Conducted for
Department of the Army
Waterways Experiment Station
Corps of Engineers
Vicksburg, Mississippi

June 1997

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OPERATIONS MANUAL FOR COMPUTER
PROGRAMS FIELD AND LAB

(FOR CALIBRATION OF HEAVY WEIGHT/FALLING WEIGHT
DEFLECTOMETERS)

for

Department of the Army
Waterways Experiment Station
Corps of Engineers
Vicksburg, Mississippi

June, 1997
ABSTRACT

Falling Weight Deflectometers (FWD) are presently being used by many highway agencies. The primary function of FWD devices is to measure a deflection basin due to a load imparted to the pavement. Deflection basins measured in the field are used in backcalculating modulus profiles of pavement sections. As such, it is critical to determine the deflection basins in the field with accuracy. Velocity transducers (also called geophones) or other deflection sensors are used to determine the deflections, and load cells are utilized to measure applied loads.

It has become increasingly important in recent years to be able to evaluate the performance of the deflection and load sensors of the Falling Weight Deflectometer devices. It has been shown that a small error in the deflection measured in the field may yield significantly erroneous modulus values. As such, a reliable method for evaluating the accuracy of the sensors used for determining these deflections is necessary.

This report contains user's manual for two computer programs called "FIELD" and "LAB" used in reference calibration process developed at UTEP. The two programs have been developed to control the acquisition and digitization of sensors' signals, to reduce the collected data, and to present the data. The programs are coded for an IBM-PC Compatible equipment with DT 2825 Analog-to-Digital board manufactured by Data Translation™, Inc. The programs are written in FORTRAN and compiled with MICROSOFT™ FORTRAN (5.1) Compiler.

The computer program FIELD is capable of: 1) controlling the acquisition and retrieval of the analog data captured by the sensors; 2) reducing the collected data; and 3) developing a summary file from the results. The program provides software-controlled initialization and identification of the A/D board and facilitates the collection of data using Direct Memory Access (DMA). The acquired data are stored in a file for further processing.

The program LAB can be used to reprocess previously collected data. In addition, the collected data and reduced results can be graphically inspected.
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1. INTRODUCTION

Programs FIELD and LAB are interactive programs coded for the purpose of calibrating Falling Weight Deflectometer (FWD) devices. The programs were developed to control the acquisition, digitization and retrieval of analog data produced by the calibration sensori, to reduce the collected data and to present the data. The programs provide software-controlled initialization and identification of the analog-to-digital conversion (A/D) board and facilitates the collection of data using Direct Memory Access (DMA).

These programs are coded for an IBM compatible computer equipped with a DT 2825 A/D board, manufactured by Data Translation, Inc. The program is written in FORTRAN and compiled with Microsoft Version 5.1 FORTRAN compiler. In addition, two graphics libraries are also utilized.

2. INITIAL PREPARATION

Software, hardware and mechanical equipment needed:

1) IBM Compatible PC
2) Dos 6.2 or later versions
3) Signal Conditioning unit (see Appendix F)
4) Three well-calibrated geophones (see Appendix F)
5) Three load cells (see Appendix F)
6) Triggering mechanism (the Proxi-switch) (see Appendix F)
7) Proper connectors for geophones and load cells.

To operate the system:

1) Install the data acquisition board in the computer
2) Connect the data acquisition board to the back panel of the signal conditioning unit using the 50-pin ribbon cable.
3) Connect the three geophones to the front panel of the signal conditioning unit. Make sure that proper geophone is connected to proper channel of signal conditioning unit (e.g., Geophone 1 should be connected to the connector labeled Geophone 1, etc.).
4) The three cables with BNC connectors on both sides are used for connecting the load cells to the signal conditioning unit. Once again, make sure that proper load cell is connected to proper channel. If the load cells are connected properly, both the yellow and red lights directly above the connector will be off. An illuminating yellow light indicated that there is a short in the system. Probably the cable or one of the connectors has gone bad. If the red light continuously stays on, it means that
the system is open. If the red light blinks during testing, the load cell is being
overloaded or one of the connections is loose.
5) Connect the prox-switch to the appropriate connector on the front panel. The
switch itself should be placed on the FWD device.
6) Turn the signal conditioning unit on using the switch on the back panel.
7) Carefully position the load plate under the FWD loading pad. This step is
needed only if a load calibration has to be carried out. Make sure that all the load cell
 cables are away from the moving parts. Do not forget to cover the load cells with
the cover plate.
8) Position the geophones provided by the calibration system close to the sensors of
the FWD.
9) Activate the software as described below.

