Seismic Pavement Analyzer
(patent pending)
Operation Manual

Texas Department of Transportation

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<th>Title</th>
</tr>
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Executive Summary

This document contains the user's manual for the project-level measurement device called the Seismic Pavement Analyzer (SPA). The equipment has been designed and built to meet the needs of the pavement and maintenance engineer. The SPA is an effective tool for identifying and measuring the precursors of pavement distress in early stages.

The following five distress precursors are addressed:

1. Moisture in base layer (flexible pavement)
2. Voids or loss of support under joints (rigid pavement)
3. Overlay delamination
4. Fine cracking
5. Pavement aging.

To effectively diagnose the specific distress precursors identified, an equivalent number of independent pavement parameters are required. These parameters are measured using equipment similar to a falling weight deflectometer, but the computer processing and interpretation algorithms are more sophisticated than those used with the falling weight deflectometer.

The potential savings are tremendous. First, if the precursor of distress is detected and measured, the potential problem can be resolved with preventive maintenance at a fraction of the cost of later rehabilitation. Second, the device will enable the maintenance engineer to distinguish between maintainable sections and those that require rehabilitation. This enables the highway agencies to direct the available maintenance funds toward maintainable projects.

The equipment can be used for two distinct purposes. The first is to perform more detailed analyses of pavement conditions identified in the network-level surveys and to diagnose specific distress precursors to aid in selection of the maintenance treatment. The second is to monitor pavement conditions after a maintenance treatment has been applied to determine its effectiveness.

The operation of the system is quite simple because it is automated. Most of the data reduction is done rapidly in the field, and the results are saved in a database for further analysis. A graphic representation of the data collected in the field can be produced on demand to enable an engineer to identify the troublesome areas of the pavement as the data is collected.

Finally, the software presents the diagnosis of pavement conditions in
engineering terms (as opposed to stiffness parameters).

The advantages of the device are several. The Seismic Pavement Analyzer is highly accurate and precise in determining the state of the pavement. It uses methods based on accepted engineering physics principles. The field testing and data reduction methodologies are compatible with the theoretical assumptions. The hardware is relatively inexpensive. The device is expected to be inexpensive to modify because only the software should require updating or replacement.
Introduction

This document describes the operation of the software and hardware of the Seismic Pavement Analyzer (SPA) originally developed under Project H-104B for the Strategic Highway Research Program (SHRP) and extensively developed and modified for the Texas Department of Transportation. Technical specifications for the SPA are included in appendix A.

The device consists of a towed trailer, a computer with special data acquisition hardware and software, and a power supply for the trailer and computer. The operation of the trailer is controlled exclusively through the computer; consequently the user's manual deals primarily with operating the software. Aspects of hardware operation are described in chapter 2 and in appendix A. The following section describes the overall structure of the user interface software.

The overall structure of the SPA is that of an interactive controller program that sets up tables and executes specific functions of the SPA hardware through software control. Figure 1.1 shows a schematic of the main functions. The data presentation and data acquisition boxes are stand-alone programs that are executed by the user interface. These stand-alone programs take their data from parameters initialized by the setup tables option of the user interface. They generally require knowledge only of the project specific configuration files and should not necessarily require interaction with the user. By breaking software functions into separate programs, functions are easily added or modified, system maintenance and testing are simplified, and hardware requirements are minimized.
Figure 1.1 - Diagram of general SPA structure. A single main controller program handles user interaction and command execution.

User Interface Appearance

The interactive controller program presents options to the user through a set of three types of screens. These three screens are for menu choices, dialogue interaction, and list selection. Output to the user is in the form of tables and graphs. Graphic display of data is a strong requirement; consequently, a graphic interface is used. The software will support Hercules, color graphics adaptor (CGA), enhanced graphics adaptor (EGA) and video graphics adaptor (VGA) monochrome or color displays.

The menu screen lets the user select one of a set of options for immediate action. A sample menu for the main level of the interactive controller program is shown in figure 1.2. The menu is outlined with a double line, while a single-line box indicates the menu option ready to be selected. Selection of one of these options may execute another of the three interactive screen types or some other specific action. A return <RET> key selects the active option; the
escape <ESC> key exits the menu without a specific selection; and arrow keys change the active option.

Figure 1.2 - Main menu options for the controller program. The option to be selected is outlined with a box and is selected by the return <RET> key. The escape <ESC> key exits a menu without choice.

A dialogue screen lets the user interactively edit text fields or choose menu options. A sample dialogue box is shown in figure 1.3. The current edit field is indicated by the arrow (=>) and menu options are highlighted by a single-line box as shown in figure 1.3. The active edit field or menu option is chosen with the arrow keys or <RET> key, and the dialogue is exited and saved with the <ESC> key.

Figure 1.3 - A sample dialogue menu for selecting program options and editing text fields. The dialogue is exited and saved using the escape <ESC> key.

A list screen lets the user activate a fixed list of options for programs to be executed by the controller program. A short sample list for selecting measurement types is shown in figure 1.4. An arrow (=>) in the left-hand column indicates the item to be changed. This arrow is moved using the arrow keys. Cursor control keys (-> or <-) will toggle the item back and forth between the active and inactive columns. The list is exited and saved using the <ESC> key.

Menu, dialogue, and list-option selections are all saved and the next time the screen is used, previous menu choices are restored. As long as the menu is properly exited, this status is saved through all program operations. Thus, frequently used menu options are quickly selected with minimal key strokes.
Figure 1.4 - Sample list menu for selecting data collection options. The arrow highlights the option that may be toggled between active or inactive using the <RET> key. The list is exited and saved using the <ESC> key.

Software Structure Philosophy

The software controlling the Seismic Pavement Analyzer has been designed to accommodate three main modes of use. These three modes are (1) routine data collection by a technician; (2) setting up options for routine data collection by the project engineer or technician; and (3) diagnostics or general interactive data collection and analysis by the project engineer or researcher.

In routine data collection, the technician needs only to command the computer to collect data. Software then reports selected analysis results to the user's screen, and complete analysis results to the data archive, after successful completion of data collection. If data collection is unsuccessful, the program notifies the user and suggests corrective actions. Options for equipment diagnostics, calibration, and operator comments are also readily available in this mode of operation.

The mode for setting up options and tables is designed so that a wide array of default information may be set up by an experienced operator. The operator has control over the measurements to be made, values to be reported, and diagnostics to be run. The operator also controls the pavement properties and equipment parameters. Some setup tables, such as standard concrete properties, are globally applicable, while others, such as pavement layers and thicknesses, are project specific. Project categories may be set up for specific types of measurements and pavement types to hold those tables and recorded data.

When the project engineer is interactively collecting and interpreting data, large amounts of detailed information are reported to the screen on a specific measurement. This is defined under the setup and analysis modes, this mode effectively provides the project engineer in the office all the information that would be collected by a technician in routine operation with all results reported to the screen after data collection.
Hardware Requirements

The Seismic Pavement Analyzer software, exclusive of the data acquisition software, is expected to run on an IBM-PC XT- or AT-equivalent platform with Hercules, color graphics adapter (CGA), enhanced graphics adapter (EGA) or video graphics adapter (VGA) graphics, 2 megabytes of random-access memory (RAM), and two floppy disk drives. A hard disk and math co-processor will be highly desirable, but not necessary, for speed of operation. Disk storage requirements are determined by the amount of data acquired in the field, as the total floppy disk or hard disk-drive space required to run the user interface, data acquisition, and interpretation software is less than 960 kilobytes. Two serial ports will be necessary for communication with the data acquisition hardware and modem.

