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BASELINE TESTS OF THE AM GENERAL DJ-5E ELECTRUCK ELECTRIC DELIVERY VAN

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16. Abstract

The AM General DJ-5E Electruck, an electric quarter-ton truck designed for use as a postal delivery vehicle, was tested at the Dynamic Science Test Track in Phoenix, Arizona, as part of an Energy Research and Development Administration (ERDA) project to characterize the state-of-the-art of electric vehicles. The Electruck vehicle performance test results are presented in this report. The Electruck is an AM General Corp. jeep that has been converted to an electric vehicle. It is powered by a single-module, 54-volt industrial battery through a silicon-controlled rectifier (SCR) continuously adjustable controller with regenerative braking applied to a direct-current (DC) compound-wound motor.

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

BASELINE TESTS OF THE AM GENERAL DJ-5E ELECTRUCK

ELECTRIC DELIVERY VAN

Miles O. Dustin, Henry B. Tryon,
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Lewis Research Center

SUMMARY

The DJ-5E Electruck, an electric quarter-ton truck designed for use as a postal delivery vehicle, was tested at the Dynamic Science Test Track in Phoenix, Arizona, between March 18 and March 25, 1977. The tests are part of an Energy Research and Development Administration (ERDA) project to characterize the state-of-the-art of electric vehicles. The Electruck vehicle performance test results are presented in this report.

The Electruck is an AM General Corp. jeep that has been converted to an electric vehicle. The propulsion system is supplied by Gould, Inc. The Electruck is powered by a single-module, 54-volt industrial battery through a silicon-controlled rectifier (SCR) continuously adjustable controller with regenerative braking applied to a direct-current (DC) compound-wound motor.

All tests were run at the gross vehicle weight of 1950 kilograms (4300 lbm). The results of the tests are as follows:

Test speed or driving cycle	Range		Road power, kW	Type of test			
				Road energy		Energy consumption	
	km	mile		MJ/km	kWh/mile	MJ/km	kWh/mile
40 km/h (25 mph)	77.2	48.0	5.0	0.447	0.200	1.230	0.550
48 km/h (30 mph)	63.2	39.3	6.8	.497	.222	1.319	.57
Schedule B	54.4	33.8	---	-----	-----	-----	-----

The Electruck was able to accelerate from 0 to 32 kilometers per hour (20 mph) in 8.7 seconds and from 0 to 48 kilometers per hour (30 mph) in 23.4 seconds. The gradeability limit was 14.4 percent.

INTRODUCTION

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

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

The U.S. Postal Service supplied a fleet vehicle for the tests. The Energy Research and Development Administration provided funding support and guidance during the project.

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

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

OBJECTIVES

The characteristics of interest for the DJ-5E Electruck are range at constant speed, range over stop-and-go driving schedules, maximum acceleration, maximum speed, gradeabilty, gradeability limit, road energy consumption, road power, indicated energy consumption, braking capability, and charger efficiency.

TEST VEHICLE

Vehicle And Component Description

The DJ-5E Electruck, shown in figure 1, is a conventional AM General jeep vehicle with a battery-powered electric drive instead of the conventional internal combustion engine. The vehicle has one bucket seat for the driver and can carry a 249-kilogram (550-lbm) payload in addition to the driver. The cargo volume is 1.05 cubic meters (37 ft^3). The vehicle is powered by a 14.9-kilowatt (20-hp) direct-current (DC) compound-wound motor coupled directly to the rear-axle drive shaft. A single-module battery and the silicon-controlled-rectifier (SCR) controller are located under the front hood, as shown in figure 2. Detailed specifications are given in appendix A.

Operating Characteristics

Driving procedures for the DJ-5E differ very little from a conventional internal combustion engine vehicle with an automatic transmission. The vehicle is accelerated forward by releasing the handbrake and pressing the accelerator pedal. Acceleration is proportional to pressure applied to the pedal. There is no transmission in the vehicle. The vehicle is stopped by applying pressure to the brake pedal. The vehicle has regenerative braking above a threshold speed, which can vary from 22.5 to 25.7 kilometers per hour (14 to 16 mph). The regenerative braking is initiated when the brake pedal is depressed, and the effect is proportional to the pedal position at or above the threshold speed. The hydraulic brakes are actuated when the vehicle is below the threshold speed. This discontinuity can be of concern to the inexperienced driver. When the brake pedal is depressed, power to the motor is removed. Therefore, when starting on a hill, the handbrake must be used instead of the footbrake. Vehicle direction is selected by means of a directional control lever located on the floor next to the driver. The lever has forward, reverse, and neutral positions. A locking device prevents accidental shifting of the lever.

INSTRUMENTATION

Measurements taken during performance testing of the DJ-5E Electruck included vehicle speed, distance traveled, and ampere-hours from and to the traction battery. The instrumentation package, located entirely aboard the vehicle, included the following:

(1) A Honeywell 195 Electronik two-channel, strip-chart recorder: This recorder is easy to calibrate, holds calibration well, and has a high input impedance. Vehicle distance and speed were recorded continuously during each test. The accuracy of the recorder is ± 0.5 percent of full scale.

(2) A Curtiss Model SHR-3 current integrator: This instrument measured integrated current into and out of the traction battery during each test by means of a 500-ampere-per-100-millivolt current shunt. The integrator was calibrated periodically to within ± 1 percent of reading.

(3) A Tripp Lite 500-watt DC/AC inverter: The inverter provided 120-volt, alternating current (AC) power to the strip-chart recorder and current integrator.

(4) A Nucleus Corporation Model NC-7 precision speedometer (fifth wheel) with a Model ERP-X1 electronic pulser for distance measurements, a Model NC-PTE pulse totalizer, and a Model ESS/E expanded-scale speedometer, and a programmable digital attenuator: The accuracy of the distance and velocity readings was within ±0.5 percent of reading.

(5) A 12-volt starting, lighting, and ignition (SLI) instrumentation battery that supplied power to the inverter and the required 12-volt supply to the fifth-wheel components.

All instruments were calibrated periodically. No significant shifts in calibration occurred between calibrations. The integrators and strip-chart recorders were calibrated with a Hewlett-Packard Model 6920 B meter calibrator, which has a 0.2-percent-of-reading accuracy and a usable range of 0.01 to 1000 volts. The fifth wheel was calibrated before each test by rotating the wheel on a constant-speed, fifth-wheel calibrator drum.

Measurements taken during the battery charge included (1) the current and voltage of the battery, measured with a Curtiss Model SHR-3 current integrator by means of a 500-ampere-per-100-millivolt current shunt and recorded on a Honeywell 195 Electronik two-channel, strip-chart recorder; and (2) the energy delivered to the charger, measured with a General Electric 1-50A single-phase residential kilowatt-hour meter.

TEST PROCEDURES

The tests described in this report were performed at the Dynamic Science Test Track, a two-lane, 3.22-kilometer (2-mile) asphalt track located in Phoenix, Arizona. A complete description of the track is given in appendix B. When the vehicle was delivered to the test track, the pretest checks described in appendix C were conducted. The first test run was a formal shakedown to familiarize the driver with the operating characteristics of the vehicle, to check out all instrumentation systems, and to determine the vehicle's maximum speed (appendix C). All tests were run in accordance with the ERDA Electric and Hybrid Vehicle Test and Evaluation Procedure ERDA-EHV-TEP (appendix E of ref. 1) at the gross weight of the vehicle, 1950 kilograms (4300 lbm).

Range Tests at Constant Speed

The vehicle speed for the highest constant-speed range test was determined during checkout tests of the vehicle. It was specified as 95 percent of the minimum speed the vehicle could maintain on the test track when it was traveling at full power. This speed was 48.3 kilometers per hour (30 mph) for the Electruck.

Range tests were run at constant speeds of 40 kilometers per hour (25 mph) and 48 kilometers per hour (30 mph). The speeds were held constant within ±1.6 kilometers per hour (1 mph). The test was terminated when the vehicle could no longer maintain 95 percent of the test speed. The range tests were run at least twice at both speeds.

Range Tests under Driving Cycles

Only the 32-kilometer-per-hour (20-mph), schedule B stop-and-go driving cycle, shown in figure 3, was run with this vehicle . The Electruck was unable to accelerate rapidly enough to meet schedule C. A complete description of the cycle tests is given in appendix E of reference 1. A special instrument, called a cycle timer, was developed at the Lewis Research Center to assist in accurately running these tests. Details of the cycle timer are given in appendix C. The cycle tests were terminated when the test speed could not be attained in the time required under maximum acceleration.

Acceleration and Coast-down Tests

The maximum acceleration of the vehicle was measured on a level road with the battery fully charged and 40 percent and 80 percent discharged. Four runs, two in each direction on the track, were made at each of these three states of charge. Depth of discharge was determined by the ampere-hours removed from the batteries. Acceleration runs were made on the southern straight section of the track, and coast-downs on the northern straight section (appendix B, fig. 13). Coast-down data were taken after the acceleration test with fully charged batteries in order to start the coast-down run from the maximum attainable vehicle speed.

