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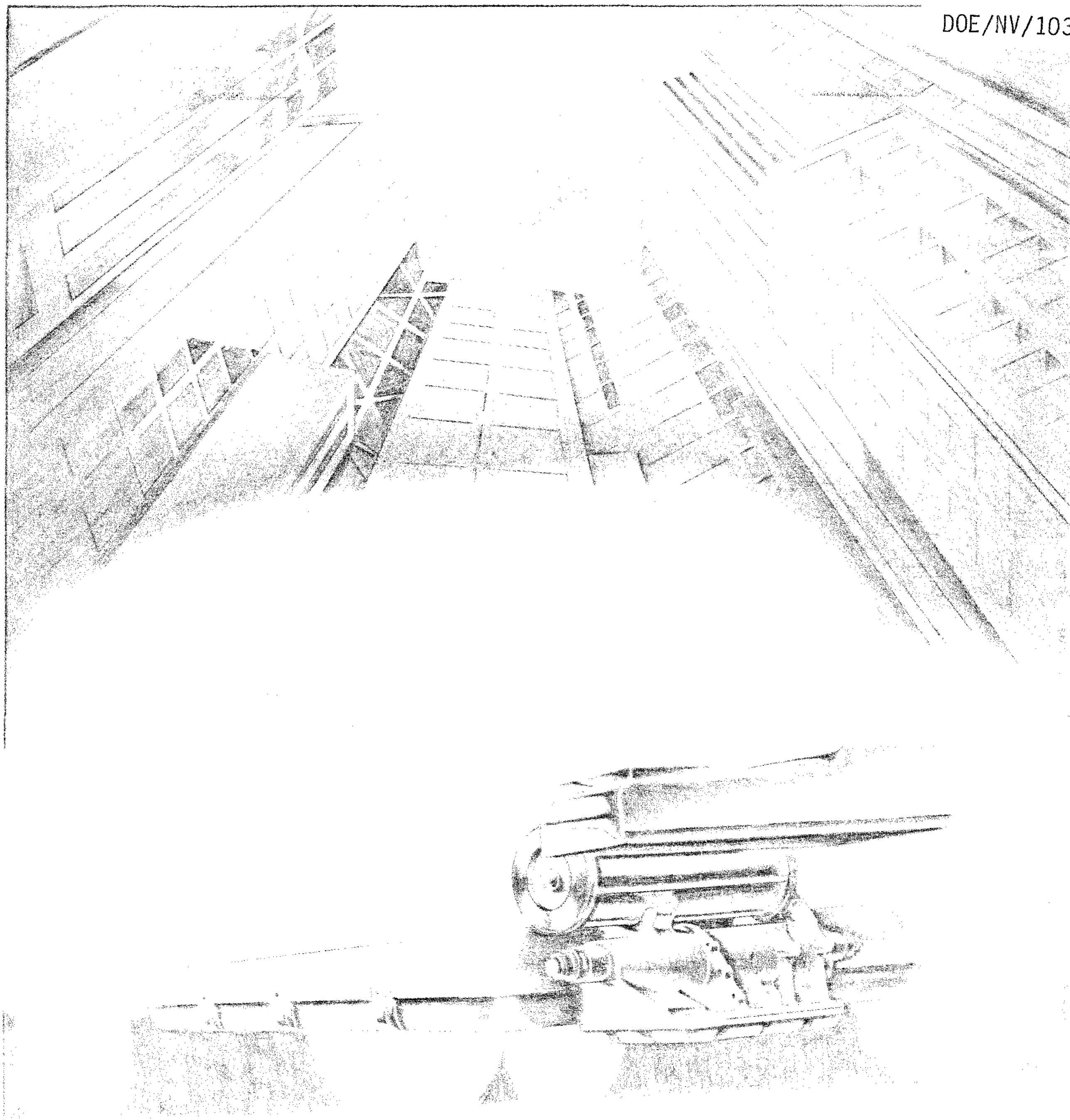

Advanced Dual Shaft Electric Propulsion System Technology Development Program

Annual Report II - September 1986

Eaton Corp. — Engineering & Research Center

Contract **DE-AC07-84NV10366**
Program Management: Idaho National Engineering Laboratory

U.S. Department of Energy
Conservation of Renewable Energy
Office of Transporation Systems

EATON

ADVANCED DUAL-SHAFT ELECTRIC PROPULSION SYSTEM TECHNOLOGY DEVELOPMENT PROGRAM

DSEP

DOE/NV/10366--8

DE89 010707

ANNUAL REPORT - II

SEPTEMBER 1986

Prepared by

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EATON CORPORATION

Engineering & Research Center

Under Contract DE-AC07-84NV10366

Idaho Operations Office

U.S. DEPARTMENT OF ENERGY

(Program Management by Idaho National Engineering Laboratory)

for

U.S. DEPARTMENT OF ENERGY

Conservation of Renewable Energy

Office of Transportation Systems

ABSTRACT

This document is the second annual report of the four year DSEP program. Intended as a condensed overall summary, this report describes the technical progress and achievements during the period from September 1985 to August 1986. A bibliography referencing all of the detailed documentation generated during this period is included.

INTRODUCTION

This document is a summary of the second year of activities in a 48-month program to advance the state-of-the-art of overall electric vehicle propulsion system technology using subsystem technologies previously developed under contract to the Department of Energy (DOE) by Eaton Corporation and Eagle-Picher Industries, Inc. The a.c. powertrain technology is an outgrowth of three generations of development by Eaton under contract to the U.S. Department of Energy (DOE). This powertrain technology (originally focused on passenger car applications) is being upgraded for the higher power capability and starting torque required for van applications. The nickel-iron battery subsystem has been designed by Eagle-Picher and is a higher voltage adaptation of the Eagle-Picher nickel-iron technology under development for DOE since 1978. These two subsystem technologies are being advanced within the context of a complete integrated propulsion system. This system is referred to as **DSEP**, an acronym representing dual shaft electric propulsion. The dual shaft terminology refers to the separate parallel motor and transaxle axes used in the Eaton powertrain design. Integration of **DSEP** into the Chrysler T-115 mini-van, a multipurpose front wheel drive vehicle, will permit assessment and evaluation of the system in an actual operating environment. The T-115 will provide a light-weight test bed vehicle with low aerodynamic drag which is ideal for EV applications. The necessary test bed vehicle modifications will be performed by ASC, Inc.

The specific tasks to be completed to meet the 48 month program objectives are:

Task 1.0	Requirements Definition
Task 2.0	Preliminary Program Review
Task 3.0	Design
Task 4.0	Fabricate and Test Nickel-Iron Energy Systems
Task 5.0	Fabricate and Test Powertrains
Task 6.0	Fabricate and Test Vehicles
Task 7.0	Final Review and Planning
Task 8.0	Management and Reporting
Task 9.0	Fabricate, Checkout, and Final Test of Engineering Model (EM) Vehicle (option)

During the first year of the program, Tasks 1.0, 2.0 and 3.0 were completed. During the second year efforts have concentrated on fabrication and test of all first article experimental hardware, Tasks 4.0 and 5.0, and conversion of a test bed vehicle, Task 6.0. This document is a summary of those efforts.

The major emphasis of the **DSEP** development is to advance existing battery and powertrain subsystem base technologies in the context of an overall total propulsion system technology. Because it is an extension of prior efforts, the **DSEP** system will offer all of the advantages of the earlier generation Eaton and Eagle-Picher subsystems combined with improved reliability, durability and safety consistent with automotive practice.

The overall system rating targets were established in the first year requirements definition. The key end-of-life mission requirements for an electric powered van were found to be:

Range	50 miles [FUDS]
Acceleration	0-50 mph: 20 secs
Top Speed	60 mph
System Life	8 yrs: 9000 mi/year

Following initial projections, trade-off studies and exhaustive iterations, the system power and energy capacity goals were set:

Peak Power	56 kw
Energy Capacity	22.5 Kw-hr

These ratings formed the basis for the **DSEP** system design.

All of the key features of prior generation subsystems are retained. The system utilizes an a.c. induction motor and control offering the following advantages over a series or shunt d.c. motor:

- Brushless
- Better power density
- Extremely rugged; can take abuse
- Better suited for mass production
- Considerably cheaper
- Can be totally enclosed for environmental protection

A two-speed, automatically-shifted transaxle is employed. The use of conventional manufacturing techniques and approaches are stressed in its design, as are the desire to maintain high efficiency and reduced complexity. A relatively near-term, long life, economical energy system is also anticipated with the Ni-Fe batteries supplied by Eagle-Picher, while using a unique approach to Ni-Fe battery design. It will provide a combination of high peak power and specific energy resulting from the DSEP emphasis on vehicle performance and powertrain compatibility.

