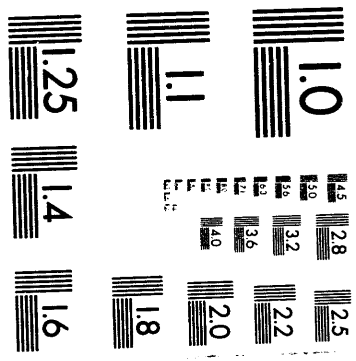
1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
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4.0
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1 of 1

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Preliminary Evaluation of the University of South Florida Mobile Data Acquisition System

The Idaho National Engineering Laboratory Versatile Data Acquisition System And The Autologger Vehicle User Survey System Produced by Instrumental Solutions of Ottawa, CN For The Site Operator Program Field Data Collection

D. M. Kiser
R. A. Richardson

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Introduction

The Electric Vehicle (EV) Site Operator Program, sponsored by the Department of Energy (DOE) and managed at the Idaho National Engineering Laboratory (INEL), is currently composed of thirteen Site Operators. In addition to operating electric vehicles for demonstration of the technology, the Site Operators also perform operational field testing. Data collected by the programs are input to the Site Operator Database at each site and transmitted, periodically, to the database at the INEL. As the program has expanded, some Site Operators have begun operating vehicles at sites remote from their offices. Other Site Operators are planning to expand their engineering and vehicle performance test programs. With the advent of these expanded test programs, it is necessary to consider in-vehicle, automated data acquisition systems.

Three of these in-vehicle, data acquisition systems have been designed and constructed:

1. The Mobile Data Acquisition System (MDAS) was designed and constructed by Sigma TecSystems, Inc. located in Tampa, Florida under guidance of the Site Operator Program.

2. The Versatile Data Acquisition System (VDAS) was designed and constructed at the INEL under the guidance of the Electric and Hybrid Vehicle (EHV) Program.

3. The AUTOLOGGER Vehicle User Survey System produced by Instrumental Solutions of Ottawa, ON.

Because the USF MDAS is a new system proposed for use by the Site Operator Program, the purpose of this report is to provide a preliminary evaluation of the MDAS by comparing the system to the proven VDAS. Data used to perform the comparison was acquired by a review of the MDAS literature provided by the USF, and by a demonstration[a] of the MDAS and its performance, provided by the USF to INEL personnel.

The USF has perceived a need for the MDAS because they are expanding their electric vehicle operations to the surrounding cities and counties. Thus, an automated means of data acquisition is needed to ensure the timely and accurate collection of data from these remotely operated vehicles. The MDAS has been in use in a vehicle for nine months, and is currently used daily in six remote vehicles. A more detailed discussion of the role of the MDAS in the USF Site Operator Program is given in the USF literature included as Appendices A, B, and C.

A brief discussion of the AUTOLOGGER is also included, for comparison, because it is being used by Southern California Edison (SCE), one of the the Site Operator Program participants who recommends the unit as a good system. The INEL personnel have not observed the unit in operation or tested the unit. The information on this unit has been furnished by Instrumental Solutions of Ottawa, On. Reproductions of the AUTOLOGGER brochures are included as Appendix D.

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a. On-site demonstration of the Mobile Data Acquisition System given by the University of South Florida, Department of Electrical Engineering to Idaho National Laboratory personnel, May 27, 1993.

Versatile/Mobile Data Acquisition System

VDAS History

The VDAS was originally conceived in the early 1980's by Edward Dowgiallo, of DOE, and Frank Pierce, of Value Systems Engineering, to fill the need of an on-board data acquisition system to monitor the operating parameters of electric vehicles. This early version of the VDAS recorded data in histograms and was the first system available to take electric vehicle operational data. The VDAS was improved when it became obvious that time correlated data was required for accurate and complete testing of electric vehicles and drivetrains. The present VDAS has evolved as experience was gained from actual testing of electric vehicles. The VDAS was designed to allow universal installation because, in general, no two vehicles are constructed and wired the same, even when obtained from the same vendor. Experience gained during this evolution also led to the implementation of data storage in non-volatile ram, isolation on individual channels, and the "watch dog" timer that shuts the system down if there is a lack of activity.

MDAS History

The need for collecting data from the electric vehicles used in the program at the University of Florida (USF) brought about the creation of the Mobile Data Acquisition System. The goal was to have all the electric vehicles in the program equipped with an on-board system to record all aspects of electric vehicle driving, including the various accessories that affect the range that the battery pack delivers. Because of the enormous amount of data that can be collected from an average drive, a number of steps were taken to alleviate the amount of data manipulation that a user would be required to perform to produce meaningful information on the electric vehicles. One step was to compress the raw data by eliminating repeated readings from the electric vehicle sensors. A second step was to use plotting and data manipulation programs that greatly reduce the amount of data processing. Data collection is accomplished through direct connection at the local sites and Cellular Telephone/Modem connection at the remote sites. Test systems have been installed in the USF vehicles, and one unit has been sent to the INEL for independent testing. Further enhancements and options will be planned after receiving feedback from users, who will ultimately determine the course of this project. As testing and evaluation continues, other parameters of interest are expected to be defined. These will be added to the system capabilities.

Autologger History

The AUTOLOGGER Vehicle Use Survey System has been designed and is produced by Instrumental Solutions of Ottawa, ON. The system has been developed to provide a relatively low-cost method of accurately tracking vehicle use. The system has been purposefully designed to be easily retrofitted onto virtually any vehicle with one common kit. Originally, the unit was developed for use in large-scale vehicle travel surveys, but has more recently been used by several electric vehicle trial operations including SCE and the University of Ottawa (20 G-Vans).

The basic AUTOLOGGER is a multiple channel data recorder (2 pulse counting channels and 4 status [on/off] channels which can store data on the RAM or on a removable data card (so that the information can be easily and cheaply retrieved from remote vehicles). This basic unit is passive to the driver and can track vehicle usage for long periods depending on the driving report detail required. Some of these units now in use are operated for 6 months between readings.

On to the basic AUTOLOGGER unit can be added an interactive keypad which provides collection of information from the driver. The keypad can "ask" (red flashing lights) up to 8 questions and has 5 answers (4 buttons plus no answer). The sequencing of the questions is controlled by software; and thus, questions can be asked at the start of the trip, during the trip, at the end of the trip, or for random trips. The questions and answers, themselves, are printed on a removable card that is inserted into the keypad. The system allows for a change in the questions throughout the survey. SCE is using this system on their electric vehicle consumer test fleet.

Because of SCE's interest in recording charging events (time, duration, and energy transfer rates), an electrical energy meter (**Energy Watch**) has been developed which plug-connects to the AUTOLOGGER. This unit is housed in a metal 7.5 x 4.5 x box and handles 115/230 vAC at 10 A.

The LCD display indicates real average power (W), cumulative energy (0.1 kW·h) and elapsed time of charge. In the SCE case, each charging event is time stamped and the energy transfer every 15 minutes is recorded. The exact report format is changeable in software. Storing this data on the data card allows for over a month's data to be collected before the card is full.