Braking Tests

Braking tests on the vehicle were conducted

(1) To determine the minimum stopping distance in a straight-line emergency stop

(2) To determine the controllability of the vehicle while braking in a turn on both wet and dry pavement

(3) To determine the brake recovery after being driven through 0.15 meter (6 in) of water at 8 kilometers per hour (5 mph) for 2 minutes

(4) To determine the parking brake effectiveness on an incline

Instrumentation used during the braking test included a fifth wheel programmed to determine stopping distance, a brake pedal force transducer, and a decelerometer. A complete description of the braking tests is given in the discussion of test results and in appendix E of reference 1.

Tractive Force Tests

The maximum grade climbing capability of the test vehicle was determined from tractive force tests by towing a second vehicle. The driver of the towed vehicle, by applying the footbrake, maintained a speed of about 3 kilometers per hour (2 mph) while the test vehicle was being driven with wide-open throttle. The force was measured by a 13 000-newton (3000-lbf) load cell attached to the tow chain between the vehicles. The test was run with the batteries fully charged and 40 and 80 percent discharged.

Charger Efficiency Tests

Two methods were used to determine charger efficiency as a function of charge time. In the first method, a residential kilowatt-hour meter was used to measure input power to the charger by counting rotations of the disk and applying the meter manufacturer's calibration factor. The charger output power was determined by multiplying the average value of current by the average value of voltage. Residential kilowatt-hour meters are calibrated for sinusoidal waves only. The error in measuring input power depends on the wave shape and may be as high as 5 percent. The method of determining output power is correct only when either the voltage or the current is a constant during each charging pulse. The battery voltage does change during each charging pulse, which introduces a small error. The current shunts used to measure current are inaccurate for pulsing current. The error depends on frequency and wave shape and may exceed 10 percent.

In the other method used for determining charger efficiency a 50-kilowatt power meter was used on both the input and output of the charger and a Hall-effect current probe was used for current measurements. To minimize errors the same meter and current probe were used for both the input measurement and the output measurement. The average power measured was about 4 percent of full scale. The influence of these inaccuracies on the determination of charger efficiency is discussed in the component section of this report.

TEST RESULTS AND DISCUSSION

Range

The data collected from all the range tests are summarized in table I. Shown in the table are the test date, the type of test, the environmental conditions, the range test results, the ampere-hours into and out of the battery, and the energy into the charger. These data were used to determine vehicle range, battery efficiency, and energy consumption.

During most of the test period, the winds were variable and gusty. Even though the wind was less than 16 kilometers per hour (10 mph), on several occasions the wind was blowing in different directions and at different velocities at two positions on the track. There was no indication that this variation in wind velocity significantly affected the range or other test results as long as the measured winds were less than about 16 kilometers per hour.

The maximum speed of the vehicle was measured during the checkout tests. It is defined as the average speed that could be maintained on the track under full power. The measured maximum speed was 56 kilometers per hour (35 mph) for this vehicle. This differs from the maximum speed used in the range tests.

During the schedule B tests, it was observed that no measurable current was returned to the battery from regenerative braking. This occurred because the vehicle speed fell to about 24 kilometers per hour (15 mph) during the coast period of the cycle. This speed is about the threshold level of the regenerative braking according to the manufacturer. Below this speed, regenerative braking does not work.

Maximum Acceleration

The maximum acceleration of the vehicle was determined with the batteries fully charged and 40 and 80 percent discharged. Vehicle speed as a function of time is shown in figure 4 and table II. The average acceleration was calculated for the time period t_{n-1} to t_n, where the vehicle speed increased from V_{n-1} to V_n, from the equation

$$a_n = \frac{V_n - V_{n-1}}{t_n - t_{n-1}}$$

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

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

Maximum acceleration as a function of speed is shown in figure 5 and table III.

Gradeability

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

$$G = 100 \tan (\sin^{-1} 0.1026\ a_n) \qquad \text{for V in km/h}$$

in SI units

or

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

in U.S. customary units

where $\bar{a}_n$ is average acceleration in meters per second squared (mph/sec). The maximum grades the DJ-5E Electruck can negotiate as a function of speed is shown in figure 6 and table IV.

Gradeability Limit

Gradeability limit is defined by the SAE J227a procedure as the maximum grade on which the vehicle can just move forward. The limit was determined by measuring the tractive force with a load cell while towing a second vehicle at about 3 kilometers per hour (2 mph). It was calculated from the equations

$$\text{Gradeability limit in percent} = 100 \tan \left(\sin^{-1} \frac{P}{9.8\ W}\right)$$

in SI units

$$\text{Gradeability limit in percent} = 100 \tan\left(\sin^{-1}\frac{P}{W}\right)$$

in U.S. customary units

where

P tractive force, N (lbf)

W gross vehicle weight, kg (lbm)

The DJ-5E Electruck was capable of exerting the following tractive forces for three states of battery discharge:

(1) Fully charged, 2740 newtons (615 lbf)

(2) 40 Percent discharged, 2740 newtons (615 lbf)

(3) 80 Percent discharged, 2670 newtons (600 lbf)

At a vehicle weight of 1959 kilograms (4319 lbm) the resulting gradeability limits were

(1) Fully charged, 14.4 percent

(2) 40 Percent discharged, 14.4 percent

(3) 80 Percent discharged, 14.1 percent

Road Energy Consumption

Road energy is a measure of the energy consumed per unit distance in overcoming the vehicle's aerodynamic and rolling resistance plus the energy consumed in the differential drive shaft. It was obtained during coast-down tests, when the differential was being driven by the wheels, and thus may be different than the energy consumed when the differential is being driven by the motor.

Road energy consumption E_n was calculated from the following equations:

$$E_n = 2.78\times10^{-4} W \frac{V_{n-1} - V_n}{t_n - t_{n-1}}, \text{ MJ/km}$$

or

$$E_n = 9.07\times10^{-5} W \frac{V_{n-1} - V_n}{t_n - t_{n-1}}, \text{ kWh/mile}$$

where

W vehicle mass, kg (lbm)

V vehicle speed, km/h (mph)

t time, s

The results of the road energy calculations are shown in figure 7 and table V. It was not possible to disconnect the motor from the drive train during coast-down tests. However, the data have been corrected for motor friction and windage losses by means of factors supplied by the motor manufacturer. The losses are approximately 10 percent.

Road Power Requirements

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

$$P_n = 3.86\times10^{-5} W \frac{V_{n-1}^2 - V_n^2}{t_n - t_{n-1}}, \text{ kW}$$

or

$$P_n = 6.08\times10^{-5} W \frac{V_{n-1}^2 - V_n^2}{t_n - t_{n-1}}, \text{ hp}$$

The results of road power calculations are shown in figure 8 and table VI. For the coast-down tests, it was not possible to isolate or disconnect the motor from the drive train. However, the data have been corrected for motor friction and windage losses by means of factors supplied by the motor manufacturer. The losses are about 10 percent.

Indicated Energy Consumption

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

The energy input to the battery charger was measured with a residential kilowatt-hour meter after each range test. Some overcharge of the batteries was usually required in order to assure that all battery cells were fully charged and that the pack was equalized. The reported energy usage may be higher than would be experienced with normal vehicle field operation. Indicated energy consumption as a function of vehicle speed is presented in figure 9 and table VII for the constant-speed tests.

Braking Capability

Simplified braking capability tests were conducted according to the procedure outlined in appendix E of reference 1 in order to provide a preliminary evaluation of the vehicle's braking capabilities. The procedure also includes tests for handling, at ERDA's direction, but they were not conducted on this vehicle.

Straight-line stops. - Six straight-line stops from 48.3 kilometers per hour (30 mph) were made, three from each direction. Stopping distance varied from 15.8 meters (52 ft) to 17.1 meters (56 ft).

Stops on a curve. - Three stops were made going into a 0.3-g curve from 48 kilometers per hour (30 mph) on dry pavement turning right, and three stops were made on the same curve turning left. No difficulties were encountered in stopping within the 3.6-meter (12-ft) lane. The stopping distance varied from 16.2 meters (53 ft) to 20.7 meters (68 ft). The tests were repeated in a 0.2-g turn on wet pavement. Again the vehicle stopped smoothly with no problems. The stopping distances varied from 19.5 meters (64 ft) to 24.7 meters (81 ft).

Wet brake recovery. - Three baseline stops were made from 48 kilometers per hour (30 mph) with dry brakes, decelerating at 3 meters per second squared (10 ft/sec^2). The average pedal force was 440 newtons (99 lbf). After driving through 0.15 meter (6 in.) of water at 8 kilometers per hour (5 mph) for 2 minutes, the tests were repeated. The first stop was made with a pedal force of 471 newtons (106 lbf), the second was made with a pedal force of 484 newtons (109 lbf). Even though the brakes were fully recovered by the third stop, the brake pedal force exceeded the maximum allowable in the procedure for the baseline, 3.05 meters per second squared (10 ft/s^2).

