Version

1.0e

GEOMEDIA RESEARCH & DEVELOPMENT

Free-Free Resonance Measurement

FFRC-A Manual

FREE-FREE CORE RESONANCE ANALYZER

FFRC-A Users Manual

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QUICK OPERATION

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1) Connect the USB cable to the FFRC-A unit.
2) Connect the USB cable to the laptop computer. You should hear the computer's connect signal.

Equipment Check

3) Start the FFRC software. You should be located in the "FFRC Setup" page of the interface. Check that the serial number and electronics test message are displayed in the message box at the top of the software form.

Default Setup

4) Select the default material type.
5) Enter modifications to the default ID, diameter, length, and mass.
6) Place the FFRC-A unit on your reference core sample.
7) Hit the run button. You will hear several taps testing seating and gain level, and the waveform and frequency spectrum graphs should display curves.

Sample Measurement

8) Hit the "FFRC Testing" tab.
9) Enter the Sample ID
10) Measure and enter the core diameter and length.
11) Measure and enter the core mass. You should see the computed density with a green quality control light.
12) Hit the Run button. You will hear a sequence of taps, and will see a sequence of waveform graphs and resonance spectra displayed on the graphs. At the end of three hits, you will see measured resonant frequencies and computed moduli. Repeatable/reliable measurements will display a green light, small frequency variations in resonance frequencies will give a yellow light, while unreliable measurements will display a red light.
13) Hit the Accept button, and the sample values will be transferred to the table, sample parameters will be reset to defaults, and measurement results cleared.

Exit

14) Hit the Archive button, and enter a file name to save the measurement summary table.
15) Hit the X button in the form upper right. If you have not Archived the measurement table, you will be presented with a dialog to enter a file name to save the table.

HARDWARE COMPONENTS

The Free-Free Core Resonance device (FFRC-A) is shown in the adjacent illustration. It is simply placed on a sample cylinder or core, and under computer control it impacts on the sample, and records vibration modes in the sample. In most samples, the vibration modes are dominated by the resonance of the compression wave and shear waves trapped in the core. The ultrasonic Young's Modulus (and shear modulus on concrete) are derived from analysis of these modes.

Parts of the FFRC-A device that are numbered in the illustration, are named as follows.

1. Handle.
2. USB cable and connector.
3. Auxiliary accelerometer connection.
4. Auxiliary accelerometer connection.
5. Rubber damping pad (usually black adhesive neoprene).
6. Cylinder with solenoid impactor.
7. Cylinder with accelerometer vibration sensor in the foot.

The auxiliary accelerometer connections are not used in current modal analysis techniques, but are made available for both research and future applications.

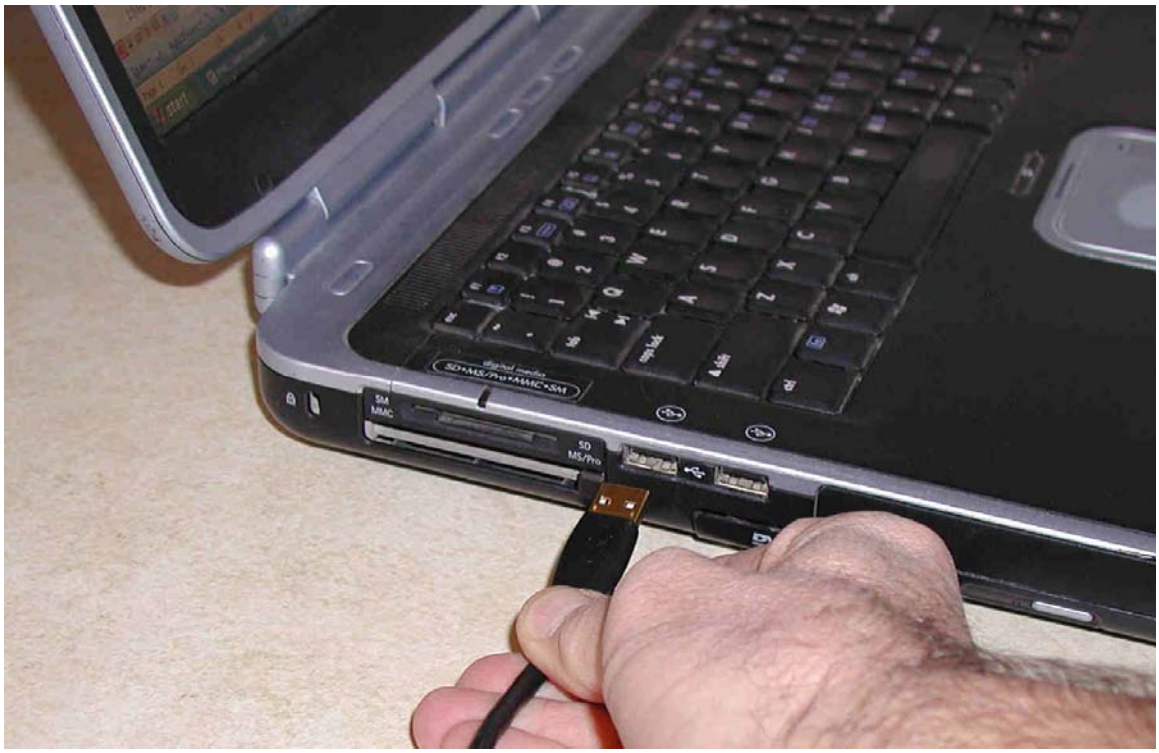
DETAILED OPERATION

Connection

A custom 5m long cable is provided to connect the FFRC-A to your laptop computer. One end of this cable has a standard USB-A connector for the computer, while the other end has a rugged, environmental connector for the FFRC-A. Power for the FFRC-A is supplied by the laptop computer through this cable; there are no batteries or power connectors in the FFRC-A.

Connect the FFRC-A to the cable by aligning the pins and key of the connector to the socket, and screwing the outer ferrule in to the socket. Please ensure the connector and socket are clean before assembly. It may be necessary to push the connector in, while turning the ferrule, when the connector is new.