NICKEL-IRON ENERGY SUBSYSTEM DEVELOPMENT

The second year of the **DSEP** battery technology development concentrated on hardware design, tooling-up for proof-of-concept subsystem fabrication and initial hardware manufacturing. The major highlights for the year included:

- Completion of the NIF-170-5 Module Tool-Up and Fabrication Capability
- NIF-170-5 Module Qualification Testing
- Completed Module First Article Review
- Fabricated and Delivered First Two Complete Energy Storage Systems
- Demonstrated Energy Storage System Performance to the Derived Battery Requirements

The photographs presented as Figures 1 and 2 show the NIF-170-5 module components and the complete module assembly respectively. Twenty-eight of these modules comprise the complete **DSEP** system. This hardware is the result of the design and development efforts of the first year of the **DSEP** program. Production capability for the **DSEP** nickel-iron battery hardware required some changes to the fabrication facility at Eagle-Picher, however, the plaque processing lines were unaltered due to the identical nature of the plaque to previous processes. The assembly techniques and fixtures used were the most effected by the current hardware design and included new processes for module assembly, container to case heat sealing and terminal finishing. All of these process modifications were chosen to enhance the batteries reliability as well as accommodate potential future quantity manufacturing capabilities.

Module qualification testing was performed per Eagle-Picher QTP-359 and test results documented in the **DSEP** Program First Article Review Report dated December 18, 1985. This report detailed the acceptable performance of the module to both high and low ambient temperature storage, (71°C & -18°C), simulated in-vehicle vibration, and electrical performance, as well as physical and dimensional conformance. Life cycle testing of a module to a FUDS profile is ongoing with over three hundred (300) 100% DOD cycles

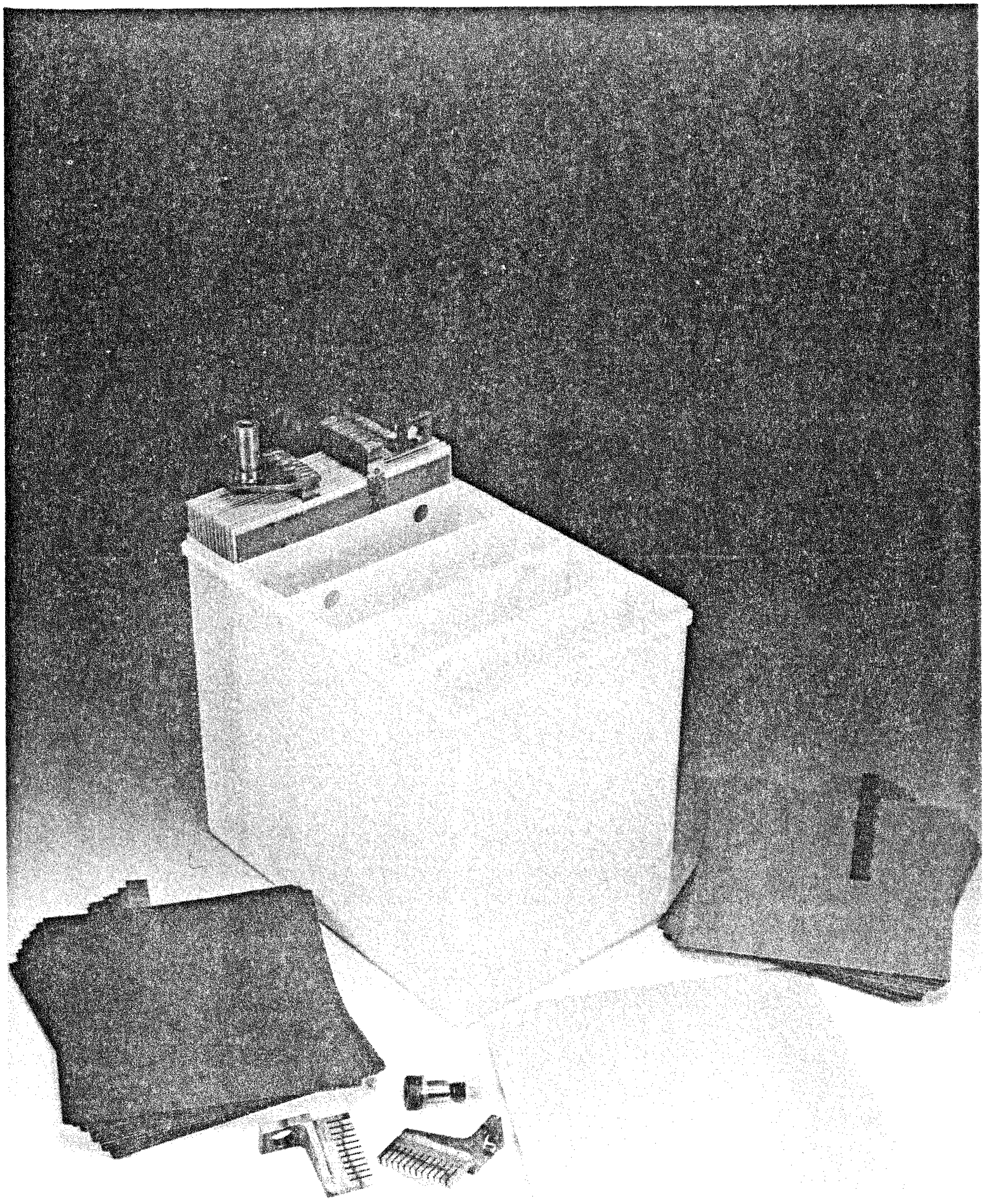


Figure 1 DSEP Energy System Module Hardware

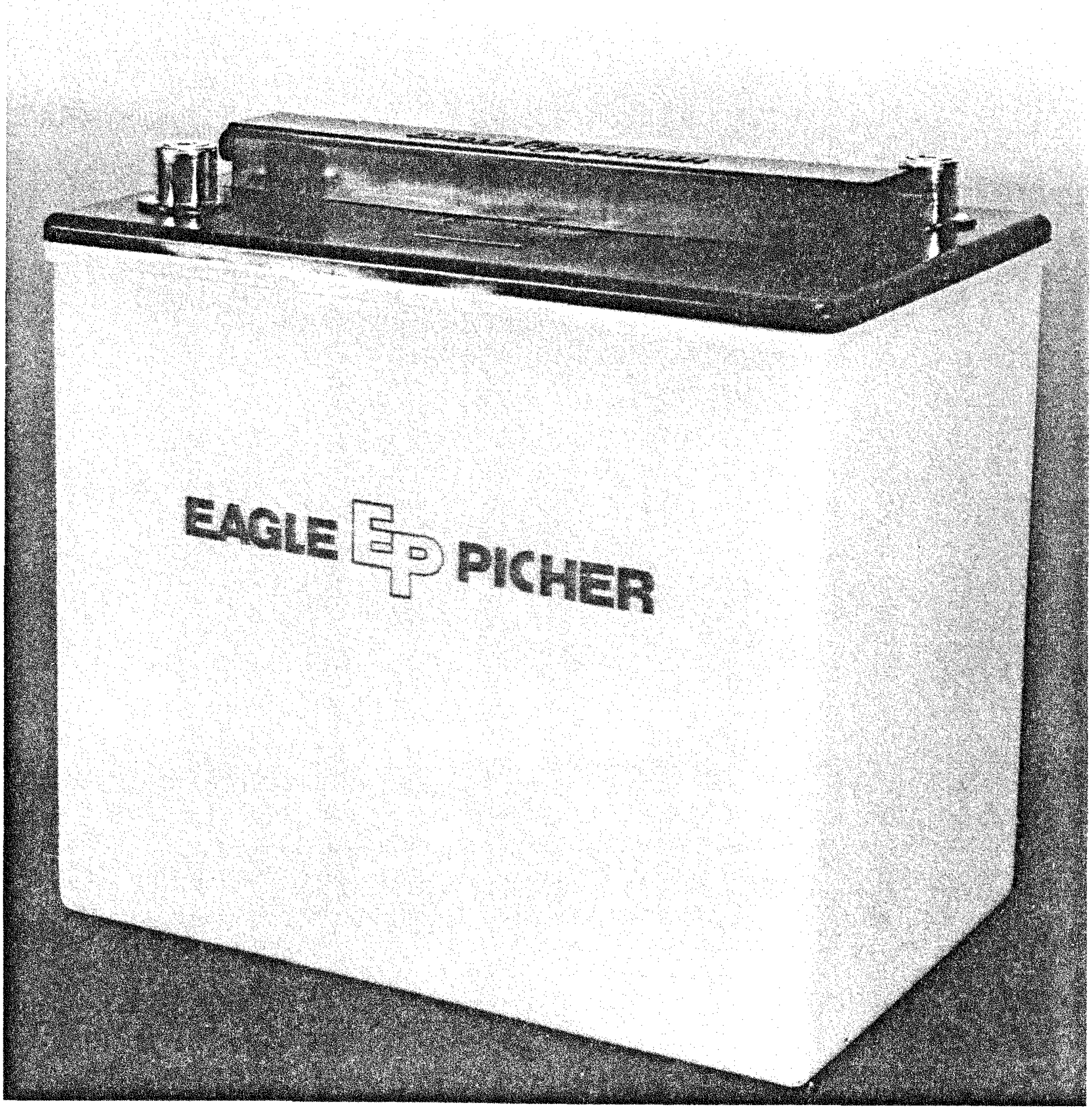


Figure 2 DSEP Energy System Module

completed at this time. This is equivalent to approximately 19,000 vehicle miles at an estimated 450 WHr/mi and represents 25% of the cycle life goal of the system. Table 1 is the test summary of the NIF-170-5 nickel iron module qualification.

