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DESIGN ENHANCEMENT OF A LOW COST
ROUGHNESS MEASURING DEVICE

By

Lowell V. Babb

RESEARCH REPORT 279-2F

Development and Evaluation of a Low Cost
Profilometer and Roughness Measuring Unit

Study No. 8-10-80-279

conducted for

The Texas Department of Highways and Public Transportation

in cooperation with the
U.S. Department of Transportation
Federal Highway Administration

January 1983

The contents of this report reflect the views of the author, who is responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views of policies of the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

PREFACE

This project report describes the enhancement features and results of continuing research on the "Development and Evaluation of a Low Cost Profilometer and Roughness Measuring Unit," Research Project 8-10-80-279. The measurement method was developed by Dr. Roger S. Walker. Dr. Walker implemented the method on two prototype units. The objective of this effort was to enhance the user features of the device by making it capable of continuous data gathering, adding a printer output device as well as storing data on a magnetic tape cassette, and by providing thumbwheel switches for test identification. The unit has been completed and tested.

The assistance of Dr. Walker of McClelland Engineers, and John Nixon, Ken Hankins, and Curtis Goss of the Department of Highways and Public Transportation is especially appreciated.

Lowell V. Babb

January 1983

ABSTRACT

This report describes design enhancement to the low cost roughness measuring device called the SIometer. The unit provides output of Serviceability Index (SI) values. Two prototype units with certain limitations have been field tested by the Department of Highways and Public Transportation. This report describes a third unit which incorporates many design enhancements to facilitate continuous data collection, analysis, display, and storage of road roughness parameters. The improved unit is fully described and data from field tests with the unit in five vehicles are presented.

KEY WORDS: SIometer, Surface Dynamics, Profilometer, Mays Ride Meter, Serviceability Index, autoregressive process, road roughness, road profile.

SUMMARY

For many years, engineers have been interested in instruments for measuring road roughness. As the many miles of interstate and other highways begin to deteriorate, this interest has increased. A new method for obtaining road profile estimates was developed by Roger S. Walker. This method is easily implemented with an accelerometer and a microcomputer that can be mounted in most vehicles. The method identifies the characteristics of the vehicle in which the accelerometer is installed from the vertical acceleration measurements, and then corrects for these characteristics to yield an estimate of road profile. From this profile, a roughness statistic is computed, related to Serviceability Index, and then displayed.

This report describes the second stage of development of this process and, specifically, gives information about design enhancements to the original prototypes. Hardware and software have been added to allow continuous data collection, analysis, display, and storage of Serviceability Index parameters as well as test highway identification data. The unit is intended to be a relatively inexpensive survey tool with direct data entry (via tape cassette) into the Department of Highways and Public Transportation inventory computer systems.

IMPLEMENTATION STATEMENT

An improved, more flexible prototype for measuring pavement roughness has been developed. Based on two previous prototypes that have been field tested by the Department of Highways and Public Transportation, the new unit is more flexible in its field application. It provides automatic data collection, analysis, display, and storage. The new unit provides full coverage over tested road sections in a manner that is directly compatible with the Department of Highways and Public Transportation inventory computers.

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INTRODUCTION

The nation's highway system must be constantly maintained. In order to objectively determine the maintenance priorities of the system, a means is needed to survey the roadway system and quantify its condition. The objective of this study was to continue development of a low cost road roughness measuring device that may have wide application within Texas and the nation. The instrument is designed to be operated in a standard vehicle and not require specialized personnel. To further reduce labor costs associated with roadway surveying, the unit includes a tape cassette data storage device for direct transfer of information to Highway Department inventory computer systems.

Other techniques are available for measuring highway roughness. One device is called the Mays Ride Meter (MRM). This device is relatively simple and inexpensive, but its operation is affected by the mass and suspension system of the test vehicle. Alternately, the MRM can be mounted on a special trailer which then increases the operational complexity when using the device. On the other end of the scale is the Surface Dynamics Profilometer measuring unit. This is a dedicated vehicle with onboard acceleration measurement devices and a mini-computer data acquisition and analysis system. This device is relatively expensive to purchase and to operate.

The above two devices have been calibrated to directly provide a Serviceability Index (SI) for a measured highway. Originally, the SI value was experimentally determined based on observations of vehicle passengers riding in different vehicles on different test sections. Statistically, both of the above units can be analyzed to yield a representative SI for a tested section. A special calibration of each unit, however, is required.

To overcome the deficiencies and/or operational costs of the above devices and to yield a direct measure of SI, development was undertaken at the University of Texas-Arlington by Dr. Roger S. Walker. Dr. Walker used a system that contained three principal components: a vertical accelerometer, a micro-computer, and the software to implement the process. The device is called the SIometer. The accelerometer measures the vertical accelerations of the car body directly above the vehicle rear axle. Using a specially-developed autoregressive computation procedure, the

characteristics of the car suspension system and tires are removed from the measurement of the vertical acceleration. A direct measure of the road roughness then results which is independent of the measuring vehicle. This process is described in detail in the Texas State Department of Highways and Public Transportation Report No. 279-1, "A Self-Calibrating Roughness-Measuring Process."

Dr. Walker implemented the measurement process in two prototype units that could acquire 1000-ft sections of data and provide a measure of SI within 30 to 45 seconds. Real time, full coverage operation was not possible. The objective of this project was to provide complete highway coverage at normal operating speeds and also to provide operator convenience features for data identification, display, and on-line storage.

The improved system will be described in detail in the next section. Brief operational procedures are described as well. Finally, road test results are presented along with a listing of the supporting documentation provided with the unit. A companion document entitled "Operator's Manual - Low Cost Roughness Measuring Device," McClelland Engineers' Report Number 0182-0165, is reproduced and included herein as Appendix A. This manual gives detailed operational procedures for the SIometer.

SYSTEM DESCRIPTION

The original prototype SIometer consisted of three hardware units: an accelerometer, a micro-computer chassis, and an operator console. The unit would record vertical acceleration data as the vehicle travelled over the highway. A block of data approximately 1000-ft long would be collected, then analyzed and displayed as an SI value on the operator console. The unit then required an operator command to collect data over subsequent sections. The computational speed was such that at a continuous 50 mph test speed, data taken over a 1000-ft section would require the vehicle to traverse about 3000 additional feet prior to the SI number being displayed. No data was collected during this time. As a routine highway operational tool, this was not acceptable. In addition, all identification of the various test sections was done manually in notebooks. This data would then have to be keypunched for ultimate input into the Highway Department inventory computer.

To overcome the above deficiencies and develop an economical, fully operational tool, the following design enhancements were undertaken:

1. Assembly and layout changes were implemented to result in a more rugged instrument. Extensive use of printed circuit board technology considerably ruggedized the system wiring.
2. An integral printing device was included on the instrument to provide hardcopy SI values directly related to test section location (mile posts).
3. A cassette tape recording device which also records the SI values based on highway location was also included in the enhanced SIometer.
4. Additional hardware and software were included to allow continuous roughness information to be gathered. This is done primarily by using three slave micro-computers that operate on 0.2 mile data samples independently. While the information for a given sample lags about 30 seconds, continuous coverage of the highway is achieved.

5. A self-test feature was included on the unit to ensure proper operation of each computer board. A computer generated test section is input to each board and the resulting SI value compared to a standard.
6. Data is recorded based on time or distance. This is operator selectable within the unit. Distance-based data collection allows the car to run at a nominal 50 mph but requires addition of a magnetic speed sensor onto the vehicle drive shaft. Time-based data requires the vehicle speed to be exactly 50 mph but does not require additional equipment. The time-based mode is particularly useful for system demonstrations.
7. A series of thumbwheel switches was provided to allow entry of test section identification data. These include highway number, lane, mile post, etc. This test section identification data is also printed on the paper tape and written onto the cassette to facilitate data analysis.

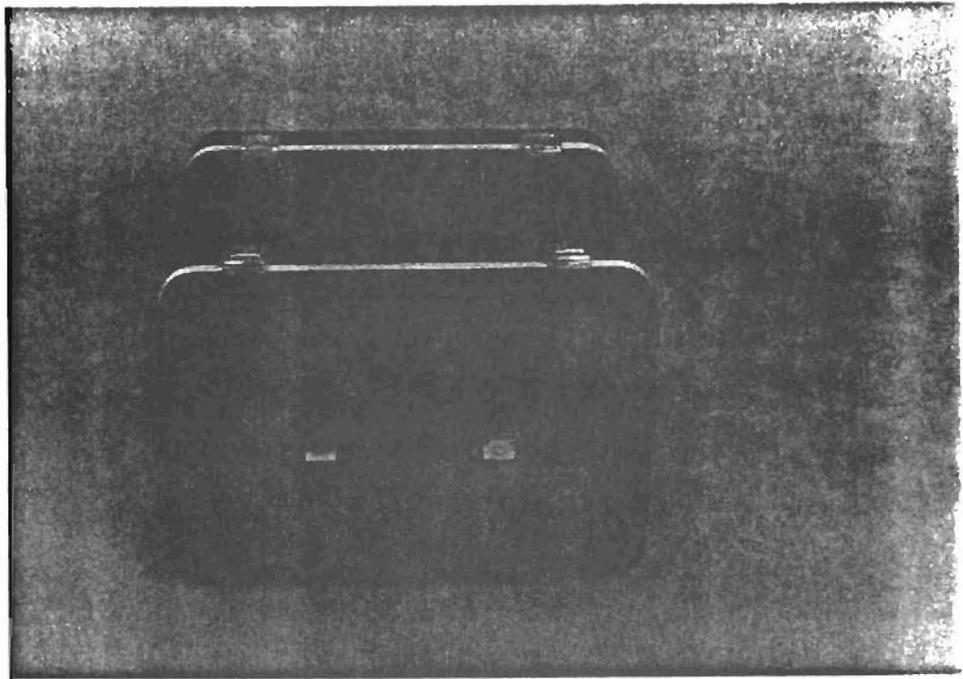
Hardware Description

The enhanced design SIometer is completely self-contained in the system carrying case as shown in Figure 1(a). When installed in the vehicle, the chassis lid is opened and the different modules for the system can be removed from the case. Connecting cables are provided for each component.

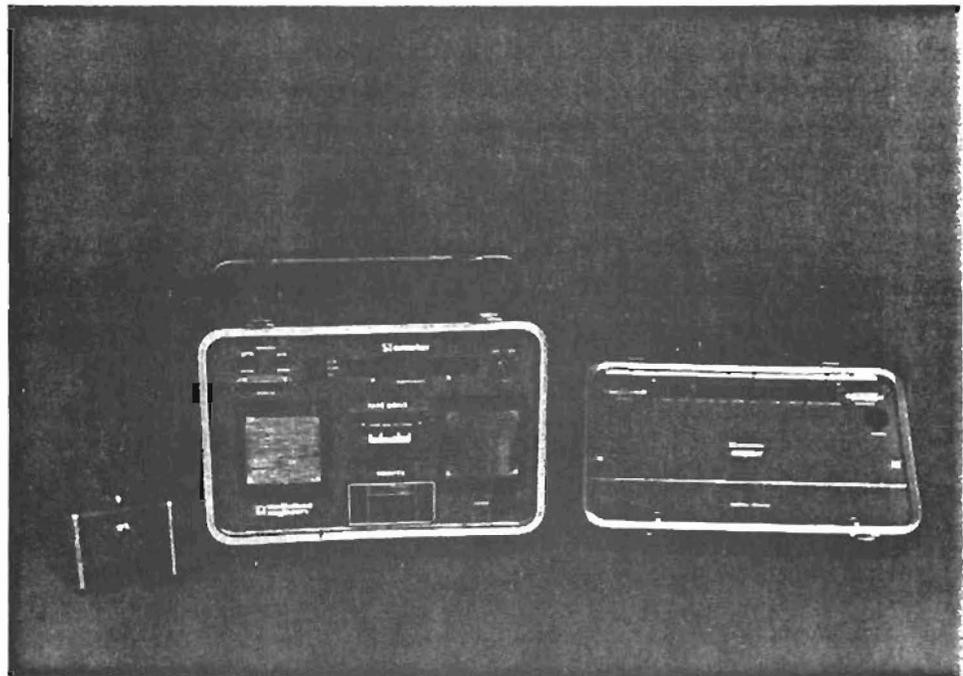
As shown in Figure 1(b), the system chassis includes the micro-computers, power converter, and interface electronics. Thumbwheel switches are provided to input coefficients for the mathematical processes. The printer and tape cassette units are also installed in the system chassis. Fan ventilation is provided through the front panel filter screens as well as baffling within the unit. The system chassis also has a mode switch which allows the operator to select one of three operating modes.

MODE 1 - TEST

In this mode, a test routine is run which verifies operation of the computer. This would normally be done at the beginning of each test day.



(a)



(b)

Figure 1. SIOMETER SYSTEM

MODE 2 - NORMAL

The normal mode allows SI values to be computed, displayed, and recorded.

MODE 3 - ALPHA/BETA

In this mode, the slope variance of the road profile is printed for a single 0.2-mile long road section. This value is used when calibrating the mathematical coefficients which compute the SI values.

The lid to the container case is normally placed in the front seat of the vehicle. The lid contains a series of thumbwheel switches to identify the test section.

Once a test section has been completely identified, the only operator controls necessary are on the operator console. This console includes a 16-digit display. This display provides SI values and test section location information to the operator in the normal operating mode. Initially, the display prompts the operator to perform certain actions necessary to operate and properly document a test run. The console also contains six pushbutton switches for operator entry. The green switch starts the SIometer process. The red switch causes the SIometer to pause. In this mode, data from test sections already acquired are analyzed and printed out. Once this bookkeeping procedure has been completed, the operator can then continue on a different test section or remove power from the system. The remaining four pushbutton switches allow the vehicle operator to input four distinct comments on each SIometer test section. It has been suggested that one digit could denote mile posts, a second digit could denote bridges, etc.

The accelerometer is installed in a small, weighted case. This case includes the vertical accelerometer, power converter, and filtering.

The vehicle speed input is provided by a coil which mounts near the driveshaft of the test vehicle. Magnets are affixed to the driveshaft and detected by the coil. Circuitry in the system chassis computes the proper sampling interval in terms of distance. An internal automatic calibration feature allows the system to be used on vehicles with different wheel sizes and different numbers of magnets on the driveshaft.

Operational Concept

The system uses a distributed microprocessor network to achieve continuous data coverage. A block diagram of the entire system is shown in Figure 2. Internally, the Intel multibus is used for the communications channel between the master and slave computers and the analog-to-digital converter. An interface board for the speed sensor and the printer is also fabricated in the multibus format. The master microcomputer is the system bookkeeper. It distributes data from the A/D board to individual computers. These slaves perform the data analysis and return the resulting SI value to the master. The master then outputs the SI and associated test identification data to the display, printer, and tape cassette.

Power for the system is provided by a DC-to-DC converter which takes 12 volts from the vehicle battery and converts it to a regulated +12 volts and +5 volts for the associated electronics.

Data Output

A sample data chart from a test run is shown in Figure 3. The chart includes a summary of the header information and also SI values for a 1.2-mile test run (6 SI values). This same information is displayed to the operator on his console during a test run and is also output to the tape cassette unit during a test run.