Connect the cable USB-A connector to your laptop computer. If your computer's audio is enabled, you should hear the appropriate operating system signal that a USB device has been connected. Connecting the cables will power up the FFRC-A into its standby

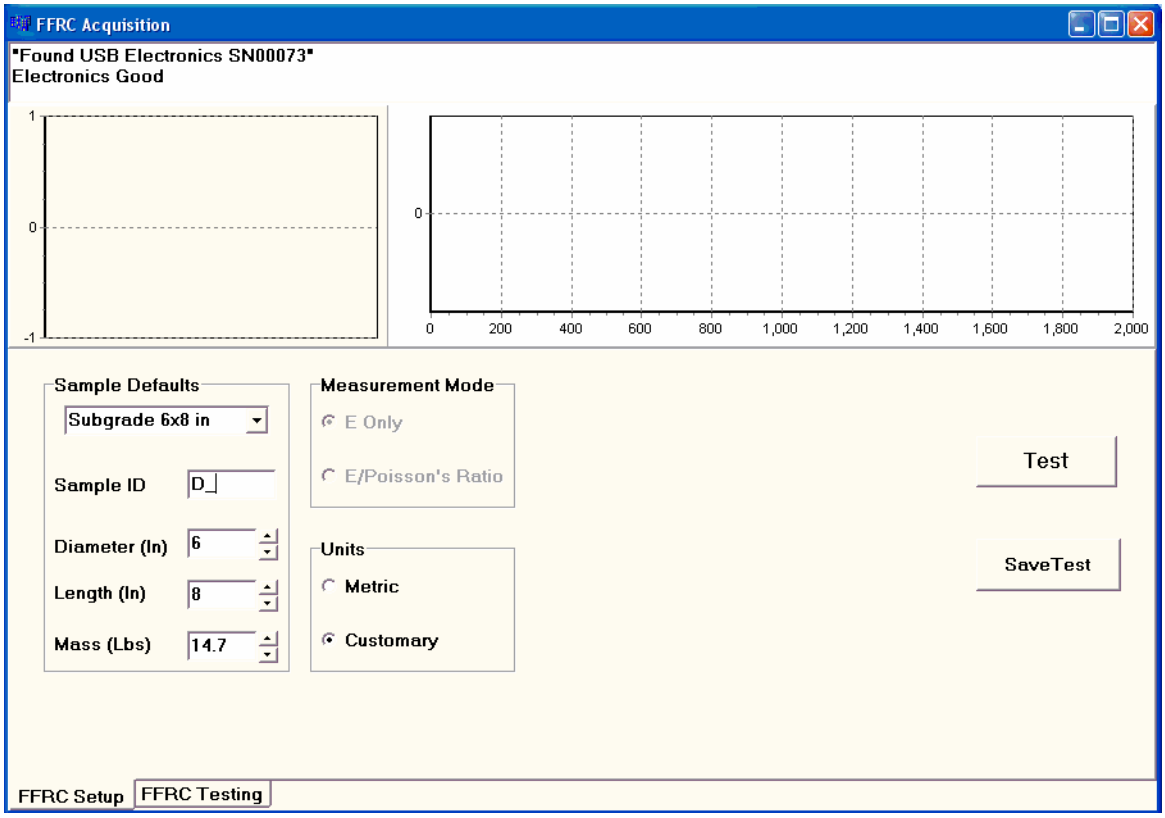


mode where it is ready to respond to the testing software.

The FFRC-A device is turned off simply by unplugging the cable – it is not necessary to disable the device from the operating system. It will be necessary, however, to exit software that attempts to access the FFRC-A before plugging it in again. Re-plugging the FFRC-A in creates a new operating system device ID that the software will not recognize. Your general operational sequence should be to exit all FFRC software before plugging in the cable.

Equipment Check

On starting the FFRC interface software, you will see a screen similar to the following.



From top to bottom, there is a message area, a graph area for time-domain waveforms and frequency spectra, a control area on the lower left to setup defaults for subsequent measurements, and the control area on the lower right. At the very bottom there two tabs showing that you are in the FFRC Setup function, and can move to the FFRC Testing function.

In the message area you will see a message indicating that the software has read back the equipment serial number from the FFRC-A unit. You will see a message displayed below this briefly indicating that the electronics are being tested for basic function, replaced by a message indicating the outcome of this test.

In the event the laptop and software can't communicate with the FFRC-A, you will see the message ***No FFRC Unit Attached*** displayed in this message area. You should recheck the cable connection, ensuring you hear the operating system's signal when disconnecting and connecting the cable. You may hit the Test button on the lower right to recheck the communication with the FFRC-A.