Computer programs and files needed:

1) CALIBRAT.DFT: This file contains the nature and the number of drops to be
used in the calibration process and example is given in Appendix A.
2) FIELD.EXE: This file is used to execute the FIELD Program.
3) LAB.EXE: This file is used to execute the LAB Program.

We recommend that all these items be located in a directory called "WES_CAL".

Program FIELD may not execute if:

1) File CALIBRAT.DFT is not available.
   Generate the file as instructed in Appendix A and repeat the execution.

2) Data acquisition board is not properly installed.
   Make sure that the data acquisition board is installed properly in the computer.
   Make sure that the data acquisition driver is included in the CONFIG.SYS file.

3) Geophone 1 is not connected to the filter box.
   Connect Geophone 1 to the box and repeat tests, if instructed by the software.

4) The prox-swich is either not properly connected or not properly placed.
   Make sure that the switch is properly connected to the filter box.
   The prox-swich may needs to be moved up or down as instructed by the software.

---

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3. EXECUTION OF PROGRAMS

Programs FIELD and LAB have been designed for the ease of operation. Program FIELD is designed to collect the data in the field for calibration of deflectometer devices. Program LAB is designed to perform reduction and translation of the data collected using FIELD program.

3.1. Execution of Program Field

The program can be started by typing "FIELD" at the DOS prompt. The execution of the program is described in the following steps:

STEP 1:  Program Initiation

This step is self-explanatory.

==================================================================

PROGRAM FIELD (06-19-97)
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CENTER FOR HIGHWAY MATERIALS RESEARCH
THE UNIVERSITY OF TEXAS AT EL PASO

==================================================================

TO STOP EXECUTION AT ANY TIME, PLEASE ENTER -99

GEOPHONE 1 SHOULD BE CONNECTED TO SYSTEM
OTHERWISE, THE SYSTEM WOULD NOT FUNCTION

PRESS RETURN TO CONTINUE
STEP 2: Reporting the status of the system

In this step, the set-up for each channel of the data acquisition board is reported. The computer screen illustrates the following:

THE DEFAULT VALUES ARE:

TOTAL NUMBER OF CHANNELS = 6
NUMBER OF GEOPHONES = 3
NUMBER OF LOAD CELLS = 3

<table>
<thead>
<tr>
<th>CHANNEL</th>
<th>GAIN</th>
<th>ID</th>
<th>NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>G1</td>
<td>GEO 1</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>G2</td>
<td>GEO 2</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>G3</td>
<td>GEO 3</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>L1</td>
<td>LCEL 1</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>L2</td>
<td>LCEL 2</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>L3</td>
<td>LCEL 3</td>
</tr>
</tbody>
</table>

TIME SPAN FOR COLLECTING DATA (Seconds) = .1250
DATA POINTS PER CHANNEL = 256
ANY CHANGES TO DEFAULT VALUES (Y/N)?

With the data acquisition board provided, the gain of each channel can be selected individually. The gain is typically changed if the voltage output from a sensor is significantly smaller than ± 10 V. Practically speaking, all the sensors in the calibration device provide adequate voltage. Therefore, the adjustment of the gain is not necessary. See Appendix B for ways to change the gain.

The ID and name are used to identify the geophones provided with the calibration system. The program utilizes this information to obtain the calibration parameters internally. Please do not change the default ID's and names if you utilize the system just for calibration purposes. If the names or ID's are changed, the program will ask for the new calibration parameters. See Appendix B for more information.

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An adequate time window for collecting FWD data is 125 msec. However, if longer or shorter time spans are needed, this value can be easily changed as shown in Appendix B. The shortest and longest period depends on the limitations of the data acquisition board. Please familiarize yourself with these limitations before changing the time period. The software, in some instances, may warn you of potential problems.