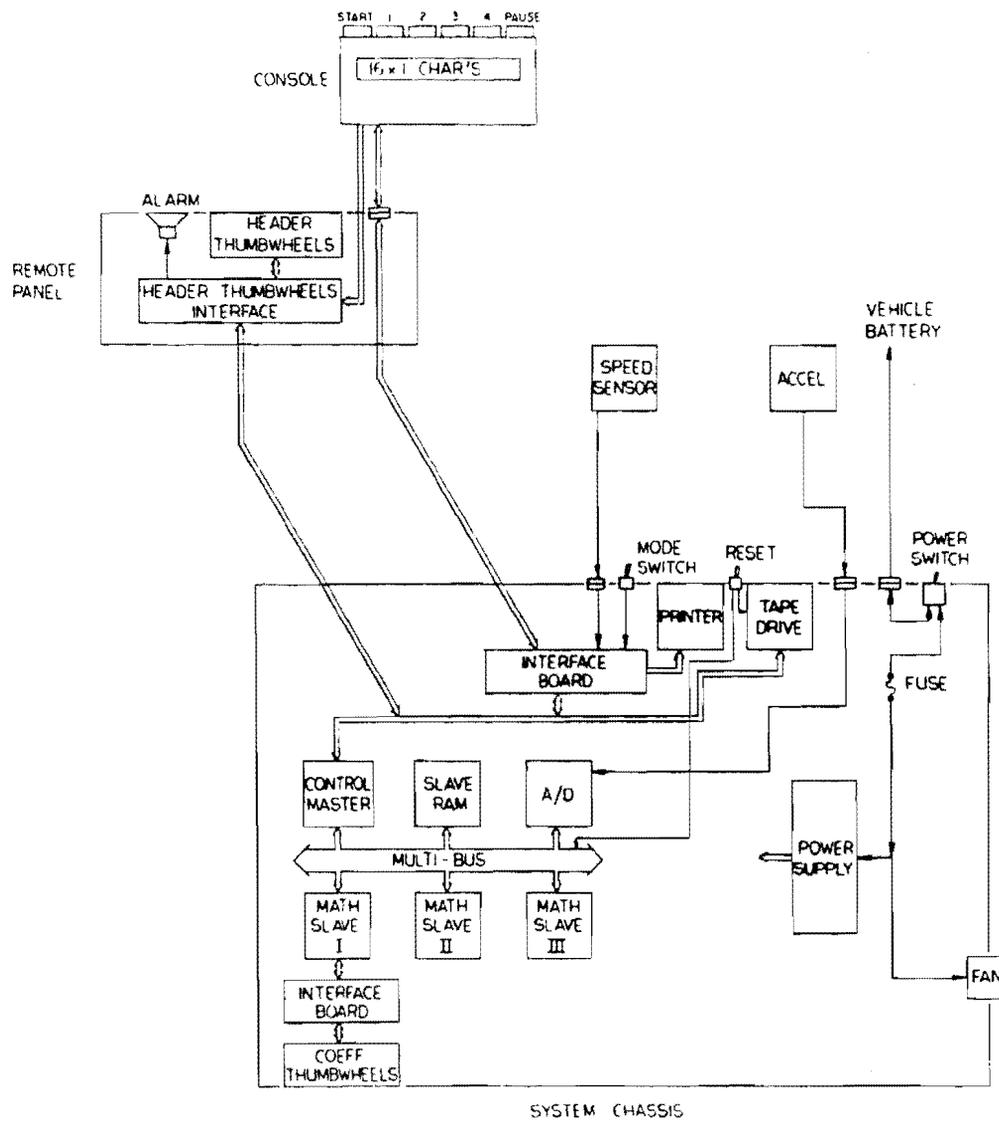


Figure 2. SYSTEM BLOCK DIAGRAM

```
.....FINISHED.....
4.0  0149.3  ___4
5.0  0149.5  ___3_
5.0  0149.7  _2__
5.0  0149.9  1___
5.0  0150.1  ____
5.0  0150.3  ____
5.0  0150.5  ____
SI   MILE  COMM.
```

```
SI  MODE
```

```
COMMENT      2
DISPL.      +0.5
MILE POST    150
LANE         02
NUMBER       0059
HIGHWAY      01
COUNTY      090
DISTRICT     12
DATE:       01/18/80
```

Figure 3. SAMPLE DATA PRINTOUT

SYSTEM OPERATION

Detailed operational procedures are included in a companion document entitled, "Operator's Manual - Low Cost Roughness Measuring Device," McClelland Engineers' Report No. 0182-0165. This manual is reproduced in Appendix A. The procedures are summarized below.

Installation in Test Vehicle

The system chassis will normally be put in the rear seat of the vehicle. The chassis lid can then be placed on the front seat to allow convenient operator access. The operator's console will generally be handheld during a test run. The accelerometer is placed in the trunk of the vehicle directly over the rear axle. Cabling to the accelerometer is small diameter and can generally be fit through a rear window and the trunk lid. The power connections for the system can be made directly to the battery or a fuse box internal to the vehicle. At least 20-amp capacity is required.

If the test is to be run based on distance, the speed sensor must also be installed beneath the vehicle. This requires four magnets to be epoxied to the driveshaft. In addition, the sensor coil must be affixed to a bracket beneath the vehicle. This normally takes about one hour and is best done with the vehicle on a maintenance rack.

Equipment Calibration

Initially, the system chassis mode switch is placed in the "TEST" position, and the system is powered and reset. The system will then prompt the operator through a test sequence resulting in a printout indicating the system is operational. The mode switch is then placed in the "NORMAL" position.

Two more calibrations are required at this point. The vehicle speed system is calibrated by running the vehicle at 50 mph and pushing the console "START" button. The system then sweeps through a series of calibration values seeking to standardize the sampling interval. This calibration procedure takes into account different wheel sizes, driveshaft gear ratios, and other characteristics.

Once the speed calibration is complete, the vehicle characteristics must be determined. This is done by running another test section in response to operator prompts on the console. After collecting a specified number of data points, the system then runs the autoregression analysis and computes a number of system coefficients. These coefficients are used to model the vehicle suspension system so their effects can be eliminated from the SI computation.

SI Test Run

After the calibrations are complete, the operator is prompted to update his header information. Once he is satisfied with the header, the console instructs him to proceed to 50 mph and press "START" at the beginning location of the test run. At this point, the system acquires data in real time in 0.2-mile increments. SI values are calculated and automatically output onto the peripheral devices. To end a test run, the operator presses the "PAUSE" button. The console then instructs the operator that the system is completing calculations for the last two data sections. Once complete, the system then prompts the operator to turn off the power or continue with a subsequent test run.

Alpha/Beta Test Run

This mode of operation is provided on the unit to allow calibration of different vehicle types with the Serviceability Index numerical value. In this mode, the actual slope variance of a given 0.2 mile section is computed and output on the printer in hexadecimal format. An SI value is then calculated using the current alpha and beta coefficients stored in memory.

In actual operation, successive runs over a given test section would be performed and the slope variance numbers used in a least squares regression to determine new alpha and beta coefficients.

SYSTEM TEST/RESULTS

The system was tested on a roundtrip highway section in Houston. The test section was located on Highway 59, also known as the Southwest Freeway. A roundtrip circuit containing 12 test sections was set up. The SIometer was then installed in five different test vehicles as described below.

- VEHICLE #1 - 1978 Chevrolet Concourse
- VEHICLE #2 - 1978 Ford Granada
- VEHICLE #3 - 1982 Reliant K Wagon
- VEHICLE #4 - 1978 Oldsmobile Cutlass, 4-Door Salon
- VEHICLE #5 - Plymouth Horizon

The SI values for each test run in each vehicle (180 runs in all) are shown in Figure 4.

No attempt is made to evaluate the data results from these test runs, although several possible reasons for the wide range of values are offered.

1. With the exception of the runs in the 1978 Oldsmobile which were based on distance, the remainder of the runs were run on a time base on two 1.2-mile test sections. If the vehicles could not run exactly at 50 MPH, then the actual road surveyed from run to run would not be synchronized.
2. The wheel path on the various test runs must be identical for the SI values to perfectly correlate. This is of course impossible on an actual roadway situation.
3. The computational algorithm assumes a linear suspension system. Several of the cars were up to five years old with faulty shock absorbers. This would account for some of the differences.

We recommend that additional testing be undertaken in conditions which are more highly controlled. A series of tests of this type were undertaken with the original prototypes, and the data was much more satisfactory. The new SIometer described in this report uses exactly the same computational algorithms and should, therefore, yield identical results under controlled testing.

<u>Test Section</u>	<u>1978 Chevrolet Concourse</u>			<u>1978 Ford Granada</u>			<u>1982 Reliant K Wagon</u>			<u>1978 Oldsmobile Cutlass</u>			<u>Plymouth Horizon</u>	
1	3.1	3.1	3.2	3.1	3.3	2.8	2.7	3.1	2.5	3.3	3.3	3.4		
2	3.8	3.7	3.6	2.7	2.7	3.4	2.5	2.5	2.3	3.2	3.2	3.2		
3	3.5	3.4	3.5	3.2	3.3	2.4	2.1	2.5	2.4	3.1	3.3	3.3		
4	3.9	3.6	3.7	2.7	2.9	3.3	2.0	2.2	2.8	3.1	3.2	3.2		
5	3.6	3.5	3.9	3.1	3.3	3.2	2.5	2.8	2.8	3.4	3.4	3.5		
6	3.8	3.9	4.6	3.2	3.1	3.3	2.9	2.4	2.9	3.3	3.1	3.3		
7	3.4	3.2	3.3	3.3	2.9	2.9	2.3	2.5	2.4	2.5	2.4	2.7		
8	3.8	3.6	3.6	3.0	3.2	3.2	2.0	1.5	2.9	3.5	3.4	3.5		
9	3.5	3.5	3.8	2.9	2.5	2.9	2.3	2.6	2.5	2.8	2.8	2.8		
10	3.7	3.6	3.8	3.1	2.8	3.5	2.3	2.3	3.0	3.2	3.2	3.4		
11	3.5	3.6	3.5		2.7	2.8	2.7	2.5	2.8	3.2	3.1	3.4		
12	3.6	3.3	3.9		3.3	3.3	3.0	3.1	3.1	3.3	3.2	3.7		

Figure 4. TEST RUN DATA

SUPPORTING DOCUMENTATION

In addition to the previously mentioned Operators Manual which is included in Appendix A of this report, a package of supporting documentation was also supplied under this contract. This supporting documentation includes drawings, software listings, flowcharts, and vendor manuals of the different devices used in the enhanced design SIometer.

A P P E N D I X A

OPERATOR'S MANUAL

LOW COST ROAD ROUGHNESS
MEASURING DEVICE

REPORT NO. 0182-0165

McClelland Engineers, Inc.

January 1983

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I L L U S T R A T I O N S

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INTRODUCTION

This operator's manual includes detailed instructions on the installation and operation of the SIometer. The SIometer has been developed as a low cost road roughness measuring device.

Background

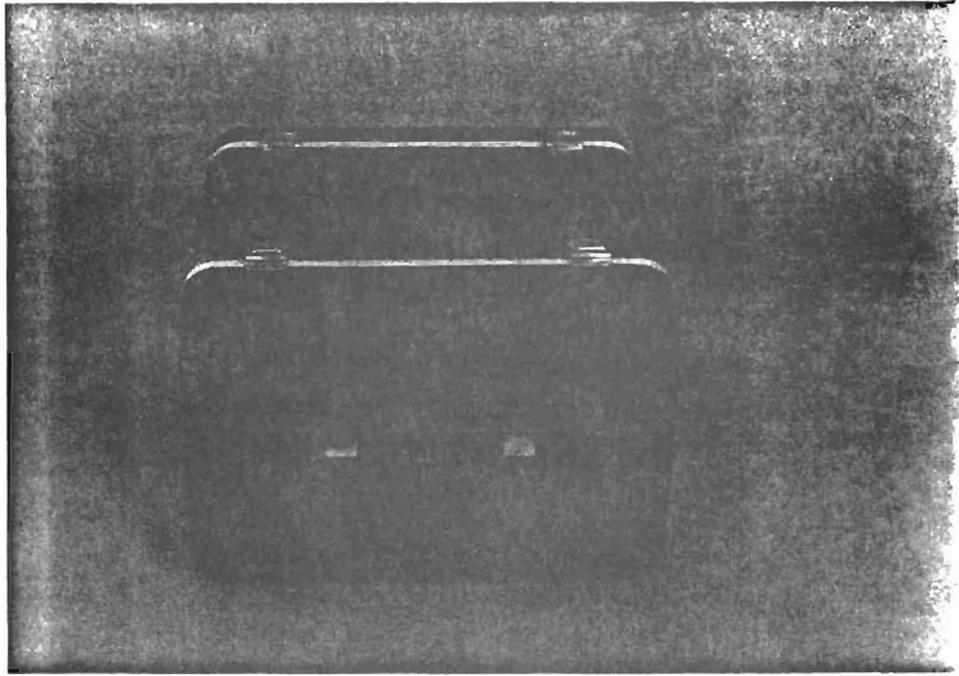
To properly allocate maintenance funding for the nation's highways, a quantitative, objective measurement of highway parameters is required. One of the applicable parameters is called Serviceability Index (SI). This index rates a highway from 0.0 to 5.0, with the low values indicating a very rough road and the high values a very smooth road. The SI was originally formulated based on a statistically significant number of personal observations of several highway sections. The SIometer has been built to provide the SI values directly from an instrument mounted in a typical highway vehicle.

The concept was developed by Dr. Roger S. Walker while at the University of Texas-Arlington. An accelerometer measures the vertical accelerations of a vehicle car body directly over the rear axle. This data is input to a microprocessor which has an autoregressive computational algorithm. The purpose of the algorithm is to remove the vehicle car body suspension characteristics from the data. The resulting data which is indicative of the highway roughness is then converted into SI values. The full mathematical process and a description of the prototype development is included in Highway Department Research Report 279-1, "A Self-Calibrating Roughness-Measuring Process."