Operation of computationally intensive interpretation functions such as the Spectral Analysis of Surface Waves (SASW) inversion would require an AT or equivalent platform with a math co-processor.
Start-Up and Main Menu Options

The Seismic Pavement Analyzer (SPA) consists of two assemblies, a trailer and a computer box. The trailer is connected to the computer through an unbiblical conduit coming from the front of the trailer (Fig. 2.1, item A). The computer is connected to the 12 volt battery of the tow vehicle. If performing "local" data acquisition a keyboard and monitor are connected directly to the computer (Figure 2.2a), otherwise for "remote" data acquisition a laptop or modem is connected to the COM1 serial port on the computer (Figure 2.2b).
Figure 2.1 Schematic of trailer functions. Labeled items have the following functions: (A) electrical umbilical to computer, (B) transducer mounting bar, (C) transducer air cylinders, (D) transducers, (E) air regulators, temperature and firing circuit, (F) air compressor, (G) electrical distribution, (H) compressor battery, (I) high-frequency hammer, (J) low-frequency hammer.
The Seismic Pavement Analyzer (SPA) is started by turning on the two 12-volt DC power switches. First turn on the one switch that starts the computer. After the computer has booted up, turn on the other power switch that sends power to the trailer. The air compressor in the trailer will start and operate for several minutes (Fig. 2.1, item F). Once the air compressor in the trailer has shut off, check that operating pressures on the regulator gauges (located in box E, Fig. 2.1) are satisfactory (45 psi hammer firing, 35 psi hammer lower, 25 psi transducer hold-down) (Fig. 2.3).
Figure 2.3 Regulator pressure settings in trailer.

The power switch for the trailer may be turned on, without the computer on, to enable the air compressor to run. If the computer is turned on after the trailer power switch is on, the transducers and hammers on the trailer may activate during the bootup phase when the computer is in an unknown state. PLEASE KEEP HANDS AND FEET CLEAR OF THE HAMMERS IF YOU START UP THIS WAY AND PLEASE TURN ON THE TRAILER POWER ONLY WHEN THE TRAILER AND VEHICLE ARE NOT MOVING.

Start-up Software

The Seismic Pavement Analyzer software is located in the subdirectory named c:spa. Upon starting the computer, the following three disk operating system (DOS) commands will bring up the software for use.

DOS> c
DOS> cd spa
DOS> useriat

These commands may be typed by the user or inserted in the "autoexec.bat"
file for automatic execution when the computer is turned on. The main menu (Figure 2.4) should now appear on your screen. In the event the Seismic Pavement Analyzer software does not start, refer to appendix B for troubleshooting.

As described briefly in the introduction, the Seismic Pavement Analyzer software is designed to be used by three classes of users: the technician performing routine data collection; the engineer or technician setting up the machine for data collection; and the engineer performing interactive data collection or research. The structure of the main menu, shown in Figure 2.4, reflects this division of function. The “Acquisition” option contains functions used in routine data collection. The “Analysis” option contains functions used by the engineer interpreting data, and the “Table Setup” option is used to configure the SPA. The following sections contain more detailed descriptions of these three functions.

Acquisition

The first menu option (Fig. 2.4), Acquisition, contains four suboptions necessary for the technician performing routine data collection. The following three suboptions are available under the Acquisition heading and are described in more detail in Chapter 2. The Data Collection suboption sends commands for data acquisition, reports any malfunctions, and retrieves and archives collected data. The Save Waveforms option saves the waveforms for later, more extensive analysis. The Hardware Diagnostics suboption replaces the trailer wiring and transducers with computer-controlled electronic signals to monitor correct operation of the computer unit electronics and software. The Software Diagnostics suboption will run the data acquisition software on previously collected waveforms to test operation of the computer and software. The Calibration suboption pulls up another menu for selection of specific calibration procedures.

![Main Menu Options Diagram](image)

Figure 2.4 - Main menu options and suboptions for the acquisition option.

10
Analysis

The second menu option, Analysis (Fig. 2.5), contains the options necessary for analyzing and viewing data collected with the Acquisition option. The experienced engineer may review routinely collected data or may switch back and forth between Analysis and Acquisition functions. The figure's five suboptions are available under the Analysis function and are described in more detail in Chapter 3.

The Select Measurements option brings up a menu that permits selection of specific data sets and data attributes that will be used in other analysis functions. The Display Measurements suboption presents a graphic summary of collected data and analysis results. The SASW Inversion displays a dialog menu of modifiable options and calculates shear modulus and Young's Modulus profiles from frequency-dependent phase data. The Distress

![Main Menu Options](image)

Figure 2.5 - Main menu options and suboptions for the analysis option.

Identification suboption implements Identification of the type of pavement distress on the data sets selected in the Select Data Set option in this menu. The SASW and Distress Identification functions are not currently implemented awaiting experience with the SPA. They will be incorporated with TxDOT's guidance on how they can best assist the engineer in his job.

Table Setup

The third menu option, Table Setup (Fig. 2.6), will be used by the experienced engineer or technician to define data collection and analysis defaults. The five suboptions are described in more detail in Chapter 4.

The Screen Reporting selection brings up a menu of options on the types of
information that are reported to the user's screen, and the Data Base Reporting those that are saved by the data base, during routine or research data acquisition. The Measurement Options selection allows the user to set up the types of measurements to be made during data acquisition. The Setup Tables selection brings up a menu of user-modifiable tables that deal with project definition, concrete and asphalt properties, and the expected pavement structure. The Remote/Local setup is defined under this function. The Help suboption gives a brief description of the operation of each of the options in this menu.

Figure 2.6 - Main menu options and suboptions for the table setup option.

Help

The fourth menu option, Help (figure 2.7), brings to the screen a text window with similar information as contained in this section. Help options are available in all appropriate menus and are specific to the context of the software. For instance, while in the Analysis option of the main menu, only information useful for analysis options is available with its help command.

Figure 2.7 - Main menu options with help option selected.

Exit

The fifth menu option, Exit (Fig. 2.8) permits a graceful exit from the Seismic
Pavement Analyze: software into the personal computer's (PC's) operating system. The Acquisition option is restored when the software is rerun. Choosing the Exit option is equivalent to using the <ESC> key to exit this menu.

Figure 2.8 - Main menu options with exit option selected.
Acquisition

The Acquisition option of the main menu is shown in Figure 3.1 and permits the selection of the five functions involving data acquisitions. These five functions are Data Collection, Save Waveforms, Hardware Diagnostics, Software Diagnostics, and Calibration. Each of these functions is a subheading in this chapter.

![ACQUISITION MENU]

Figure 3.1 - Menu options for controlling the hardware, pneumatics, and data acquisition subsystem. The single-line box highlights the Data Collection option to be selected with the <RET> key.

The Data Acquisition, Hardware Diagnostics, and Software Diagnostics functions each execute the data acquisition software with input from a different data source. Data Acquisition collects data from transducers on the trailer. Hardware Diagnostics takes data from electronic calibration circuits, and Software Diagnostics takes data from a software file.

Data Acquisition

Choice of the Data Acquisition option will initiate hardware data collection.
and reporting back to the user’s screen and data base. With selection of this option, the hammers and transducers will lower to the pavement surface, there will be a one or two second wait, the high-frequency hammer will fire up to eighteen times, the low-frequency hammer will fire up to six times, there will be a five to ten second pause, and then the hammers and transducers should rise. Any unusual conditions will be reported to the screen, and the operator will be prompted for comment.