Table 1

NIF-170-5 Module Qualification

Test Summary

Initial Stored Energy (FUDS)	-	31 kWHr (Battery Equivalent)
Initial Power @ 80% D.O.D. (400 A Limit)	-	55-56 kW (Battery Equivalent)
System Weight	-	1675 # (Less Fiberglass/Metal Composite cover)
Cycle Life (100% D.O.D.)	-	310 (Ongoing)

The first two (2) of the scheduled total of 6 complete energy storage subsystems (with spares) were fabricated, tested and delivered during the second quarter of the report year. Subsystem #1, a formal contractual deliverable, was shipped to NBTL for characterization under **DSEP** funding, and subsequent life cycle testing. Subsystem #2 was delivered to Eaton's Research Center for integrated dynamometer component testing. When not supporting the dynamometer tests, this system is also being life cycled at a C/3 rate while on a vibration shake table to determine the long term effects of road-like vibration during discharge. Figures 3 and 4 are photographs of the complete energy system #2. The first of four specially designed **DSEP** battery chargers built by Lester Manufacturing Co. was delivered to Eaton to support subsystem #2.

Testing of the complete Nickel-Iron energy storage subsystem #1 at the NBTL has demonstrated the new battery initial performance shown in Table 2. These are compared to the end-of-life **DSEP** battery goals derived from the mission requirements.

Table 2

Nickel-Iron Energy Subsystem #1

Goals and Initial Performance

	DSEP Goal*	**Initial Performance**
Stored Energy: (FUDS)	22.5 kWHr	28 kWHr (FUDS) 28 kWHr (C/2)
Peak Power (400 A Limit @ 80% D.O.D.)	56 kW	55-56 kW
Volume	16 $Ft.^3$	15 $Ft.^3$
Weight	1600-1750 lbs.	1675 lbs.

* End-of-Life (100% D.O.D.)

The requirement of 56 kW at 80% D.O.D. 400A limit and end-of-life remains the only questionable attribute. Stored energy of 22.5 kWHr (100% D.O.D.) at end-of-life (1200 cycles) would appear to be attainable from historical Nickel-Iron module and battery testing given the initial NBTL performance, establishment of the proper charge profile, and extrapolating the projected capacity decay to projected end-of-life. The volume and weight constraint targets are consistent with the existing hardware design.

Testing of both individual modules and the complete 28 module battery subsystem have indicated that the capability exists to appropriately thermally manage the Nickel-Iron subsystem to meet the **DSEP** program mission goals.

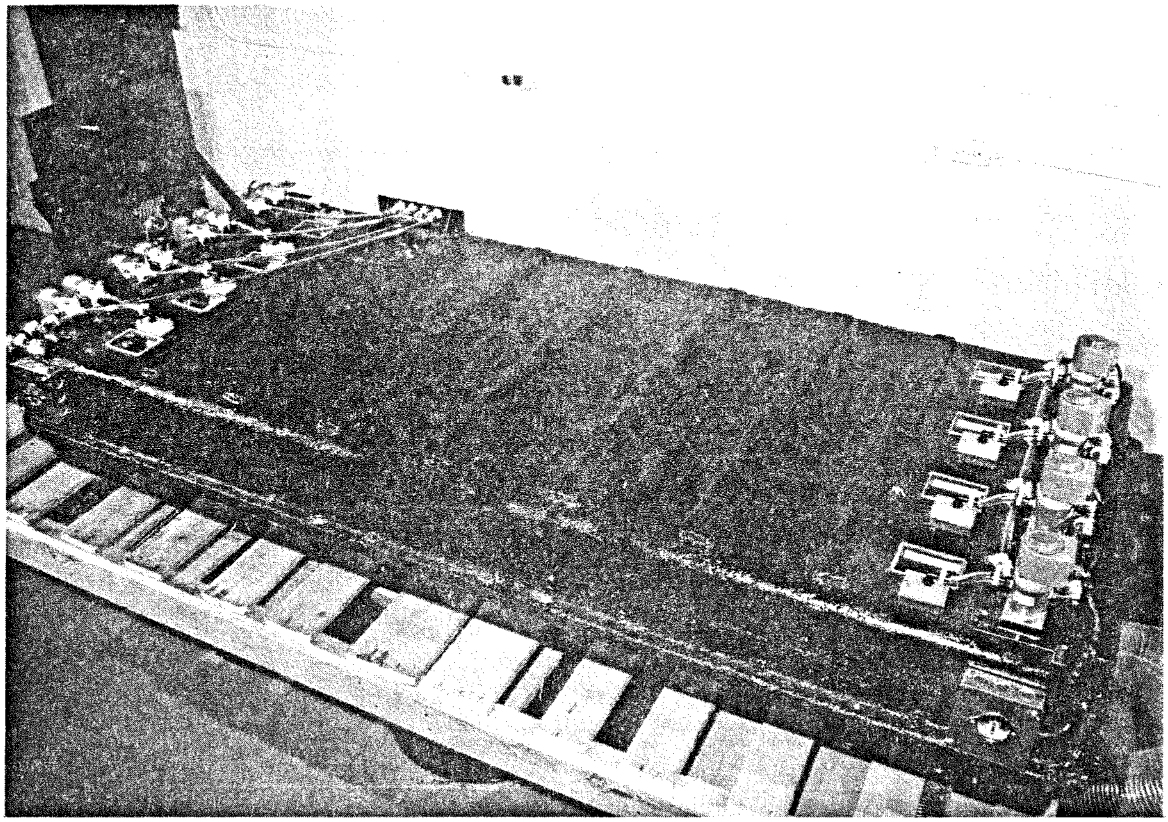


Figure 3 DSEP Energy System #2 with Cover in Place

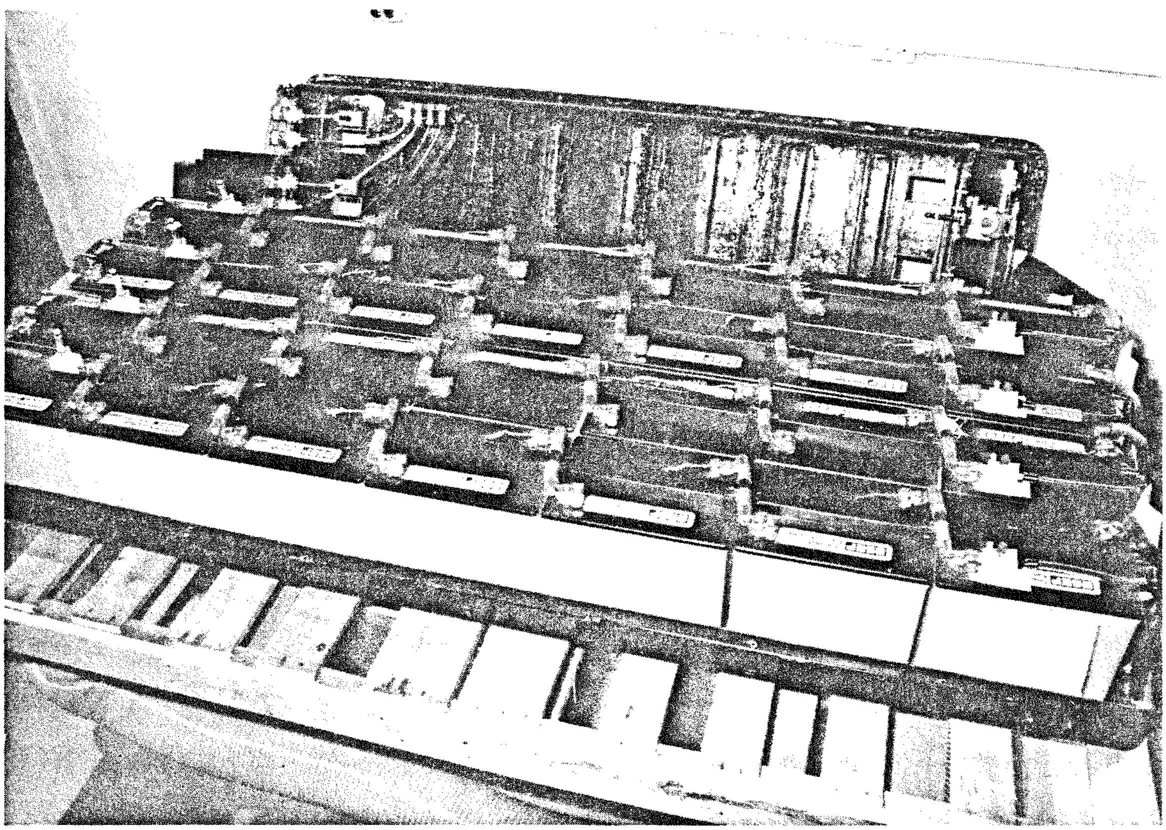


Figure 4 DSEP Energy System #2 with Cover Removed

POWERTRAIN DEVELOPMENT

The major elements of the powertrain are the traction motor, the two speed automatically shifted transaxle, the dc to ac power inverter, and the motor and system logic controller. Development of these components during the second year of the **DSEP** program followed a logical progression from the completion of detailed designs, fabrication of first article experimental hardware, functional bench testing, individual performance testing on the dynamometer, and then an integration of all the components for full system dynamometer testing. The **DSEP** powertrain is currently in the last phases of integrated dynamometer testing in preparation for test bed vehicle installation. Figures 5 and 6 depict the various **DSEP** components on test in the dynamometer laboratory. A summary of the development for each individual component is provided below. As a contract deliverable, detailed test plans for each individual component, as well as the integrated dynamometer testing were furnished to DOE.