Analog-to-Digital (A/D) channel capability can also be modularly added to the AUTOLOGGER by a plug adaptor. This system was released to SCE in early July and will provide a very flexible and cost-effective means of monitoring battery condition to the module level. SCE and several other research groups want to measure voltage and temperatures at the individual module level.

This immediately presents a wiring complexity and cost problem (36 modules x 2 channels x 2 wires = 144 wires). A proposed solution is to set up a serial data network in which there are local "nodes" which monitor 4 channels each, and the individual nodes are connected by a single 5-wire cable in daisychain fashion. Up to 256 channels can be added in this fashion.

Of particular importance in electric vehicle battery monitoring is the isolation of the voltage measurement. This allows for far more accurate and "cleaner measurement" of the battery voltage. In order to isolate the "high" voltage measurement circuits (12 V), each high-voltage channel has its own isolated amplifier.

A self-powered vehicle monitoring device is to be released by Instrumental Solutions in the Fall of 1993 which will, when mounted in the engine compartment, record engine hours and movement hours remotely. It will display cumulative times and have an RS-232 port which will allow for a time history report to be downloaded to a PC.

Summary of Data Types Collected

MDAS

The MDAS is currently configured to take measurements of the following parameters:

- Time and date
- Vehicle speed
- Battery current
- Battery voltage
- Battery temperature
- Inside air temperature
- State of air conditioner
- Regenerative braking current
- Outside air temperature

VDAS

The VDAS is currently set to take measurements of the following parameters:

- Time and date
- Accelerator position
- DC charge power
- Incline
- Key On/Off
- Air conditioner status
- Vehicle velocity
- Battery current
- Battery voltage
- Battery power
- Acceleration
- Motor temperature
- Battery temperature 1
- Battery temperature 2
- Auxiliary battery voltage
- Auxiliary battery current
- AC power input
- Charge current

Site Operator Field Data

The present Site Operator field data that is being collected and input into the Site Operator Database is:

- Vehicle number
- Operator number
- Odometer reading
- Kilowatt-hour reading before and after charge
- Driver number
- Passenger load code
- Vehicle status
- Type of driving code
- Maintenance data including:
  - Service code
  - Failure code, if any
  - Amount of water added to battery

From the current Site Operator Data being collected, only the odometer reading and kilowatt-hour readings can be recorded by MDAS or VDAS.

AUTOLOGGER

The AUTOLOGGER provides the following basic data:

- Total distance travelled
- Trip length distributions
- Speed profiles
- Trip time distributions
- Acceleration profiles
- Engine idle time distribution

Description of Data Collected by MDAS

The MDAS is currently taking battery current from a thermally compensated HALL sensor. Battery voltage is obtained from a high isolation differential amplifier directly off the traction battery. Temperature measurements are taken from low-cost resistive type sensors. Vehicle speed is taken from an in-line transducer that is placed in the vehicle's speedometer cable.

Data is being collected at a 2-cycle/s (Hz) rate. The data is then processed with the Electric Vehicle Data Collection and Analysis software to produce the following output:

- Total time
- Total distance
- Average speed
- Average acceleration
- Average energy
- Total kilowatt-hours/mile
- Time at rest
  - Regenerative braking (kW·h)*
  - Air conditioner use by percentage

Several plots are generated from the data that include:

- Speed over time
- Current over time
- Voltage over time
- Temperature over time
- Kilowatt-hours over time
  - Air conditioner over time*

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* Those items flagged with an "*" symbol are items that will be added in the future.

Issues Concerning Potential Data Reliability and Data Quality

The INEL experience with the development of the VDAS lead to the concerns for the reliability and quality of MDAS data as follows:

Isolation

At the INEL, experience with electric vehicle measurements has shown that steps must be taken to ensure electrical isolation of the data system from the vehicle. Failure to do this could lead to high electrical potential differences, and the subsequent destruction of components of the vehicle or data acquisition system. Electrical isolation requires isolating the data system power sources from the vehicle power sources and isolating the measurement transducer data signals from the vehicle.

Calibration

The MDAS unit is preconfigured and calibrated in the shop prior to delivery, but may be field calibrated at any time. The INEL has written the VDAS software[1] to allow in-vehicle configuration and calibration.

Risks/Problems Involved In-Shop Calibration versus In-Vehicle Calibration. In place calibration of any data acquisition system will always yield more accurate data than a shop calibrated unit since the calibration is a total end-to-end check of the system. By calibrating in-vehicle compensation can be performed for any losses due to cabling in the vehicle. Offsets of the zero- and full-range data points caused by the transducers or associated vehicle equipment can also be nullified. The ability to do in-vehicle VDAS calibration evolved because the system is usually installed and maintained at the Site Operators' vehicle maintenance shop where equipment is not on-hand to do bench calibrating. This will usually be the case in normal applications. Maximum current into the MDAS, from any sensor, is 0.25 mA. At 20°C, it would require 4.5 miles of 22 AWG wire to cause 1% of full-scale loss. Thus, the losses due to cabling are insignificant.

Included in the design of the VDAS is a test fixture that will output a very stable voltage or current. Use of this tool in conjunction with an accurate voltmeter enables a technician to perform end-to-end calibrations of the system in the test vehicle.

Data Loss

As indicated by the University of South Florida during their demonstration to the INEL personnel, and the MDAS flyer[b,c], data is being stored to MDAS dynamic random access memory (RAM). This data is then written to a floppy disk when the vehicle is stopped. This procedure is adequate as long as power to the data acquisition system is not interrupted. However, if a vehicle should experience a battery power failure, the data leading up to this failure would be lost when power to the MDAS is lost. To account for this kind of event, the VDAS is equipped with a Static RAM (SRAM) and battery back-up system. Thus, when power is restored to the VDAS, the information is transferred from the SRAM to a floppy disk.

Data Acquisition System Power Considerations

When powering the data acquisition system from either the vehicle traction battery or auxiliary battery, the net result is that power from the traction battery is being used to run the data acquisition system. For an auxiliary battery, losses of a dc-dc converter also occur. If the energy consumed by the data acquisition system is insignificant, then powering from either of these sources is desirable; otherwise, the data acquisition system must be powered from its own separate battery. The VDAS is powered by its own separate battery, and the MDAS is powered by the vehicle battery system; although, a back-up battery is available. To conserve energy during long periods of inactivity, the MDAS provides a powered-down mode so that when no vehicle activity is occurring, the data system is shut down.

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b. Product flyer, "Mobile Data Acquisition System," Sigma Tec Systems, Inc., Tampa, Florida, 1993.

c. Product flyer, "EV-SOFT, Electric Vehicle Data Collection and Analysis Software," University of South Florida, Department of Electrical Engineering, Tampa, Florida, 1993.

Sampling Rate

The MDAS sampling rates may be set by the user to any multiple of miliseconds, up to a 1 kHz sampling rate. A 2 Hz rate for trip data was selected, based on USF Site Operator experience. The 2 Hz rate was also shown to be adequate by the German EV Program as published in the EVS-11 International Conference Proceedings.[3] At the University of South Florida demonstration, the MDAS was taking data at a 2 Hz rate. For inputs such as temperature, this is more than adequate. For voltage, current, acceleration, and power measurements, this is not frequent enough to detect high-speed pulses developed by current electric vehicle drivetrains. Also, to avoid aliasing problems, data should be acquired at a rate that is 5 to 10 times faster than the Nyquist limiting sample frequency. For comparable measurements, the VDAS sampling rate has been set to a 10 Hz rate with good results.