Parking brake. - Tests were conducted to determine parking brake effectiveness, the parking brakes would not hold the vehicle on a 30-percent grade with the vehicle in either an uphill or a downhill position on the grade.

COMPONENT PERFORMANCE AND EFFICIENCY

Battery Charger

The results of the charger efficiency tests are presented in figure 10 for two methods. The first method used the kilowatt-hour meter and current shunt. The second method used the 50-kilowatt power meter to measure input and output power. The results are presented in terms of percent efficiency as a function of output current. The calculated energy efficiency for the charger was 72.4 percent using the first method and 75.0 percent using the second.

Batteries

Battery capacity check. - Before the road testing sequence was begun, the batteries were checked for terminal integrity and capacity. The terminal integrity was established using the 300-ampere discharge test described in appendix C. Battery capacity was established through a constant current discharge of 55 amperes until a terminal voltage of 1.72 volts per cell (VPC) was reached. The discharge voltage of the battery pack is shown in figure 11. As shown, the battery voltage was 55.5 volts (2.06 VPC) at the start of discharge and 46.5 volts (1.72 VPC) at the end of the test. The total capacity removed was 298 ampere-hours, which is 90 percent of the rated capacity of 330 ampere-hours. As a result of this test, the battery did meet the 80-percent criteria in appendix C, and road testing proceeded.

Battery charging profile. - A typical battery charging profile is presented in figure 12. Charging typically took 10 to 12 hours, which included a 1- to 3-hour equalization charge. The battery current at the start of charge was about 45 amperes; it began to taper down to 10 amperes at a battery voltage of 64 volts (2.4 VPC). In the typical charging profile presented, equalization began at 9 hours into charge, when the battery voltage reached 70 volts (2.6 VPC). At this point the battery voltage remained constant while the current decreased from 10 amperes to 7.5 amperes.

The battery charger used typically overcharged the battery about 8 percent as can be seen by reference to table I. A 10-percent overcharge is generally accepted as desirable to reduce gassing and to equalize the batteries.

Battery data summary. - Table VIII is a summary of documented battery data. The specific gravities of a fully charged battery range from 1.279 to 1.286, while those of a fully discharged battery depend on the test performed and range from 1.110 to 1.148. The battery temperature did increase during the test. An increase of 8° C (14° F) above starting temperatures was noted.

VEHICLE RELIABILITY

The Electruck proved to be exceptionally reliable throughout the test period. But for a single exception, no problems occurred during charging or during the performance test period. During the traction force tests, when the motor was drawing high current, the vehicle stopped running. After sitting for a few minutes, the vehicle again became operable. This occurred twice during the traction force tests. The problem was discussed with the motor and controller manufacturer; a cause has not been determined.

APPENDIX A

VEHICLE SUMMARY DATA SHEET

1.0 Vehicle manufacturer AM General Corp.
South Bend, Indiana

2.0 Vehicle DJ-5E Electruck 5300087

3.0 Price and availability Upon request

4.0 Vehicle weight and load

4.1 Curb weight, kg (lbm) 1633 (3600)

4.2 Gross vehicle weight, kg (lbm) 1950 (4300)

4.3 Cargo weight, kg (lbm) 249 (550)

4.4 Number of passengers 1

4.5 Payload, kg (lbm) 318 (700)

5.0 Vehicle size

5.1 Wheelbase, m (in.) 2.06 (81)

5.2 Length, m (in.) 3.45 (136)

5.3 Width, m (in.) 1.60 (63)

5.4 Height, m (in.) 1.79 (70.5)

5.5 Head room, m (in.) 1.05 (41.5)

5.6 Leg room, m (in.) 0.686 (27)

5.7 Frontal area, m^2 (ft^2) 2.1 (23)

5.8 Road clearance, m (in.) 0.170 (6.7)

5.9 Number of seats

6.0 Auxiliaries and options

6.1 Lights (number, type, and function) 2 head, 4 park and tail, 4 side, brake warning, motor high temperature, turn signals and indicators, high beam, dome, hazard flasher

6.2 Windshield wipers two-speed
6.3 Windshield washers pushbutton
6.4 Defroster two-speed fan with pullout control
6.5 Heater $0.0416\text{-}m^3$ (11-gal) fuel tank
6.6 Radio none
6.7 Fuel gage 0- to 100-percent charge
6.8 Amperemeter none
6.9 Tachometer none
6.10 Speedometer 0 - 144.8 km/h (0 - 90 mph)
6.11 Odometer yes
6.12 Right- or left-hand drive right
6.13 Transmission none
6.14 Regenerative braking yes
6.15 Mirrors 2 side, 1 front, 1 rearview
6.16 Power steering no
6.17 Power brakes no
6.18 Other

7.0 Batteries

7.1 Propulsion batteries

7.1.1 Type and manufacturer EV-27-66E-11; Gould, Inc.

7.1.2 Number of modules 1
7.1.3 Number of cells 27
7.1.4 Operating voltage, V 54
7.1.5 Capacity, Ah 330 (6-h rate)
7.1.6 Size of each battery, m (in.) height, 0.584 (23); width, 0.483 (19); length, 0.737 (29)
7.1.7 Weight, kg (lbm) 590 (1300), including tray
7.1.8 History (age, number of cycles, etc.) not available

7.2 Auxiliary battery

7.2.1 Type and manufacturer group 27; Gould, Inc.

7.2.2 Number of cells 6

7.2.3 Operating voltage, V 12

7.2.4 Capacity, Ah 93 (20-h rate)

7.2.5 Size, m (in.) height, 0.222 (8.75); width, 0.175 (6.88); length, 0.260 (10.25)

7.2.6 Weight, kg (lbm) 20.4 (45)

8.0 Controller

8.1 Type and manufacturer SCR infinitely variable; Gould, Inc.

8.2 Voltage rating, V 54

8.3 Current rating, A 550 to motor

8.4 Size, m (in.) height, 0.610 (24); width, 0.254 (10); length, 0.305 (12)

8.5 Weight, kg (lbm) 68.0 (150)

9.0 Propulsion motor

9.1 Type and manufacturer DC compound; Gould, Inc.

9.2 Insulation class H

9.3 Voltage rating, V 54

9.4 Current rating, A 550 at rated power

9.5 Horsepower (rated), kW (hp) ~14.9 (20), continuous duty

9.6 Size, m (in.) diam, 0.298 (11.72); length, 0.411 (16.2)

9.7 Weight, kg (lbm) 119 (263)

9.8 Speed (rated), rpm 2900

10.0 Battery charger

10.1 Type and manufacturer Combination on and off board; Gould, Inc.

10.2 On- or off-board type	off	on
10.3 Input voltage required, V	240/480	120
10.4 Peak current demand, A	20/10	20/15

10.5 Recharge time, h 10

10.6 Size, m (in.) height, 0.254 (10); width, 0.356 (14); length, 0.457 (18) for on-board unit

10.7 Weight, kg (lbm) 113/40.8 (250/90)

10.8 Automatic turnoff feature yes

11.0 Body

11.1 Manufacturer and type AM General Corp.; jeep

11.2 Materials steel

11.3 Number of doors and type 2 side (sliding); 1 rear

11.4 Number of windows and type windshield, rear quarter (2), rear door, side door (2 + 2); glass

11.5 Number of seats and type 1; bucket

11.6 Cargo space volume, m^3 (ft^3) 1.05 (37)

11.7 Cargo space dimensions, m (ft) ~1.14×1.45×0.69 (3.75×4.75×2.25)

12.0 Chassis

12.1 Frame

12.1.1 Type and manufacturer rail, boxed side members; AM General Corp.

12.1.2 Materials steel

12.1.3 Modifications none

12.2 Springs and shocks

12.2.1 Type and manufacturer leaf, semielliptical; F & R

12.2.2 Modifications shocks - direct acting

12.3 Axles

12.3.1 Manufacturer Spicer

12.3.2 Front reverse Elliot tubular

12.3.3 Rear semifloating

12.4 Transmission

12.4.1 Type and manufacturer

12.4.2 Gear ratios ______

12.4.3 Driveline ratio 5.89 (rear axle)

12.5 Steering

12.5.1 Type and manufacturer worm and roller; Ross

12.5.2 Turning ratio 24

12.5.3 Turning diameter, m (ft) 10.57 (34.67)

12.6 Brakes

12.6.1 Front drum

12.6.2 Rear drum

12.6.3 Parking two-position lever; rear wheels

12.6.4 Regenerative yes

12.7 Tires

12.7.1 Manufacturer and type Goodyear radial

12.7.2 Size CR78-15, load range C

12.7.3 Pressure, kPa (psi):

Front 248.2 (36)

Rear 220.6 (32)

12.7.4 Rolling radius, m (in.) 0.318 (12.5)

12.7.5 Wheel weight, kg (lbm):

Without drum 20.2 (44.5)

With drum 25.6 (56.5)

12.7.6 Wheel track, m (in.):

Front 1.31 (51.5)

Rear 1.27 (50.0)

13.0 Performance

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

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

13.3 Tested at cruise speed, km/h (mph) ______

APPENDIX B

DESCRIPTION OF VEHICLE TEST TRACK

The test track used to conduct the tests described in this report is located in Phoenix, Arizona. The track is owned and operated by Dynamic Science, a subsidiary of Talley Industries.