When the device is first run on a different pavement it will make more hammer hits than it will several tests later. This is done while the software learns the appropriate hammer firing parameters and amplifier gains needed to collect good data. On relatively uniform pavement, the high-frequency hammer should drop from eighteen to a minimum of twelve hits, and the low-frequency hammer should drop from six to a minimum of three hits.

Should the hammers continue hitting beyond limits defined above, the operator should hit <Ctrl-C> on the keyboard; this is the common method to interrupt programs in DOS. This will interrupt the software, raise the transducers and hammers, and make a report to the database error handling files.

Should hammers fail to raise, or hammers not stop hitting, please refer to Appendix B for troubleshooting help.

Save Waveforms

The Save Waveforms option performs a data compression and archiving operation of the time domain waveforms present in the file named “dr2dbin” located on the ramdrive. If the last step was data acquisition, the most recent waveforms are archived in the project directory labeled with the tag used in data collection. If the last step did not create the waveforms, the archive waveforms may overwrite previously archived waveforms with the same tag.

This option may be selected only when the machine is run in the Local Acquisition mode (see chapter 5, Acquisition Mode, figure 5.12). These data may be used for later detailed interpretations, for comparison with core samples, or for detailed diagnosis of equipment operation. To reanalyze these waveforms, please see the following section on Software Diagnostics. Some restraint should be exercised in using this option, as up to 160 kilobytes of data are saved to disk with each operation.

Hardware Diagnostics

Selection of the Hardware Diagnostics option replaces the trailer hardware (hammers, accelerometers and geophones) with electronic calibration signals. This directly tests the functioning of the electronic amplifiers, A/D conversion, I/O board, computer, and software. Correct functioning during this option also indirectly tests the trailer wiring and transducers. Combining this test with diagnostics acquired during normal operation or open or shorted cable conditions can help distinguish types of failure in the trailer.
With experience and guidance from TxDOT, we will add more specific diagnostic software into this function.

**Software Diagnostics**

Selection of the Software Diagnostics option runs the data acquisition software with its input taken from a data file. This option is not fully implemented to provide diagnostics, but can be used to reanalyze previously collected waveforms by copying the data file to dirrd.bin.

**Calibration**

The Calibration suboption has not yet been implemented under the user interface. It is necessary to manually collect this data and rewrite the calibration table used by the data acquisition software. The following section should be viewed as a proposal for how this option will work.

Selection of the Calibration option will bring up another menu (figure 3.2) from which specific calibration procedures may be selected. Time intervals for calibration have not yet been determined, as no changes in calibration have been observed to date.

The amplitude calibration is used to calibrate the low-frequency load cell and the closest geophone for the mechanical impedance test. It will require you to provide an independently measured load amplitude and velocity amplitude.

The distance calibration sequence will be incorporated in purchased hardware from a commercial vendor of vehicle-mounted distance meters.

```
<table>
<thead>
<tr>
<th>CALIBRATION MENU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amplitude</td>
</tr>
<tr>
<td>Distance</td>
</tr>
<tr>
<td>Velocity</td>
</tr>
<tr>
<td>Temperature</td>
</tr>
<tr>
<td>Source Control</td>
</tr>
</tbody>
</table>
```

Figure 3.2 - Menu for selection of specific calibration options. The single-line box highlights the selected option.
The Velocity calibration requires a standard slab of known compressional velocity. The Seismic Pavement Analyzer is lowered onto the standard slab and the Velocity option is selected. The menu shown in figure 3.3 is brought up listing source-detector spacings in dialogue entries for verification and also requesting the velocity of the standard slab in a dialog entry.

The Temperature calibration sequence requires that both the pavement and air thermocouples be placed sequentially in an ice bath and hot water bath with water temperatures measured with a thermometer. Selection of the Temperature option will bring up the dialogue box shown in Figure 3.4. With the thermocouples in the Cold Bath Sample, the user selects that menu entry, hits the <RET> key, and a digital, uncalibrated temperature reading is taken after the temperature has stabilized. The user then moves the cursor to the Thermometer Reading entry to the right and enters the reference thermometer reading. The user then places the thermocouples in the hot water and selects Hot Bath Sample, waits for a stable digital temperature reading, and enters the reference thermometer reading. Following calculation of new calibration constants, deviations of the old temperature calibration are recorded in the data base. The user may calibrate the system in either English units or metric (International System of Units or SI) units.

![Velocity Calibration Menu](image)

**Velocity Calibration Menu**

Spacing of Source to Detector (m)

<table>
<thead>
<tr>
<th>Source</th>
<th>Spacing (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>0.076</td>
</tr>
<tr>
<td>A2</td>
<td>0.152</td>
</tr>
<tr>
<td>A3</td>
<td>0.305</td>
</tr>
<tr>
<td>A4</td>
<td>0.607</td>
</tr>
<tr>
<td>A5</td>
<td>1.219</td>
</tr>
</tbody>
</table>

Standard Slab Velocity: 4913.

- Calibrate Velocity
- Help
- Exit

![Figure 3.3 - Velocity calibration menu](image)

Figure 3.3 - Velocity calibration menu. Source-detector spacings are alterable in dialog entries. The calibration velocity is entered in a dialog entry, and the calibration procedure is selected by a menu entry.
TEMPERATURE CALIBRATION MENU

<table>
<thead>
<tr>
<th>Cold Bath Sample</th>
<th>Cold Bath Temperature =&gt; 1.2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot Bath Sample</td>
<td>Hot Bath Temperature =&gt; 97.4</td>
</tr>
</tbody>
</table>

Figure 3.4 - Menu entries for temperature calibration. Cold Bath Sample and Hot Bath Sample are menu entries that initiate a digitized temperature recording. Upon taking the digital sample, the user records the reference thermometer reading in the dialog entry.
Analysis

The Analysis option of the main menu (Figure 2.2) permits selection of four suboptions shown in Figure 4.1. These four functions are Select Measurements, Display Measurements, Spectral Analysis of Surface Waves (SASW) Inversion, and Distress Identification. Each of these options is a separate section in this chapter.

![ANALYSIS MENU]

Select Measurements
Display Measurements
SASW Inversion
Distress Identification
Help

Figure 4.1 - Menu options for controlling analysis and data-plotting software.

Analysis functions are likely to be used in two modes. In the first, the project engineer or technician will review and analyze a series of measurements routinely collected on a particular project. In the second, the project engineer is likely to be making a detailed set of analyses and judgments interactively with measurements, occasionally referring back to previous measurements of a similar type. Consequently, analysis functions are controlled by the context of other program operations. For instance, if data collection has just occurred, Display Measurements, SASW Inversion, and Distress Identification functions all operate on the most recently collected measurement. Review or analysis of previously collected data sets is accessed through the Select Measurements option. The program remains in that mode.
Select Measurements

Selection of the Select Measurements entry brings up a list menu of previously collected and unarchived data in the currently active project directory (figure 4.2). See Chapter 5 about the Project Directory selection option for instructions on how to select this option. Specific measurements may be toggled between active (for analysis) and inactive (to be ignored). Measurements are identified by a unique number (called a ‘tag’), time, and distance. The measurements that are shown in this list menu can come from two sources. Data that have been recently collected and not yet loaded into the data base manager will be displayed in this list. In addition, if data are retrieved from the data base manager into the appropriate project directory, it will be available for display or analysis through this list.

<table>
<thead>
<tr>
<th>DEMONSTRATION DATA</th>
<th>Active</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tag 1</td>
<td></td>
</tr>
<tr>
<td>Tag 2</td>
<td></td>
</tr>
<tr>
<td>Tag 3</td>
<td></td>
</tr>
</tbody>
</table>

Figure 4.2 - List menu for selecting data sets to be reviewed, plotted, or analyzed.