The VDAS is capable of taking data at sample rates of 15 ms or greater. Under normal operating conditions, data is sampled every 100 ms. However, all data is not stored at this rate. Individual channels can be set to record data at whatever rate the user desires. For example, individual channels can be set to accumulate data over time, such as ampere-hours returned to the battery during charge, or total kilowatts of energy used during a complete trip. Data channels can also be set to average these samples over a user determined time interval. During the charge mode of operation, data is stored only if any of four channels exceeds a differential value entered by the user. For example, if the charge current changes by more than 0.25 A, then all the channels are recorded at that time. If a problem is detected, the capability still exists to capture and store data at faster rates.

Charge Data

Although not on the list of data taken during the USF presentation, charge current was displayed in the sample data printouts that were distributed. The printouts do not indicate that battery temperatures are being collected during battery charge nor is charger input power.

Currently, electric vehicles are equipped with either on-board or off-board chargers. On-board chargers are more convenient since the MDAS or VDAS will also be on-board. With an off-board charger, transducer cables from the charger must be connected to the VDAS unit. This is usually done by having the operator connect the transducer cables at the same time the charger is connected.

Incline

The MDAS is not equipped to measure the angle of incline of the vehicle. This information may be of interest to site operators in determining the vehicles' operating capabilities in various terrains for varying accelerations.

Acceleration is not a difficult thing to measure by an MDAS or VDAS system. It is, however, one of the costliest because of the high cost of good transducers. Another consideration when taking acceleration data is that in order to see all the small variances of the vehicle's operation, data needs to be both captured and stored at approximately a 100 ms rate. However, when data is stored at this rate, the amount of disk space consumed is significant.

Incline is harder to measure than acceleration because inclinometer is not available that will respond fast enough to register small deviations in the vehicles' inclination. The VDAS accelerometers have an output that is proportional to acceleration of gravity times the cosine of the angle of inclination. If the vehicle acceleration is derived from the vehicle velocity measurement, then the vehicle angle of inclination can be computed.

Power Measurement

In the MDAS, vehicle power is calculated by multiplying battery voltage times battery current. Tests at the INEL have determined that this is not a true representation of the actual power consumed and could be as much as 7% in error. Separate transducers are currently used with the VDAS to measure vehicle battery power output and input, respectively. The time between current and voltage measurement is 1 ms, which virtually eliminates any phase error in power measurement.

Sensor Accuracy Versus Cost Tradeoffs

An evaluation of the data requirements of electric vehicles in Site Operator applications should determine the degree of accuracy of the transducer required. Tests at the INEL have shown that calculating power from traction battery voltage and current yield a result that is in error by 2.5 to 7%. Temperature and speed transducers can be found that are somewhat less expensive than those used by the VDAS with accuracy sufficient for the Site Operators' needs. There are currently no inclinometers on the market today with a response time short enough for electric vehicle use. Therefore, measurement of incline must be done as discussed previously.

VDAS/MDAS Cost Issues

The VDAS is a more costly system than the MDAS for the following reasons:

1. The VDAS utilizes static random access memory to store data until it can be safely copied to disk. This type of memory is expensive, but necessary to prevent data loss if power is lost to the unit. A battery back-up can be provided for the MDAS.

2. The VDAS has an isolation board that isolates the analog data channels from the vehicle system being measured. The MDAS is also isolated from traction battery voltage. Isolation is necessary to prevent burn up of hardware due to electrical ground loops.

3. The VDAS unit uses isolated power supplies in order to minimize the chances of ground loops and to prevent input power noise from effecting the data system.

4. The VDAS is a scientific test instrument designed to acquire time- varying engineering and time-varying vehicle performance data . The MDAS is currently a general purpose unit designed to acquire vehicle operational data.

Operating Temperature Ranges for MDAS and VDAS

No MDAS operating temperature experience was presented in either the USF demonstration or in the MDAS flyer. However, USF has stated that the MDAS power supply is isolated to 500 VDC, operates from -25 to 85°C, and has noise rejection better than 1% over a 20 MHz bandwidth. The MDAS also has 12 bit accuracy for 0.1%, or better, full-scale resolution. Operation of the VDAS has been reliable at temperatures above 0 and below 50°C, and unreliable at temperatures below 0°C. No

VDAS experience has been acquired at temperatures above 50°C. Assuming that of the current Site Operators (the coldest ambient conditions will exist at Ft. Collins, Colorado, and the warmest conditions at Phoenix, Arizona), the "ASHRAE Handbook for Heating and Ventilating,"[2] reports that equipment median extreme design conditions for these areas range from -28 to 43°C. For the United States as a whole, the temperature extremes range from -39°C at Bemidji, Minnesota (-51°C at Fairbanks, Alaska) to 45°C at Needles, California. It is apparent that some consideration of operating at temperatures lower than 0°C should be given to both the MDAS and VDAS for use by some of the cold-weather Site Operators.

Remote Downloading of Data and Data Compression

MDAS's optional capability for remote downloading of data uses cellular or land-line telecommunications. This capability is not currently available in the VDAS; and thus, no operating experience is available. This capability was part of the USF demonstration and communication between the USF Laboratory and an MDAS unit in a nearby parking lot. It appeared to be effective at 1200 baud transmission rate. Both the demonstration and the MDAS flyer state that ASCII data compression of up to 90% is done to minimize telemetry and media time and expense. However, both the MDAS and the VDAS store data in binary form which current data compression technology will only compress by 18 to 30%. By adapting the current V.32 or V.40 telecommunication modem technology, both the MDAS and the VDAS could be improved to provide 14,4000 baud transmission rates, with automatic, in-line data compression/expansion capabilities.

The optional AUTOLOGGER system to be released in the Fall of 1993 contains a RS-232 port that will allow downloading of data to a PC. This system can also be used with a telephone modem to provide telecommunications.

Potential Use of An In-Vehicle Data Acquisition System In the Site Operator Data Collection Process From A Site Operator Database User's Point-of-View

Data currently collected by the Site Operators is intended to give a general idea of the cost of operating various types of electric vehicles in various driving and weather conditions. For this reason, the data collected is a limited form of maintenance and operational data. The type of data taken is summarized in Section 1. As long as the field-test data desired by the electric vehicle is limited to cost and use with a relatively small number of vehicles, then the current collection technique is most cost effective. This method uses the vehicle operator to record data items when the vehicle is driven, or the vehicle technician to record data items when the vehicle is maintained.

If the scope of the Site Operator Program is expanded to become a more full-fledged field-testing and evaluation program, and as the total number of vehicles increases, then the amount of data to be handled will increase. Thus, a more automated means of collecting operational data (i.e., an in-vehicle data acquisition system) must be implemented in order to minimize data errors and data collection costs. The collection of maintenance or reliability data, however, will remain a human data collection process and will not benefit from an automated system. The use of an automated system becomes even more important if the vehicle is operated and/or maintained at remote sites.

