	18.0
16	Freeway	No	0.2	53[e]	90	94	119	1.03	25.8
8	Slight hills	No	7.8	12.7	90	100	118	n.a.	16.1
9	Steep hills	No	3.4	16.4	82	90	120	1.43	14.2
4A	Heavy traffic	Yes	4	15.6	84	89	115	1.51	7.6
10	Medium traffic	Yes	3	18.6	86	92	118	1.33	9.1
2A	Light traffic	Yes	2	24.2	96	88	116	1.25	10.3
7A	Highway driving	Yes	1	20.7	88	88	110	1.20	10.2
16A	Freeway travel	Yes	0.2	51[e]	90	90	116	1.18	23.0
11	Slight hills	Yes	7.8	13.3	88	84	122	1.58	10.1
12	Steep hills	Yes	3.4	15.8	88	83	120	1.60	9.5
17A	Weekend effect[f]	No	3	19.2	88	78	114	1.34	14.5
13B	Range repeatability	No	3	19.6	79	92	118	1.23	17.5
13BB	Range repeatability	No	3	19.6	85	88	120	n.a.	16.7
13A	J227ac	Yes	2.6	16.5	90	96	125	1.15	19.1

[a] Test data are presented out of sequence for clarity.
[b] With maximum payload = tests at gross vehicle weight of 6660 lb (approximately 1000-lb payload + 200-lb driver)
[c] Approximate average
[d] Average speed over route, including traffic signal stops
[e] Average cruise speed; actual speeds varied from 40 to 55 mph
[f] Lower initial electrolyte temperature due to vehicle standing idle for a weekend
n.a. Data not available

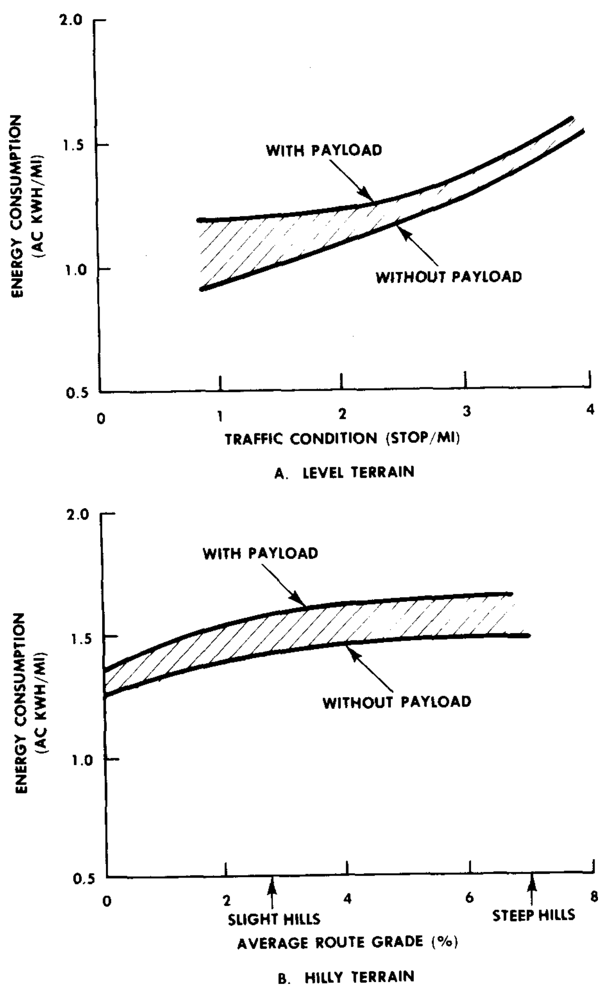

Figure 7-6. Jet 1400 Energy Consumption.

c. Most drivers felt job performance would be about the same, although driving would be at a slightly slower speed.
d. Opinions regarding driver comfort were divided. Drivers most liked the smooth and quiet ride and the non-polluting nature of the vehicle.
e. Drivers most disliked the low power, limited range, and absence of driver comforts (e.g., radio, air conditioning, and power steering).

Of the five SCE test drivers interviewed, one stated he would be willing to continue driving the vehicle, and three would be willing to drive it if changes were made to the vehicle (more power and greater range).

CONCLUSIONS

The Jet 1400 appears suited for personnel transport roles involving up to seven passengers (in addition to driver) and limited cargo (e.g., baggage), on all work routes including limited freeway travel and steep hills. The large size of the vehicle may be less than optimum for service roles involving few passengers, little payload, or involving tight parking and maneuvering. Driver acceptance is expected to be fair — the slow acceleration characteristic of the vehicle may be unacceptable for many drivers.

The maximum useful range, as tested, was between 25 miles (on level freeway with no payload) and 8 miles (carrying maximum payload in heavy traffic), with AC energy consumptions between 1.0 and 1.6 kWh/mile, respectively.

Based on the apparent reliability of the propulsion system and other components, the vehicle is expected to be reliable in field operation.

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Section 8
LUCAS VAN RESULTS

The test and evaluation results for the Lucas-Bedford CFE Cargo Van were derived from 1500 miles of road testing with Lucas batteries.

PERFORMANCE TESTS

Top Speed

Top speed varied insignificantly with range, and the maximum attained was 54 mph driving on the freeway without payload and with fully-charged batteries. Top-speed performance as a function of range can be seen in the speed profiles shown in Figure 8-1.

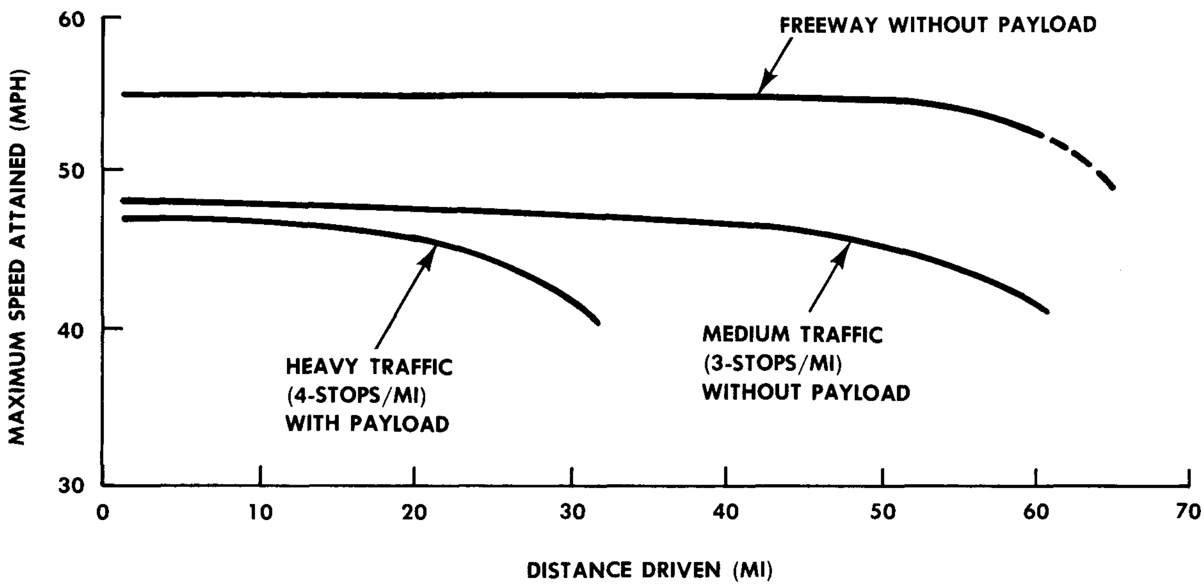

Figure 8-1. Lucas Van Maximum Speed Versus Distance Driven.

Acceleration

Acceleration performance profiles are shown in Figures 8-2 and 8-3, and the elapsed times to achieve selected speeds with fully charged batteries are summarized in Table 8-1.