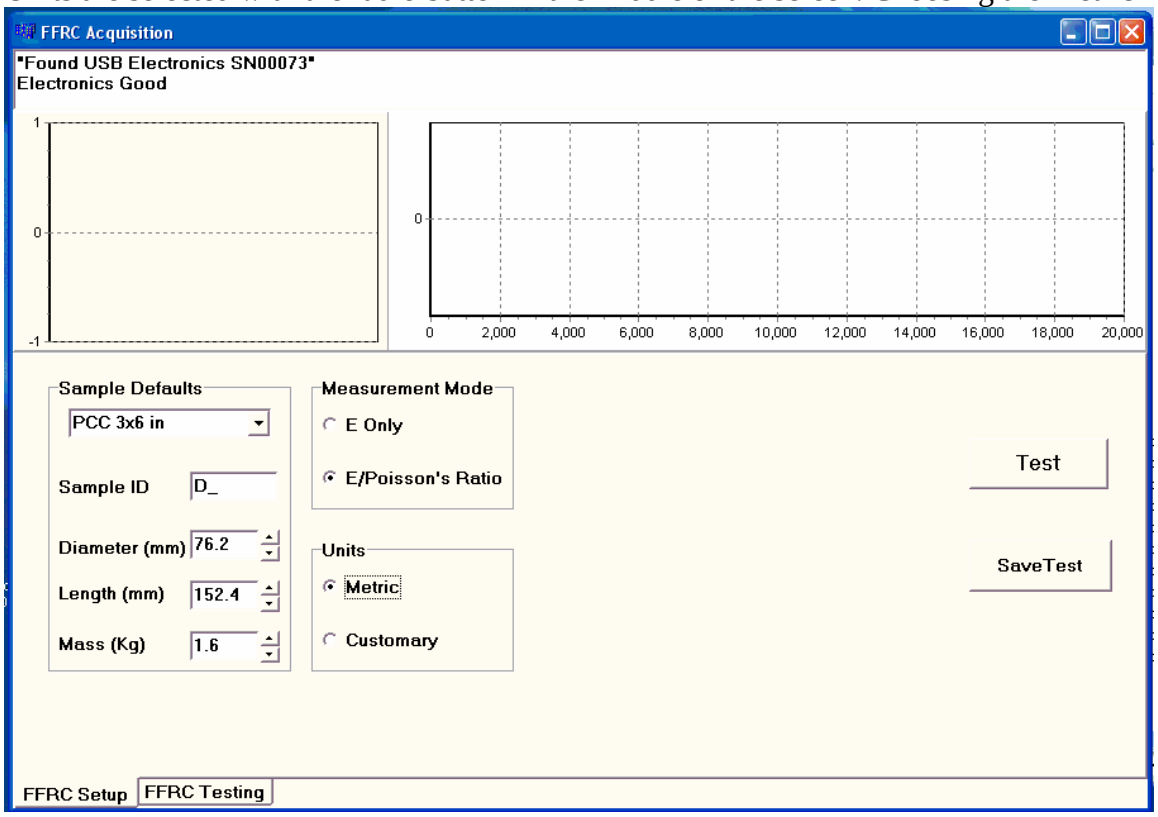
You may hit the Test button on the lower right at any time. If the FFRC-A has not been connected yet, it will go through the basic electronics tests, and proceed to hit several times to adjust gains. As long as the FFRC-A unit is standing on a table top, or some surface, the waveform and spectrum will be displayed for the final hit. If the FFRC-A is lying down so that the source impactor and accelerometer are not touching, the unit may not trigger, but in any case the graphs will not show sensible data. You must pass this initial electronics test to enable testing on the FFRC Testing page.

If you can't get the basic connection to operate, you should go to the Troubleshooting section for several more simple tests.

Default Setup

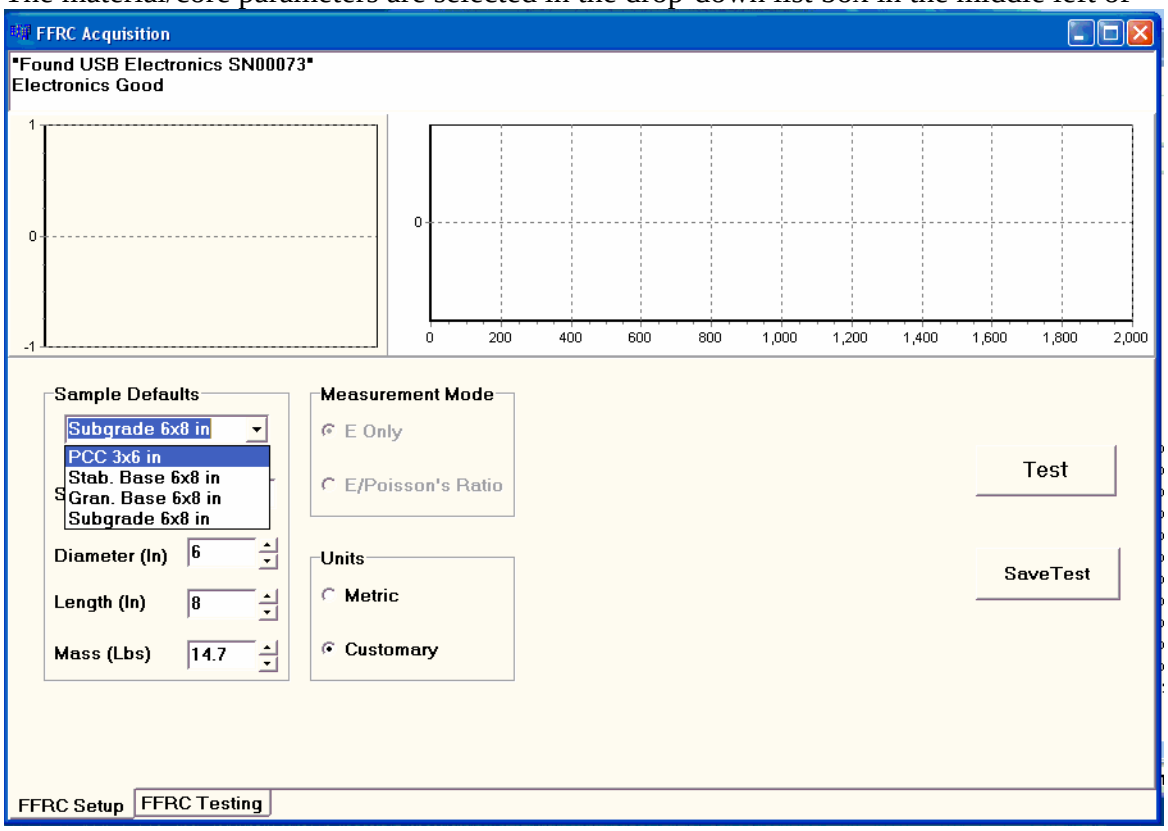
There are three steps in setting up the hardware for routine measurements. 1) Select whether you will show results in metric units or customary units. The default is to user customary units. 2) Select the type and general size of core on which you expect to be making measurements. 3) Adjust settings to the default values for step 2.