As the powertrain development progressed, two significant changes were made to the system. First, in keeping with the modular nature of the componentry, a fifth distinct element, the vehicle interface unit, was added. This component, although merely an enclosure housing several smaller devices, serves as the power distribution point for all of the test bed vehicle subsystems, as well as the interface between the high voltage propulsion system and the standard vehicle 12 volt operating system. Contained within the enclosure are such necessary items as the main power contactor, battery charger plug receptacle, state of charge circuitry, hydrogen gas detection circuitry, various control relays, and the accessory pump and blower motor control circuitry. To date, most of these items have either been procured or are undergoing design and fabrication. Functional test of the complete interface unit will occur during overall system installation into the test bed vehicle.

The second change to impact the powertrain development was to discontinue work already in progress on an Eaton designed dc-dc converter for the 12 volt system in favor of an existing commercially available unit. The original **DSEP** inverter design was to incorporate the auxiliary converter and necessary power supplies within its circuitry as well as its enclosure. The switch to the unit furnished by VICOR Inc. resulted in simplification of the inverter interfacing, as well as in reducing the test and refinement necessary to perfect the Eaton unit.

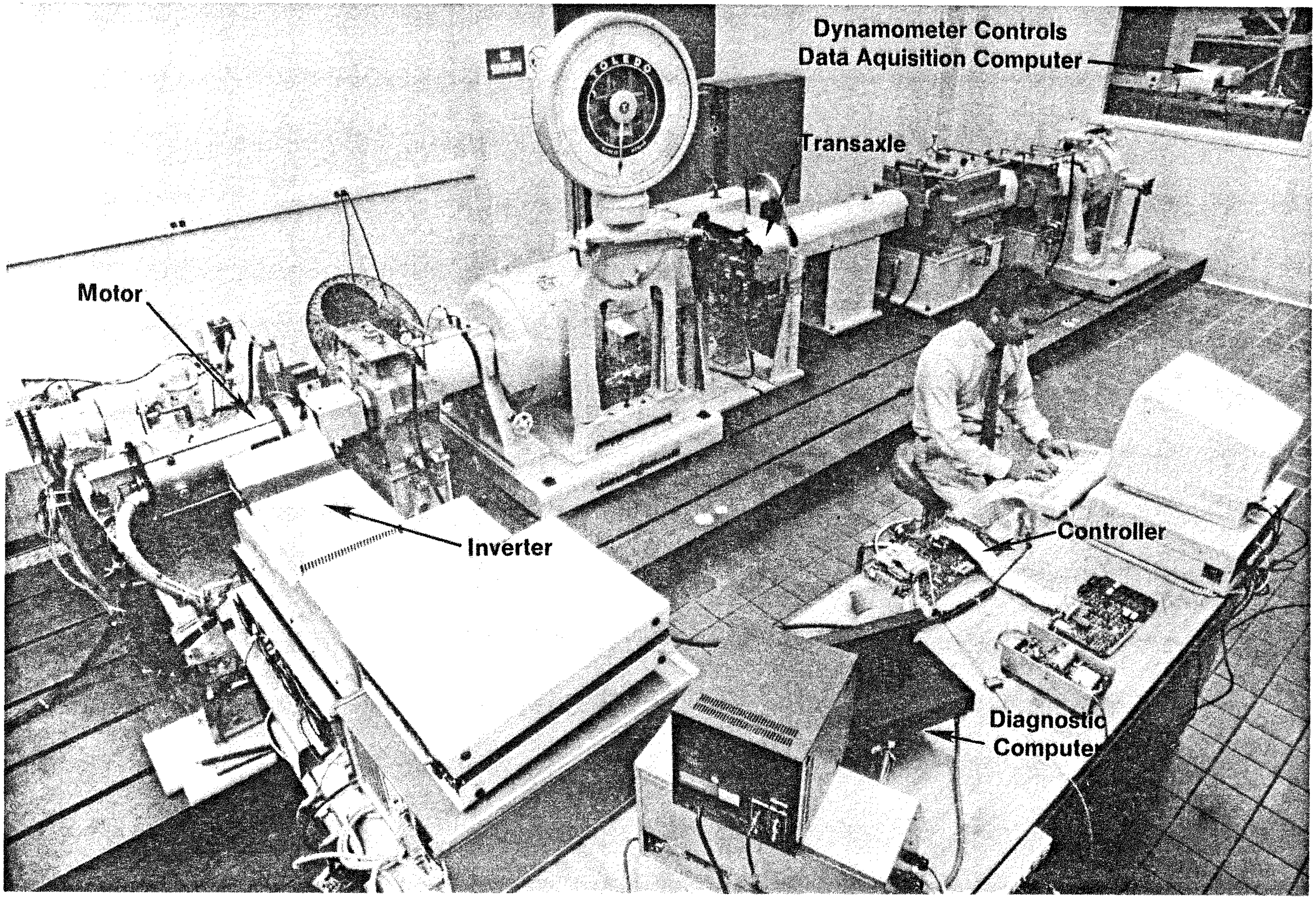


Figure 5 DSEP Dynamometer Laboratory

Figure 6 DSEP Dynamometer Laboratory

TRANSAXLE

The first **DSEP** transaxle shown in Figure 7 with the **DSEP** motor and in Figure 8 on the dynamometer test fixture has been fully function tested, performance mapped, and qualified for mating with the motor and subsequent full system testing. Most design objectives and specified performance were achieved in the early stages of the development. Basic functions, structural soundness, freedom from excessive leakage, noise and vibrations, and adequate heat dissipation capability appeared satisfactory from observations of loaded dynamometer tests across the performance spectrum. Only a minor adjustment in the lube/cooling oil flow distribution to the ratio-changing section of the transaxle was required before the start of extensive mechanical efficiency tests.

All key performance specifications have been verified on the dynamometer:

- 12,000 rpm input to chain drive
- 30 kw continuous power
- 48 kw intermittent peak power
- Greater than 90% efficiency at rated power

A graph of the transaxle efficiency in both gears at rated power is shown in Figure 9.

Beyond meeting all of the basic design and performance specifications, the **DSEP** transaxle incorporates a number of additional characteristics to enhance its utility, facilitate its use, provide a greater margin of overcapacity, and to improve its performance relative to the earlier Eaton designs:

* The design is conducive to high volume production with emphasis on low manufacturing cost, reduced parts count, and greater reliability.