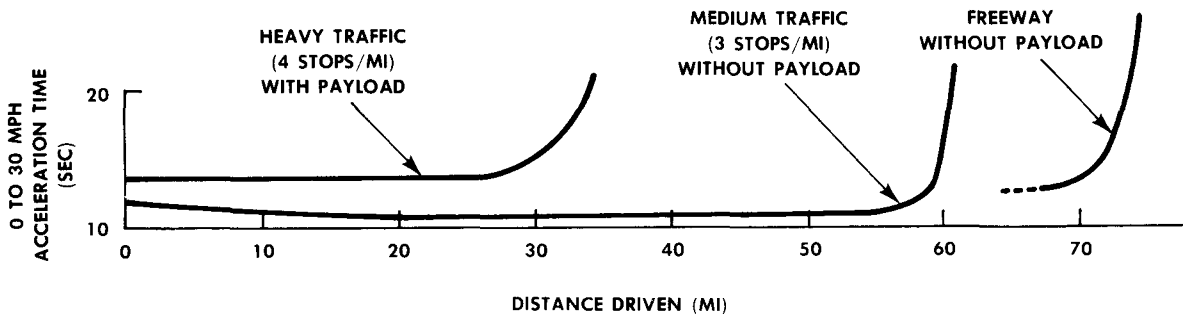

Figure 8-2. Effects of Distance Driven on Lucas Van Acceleration Performance.

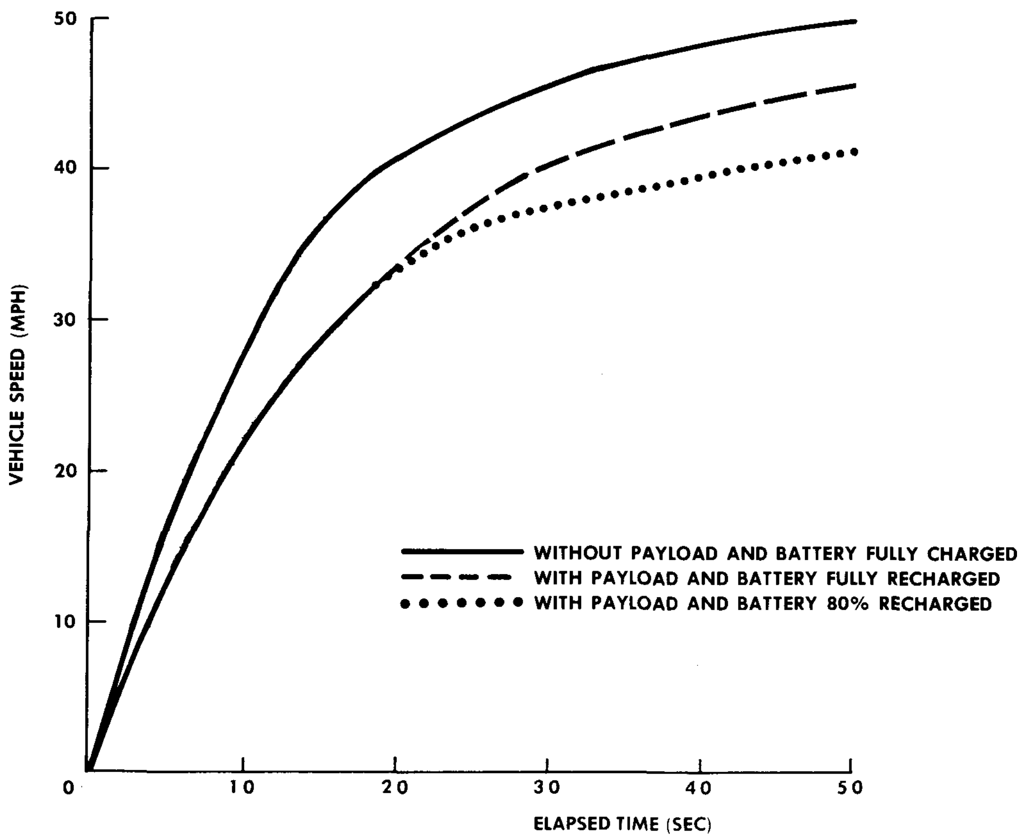

Figure 8-3. Lucas Van Acceleration Profiles.

Table 8-1.
LUCAS VAN ACCELERATION TIMES.

Speed (mph)	Elapsed Time (sec) Without Payload	With Max Payload
20	6.2	8.8
30	11.2	16.4
40	18.7	40.8
50	49.8	—

Traffic Conditions and Payload Effects on Range

The effect of traffic conditions (expressed in stops/mile) on the useful driving range of the vehicle is shown in Figure 8-4.

The useful ranges in the freeway driving tests were 73.9 total miles without payload (66.4 miles freeway and 7.5 miles surface streets), and 63.9 total miles with payload (57.9 miles freeway and 6.0 miles surface streets).

Terrain and Payload Effects on Range

The effect of terrain and payload on useful vehicle range is shown in Figure 8-5.

Summary of Range Tests

Results of the individual range tests and test conditions are summarized in Table 8-2.

FIELD RELIABILITY

There were three failures of the main controller fuse in 1500 miles of road testing. Based on disassembly and examination of two fuses, these failures were apparently due to fatigue failures in the metal fuse elements.*

The Lucas controller had a creep function that enabled the vehicle to be slowly pulled off the road following fuse failure, which was a desirable safety feature.

* Each fuse contained three parallel current-carrying elements having small, notched, cross-sections (on the order of one millimeter across). Fatigue failure of one of the three current-carrying elements was followed by thermal failure of the remaining two.

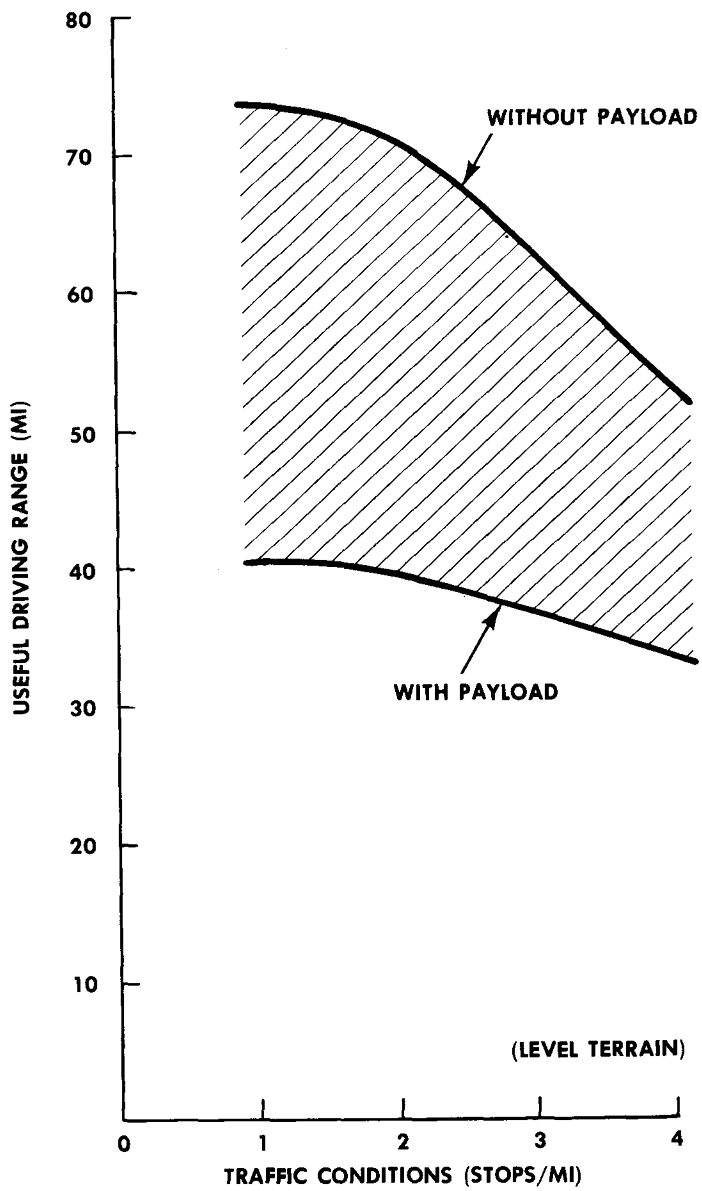

Figure 8-4. Effect of Traffic Conditions on Lucas Van Range.

