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PRELIMINARY RESULTS OF STEADY STATE CHARACTERIZATION OF THE NEAR TERM ELECTRIC VEHICLE BREADBOARD PROPULSION SYSTEM

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NOTICE

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E-502

INTRODUCTION

The NASA-LeRC under the direction of DOE is responsible for the test and evaluation of electric and hybrid vehicle propulsion systems and components. In September 1978, a contracted effort was undertaken with the General Electric Company to design, fabricate, and deliver a breadboard version of the GE-NTEV (ETV-1). The breadboard was built using exact duplicate vehicle propulsion system components with a few minor exceptions. Full instrumentation was provided to measure individual component efficiencies and to measure power flow through the propulsion system. The breadboard was checked out at GE and shipped to Lewis for installation in the Road Load Simulator Facility. Due to temporary unavailability of the LABECO dynamometer, the breadboard was coupled to an existing 50 hp dynamometer for the tests described in this report.

OBJECTIVES

The prime objectives of testing with the temporary 50 hp dynamometer were to gain familiarity with the new facility operation and instrumentation systems and provide steady state data and characterization of the propulsion system and its components.

TEST DESCRIPTION

Figure 1 shows the speed-torque regime in which the NTEV propulsion system can operate. Within this regime is a shaded area showing the portion that was run with the 50 hp dynamometer. Electronic wattmeters and speed-torque transducers provided power measurement data at the input and output of each component for efficiency calculation. The data were recorded on the LeRC central data system and outputted in a tabular format containing engineering units as well as final calculations of efficiencies. Six power measurements are used to determine the system power flow as shown in figure 2.

PBAT	Battery power
PARM	Motor armature power
PFLD	Motor field power
PACSY	Accessory power
HPMOT	Motor shaft power
HPTAXL	Transaxle output power

Motor input power, PMOT, is calculated by adding PARM and PFLD. The component efficiencies are then arrived at by using the basic equation:

$$\eta = \frac{P_{out}}{P_{in}}$$

Therefore:

$$\eta \text{ Motor} = \frac{\text{HPMOT}}{\text{PMOT}}$$

$$\eta \text{ Transaxle} = \frac{\text{HPTAXL}}{\text{HPMOT}}$$

$$\eta \text{ Controller} = \frac{\text{PMOT}}{\text{PBAT-PACSY}}$$

$$\eta \text{ System} = \frac{\text{HPTAXL}}{\text{PBAT}}$$

All tests were run using EV-106 batteries as the power source. Data were taken at various states of charge (S.O.C.) to assess the effect of S.O.C. on the efficiencies.

TEST RESULTS

The propulsion system is divided by instrumentation into five major components - battery pack, controller (containing armature chopper, field chopper, and microcomputer logic), shunt motor, transaxle, and accessory charger. The accessory charger, which is housed in the PCU (power conditioning unit), continuously charges the accessory battery from the propulsion battery. The accessory battery primarily operates the cooling fan, the control relays and status lamps. Since this single cooling fan cools both controller and motor, it was felt that neither component should be penalized for the total accessory load hence the accessory power is measured separately.

The data indicate that the accessory load is a near constant 300 watts. This is somewhat less than in the ETV-1 car due to the additional brake lights, dash illumination, and purge fan used in the vehicle.

The armature circuit within the PCU operates in two basic modes. From 0 to 25 mph (motor base speed) the armature chopper is functioning to control the average current and thus the power to the motor. The controller losses are greatest in this mode but even under these conditions the controller efficiency is in excess of 85 percent at the conditions run. At vehicle speeds above 25 mph motor control is provided by the field chopper with the armature chopper applying full battery voltage to the motor armature. The field power is very small when compared to the armature power in this case, and the controller loss above speeds of 25 mph is negligible. The controller losses were isolated by the subtractive method. Due to the high efficiency of the controller, the classical problem of isolating small parameters by subtracting two large quantities prohibits obtaining the exact controller losses at this time. However, and envelope of the controller efficiency is presented in figure 3 showing the areas that encompass all data taken. The transition region around armature bypass was not specifically investigated because of its discontinuous nature.

The dominant loss in the system is the motor. A plot of motor efficiency versus vehicle speed on lines of constant transaxle output torque are given in figure 4. Peak motor efficiencies for the conditions tested are between 90 percent at the low torques and 80 percent at the higher torques.

The transaxle, a double reduction chain drive with integral differential, reduces the motor output speed by a ratio of 5.48:1. The efficiencies of this transaxle are plotted in figure 5 in a similar manner to the motor data. The total system efficiency is shown in figure 6. Peak efficiencies, at all torque levels tested, are near 80 percent. Variances in the component losses due to S.O.C. and component temperature appear to be small; in the order of 3 percent. Separation of these effects plus testing at the high torque conditions will be performed when the Road Load Simulator is complete.