The test track is a paved, continuous two-lane, 3.2-kilometer- (2-mile-) long oval with an adjacent 40 000-square-meter (10-acre) skid pad. The inner lane of the track is not banked and was used for all cycle tests and all constant-speed tests of 56 kilometers per hour (35 mph) or under. The outer lane has zero lateral acceleration at 80 kilometers per hour (50 mph) and was used for tests over 56 kilometers per hour (35 mph). An elevation survey of the track is shown in figure B-1. Average grade is 0.66 percent on the northern straight section and 0.76 percent on the southern straight section. The surface of the track and skid pad is asphaltic concrete with a dry locked-wheel skid number of 82 and a wet locked-wheel skid number of 71.

Wet and dry braking-in-turn tests were conducted on the skid pad. Wet recovery tests were conducted on the test track after driving through the wet-brake water trough located near the northern straight section of the tracks. Both 20- and 30-percent grades are available for parking brake tests.

APPENDIX C

VEHICLE PREPARATION AND TEST PROCEDURE

Vehicle Preparation

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

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

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

Test Procedure

Each day, before a test, a test checklist was used. Two samples of these checklists are shown in figure C-2. The first item under driver instructions on the test checklist is to complete the pretest checklist (fig. C-3).

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

(1) Average specific gravity of the battery

(2) Tire pressures

(3) Fifth-wheel tire pressure

(4) Test weight of the vehicle

(5) Weather information

(6) Battery temperatures

(7) Time the test was started

(8) Time the test was stopped

(9) Ampere-hours out of the battery

(10) Fifth-wheel distance count

(11) Odometer readings before and after the tests

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

To prepare for a test, the specific gravities were first measured for each cell and recorded. The tire pressures were measured and the vehicle was weighed. The weight was brought up to the GVW by adding sandbags. The instrumentation was connected, and power from the instrumentation battery was applied. All instruments were turned on and warmed up. The vehicle was towed to the starting point on the track. If the data were being telemetered, precalibrations were applied to both the magnetic tape and the oscillograph. The fifth-wheel distance counter and ampere-hour integrator counter were reset to zero, and thermocouple reference junctions were turned on. The test was started and was carried out in accordance with the test checklist. When the test was terminated, the vehicle was brought to a stop and the post-test checks were made in accordance with the post-test checklist (fig. C-5). The driver recorded on the vehicle data sheet the time, the odometer reading, the ampere hour integrator reading, and the fifth-wheel distance reading. The post-calibration steps were then applied to the magnetic tape and the oscillograph. At the end of the test, weather data were recorded on the vehicle data sheet. All instrumentation power was turned off, the instrumentation battery was disconnected, and the fifth wheel was raised. The vehicle was then towed back to the garage, the post-test specific gravities were measured for all cells and the vehicle was placed on charge.

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

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

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

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

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

REFERENCES

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

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

TABLE I. - SUMMARY OF TEST RESULTS FOR DJ-5E ELECTRUCK[a]

(a) SI units

Test date	Test condition (constant speed, km/h; or driving schedule)	Wind velocity, km/h	Temperature °C	Range, km	Cycle life, number of cycles	Current out of batteries, Ah	Current into batteries, Ah	Energy into charger, MJ	Indicated energy consumption, MJ/km	Remarks
3/18/77	40.2	14.0	13	70.8	—	242	258	94	1.32	Gusts to 24 km/h
3/19/77	48.3	5 - 8	21	64.4	—	238	261	83	1.30	—
3/20/77	40.2	6	24	80.1	—	261	288	94	1.16	—
3/21/77	48.3	3	27	61.9	—	232	263	83	1.25	—
3/22/77	B	6 - 10	39 - 49	57.1	178	288	309	130	2.26	—
3/23/77	40.2	8 - 11	18 - 35	80.6	—	273	291	90	1.12	—
3/24/77	B	0 - 6	26 - 49	54.1	168	280	310	97	1.79	Regenerative braking disconnected
3/25/77	B	0 - 16	24 - 30	51.8	158	274	299	97	1.88	Regenerative braking disconnected

(b) U.S. customary units

Test date	Test condition (constant speed, mph; or driving schedule)	Wind velocity, mph	Temperature, °F	Range, miles	Cycle life, number of cycles	Current out of batteries, Ah	Current into batteries, Ah	Energy into charger, kWh	Indicated energy consumption, kWh/mile	Remarks
3/18/77	25	9	55	44.0	—	242	258	26	0.59	Gusts to 15 mph
3/19/77	30	3 - 5	69	40.0	—	238	261	23	.58	—
3/20/77	25	4	75	49.8	—	261	288	26	.52	—
3/21/77	30	2	81	38.5	—	232	263	23	.56	—
3/22/77	B	4 - 6	71 - 81	35.5	178	288	309	36	1.01	—
3/23/77	25	5 - 7	50 - 67	50.1	—	273	291	25	.50	—
3/24/77	B	0 - 4	58 - 71	33.6	168	280	310	27	.80	Regenerative braking disconnected
3/25/77	B	0 - 10	56 - 62	32.2	158	274	299	27	.84	Regenerative braking disconnected

[a]Vehicle would not negotiate the C or D cycle because of limited acceleration and low maximum speed.

TABLE II. - ACCELERATION TIMES FOR DJ-5E ELECTRUCK

Vehicle speed		Amount of discharge, percent		
km/h	mph	0	40	80
		Time to reach designated vehicle speed, s		
0	0	0	0	0
6.4	4	1.68	1.35	1.18
12.9	8	3.00	2.75	2.63
19.3	12	4.30	4.25	4.65
25.7	16	6.03	6.30	6.78
32.2	20	8.53	9.13	9.90
38.6	24	12.10	13.15	14.30
45.1	28	17.98	19.73	22.35
51.5	32	35.68	36.00	43.45

TABLE III. - ACCELERATION CHARACTERISTICS OF DJ-5E ELECTRUCK

Vehicle speed		Amount of discharge, percent					
km/h	mph	0		40		80	
		Vehicle acceleration					
		m/s^2	mph/s	m/s^2	mph/s	m/s^2	mph/s
1.6	1.0	0.867	1.94	1.12	2.50	1.49	3.33
4.8	3.0	1.38	3.08	1.63	3.64	1.54	3.45
8.0	5.0	1.15	2.58	1.22	2.74	1.16	2.60
11.3	7.0	1.44	3.23	1.34	2.99	1.14	2.56
14.5	9.0	1.42	3.17	1.14	2.56	.94	2.11
17.7	11.0	1.34	2.99	1.24	2.78	.85	1.90
20.9	13.0	1.19	2.67	1.01	2.27	.94	2.11
24.1	15.0	.95	2.13	.76	1.71	.81	1.82
27.4	17.0	1.22	1.74	.67	1.50	.63	1.41
30.6	19.0	.66	1.48	.59	1.33	.53	1.18
33.8	21.0	.55	1.23	.48	1.08	.46	1.03
37.0	23.0	.46	1.02	.41	.92	.37	.82
40.2	25.0	.35	.78	.41	.74	.27	.61
43.4	27.0	.27	.60	.23	.52	.18	.42
46.7	29.0	.17	.37	.15	.34	.12	.27
49.9	31.0	.07	.16	.08	.19	.07	.15

TABLE IV. - GRADEABILITY OF DJ-5E ELECTRUCK

Vehicle speed		Amount of discharge, percent		
km/h	mph	0	40	80
		Grade vehicle can climb, percent		
1.6	1.0	[a]14.4	[a]14.4	[a]14.4
4.8	3.0	14.15	16.79	15.89
8.0	5.0	11.82	12.57	11.91
11.3	7.0	14.86	13.73	11.73
14.5	9.0	14.68	11.73	9.65
17.7	11.0	13.73	12.75	8.68
20.9	13.0	12.24	10.38	9.65
24.1	15.0	9.74	7.80	8.31
27.4	17.0	7.94	6.84	6.43
30.6	19.0	6.75	6.06	5.38
33.8	21.0	5.61	4.92	4.69
37.0	23.0	4.65	4.19	3.73
40.2	25.0	3.55	3.37	2.77
43.4	27.0	2.73	2.37	1.91
46.7	29.0	1.68	1.55	1.23
49.9	31.0	.73	.86	.68

[a]Determined from tractive force tests.