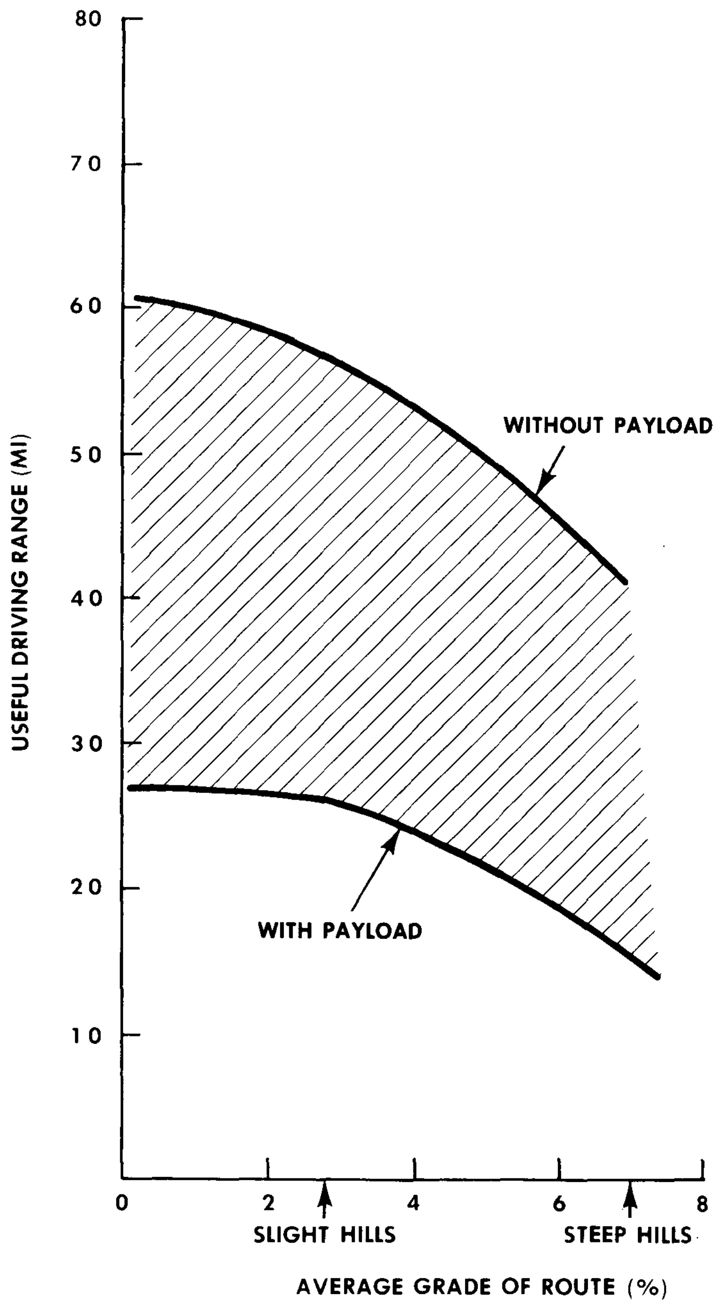

Figure 8-5. Effect of Terrain and Payload on Lucas Van Range.

Table 8-2.
SUMMARY OF LUCAS VAN RANGE TEST DATA

Test No.[a]	Description	With Maximum Payload[b]	Stops/ Mile[c]	Average Speed[d] (mph)	Ambient Temperature (°F)	Battery Temp (°F) Initial	Battery Temp (°F) Final	AC Energy Consumption (kWh/mi)	Range (mi)
4	Heavy traffic	No	4	18.2	100	96	110	1.10	53.5
3	Medium traffic	No	3	20.3	93	106	116	0.99	60.8
3A	Repeatability	No	3	21.3	98	104	118	n.a.	60.8
2	Light traffic	No	2	20.8	90	103	116	0.83	71.7
7	Highway	No	1	30.3	83	102	110	0.70	72.8
16	Freeway	No	0.2	54[e]	70	87	105	0.77	73.9
8	Slight hills	No	7.8	12.7	85	94	114	n.a.	37.2[f]
9	Steep hills	No	3.4	18.2	82	98	116	n.a.	40.6
4A	Heavy traffic	Yes	4	17.8	88	90	116	1.33	33.7
10	Medium traffic	Yes	3	19.6	90	92	108	n.a.	36.5
2A	Light traffic	Yes	2	23.5	68	85	102	1.15	40.0
7A	Highway driving	Yes	1	27.4	65	84	102	n.a.	40.0
16A	Freeway travel	Yes	0.2	52[e]	79	84	102	0.81	63.9
11	Slight hills	Yes	7.8	13.3	70	88	119	1.77	26.3
12	Steep hills	Yes	3.4	16.2	70	86	107	1.84	15.4
17A	Weekend effect[g]	No	3	21.1	85	82	108	1.04	52.9
13B	Range repeatability	No	3	21.3	68	102	112	n.a.	56.5
13BB	Range repeatability	No	3	22.0	70	102	106	1.02	54.1
13A	J227ac	Yes	2.6	15.8	65	96	110	0.94[h]	44.7

[a] Test data are presented out of sequence for clarity.

[b] With maximum payload = tests at gross vehicle weight of 7716 lb (approximately 1800-lb payload + 200-lb driver)

[c] Approximate average

[d] Average speed over route, including traffic signal stops

[e] Average cruise speed; actual speeds varied from 48 to 59 mph

[f] Regenerative braking operating improperly

[g] Lower initial electrolyte temperature due to vehicle standing idle for a weekend

[h] Estimated (charging problem)

n.a. Data not available due to circuit breaker trip during charging

Reliability Assessment

The absence of any failures in major components of the propulsion system during the rigors of the test program suggests that the inherent reliability of the propulsion system is good. The controller fuse, however, appears prone to fatigue failures (because of the notched-element design with small cross section), and repetitive failures can be expected to occur in the field. The need for an improved fuse (with more fatigue-resistant elements) is indicated.

ENERGY CONSUMPTION

The AC energy consumption is shown in Figure 8-6 for various conditions of traffic, terrain, and payload.

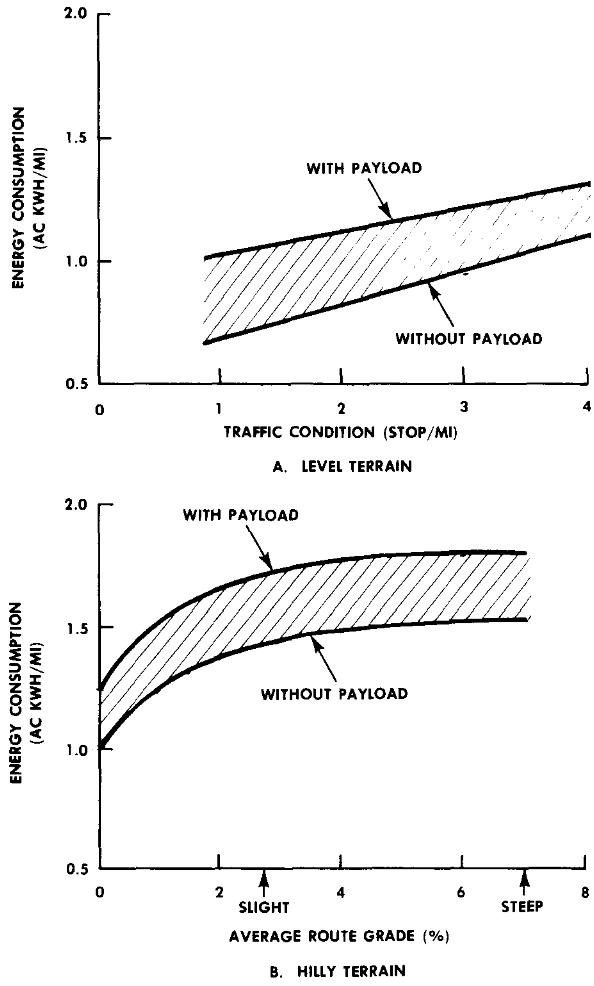

Figure 8-6. Lucas Van Energy Consumption.