The data points per channel is set as 256. This is a good compromise for obtaining good resolutions in both the time and frequency domain analyses and data presentation. This value can be easily changed. However, the new value has to be a power of 2, such as 128, 512, 1024, etc. See Appendix B for means of changing this value.

To change any of the parameters mentioned above, you need to respond "YES" (or "Y") to the question asked at the end of this step. In this case refer to Appendix B for detailed instruction. However, the answer to this question is typically "NO" (or "N").

**STEP 3: Creating data files**

In this step, the device and the sensors to be calibrated are identified. The following will appear on the screen.

NOW BOARD IS READY TO COLLECT THE DATA

INPUT THE IDENTIFICATION NAME

Any arbitrary name containing numbers or letters (e.g. F123, Test, etc.) can be utilized here. Some agencies with more than one FWD use the serial number of the device. The response has to have exactly four letters. If more or less letters are used, the program will either truncate the name to four letters or it will warn you and ask you to modify the name.

The program will automatically "date-stamp" the filename; that is, it will add a four-digit number to the end of the name you selected to develop an appropriate filename. The first two digits of the added number corresponds to the year, and the last two digits corresponds to the month of calibration. For example, if the Identification Name is typed in June, 1997 as "TEST", the Filename used will be "TEST9706". Notice that 97 corresponds to the year and 06 corresponds to the month when the calibration was performed.

Several files with the same filename but, different extensions are typically generated. These files include: 1) individual files that contain the raw voltages measured with the three load cells and the three geophones; 2) a summary file containing the loads and deflections measured with the calibration system for different drops. These files are
described in more detail later on. To develop the summary data file, the following two questions should be answered:

**FIRST FWD SENSOR (GEOPHONE OR SEISMMOMETER) TO BE CALIBRATED?**

**SECOND FWD SENSOR TO BE CALIBRATED?**

The responses to these questions should be two one-digit numbers. As soon as these questions are answered, the computer will generate an ASCII data file. The filename was established above. The extension will be in the form "Snn\_n\_", where "S" signifies that the file is a summary file and \( n_1 \) and \( n_2 \) are the two one-digit numbers obtained from the above questions. As an example, if Sensors 1 and 5 are being calibrated, the summary file will have an extension of "S15" and the entire filename will be "TEST9706.S15". It should be mentioned that the summary file will overwrite all older versions of the same file. Therefore, you should make sure that the older versions of the summary files are backed up before executing the program. Typical contents of a summary file are described in Appendix C.

The program will also attempt to create a data file with the filename established above but with a file extension "001" (e.g. "TEST9706.001"). This file will contain the raw voltage output from different calibration load cells and/or calibration geophones. The extension acts as a counter and for each drop height and each repeat a new file will be created. If the SHRP calibration protocol is followed for calibration of each set of sensors, twenty files will be generated.

If this file does not exist, the program will proceed to Step 4. If the file exists, the following messages will appear:

**FILE EXISTS... FIND NEXT AVAILABLE EXTENSION? (Y/N)**

If the answer is no, then the program will erase the old version of the file and rewrite the current information in it. If the answer is yes, then the software will check for the next available extension. For example, if in a previous session in that month files "TEST9706.001" through "TEST9706.015" were generated, the current information will be written in a data file "TEST9706.016". Typically, these files can be discarded, unless they are needed for a more thorough analysis of the data or for research purposes.
Step 4: Acquiring and Reducing Loads and Deflections

In the next step, the following information will appear.

DROP HEIGHT 1 REPEAT 1

HIT RETURN TO BEGIN ACQUISITION...

The first line appears as a reminder to the operator. The drop height counter varies from 1 to 4, and the repeat counter varies between 1 to 5. The numbers are read from data file "CALIBRAT.DFT". See Appendix A for more information with regards to CALIBRAT.DFT.

The "RETURN" button should be pressed to activate the data acquisition board. It is recommended that the operator of the FWD and the person conducting the calibration coordinate. The "RETURN" button should be pressed at about the same time that the FWD load is being released. Ignoring to do so may result in a timeout error. The FWD weights should be in the raised position before the "RETURN" button is pressed.