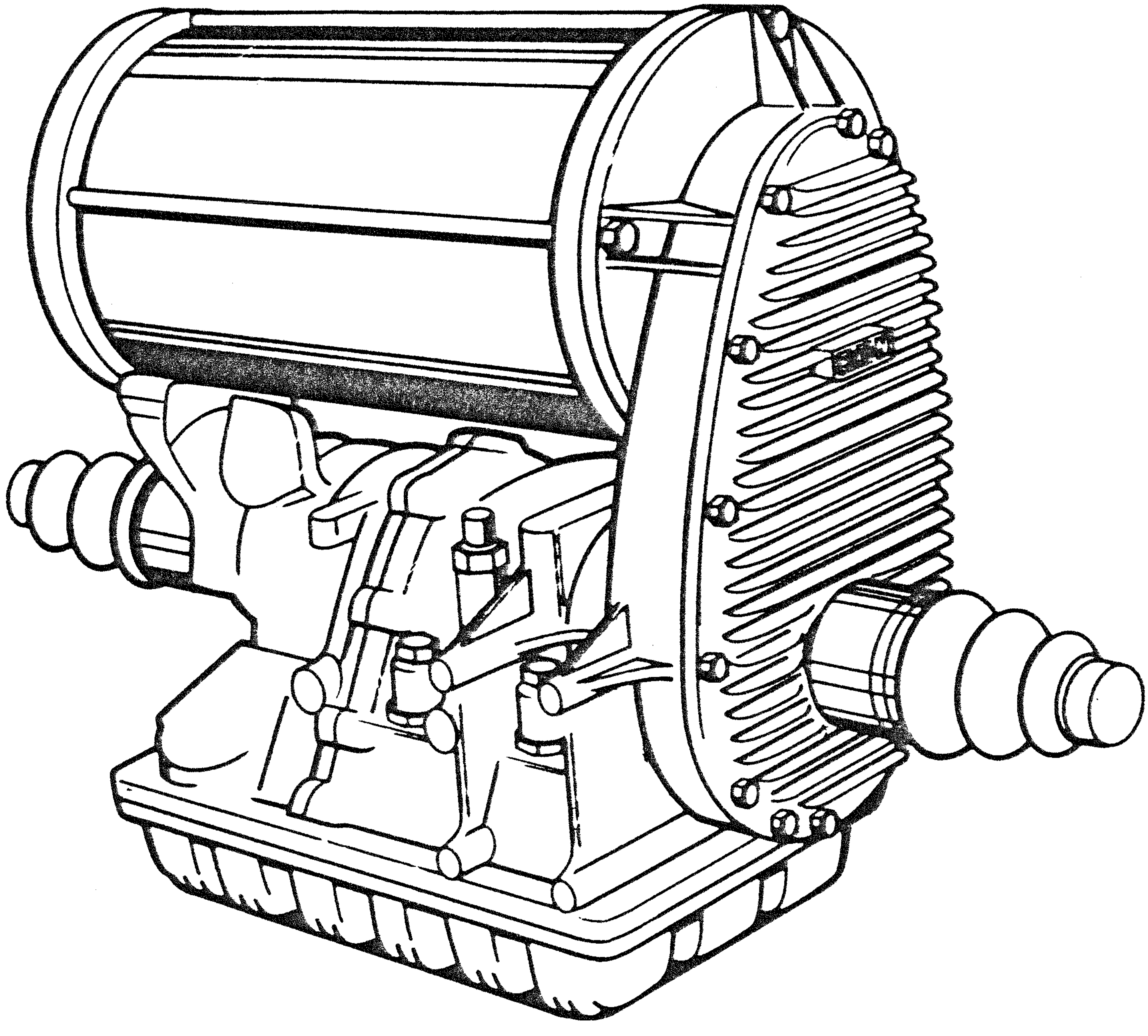


Figure 7 DSEP Motor and Transaxle

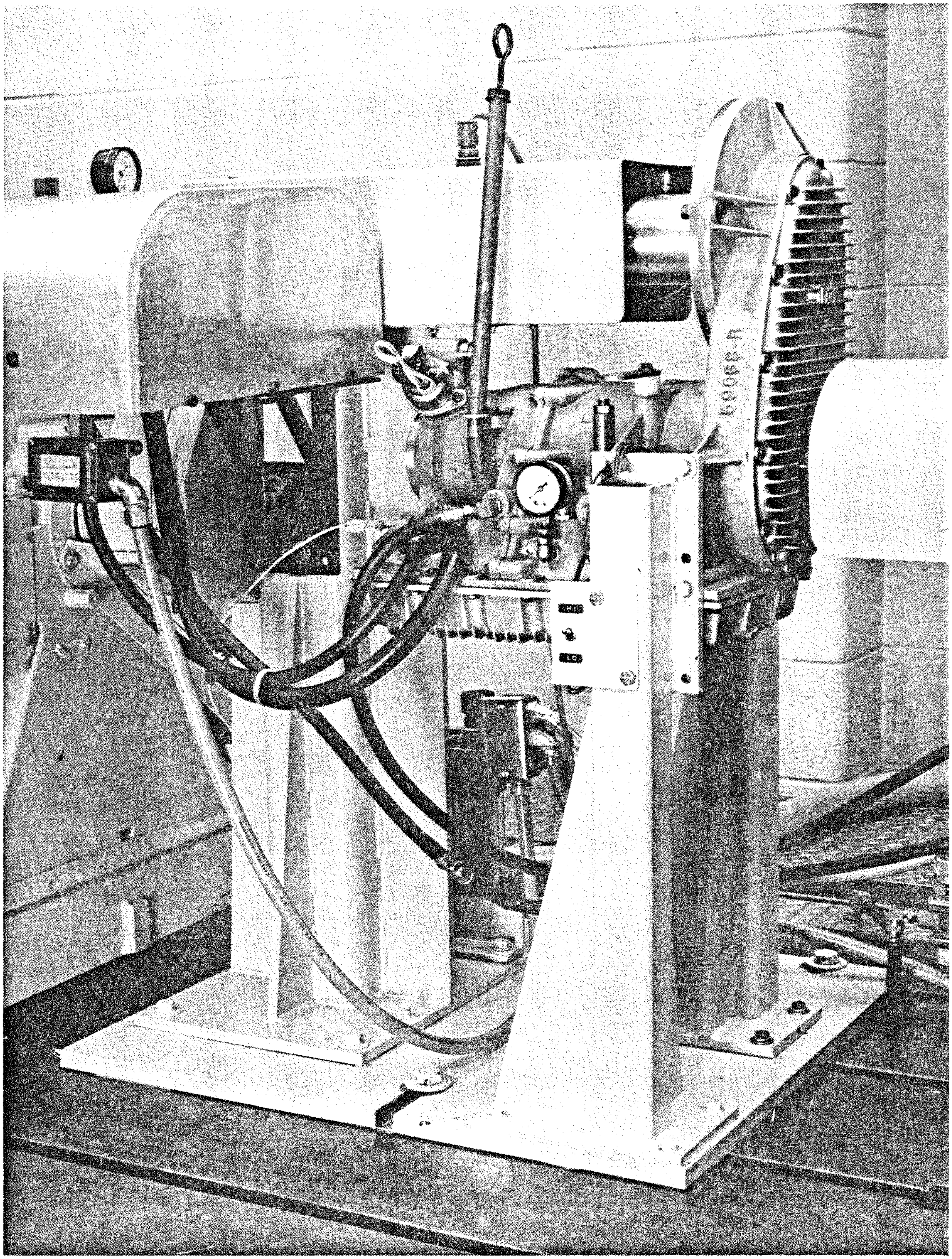


Figure 8 DSEP Transaxle Mounted on Dynamometer Test Stand

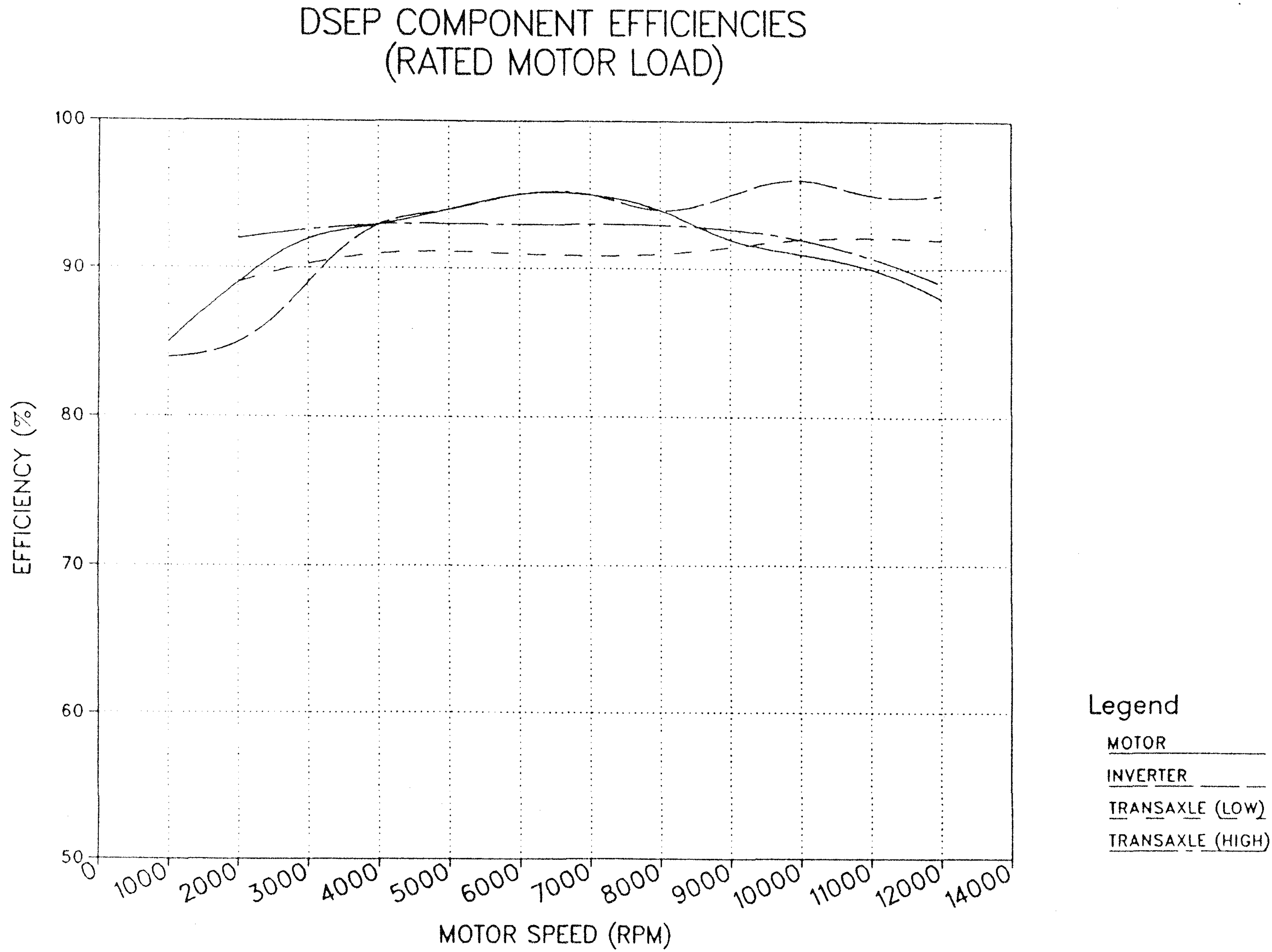


Figure 9 DSEP Component Efficiencies Rated Load

* The design incorporates all the functional refinements developed in the earlier generation Eaton electric vehicle transaxles, while avoiding the undesirable aspects of the earlier versions (including some designs currently used in the auto industry). These include pressurized shaft seal rings, power recirculation, overrunning clutches, tubing used in hydraulic lines, and internal feed of cooling oil to the motor.