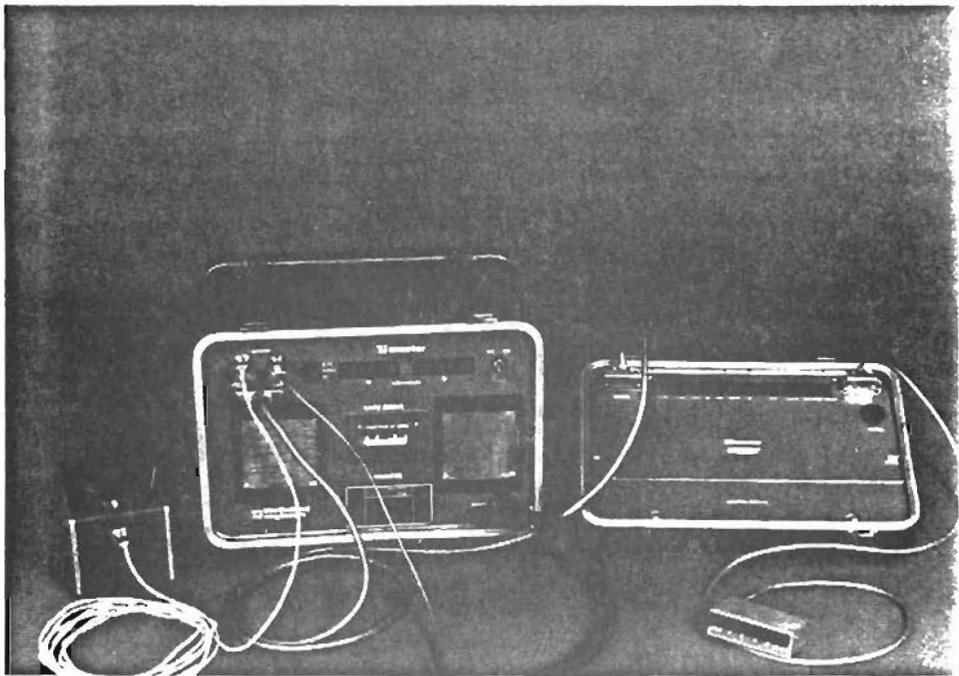
System Description

Hardware Description. The enhanced design SIometer is shown in Figure 1. The unit is completely self-contained in the system carrying case as shown in View A. When installed in the vehicle, the chassis lid is opened and the different modules for the system can be removed from the case. Connecting cables are provided for each component.

As shown in Figure 1B, the system chassis includes the micro-computers, power converter, and interface electronics. Thumbwheel switches are provided to input coefficients for the mathematical processes. Also, the



(a)



(b)

Figure 1. SIOMETER SYSTEM

printer and tape cassette units are installed in the system chassis. Finally, fan ventilation is provided through the front panel filter screens as well as baffling within the unit. The system chassis also has a mode switch which allows the operator to select one of three modes.

MODE 1 - TEST

In this mode, a test routine is run which verifies operation of the computer. This would normally be done at the beginning of each test day.

MODE 2 - NORMAL

The normal mode allows SI values to be computed, displayed, and recorded.

MODE 3 - ALPHA/BETA

In this mode, the slope variance of the road profile is printed for a single 0.2-mile long road section. This value is used when calibrating the mathematical coefficients which compute the SI values.

The lid to the container case is normally placed in the front seat of the vehicle. The lid contains a series of thumbwheel switches which provide identification of the test section.

Once a test section has been completely identified, the only operator controls necessary are on the operator console. This console includes a 16-digit display. This display provides SI values and test section location information to the operator in the normal operating mode. Initially, the display prompts the operator into certain actions necessary to operate and properly document a test run. The console also contains six pushbutton switches for operator entry. The green switch starts the SIometer process. The red switch causes the SIometer to pause. In this mode, data from test sections already acquired are analyzed and printed out. Once this bookkeeping procedure has been completed, the operator can then continue on a different test section or remove power from the system. The remaining four pushbutton switches allow the vehicle operator to input four distinct comments on each SIometer test section. It has been suggested that one digit could denote mile posts, a second digit could denote bridges, etc.

The accelerometer is installed in a small, weighted case. This case includes the vertical accelerometer, power converter, and filtering.

The vehicle speed input is provided by a coil mounted near the driveshaft of the test vehicle. Magnets are epoxied to the driveshaft and vary the magnetic field in the coil. Circuitry in the system chassis computes the proper sampling interval in terms of distance. An automatic internal calibration feature allows the system to be used on vehicles with different wheel sizes and different rear axle ratios.

Operational Concept. The system uses a distributed microprocessor network to achieve the continuous data coverage. A block diagram of the entire system is shown in Figure 2. Internally, the Intel multibus is used for the communications channel between the master and slave computers and the analog-to-digital converter. An interface board for the speed sensor and the printer is also fabricated in the multibus format. One of the microcomputers, called the master, is the system bookkeeper. It distributes data from the A/D board to individual computers. These slaves perform the data analysis and return the resulting SI value to the master. The master then outputs the SI and associated test identification data to the display, printer, and tape cassette.

Power for the system is provided by a DC-to-DC converter which takes 12 volts from the vehicle battery and converts it to regulated ± 12 volts and ± 5 volts for the associated electronics.

Data Output. A sample data chart from a test run is shown in Figure 3. The chart includes a summary of the header information and also SI values for a 1.2-mile test run (6 SI values). This same information is displayed to the operator on his console during a test run and is also output to the tape cassette unit.

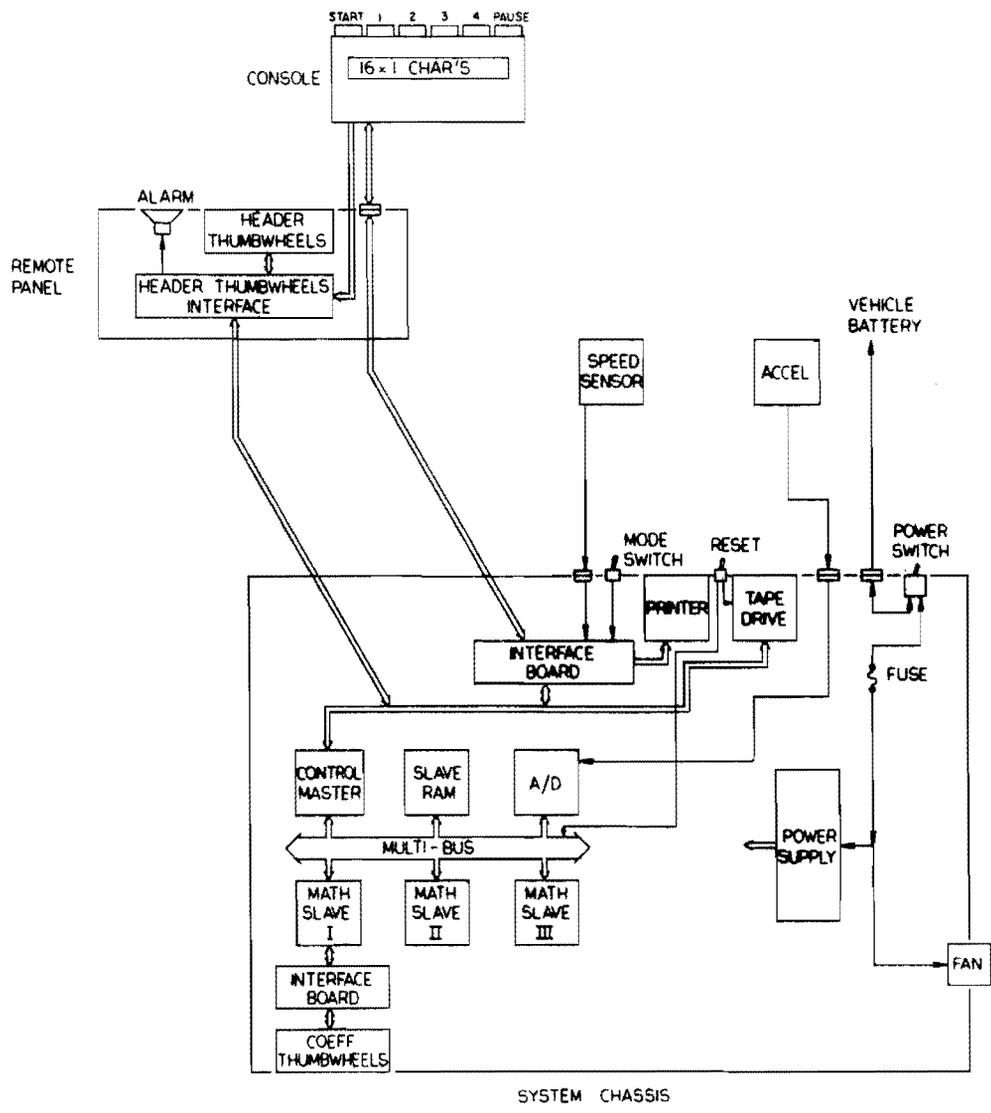


Figure 2. SYSTEM BLOCK DIAGRAM

.....FINISHED.....
4.9 0149.3 ___4
5.0 0149.5 __3_
5.0 0149.7 _2__
5.0 0149.9 1___
5.0 0150.1 ____
5.0 0150.3 ____
5.0 0150.5 ____
SI MILE COMM.

SI MODE

COMMENT 2
DISPL. +0.5
MILE POST 150
LANE 02
NUMBER 0059
HIGHWAY 01
COUNTY 093
DISTRICT 12
DATE: 01/18/83

SYSTEM INSTALLATION IN TEST VEHICLE

Accelerometer

The accelerometer is installed in the trunk of the vehicle, preferably on a rigid metal surface. It should be placed directly over the rear axle. Care should be taken to ensure that the accelerometer is firmly seated onto the car surface.

The cable for the accelerometer can be run through the trunk and window rubber moldings without damage. Figure 4 shows the accelerometer unit installed in the trunk of a test vehicle.

Speed Sensor

SIometer tests can be run using either time or distance-based sampling. When distance-based sampling is desired (selectable by an internal toggle switch on the system chassis), a vehicle speed pick-up coil must be mounted beneath the vehicle adjacent to the driveshaft. In addition, four magnets must be epoxied onto the vehicle driveshaft. As the driveshaft turns, the pick-up coil detects the passage of the magnets by a change in its magnetic field. This signal is then fed to the system chassis, and vehicle speed is determined. Installation of the speed sensor on a test vehicle is shown in Figure 5. Detailed instructions for mounting the coil and the magnets are given in Appendix A.

System Chassis

The system chassis will generally be placed in the rear seat of the vehicle. Once the system has been set up, operator intervention on the chassis will be infrequent. The chassis is shown in a test vehicle in Figure 6. While the orientation of the chassis is primarily at the operator's convenience, care must be taken not to obstruct the intake and exhaust air screens on the front panel.

Four cables are connected to the system chassis.

Power Cable. This cable is a heavy gauge two-conductor cable that can be connected directly to the vehicle battery using a set of jumper cable clamps, or more permanently in the vehicle fuse box located in the driver's compartment. The wiring used should have a 20-amp capability and be as short as possible to reduce voltage drop in the cable.

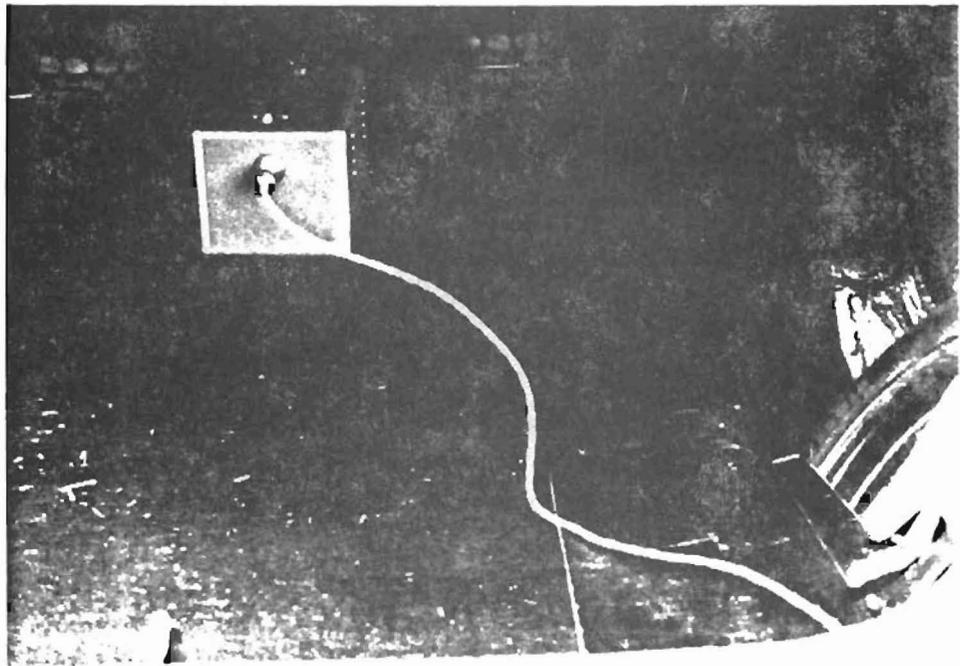


Figure 4. ACCELEROMETER INSTALLATION

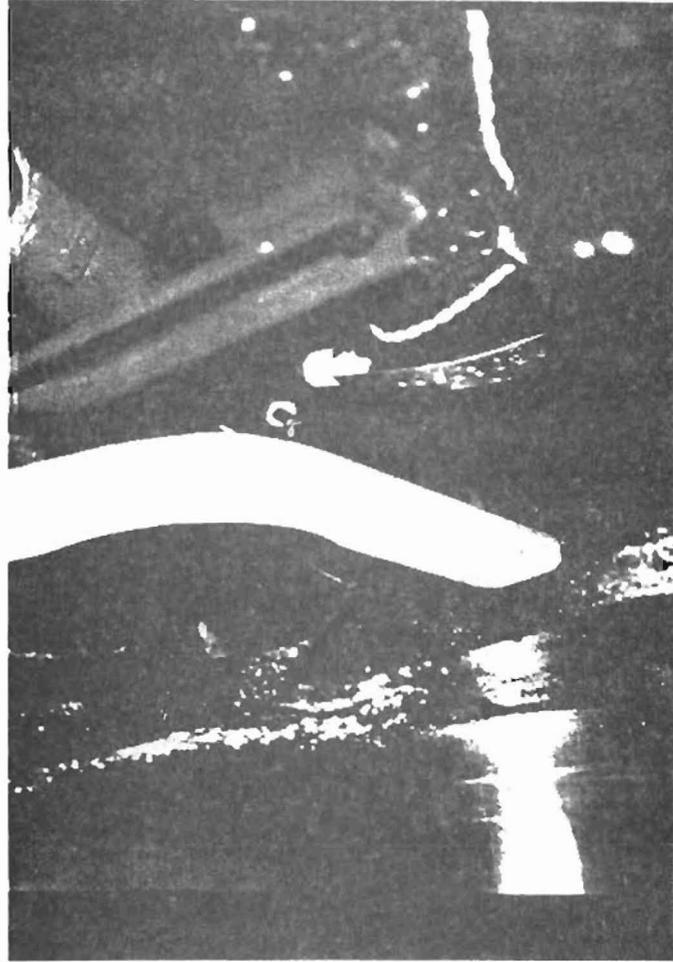


Figure 5. SPEED SENSOR INSTALLATION

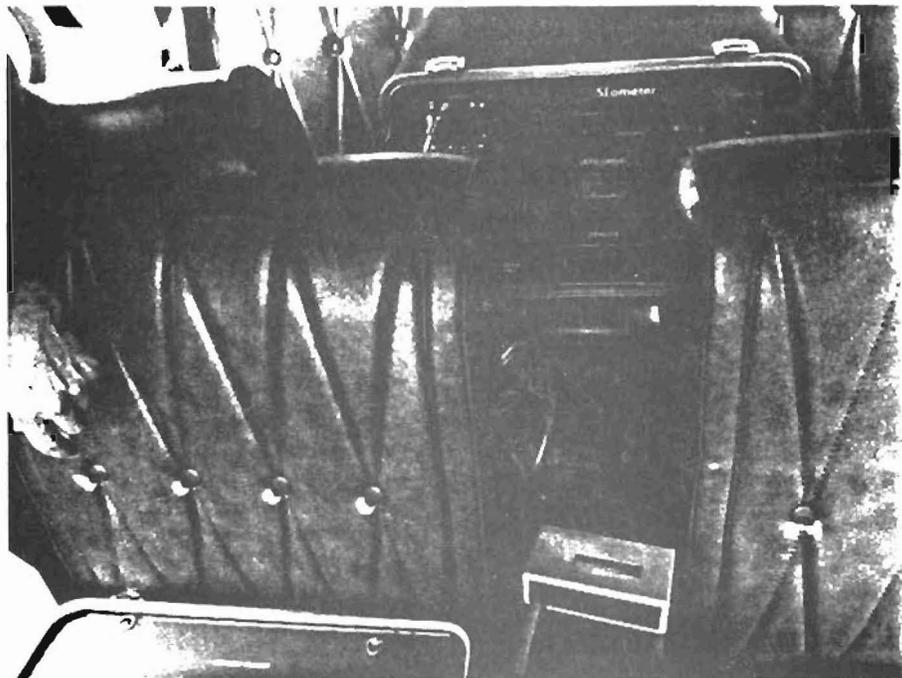


Figure 6. SYSTEM CHASSIS INSTALLATION

Accelerometer Cable. A 3-pin connector is provided on the accelerometer cable to mate directly to the system chassis.