The next comment will be:

PLEASE WAIT WHILE DATA IS COLLECTED......

This message suggests that the system has successfully collected the data and is in the process of reducing the data.

Alternative messages may appear. These massages can be:

MOVE THE TRIGGER PROXI-SWITCH UP SLIGHTLY THEN REPEAT TEST
ALSO MAKE SURE THAT GEOPHONE 1 IS SECURELY CONNECTED TO FILTER BOX..

Or

MOVE THE TRIGGER PROXI-SWITCH DOWN SLIGHTLY THEN REPEAT TEST
ALSO MAKE SURE THAT GEOPHONE 1 IS SECURELY CONNECTED TO FILTER BOX..

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These massages signify that the response from Geophone 1 of the calibration system is failing the quality control tests built in the software. The reasons for failing the quality control tests are several:

1) The proxí-swiçch is too close or too far from the impact plate.
   To remedy this problem, move the proxí-switch upwards or downwards (as suggested by the message) in 1-in. increments and repeat the process until the error message disappears.

2) The "RETURN" button was pressed too late.
   To remedy this problem, try to coordinate better with the FWD operator and repeat the test.

3) Geophone 1 of calibration system has problems.
   Please give us a call for instructions.

4) The filter box is malfunctioning.
   Please call us for instructions.

If the system if functioning properly, the following will appear next:

<table>
<thead>
<tr>
<th>EXT</th>
<th>HT/RPT</th>
<th>LOAD</th>
<th>PEAK</th>
<th>PEAK TO PEAK</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>GEO1</td>
<td>GEO2  GEO3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>9000</td>
<td>12.00</td>
<td>12.00 12.00</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td></td>
<td>12.30</td>
<td>12.30 12.30</td>
</tr>
</tbody>
</table>

SAVE THIS DATA? (Y/N) (- TO TERMINATE PROGRAM)
Different columns provide the following information:

**EXT**  The extension of the file that will contain the raw voltages from this drop height. As an example, the file "TEST9706.001" will contain the information provided above.

**HT**  The FWD drop height used.

**RPT**  The repeat number corresponding to the drop height.

**LOAD**  The magnitude of load measured with the calibration loading system.

**PEAK**  The peak deflections measured with the calibration system. Peak deflection is defined as the difference between the deflection at time zero to the maximum deflection measured. GEO1, GEO2, and GEO3 refer to the three geophones used by the calibration system.

**PEAK-to-PEAK**  The peak-to-peak deflections measured with the calibration system. This refers to the difference between the maximum rebound of the pavement and the maximum deflection of the pavement.

The response to the question can be YES (or Y), NO (or N) or - (negative sign).

For a YES response, the software will write the results in an identical format in the summary file (for our example file TEST9706.S15). In addition it will generate the raw voltage data file (in our example TEST9706.001). The execution will then be transferred to the beginning of Step 4, so that data for other repeats or drop heights can be collected and processed. If all the drop heights and repeats requested in file CALIBRAT.DFT are exhausted, the execution of the software will stop.

For a NO response, the load and deflections currently obtained will be discarded and Step 4 for the same drop height and repeat number will be repeated.

For a "-" response, the execution will be terminated instantly.

Upon successful completion of the calibration process, the following message will appear:

*Stop - Program terminated.*
3.2. Execution Of Program Lab

The program can be started by typing "LAB" at the DOS prompt. The execution of the program is described in the following steps:

STEP 1: Program Initiation

This step contains a greeting message and a question.

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THE UNIVERSITY OF TEXAS AT EL PASO

TO STOP EXECUTION AT ANY TIME, PLEASE ENTER -99

PLEASE CHOOSE ONE OPTION

< T > REDUCE AND TRANSLATE DATA
< R > ONLY REDUCE DATA

If Option "T" is selected, the software will reduce and translate any data file saved with program FIELD. An example of these files is TEST9706.001 (see Section 3.1). These files are written in binary format for speed of operation and for conserving disk space.