CONCLUDING REMARKS

Characterization of the propulsion system over the lower half of the speed-torque operating range has shown the system efficiency to be composed of a predominant motor loss plus a speed dependent transaxle loss. At the lower speeds with normal road loads the armature chopper loss is also a significant factor. At the conditions corresponding to the J227a "D" cycle, for which the vehicle system was specifically designed, the efficiencies are near optimum.

Now that these tests with the temporary dynamometer are complete, an assessment of the facility measurement and operation systems can be made. The ability to make accurate and repeatable real time electrical power measurements under the influence of armature chopper, field chopper, and accessory charger operation has been demonstrated. Effects of common-mode voltages which vary over the operating range produce negligible interaction between the wattmeters. The data system provides continuous measurement and calculation of engineering data to be displayed on the control room CRT display allowing real-time assessment of the experiment.

All facility support systems are operational including the battery simulator composed of an M/G set and capacitor bank. Exploratory tests were performed using the battery simulator to power the propulsion system over the operating range. These exploratory tests showed that use of the battery simulator should allow separation of S.O.C. and temperature effects on the operation of the propulsion system. Installation of the remaining facility item, the Road Load Simulator absorber system, will provide the high torque capability for completion of the steady-state characterization and the dynamic capability for transient evaluation of the propulsion system.

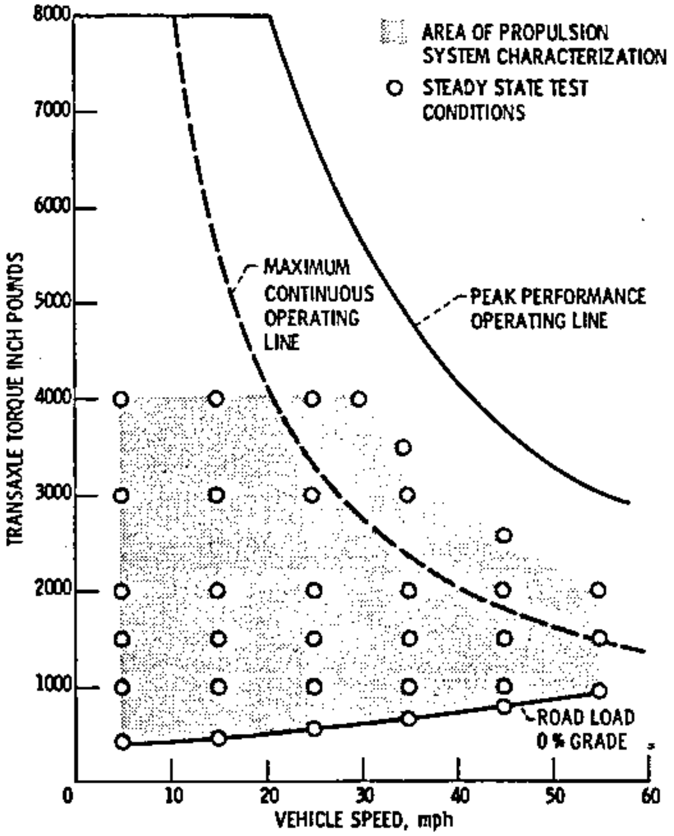

Figure 1. - Propulsion system speed-torque operating envelope.

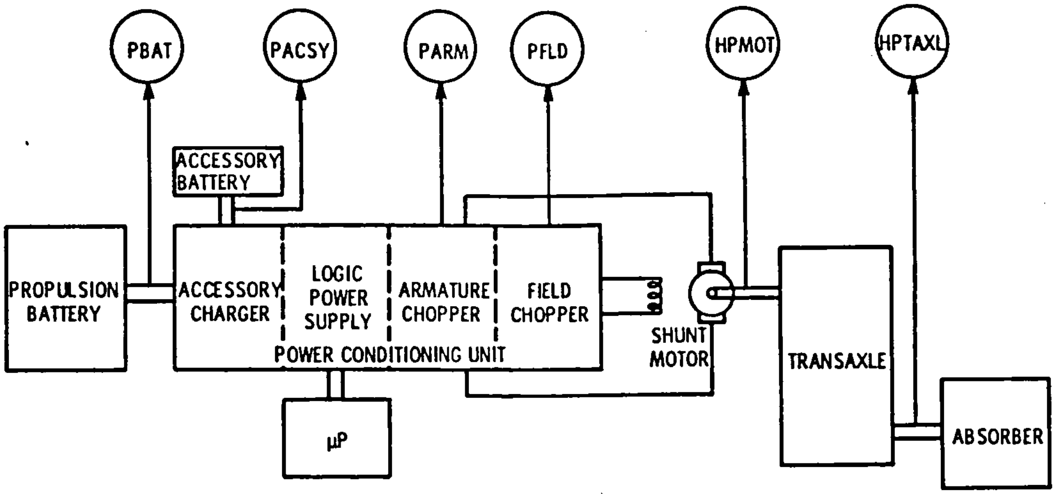

Figure 2. - Power flow measurement block diagram.