TABLE V. - ROAD ENERGY CONSUMPTION

OF DJ-5E ELECTRUCK

Vehicle speed		Road energy consumed	
km/h	mph	MJ/km	kWh/mile
1.6	1.0	0.159	0.071
8.0	5.0	.170	.076
14.9	9.0	.235	.105
20.9	13.0	.235	.105
27.4	17.0	.275	.123
33.8	21.0	.333	.149
40.2	25.0	.404	.181
46.7	29.0	.434	.194
53.1	33.0	.476	.213
56.3	35.0	.541	.242

TABLE VI. - ROAD POWER REQUIREMENTS

OF DJ-5E ELECTRUCK

Vehicle speed		Road power required	
km/h	mph	kW	hp
1.6	1.0	0.07	0.09
8.0	5.0	.38	.51
14.9	9.0	.95	1.27
20.9	13.0	1.36	1.82
27.4	17.0	2.09	2.80
33.8	21.0	3.13	4.20
40.2	25.0	4.52	6.06
46.7	29.0	5.63	7.55
53.1	33.0	7.04	9.44
56.3	35.0	8.46	11.35

TABLE VII. - INDICATED ENERGY CONSUMPTION OF

DJ-5E ELECTRUCK

Vehicle speed or driving schedule		Indicated energy consumption	
km/h	mph	MJ/km	kWh/mile
40.2	25	1.32	0.59
		1.16	.52
		1.12	.50
48.3	30	1.27	.57
		1.36	.61
Schedule B		1.81	0.81
		1.86	.83
		2.26	1.01

TABLE VIII. - BATTERY TEST DATA SUMMARY FOR DJ-5E ELECTRUCK

Test date	Vehicle speed or driving schedule		Battery average specific gravity		Battery temperature			
					Before test		After test	
	km/h	mph	Before test	After test	°C	°F	°C	°F
3/18/77	40.2	25	1.280	1.133	17	62	28	82
3/19/77	48.3	30	1.286	1.144	24	76	33	92
3/20/77	40.2	25	1.281	1.123	26	80	32	90
3/21/77	48.3	30	1.280	1.148	25	78	34	94
3/22/77	Schedule B		1.287	1.110	27	81	37	98
3/23/77	40.2	25	1.285	1.110	29	84	37	98
3/24/77	Schedule B		1.279	1.110	25	78	33	92
3/25/77	Schedule B		1.284	1.110	28	82	34	94

Figure 1. - AM General DJ-5E Electruck.

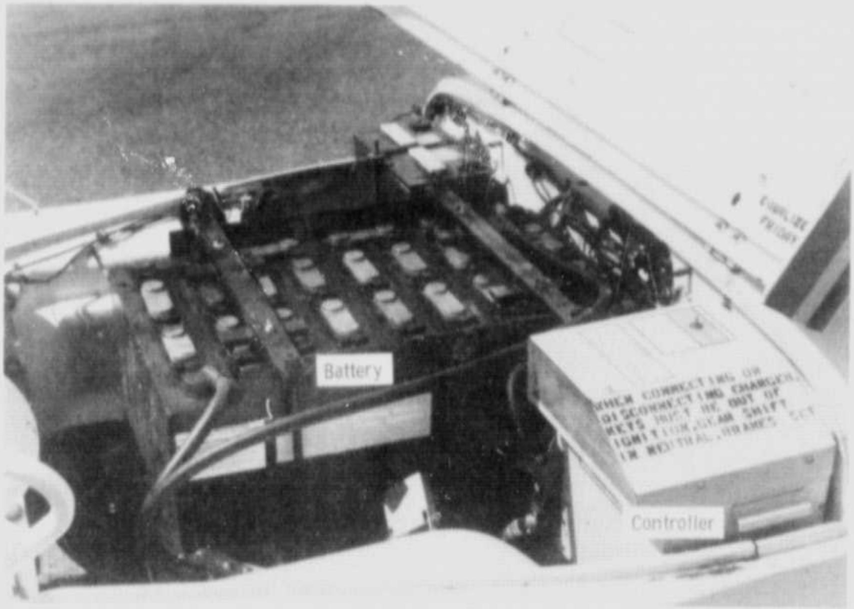
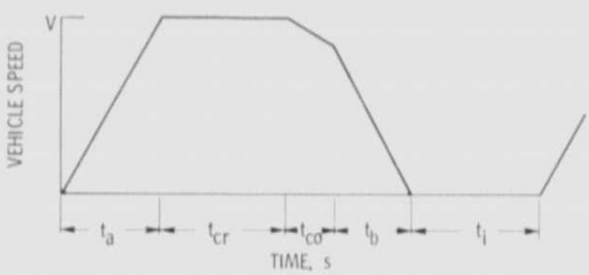


Figure 2. - View under hood of DJ-5E Electruck, showing battery and controller.



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

Figure 3. - SAE J227a driving cycle schedules.

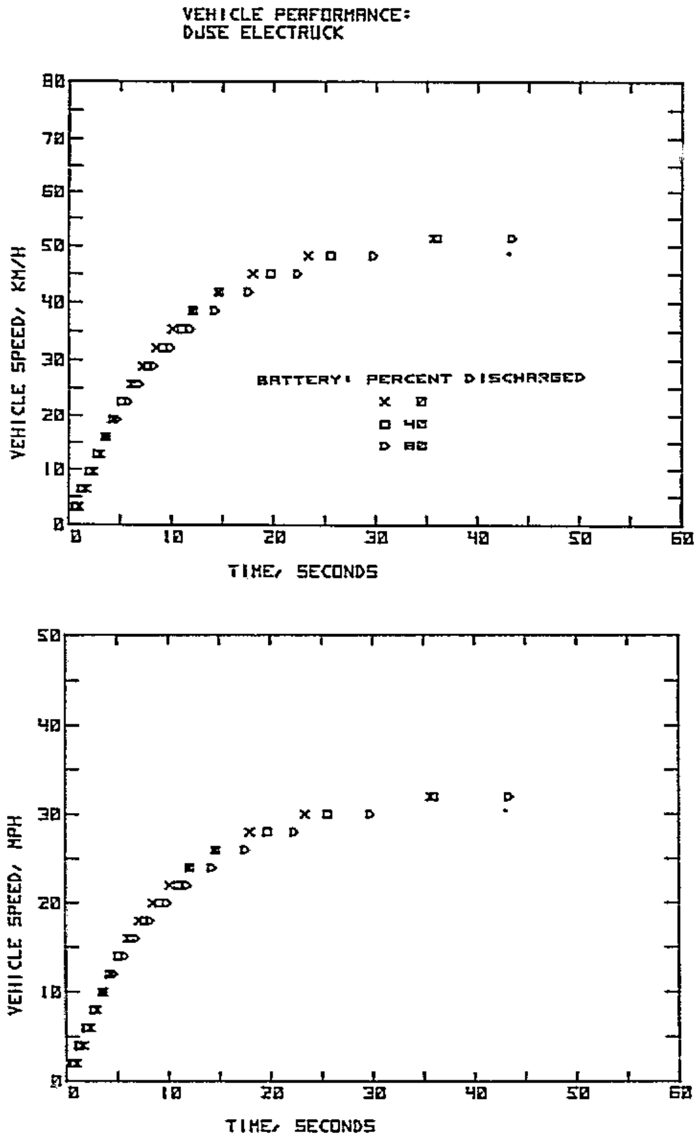


Figure 4. - Vehicle acceleration.