As the data is currently gathered, it is input to the INEL Site Operator Database, a personal computer (PC) based database system. Periodically, once per month or once per quarter, the Site Operators send the data to the INEL. At the INEL, the data is collated into the computer network version of the database where it is accessible to electric vehicle community members registered for access. In the analysis of the results by the INEL, the data shows reasonable trends in operational and maintenance terms. However, deficiencies in the data collection process effect the credibility of results that requires a significant effort to check and eliminate bad data. The following discussion summaries the current efforts in collecting Site Operator vehicle operational data.

> Of the thirteen Site Operators in the Program during FY-93, eleven have reported that they have installed the database, and two have been unable to install the database. Of the Site Operators reporting data, four are using the current INEL Site Operator Database; two sites report data using either Lotus 1-2-3 spreadsheets or an older Clipper/dBase III version of the

Site Operator Database. Data received by these two sites required special handling. The remaining sites report their activities in quarterly report that contain some data, but this data is summarized in a very limited scope, and the reporting format is inconsistent.

Other problems encountered while analyzing the Site Operator data is that it requires extensive data checking be performed in order to eliminate blank records or records containing zeros in the data fields; to eliminate duplicate records entered to correct previous errors; and to determine if records are stand-alone or cumulative records. A record is a stand-along if the vehicle batteries are charged after each trip. Records are cumulative if the vehicle batteries are not charged until after several trips.

Conclusions and Recommendations

The VDAS system provides a laboratory level of accuracy and functionality for collection of operating data. This level is not justified for the Site Operator Program

At less cost, the MDAS system can provide basic operating data suitable for field testing and evaluation. The system also provides the capability for remote access of the data. Any potential problems with the system, isolation and accuracy, can be addressed with the test unit now at the INEL. The system can be modified as required.

The interactive keypad data entry system in the AUTOLOGGER can provide a more error-free means of entering manual entry data, such as, driver code, payload code, etc. The data storage card also has merit and appears to be a more reliable storage medium than disks.

It is recommended that a number of vehicles in the Site Operator Program be equipped with the MDAS system, and that AUTOLOGGER units be acquired for testing at the INEL.

REFERENCES

1. Richardson, R.A, Berg, R.G., "Versatile Data Acquisition System Model II User's Manual," EG&G Report, EG&G-EP-9846, September 1991.

2. "Handbook of Fundamentals," American Society of Heating, Refrigerating, and Air Conditioning Engineers, New York, NY, 1967.

3. "The 11th International Electric Vehicle Symposium Proceedings," World Electric Vehicle Association, Florence, Italy, September 27-30, 1992.

APPENDIX A

UNIVERSITY OF SOUTH FLORIDA
MOBILE DATA ACQUISITION SYSTEM

UNIVERSITY OF SOUTH FLORIDA

The University of South Florida (USF) is currently operating a fleet of four vehicles (two G-Vans and two converted S-10 Chevrolet pick-ups). One of the G-Vans is being operating by Florida Power Corporation as a demonstration vehicle. Two of the EVs are located at the USF and operated under the guidance of the Department of Electrical Engineering. The remaining EV will be located in downtown Tampa and operated by the City of Tampa. These EVs will be tested in a "commuter" type environment consisting of regular trips of constant distance in normal rush-hour traffic patterns. In addition, three Chevy S-10 pick-up trucks have been purchased with funding from the Florida Energy Office. Additional EVs are being acquired and operated by the Florida Power Corporation and data from these operations will be included in a common database with those of the USF. These vehicles will all operate in the Tampa, St. Petersburg metropolitan area.

Eight additional conversion vehicles will be located in the following Counties throughout the State of Florida: Hillsborough, Orange, Alachua, Volusia, Pinellas, Dade, Polk, Duval, Brevard, Orange, and Brevard. The map in Figure 13 indicates the locations of these stations.

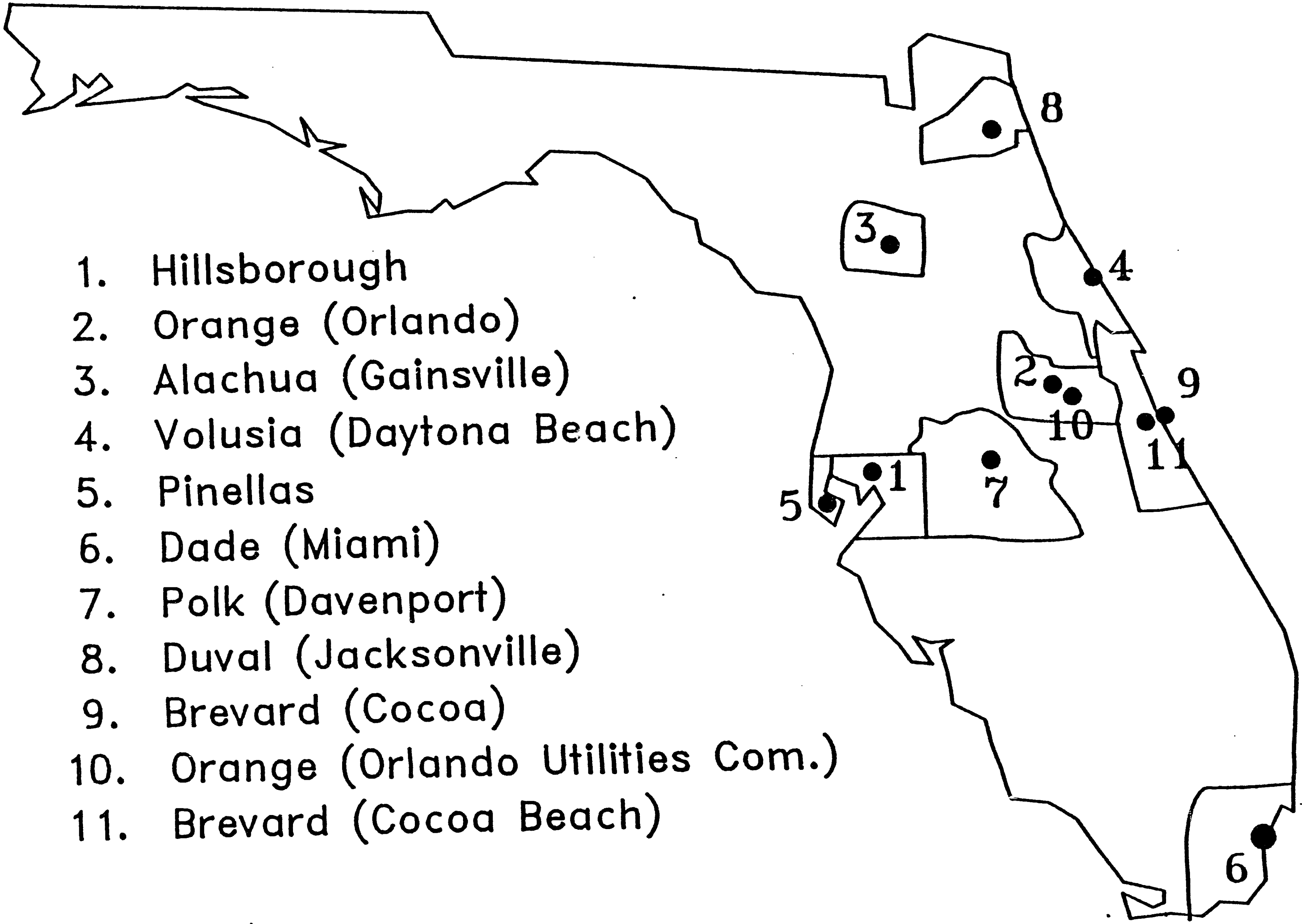
In accordance with the stated objectives, these vehicles will be tested to determine the reliability, range, necessary maintenance, and optimum charging scheme required to enable EVs to compete with their internal combustion engine counterparts in selected applications. The location of the electric cans and vans may vary to allow all participants the opportunity to evaluate each vehicle.