Units are selected with the radio button in the middle of the screen. Choosing the Metric



setting, as shown, will display lengths in millimeters, mass in kilograms, density in kg/m^3, and moduli in MPa (megapascals). Selecting the Customary units, shown in all subsequent figures, will display lengths in inches, mass in pounds, density in lbs/ft3, and moduli in KSI. Changing units in the middle of a set of measurements acts only from that point on – any earlier measurements will remain displayed in the original units.

The material/core parameters are selected in the drop-down list box in the middle left of



the screen. On selecting the material and general core dimensions, the default settings for core properties, analysis and display parameters, and hardware settings are loaded into the software. You may immediately see the frequency of the graph x-axis change, in addition to changes in the default ID, diameter, length, and mass.

If you place the FFRC-A unit on a core or calibration sample, you may hit the Test button to ensure you are seeing the type of measurements to which you are accustomed. Now is the time to adjust the sample defaults should resonance spectra not appear correct. When in doubt select an entry that has a shorter core length on PCC (to increase the frequency range), or select a softer material (to lower the frequency response) on bases and soils to simplify complex spectra.

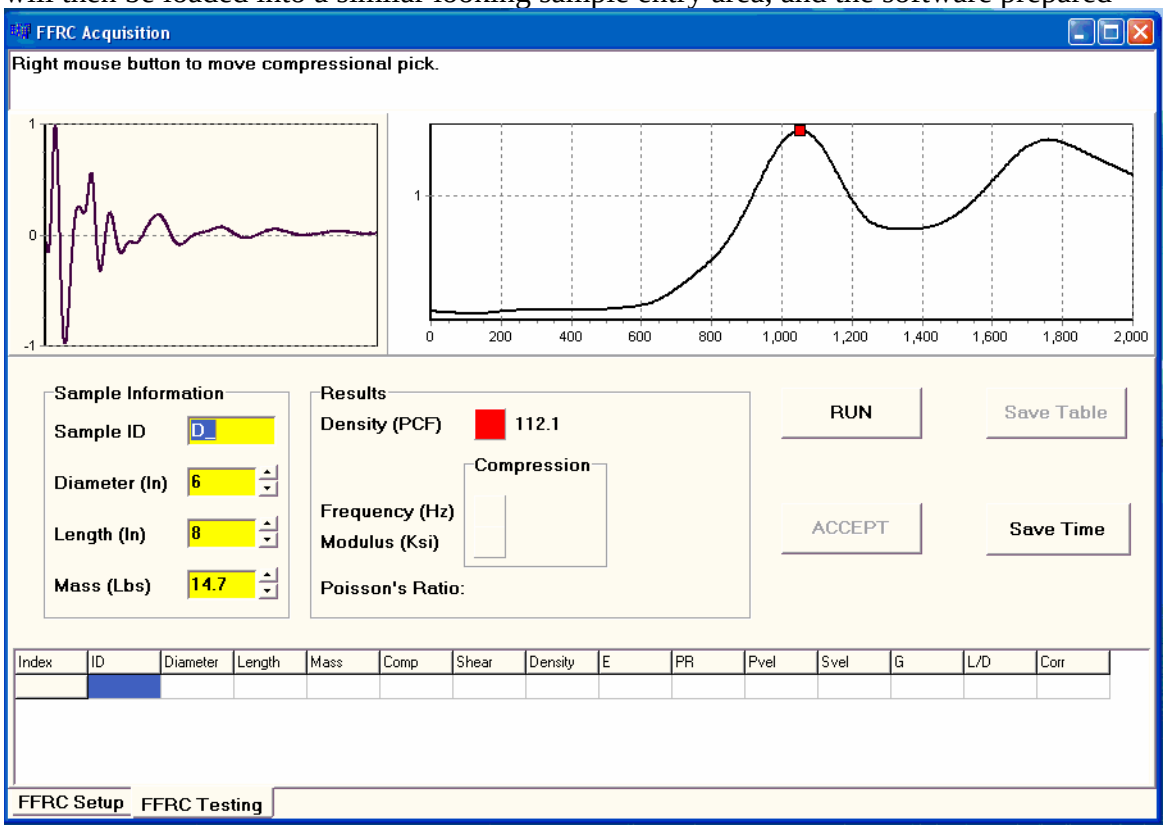
At this point you may enter changes to the default ID, default core length, diameter, and mass, if you expect to be working with consistently-sized core samples.

If you are making measurements on PCC core samples, the default setting is to enable the Measurement Mode selection box, and to expect to measure both compressional and shear resonance peaks. You may select the E-only setting and measure compressional resonance peaks only. All other material types default to the E-only due to the poor quality of shear resonance modes. These setting can by over-ridden in the setup table described in the section on DEFAULT SETUP.

If you wish to save the measured waveform, you may hit the “Save Test” button, and you will get a dialog to save the data in the graph into a tab-delimited file. This should only be necessary if you see unusual results and want to save them for review by a specialist.