DRIVER EVALUATIONS

The results of the driver evaluations are summarized as follows:

a. Driving performance on city streets (acceleration, speed, hill climbing, and steering) was satisfactory for most drivers, at least most of the time, except for one opinion that the EV had insufficient power to mix with traffic.
b. Drivers' opinions on vehicle safety were divided. Although most drivers felt safety was acceptable, two drivers felt unsafe in the vehicle because of reduced power, braking, and visibility.
c. Most drivers felt job performance would be slightly reduced using the test vehicle.
d. Drivers' opinions regarding driver comfort were divided. Drivers most liked the quiet ride, the gasoline-independent nature of the vehicle, and handling.
e. Drivers most disliked the right-hand drive and poor visibility (which affected their feeling of safety), and low power.

Of the five SCE test drivers one would be willing to continue to drive the vehicle, and two only if changes were made to the vehicle (left-hand drive, increased visibility, and increased power).

CONCLUSIONS

The Lucas Bedford CFE Van appears suited for transport roles involving large volume or high weight cargos (2000 pound), on all work routes including freeways and steep hills. The large size of the vehicle is likely to be less than optimal for service roles involving little payload, or tight parking and maneuvering situations. Driver acceptance is expected to be fair. Driver acceptance would be better if the vehicle had a standard left-hand drive.

The useful range of the vehicle, as tested, is between 74 miles on level freeway without payload and 15 miles in steep hills carrying maximum payload, with AC energy consumption between 0.8 and 1.8 kWh/mile, respectively.

Although the inherent reliability of the major propulsion system components appears to be good, repetitive failures of the controller fuse can be expected in field service.

Appendix A
VEHICLE SPECIFICATIONS AND OPERATIONAL CHARACTERISTICS

This appendix contains additional information on each test vehicle.

The specifications were those taken from the actual test vehicle, primarily to identify the components. Since EVs in general are constantly being refined and redesigned, it is not uncommon for manufacturers to change components or their design without notification. The reader is therefore cautioned that the results obtained apply only to a vehicle with these components and specifications, which may differ from later models of the same vehicle.

The following 12 physical/operational characteristics of the vehicle were measured to assist in describing the vehicle and evaluating its suitability for various service roles:

1. Ground Clearance — Measured with and without payload at the lowest points under the front, middle, and rear of the vehicle.
2. Speed Bump Test — Tests were conducted in increments of 5 mph up to 25 mph (the highest speed likely to encounter speed bumps) to determine the safe speed at which a 3-1/2-inch-high asphalt "speed bump" could be crossed without bottoming out, loss of steering control, or otherwise affecting normal vehicle operation.
3. Turning Diameter — The minimum diameter within which the vehicle could turn was measured.
4. Fuel Gauge Accuracy — The correlation of the battery "fuel gauge" readings to useful range were measured.
5. Recharge Time — The time required to restore the propulsion batteries to fully charged condition, based on charger tests and the discharge levels during normal vehicle operation.
6. Battery Service Time — The elapsed time and frequency of service found necessary to service the battery (checking specific gravity, adding water, and wiping down surfaces) during the test program was reported for each vehicle.
7. Cargo Volume — The unobstructed internal dimensions and the volume available for cargo were reported. In some cases the "permanently usable" cargo volume was less than the total volume because removal of internal floor covers for access to batteries (for servicing) was necessary, and this was noted.
8. Loading Height — The minimum height of the cargo floor above the ground at a loading door was measured.

9. Interior Noise — Measurements in the cab were made 12 inches away from the driver's right ear with a General Radio No. 156-8-sum sound meter. Tests were conducted with all windows open, and with windows closed, on a smooth and level asphalt street (with no buildings, other vehicles, or obstacles within 50 feet), in four vehicle operational modes: (1) maximum db during maximum acceleration to 20 mph, (2) 30-mph steady cruise, (3) 45-mph steady cruise, and (4) 55-mph steady cruise.
10. Door Opening — The opening dimensions and swing angle of the driver's door were measured.
11. Steering Torque — The maximum torque required to turn the steering wheel (lock to lock) on a smooth, dry concrete slab was measured.
12. Stopping Distance — The stopping distance on a smooth and level asphalt street, with and without payload, from 40 mph was measured for four tests in each direction and the average was reported.

JET 007

SPECIFICATIONS

Name: Electrica Model 007, Manufactured: December 1979
Manufacturer: Jet Industries, 7101 Burleson, Austin, Texas 78741
Serial Number (chassis): CWY 11766

Weight: 3970 G.V.W.
-3510 O.E.W.
460-lb difference: 290-lb payload + 170-lb driver

Dimensions: 173 inches long, 66 inches wide, 51 inches high, 97 inch wheelbase

Motor: General Electric Series-wound DC Model 5BT1346B46
23 HP, 99.4 volts, 18.5 amps, 3285 rpm, Class-H.
9 inches diameter x 18 inches long, 160 lb

Battery Pack: Ratings: 120 volts, 32.4 whr/kg at 75-amp rate.
20 Exide Model XPV-23 Lead-Acid Batteries. New
(600 miles when received), Weight: 1280 lb

Accessories Battery: Exide HC-24, Number: 1
Volts: 12, Age: New

Controller: General Electric Model EV-1, Type: SCR
Rating: 120 volts, 500 ADC without regenerative braking

Charger: Lester, off-board. Model 120LCR25-5ET, Ferro-resonant type,
240 volts AC (single phase) 20 amp max input,
150 volts DC 25 amps output (max)

Transmission: Type: 4-speed manual with clutch, Mfg by: Toyo Kogyo

Tires: Firestone P165/75R13 Radial, Cold inflation pressure: 45 psi
Rolling radius: 10.8 inches

OPERATIONAL CHARACTERISTICS

Ground Clearance — Measurements to the ground (in inches) from lowest part of the vehicle were as follows:

Contents	Front	Middle	Rear
Driver only	5.8	6.8	6.3
Driver and payload	5.8	6.3	5.8

The lowest point of the loaded vehicle was the rear cross member.

Speed Bump Test — No bottoming or control problems occurred at speeds up to 25 mph.

Turning Diameter — The vehicle could turn with clearance within a 34-foot-diameter circle.

Fuel Gauge Accuracy — The vehicle was equipped with a battery capacity gauge similar to an ICE "fuel gauge." The gauge read from 100% to 0% and its correlation to the fraction of usable range remaining is shown for selected road tests in Figure A-1.

Recharge Time — In normal vehicle operation (i.e., driving 60% to 80% of maximum range each day), the battery recharge time was approximately 10 to 12 hours on 240 VAC.

Battery Service Time — The batteries generally required the addition of water every two weeks, which required 20 minutes. Complete battery servicing (recommended every month) included checking the specific gravity, watering, and wiping down surfaces, and required an additional 40 minutes.

Cargo Volume — The unobstructed dimensions of the cargo compartment behind the rear seat were approximately 6 to 12 inches high by 48 inches wide by 32 inches deep. With the rear seat folded down, there was a 30-inch-high by 51-inch-wide by 20-inch-deep volume behind the front seat, or 17 cubic feet was permanently usable; i.e., there was no need to remove the cargo for access to the batteries for servicing.

Loading Height — The loading height was 30 inches above the rear cargo door.

Interior Noise — The maximum weighted sound levels (db) were measured as shown in Table A-1.