1. Mobile Data Acquisition System (MDAS)

   One of the tasks of the USF PV-EV project team is the collection of performance data from EVs. Of primary importance, is power supplied to, and delivered by, these vehicles. This power flow is naturally observable as power supplied to the main battery pack via charging and power drawn from it by way of vehicle travel.

   Some parameters to be measured have been selected to investigate various methods of charging the main batteries, as well as the characteristics of the batteries, themselves. These data include battery current, voltage, and temperature in the time domain.

Figure 13. Potential USF electric vehicle sites.



The study of the load on the batteries during actual use requires monitoring battery voltage, current, and temperature, as well as vehicle velocity and the status of the major power consuming accessories, primarily air-conditioning and heating.

Also of great interest is the effect of regenerative braking on the overall power consumption of the vehicle. This data is observed as current flowing into the batteries during forward braking.

Collection of the information necessary for these studies demands a dedicated data acquisition system in each vehicle capable of measuring the various inputs and storing that information in a suitable medium for later evaluation.

A timely and efficient method to collect these data from all vehicles under test is vital to this study, so a telephone link between all vehicles and the central data processing and control computer located at USF is currently under development. At the time of this report, a prototype cellular telephone interface has been designed and tested with success.

To allow future upgrades and software compatibility, as well as control costs, "off-the-shelf" components were used wherever possible. To that end, the IBM compatible 80286 computer was selected that allow the use of available A/D converter cards, modems, disk drives, and other peripherals.

The design and fabrication of several circuits to adapt these computers for a mobile environment has been accomplished, creating a unique and proprietary system.

This quarter has seen the evolution of the MDAS from a single prototype to an integrated mass-producible system. All the software necessary to collect the data of interest, store it in a universally compatible medium, and transmit it over commercial cellular or line telephones in a secure format has been written in the powerful "C" language.

The entire package has been designed for ease of installation and operation. No special training is required for the user. The MDAS is also completely modular for ease of service.

The following provides a more detailed description of the system:

MOBILE

- Instant set-up: No additional configuration or software required of the user. All calibration is done during assembly and automatically checked periodically by software. The user need only supply battery power and transducer inputs.

- Stand along operation: No external circuitry or operator input required. Once in place, this system can be totally self-operating.

- Twelve to eighteen VDS operation: 1.2 A normal operation, 2 A maximum draw during disk I/O, 30 mA standby idle mode.

AUTO TURN-ON

- Triggered by 5 to 12 v input pulse from one of 3 input ports (e.g., ignition switch or charging interlock, or from telephone ring detection circuit). Automatic power-down via software control to conserve battery power.

- Watch dog alarm indicator on hardware error. Audio alarm sounds if PC should fail. This situation will require only a push of the reset button, and possibly replacement of the data disk.

DATA ACQUISITION

- A/D software is automatically invoked on "power up" by way of the PC AUTOEXEC.BAT file with command line parameters set to select conversion speed and number of channels to sample. No rewriting and compiling of complex code is required to customize the system operation for different user requirements.

- Analog data conversion rates from minutes to 200 micro seconds.

- Interrupt driven A/D conversion allowing "Real-Time" foreground data processing and feedback.

- The A/D converter accepts input from any transducer capable of supplying -10 V to + 10 V to input terminals.

- Input signal conditioning and anti-aliasing circuitry on board to ensure reliability of analog measurements.

- One F/V converter for measuring speed is supplied with each system.

- Built in 1.235 V reference for thermistors, along with the software and circuitry to measure two temperature channels.

- One D/A output channel is available for special applications.

- Six digital output bits are provided for possible control applications.

SYSTEM

- Software and hardware telephone interface (cellular or line) will be available for each system for data retrieval, as well as possible remote control applications.

- Data is stored in compressed binary form to minimize storage and transmission time, space, and costs. Thus far, data storage requirements have been reduced by up to 70% of the original ASCII format requirements, with still more compression under investigation.

- Stored data is encrypted for security and error checking; therefore, it cannot easily be decoded for unauthorized use.

- The controller is a complete 12 MHz 80286 IBM compatible computer, with 2 MBytes of RAM, and compatible with most IBM software, allowing use of CPU for other jobs.

- On-site data analysis, including real-time, is available. Data may be retrieved manually from disk or by telephone for remote site analysis.

- Task scheduling, driver logs, and maintenance records are only a few of the other applications that may also be performed by the same computer.

- Real-time feedback will be provided to vehicle operators by way of an optional LED display array, currently under development, along with operator input to the system from a dashboard mount numeric keypad (for driver ID#, etc.).

2. Automatic Data Retrieval System

The Automatic Data Retrieval System (ADRS) addresses the problem associated with retrieving performance data from a network of remotely located EVs on a daily basis by using an automated wireless system. The EV's operating location routinely varies with driver and assignment changes throughout the year. Traditional data retrieval, through the use of designated modem lines and floppy disk handling, then becomes a problem. Automation of the entire retrieval system is the goal of this research. The ADRS devised for this purpose involves the use of a cellular telephone network to download data from a series of remotely located EVs in this program. The first prototype was built during this quarter.

The ADRS that has been designed utilizes the GTE Mobilnet-Florida Region Cellular Telephone Network. The EVs in the Program are equipped with a data acquisition computer, a 2400 bits per second (bps) modem, a ring detection circuit, a cellular modem-to-phone interface unit, and a cellular transceiver.

The following scenario describes the application of the ADRS: At midnight of each testing day, the main University Laboratory Computer will dial an EV's cellular phone number. The MDAS computer, after receiving the dialed retrieval command will then begin downloading the day's performance data through the cellular network using a XMODEM-1K transfer protocol. The lab computer will then call the next EV on the director list and retrieve it's testing data. The retrieval system utilizes the routine ability of the cellular network to automatically locate each EV by the vehicle's cellular phone number. The system, through software control, provides automatic retrieval that eliminates the errors of human interface and produces performance data that can be considered valid.

3. Human Factors Considerations

A major consideration in the continuing development and improvement of EVs is the extent to which they will be accepted by the driving public. Accordingly, a significant part of our effort will be directed to systematic evaluation of public acceptance of the vehicles and an assessment of the reasons for dissatisfaction along with the nature of reservations and complaints of individuals who have had experience using them.