* The design makes maximum utilization of componentry available from production automatics, such as gear and clutch elements, bearings, and splined connections in order to minimize experimental hardware cost.

MOTOR

Detailed design, fabrication, and basic function verification testing of the first **DSEP** a.c. traction motor was completed by the Eaton Electric Drives Division and the unit was shipped to the Engineering and Research Center in November of 1985. The motor was the first component to be functionally ready. Dynamometer testing of the motor over its full speed and load range could not be performed until both the **DSEP** inverter and controller had been qualified. In the interim, the motor was used solely as a load for the inverter testing, during which time it was discovered that the motor exhibited abnormally high temperatures, lower than expected efficiencies, and a measured excessive slip speed, indicated a problem with the rotor casting. Through the use of ultrasonic scanning techniques it was confirmed that large voids were present in the cast aluminum rotor bars. Due to the relatively non-standard (but fully practical) long length-to-diameter ratio of the **DSEP** motor, modifications to the rotor casting process were required and implemented at the manufacturing plant. A properly cast rotor was fabricated, installed in the motor, and utilized for formal efficiency mapping and thermal rating testing. As shown in Figure 9, motor efficiencies at rated load are quite high throughout the operating speed range. The motor is shown in Figure 10 mounted on the dynamometer.

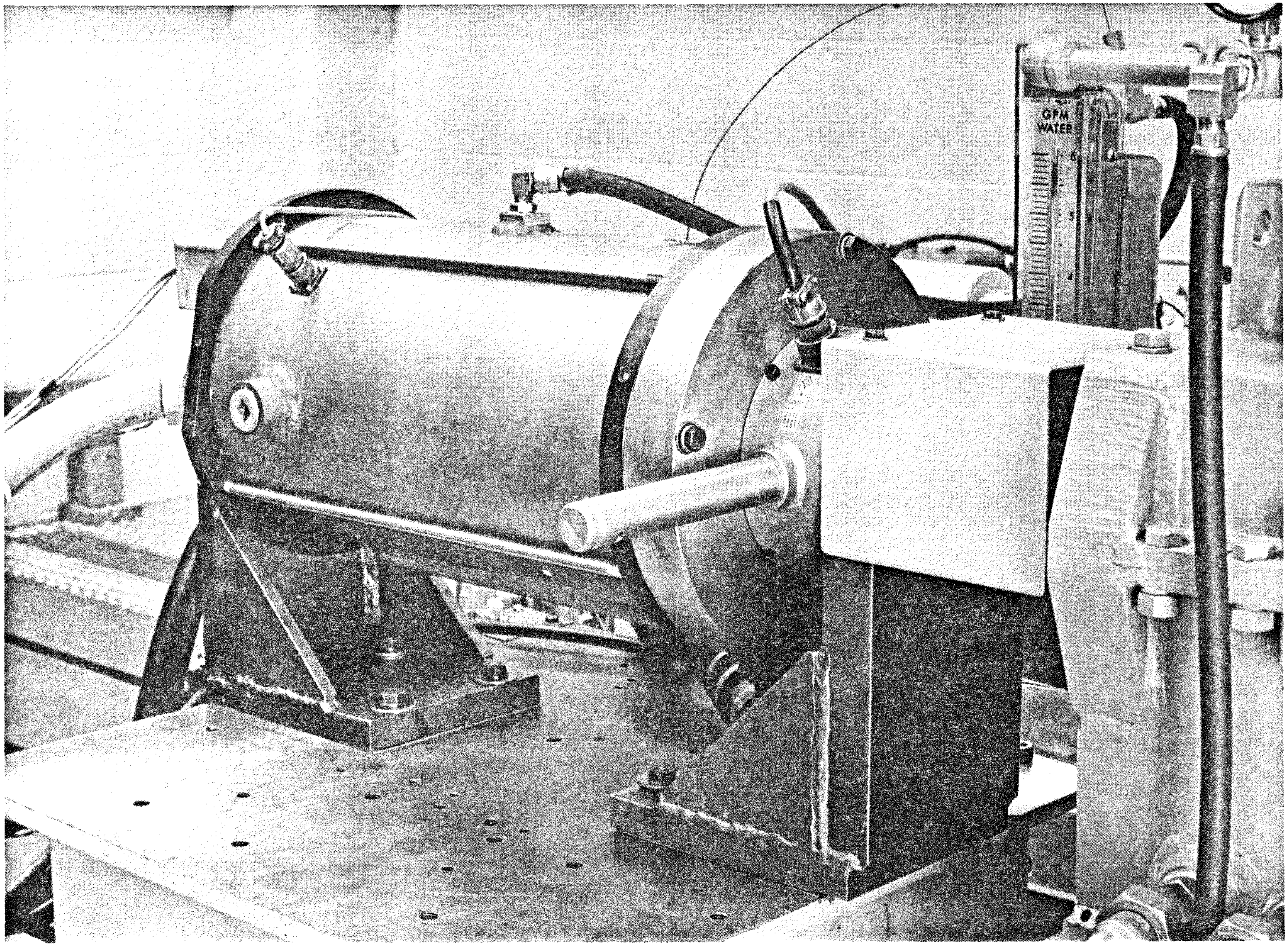


Figure 10 DSEP Motor Mounted on Dynamometer Test Stand

INVERTER

Functional qualification, fault, efficiency and thermal testing of the inverter has been completed. Rated load performance is shown to be quite good as indicated in Figure 9. Fault testing proved to be very successful and no components exhibited unacceptable temperature rises. Through the testing phase of the inverter development, minor changes were required to the original design. Improvements were made to reduce sensitivity to noise, increase voltage capacity of discrete components, and optimize power supply voltages.

The **DSEP** inverter uses six bipolar power transistors in three half bridge 'legs' to convert the battery's dc voltage to the variable voltage, variable frequency alternating current required by the induction motor. The inverter package also contains the low voltage power supply for the entire propulsion system, the interface circuitry to allow the system controller to command and monitor the inverter, and the voltage isolating base drivers and current sensors.

The inverter package has been designed for simplicity of construction and ease of service, as shown in Figure 12. It is constructed on an aluminum plate through which are mounted four extruded heat sink sections. Three of these sections are dedicated to the inverter half bridges while the last serves as a heat sink for the system power supply. The power transistors are readily available in plastic packages. These packages are mounted to grounded heat sinks without the need for insulating material. Individual heat sink extrusions are used for each leg of the inverter to allow for a low cost package and to obtain the closely spaced long fins necessary for efficient heat transfer to ambient air.

Individual base drive circuits for each transistor are also mounted on the heat sink to minimize lead length to the transistor and prevent base current oscillations. Field effect transistors are used in the base drive to reduce the required supply voltage and power. An active current limit makes the driven transistor's base current independent of supply voltage variations, while active regulation of the driven transistor's collector-base voltage allows lower quasi-saturation voltage and more stable transistor operation. The base driver will automatically turn off the driven transistor if excess motor current or an output short circuit causes the transistor to come out of saturation. This condition also is signaled to the interface circuitry to indicate a fault.