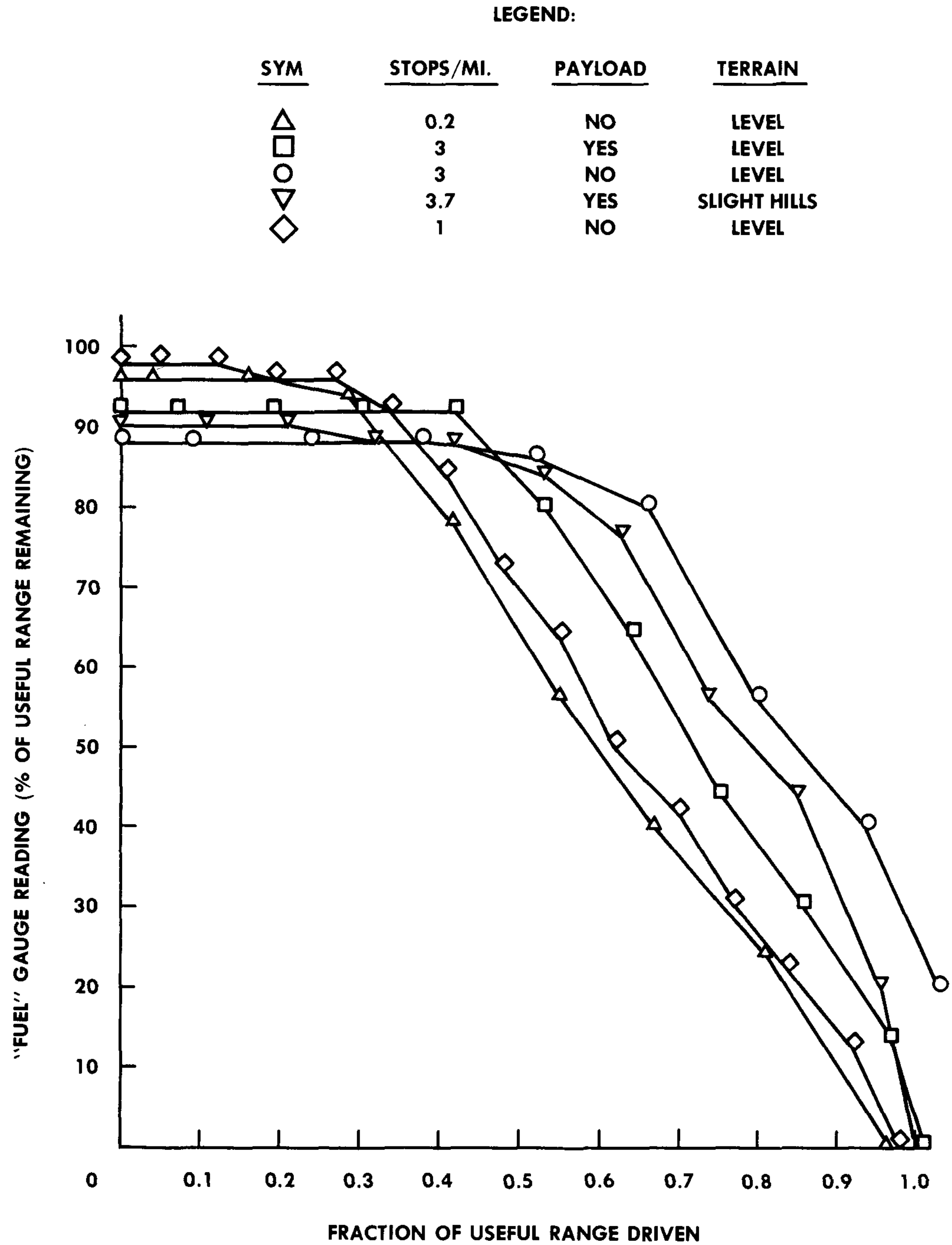

Figure A-1. Jet 007 Battery "Fuel" Gauge Range Correlation.

Table A-1
NOISE LEVELS INSIDE JET 007
(Max dbA)

Vehicle Operation Mode	Windows Open	Windows Closed
Max acceleration to 20 mph	67	65
30-mph steady cruise	69	66
45-mph steady cruise	73	70
55-mph (freeway)	80	71

Door Opening — The driver's door swung open approximately 75°, with opening dimensions of 34 inches high by 48 inches wide.

Steering Torque — The torque required to turn the steering wheel was 36 pound-inches.

Stopping Distance — The average stopping distance from 40 mph was 70 feet with driver only and 87 feet with payload.

JET 750

SPECIFICATIONS

Name: ElectraVan Model 750, Manufactured: December 1979
Manufacturer: Jet Industries, 7101 Burleson, Austin, Texas 78741
Serial Number (chassis): CWY 11766

Weight: 4600 G.V.W.
-3720 O.E.W
880-lb difference: 710-lb payload + 170-lb driver

Dimensions: 180 inches long, 64 inches wide, 60 inches high, 108 inch wheelbase

Motor: General Electric Series-wound DC Model 5BT1346B46
23 HP, 99.4 volts, 18.5 amps, 3285 rpm, Class-H,
9 inches diameter x 18 inches long, 160 lb

Battery Pack: Ratings: 120 volts, 32.4 whr/kg at 75-amp rate,
20 Exide Model XPV-23 Lead-Acid Batteries, New
(300 miles when received), Weight: 1280 lb

Accessories Battery: Exide HC-24, Number: 1, Volts: 12, Age: New

Controller: General Electric Model EV-1, Type: SCR,
Rating: 120 volts, 500 ADC, without regenerative braking

Charger: Lester, off-board, Model 120LCR25-5ET, Ferro-resonant type,
240 volts AC (single phase) 20 amp max input,
150 volts DC 25 amps output (max)

Transmission: Type: 4-speed manual with clutch, Mfg by: Toyo Kogyo

Tires: Remington 6.00x14 LT bias-ply, Cold inflation pressure: 45 psi
Rolling radius: 12.5 inches

OPERATIONAL CHARACTERISTICS

Ground-Clearance — Measurements to the ground (in inches) from the lowest part of the vehicle were as follows:

Contents	Front	Middle	Rear
Driver only	7.5	9.0	7.5
Driver and max payload	7.5	8.1	7.4

The lowest point of the vehicle was the bottom of the differential.

Speed Bump Tests — No bottoming or steering control problems occurred at speeds up to 25 mph.

Turning Diameter — The vehicle could turn with clearance within a 41-foot 2-inch diameter circle.

Fuel Gauge Accuracy — The vehicle was equipped with a battery capacity gauge similar to an ICE "fuel gauge." The gauge read from 100% to 0% and its correlation to the fraction of usable range remaining is shown for selected road tests in Figure A-2.

Recharge Time — In normal vehicle operation the vehicle recharge time was 8 to 10 hours, recharging on 240 VAC.

Battery Service Time — The batteries usually required the addition of water every two weeks, which required 20 minutes. Complete battery servicing (recommended every month) included checking the specific gravity, watering, and wiping down surfaces and required an additional 40 minutes.

Cargo Volume — The usable interior dimensions of the truck bed were 49 inches long by 58 inches wide by 16 inches deep (approximately 26 cubic feet). This volume was permanently usable; i.e., the cargo did not need to be removed for access to the batteries for servicing.

Loading Height — The loading height was 26 inches above the ground at the tailgate.

Interior Noise — The A-weighted sound levels (db) were measured as shown in Table A-2.