Speed Sensor Cable. A 2-pin connector on the speed sensor cable mates directly to the appropriate connector on the system chassis.

Remote Panel Cable. A multi-pin connector is provided on the system chassis for the remote panel connection.

Remote Panel/Console

The remote panel contains the thumbwheel switches for identifying a test section. This panel will generally be placed in the front seat of the vehicle convenient to the system operator. While underway on a test run, the operator need not refer to this panel. However, at the beginning of each test run, the identification information (header) must be updated.

A small handheld console is connected to the remote panel via a cable. This console contains a LCD data display device and six pushbutton switches for operator control. The remote panel and console are shown in a test vehicle in Figure 7.

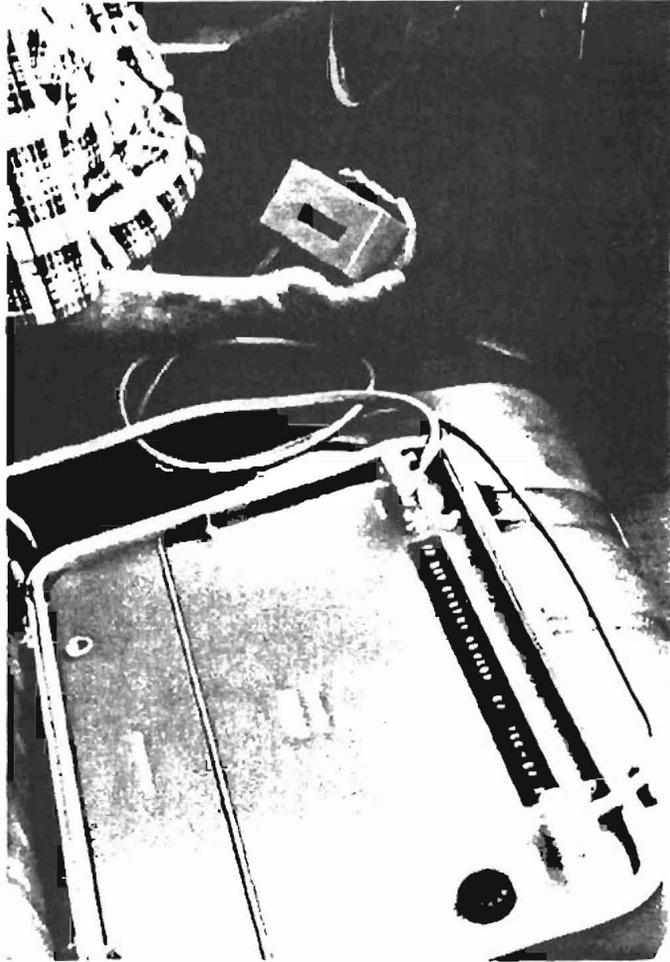


Figure 7. REMOTE PANEL/CONSOLE INSTALLATION

OPERATIONAL PROCEDURES

System Functions

A simplified flowchart of the SIometer operational functions is shown in Figure 8. After installation of equipment in the vehicle and some preliminary set-up operations, the system is powered up.

CAUTION: DO NOT POWER UP THE SIOMETER UNTIL THE VEHICLE HAS BEEN STARTED. WHEN A VEHICLE IS STARTING, ITS 12-VOLT POWER SYSTEM IS EXTREMELY NOISY AND THESE VOLTAGE SPIKES COULD DAMAGE THE SIOMETER HARDWARE.

After manual reset, the system initializes the computers. If desired, a self-test program can be run. For vehicle tests, two calibration procedures are required. Test identification information is also entered via thumbwheel switches during this phase of the operation.

The operator then selects the normal SI mode or the Alpha/Beta mode. In the normal SI mode, the operator is instructed via the system console to press the "START" when the vehicle is operating at 50 mph and passes the test start point. The SIometer then collects 0.2-mile data increments, computes the SI value, and displays, prints, and stores this data on the tape cassette. In the Alpha/Beta mode, the profile slope variance is printed on the paper tape for a single section of data.

These system functions are described in detail in the following sections. In addition, samples of the printed output are provided for reference.

Set-Up

After the system has been installed in the test vehicle, several set-up operations are required. The first decision to be made is the basis for sampling. A toggle switch internal to the system chassis selects either time or distance-based sampling. This switch is shown in Figure 9. In the time select mode, an internal clock automatically collects three data samples per foot, assuming a vehicle speed of 50 mph. In the distance-based sampling configuration, data signals from the speed pick-up coil are used to provide the sampling at three samples per foot. A special calibration routine allows the speed system to be conveniently calibrated in any test vehicle.

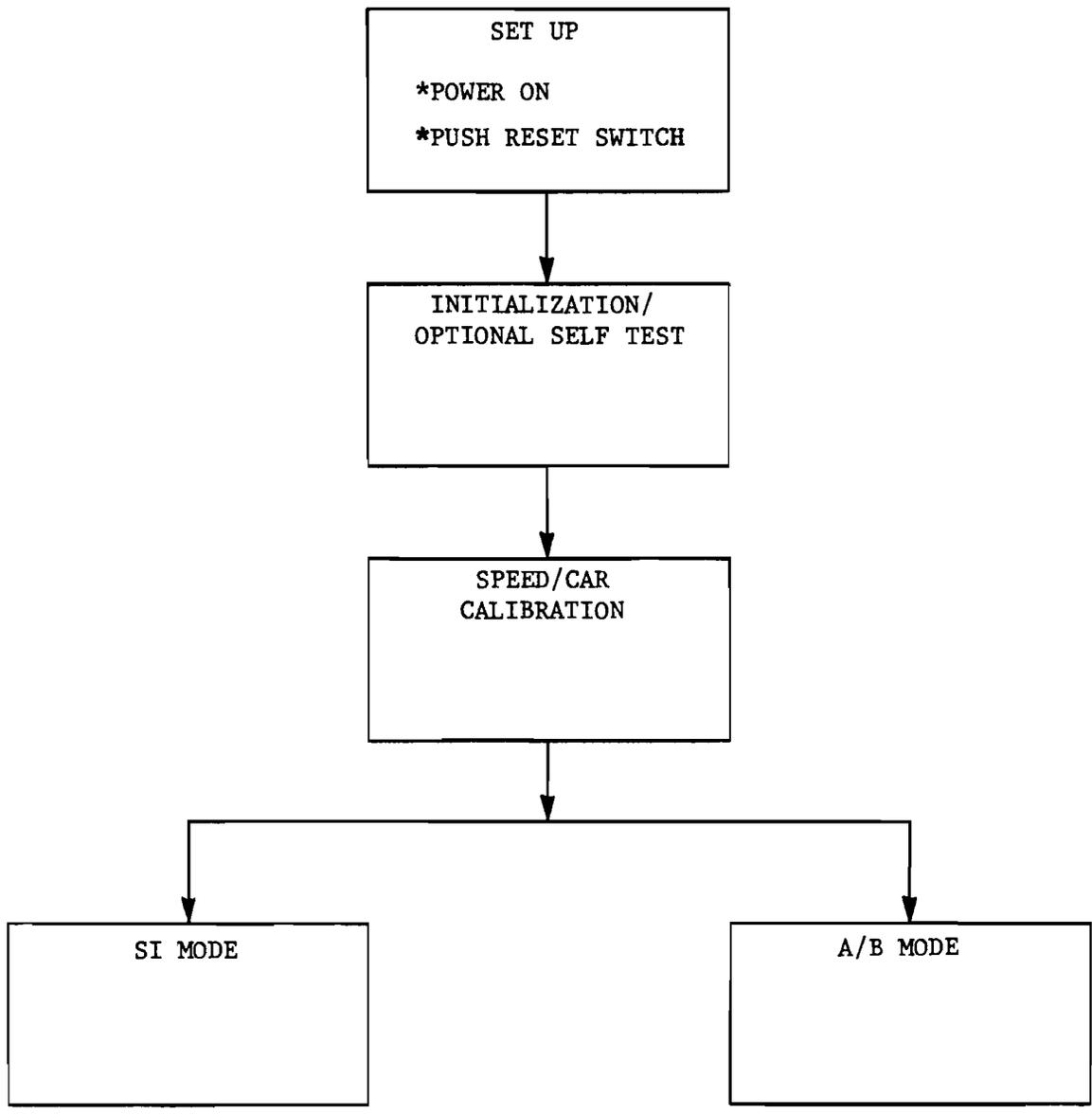


Figure 8. SYSTEM FUNCTIONAL FLOWCHART

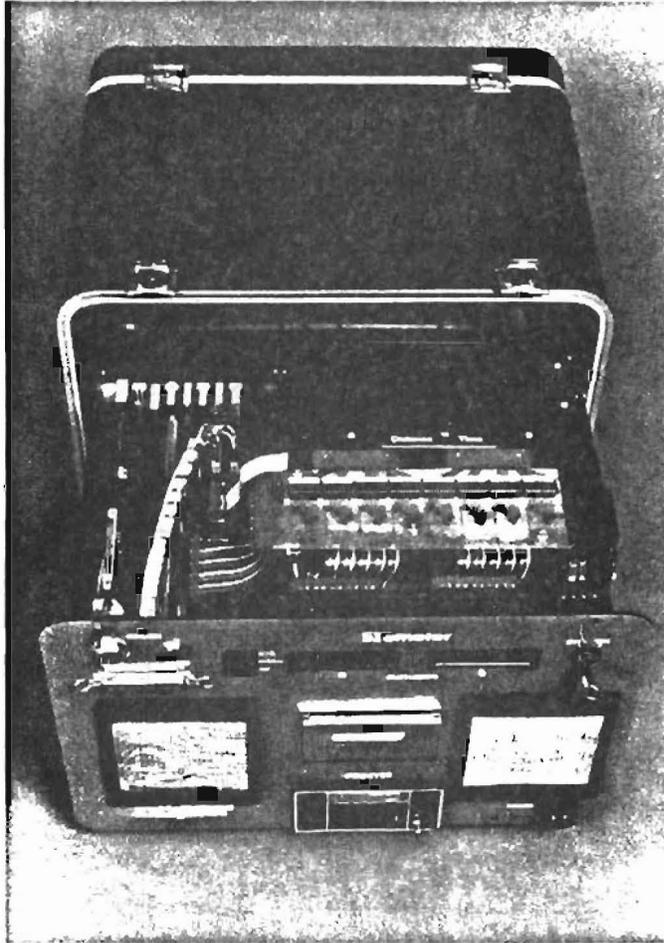


Figure 9. SPEED/DISTANCE SET-UP

The operator must also ensure there is a sufficient paper supply for the printer. When the paper is reaching the end of the roll, a dark line traverses across the paper strip. In addition, a logic signal is provided to the computer to alert the operator.

The operator can also select whether or not to use the tape cassette storage device. If the tape is selected, a new tape should be installed in the unit. Care must be taken to ensure that the write protect tabs on the test cassette have not been removed. Only high-quality, Phillips-type cassettes are recommended.

Initialization/Optional Self-Tests

In this phase of the operation, the system is powered using the key-switch on the system chassis. After manual reset, the functions shown on the flowchart (Figure 10) are performed. A display prompts the operator to select the mode of operation. If the "TEST" mode is selected, an acceleration data string is internally generated by the computer and input to each of the three slave computers. Each of the slaves then computes the slope variance and SI values after performing a simulated vehicle suspension system calibration. The outputs from each of the three computers must be identical and accurate when compared to correct values which are stored in the system memory. If all of these checks are properly performed, the printer and display list that the system is "OK." The test mode printout is shown in Figure 11. If the checks are not passed, this start-up procedure should be performed again. If the system still fails the test, consult the troubleshooting section of this manual.

Once this test has been passed, the operator is then asked if he desires printer and tape storage of the data. If tape storage desired, he is prompted to load the cassette into the unit and press the "START" button. This initiates the load sequence for the tape which includes a complete rewind of any tape to the beginning of test as well as erasure of any data existing on the tape.

CAUTION: AT THE END OF A SIOMETER TEST RUN, THE CASSETTE IS NOT REWOUND. A NEW TAPE MUST BE USED IF THE SYSTEM IS RESET.