Inverter Cross Section

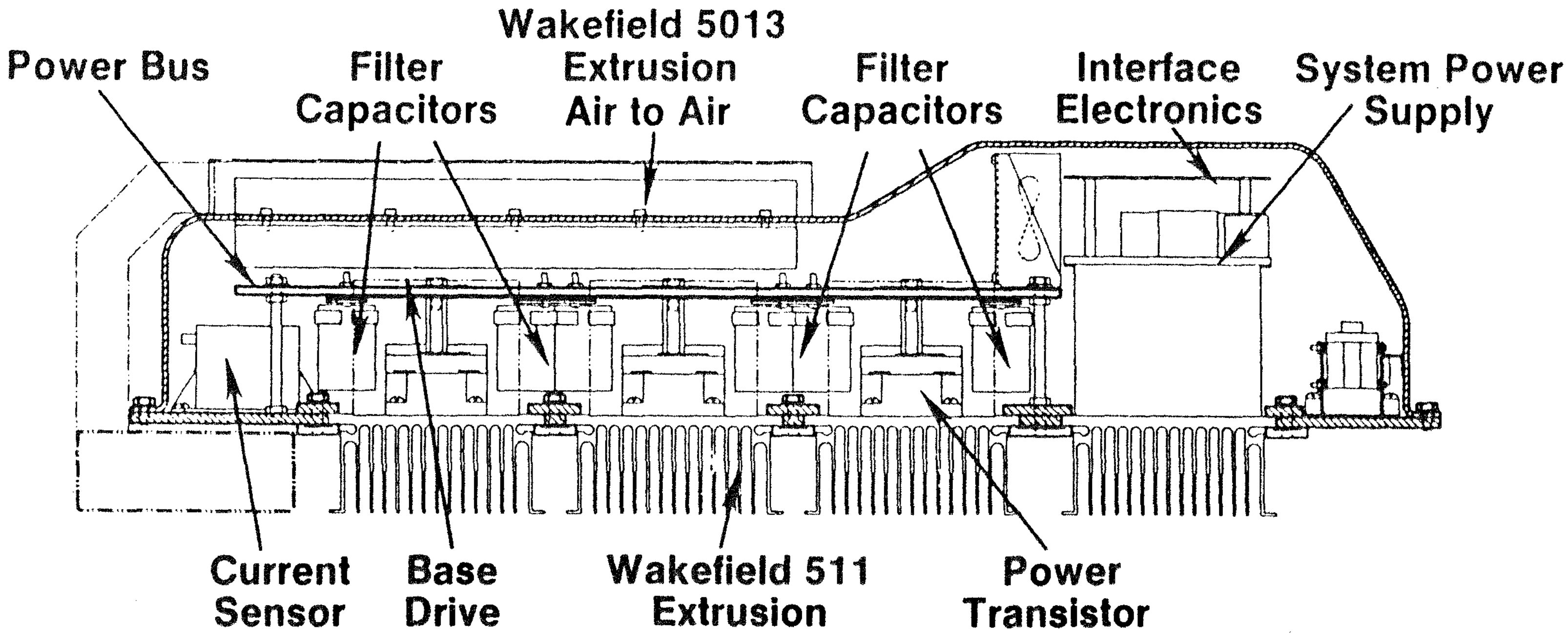


Figure 11

The system power supply provides multiple isolated outputs with reasonably good regulation. This has been accomplished with a dual stage design. A non-isolated chopper first reduces the traction battery voltage to a regulated potential of about 100 volts. This regulated source feeds a parallel inverter which drives a toroidal transformer with multiple secondaries. Since the parallel inverter generates a square wave signal, each output may be rectified directly into a filter capacitor without the need for an output filter inductor. Thus each output voltage is essentially independent of other outputs and suffers no significant voltage droop under transient load conditions.

The power buses are preassembled to a single insulating panel to form a 'high power' printed circuit board. Several separate banks of small electrolytic filter capacitors are attached to the bottom of this panel so that they will fit between the inverter's switching legs. This entire assembly is fitted over the transistor and all electrical connections are made using bolts accessible from the top of the bus assembly. Individual base drivers for each transistor are mounted at the outside edges of each heat sink to complete the power circuit assembly.

The power supplies and the interface circuitry are stacked over the fourth heat sink in the inverter package. The inverter power supply is next, followed by an interface board. Logic and low voltage power connections are made through the base plate immediately adjacent to these circuit boards.

Two brushless fans circulate the internal inverter air between the top of the power bus and an air to air heat exchanger. The internal air returns beneath the power bus where it helps cool the electrolytic capacitors.

The inverter cover is flanged to attach to the base plate. When this cover is removed the inverter is accessible from all sides. Power transistors are easily replaced by removing the base driver, power bus bolts, and transistor mounting bolts. The mounting bolts are accessible through holes in the power bus. The transistor may then be replaced without the need to disturb adjacent devices or remove the power bus assembly.

CONTROLLER

The **DSEP** controller performs all functions related to vehicle and motor control:

- Field oriented control for fast motor torque response
- Control of an outer torque loop for stabilization of vehicle resonances
- Gearshift coordination
- Operator input interfacing
- Fault monitoring and protection
- Dashboard display
- Diagnostics communication

This considerable processor load is handled adequately by a single 16-bit microcontroller chip from Intel (device #8097).

Two identical units were built from the first **DSEP** controller design. One unit is used for dynamometer testing with the inverter and controller. The other unit is used in the Eaton microprocessor lab for software development.

On going hardware changes are made to both units to insure compatibility. A separate test box which simulates all of the system inputs to the controller such as motor tach encoder signals, discrete sensor inputs, inverter faults and resets, etc. was fabricated to aid in the software testing and debugging.

Of all the major **DSEP** components, the controller continues to be the component requiring the most effort, and is the furthest from final qualification for vehicle test. The main thrust of the effort is in the software development. This work will continue throughout the dynamometer testing of the complete system, and into the vehicle testing as well. As the software programming becomes refined and more sophisticated, minor hardware changes are constantly required to adapt to the timing, signal, and sampling requirements dictated by the software.

From the list of controller functions above, hardware and software have been verified to date to perform all but gearshifting and outer loop control in actual vehicle operation. Of particular significance is the excellent torque response, stability, and speed regulation of the motor demonstrated to date on the dynamometer; providing confidence that vehicle driveability will be acceptable.

The necessary commitment to properly documented, updated, and efficient software programming for the controller has been maintained. This has been carried out in the state-of-charge (SOC) software, the communications software, and the programming for the diagnostic computer as well. Development of the software, from establishing flowcharts, algorithm creation, writing code, debugging, and testing the code has consumed a major portion of the DSEP engineering manpower. To date over 8000 lines (excluding comments) of high order language code have been written and fully tested.

In order to optimize all of the control parameters on a real time basis and to be able to interrogate the controller to resolve operational problems a GRiD PC has been procured as a diagnostic tool. The necessary software has been fully developed to provide communication between the controller and this computer, along with the routines for graphical display, analysis, and interpretation of variables. This computer will be a vital tool in final dynamic testing on the dynamometer, and in vehicle operation.

ANCILLARY SYSTEMS DEVELOPMENT

Three ancillary systems are associated with the main **DSEP** system. The power brake and power steering systems are required for operation in the test bed vehicle. The third ancillary, the state-of-charge system, is required to properly interface the battery system and the off-board charger, as well as provide an indication of remaining range to a vehicle operator.

Test bed vehicle power braking will be accomplished using the existing vehicle foundation brake system and vacuum booster with the addition of a continuously running electric driven vacuum pump. This system has been in operation throughout the past year on the mechanical model test vehicle and meets all of the necessary braking requirements with minimal power consumption and least modification to the production brake system.

The test bed vehicle will be supplied with power steering in a somewhat unique fashion by utilizing the same hydraulic source as the **DSEP** transaxle/motor lubrication system. A common electric motor and hydraulic pump will supply lubrication and cooling for the transaxle and motor, pressure for the transaxle clutches, and pressure for the production power steering rack. Mechanical model vehicle testing has confirmed proper steering efforts at the projected **DSEP** axle loadings with the system. All dynamometer testing of the transaxle to date has employed the common hydraulic system as well. System pressures, and cooling flow rates have not yet been optimized, but the chosen system appears adequate.

Full qualification of the soc system for test vehicle installation has not yet been achieved. The initial soc circuitry was bench tested and verified in breadboard hardware. Actual function testing while interfaced with the second **DSEP** energy subsystem and the Lester charger revealed some minor errors in communication protocol between the soc and the charger, as well as some intermittent problems traced to the temporary nature of the breadboard circuitry. As a result, the hardware has been committed to printed circuit boards and will be retested.

TEST BED VEHICLE

All design, fabrication, and testing of the necessary modifications to install and test the **DSEP** system in a Chrysler T-115 mini-van were completed during the second year of the program. Figure 13 is a graphic representation of the **DSEP** system positioned in the test vehicle. Included in the final phases of the design process was the interfacing of the single point watering and the hydrogen gas venting systems for the battery into the vehicle. Using a lengthy iterative FMEA procedure, a rather complex system was designed to insure safe operation and minimize maintenance.

Final projections for the first test bed vehicle weight based on actual component and hardware weights exceeded the original target by approximately 400 lbs. This excess impacts the system power and energy requirements as well as suspension and brake component loadings. Since the original **DSEP** power requirements were conservatively based on a test vehicle at full payload, restating them at half payload (in keeping with standard automotive industry practice), i.e. 600 lbs less, relieved any impact to the system power ratings and still allowed compliance with mission goals. The effect of the added weight on the vehicle structure was evaluated during the testing phase.

A multi-phase fabrication and test procedure was followed. First, using a body-in-white procured from Chrysler, all of the structural changes necessary to house the battery were implemented. In addition, a 7" stretch of the wheelbase was incorporated to reflect the actual production T-115 vehicle which will be available in the spring of 1987. The longer wheelbase T-115 will be the eventual **DSEP** test bed. However, it was necessary for ASC to lengthen the first TB1 vehicle frame as it will be required before the longer wheelbase vans are available. A series of static body bending and torsional twist tests were then performed on the body-in-white to evaluate the "stiffness" of the modifications. A battery tray and cover were also fabricated, and loaded with a complement of "dummy" battery modules artificially weighted to simulate the full battery pack weight. This assembly was used to evaluate techniques for installation and removal of the battery pack from the vehicle, to determine the possibility of pack damage from cargo