Display Measurements

Selection of the “Display Measurements” option brings up an experimental graph summarizing the modulus and thickness measurements made by the Seismic Pavement Analyzer (SPA). Figure 4.3 shows a sample of this summary display. The graph is a schematic pavement cross-section divided into three layers. The top layer shows the paving layer properties, underlain by a base layer, with the bottom layer representing the subgrade properties. The width of the left-hand box is proportional to a normalized shear modulus, and the width of the right-hand box in the paving layer is proportional to Young’s Modulus. The box heights are proportional to the normalized thicknesses. The distance the paving layer is floating above the empty box is proportional to the normalized impact echo amplitude height. The separation between the base layer and paving layer is proportional to the normalized damping in the mechanical impedance test. Default properties used for normalization are the expected values selected in the Pavement Structure option of Table Setup (chapter 6). If the Select Data Set Measurements option has not been activated since the last data acquisition stop, the most recently
collected measurements will be reported to the screen.

Figure 4.3 - Sample schematic pavement cross-section description. Boxes represent paving layers; height is proportional to thickness; and widths are proportional to shear Modulus and Young's Modulus estimates in the layer.

Page up, Page down, Home, End and arrow keys can be used to scroll the pavement cross section. An 'x' will exit the pavement picture and return you to the user interface software.

Commercial spreadsheets can provide the user with many other types of graphs of measurements from the SPA. The SPA data base records may simply be loaded into the spreadsheet for display, computations, or statistical analysis. This data base file resides in the project directory specified in Setup Tables (Directory Selection) with the name "moduli.txt."

SASW Inversion and Distress Identification

The SASW Inversion and Distress Identification options are not currently implemented awaiting guidance from TxDOT on how they wish to use this function.

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Table Setup

The Table Setup option of the main menu (figure 2.3) permits selection of the four suboptions shown in figure 5.1. These four functions are Screen Reporting, Data Base Reporting, Measurement Options, and Setup Tables. Each of these options is a separate section in this chapter.

![Setup Table Menu]

Figure 5.1 - Menu options for setting up default data collection, display, and reporting selections.

The structure of these options has been designed so that the computer screen shows technicians performing routine data collection the quantity and level of information required to perform the job successfully at their training level. The project engineer reviewing data after collection requires a different quantity and level of information from the database. Provision is also made in these options for the Seismic Pavement Analyzer (SPA) to be repaired or to perform in a suspect state of repair. Extensive, but probably inadequate, diagnostics are also available.
Screen Reporting

Upon selection of the Screen Reporting menu item, a menu of two options is brought to the screen (Figure 5.2) that breaks the Report category into two options, Diagnostic Level and Parameter Display.

A list of options for diagnostic reporting is given in figure 5.3.

![SCREEN REPORT OPTIONS]

- Diagnostic Level
- Parameter Display

Figure 5.2 - Menu options permitting selection of specific types of screen reports.

Different levels of condition messages are available under the Diagnostic Level option. Under the Suggest Repairs, serious malfunctions that prevent collection of good measurements are reported. Message Malfunction Warning, reports instrument conditions that might lead to degradation of data quality, but reports not necessarily require immediate attention. Full Status Report lists all negative status conditions in the hardware and software that might be useful in repair or field checking before initiating a project.

![DIAGNOSTIC LEVELS]

- Suggest Repairs
- Malfunction Warning
- Full Status Report

Figure 5.3 - List of options for diagnostics to be displayed to the user during data collection and instrument testing, available under either data base or screen reporting options. The currently active option is highlighted by the box when it is accessed.

The Parameter Display option is currently only configured to give a yes or no output, and requires an act of God to be set to yes. This will be modified with experience applying the SPA.
Data Base Reporting

Selection of the Data Base Reporting option (Figure 5.1) will bring up a menu shown in Figure 5.4. Data base and record forms are not standard among prospective users, so records and tables are formatted for compatibility with several commercial personal computer (PC) data base packages.

The Parameter Display options currently is only configured to give a yes or no option, and requires an act of God to be set to yes.

![DATABASE REPORT OPTIONS]

- Diagnostic Level
- Standard Formats

Figure 5.4 - Menu selection to set up data base entries documenting test, conditions, results, and diagnostics.

The Diagnostic Level is identical to that under the Screen Display option (Figure 5.3). Typically, diagnostics at the malfunction level are routinely saved in the database. By default, all data are currently archived in a format for entry into Borland’s Paradox data base. As additional needs or data bases are accommodated, the Standard Formats option will be implemented to allow these.

Measurement Options

On selection of Measurement Options, a list of possible measurements to be reported from the Seismic Pivement Analyzer is given (Figure 5.5). Items may be toggled between the inactive and active modes using the return <RET> key.

The list of measurement options may not be displayed in its entirety on the screen at one time, as it is too long for some screens. The lists will scroll up-and-down through use of the up and down arrow cursor controls, as well as the "PgUp" and "PgDn" keys.
Figure 5.5 - List of options for measurements to be collected.

Setup Tables

The Setup Tables option allows definition of the analysis and collection environment of the SPA. The units and dimensions of measurements are implicitly defined in the tables that can be modified in this section. All tables are currently defined in International System of Units (SI). If some other system of units is desirable, the source-receiver geometry, pavement properties, pavement structure, and calibration tables must be changed to reflect consistent units. The units are implicitly defined by the values of numbers used in the tables; the software expects no explicit units.

On selection of the Setup Tables option, the menu shown in Figure 5.6 appears on the screen giving a list of the tables to be edited.
Figure 5.6 - Menu options to select specific setup tables and options.

Upon selection of the Source-Receiver Geometry option, the spacing table (Figure 5.7) specific to the current working directory is loaded into the DOS system editor. If changes are made, those spacings are moved to the working table for data acquisition. Units of these spacings are implicitly assumed to match those used for modulus values.

The spacing table abbreviations L2 and L1 represent the low-frequency and high-frequency load cells respectively. G1-G3 and A1-A5 are the representations of consecutive geophones and accelerometers. The entry L1A3 0.3048 then implies that the distance between the high-frequency load cell and accelerometer number 3 is 0.3048 meters.

L2L1 0.063
L2G1 0.139
L2G2 0.084
L2G3 0.178
L1A1 0.075
L1A2 0.152
L1A3 0.305
L1A4 0.609
L1A5 1.219

Figure 5.7 - Source-receiver geometry table for modifying spacings.

Paving Layer Properties

Selection of the Pavement Properties option will execute the system editor on the file of globally applicable pavement properties. This table is the
summary used by the software, and can more easily be accessed through use of the Pavement Structure option described in the following paragraph.

Selection of the Pavement Structure option will bring up the menu of figure 5.8 permitting selection of the pavement layer for which you wish to modify properties. Selection of one of these layers will bring up a dialog (Fig. 5.9) that sets minimum, maximum, and expected layer properties, along with an entry to describe the material. Selection of any of the layers from Fig. 5.8 gives a choice of materials relatively similar to that of Fig. 5.9. If you exit the dialog of Fig. 5.9 without selecting Save Changes, the modified values will not be incorporated into the analyses.