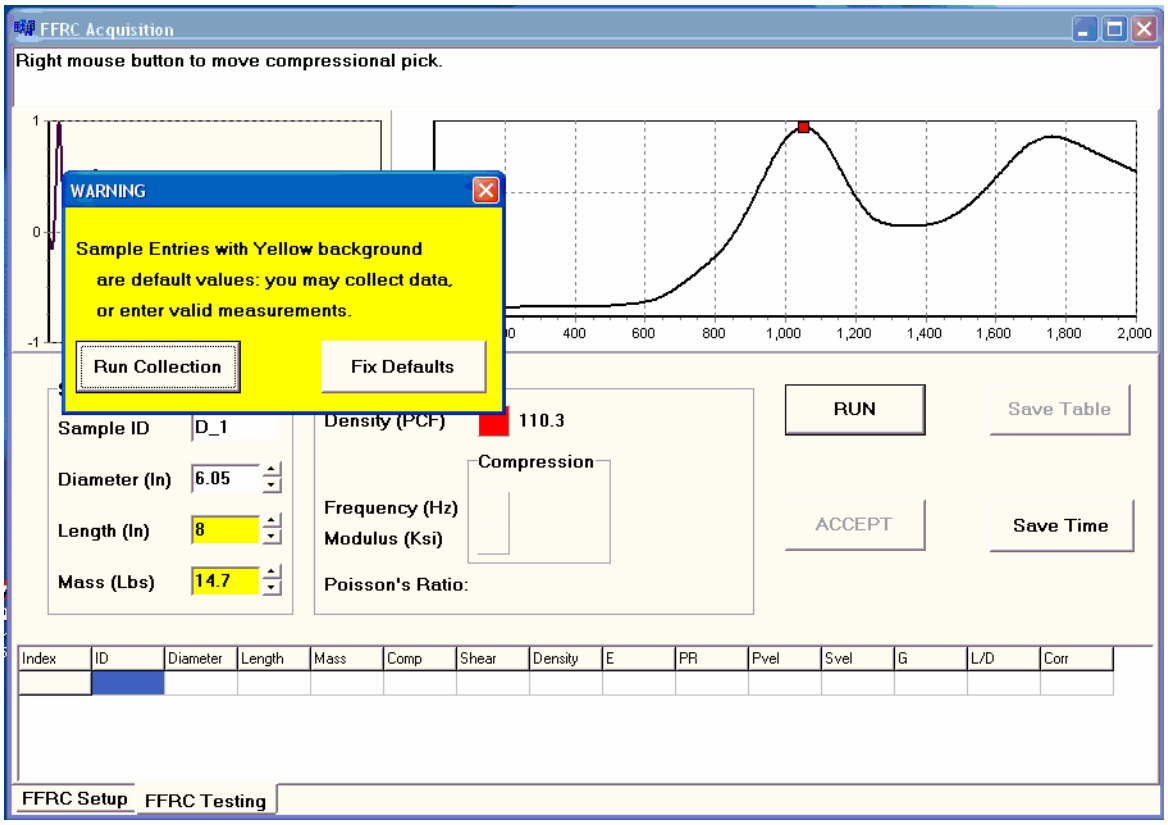
Sample Measurement

When software setup is complete, select the FFRC Testing tab. Your default core settings will then be loaded into a similar looking sample entry area, and the software prepared



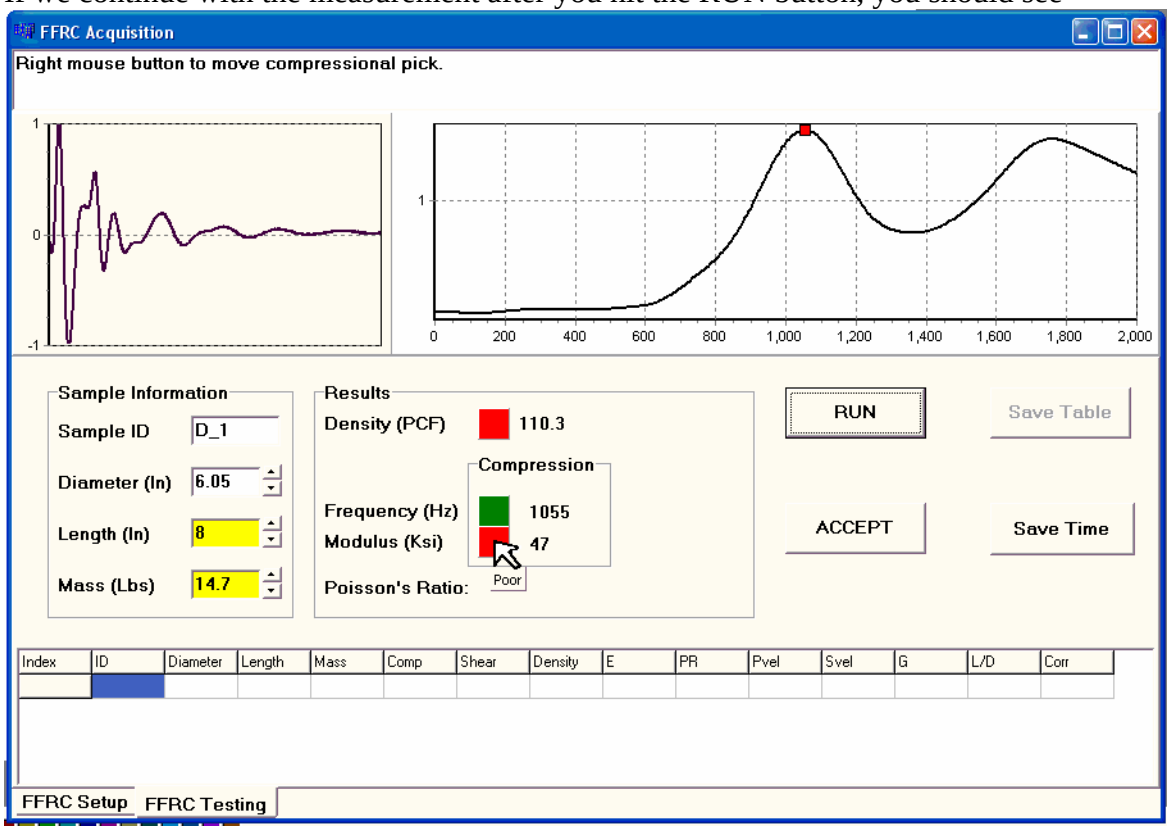
for routine testing. The default values for Sample Information are highlighted in yellow background. When you modify (or enter/exit without modification) the entry area, the yellow will change to a white background color, indicating that you have confirmed this is no longer a default value. The results value shows a computed density from the default values, with a red quality indicator, showing it is derived from multiple defaults. When you measure all three core properties, the density quality indicator will change to green. If only two of three core properties are measured, the density quality light changes to yellow.

The RUN button will be enabled if you have passed the initial test procedures on connecting the equipment. You may attempt to RUN the measurement without measuring or confirming the default sample values, and you will receive a warning screen that lets you over-ride the



recommendations. You may hit Run Collection to continue the acquisition, or hit Fix Defaults, to go back and entered measured values for the defaults still highlighted in yellow.