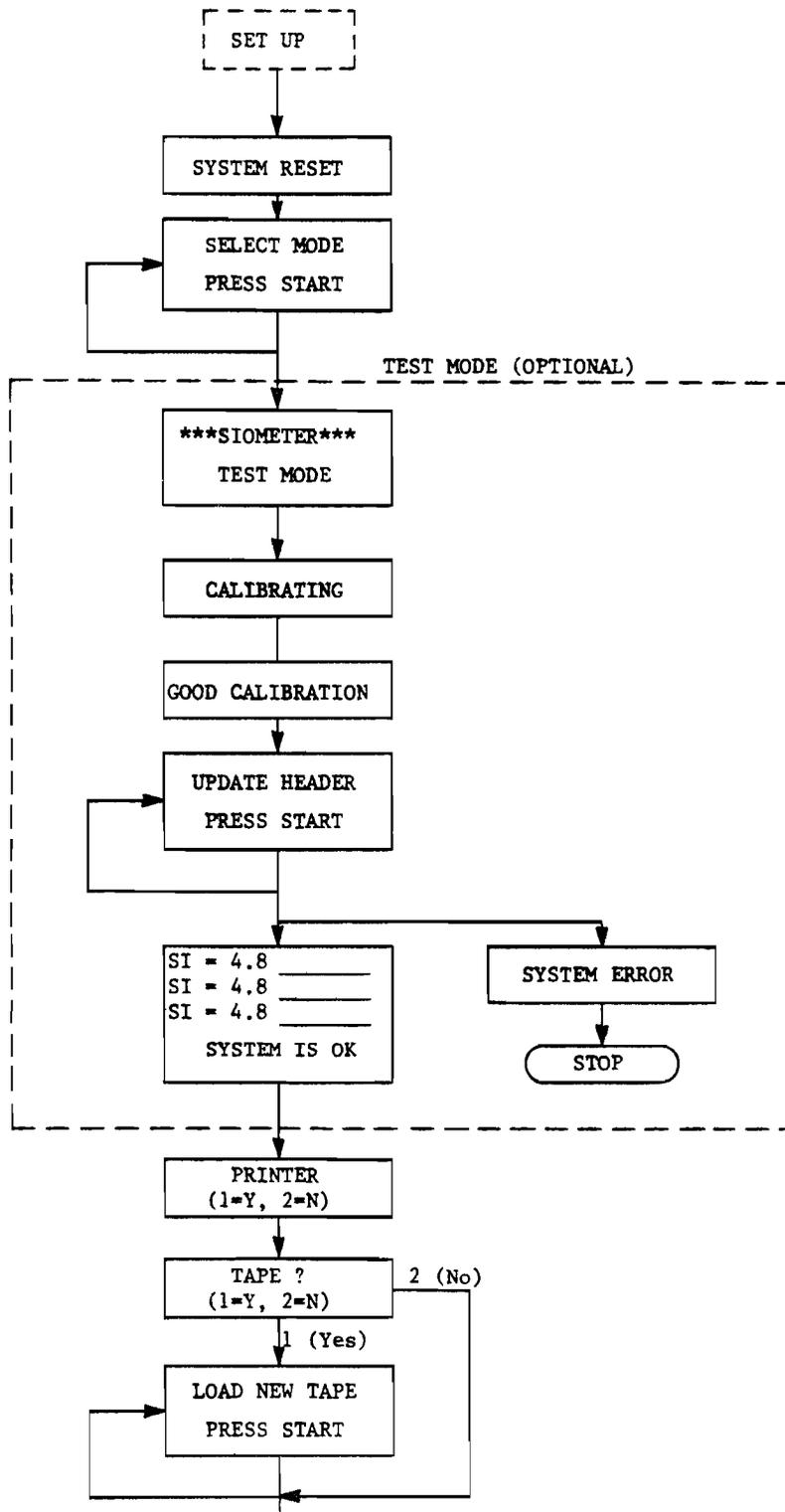


Figure 10. INITIALIZATION/OPTIONAL SELF-TEST FLOWCHART

SYSTEM IS OK
4.8 0150.1 ----
4.8 0150.3 ----
4.8 0150.5 ----
SI MILE COMM.

COMMENT 2
DISPL. +0.5
MILE POST 150
LANE 02
NUMBER 0059
HIGHWAY 01
COUNTY 093
DISTRICT 12
DATE: 01/18/83

GOOD CAR CALIB..

TEST MODE

*** SIOMETER ***

Figure 11. TEST MODE PRINTOUT

Speed/Car Calibration

Referring to the Figure 12 flowchart, the operator is then instructed to update the header which is the test section identification data. The thumbwheel switches on the remote panel allow the operator to input nine distinct values.

Date	mm/dd/yy	
District	XX	(2 decimal digits)
County	XXX	(3 decimal digits)
Highway	XX	(2 decimal digits)
Number	XXXX	(4 decimal digits)
Lane	XX	(2 decimal digits)
Milepost	XXX	(3 decimal digits)
Displacement	+X.X	
Comment	X	(1 decimal digits)

The lane number key is given below where the letters correspond to standard Highway Department nomenclature which have been converted over to decimal digits. Note that the decimal digits determine if the mileposts are increasing or decreasing. Decreasing mileposts are given by digits 0-4 and 10-12. Increasing mileposts are indicated by digits 5-9 and 17-19.

Lane Designation

<u>Letter</u>	<u>Number</u>
L-	0-
M-	1-
N-	2-
O-	3-
P-	4-
V+	5+
U+	6+
T+	7+
S+	8+
R+	9+
X-	10-
Y-	11-
Z-	12-
C+	17+
B+	18+
A+	19+

The milepost and displacement entries are used to accurately locate the beginning point of a test. The comment can be used at the operator's discretion.

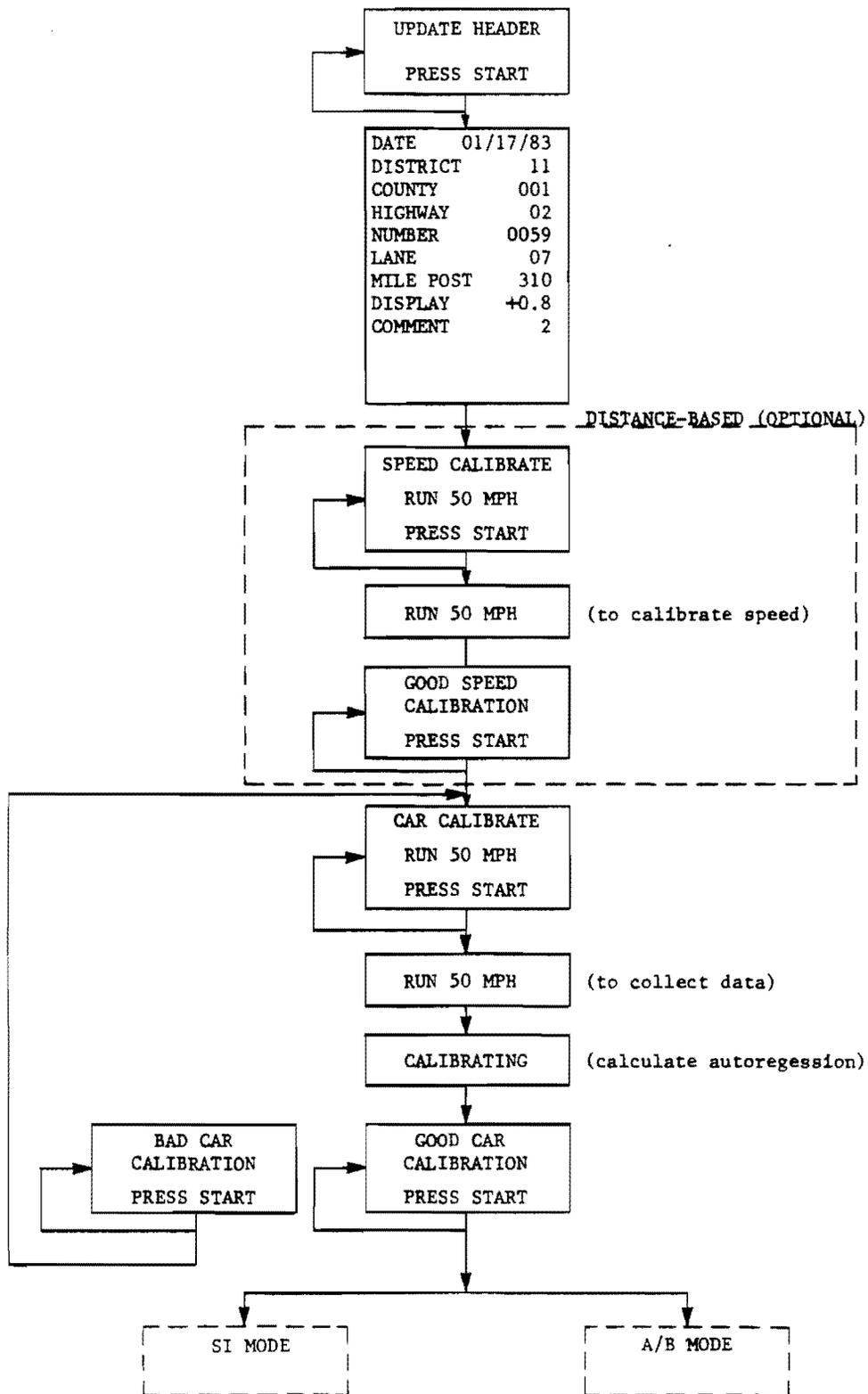


Figure 12. SPEED/CAR CALIBRATION FLOWCHART

Speed Calibrate. Speed calibration is performed by running the vehicle at 50 mph and pressing the console "START" button. The computer automatically determines the frequency of signals coming from the speed pick-up coil and relates that internally to 50 mph. During a test run, as the vehicle travels slower and faster than 50 mph, the SIometer automatically adjusts the sampling time interval to yield exactly three samples per foot of vehicle travel. This feature also allows the test vehicle location data to be accurately synchronized.

If time-based sampling is selected, the speed calibration routine is bypassed.

Car Calibrate. To determine the vehicle suspension characteristics, a second calibration is required over a representative test section. The vehicle is again accelerated to 50 mph and under console prompting the operator presses the "START" button. The system collects a specified segment of data and computes the vehicle characteristics and their mathematical formulation. This process takes about two minutes. During this process, the operator console is flashing with "CALIBRATING."

Normal SI Operation

After calibration is complete, the system can be run in the SI mode. As shown on the Figure 13 flowchart, the operator is prompted to once again update the header information. As the vehicle passes the indicated starting point at 50 mph, the operator presses the "START" button on the console and data gathering is initiated. Because of the processing delay, the first SI value is displayed about 45 seconds later. Subsequent values are output at approximately 15-second intervals.

At the end of the test run, the "PAUSE" button is pushed. Data already collected is then computed and output for an additional 30 to 45 seconds. After completion, "FINISH" is displayed. The operator may then continue with the next test section or power down.

A sample SI mode printout is shown in Figure 14.

CAUTION: IF THE TEST RUN IS TO BE CONTINUED, THE HEADER INFORMATION MUST BE UPDATED.

Alpha/Beta Mode Operation

As shown in Figure 15, the Alpha/Beta mode uses a procedure similar to the SI mode. However, only one 0.2-mile data string is collected. The slope variance is printed in hexadecimal format.

After header update, additional tests can be run. A sample printout is shown in Figure 16.

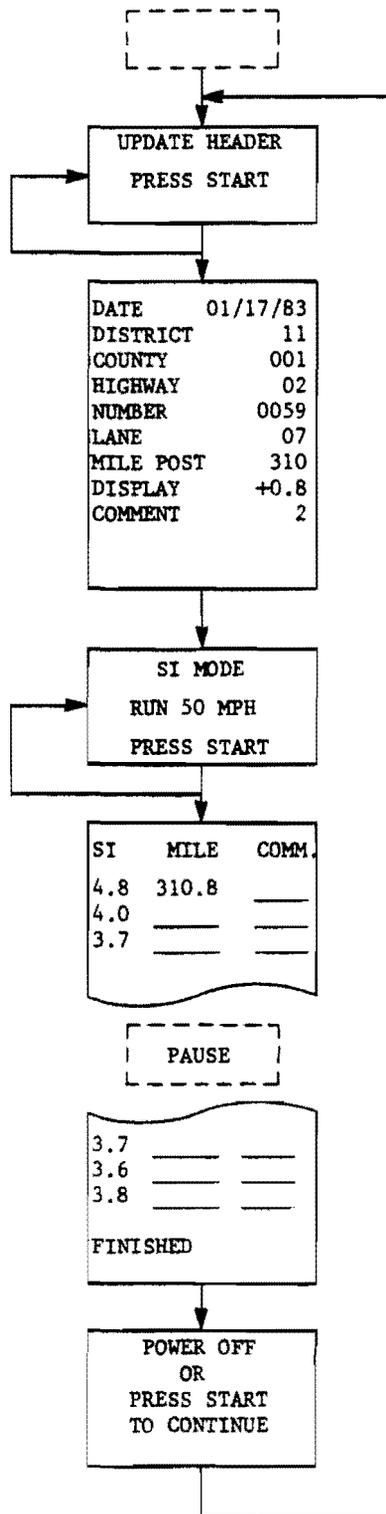


Figure 13. NORMAL SI MODE FLOWCHART

```
.....FINISHED.....
4.7  0149.3  ___4
5.0  0149.5  __3_
4.8  0149.7  _2__
4.5  0149.9  1___
4.5  0150.1  ____
4.5  0150.3  ____
4.9  0150.5  ____
SI   MILE  COMM.
```

SI MODE

```
COMMENT      2
DISPL.       +0.5
MILE POST    150
LANE         02
NUMBER       0059
HIGHWAY      01
COUNTY      093
DISTRICT     12
DATE: 01/18/83
```

GOOD CAR CALIB..

GOOD SPEED CALIB

```
COMMENT      2
DISPL.       +0.5
MILE POST    150
LANE         02
NUMBER       0059
HIGHWAY      01
COUNTY      093
DISTRICT     12
DATE: 01/18/83
```

*** SIOMETER ***

Figure 14. NORMAL SI MODE PRINTOUT

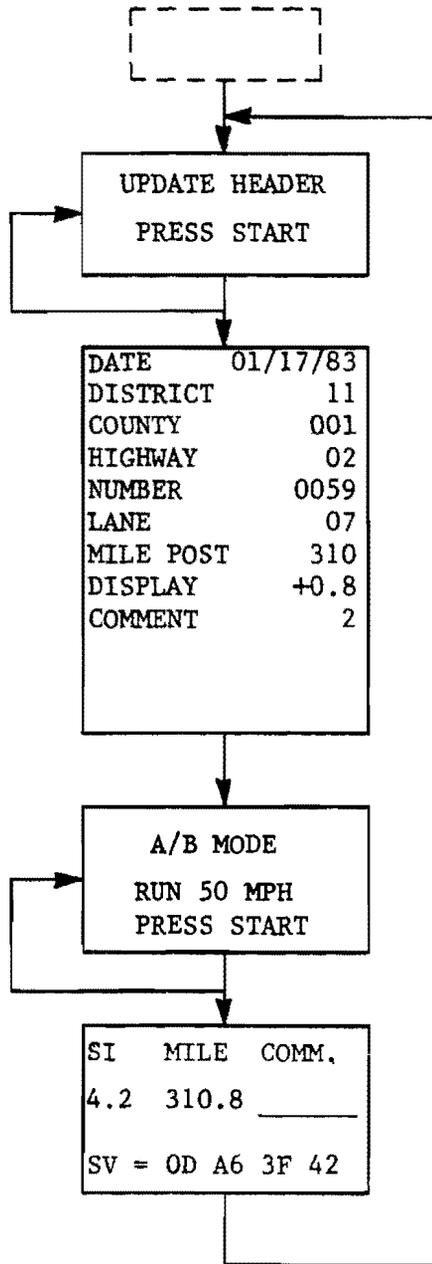


Figure 15. A/B MODE FLOWCHART

SV = 05 80 34 AB
5.0 0150.5 ----
SI MILE COMM.

A/B MODE

COMMENT 2
DISPL. +0.5
MILE POST 150
LANE 02
NUMBER 0059
HIGHWAY 01
COUNTY 093
DISTRICT 12
DATE: 01/18/83

GOOD CAR CALIB..