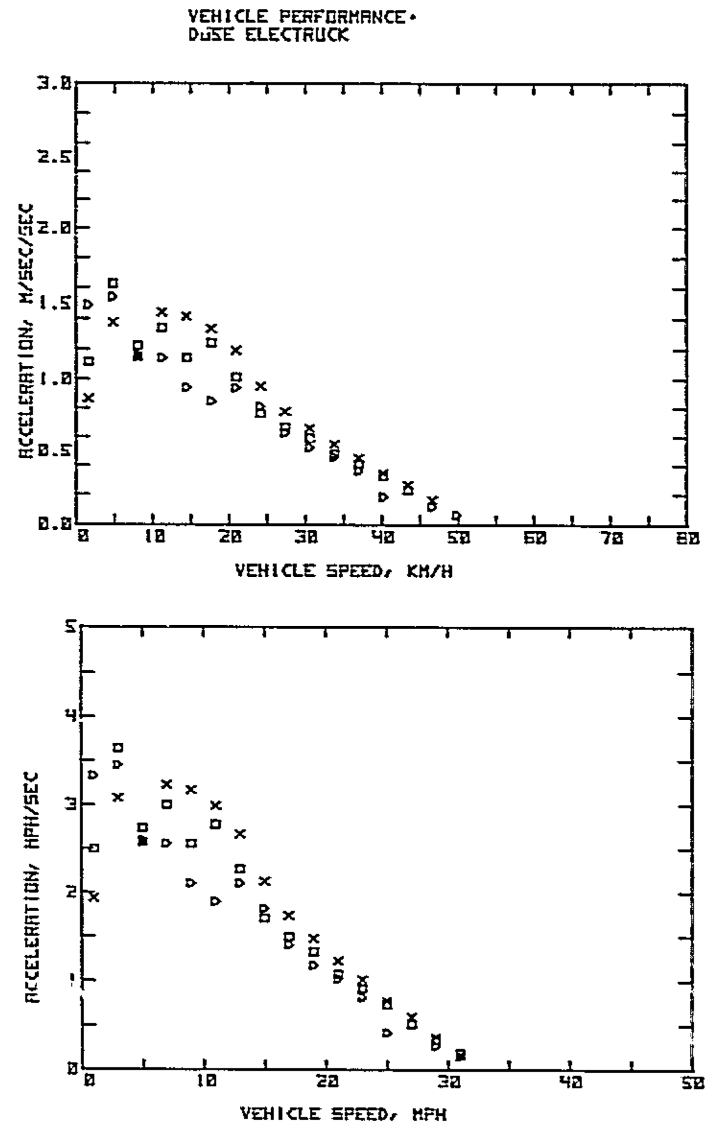


Figure 5. - Acceleration as a function of speed.

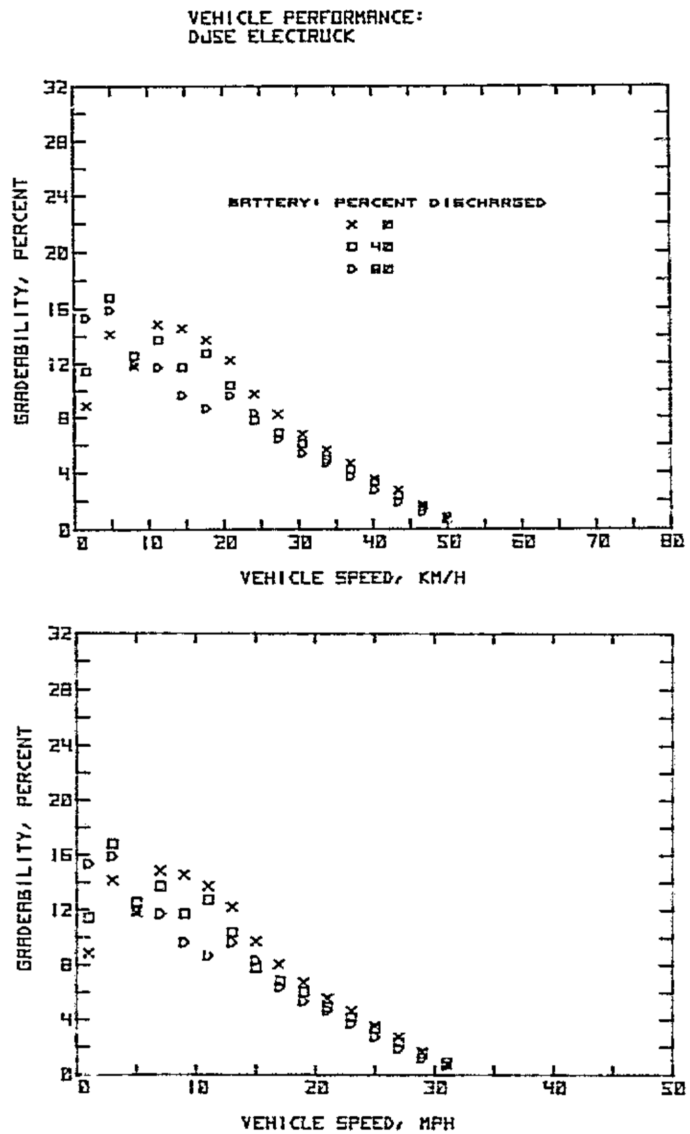


Figure 6. - Gradeability as a function of speed.

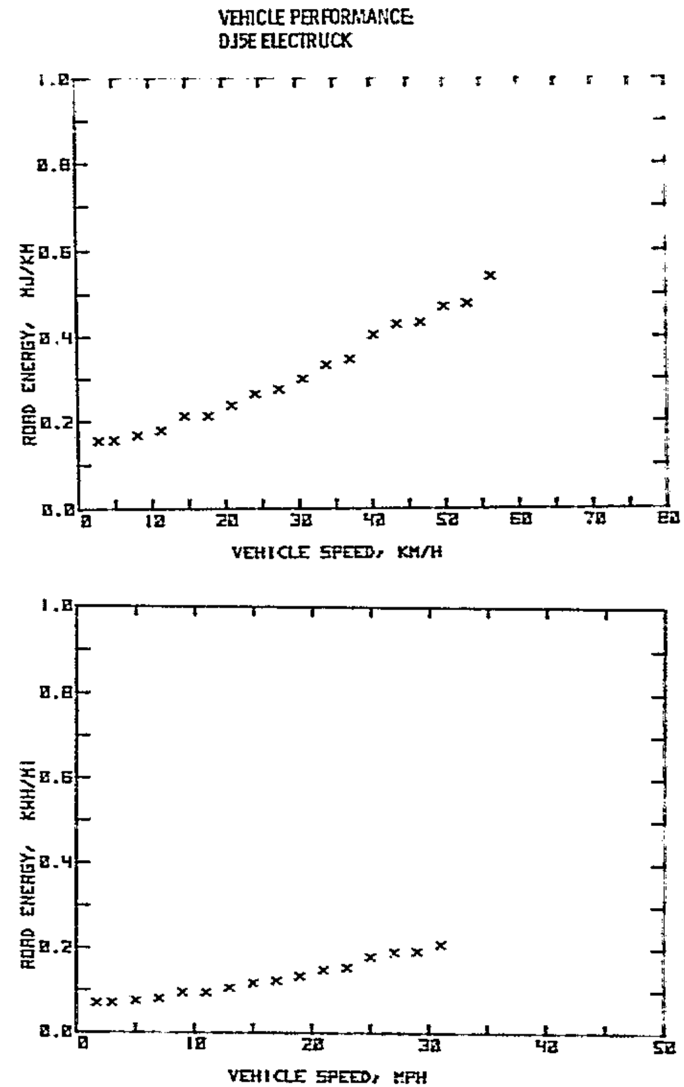


Figure 7. - Road energy as a function of speed.

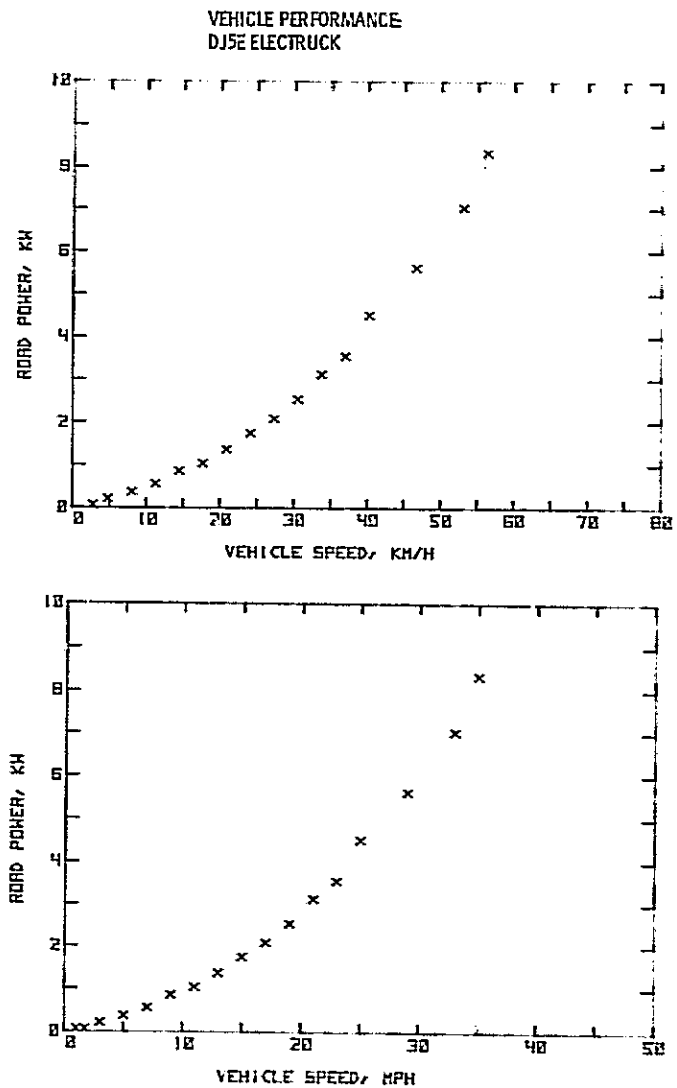


Figure 8. - Road power as a function of speed.