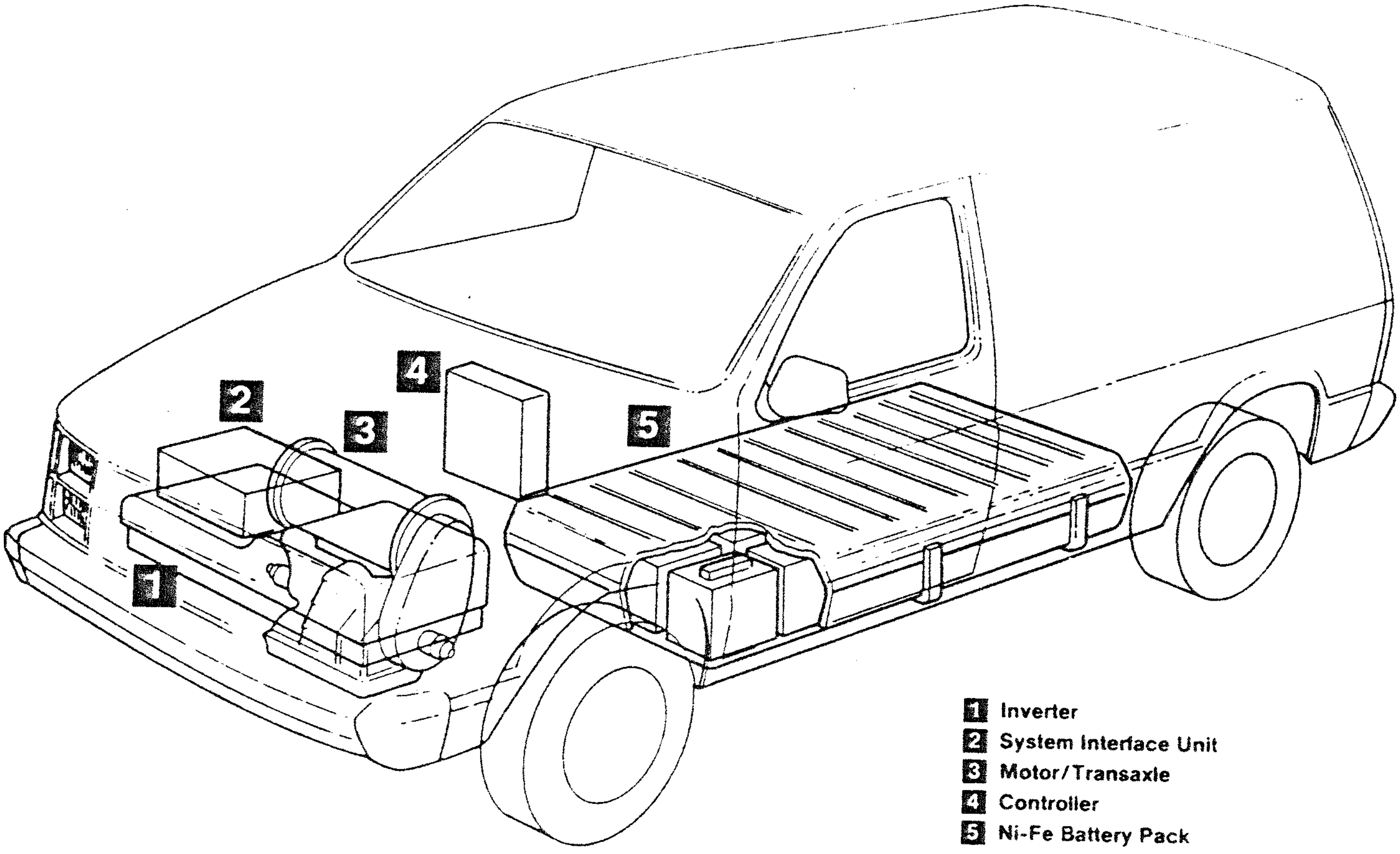


Figure 12 Components in Vehicle

floor deflection due to heavy payloads, and to perform in-vehicle air flow tests to confirm the sizing of the battery thermal management and dilution blower.

Incorporating all of the knowledge gleaned from the body-in-white exercise, similar structural modifications were then made to an actual vehicle. The frame was lengthened, battery pack modifications were made, and the pack with its "dummy" modules was installed. The gasoline engine and powertrain were left in place. This allowed for some actual dynamic testing of the vehicle before installation of the **DSEP** propulsion system. Figure 14 depicts TB1 in this configuration. Testing of the vehicle was conducted at the Chrysler Proving Ground in Chelsea, Michigan. Evaluations of the handling, suspension, steering, braking, and integrity of the structural modifications were performed. Results of the testing were very favorable. Some changes to the front and rear springs were identified to improve the ride and handling. All other evaluations met or exceeded the test criteria.

Upon completion of the track testing, TB1 was returned to ASC, the gasoline powertrain and accessories were removed, and all of the **DSEP** system bracketry was installed. The vehicle has been returned to Eaton for installation of the **DSEP** system upon completion of the dynamometer testing.

Throughout all of the efforts associated with modifying and preparing the test vehicle, Chrysler Corporation engineering has been very helpful and supportive. Data, information, and consultation has been readily provided. Procurement of prototype hardware has been expedited whenever possible. Chelsea Proving Ground personnel have shown genuine interest and been very cooperative.

PROGRAM MANAGEMENT

Throughout the second year of the program, Eaton Corporation has continued to provide all the necessary personnel, materials, equipment, facilities, and services required to manage, plan, implement, and control the technical progress and costs of the contract, including the subcontracts. Special emphasis has been placed on all aspects of the program to ensure personnel safety while working with batteries and powertrain components.

Figure 13 DSEP Test Bed Vehicle

When contractually required or when technically or programmatically appropriate, necessary review meetings have been held, presentations have been made, and report documentation furnished. Technical progress is on schedule. The attached network chart reflects current milestone status within the overall program.

During the second fiscal quarter of 1986, a transition was made from DOE sponsored program management by the Aerospace Corporation in Washington, D.C. to the Idaho National Engineering Laboratory.

EATON ENGINEERING & RESEARCH CENTER

DSEP ADVANCED DUAL SHAFT ELECTRIC PROPULSION SYSTEM TECHNOLOGY DEVELOPMENT PROGRAM

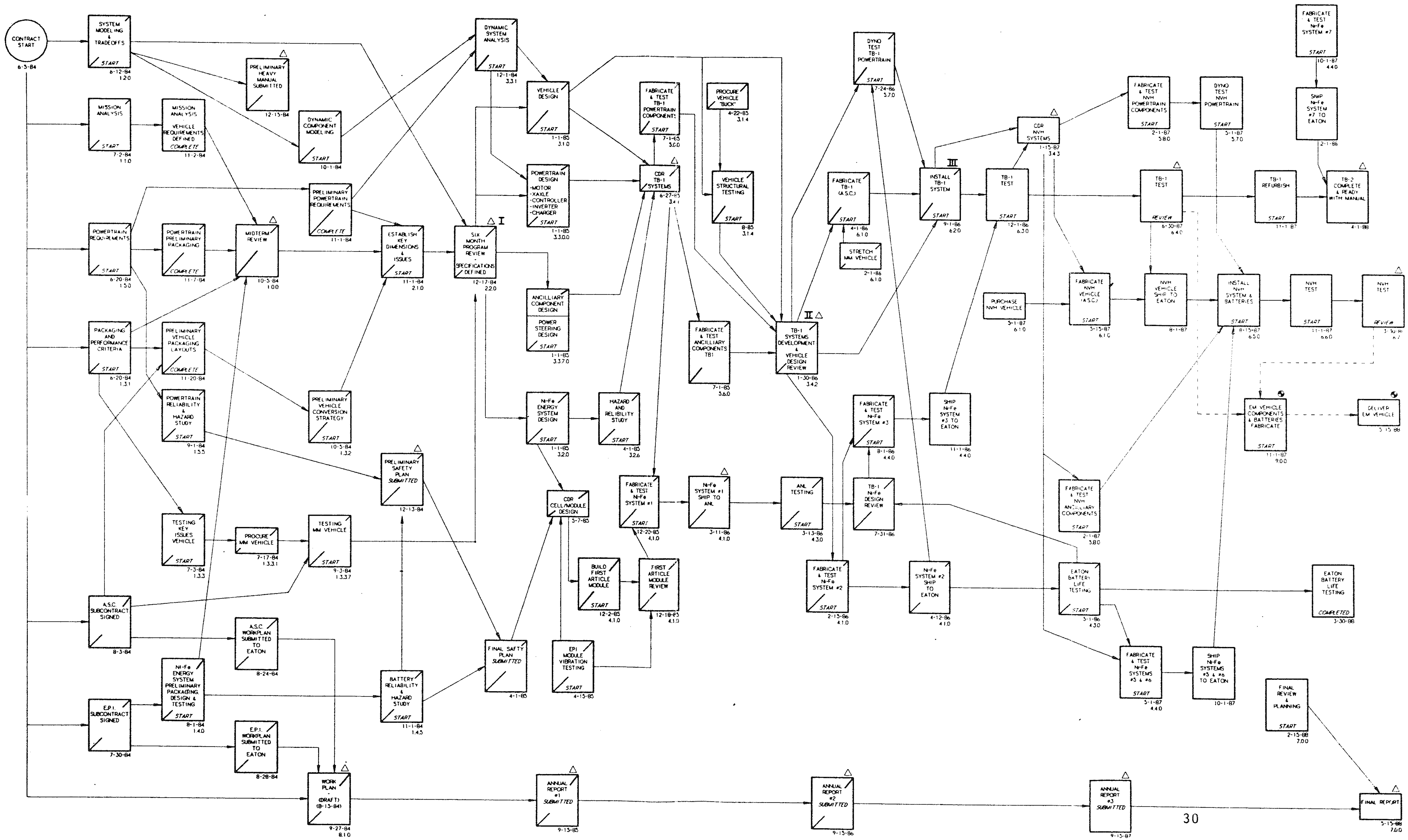
DE-AC07-84NV10366

9-3-86

△ DELIVERY ITEM OR CONTRACT DUE DATE

OPTIONAL TASK

I-III GO-NO GO DECISION POINTS



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