GOOD SPEED CALIB

COMMENT 2
DISPL. +0.5
MILE POST 150
LANE 02
NUMBER 0059
HIGHWAY 01
COUNTY 093
DISTRICT 12
DATE: 01/18/83

*** SIOMETER ***

Figure 16. A/B MODE PRINTOUT

MAINTENANCE

The only maintenance foreseen for the SIometer system is periodic cleaning of the electronic components. While the unit is completely dustproof in its storage mode, during operation dust can be ingested into the unit and deposited on the electronic circuit boards. When this occurs, there is a possibility of electrical malfunction due to low resistance paths between components. The fan inlet is protected by a filter and screen and these should be periodically cleaned. Cleaning the printed circuit boards in an ultrasonic bath is recommended.

The tape cassette recording heads should be periodically cleaned following the manufacturer's instructions.

TROUBLESHOOTING GUIDE

This troubleshooting guide is written to instruct a system technician in basic isolation of malfunctioning subsystems. It is not intended to describe detailed repair procedures for the system. These detailed repairs would best be done by the manufacturer of the subsystem or by an experienced analog/digital electronics technician.

<u>Symptom</u>	<u>Cause</u>	<u>Remedy</u>
1. Reset switch inoperative.	a. Low battery voltage.	a. Measure battery voltage and verify between 11.5 and 14 VDC.
	b. Power supply failure.	b. With reference to system power wiring schematic, (Appendix B), verify DC input and output voltages.
	c. Damaged wiring.	c. Examine wiring.
2. Printer inoperative.	a. Low paper supply.	a. Add paper and verify internal test program on printer.
	b. Misaligned paper indicating end of roll.	b. Manually align paper.

- | | |
|-------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------|
| c. Improper printer supply voltage. | c. Verify nominal 12 volts on power input terminal strip. |
| d. Printer electronic malfunction. | d. Remove printer from system chassis and verify independently using known 12-volt DC supply. If still inoperative, return to manufacturer. |

NOTE: If printer is malfunctioning on an actual road test, the SIometer program can be reinitialized and the printer logically removed from the system by answering "NO" to the printer prompt. In this manner, testing can continue with the data being displayed with the console and recorded on the tape cassette.

- | | | |
|-------------------------------|--------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 3. Tape cassette inoperative. | a. Improperly loaded tape. | a. Ensure that write/protect tabs on the cassette are not removed. |
| | b. Improper supply voltage. | b. Referring to system power wiring diagram, verify proper supply voltage. |
| 4. Unusual SI values. | a. Improper system hook-up. | a. Verify all cables are properly connected and the time/distance switch is in proper position. |
| | b. Computer malfunction. | b. Reset system and run the test mode. If proper values are output, the computers are operational. |
| | c. A/D board failure. | c. Reference A/D board manual and verify proper analog input and digital output. |
| | d. Accelerometer malfunction. | d. Monitor accelerometer output signal at <u>+1</u> G case orientation. |
| 5. Speed control inoperative. | a. Faulty pick-up orientation. | a. Verify nominal signal coming from speed coil pick-up is at least 1 volt peak-to-peak. A pulse generator can be used to test the system in the laboratory. |

APPENDIX A

DETAILED SPEED PICK-UP MOUNTING

STEP-BY-STEP INSTALLATION

ROAD SPEED PICKUP MOUNTING

Refer to Pictorial 1-1 (Illustration Booklet, Page 2).

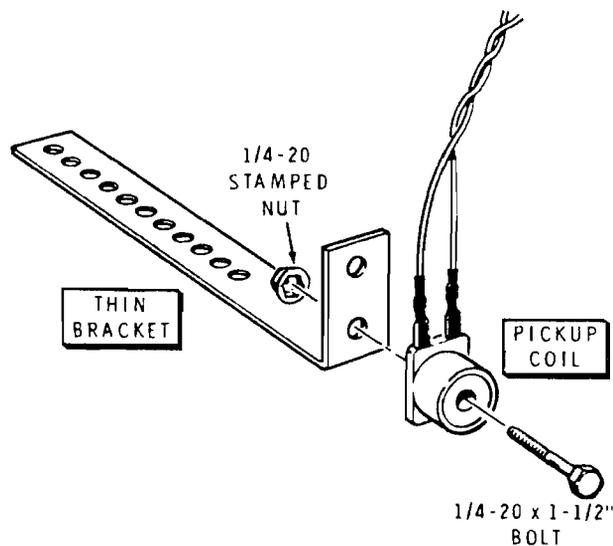
The road speed pickup parts must be mounted on the bottom of the vehicle in the area directly behind the transmission. To install these parts, it is necessary for you to block both **front** wheels (front and back) and place the transmission in neutral. Do not engage the parking brake. Jack up the rear of the vehicle so you have enough room to work under it. Then support the rear of the vehicle on jack stands with the rear wheels off the floor so they can turn freely. **NEVER GET UNDER ANY VEHICLE THAT IS SUPPORTED ONLY BY A JACK. BE SURE IT IS SOLIDLY SUPPORTED BEFORE YOU GET UNDER IT.**

- () Refer to Detail 1-1A and mount the pickup coil in the indicated hole in the short leg of the pickup coil (thin) bracket with the 1/4-20 x 1-1/2" bolt and the 1/4-20 stamped nut. Tighten the nut finger tight only at this time.

Read the following "Mounting Requirements" and "Precautions" sections before you mount the pickup coil and magnets in the following steps.

Mounting Requirements

1. The pickup coil (thin) bracket must be mounted to the floor pan on the vehicle so the pickup coil is within the front 12" of the drive shaft.
2. The head of the pickup coil bolt must be between 3/4" and 1-1/4" from the side of the drive shaft.
3. The magnets must be positioned opposite each other on a line around the drive shaft. This line must be in line with the center of the pickup coil bolt.
4. The blue and gray wires of the pickup coil must be positioned towards the front of the vehicle and up into the left (driver) side of the engine compartment for connection later.



Detail 1-1A

Precautions

1. The pickup coil must be located away from the exhaust pipe and/or the catalytic converter.
2. The blue and gray twisted wires of the pickup coil must be secured away from the exhaust system, the front universal joint, transmission linkage, or any other hot or moving parts.
3. Be sure there are no wires (power seat, seat belt, etc.) above the floor where you drill the mounting holes for the pickup coil bracket.

NOTE: The pickup coil bolt should be on an imaginary line through the center of the drive shaft. Therefore, it may be necessary to mount the pickup coil in the other hole in the short leg of the pickup coil bracket. Position the short leg of the pickup coil bracket downward, or bend the bracket as required.

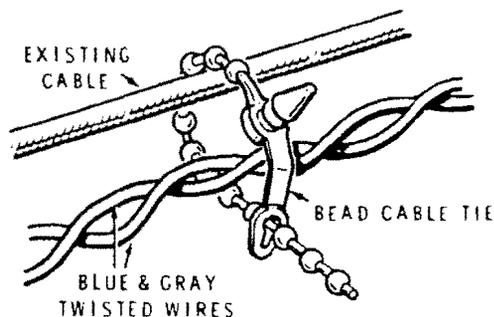
- () Find the pickup coil mounting location under the floor pan. The coil must be within the front 12" of the drive shaft and between 3/4" and 1-1/4" away from the drive shaft.



- () Use the pickup coil bracket as a template and mark two hole locations on the floor pan.
- () While you hold the pickup coil in place, make a mark on the drive shaft that is in line with the center of the pickup coil mounting bolt. Set the pickup coil aside temporarily.
- () Continue the mark on the drive shaft all the way around by rotating the drive shaft by hand. Use a pointed tool such as a center punch, screwdriver blade, or the edge of a file.
- () Thoroughly clean an area about 1" wide around the drive shaft down to shiny metal. If any oil or grease gets on this area, you must remove it with a solvent.
- () Read the instructions on the epoxy packet (including the caution). Follow the instructions; then apply a generous amount of epoxy onto the **metal base plate** side (or curved side) of the two magnets.
- () Install the magnets on the center line around the drive shaft. Make sure the magnets are opposite each other as shown in Pictorial 1-1 and inset drawing #2 on Pictorial 1-1. You can use the two sides of the universal joint yoke as a reference to get the magnets opposite each other on the drive shaft.
- () Apply some of the epoxy on the bolt threads and stamped nut that hold the pickup coil to the thin bracket.

NOTES:

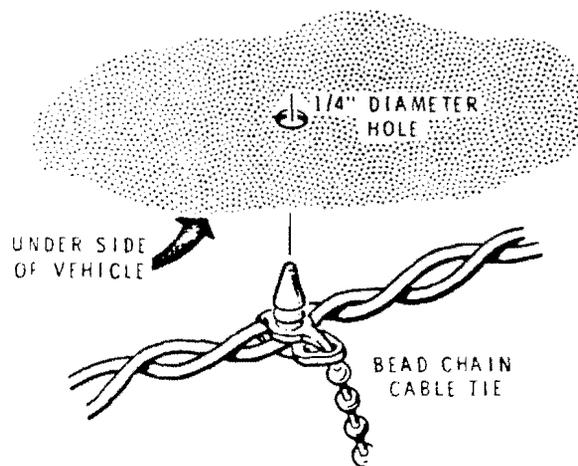
1. As a precaution, remove your wrist-watch before you start working with the magnets in the following steps.
 2. You will be using an epoxy type adhesive in the next step. This epoxy will set in just 3-5 minutes at room temperature, and in even less time when it is hot. Therefore, advance preparation is necessary. You will need a flat piece of glass, plastic, metal, or cardboard on which to mix the epoxy. You will also need a wooden match, toothpick, or small paddle for stirring.
- () Drill 3/16" diameter holes at the two locations marked on the floor pan earlier.
 - () Rotate the pickup coil on its bracket so the blue and gray twisted wires will point towards the front of the vehicle when the bracket is mounted and tighten the hardware. DO NOT overtighten the nut, as this could damage the pickup coil.



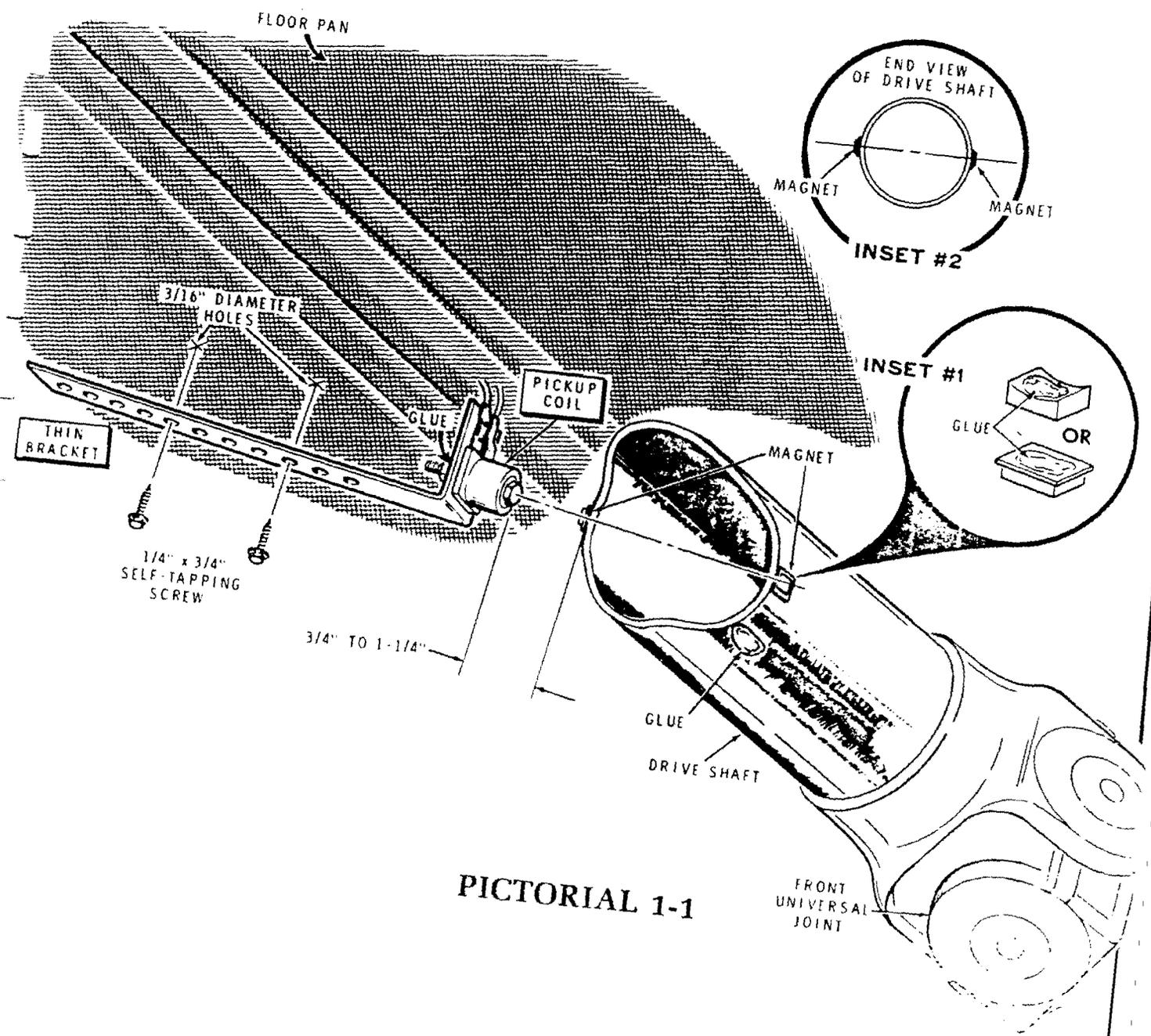
Detail 1-1B

- () Mount the pickup coil to the floor pan with two $1/4 \times 3/4$ " self-tapping screws through the proper holes in the pickup coil bracket. DO NOT overtighten the screws, as this could strip out the holes in the floor pan.
- () Route the blue and gray twisted wires (coming from the pickup coil) towards the front of the vehicle and up into the left (driver) side of the engine compartment for connection later. Secure these wires away from any hot or moving parts.
- () Refer to Detail 1-1B and secure these wires in place to existing vehicle parts (frame, speedometer cable, existing clamps, etc.) with the bead cable ties. (If there are no existing parts to install the cable ties around, you can drill a $1/4$ " hole in the floor pan and push the tip of the cable tie into the hole as shown in Detail 1-1C).

This completes the installation under the vehicle. Carefully remove the jack stands and lower the vehicle to the floor. Place the transmission in park (or in a gear if the vehicle has a standard transmission) and remove the blocks from the front wheels.