![Pavement Properties Menu](image)

**Figure 5.8** Menu selections to select the pavement layer that you want to modify properties for.

![Pavement Layer Properties Table](image)

<table>
<thead>
<tr>
<th>Property</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Expected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shear Modulus</td>
<td>1.0e8</td>
<td>&gt; 1.0e10</td>
<td>&gt; 2.0e9</td>
</tr>
<tr>
<td>Layer Thickness</td>
<td>0.10</td>
<td>&gt; 0.20</td>
<td>&gt; 0.15</td>
</tr>
<tr>
<td>Echo Amplitude</td>
<td>0.22</td>
<td>&gt; 1.8</td>
<td>&gt; 0.33</td>
</tr>
<tr>
<td>Young's Modulus</td>
<td>1.0e9</td>
<td>&gt; 5.0e10</td>
<td>&gt; 1.1e10</td>
</tr>
<tr>
<td>Material</td>
<td>PCC</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

![Save Changes Button](image)

**Figure 5.9** Dialog for setting pavement layer properties. Minimum and
maximum values are used to report unusual results in data collection, and the expected values tell software where to start solution searches.

**Project Directory**

Under the operating directory of the SPA, a directory named "PROJECTSV" is reserved for newly created or previously existing project subdirectories. Project directories may be created and accessed that are not under this reserved directory, but some aspects of routine operation will not be visible to the user.

Selection of the Project Directory option brings up a dialog menu showing the currently active directory, with options for change (Figure 5.10). The Active Directory entry is a dialogue entry that indicates the project directory that is currently active and permits creation of a new name, or selection of an unreserved project directory. An old project directory may be typed in, or if a new directory name is entered the selection of the New Directory menu item will create the directory and copy setup tables into it.

![Directory Selection Menu](image)

Figure 5.10 - The Directory Selection Menu displays the currently active directory, permits creation of a new directory name entered in the field, or lets you select an active directory from a list.

The List Directories menu option will bring up a list menu of currently available directories with the currently active directory in the Active zone (Figure 5.11). An existing directory may be moved to the Active zone to select it as the current operating directory. If multiple directories are selected to be active, the software will complain until only one directory is selected. Only project directories in the "PROJECTSV" subdirectory are shown in this list.
Figure 5.11 - Project directory selection list. Only one directory should be moved to the active column and it is selected by hitting <ESC>.

 Acquisition Mode

Selection of the Acquisition Mode option brings up a menu allowing you to select between two options (Figure 5.12).

Figure 5.12 - Menu to permit selection of whether acquisition is made using two computers connected by modem or null modem (Remote) or by one computer (Local).

Selection of the Remote Acquisition option (Figure 5.12) assumes that the user interface software resides on a different computer than the data acquisition software and that the two are connected through a cable or through modems and a phone line. Selection of the Local Acquisition option assumes that the data acquisition software and user interface are on the same computer.

29
Menu and Interpretation Templates

This section describes the structure of the user-accessible files that define the functions and actions of the user interface software. This section is of use to those who need to translate the user interface into a different language, to modify the menus, or to change the result of choosing a specific menu option.

Three types of interactions have been defined between the user and the interface software: selection of an item from a menu, entry or modification of values in a dialogue, and activation of multiple entries from a list of items. Each of the screen displays for these interactions is controlled by a specific file, named with a specific three-letter disk operating system (DOS) file type, with a special structure. Information about the menu, dialogue, or list location are held in "*.imp" file name. For dialogues and lists, the "*.imp" file contains a file name for the values in "*.val" file names and for lists in "*.lst" file names. These files are contained in the template subdirectory under the main directory for the Seismic Paveement Analyzer (SPA).

Each template file, regardless of the type of interaction, contains several common attributes. The first portion defines the location of the screen window, the window attributes, and the title for the window. This portion is followed by a file name that points to some subsequent menu or data file, depending on the type of interaction. Subsequent entries are menu or dialogue entries followed by a character string returned to the calling program. In most cases, this character
string is expected to point to the subsequent menu file for that option. The
three following sections discuss the different types of interactions and file
formats in more detail.

5 5 90 20 -1 -1 -1 -1 Line 1
40 10 MAIN MENU OPTIONS Line 2
NORMAL Line 3
10 70 0 Acquisition Line 4
\"menus\template/acq.tmp\" Line 5
30 70 0 Analysis Line 6
\"menus\template/anal.tmp\" Line 7
50 70 0 Table Setup Line 8
\"menus\template/setup.tmp\" Line 9
75 70 0 Help Line 10
\"menus\help\main.txt\" Line 11
90 70 0 Exit Line 12
Line 13

Figure 6.1 - Sample menu template for the main controller menu with line
numbering on the right.

Menus

A sample of a menu template that creates the main controller menu (Figure
1.2) is shown in Figure 6.1. A description of the significance of each entry
follows.

Line 1

Entry 1: Left edge of menu in percent of screen size.
Entry 2: Top edge of menu in percent of screen size.
Entry 3: Right edge of menu in percent of screen size.
Entry 4: Bottom edge of menu in percent of screen size.
Entry 5: Foreground color (-1 default).
Entry 6: Background color (-1 default).
Entry 7: Text color (-1 default).
Entry 8: Line width (-1 default).

Line 2

Entry 1: Lower left title position X, percent of menu size.
Entry 2: Lower left title position Y, percent of menu size.
Entry 3: Title text string.

Line 3

Entry 1: File name allowed but is not used in menus.
Line 4  Entry 1: Menu text position horizontal, percent of menu size.
Entry 2: Menu text position vertical, percent of menu size.
Entry 3: (-1) non-menu text string.
(0) menu text string.
(>0) X dialogue position, percent of menu size.
Entry 4: Menu text string for Acquisition option.

Line 5  Entry 1: Text string returned to software upon selecting this menu option. File name for the Acquisition template file.

Line 6, 7  Menu item and template file for Analysis.

Line 8, 9  Menu item and template file for Table Setup.

Line 10, 11  Menu item and help file for Help option.

Line 12, 13  Menu item for Exit with no text returned.