A questionnaire has been prepared for use in the selection of subjects who will be given experience of several weeks driving electric cars. It will provide an assessment of prior attitudes about EVs, their importance for the environment, and also information about the driving habits of the respondents. Procedures for selection of subjects, preliminary briefing prior to driving, and debriefing at the end of the test period have been formulated.

4. Photovoltaic Solar Power

Another unique feature of this program is the use of photovoltaic arrays to charge the EVs. Because of the interconnection of the photovoltaic arrays with the power grid, power generated during the day can be routed directly to the local power company. This allows for power to be collected and provided to the grid while the vehicles are absent from the charging bays. In the evening when the vehicles return, the power "stored" to the grid can be recovered for charging. The present system design will provide 20 kW peak thus making the USF one of the larger photovoltaic co-generation sites in the State of Florida.

The system has been designed for direct DC-DC charging of batteries by a photovoltaic array. The conceptual design was conducted by a two-step iterative process as follows:

- A system was devised involving the use of a common DC bus fed by Solar Arrays and the utility. Investigation indicated that some components of this system suffered from high prices and limited availability.

- A simpler design was established that circumvented the need for the problematic components. Schematics have been drawn up, components chosen, and parts ordered for the simpler system that is currently under development.

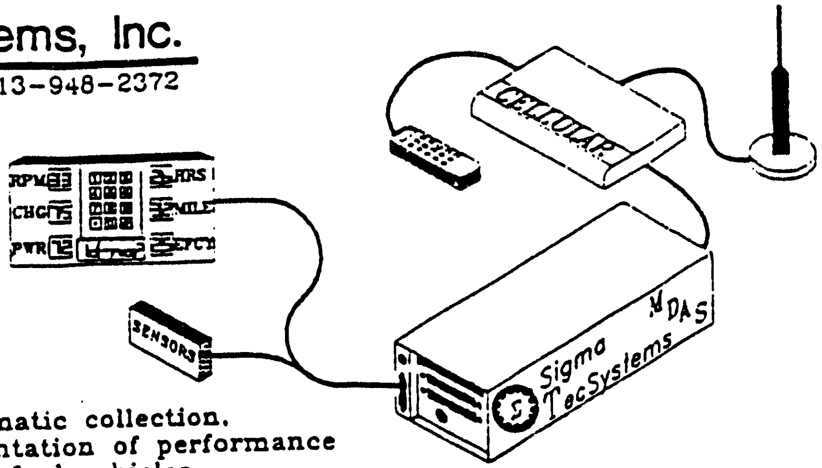
APPENDIX B

FEATURES & OPTIONS
OF
MOBILE DATA ACQUISITION SYSTEM

Sigma TecSystems, Inc.

Tel/Fax 813-948-2372

MOBILE DATA ACQUISITION SYSTEM



A complete system for the automatic collection, transmission, analysis and presentation of performance data for electric and alternative fuel vehicles.

FEATURES	ADVANTAGES
• Instant setup	• Preconfigured, calibrated and tested.
• User friendly	• No special training or maintenance required.
• Battery Operated. 10 to 12 VDC	• 30mA standby, 1.2A normal operation. 2A maximum current draw during disk I/O.
• Auto ON/OFF	• Self turn-on if 5V to 12V pulse sensed from any of 3 inputs or from telephone ring. Software power-down after task completion.
• Watchdog alarm	• Audible alert on hardware or software error.
• Power Failure Detector	• Automatic reset of CPU if power falls outside proper operational window.
• 16 Analog input channels	• Accepts any -10V to +10V transducer input.
• Built-in Anti-Aliasing Circuitry	• Eliminates measurement errors due to noise on any analog input channel.
• 8 Digital Input Ports	• Monitor the state of 8 separate devices.
• 8 Digital Output Ports	• Control 8 separate devices via SCRs or relays.
• Sensor Input ready	• Built in F/V converter to measure speed. Precision voltage reference for thermistors.
• 2 Serial Ports	• Serial interface for optional concurrent processors or I/O devices.
• Secure Disk Data Storage	• Reliable 1.44M floppy disk for portability.
• Up to 4 MBytes of RAM	• All data written to RAM until system is at rest.
• Compressed Binary Data	• Secure encrypted data, compressed up to 90% from ASCII to minimize telemetry and media time and expense.
• 100% IBM compatible	• Vast selection of IBM compatible software and hardware for custom applications and expansion.

OPTIONS	ADVANTAGES
• Cellular Link	• Cellular phone software and hardware interface for automatic remote data retrieval.
• Telephone Ring Detection	• Use standard telephone lines, if convenient, for data communications.
• Mini Console	• Realtime feedback or instructions for operator or monitor, with keypad entry for special tasks.
• Data Presentation Software	• On-site analysis, graphics and hardcopy of user selected parameters.

Sigma TecSystems, Inc.
P. O. Box 271646, Tampa, Florida 33688-1646 Tel/Fax: 813-948-2372

THE SIGMA TECSYSTEMS MDAS: NOT JUST A DATA LOGGER!

The Sigma Tecsystems Mobile Data Acquisition System (MDAS) was specifically designed for applications in electric (EV) and alternative fuel vehicles. Generic data loggers (GDLs) are not particularly suited for use in EVs but are best used for slowly occurring events or short time spans. The following will explain some of the differences and show why the MDAS out performs GDLs in electric and alternative fuel vehicle installations.

PERFORMANCE

Sampling rates of up to 5000 Hz can be implemented with MDAS. Although a sampling rate of 64 per second will exceed any present measurement requirements in an EV, the capability to switch to a high sampling rate under software control is sometimes used to more closely examine specific EV phenomena.

SIZE

Overall outside dimensions of 3.25" x 6" x 12" make the MDAS convenient to install in an EV and yet house a complete IBM compatible CPU, modem, power supply, A/D card, Signal Conditioning card, and 1.44 Meg. floppy disk drive. The MDAS designers have sacrificed a little extra size over the typical GDL for the unlimited compatibility and expandability of the IBM platform.

POWER CONSUMPTION

No separate batteries are required by the MDAS since it derives power from the existing vehicle auxiliary battery. To conserve power the MDAS shuts itself off when the EV is idle, then automatically powers up on several stimuli indicating EV activity or incoming telephone call.

SENSITIVITY

With 12 bit resolution on 16 A/D channels the MDAS is capable of accuracy of .005 volts per input for a 20 volt input range. This accuracy exceeds that of any transducers currently used in EVs but ensures that the A/D conversion process has the precision required for scientific research.

SIGNAL CONDITIONING

All inputs to the MDAS A/D channels are fully conditioned by double pole active filters providing a 60dB per decade attenuation of noise.

SPEEDOMETER INPUT

On board circuitry allows the direct input of an EV speedometer signal for speed, acceleration and distance measurements. The typical GDL requires additional circuitry to accomplish these measurements.

THERMISTOR INPUTS

Four channels are provided for the direct connection of external thermistors. An on board precision voltage reference allows accurate temperature measurements of EV cab, battery and ambient temperatures. A GDL would require additional circuitry for these measurements, while the MDAS comes with easy to install thermistors.

STORAGE MEDIA

It has been determined that daily measurements on EVs may require the storage of up to 200 Kbytes of information. The MDAS can typically retain up to a full week of vehicle performance data, while the typical GDL cannot even hold one day's requirements! The MDAS saves considerable time and expense in data transferal and operator intervention.