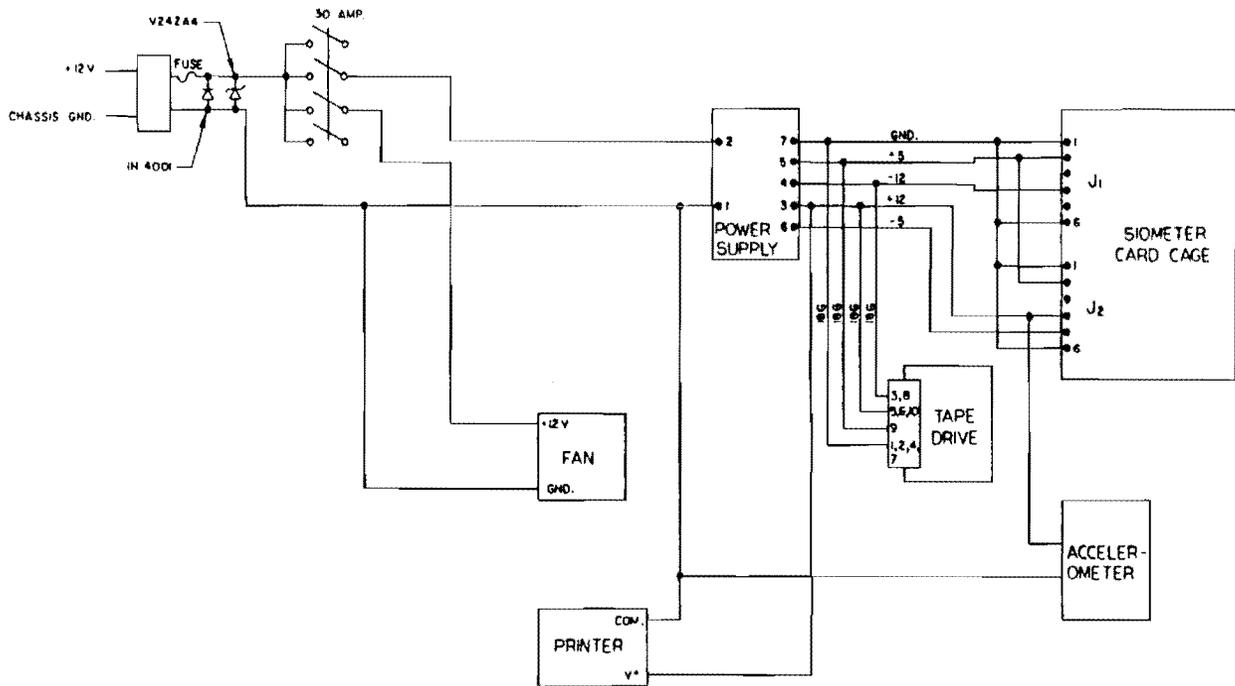
Detail 1-1C



PICTORIAL 1-1

FRONT UNIVERSAL JOINT

APPENDIX B
WIRING SCHEMATICS



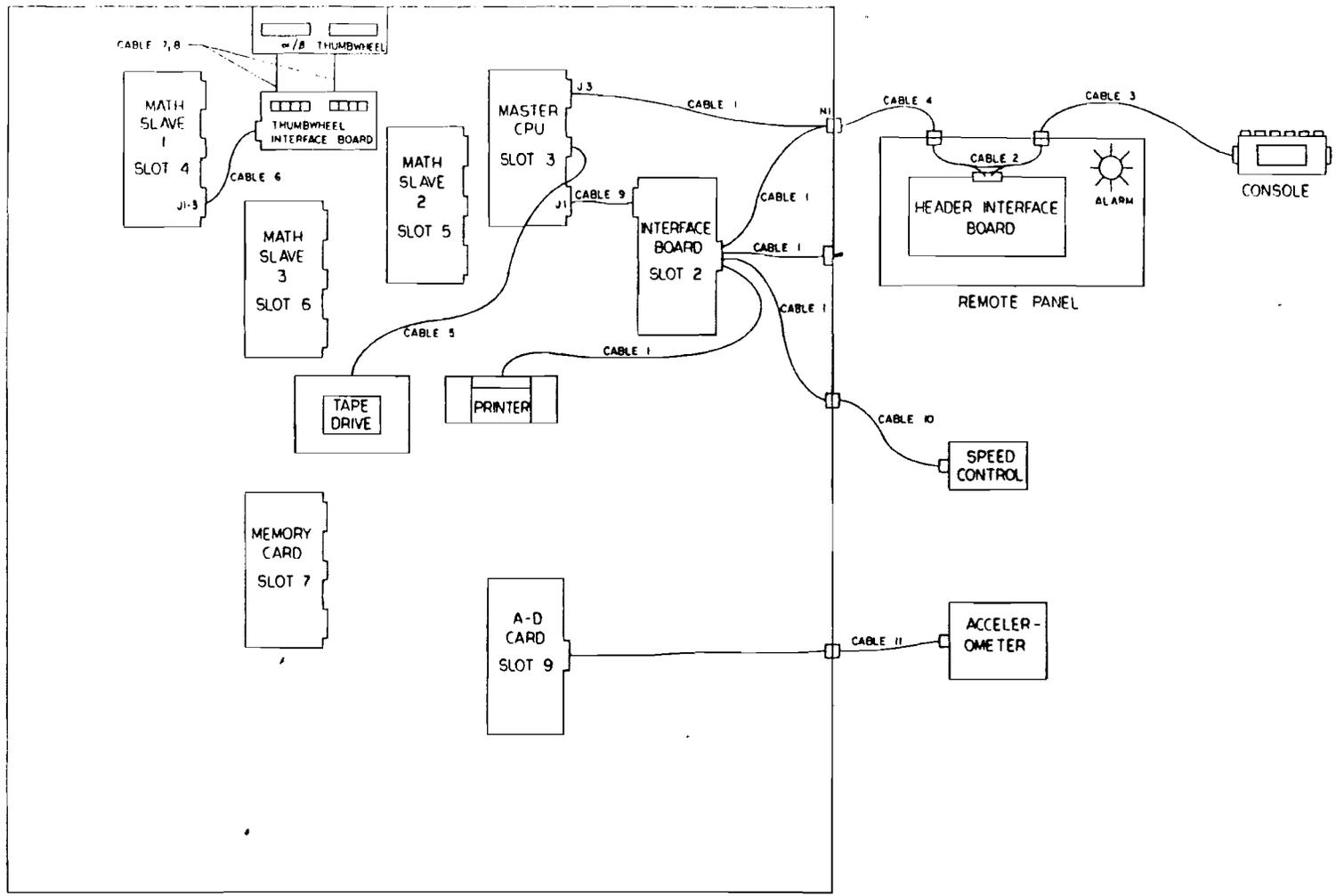
51

DIMENSIONAL TOLERANCE UNLESS OTHERWISE SPECIFIED K ± .100 XX ± .020 XXX ± .005 FRACTIONS ± 1/32 ANGULAR ± 1° SURFACE FINISH IN MICRO INCHES UNLESS OTHERWISE SPECIFIED ✓ NEXT ASS'Y. NO.	SIGNATURE	DATE	MCCLELLAND ENGINEERS
	DR. PHAT	1/4/63	
	EN <i>Goodell</i>	<i>1/11/63</i>	
	APP		
	AUTH		
			SCALE
			SHEET

POWER DISTRIBUTION WIRING DIAGRAM

SIZE C DWG. NO.

SCALE SHEET



SYSTEM CHASSIS

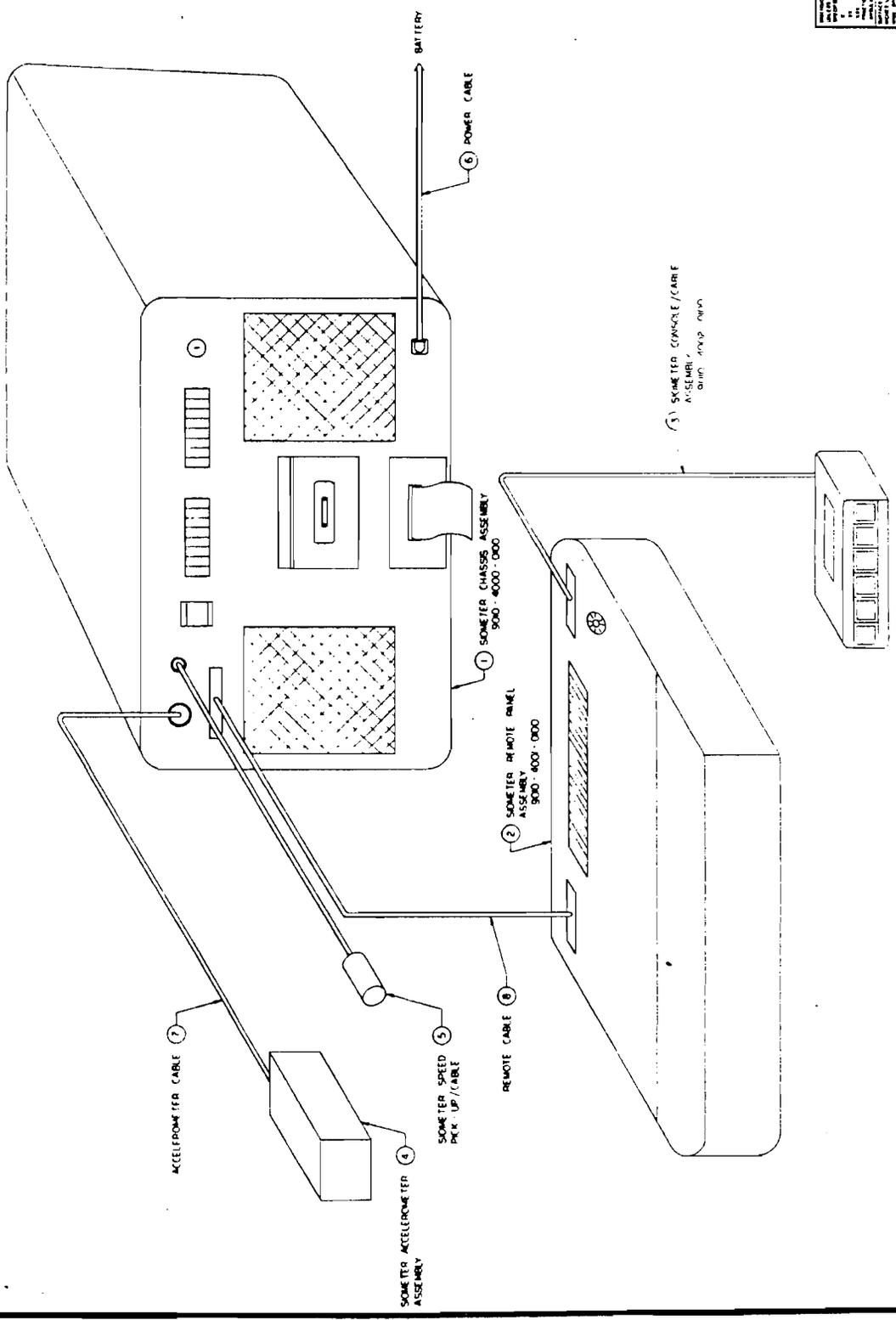
52

DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED .1 ± .000 .XX ± .020 .XXX ± .005 FRACTIONS ± 1/32 ANGULAR ± 1° SURFACE FINISH IN INCHES UNLESS OTHERWISE SPECIFIED APP. AUTH.	SIGNATURES	DATE	McCLELLAND ENGINEERS LOGIC WIRING SCHEMATIC SIZE DWG. NO. C
	DR. PHAT	1/5/83	
	EN <i>Euler</i>	1/10/83	
	ENL		
NEXT ASSY. NO.	SCALE	SHEET	

APPENDIX C

ASSEMBLY DRAWINGS/BILLS OF MATERIAL

ACCELAND ENGINEERS	
DATE	REV
19/01/78	1
SOMETER SYSTEM ASSEMBLY	
D 900-3000-000	
SCALE	



McCLELLAND ENGINEERS
Geotechnical Consultants
BILL OF MATERIALS

TITLE SIOMETER SYSTEM ASSEMBLY

BY Eichel DATE 1/20/83

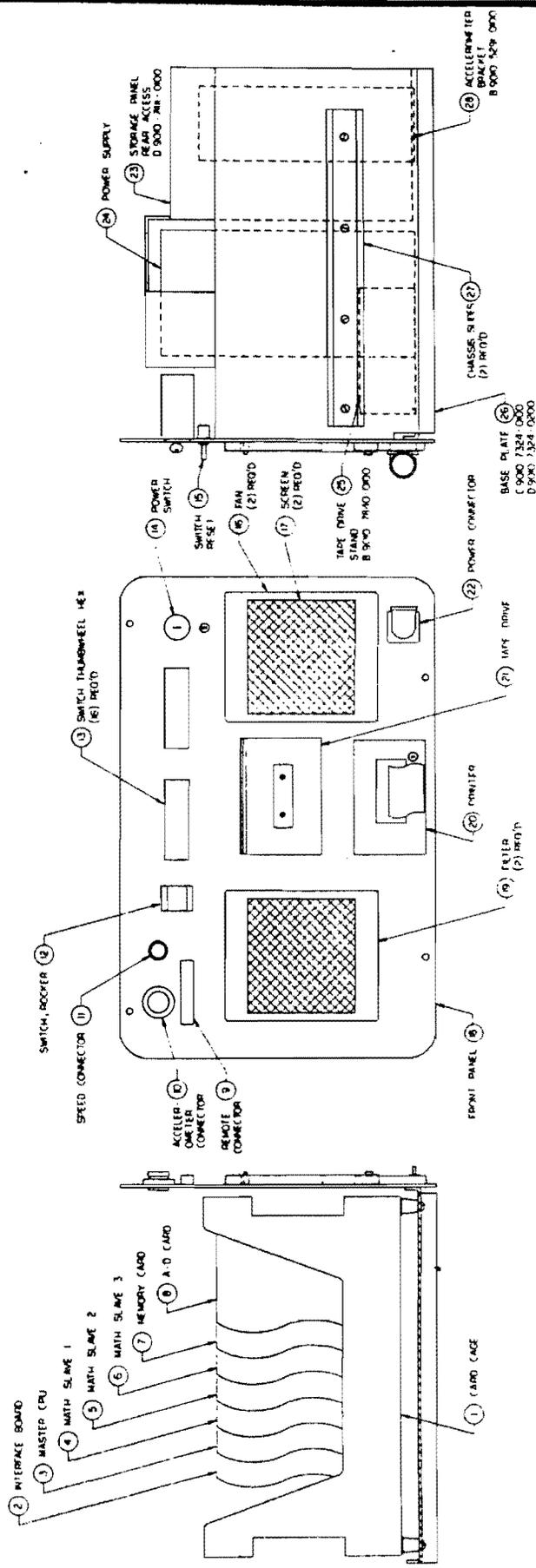
CHECKED BY Nguyen DATE 1/20/83

B/M NO. 9010-3000-0100

SHEET NO. 1 OF 1

NEXT ASSEMBLY _____

ITEM NO.	UNIT QTY.	DESCRIPTION	MEI DRAWING NO.	NOTES
1	1	SIOMETER CHASSIS ASSEMBLY	9010-4000-0100	
2	1	SIOMETER REMOTE PANEL ASSEMBLY	9010-4001-0100	
3	1	SIOMETER CONSOLE/CABLE ASSEMBLY	9010-4002-0100	
4	1	SIOMETER ACCELEROMETER ASSEMBLY		SUPPLIED BY TEXAS HIGHWAY DEPARTMENT
5	1	SIOMETER SPEED PICK-UP/CABLE		HEATHKIT; 250-3011
6	1	POWER CABLE		
7	1	ACCELEROMETER CABLE		
8	1	REMOTE CABLE		
9	2	MAGNETS		HEATHKIT; 250-3033
10	2	PICK-UP COIL MOUNTING BRACKET		HEATHKIT; 250-3013