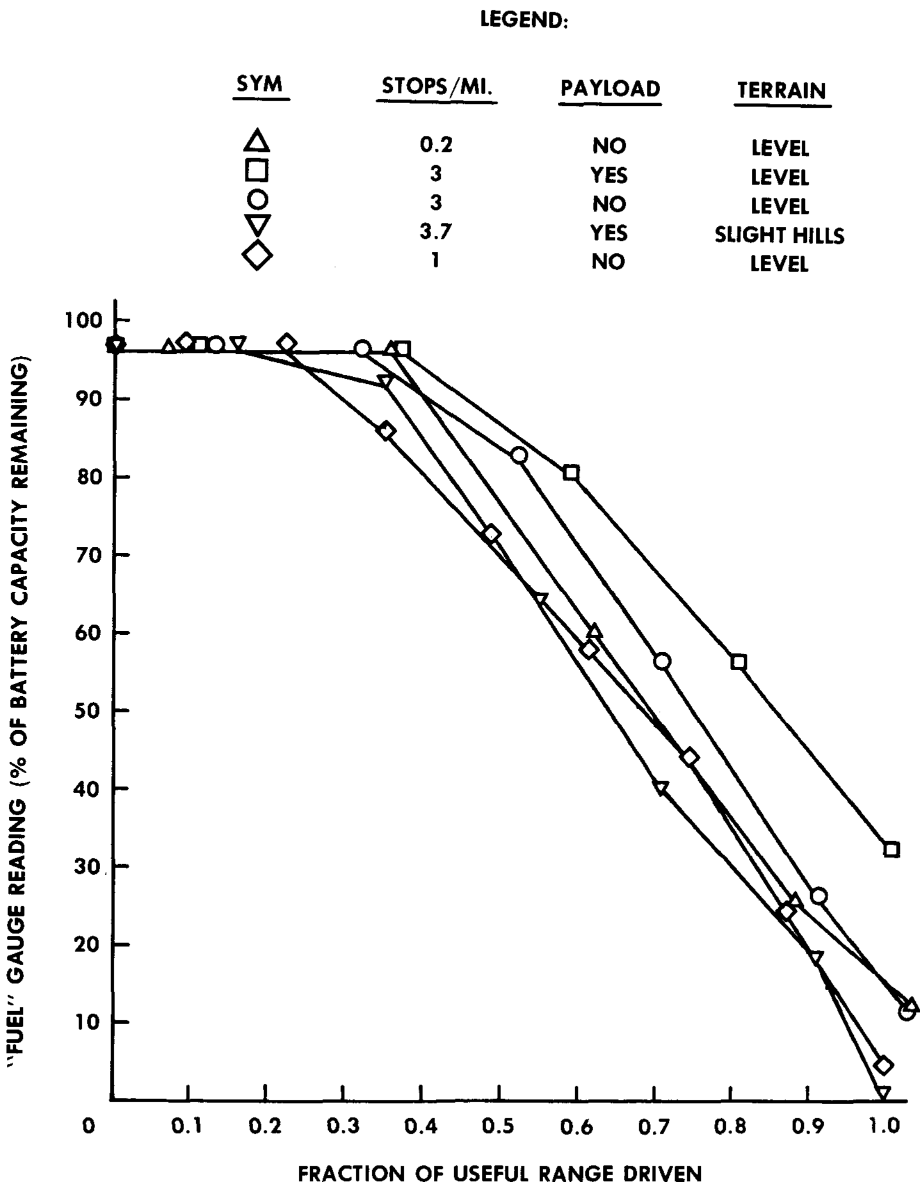

Figure A-2. Jet 750 Battery "Fuel" Gauge Range Correlation.

Table A-2
NOISE LEVELS INSIDE JET 750
(Max dbA)

Vehicle Operation Mode	Windows Open	Windows Closed
Max acceleration to 20 mph	69	67
30-mph steady cruise	70	67
45-mph steady cruise	75	72
55-mph (freeway)	80	76

Door Opening — The driver's door swung open approximately 75°, with opening dimensions of 40 inches high by 30 inches wide.

Steering Torque — The torque required to turn the steering wheel was 24 pound-inches.

Stopping Distance — The average stopping distance from 40 mph was 78 feet with driver only and 86 feet with maximum payload.

JET 1400

SPECIFICATIONS

Name: ElectraVan Model 1400, Manufactured: May 1979
Manufacturer: Jet Industries, Inc., 7101 Burleson, Austin, Texas 78741
Serial Number (chassis): B22JE9X182554

Weight: 6660 lb G.V.W.
-5460 lb O.E.W.
1200-lb difference: 1030-lb payload + 170-lb driver

Dimensions: 179 inches long, 79 inches wide, 77 inches high, 109 inch wheelbase

Motor: General Electric Model 53T1366981
HP-37, Volts-126, Amps-230, RPM-2030, Class-CLH
Dimensions - 11 inch diameter, 18 inches long, 255 lb

Battery: SLG Deep Cycle Group No. GC-2, Number: 24, Volts: 6, Age: New,
Weight: 62 lb ea. (approx.), Rating: 180 AH at 2 hr rate

Accessories Battery: Exide HC-24, Number: 1, Volts: 12, Age: New

Controller: General Electric Model EV-1, Number: 2C5C10EAD
Voltage: 450, Current: 500 Amp, without regenerative braking

Charger: General Electric, off-board, Model CR178 EVSP44, SCR Type,
Input: 208 VAC at 30 amps to 240 VAC at 20 amps
Output: 178 VDC at 25 amps (initial rate)

Transmission: Dodge 3-speed manual No. C11542A, Ratios: 2.99/1.77/1.00

Tires: Goodyear 4L 78x15 bias-ply, cold inflation pressure 40 psi,
rolling radius 13.8 inches

OPERATIONAL CHARACTERISTICS

Ground Clearance — Measurements to the ground (in inches) from lowest part of the vehicle were as follows:

Contents	Front	Middle	Rear
Driver Only	7.1	13.3	8.4
Driver and Maximum Payload	6.8	12.4	8.1

The lowest point on the vehicle was the bottom of the A-frame arm.

Speed Bump Tests — No bottoming or control problems occurred up to 25 mph.

Turning Diameter — The vehicle could turn with clearance within a 43-foot-diameter circle.

Fuel Gauge Accuracy — The vehicle was equipped with a battery capacity gauge similar to an ICE "fuel gauge." The gauge read from 100% to 0% and its correlation to the fraction of usable range remaining is shown for selected road tests in Figure A-3.

Recharge Time — In normal vehicle operation the recharge time was 8 to 10 hours on 240 VAC.

Battery Service Time — The batteries usually required the addition of water every two weeks, which required 30 minutes. Complete battery servicing (recommended every two months) included adding water and wiping down surfaces, which required an additional 30 minutes.

Cargo Volume — The dimensions of the interior compartment were 52 inches high by 63 inches wide by 96 inches deep (approximately 180 cubic feet if the rear seats were removed). Of this volume, 38 cubic feet was usable for luggage, but needed to be removed for access to the batteries for sevricing.

Loading Height — The loading height was 24 inches above the ground, at the side doors.

Interior Noise — The A-weighted sound levels were measured as shown in Table A-3.