APPENDIX C

ELECTRIC VEHICLE DATA COLLECTION AND ANALYSIS SOFTWARE

University of South Florida
Department of Electrical Engineering
Tampa, Florida

EV-SOFT

Electric Vehicle Data Collection and Analysis Software

CURRENT FEATURES

- Readily accepts import of MDAS formatted data Files.
- Groups data files by vehicle and date.
- Applies data compression techniques to reduce overall database size.
- Automatically converts binary files to ASCII.
- Breaks daily data files into individual trip and charge records.
- Automatically applies mathematical transformations to data.
- Provides Averaging over user defined interval.
- Provides summary of data over user defined range.
- Provides plot ready output files for measured data.

FUTURE FEATURES

- Accepts any ASCII formatted data file.
- On screen graphical data trending with user defined triggering thresholds.
- User selectable digital filters and averaging periods.
- User configured vehicle files for specific component performance tracking.
- Graphical data plotting output which is compatible with most PC wordprocessors.

INPUT/OUTPUT PARAMETERS

Accepted Measurements	Summary Value Output	Plot File Output
Time	Total Time	Speed over Time
Speed	Total Distance	Current over Time
Battery Current	Average Speed	Voltage over Time
Battery Voltage	Average Acceleration	Temperature over Time
Battery Temperature	Average Energy	KWh over Time
Inside Air Temperature	Total KWh/Mi	A/C ON over Time
State of A/C and Access	Time at rest	
Regen. Braking Current	Regen. Braking KWh	
Outside Air Temperature	A/C use by %	
	OAT IAT Delta	

APPENDIX D

INSTRUMENTAL SOLUTION'S AUTOLOGGER DATA COLLECTION SYSTEM INFORMATION

AUTOLOGGER

A Simple Long Duration Data Collection System

The **AUTOLOGGER** system is an economical vehicle data collection tool designed to accurately capture long term information on vehicle use. The system is the ideal tool for those organizations that want to gather information on vehicle use on the temporary or permanent basis, whether as part of their fleet management or for transportation research studies. The hardware quickly installs on virtually any type of vehicle and offers the user the flexibility of using existing analysis programs or economically writing customized programs.

AUTOLOGGER FEATURES

EXPANDABLE DATA COLLECTION - the unit is capable of monitoring two counting channels and three status (on-off) channels. In the basic vehicle "tachograph" configuration, the following events are monitored Speed, Acceleration, Trip Distance, Trip Time, Engine Idle Time. The number of items is expandable to meet particular data collection requirements.

SYSTEM FLEXIBILITY - installs on ANY type of drivetrain.

FAST INSTALLATION OF HARDWARE - less than 30 minutes at the owner's site, no special tools required, except a portable computer (palmheld or larger).

FLEXIBLE DATA RECOVERY - the system can store data on its internal memory or on a removable data card that can be then be sent back to the processing office. The use of data-on-card mode minimizes the cost of data retrieval in remote locations.

REPROGRAMABLE - the onboard data analysis program is stored on the removable data card and thus can be modified at any time by card replacement.

RUGGED LONG-LIFE CONSTRUCTION - designed to survive all standard automotive operating conditions for the life of the vehicle.

DOS and MAC COMPATIBLE - communication is based on RS-232 interface and thus can be used with either DOS or Macintosh operating systems.

SYSTEM INITIALIZATION - a supplied setup procedure sets the time and date, vehicle ID and calibrates the speed sensor to the vehicle.

EASE OF USE - once installed, the system operates automatically with no input required from the driver. When the data is to be extracted, the operator can either remove the data card or download directly by connecting a portable computer.

SYSTEM STATUS INDICATOR - an exterior indicator light on the processing unit verifies proper system operation.

BACK-UP CLOCK BATTERY - the backup clock battery allows the vehicles battery to be disconnected for vehicle maintenance without effecting the stored data.

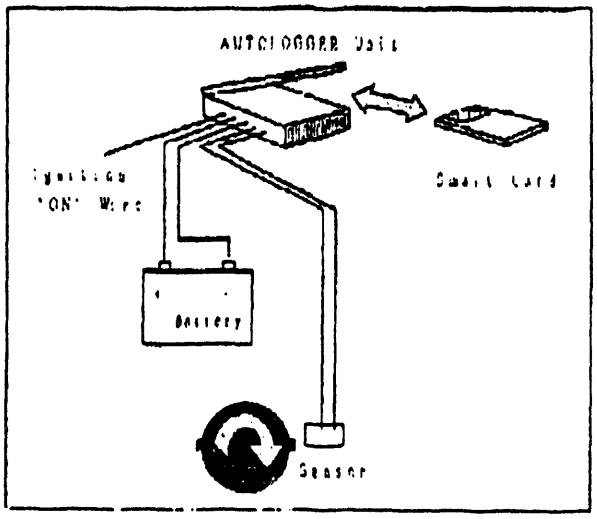
Manufactured by *Instrumental Solutions*, 190 Bronson Ave., Ottawa, ON, K1R 6H4 Phone: (613) 237-1565 Fax: (613) 234-2107

AUTOLOGGER INSTALLATION and SUPPORTING EQUIPMENT REQUIREMENTS

INSTALLATION KIT

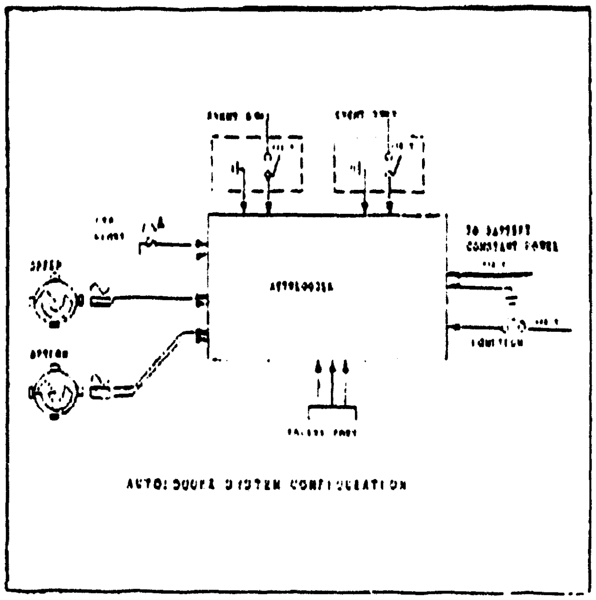
The complete installation kit consists of the following items:

* **AUTOLOGGER** unit,
* wheel rotation sensor,
* mounting bracket,
* electrical interface wiring
* 1 program/data card
* installation instructions



SUPPORTING EQUIPMENT

* portable computer with communication port (RS-232)
* desktop card reader/programmer.
* extra program/data cards as needed.



OPTIONAL FEATURES

Additional events can also be monitored such as road gradients, temperatures, and brake applications with add-on sensors

AUTOLOGGER *PLUS*

This option adds an external keypad that allows the driver to input answers to a user defined series of questions (driver, passengers, task type, etc). The standard keypad provides for up to 5 questions with 5 possible answer selections.