MCDLELLAND ENGINEERS	
DATE	1961
BY	
CHECKED BY	
APPROVED BY	
DESIGNED BY	
DRAWN BY	
SCALE	
TITLE	SCHEMATIC CHASSIS ASSEMBLY
PROJECT NO.	9000-4000-0070
REV.	D
DATE	1961

McCLELLAND ENGINEERS
Geotechnical Consultants
BILL OF MATERIALS

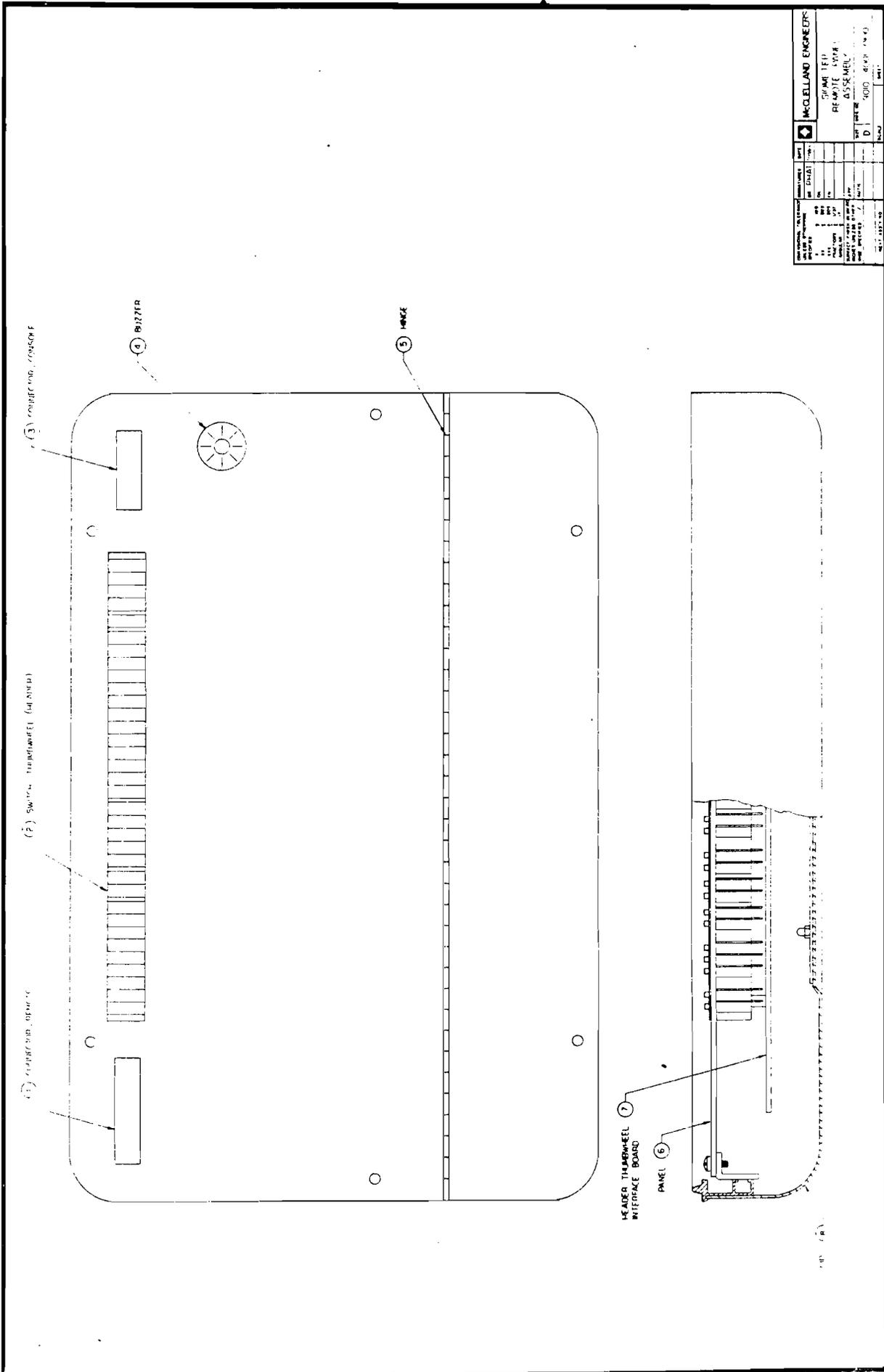
TITLE SIOMETER CHASSIS ASSEMBLY BY Eichel DATE 1/20/83
 CHECKED BY Nguyen DATE 1/20/83
 B/M NO. 9010-4000-0100 SHEET NO. 1 OF 2
 NEXT ASSEMBLY _____

ITEM NO.	UNIT QTY.	DESCRIPTION	MEI DRAWING NO.	NOTES
1	1	CARD CAGE		ELECTRONIC SOLUTIONS; SBC-609
2	1	INTERFACE BOARD		
3	1	MASTER CPU BOARD		MATROX; ZBC-80
4	1	MATH SLAVE 1		MATROX; ZBC-80
5	1	MATH SLAVE 2		MATROX; ZBC-80
6	1	MATH SLAVE 3		MATROX; ZBC-80
7	1	MEMORY CARD (64K)		ARTEC MULTIPLE MEMORY BOARD
8	1	A/D BOARD		ANALOG DEVICES; RTI-1202R
9	1	REMOTE PANEL CONNECTOR		AMPHENOL; 57-40-500
10	1	ACCELEROMETER CONNECTOR		AMPHENOL; 91-PC3F
11	1	SPEED CONNECTOR		AMPHENOL; 80-PC2M
12	1	NORMAL-TEST-A/B SWITCH		
13	16	A/B THUMBWHEEL SWITCH		EECO; 197634GN
14	1	POWER SWITCH		MICRO SWITCH; PKX BM 124 1DD
15	1	RESET SWITCH		
16	2	FAN (12 VDC)		4112X PAMOTOR; 57F1001
17	2	SCREEN (FAN)		5503 PAMOTOR
18	2	FILTER (FAN)		5502 PAMOTOR
19	1	FRONT PANEL		
20	1	PRINTER		MEMODYNE MAP-20 PBC
21	1	TAPE DRIVE		MEMODYNE M80
22	1	POWER CONNECTOR		
23	1	STORAGE PANEL - REAR ACCESS	D9010-7411-0100	
24	1	POWER SUPPLY		GENERAL TRANSFORMER (RON DOW)
25	1	TAPE DRIVE STAND	B9010-7840-0100	
26	1	BASE PLATE	C9010-7324-0100/ D9010-7324-0200	
27	2	CHASSIS SLIDE		
28	1	ACCELEROMETER BRACKET	B9010-5291-0100	
29		INTERFACE BOARD - PRINTER/DISPLAY/SPEED - LAYOUT SKETCH	D9010-2000-3100	
30		INTERFACE BOARD - PRINTER/DISPLAY/SPEED - SCHEMATIC SKETCH	D9010-2000-1100	
31		INTERFACE BOARD - PRINTER/DISPLAY/SPEED - ARTWORK	D9010-2000-2100	
32		INTERFACE BOARD - COEF. THUMBWHEELS - LAYOUT SKETCH	D9010-2001-3100	
33		INTERFACE BOARD - COEF. THUMBWHEELS - ARTWORK	C9010-2001-2100	

McCLELLAND ENGINEERS
Geotechnical Consultants
BILL OF MATERIALS

TITLE STOMELER CHASSIS ASSEMBLY BY Elchei DATE 1/20/83
 _____ CHECKED BY Nguyen DATE 1/20/83
 B/M NO. 9010-4000-0100 SHEET NO. 2 OF 2
 NEXT ASSEMBLY _____

ITEM NO.	UNIT QTY.	DESCRIPTION	MEI DRAWING NO.	NOTES
34		INTERFACE BOARD - COEF. THUMBWHEELS - SCHEMATIC SKETCH	D9010-2001-1100	
35		MOUNTING BOARD - COEF. THUMBWHEELS - LAYOUT SKETCH	B9010-2002-3100	
36		MOUNTING BOARD - COEF. THUMBWHEELS - ARTWORK	B9010-2002-2100	
37		POWER WIRING SCHEMATIC	C9010- 2003-1100 <i>2004-7100</i>	
38		LOGIC WIRING SCHEMATIC	C9010- 2004-1100 <i>2005-3100</i>	
39		FRONT PANEL OVERLAY ARTWORK	C9010-7410-A100	D&W NAMEPLATING
40		BRACKET BOX MOUNTING	B9010-5292-0100	



<input checked="" type="checkbox"/> MOCELLAND ENGINEERS 5101 15th St. N.W. Seattle, WA 98107	
PROJECT NO. _____ DRAWING NO. _____ DATE _____ SCALE _____ SHEET NO. _____	SHEET NO. _____ TOTAL SHEETS _____ PROJECT NO. _____ DRAWING NO. _____ DATE _____ SCALE _____ SHEET NO. _____

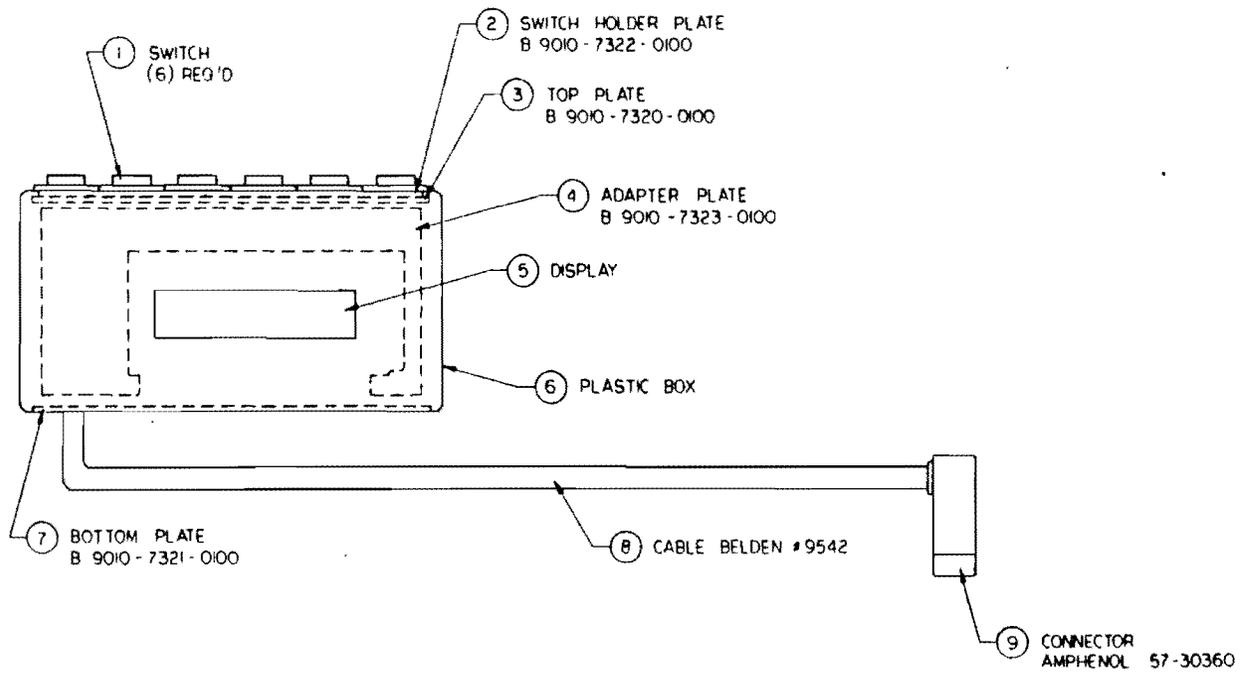
McCLELLAND ENGINEERS
Geotechnical Consultants
BILL OF MATERIALS

TITLE SIOMETER REMOTE PANEL ASSEMBLY

B/M NO. 9010-4001-0100
NEXT ASSEMBLY _____

BY Eichel DATE 1/20/83
CHECKED BY Nguyen DATE 1/20/83
SHEET NO. 1 OF 1

ITEM NO.	UNIT QTY.	DESCRIPTION	MEI DRAWING NO.	NOTES
1	1	CONNECTOR (REMOTE)		AMPHENOL; 5740 500
2	26	HEADER THUMBWHEEL SWITCH		SOUTHWEST ELEC.; CHERRY SWITCH
3	1	CONNECTOR (CONSOLE)		AMPHENOL, 5740 360
4	1	BUZZER		AI 331; PROJECT UNLIMITED; SOUTHWEST ELEC
5	1	HINGE		
6	1	PANEL	C9010-7416 -0100	
7	1	HEADER THUMBWHEEL INTERFACE BOARD	D9010-2003-0100	
8	1	LID		
9	1	HEADER THUMBWHEEL INTERFACE BOARD - ARTWORK	D9010-2003-2100	
10	1	HEADER THUMBWHEEL INTERFACE BOARD - SCHEMATIC SKETCH	D9010-2003-1100	
11	1	CABLE HARNESS		
12		PANEL OVERLAY - ARTWORK	C9010-7416 -A100	D&W NAMEPLATING
13	1	BRACKET (6)/DIVIDER (1)	C9010-5290-0100	



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DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED X ± .005 XX ± .010 XXX ± .015 FRACTIONS ± 1/32 ANGULAR ± 1° SURFACE FINISH IS 32 RMS UNLESS OTHERWISE SPECIFIED /	SIGNATURES	DATE	MCCLELLAND ENGINEERS SIOMETER CONSOLE / CABLE ASSEMBLY DWG. NO. 9010 - 4002 - 0100 SCALE SHEET
	DR PHAT	7/19/63	
	EN <i>Enthal</i>	<i>W. Lee</i>	
	CHK		
APP			SIZE C
AUTH			
NEXT ASS'Y. NO.			

McCLELLAND ENGINEERS
Geotechnical Consultants
BILL OF MATERIALS

TITLE SIOMETER CONSOLE/CABLE ASSEMBLY

B/M NO. 9010-4002-0100
NEXT ASSEMBLY _____

BY Etchel DATE 1/20/83
CHECKED BY Nguyen DATE 1/20/83
SHEET NO. 1 OF 1

ITEM NO.	UNIT QTY.	DESCRIPTION	MEI DRAWING NO.	NOTES
1	6	SWITCH		B&K; Model #8168 + J81 Bezel
2	1	SWITCH HOLDER PLATE	B9010-7322-0100	
3	1	TOP PLATE	B9010-7320-0100	
4	1	ADAPTER PLATE	B9010-7323-0100	
5	1	DISPLAY		Daystar (IEE); #3802-02-016E
6	1	HANDHELD CONSOLE BOX	B9010-5270-0100	City Electronics (modified)
7	1	BOTTOM PLATE	B9010-7321-0100	
8	1	CABLE, 6-FT		BELDEN #9542;
9	1	CONNECTOR		AMPHENOL #5730360; CITY ELECTRONICS
10	1	CONSOLE INTERNAL WIRING DIAGRAM	C9010-2006-8100	