Reducing refers to reading the raw voltage data from a file and reprocessing the data into deflections and load. The subroutine used for this purpose is identical to that used in program "FIELD". Naturally, as shown later, the output is also very similar.

Translating refers to reading the raw voltage data from binary files and writing the raw data as well as reprocessed data (i.e. actual deflection and load time-histories) in an ASCII format. In this manner, the raw or reduced data can be easily utilized in any spreadsheet program.
If Option "R" is selected, the program will only "reduce" the data and will not "translate" it.

STEP 2: Preparation for data files

In this step, the files to be processed are identified. The following will appear on the screen.

INPUT THE IDENTIFICATION NAME

The four-letter name assigned to the files during the execution of program FIELD should be input here. See Step 3 in the previous section for more detail. As an example, "TEST" should be input, if we are hypothetically reprocessing the data we collected with program FIELD.

INPUT DATE STAMP

The date stamp attached to the data files during the execution of program FIELD should be input here. Once again, see Step 3 in the previous section for more detail. As an example, for the example followed in the previous section, the date stamp would be "9706".

Once again, to establish a summary file, the following two questions should be answered.

FIRST FWD SENSOR (GEOPHONE OR SEISOMETER) TO BE CALIBRATED?

SECOND FWD SENSOR TO BE CALIBRATED?

A summary file very similar to that obtained during the execution of program FIELD will be generated. The summary file will be the same as the data files to be reprocessed (e.g. "TEST9706"). However, the extension will be "Rn.n", where "R" signifies that the file is a reprocessed summary file and n and n are the two one-digit numbers obtained from above questions. As an example, if Sensors 1 and 5 are being calibrated, the summary file will have an extension of "R15" and the entire filename will be "TEST9706.R15".
STEP 3: Reprocessing of Data

In this step, a specific file to be processed is identified. The following will appear on the screen.

ENTER THE FILE EXTENSION

The extension of a specific file to be reduced is input at this time. This extension should be a three-digit number as described above.

As soon as a valid extension is input, the reprocessing of the data will be carried out. The final outcome will be similar to:

```
EXT   HT/RPT  LOAD  PEAK  PEAK TO PEAK
GEO1  GEO2  GEO3  GEO1  GEO2  GEO3
9000.  12.00  12.00  12.00  12.30  12.30  12.30
```

press return to continue

The outcome is well-described in the previous section. The only differences between the results from program FIELD and this program are that the serial number, drop height and repeat are omitted.

As soon as this step is completed, the reduced load and deflections are written in the summary file established in the previous section (e.g. TEST9706.R15). In addition, if translation is requested, a file with the same name and extension as the file containing the raw data will be created, but with one difference. The first character of the extension will be changed to T. For example, if file TEST9706.003 is being reprocessed, the file containing the ASCII results will be TEST9706.T03. An example of a translated file is shown in Appendix D.

In the next step, the graphics subroutines are used to create the plots of either raw or processed data. The following menu appears on the screen.

```
PLEASE ENTER THE PLOT OPTION
< 1 > RAW DATA OF CHANNEL NUMBER 1
< 2 > RAW DATA OF CHANNEL NUMBER 2
< 3 > RAW DATA OF CHANNEL NUMBER 3
< 4 > RAW DATA OF CHANNEL NUMBER 4
< 5 > RAW DATA OF CHANNEL NUMBER 5
```
< 6 > RAW DATA OF CHANNEL NUMBER 6
< 7 > REDUCED DATA OF CHANNEL NUMBER 1
< 8 > REDUCED DATA OF CHANNEL NUMBER 2
< 9 > REDUCED DATA OF CHANNEL NUMBER 3
<10> REDUCED DATA OF CHANNEL NUMBER 4
<11> REDUCED DATA OF CHANNEL NUMBER 5
<12> REDUCED DATA OF CHANNEL NUMBER 6

<19> CONTINUE REDUCTION OF DATA
<20> QUIT

Any data set can be inspected on the screen. In addition, a cursor is available where the approximate coordinates of a given point can be determined. Any number of graphs can be inspected. As soon as this step is completed, the user can either utilize Option 19 to reprocess another file, or can utilize Option 20 to exit the program.
APPENDIX A