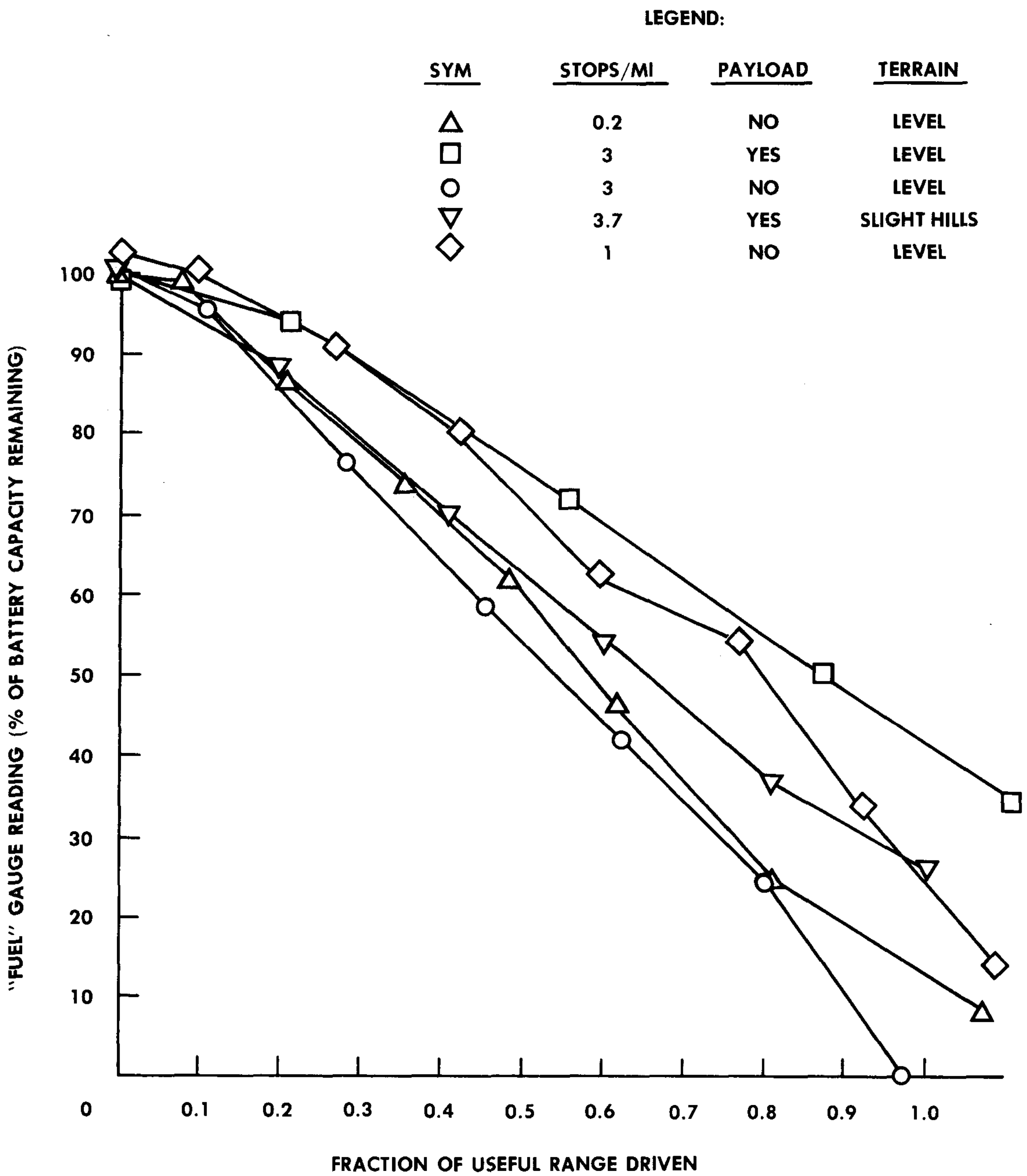

Figure A-3. Jet 1400 Battery "Fuel" Gauge Range Correlation.

Table A-3
NOISE LEVELS INSIDE JET 1400 VAN
(Max dbA)

Vehicle Operation Mode	Windows Open	Windows Closed
Max acceleration to 20 mph	68	66
30-mph steady cruise	68	66
45-mph steady cruise	74	69
55-mph (freeway	75	72

Door Opening — The driver's door swung open approximately 60°, with opening dimensions of 57 inches high by 41 inches wide.

Steering Torque — The torque required to turn the steering wheel was 160 pound-inches.

Stopping Distance — The average stopping distance from 40 mph was 81 feet with driver only and 93 feet with maximum payload.

LUCAS VAN

SPECIFICATIONS

Name: Lucas Bedford Electric Van, Manufactured: March 1979
Manufacturer: Lucas Batteries Ltd., Electric Vehicle Project
Evelyn Road, Sparkhill, Birmingham, England
Serial Number (chassis): LBV 0005

Weight: 7716 G.V.W.
-5511 O.E.W.
2205-lb difference: 2035-lb payload + 170-lb driver

Dimensions: 168 inches long, 88 inches wide (including mirrors),
78 inches high, 106 inch wheelbase

Motor: Lucas Series-wound DC Model MT286, 50 HP, 216 volts, 400 amps,
4500 rpm, Class-F, 11.26 inches diameter x 21 inches long, 312 lb

Battery Pack: Ratings:216 volts, 180 AH at 2 hr rate, 36 Lucas Model EV5 Lead-Acid Batteries,
New — 26 cycles, (when received), Weight: 2205 lb without frame

Accessories Battery: Lucas A13, Number: 1, Volts: 12, Age: New

Controller: Lucas Model MK2 Series, Type: Chopper,
Rating: 216 volts, 400 ADC, with regenerative braking

Charger: Lucas, off-board, 240 volts AC (single phase) 45 amp input,
276 volts DC 30 amps output, 3-step constant-current rate control

Transmission: Lucas double-reduction Morse chain

Tires: Michelin 205x14 8-ply, cold inflation pressure: 65 psi front, 75 psi rear
Rolling radius: 12.9 inches

OPERATIONAL CHARACTERISTICS

Ground Clearance — Measurements to ground (in inches) from the lowest part of the vehicle were as follows:

Contents	Front	Middle	Rear
Driver only	7.3	7.0	6.3
Driver and maximum payload	7.3	5.8	6.0

The lowest point on the vehicle was the bottom of the battery pack.

Speed Bump Tests — No bottoming or control problems occurred up to 25 mph.

Turning Diameter — The vehicle could turn with clearance within a 34-foot 4-inch diameter circle.

Fuel Gauge Accuracy — The vehicle was equipped with a battery capacity gauge similar to an ICE "fuel gauge." The gauge read from 100% to 0% and its correlation to the fraction of usable range remaining was shown for selected road tests in Figure A-4.

Recharge Time — In normal operation the recharge time was 11 to 12 hours on 240 VAC.

Battery Service Time — The batteries usually required the addition of water every two weeks, a procedure which required approximately 3 hours. The lengthy battery service time resulted from (1) the necessity of jacking up the rear of the vehicle to permit battery pack removal from underneath the vehicle (Figure A-5), (2) use of the airbag battery-lifting device (Figure A-6) without its centering fixture (and unfamiliarity with the lift system/procedure), and (3) the number of cells (108) needing service. Complete battery servicing is recommended (i.e., checking the specific gravity and cleaning the battery surfaces thoroughly), each time the batteries are watered and which requires approximately an additional hour.

Cargo Volume — The dimensions of the cargo compartment were 48 inches high by 67 inches wide by 90 inches deep (approximately 165 cubic feet). This volume was permanently usable; i.e., the cargo did not need to be removed for access to the batteries for servicing.

Loading Height — The loading height was 25 inches above the ground at the rear door.