Dialogs

A sample of a dialogue template for the temperature calibration menu is shown in Figure 6.2. The structure and significance of the first two lines are the same as for the menu template of Figure 6.1. Line 5 contains the file name of default and modified values for the dialogue items. A sample of this file is shown in Figure 6.3.

```
10 30 50 70 -1 .1 -1 .1
40 39 TEMPERATURE CALIBRATION MENU

Line 1

Line 2

Line 3
tempval

Line 4

Line 5
60 30 95 Cold Bath Temperature

Line 6

Line 7
CBT

Line 8

Line 9
60 70 95 Hot Bath Temperature

Line 10

Line 11
HBT

Some message to data acquisition

Another message to data acquisition

Figure 6.2 - Dialog template for the temperature calibration menu.

Line 1, 2 Men line location and title as defined for Figure 6.1.

Line 3 Entry 1: File containing dialogue values.

Lines 4-7 Dialoge entries as defined for Figure 6.1.

Lines 8-11 Menu entries as defined for Figure 6.1.

2
Cold Bath Temperature

Line 1

Line 2

Line 3

Line 4

Line 5

3.4
Hot Bath Temperature

Figure 6.3 - Value file for the temperature calibration menu.
The value file contains two types of entries for dialogs. The first line contains the default (or last chosen) option. The next time this dialog file is accessed, the previously used menu option is the first available. Lines 2 and 3 contain the dialogue entry label and value. The label is not specifically used in the menu. Rather, it is written so that the value file is readable and not context specific when programs read parameters from the file.

Lists

A sample list template for selecting measurement options is shown in figure 6.4 for the menu shown in figure 1.4. Lines 1 and 2 define the menu window and title as in figures 6.1 and 6.2. Line 3 points to the list of options to be displayed, as pictured in the shortened list of figure 6.5.

An entry of "1" in the first column of the list of figure 6.5 indicates an active item, and an entry of "0" indicates an inactive item.

30 12 70 92
20 5 MEASUREMENT OPTIONS
.\menus\template\list.lst

Figure 6.4 - Template for the measurement list selection.

1 Ml
0 SASW
0 Pulse Echo
1 Comment

Figure 6.5 - Shortened example of list menu entries. A "1" in the first entry indicates an active item; "0" indicates an inactive item.

Messages

A sample message template for giving information to the user is shown in figure 6.6. Lines 1 and 2 are identical to other menu templates in giving the screen location and attributes, as well as the subject of the message. Line 3 contains a file name that is not currently used but may contain text information. Line 4 gives the location of the text within the box defined in line 1.

The common use of the message template is to supply error messages returned from the data acquisition software.

40 55 95 95
10 20 ERROR MESSAGE
NOFILE
20 40

Figure 6.6 - Sample message template used primarily for error reporting.
Directory Structure

This chapter presents the disk operating system (DOS) directory structure for software and data for the Seismic Pavement Analyzer (SPA). This structure is presented to help the user locate files of specific types and to help manage backups of modified files. There are three significant subdirectories the user is likely to work with: the templates, the tables, and the projects subdirectories (figure 7.1).

The templates subdirectory contains all the files that describe the menu types, locations, and interactions for the user interface software. These structures are discussed in chapter 6. In addition, the template\help directory contains text files for help options for the user interface. Should the user find the help files inadequate or in the wrong language, these files can be modified using the DOS text editor.

The tables subdirectory contains project-specific tables that determine data acquisition parameters and temporary storage files. The project-specific and globally specific tables use a "*.tbl" suffix. All "*.tbl" and "*.dat" files in this subdirectory are copied from an old project directory when the project directory is selected under Table Setup. All "*.tbl" and "*.dat" files are copied from this directory to a new project directory when it is created. Other tables are created or modified every time data acquisition occurs. Should these files be accidentally erased, it is best to restore them from a backup of the directory.

The projects subdirectory contains any project information created by the user. All data storage and project-specific modifications to tables are contained in this area. Within project subdirectories, data base tables built from data acquisition are contained in "*.txt" file suffixes; project-specific tables are contained in "*.tbl" suffixes; and data files resulting from the Save Waveforms command are contained in "*.zip" suffixes.
Figure 7.1 - DOS directory structure for software and database for the SPA.
Appendix A

System Description

Transducers, Sources, and Mounting

The major mechanical components of the Seismic Pavement Analyzer (SPA) are schematically depicted in Figure A.1. These include the electrical umbilical (A), transducer mounting bar (B), transducer lowering air cylinders (C), individual transducer holders (D), air regulator, temperature measurement, and firing controls (E), air compressor (F), wiring box (G), compressor battery (H), and two pneumatic hammers (I, J) that are raised and lowered to the pavement surface.

A schematic of the air control plumbing is shown in Figure A.2. The air control system includes a compressor, air tank, regulators, solenoid valves, and an accumulator near the hammers. The air tank for the prototype TxDOT SPA is located in the trailer frame; subsequent incarnations use a separate air tank.

The major electrical components of the Seismic Pavement Analyzer are schematically shown in Figure A.3. These include power supplies, a computer for data acquisition and analysis, signal conditioning electronics, and control electronics. Subsections of this chapter describe the individual elements of each of these three systems in greater detail.

Transducer Mounting

The transducer-mounting member of the Seismic Pavement Analyzer is a 2-in. by 6-in. U-channel that is about 6-ft. long (Figure A.1, item B). Individual geophone and accelerometer air cylinders (Figure A.1, item C) are bolted to this U-channel, transducers
Figure A.1 - Major mechanical components of the Seismic Pavement Analyzer.
Figure A.2 - Schematic of air control layout.

(figure A.1, item D) are mounted to the air cylinders, and electrical cables are routed through a conduit along side the U-channel.
Figure A1.3 Electronic system layout.
Figure A1.4 - Top view of computer assembly showing location of power supplies, computer, and replaceable boards.
Figure A1.5 - Diagram of location of electronics boards and connections.

A. 50 pin cable to computer I/O board
B. 5 pin status in (not used)
C. 6 pin control out
D. 3 pin power in
E. 50 pin cable to A/D computer board
F. 10 pin geophones in
G. 6 pin accelerometers in
H. 3 pin control in
J. 4 pin power
The transducer-mounting member is mounted to the trailer through four air springs (hidden from view) that provide vibration isolations. The weight of each transducer is counterbalanced by a spring in its air cylinder. The air cylinders have a useful throw of 16 in. and, fully retracted, the transducers have a clearance of about 8 in. and are up inside the trailer frame skid rails for high-speed travel.

Positive air pressure is required to lower transducers so that in the event of electrical or pneumatic failure, the transducers rise so that the trailer may be safely towed for repair. The individually mounted air cylinders accommodate a wide range of pavement or pothole topography with a uniform force coupling the transducer to the pavement.

Geophone and Accelerometer Mounting

Geophones and accelerometers (C, Fig. A1.1) are mounted in 2-in-diameter polyvinyl chloride (PVC) tubes that provide a non-resonant protection and centering support. The geophones and accelerometers are isolated from the air cylinders with rubber vibration isolators. Thin rubber feet are used on the transducers to provide a relatively uniform, damped coupling with various pavement surfaces.

The geophone and accelerometer holders are screwed onto the control air cylinder and tightened with lock nuts. Vibration isolation tests indicate that greater than 70-decibel signal reduction is achieved between the transducers and the frame.

Source Mounting

The high- and low-frequency pneumatic hammers (Fig. A,1, items 1 and 1, respectively) are mounted to a movable frame that is attached through air cylinders to the trailer frame. Air pressure lowers the source frame to the pavement surface to ensure uniform source height from sample to sample. The sources are raised by springs and air pressure to ensure adequate clearance during travel. The sources are isolated from the transducer-mounting member by both the lowering air cylinders and the transducer-mounting-member air springs. The mounting permits adjustment of the stroke of the hammer that may be required to control hammer force in extreme variations of pavement conditions. Load cells are included in the high- and low-frequency hammer heads to measure the applied force of the hammer bits. The load cells measure force in both extension and compression.