CALIBRAT.DFT FILE

File CALIBRAT.DFT is used so that the default drop heights and repeats can be conveniently introduced to the program. This file contains many lines of data. On each line two numbers should be typed free-format (i.e. the numbers can be typed with any spacing). The first number is the drop height and the second number is the repeat. It should be mentioned that these numbers are only for information. The drop heights and number of repeats applied by the FWD during calibration should be coordinated with this file. As an example, for the SHRIP calibration protocol (i.e. four drop heights and five repeats at each drop height), file CALIBRAT.DFT contains:

1 1
1 2
1 3
1 4
1 5
2 1
2 2
2 3
2 4
2 5
3 1
3 2
3 3
3 4
3 5
4 1
4 2
4 3
4 4
4 5

The execution of the program will be terminated as soon as the last line of the file encountered.
APPENDIX B

CHANGING DATA ACQUISITION DEFAULT PARAMETERS

In Step 2, it was indicated that the set-up for each channel of the data acquisition board can be changed. In this section, the step-by-step procedure for implementing these changes are described. As a reminder, the computer screen illustrates the following.

THE DEFAULT VALUES ARE:

TOTAL NUMBER OF CHANNELS = 6
NUMBER OF GEOPHONES = 3
NUMBER OF LOAD CELLS = 3

CHANNEL DESCRIPTION:

<table>
<thead>
<tr>
<th>CHANNEL</th>
<th>GAIN</th>
<th>ID</th>
<th>NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>G1</td>
<td>GEO 1</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>G2</td>
<td>GEO 2</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>G3</td>
<td>GEO 3</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>L1</td>
<td>LCEL 1</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>L2</td>
<td>LCEL 2</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>L3</td>
<td>LCEL 3</td>
</tr>
</tbody>
</table>

TIME SPAN FOR COLLECTING DATA (Seconds) = .1250
DATA POINTS PER CHANNEL = 256
ANY CHANGES TO DEFAULT VALUES (Y/N)?

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If the response to this question is "YES" (or "Y"), the following series of questions has to be responded to.

**DO YOU WANT TO READ DEFAULT VALUES FROM A FILE (Y/N)?**

If in the previous executions of the program a file containing new default values was created (see below to learn how to create default files), the new default values can be conveniently introduced to the program through this option. The program will simply ask for the filename containing the default values and the execution will be transferred to Step 3 in the main text.

If this option is not utilized, the software will continue with:

**WHAT VALUES DO YOU WANT TO CHANGE**

- <S> TIME SPAN FOR COLLECTING DATA
- <N> NUMBER OF DATA POINTS
- <A> ALL VALUES

If Option "S" is selected, the following will appear on the screen:

**FOR FWD DEVICE, TIME SPAN OF 0.125 Sec IS RECOMMEND. DO YOU STILL WANT TO CHANGE IT (Y/N)?**

For a negative response, the remainder of questions will be canceled. For a positive response, the following question will appear:

**ENTER TIME SPAN FOR COLLECTING DATA (Sec) =**

Of course, the desired time span is input.

If Option "N" is selected, the following question will appear:

**ENTER THE DESIRED NO OF DATA POINTS PER CHANNEL [256,512,1024]:**

The number of desired data points should be input. In this version of the program, only three options are available 256, 512 and 1024 as indicated by the program.
If Option "A" is selected, all of the above questions will sequentially appear.
Finally, the changed parameters can be saved in a file for future use. To take advantage of this option, these two questions should be answered:

DO YOU LIKE TO SAVE CHANGED VALUES IN A FILE? (Y/N)
INPUT FILE NAME FOR NEW DEFAULT VALUES
APPENDIX C

TYPICAL OUTPUT FROM PROGRAM FIELD

Execution of the FIELD program generates a summary file (as defined in section 3.1.). Load and deflections obtained for different repetitions and drop heights are summarised in this file. A typical example of a summary file is shown in this appendix.