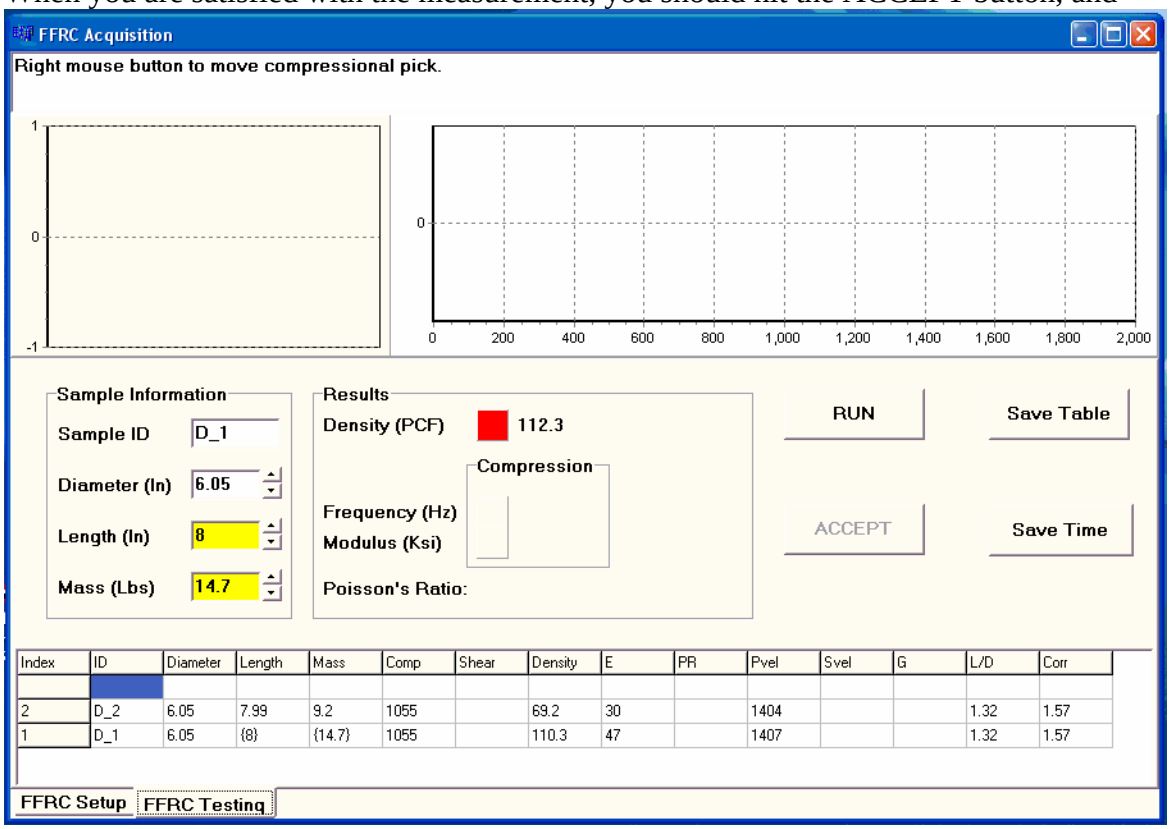
If we continue with the measurement after you hit the RUN button, you should see



results of the following type. The frequency peak at 1055 Hz was automatically selected and confirmed in all three hits, and consequently shows a green quality indicator light. If the frequency peak shifted slightly with repeated hits, the light would show yellow, and if if bouncing around to different peaks, it would show red. The computed modulus would also have a quality indicator light that reflected the quality of the density and frequency measurements. The cursor flyover of the quality lights also provides a verbal description of the condition.

You can over-ride the automatically selected frequency peak by using the right-mouse button (as mentioned in the message area), to shift the pick location. Click on the desired frequency (but with cursor off the curve). The Compressional Frequency pick in the results box will shift, and the quality lights for frequency and modulus will change to yellow to indicate this over-ride.

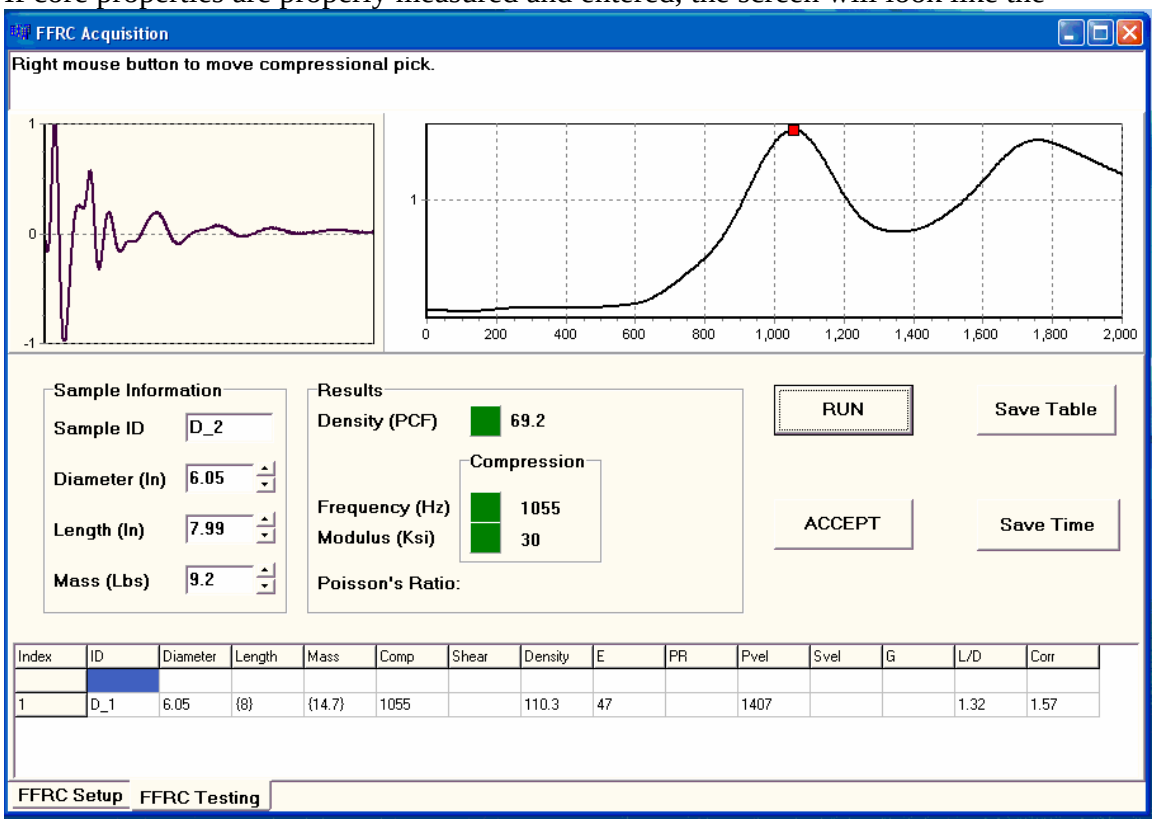
When you are satisfied with the measurement, you should hit the ACCEPT button, and