Pneumatic Control

Air pressure is used in the Seismic Pavement Analyzer to raise and lower the transducers and sources and to impact the low- and high-frequency hammers. A 12-volt DC compressor is used to charge an air tank that provides air power during operation. The air compressor is controlled by a pressure switch that turns on at 50 psi and turns off at 70 psi. Individual circuit
pressures are usually run at about 45 psi for the hammer firing, 35 psi for raising and lowering the hammer assembly, and 25 psi for holding down the transducers.

The general schematic design of the pneumatic control system is shown in Figure A.2. The following three subsections describe the design considerations for the raising/lowering mechanism, the physical pneumatic hammers, and the feedback control of hammer characteristics.

Raising/Lowering Mechanism

The lowering of the transducers and sources is accomplished through air cylinders. A cylinder-mounted spring counterbalances the transducer weight and part of the source weight so that active pressure is required only to lower the mechanisms. The transducer and source-lowering cylinders are tied to electrically controlled solenoid valves that are software controlled by the computer. These valves connect the cylinders either to outside air or to pressurized air when not activated.

Pressure to the lowering mechanisms is provided by mechanical regulators and requires adjustment only after major modifications or repairs.

Sources

Each pneumatic hammer consists of an accumulator chamber, a computer-controlled firing solenoid, and a spring-return air cylinder (Figure A.2). Air from the supply tank fills the accumulators through a common regulator. Upon receiving a signal from the computer, the solenoid turns on for several tens of milliseconds and allows the air from the accumulator into the hammer cylinder. When the solenoid turns off, the cylinder is connected to outside air pressure, the spring retracts the hammer, and the accumulator refills.

The solenoid valve is mounted directly on the cylinder. The accumulator is mounted as close to the valve as physically possible to minimize time delays and pressure losses associated with propagation of air-pressure transients.

The accumulator provides a high-volume (several cylinder volumes) of pressurized air that may be moved quickly into the cylinder to provide rapid hammer acceleration. This action isolates the hammer movement from regulator flow restrictions caused by distance from the air supply.

The cycle time for the hammer stroke and preparation for the next stroke is controlled by pneumatic line size, accumulator volume, and regulator flow rate. Using conventional 1/4- inch connections and pneumatic lines, cycle times are less than one second and are longer than the data acquisition/processing phase.

Source Feedback Control

Two factors are important in controlling the hammer hit: the force of the impact and the duration of the impact. The ideal situation is to have the
shortest impact time at a controlled force level. Impact times and force levels are influenced by external conditions such as pavement or asphalt stiffness, surface condition, and temperature.

Two controls are available over the hammer behavior. The first is the duration of the solenoid opening that determines both applied force and pulse duration. The second is the initial height of the hammer above the pavement, which is manually adjusted.

A computer feedback loop is used to control the hammer hit characteristics. The digitized load-cell signal is compared with an expected load-cell signal. When the digitized load-cell signal quality falls outside the desirable limits, the computer will adjust the solenoid opening duration and repeat the hit to either increase force, decrease force, or eliminate more than one hammer bounce. If these adjustments are not adequate, then the operator is advised by the computer of the degraded signal quality and repairs suggested.

Electronic Components

This section on the electronics of the Seismic Pavement Analyzer gives a general description of the circuits that are not purchased as systems from other vendors and must be custom built. The circuits are built on printed circuit cards mounted inside the personal computer (PC).

A general schematic of the total electronic system, including interface with the computer, is shown in figure A.3. Transducer signals collected on the trailer are indicated in the upper right. The first level of boxes to the left of the transducer signals are electronics located on the trailer and include load-cell routing, temperature conditioning, source control buffers, and compressor switching. Analog signals are run through conditioning stages, located in the tow-vehicle computer, and then go into the analog-to-digital board, which routes a computer-selected subset of 4 of the 12 signals through the programmable gain stage and into the analog-to-digital (A/D) converter. The distance measurement is input to the computer through a serial port from a commercially available distance-measuring device. The hardware diagnostics circuit injects a known signal into the signal-conditioning circuits so that overall circuit functions may be tested and compared with ideal responses. The complete electronic package is run from a DC/DC power supplies connected to the 12-volt system of the tow vehicle.

Figure A1.4 shows a schematic of the location of plug-in computer boards in the tow-vehicle computer, as seen from the top. Boards A through D are commercially available and boards F through J are specially built for the SPA. Figure A1.5 shows a more detailed view of the specialty built electronics showing connectors and board position. Transducer signals come into the relay board through connectors F and G. When the relays are not powered up, the transducers are connected to the amplifiers; but when the relays are powered, calibration signals from the Calibration board are fed into the amplifiers. Separate boards for accelerometer and geophone amplifiers are stacked vertically on the motherboard. All these boards are easily removed by pulling straight away from the motherboard.
Computer Specifications

The data acquisition software of the Seismic Pavement Analyzer (SPA) requires either an i386 or i486 class of IBM-PC AT, or equivalent, computer with a floating-point processor and 4 megabytes of RAM, five expansion slots and two serial ports. If the data acquisition software is run on the same machine as data acquisition, a Hercules, color graphics adaptor (CGA), enhanced graphics adaptor (EGA) or video graphics adaptor (VGA) graphics monitor and keyboard are required.

The user interface software of the Seismic Pavement Analyzer (SPA) runs on an IBM-PC XT- or AT-equivalent computer with Hercules, CGA, or EGA/VGA graphics, 640 Kb ram, two 720 Kb floppy disk drives, with three serial ports. An AT with a hard disk and a floating-point chip would be highly desirable, but not necessary, to increase speed of operation in analysis-intensive operations.
Appendix B

Troubleshooting

General

(1) Computer will not boot up.
   => Computer will not boot up with engine not running.
      (1) Computer power is wired through relay. Try starting engine.
   => Computer will not boot up with engine running.
      (1) Check for open in engine-computer power line.
      (2) Replace computer power supply (Fig. A1.4).
      (3) Reset boards in computer motherboard.
      (4) Replace computer motherboard.
   => Engine will not start.
      (1) Dead battery.
      (2) Computer left on.
      (3) Look for short in engine-computer power wiring.

(2) Compressor will not run.
   => Battery appears dead (less than 12 volts with voltmeter).
      (1) Replace battery charger fuse.
      (2) If no charging current, replace isolator.
      (3) Replace battery.
      (4) Look for short in wiring.
      (4) Replace compressor enable relay.

   => Battery OK, recharging current OK.
      (1) Replace compressor enable relay.
      (2) Look for open in wiring.
      (3) Replace/check compressor shutoff switch.
      (4) Replace/check compressor.

(3) Hammers and transducers will not lower.
   => Regulator air pressures are normal.
      (1) Check that power to trailer is on.
      (2) Check for open/short in trailer power wiring.
      (3) Check cable connection C (Fig. A1.5).
      (4) Reseat I/O board and Control Board in computer box
          (D and G, Fig. A1.4).
(5) Replace I/O and Control Boards D and G (Fig. A1.4).

⇒ Regulator air pressures are low.
   (1) Increase air pressure settings as per Fig. 2.2.
   (2) Check that power to trailer is on.
   (3) Check for air compressor operation.

(4) Hammers and transducers will not raise.
⇒ Hammers and transducers raise on computer reboot.