<table>
<thead>
<tr>
<th>EXT</th>
<th>HT/RPT</th>
<th>LOAD</th>
<th>PEAK GEO1</th>
<th>GEO2</th>
<th>GEO3</th>
<th>PEAK TO PEAK GEO1</th>
<th>GEO2</th>
<th>GEO3</th>
</tr>
</thead>
<tbody>
<tr>
<td>001</td>
<td>1 1</td>
<td>7101</td>
<td>-3.06</td>
<td>-1.82</td>
<td>-.60</td>
<td>3.21</td>
<td>1.91</td>
<td>.70</td>
</tr>
<tr>
<td>002</td>
<td>1 2</td>
<td>7086</td>
<td>-3.04</td>
<td>-1.79</td>
<td>-.61</td>
<td>3.18</td>
<td>1.89</td>
<td>.70</td>
</tr>
<tr>
<td>003</td>
<td>1 3</td>
<td>7122</td>
<td>-3.05</td>
<td>-1.81</td>
<td>-.61</td>
<td>3.19</td>
<td>1.90</td>
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APPENDIX D

TYPICAL OUTPUT FROM PROGRAM LAB

The execution of the LAB program prompts user to select an option of translation and reduction of data (T) or only reduction of data (R). If the option "T" is selected, the computer program LAB will create a file. The filename will be as defined in section 3.2. A typical example of a translated file is shown here. Also, the raw and reduced data for geophone and load cell is shown in Figures D.1 through D.4.

$date

TOTAL NUMBER OF CHANNELS = 8

NUMBER OF GEOPHONES = 3
NUMBER OF LOAD CELLS = 3
NUMBER OF OTHER DEVICES = 2

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<td>G2</td>
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<td>G3</td>
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<td>AUX. 2</td>
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</table>

$time

NUMBER OF DATA POINTS PER CHANNEL = 256

WES Calibration Device

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### RAW VOLTAGE OUTPUTS

<table>
<thead>
<tr>
<th>No.</th>
<th>Time</th>
<th>G1</th>
<th>G2</th>
<th>G3</th>
<th>L1</th>
<th>L2</th>
<th>L3</th>
<th>AUX. 1</th>
<th>AUX. 2</th>
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<td>.00</td>
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<td>-.10</td>
<td>-.64</td>
<td>-.82</td>
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<td>-.63</td>
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<tr>
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<td>124.</td>
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<td>.01</td>
<td>.00</td>
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<td>-.11</td>
<td>-.64</td>
<td>-.82</td>
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### ACTUAL VELOCITY SPECTRUM

**Geophone Number 1**

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<th>Real</th>
<th>Imag</th>
<th>Amplitude</th>
<th>Phase</th>
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**Geophone Number 2**

**Geophone Number 3**

### REDUCED DATA

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<th>G3</th>
<th>L1</th>
<th>L2</th>
<th>L3</th>
<th>AUX. 1</th>
<th>AUX. 2</th>
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Figure D.1 Raw Velocity Data from Geophone Number 2 of Calibration System
Figure D.2 Observed Deflections from Geophone Number 2 of Calibration System
a) Drop Height 1  
b) Drop Height 2

c) Drop Height 3  
d) Drop Height 4

Figure D.3. Observed Load from Load Cell Number 1 of Calibration System
Figure D.4 Deviation from Average of Each Load Cell of Calibration System
APPENDIX E

A TYPICAL EXAMPLE OF CALIBRATION OF LOAD CELL AND A GEOPHONE OF FALLING WEIGHT DEFLECTOMETER

Calibration of Load cell and geophones of the Falling Weight Deflectometers (FWD) is performed by comparing summary file's (of section 3.1.) load and deflection data with that of FWD data. Data from summary file can be imported in a Excel worksheet. FWD deflection and load data can then be entered in the Excel worksheet. A graph can be generated for each geophone or load cell. A best fit regression line can be generated and the slope of the best fit line is the calibration factor for the load cell or the geophone.

A typical example of Excel worksheet is shown in Table E.1. This test was performed in front of the Engineering building at UTEP. Table E.1 shows the FWD deflection (from Geophone Number 4) and load data. The data from Calibration system is shown next to the FWD data. A statistical analysis for each drop height is performed as shown in the table.