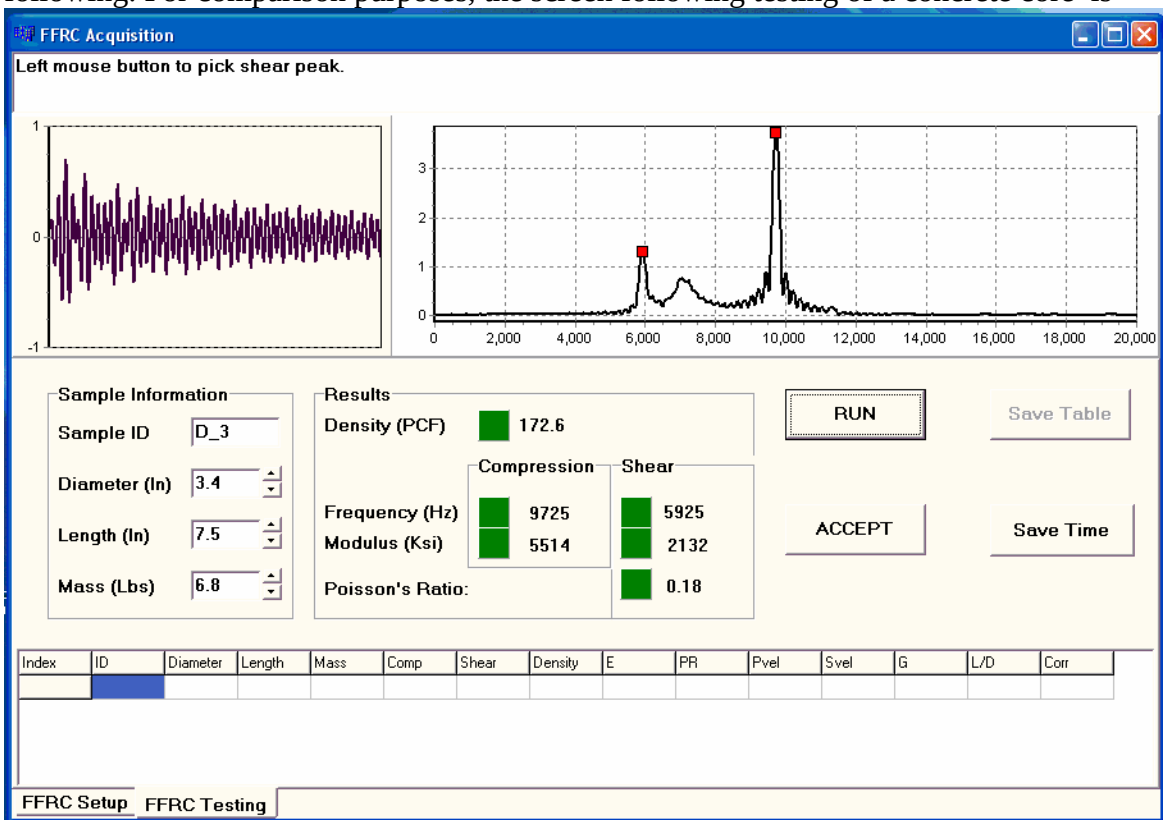
the sample information and results will be transferred to the table at the bottom of the page. If you used default core parameters, these are contained in brackets in the table. In addition,

Note in the example above that the Accept button clears Results information, but Sample Information is retained and not reset to default values. The software retains your original Sample Information on the assumption that you are likely to be retesting a given sample more than once. The Sample Information values are reset to default values when you use the mouse cursor to enter any of the four text edit boxes following use of the Accept Button.

If core properties are properly measured and entered, the screen will look like the



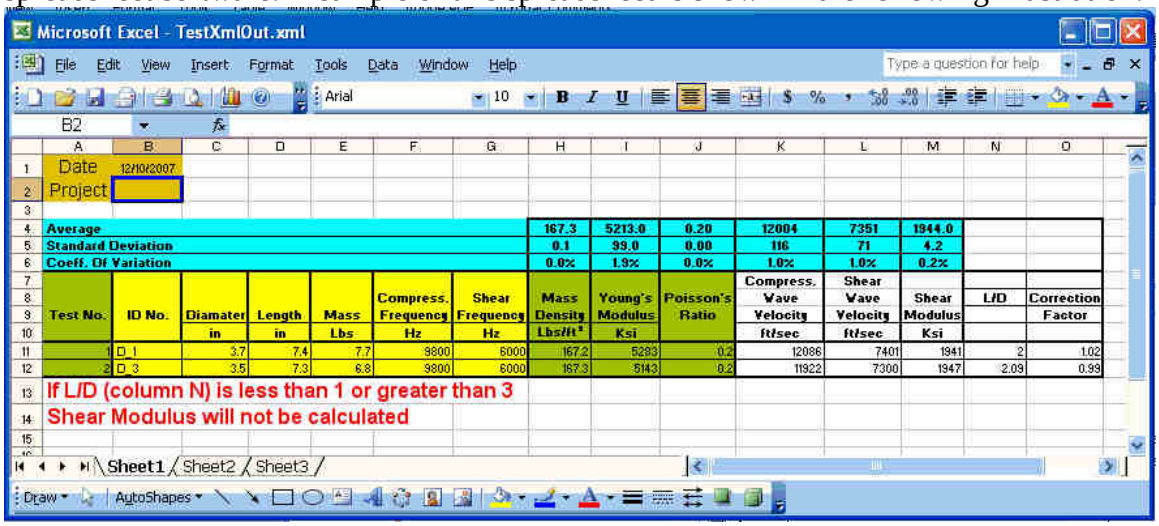
following. For comparison purposes, the screen following testing of a concrete core is