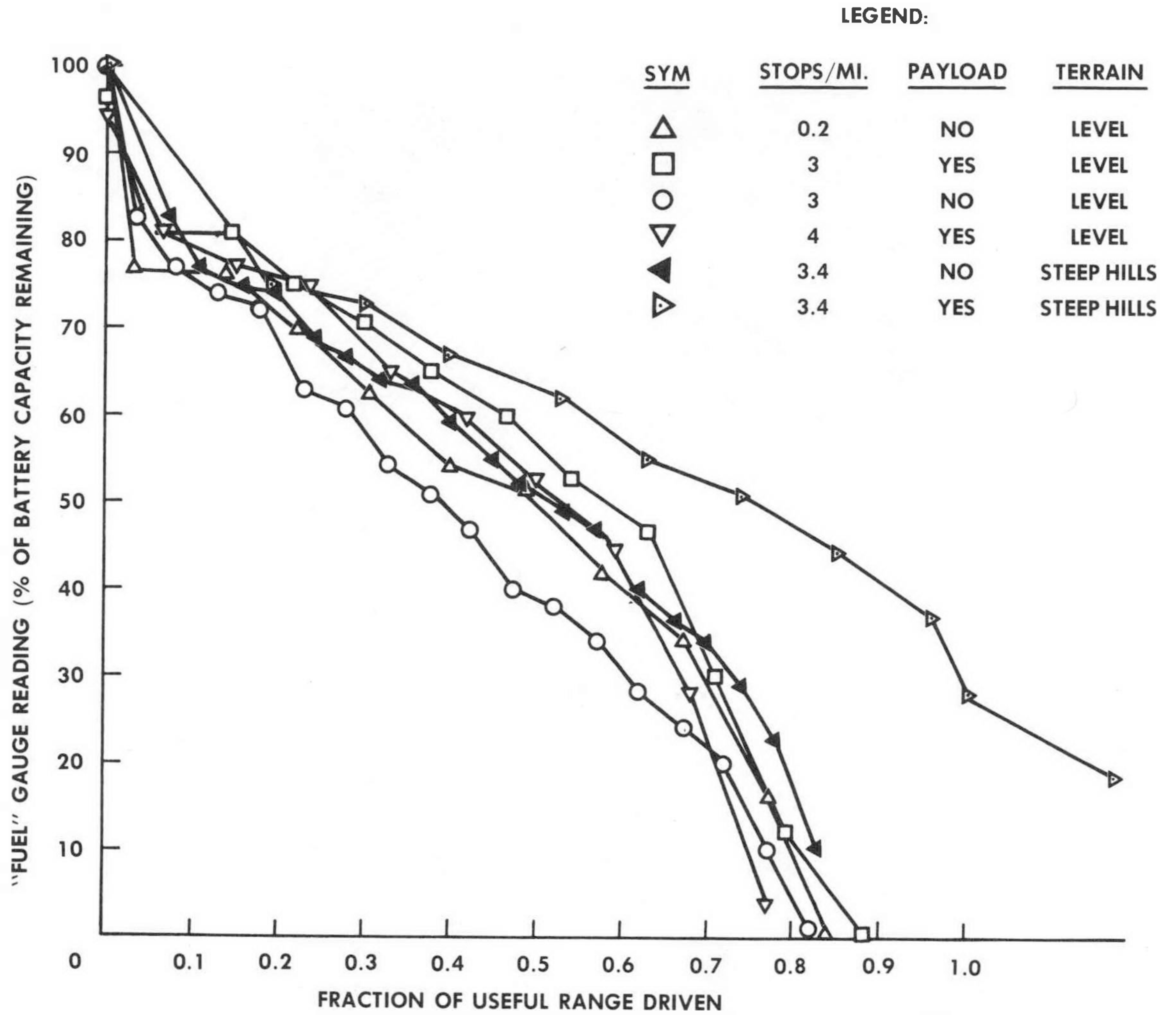

Figure A-4. Lucas Van Battery "Fuel" Gauge Range Correlation.

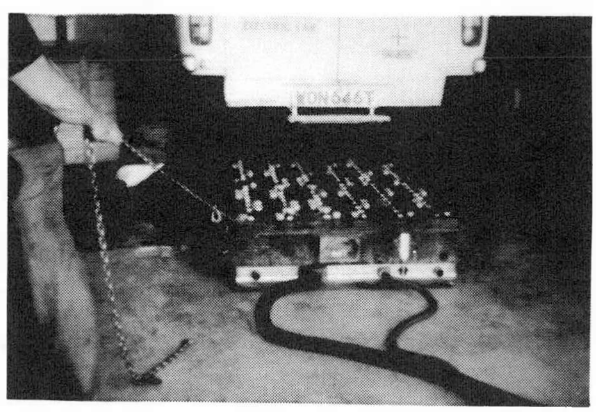

Figure A-5. Lucas Van Battery Pack Removal.

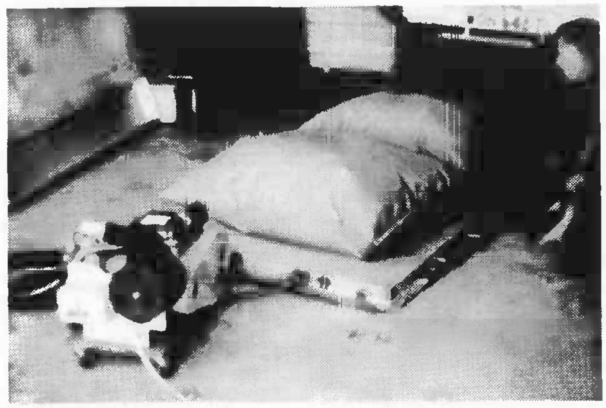

Figure A-6. Lucas Van Airbag Battery-Lifting Device.

Interior Noise — The A-weighted sound levels were measured as shown in Table A-4.

Table A-4
NOISE LEVELS INSIDE LUCAS VAN
(Max dbA)

Vehicle Operation Mode	Windows Open	Windows Closed
Max acceleration to 20 mph	78	76
30-mph steady cruise	79	79
45-mph steady cruise	83	83
55-mph (freeway)	87	86

Door Opening — The driver's door swung open approximately 70°, with opening dimensions of 54 inches high by 33 inches wide.

Steering Torque — The torque required to turn the steering wheel was 56 pound-inches.

Stopping Distance — The average stopping distance from 40 mph was 71 feet with driver only and 88 feet with maximum payload.

Appendix B

DRIVERS QUESTIONNAIRE

TEST EV____________

NAME__________________ DATE__________________ OFFICE__________________

VEHICLE____________________________ USE ________________________________

PERFORMANCE

1. Do you feel the electric vehicle has enough power to get away from lights without blocking traffic?

   ( ) yes ( ) most of the time ( ) no

2. Do you feel this electric vehicle can keep up with the fastest street traffic (no freeway) you'll usually be in?

   ( ) yes ( ) no

3. Will the vehicle climb all the hills in your route?

   ( ) yes ( ) no

4. Can you maneuver and park this vehicle as well as you can gas vehicles?

   ( ) yes ( ) yes, but only with strain and effort ( ) no

5. Does vehicle handle (steer) OK on the road?

   ( ) yes ( ) questionable ( ) no

SAFETY

6. Do you feel you can make a panic stop safely?

   ( ) yes ( ) unsure ( ) no

7. Can you stop as quickly as in your gas vehicle?

   ( ) yes ( ) not as quickly but OK ( ) no, takes too long

8. Do you feel the vehicle is as stable in turns as your gas vehicle?

( ) better than gas ( ) about the same ( ) not as good ( ) scary

9. Do you feel (if you are driving carefully) that this vehicle has enough power to get you out of trouble — for example, when making left turns across traffic?

( ) yes ( ) usually ( ) no, there'll be problems

10. Is the visibility (both front and rear) good enough so that you feel you can operate this vehicle safely?

( ) yes ( ) borderline ( ) no

11. When driving this electric vehicle, how does your overall feeling of safety compare with driving your regular gas vehicle?

( ) better than gas vehicle ( ) about the same ( ) not as good, but OK
( ) scary

JOB PERFORMANCE

12. Do you think the vehicle would be suitable for carrying your equipment?

( ) yes ( ) maybe ( ) no ( ) I don't carry equipment

13. Can you get in and out of this vehicle as quickly and conveniently as in your gasoline vehicle?

( ) better than gas vehicle ( ) same ( ) not quite as good, but OK
( ) more inconvenient or slow

14. How do you think your driving time in going from place to place will compare?

( ) faster than in gas vehicle ( ) about the same
( ) slightly slower than gas vehicle but OK ( ) much slower

15. How do you feel about hooking up the charger each night?

( ) no problem ( ) takes a little time but OK ( ) big nuisance

16. How do you feel your overall ability to perform your job would be affected by using this vehicle?

( ) better than with gas vehicle ( ) about the same
( ) not quite as good but OK ( ) could not do as good a job
( ) not suitable

COMFORT

17. How does the interior driving noise compare to your gas vehicle?

( ) quieter than gas vehicle ( ) about the same

( ) noisier than gas vehicle, but OK ( ) too noisy!

18. Is the seat comfortable enough?

( ) yes ( ) borderline ( ) no

19. Is the ride smooth enough?

( ) yes ( ) borderline ( ) no

20. Are the pedals, levers, steering, etc., easy to reach and operate?

( ) yes ( ) needs improvement ( ) no

21. Do you think the interior temperature can be kept comfortable with the existing ventilation and heater (compare to a vehicle without air condition)?

( ) yes ( ) borderline ( ) no

CONCLUSIONS

22. What do you **like** most about this electric vehicle?______________________________

____

23. What do you **dislike** most about this electric vehicle?______________________________

____

24. What changes would you make?______________________________

____

25. Would you like to continue to drive this electric vehicle?

( ) yes, permanently ( ) yes, for maybe 6 months

( ) only if changes were made ( ) no

26. I have the following suggestions: (use as much space as you want)