Data of Table E.1 is plotted in Figure E.1 to identify the calibration factors for the Geophone Number 4 and Load cell of FWD. Results indicate that load cell and geophone of FWD are underpredicting the imparted load and deflection. Hence, the load data of FWD should be divided by 0.97 and deflection data of Geophone Number should be divided by 0.93 for pavement evaluation.
| PWD | C.S. | Drop | Load | Deviation | C.O.V. (%) | Deviation | C.O.V. (%) | Deviation | C.O.V. (%) | Deviation | C.O.V. (%) | Deviation | C.O.V. (%) | Deviation | C.O.V. (%) |
|-----|-----|------|------|-----------|------------|-----------|------------|-----------|------------|-----------|------------|-----------|------------|-----------|------------|-----------|
|     |     |      |      |           |            |           |            |           |            |           |            |           |            |           |            |           |
| 1   | 2   | 3    | 4    | 5         | 6          | 7         | 8          | 9         | 10         | 11         | 12         | 13         | 14         | 15         | 16         |           |
| 1   | 2   | 3    | 4    | 5         | 6          | 7         | 8          | 9         | 10         | 11         | 12         | 13         | 14         | 15         | 16         |           |
|     |     |      |      |           |            |           |            |           |            |           |            |           |            |           |            |           |

Table E.1 FWD and Calibration System (C.S.) Load and Deflection Data

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<th>C.S.</th>
<th>Drop</th>
<th>Load</th>
<th>Deviation</th>
<th>C.O.V. (%)</th>
<th>Deviation</th>
<th>C.O.V. (%)</th>
<th>Deviation</th>
<th>C.O.V. (%)</th>
<th>Deviation</th>
<th>C.O.V. (%)</th>
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<th>C.O.V. (%)</th>
<th>Deviation</th>
<th>C.O.V. (%)</th>
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<table>
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C.O.V.(%) means Coefficient of Variation (%)
Calibration of FWD Geophone No. 4

\[ y = 0.9311x \]
\[ R^2 = 0.9991 \]

Calibration of FWD Load Cell

\[ y = 0.9695x \]
\[ R^2 = 0.9998 \]

Figure E.1. Calibration Factors for Geophone Number 4 and Load Cell of FWD
APPENDIX F

A GRAPHICAL DESCRIPTION OF DEVICE
Overall View of Items Used in Calibration System
(The load plate and the portable computer is missing)
Close-up of the Front Panel

The cables with black covers should be used to connect the load cells to the signal conditioning unit. The cables with red covers should be connected to the connections labeled GEOPHONES. It is extremely important that the numbers in the cables match the numbers for load cells and geophones. The trigger unit should be connected to the DIN connector labeled TRIGGER.

If a load cell is not connected properly to the signal conditioning unit, the yellow indicator associated with that load cell will illuminate. If a load cell cable is damaged, the corresponding red indicator will illuminate. If, during field tests, the red illuminators "blink", either the cables have gone bad, or the nominal capacity of the load cells is exceeded.

The indicator labeled POWER should continuously illuminate for the system to be operational. In this case, the system is powered.

The green indicator labeled TRIGGER will only illuminate when data is being collected.
Well-Calibrated Geophones Used for Calibration

Note that the numbers on top of the geophone should be matched with the appropriate channel of the signal conditioning unit.
Load Calibration Unit

The base plate with three embedded load cells should be covered with the top plate and should be placed under the FWD load plate. Before impacting the unit, the cables should be moved away from the plate. Under no circumstance, the unit should be impacted without a rubber pad glued to the bottom of the base plate. The load cells should be connected to corresponding BNC cables with black jackets. The Numbers on the load cells and the cables should match.
Front View of Signal Conditioning Unit

The front panel contains receptacles for three load cells, three well-calibrated, and a trigger device. Indicators lights, which are provided to show the status of the system, are described in the Close-up picture of the unit.

Rear View of Signal Conditioning Unit

The rear panel contains: 1) a 50-pin connector used to connect the signal conditioning unit to the data acquisition board; 2) an on/off switch; and 3) a standard 110 v plug.