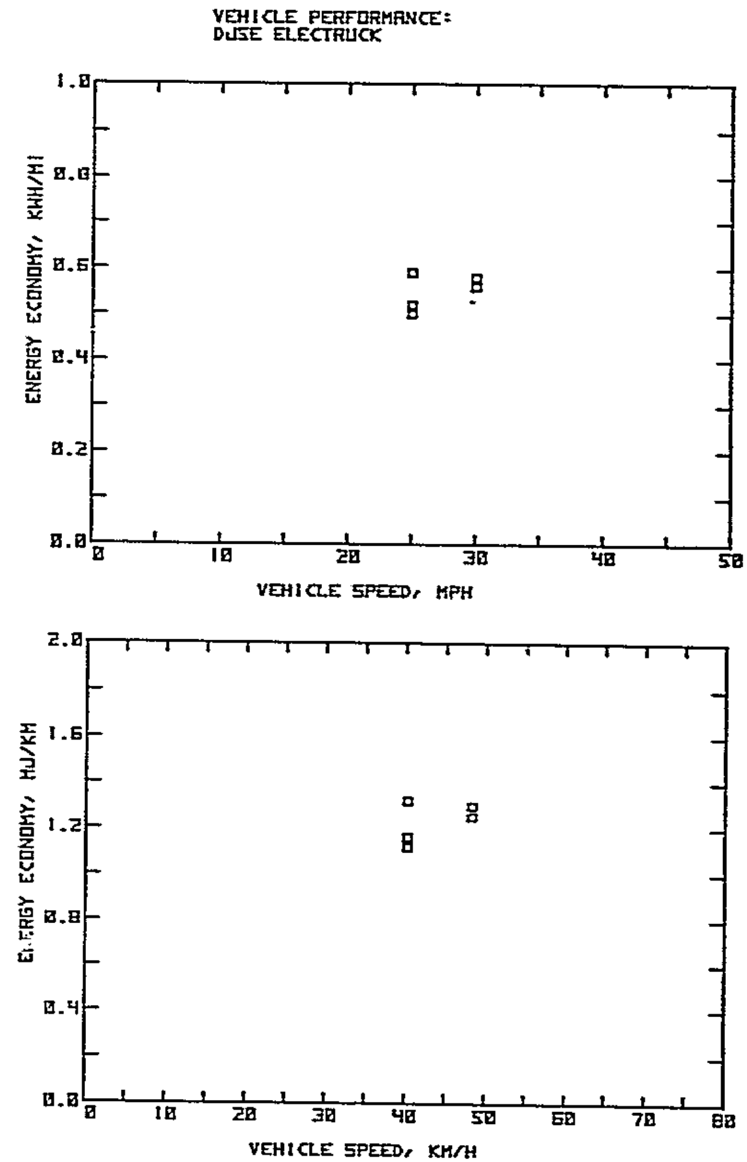


Figure 9. - Energy economy as a function of speed.

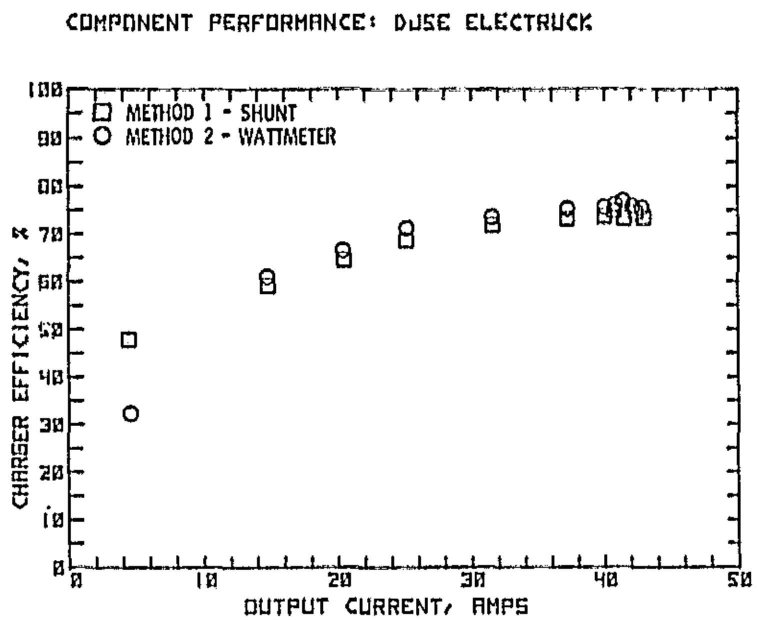


Figure 10. - Charger efficiency as a function of current.

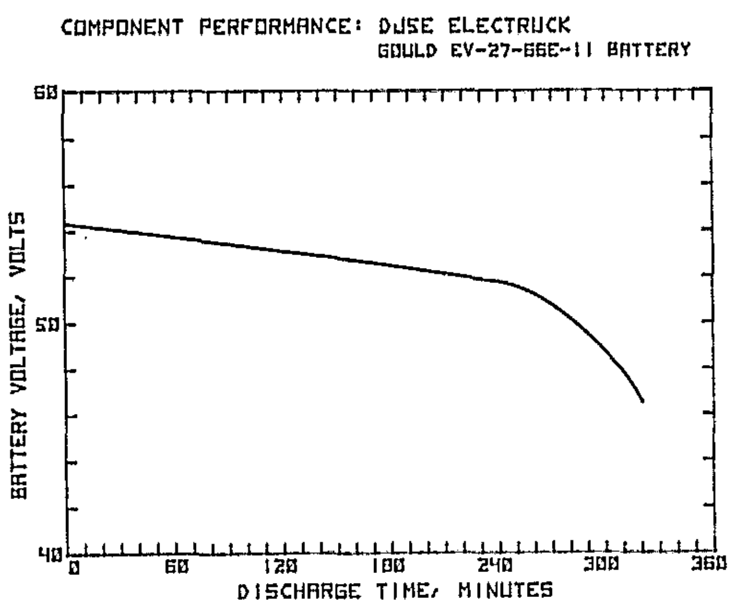


Figure 11. - Discharge capacity check (55 A).

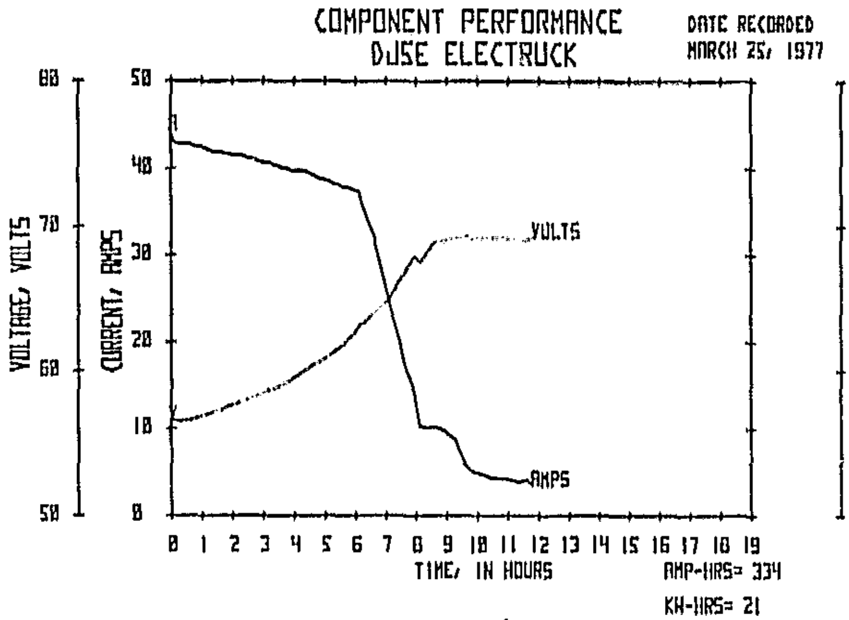


Figure 12. - Battery charger output.