The **AUTOLOGGER** system provides the user with extensive and accurate information on the use and operation of the vehicle(s).

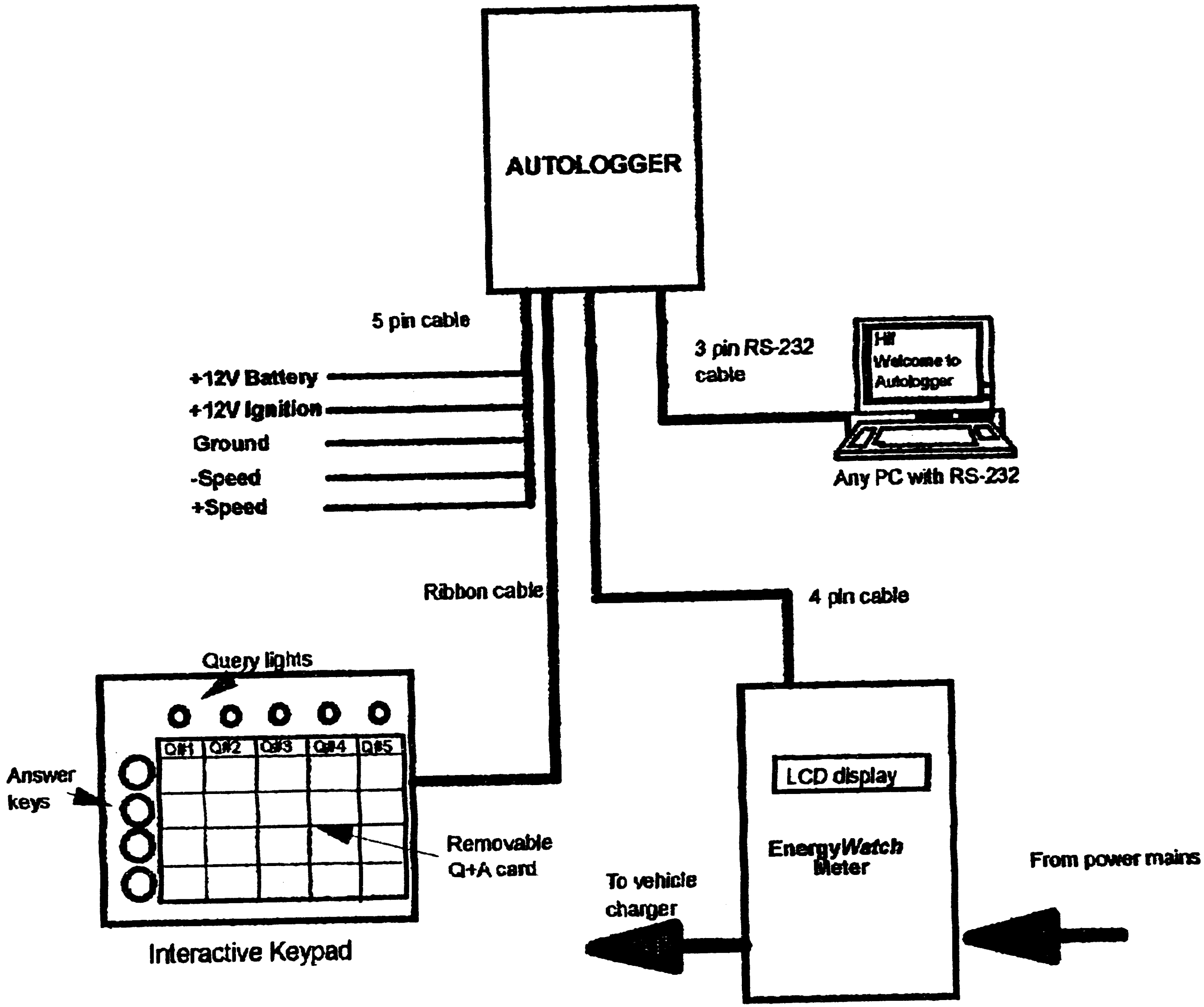
AUTOLOGGER provides the following basic data:

* total distance travelled
* speed profiles
* acceleration profiles
* trip length distributions
* trip time distributions
* engine idle time distributions

This information can be categorized by calendar day, week, month, or life-to-date, and used in trend analysis or operational profiles. Customized data outputs can be easily and economically created either by ***Instrumental Solutions*** support staff or by the user.

Manufactured by *Instrumental Solutions*, 190 Bronson Ave., Ottawa, ON, K1R 6H4 Phone (613) 237-1565 Fax (613) 234-2107

AUTOLOGGER System Components



AUTOLOGGER EQUIPMENT PRICE LIST
(U.S. Prices as of July 1993)

MASTER KIT

This kit contains all accessory material and equipment required to program, install and produce reports using the AUTOLOGGER system.

1	AUTOLOGGER Unit
1	RS-232 Port Connector
1	AUTOLOGGER Software (monthly report) on program/data card
1	Excel "macro" for data processing/reporting
1	Installation And User's Manual

Kit Price	$ 610.00
with Keypad	$ 640.00

AUTOLOGGER COMPONENTS

AUTOLOGGER unit	$ 435.00
AUTOLOGGER unit with 5X5 keypad	$ 475.00
Software (choice of standard programs listed below)	$ 160.00
Desktop Card Reader/Programmer Unit	$ 480.00
Communication Cable	$ 8.00
Replacement Speed Sensor Kit	$ 16.00
AUTOLOGGER Cards (32 Kb)	$13.25
Extra User Manuals	$4.00

AUTOLOGGER PROGRAMS

Note: Only one copy is required per application as it is reproducable by the user. The program set consists of the AUTOLOGGER program plus an Excel spreadsheet "macro" for importing and reviewing the collected data and the "loader" program.

PW-m	Weekly profile of speed, acceleration, idling, distance by time and day (km)
PW-US	Weekly profile of speed, acceleration, idling, distance by time and day (miles)
PM-m	Monthly profile of speed, acceleration, idling, distance by time and day (km)
PM-US	Monthly profile of speed, acceleration, idling, distance by time and day (miles)
DP-m	Trip driving pattern profile -speed,acceleration, distance, time per trip (km)
DP-US	Trip driving pattern profile -speed,acceleration, distance, time per trip (miles)
Keypad-m	Trip and driving profile with 5 questions per trip (km)
Keypad-US	Trip and driving profile with 5 questions per trip (miles)
Loader	Communications program that is included in the Master Kit

Custom software and survey design support is available through Autologger staff (613) 237-1565.
All prices are FOB Ottawa and exclude taxes and duties. All prices are subject to change without notice.

Energy *Watch* -Electrical Energy Meter

Part #	Description	Unit Price
Model 1-115	115 vAC/15A	US$ 600
Model 1-230	230 vAC/A	US$ 600
Model 1-AR	Autoranging version	US$ 650

A/D Net

Part #	Description	Unit Price
NS	Network Server	US$ 350
CG4	Common Ground 4 channel node	US$ 60
IS4	Isolated 4 channel node	US$ 275
2+2	2 common +2 isolated channel node	US$ 225

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DATE FILMED

4/7/94

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