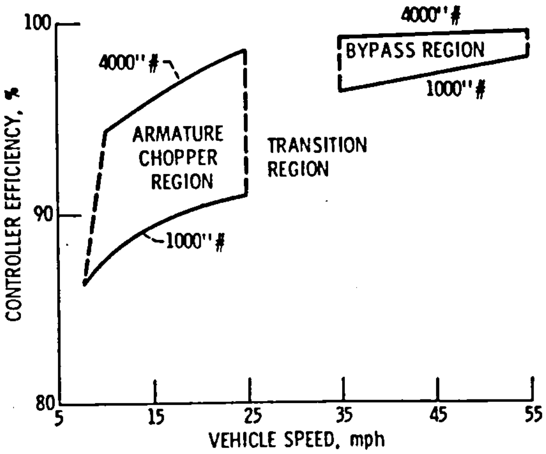

Figure 3. - Controller efficiency envelope.

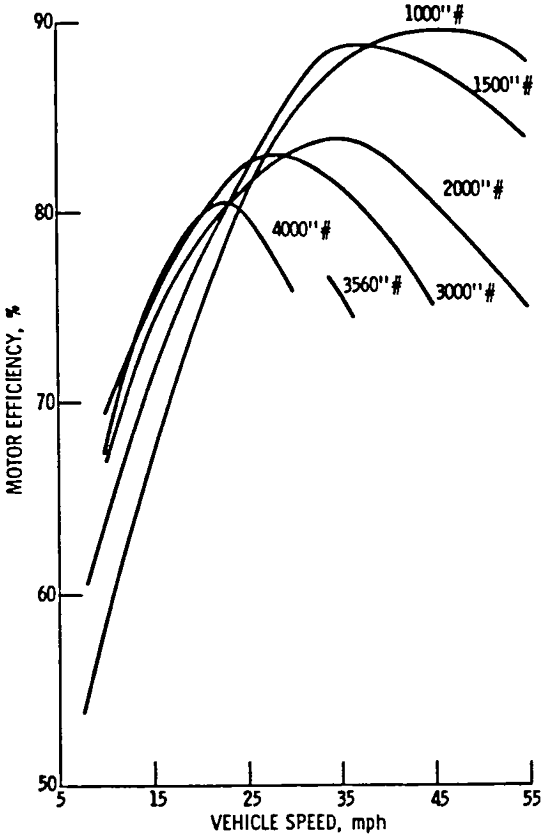

Figure 4. - Motor efficiency on lines of constant torque.

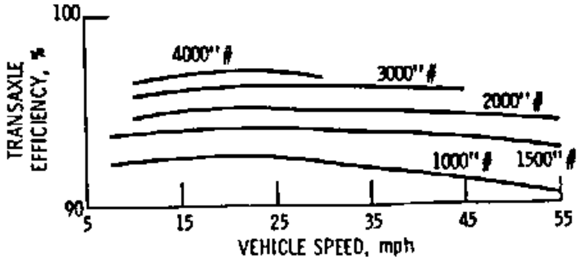

Figure 5. - Transaxle efficiency on lines of constant torque.

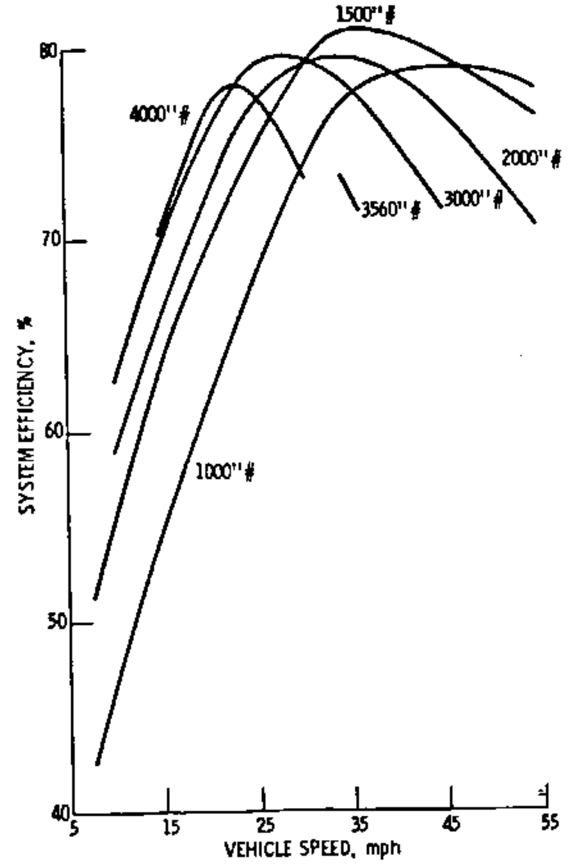

Figure 6. - System efficiency on lines of constant torque.

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16. Abstract

This report presents steady state test results on a breadboard version of the General Electric Near Term Electric Vehicle (ETV-1). The breadboard was built using exact duplicate vehicle propulsion system components with few exceptions. Full instrumentation was provided to measure individual component efficiencies. Tests were conducted on a 50 hp dynamometer in the NASA Lewis Research Center Road Load Simulator Facility.

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