   (1) Probable software failure; call UTEP for assistance.

⇒ Hammers and transducers do not raise on computer reboot.
   (1) Check plug C (Fig. A1.5) connection and wires in computer box.
   (2) Replace I/O Board D (Fig. A1.4).
   (3) Replace Control Board G (Fig. A1.4).
   (4) Call UTEP for assistance in tracing wiring short circuit.

(5) Hammers will not fire.
⇒ Air pressures are set correctly.
   (1) Check that trailer power is turned on.
   (2) Check plug C (Fig. A1.5) in computer box.
   (3) Repeat I/O Board D, Control Board G (Fig. A1.4).
   (4) Replace I/O Board D, Control Board G (Fig. A1.4).
   (5) Call UTEP for assistance in finding open/short circuits in wiring.

⇒ Air pressures low.
   (1) Increase air pressures as per Fig. 2.2.

(6) Hammers fire simultaneously.
   (1) Check plug C (Fig. A1.5) in computer box.
   (2) Reset I/O Board D, Control Board G (Fig. A1.4).
   (3) Replace I/O Board D, Control Board G (Fig. A1.4).
   (4) Call UTEP for assistance in finding open/short circuits in wiring.

Software Error Messages

Software and hardware error messages returned during data acquisition and stored in the database are generally incomprehensible numbers. The user interface converts these numbers to an English-like message for the operator during data collection. These error numbers can be looked up in the following table, or cross-referenced to the error decoding table in a database environment.

Software error messages returned to the screen or to the data base are coded together with a four-digit number indicating the source of the error message, followed by a one- to three-digit code indicating the type of error or warning. The warning or error message is accompanied by a number that indicates the importance of the condition: numbers less than 200 are severe failures requiring immediate attention; numbers from 200-399 indicate that parts of the machine are functioning while others are not; numbers from
400-999 are warnings indicating that a condition exists that might compromise data quality; and numbers greater than 600 are conditions that do not compromise data quality but should be corrected when the machine returns home.

There are three types of error messages in the following table. The complete message has both location and error (i.e., 1126 18) and indicates a specific, fixable problem. Those messages with only a location (i.e., 1126 (*) ) are for a number of specific errors that are not fixable by the operator that might occur anywhere in software, and represent more annoying software bugs. UTEP needs to be notified when these occur. The third set at the end of the list (i.e., (*) 46) are some of these specific, non-fixable bugs that can occur anywhere.

The following table contains a list of these error messages. Their source in the software is indicated by the location code.

<table>
<thead>
<tr>
<th>Location</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1100 (*)</td>
<td>Failure in the main driver program.</td>
</tr>
<tr>
<td>1100 3</td>
<td>The setup file tables\dc.cmd is incomplete.</td>
</tr>
<tr>
<td>1102 (*)</td>
<td>Failure in creating ramdrive file names</td>
</tr>
<tr>
<td>1104 (*)</td>
<td>Failure in reading ramdrive files.</td>
</tr>
<tr>
<td>1104 23</td>
<td>I do not recognize a ramdrive file name for input.</td>
</tr>
<tr>
<td>1104 24</td>
<td>Failure to read valid data from ramdrive.</td>
</tr>
<tr>
<td>1106 (*)</td>
<td>Failure in writing to ramdrive files.</td>
</tr>
<tr>
<td>1106 23</td>
<td>I do not recognize a ramdrive file name for output.</td>
</tr>
<tr>
<td>1106 25</td>
<td>Failure to write valid data to ramdrive.</td>
</tr>
<tr>
<td>1108 13</td>
<td>Can not control the trailer: bad I/O board.</td>
</tr>
<tr>
<td>1110 (*)</td>
<td>Failure in initializing the A/D board.</td>
</tr>
<tr>
<td>1112 35</td>
<td>Repair the accelerometer cables.</td>
</tr>
<tr>
<td>1112 415</td>
<td>L2 Cable open circuit.</td>
</tr>
<tr>
<td>1112 416</td>
<td>L2 Cable short circuit.</td>
</tr>
<tr>
<td>1112 417</td>
<td>A1 Cable open circuit.</td>
</tr>
<tr>
<td>1112 418</td>
<td>A1 Cable short circuit.</td>
</tr>
<tr>
<td>1112 419</td>
<td>L1 Cable open circuit.</td>
</tr>
<tr>
<td>1112 420</td>
<td>L1 Cable short circuit.</td>
</tr>
<tr>
<td>1112 423</td>
<td>A5 Cable open circuit.</td>
</tr>
<tr>
<td>1112 424</td>
<td>A5 Cable short circuit.</td>
</tr>
<tr>
<td>1112 425</td>
<td>A4 Cable open circuit.</td>
</tr>
<tr>
<td>1112 426</td>
<td>A4 Cable short circuit.</td>
</tr>
<tr>
<td>1112 427</td>
<td>A3 Cable open circuit.</td>
</tr>
<tr>
<td>1112 428</td>
<td>A3 Cable short circuit.</td>
</tr>
<tr>
<td>1112 429</td>
<td>A2 Cable open circuit.</td>
</tr>
<tr>
<td>1112 430</td>
<td>A2 Cable short circuit.</td>
</tr>
<tr>
<td>1114 35</td>
<td>Can't find the calibration file.</td>
</tr>
<tr>
<td>1114 38</td>
<td>The calibration values have been corrupted.</td>
</tr>
<tr>
<td>1114 45</td>
<td>The hardware calibration sequence file is missing.</td>
</tr>
</tbody>
</table>
1118 (*) | Failure initializing signal definitions.
1118 201 | There is a nonsense command in tables/cdc.cmd.
1118 604 | The distance measurement is not connected to the serial port.
1118 32 | I won’t lower the transducers till you stop moving.
1120 39 | A group number is outside the allowed range.
1120 7 | A group transducer definition is not familiar.
1122 5 | A diagnostic option is not familiar to me.
1124 4 | A distance table definition is not familiar.
1126 18 | One expected time signal has not been defined

routine stack under bounds.

in the group table.

1128 17 | An expected frequency domain signal is not defined
    in the group table.
1130 608 | Are we really working on a dirt road?
1130 609 | Your expected paving layer is stiffer than concrete.
1130 10 | A source-receiver spacing has not been set.
1139 11 | A source-receiver spacing has an unreasonable value.
1132 37 | Beware of unpredictable conditions.
1132 203 | Are you sure your calibration table is correct?
1132 49 | I can not open the raw binary waveform file.
1132 19 | I can’t properly address the A/D Board.
1132 26 | A hammer is not enabled.
1132 432 | Having difficulty collecting consistent signals.
1132 34 | Very high noise levels: serious malfunction if low traffic.
1134 46 | Unable to consistently control the hammers.
1136 (*) | Failure in analysis driver function.
1138 42 | Can’t reduce fire time of high-frequency hammer any more.
1138 43 | Can’t reduce fire time of low-frequency hammer any more.
1140 42 | Can’t increase fire time of high-frequency hammer any more.
1140 43 | Can’t increase fire time of low-frequency hammer any more.
1142 5 | I do not know how to make a measurement you requested.
1144 410 | Probable failure of Accelerometer 1.
1144 411 | Probable failure of Accelerometer 2.
1144 412 | Probable failure of Accelerometer 3.
1144 413 | Probable failure of Accelerometer 4.
1144 414 | Probable failure of Accelerometer 5.
1144 405 | High noise level on Accelerometer 1, calibrate if traffic is light.
1144 406 | High noise level on Accelerometer 2, calibrate if traffic is light.
1144 407 | High noise level on Accelerometer 3, calibrate if traffic is light.
1144 408 | High noise level on Accelerometer 4, calibrate if traffic is light.
1144 409 | High noise level on Accelerometer 5, calibrate if traffic is light.
1146 (*) | Failure in trying to stack frequency domain signals.
1148 (*) | Failure in computing the mechanical impedance spectra.
1150 430 | The MI spectra do not fit the expected trends.
1150 402 | The MI modulus or damping is above maximum limit.
1150 403 | The MI modulus or damping is below minimum limit.
1154 402 | USW modulus is above maximum limit.
1154 403 | USW modulus is below minimum limit.
1154 404 | Could not fit the USW phase spectrum adequately to interpret.
1154 601 | The USW modulus is replacing an already reliable estimate.
1156 (*) | Failure in stacking low-frequency SASW data.
1156 24 | Error reading low-frequency SASW transfer function.
1158 (*) | Failure in stacking high-frequency transfer function.
1158 24 | Error reading high frequency SASW transfer function.
1160 (*) | Failure in transfer function calculations.
1162 (*) | Failure in SASW interpretation.
1162 402 | Thickness or modulus estimate from SASW above maximum limit.
1162 403 | Thickness or modulus estimate from SASW below minimum limit.
1164 (*) | Failure in Impact Echo interpretation.
1164 402 | Thickness or echo amplitude from IE above maximum limit.
1164 403 | Thickness or echo amplitude from IE below minimum limit.
1166 (*) | Failed in waveform collection.
1168 (*) | Failure in setting expected values of pavement properties.
1170 42 | Can't fire the high-frequency hammer.
1170 43 | Can't fire the low-frequency hammer.
1170 44 | The source for the calibration sequence is missing.
(*) 31 | Out of free memory to allocate to a routine.
(*) 47 | A floating point error has been trapped in a routine.
(*) 48 | The operator has killed data acquisition.
(*) 610 | Writing subroutine stack over bounds.
(*) 611  | Writing subroutine stack under bounds.