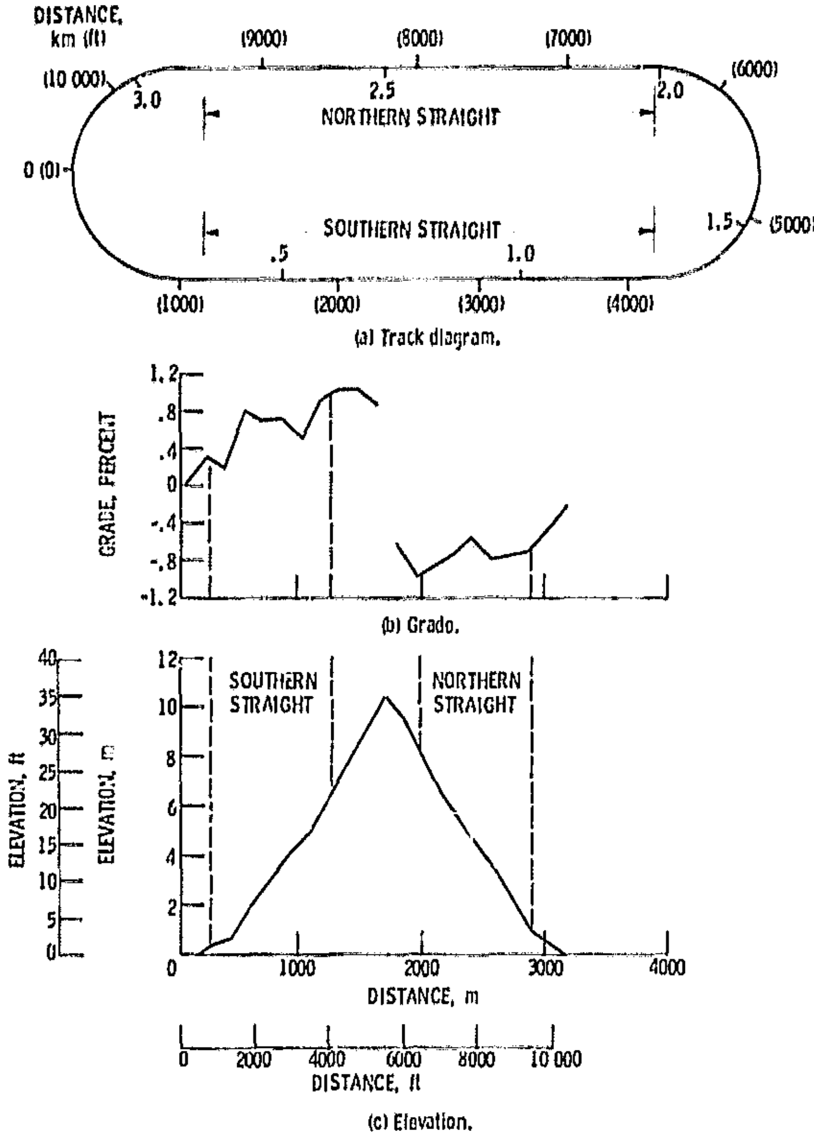


Figure B-1. - Characteristics of Dynamic Science Test Track, Phoenix, Arizona.

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

Figure C-1. - Vehicle preparation check sheet.

Vehicle ____________, ____________ mph range test, ____________ gear

Driver instructions:

1. Complete pretest checklist.
2. While on track recheck:
   Integrator - light on, in "operate" position, zeroed
   Speedometer - set on ____ mph center
   Distance - on, reset, lighted
   Attenuator - on, reset, lighted
3. At signal from control center, accelerate moderately to ____ mph.
4. Maintain ____ ±1 mph with minimal accelerator movement.
5. When vehicle is no longer able to maintain ____ mph, brake moderately to full stop.
6. Complete post-test checklist and other documentation.

Recording:

1. Set oscillograph zeros at:

Channel	Zero, in.
3	3.0
4	4.5
6	5.0
10	.75
12	1.1
13	1.2
14	2.0

2. Record all channels on magnetic tape. Check inputs at beginning of test to verify recording.
3. Run cals on all channels.
4. Remove all channels from oscillograph except 3 and 4.
5. Start recording 15 s before start of test at oscillograph speed of 0.1 in/s and tape speed of ______ in/s.
6. After 15 min into test connect channels 6, 10, 12, 13, and 14 to oscillograph and record a burst at 100 in/s while vehicle is in chopper mode.
7. Remove channels 6, 10, 12, 13, and 14 from oscillograph and continue test at 0.1 in/s with channels 3 and 4 only.
8. Document all ambient conditions at beginning, once every hour, and at the end of the test. Items recorded shall include temperature, wind speed and direction, significant wind gusts, and corrected barometric pressure.

(a) Constant-speed test.

Figure C-2. - Test checklists.

Vehicle ____________________, ____________ Cycle Test, ____________ gear

<u>Driver Instructions:</u>

1. Complete pretest checklist.
2. While on track recheck:
   Integrator - light on, in "operate" position, zeroed
   Speedometer - set on ____ mph center
   Distance - on, reset, lighted
   Attenuator - on, reset, selector on 100
   Cycle timer - verify scheduled timing with stop watch
3. At signal from control center, perform cycle test using cycle timer as basis for determining length of each phase of performance cycle. Use programmed stop watch as backup device. Cycle consists of

   Accelerate to ______ mph in ______ s

   Cruise at ______ mph for ______ s

   Coast for ______ s

   Brake to complete stop in ______ s

   Hold in stop position for ______ s

   Repeat entire cycle until vehicle is unable to meet acceleration time. Moderately brake to a complete stop.
4. Complete post-test checklist and other documentation.

<u>Recording:</u>

1. Record all channels on magnetic tape at ______ in/s. Check all channels to verify input at beginning of test.
2. Record speed and distance on oscillograph at ______ in/s.
3. Start recording data 15 s before beginning test.
4. Document ambient conditions at beginning, once every hour, and at the end of the test. Items recorded shall include temperature, wind speed and direction, significant wind gusts, and corrected barometric pressure.

(b) Driving cycle test.

Figure C-2. - Concluded.

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

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

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

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

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

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

7. Proceed with test.

Figure C-3. - Pretest checklist.

Vehicle ______________ Battery system ______________

Test ______________ Date ______________

Track data:

Driver ______________ Navigator ______________

Average pretest specific gravity ______________

Open-circuit voltage, V ______________

Tire pressure before test, psi:

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

Tire pressure after test, psi:

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

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

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

Battery temperature, °F: Before ______ After ______

Motor temperature, °F: Before ______ After ______

Time: Start ______ Stop ______

Odometer reading, miles: Start ______ Stop ______

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

Fifth wheel ______________

Basis for termination of tests ______________

____

Charge data:

Average post-test specific gravity ______________

Open-circuit voltage, V ______________

Charger used ______________

Charger input voltage, V ______________

Battery temperature, °F: Before charge ___ After charge ___

Power, kWh: Start ______ End ______ Total ______

Time: Start ______ End ______

Total charge time, min ______________

Current input, Ah ______________

Average specific gravity after charge ______________

Approval ______________

Figure C-4. - Track and charge data.

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

Figure C-5. - Post-test checklist.

Vehicle ________________ Test ______________ Date ______________

Test conditions:

Temperature, ^{o}F ________ Wind speed, mph ____________ at ____________

Barometer reading, in. Hg ______________; Other ______________

Test results:

Test time, h ______________________________

Range, miles ______________________________

Cycles ______________________________

Current out of battery, Ah ______________________________

Current into battery, Ah ______________________________

Charge time, h ______________________________

Power into battery, kWh ______________________________

Magnetic tape:

No. ____________________; Speed, in/s ______________

Comments ______________________________

Figure C-6. - Test summary sheet.

Vehicle ____________ Test ____________ Date ____________

Engineer ____________

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

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

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

Other comments ____________

Evaluation of test:

- Range, miles ____________
- Current out, Ah ____________
- Current in, Ah ____________
- Power in, kWh ____________
- Energy consumption, kWh/mile ____________

Was planned driving cycle followed? ____________

General comments ____________

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

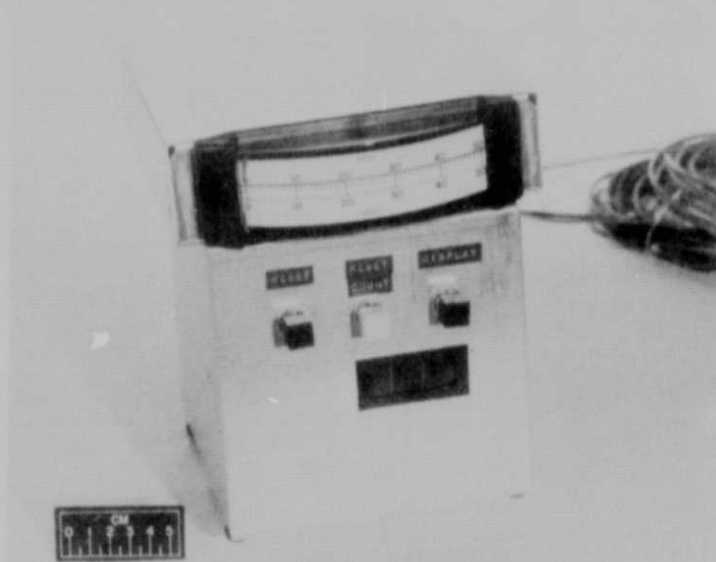


Figure C-8. - Cycle timer.