also shown. You will notice that the frequency graph covers a wider range of frequencies, shear and compressional picks are displayed, and a Poisson's Ratio is calculated. You can over-ride the automatic peak picking as before by using the right mouse button to move the compressional pick, and the left mouse button for the shear pick.

Save Measurements to Hard Drive

After one or more core resonance measurements are accepted into the table, you may use the Archive button to name and save this table into a file on the hard drive of the computer. The table information is saved into an XML format compatible with spreadsheet software. A sample of this spreadsheet is shown in the following illustration.



Columns are color coded for easy scanning, and a statistical summary of your measurement results are computed in the blue rows. You may use your spreadsheet software to reformat, customize or edit your various projects and samples.

Exit

Simply hit the red X box in the upper right of the FFRC form to exit the software at any time. You will be prompted to enter a file name to save your results table, if you haven't already done so.

TROUBLESHOOTING

No OS Signal on plugging in USB Cable

1. Make sure cable is plugged in well.
2. Ensure cable is not damaged.
3. Check known-good USB device on computer plug.

OS Signal but FFRC-A not recognized

1. Stop any FFRC software, re-plug USB cable, re-start FFRC software
2. Run USBBoardTest.exe test sequence.

3. Disconnect FFRC front panel and open. On plugging in USB cable check that board facing the front panel has two steady lights, and one slow blinking light.

FFRC Recognized but will not fire

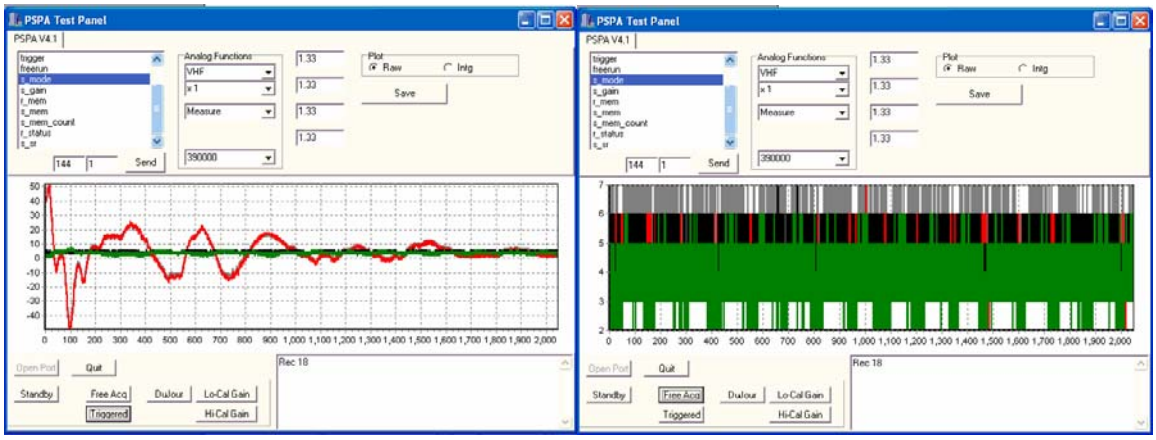
1. Run USBBoardTest.exe test sequence.
2. Unscrew handle and top plate: check for connector plugged in to solenoid firing board, burned smell or visible scorching on the solenoid firing board above the solenoid source.
3. Unplug circuit board, remove board, use screwdriver to ensure solenoid armature moves, check for intact wires both sides of board.
4. Replace solenoid firing board.

FFRC Fires but will not trigger

1. Check that accelerometer piston moves freely.
2. Run USBBoardTest.exe test sequence.
3. Unscrew handle and top plate: check that accelerometer connector plugged in, and wires intact.
4. Using voltmeter on two-pin accelerometer connector: ~ 23.7V unplugged and between 8-13V when plugged in across the red and white wire. If < 5, wires accelerometer damage. If > 15V excess resistance in wires or accelerometer damage.

USBBoardTest.exe Test Sequence

1. Start USB BoardTest.exe. “Open Port” gives *DLP-USB2 ready*.
2. Send r_ver: *<r_ver>PSPA uC V2.05</r_ver>*
3. Send r_sn: *<r_sn>Not Working</r_sn>SN00073*
4. Send r_status: *<r_status>203,208,131,2</r_status>* Time for this response ranges from zero to five seconds, depending on how recently power supplies have started. First two entries should be 195-210, third entry temperature sensor.
5. Analog Functions VHF, x1, Measure, 390,000 and Send r_mode: <s_mode>144,1,1,1</s_mode>
6. Hit Triggered Button. See figure.
7. Hit FreeAcq Button. See figure.
8. Hit Standby, and shut down program.



DEFAULT SETUP

Default File

The setup file is named MaterialParmTable.ini , and is located in the default installation directory. You can modify this file, using instructions that follow. To restore defaults, rename or delete the file by this name, and the FFRC software will create a new file with the default values when next run. The default file is as follows.

```
Materials="Cem. Stab. Base 6x8 in","Stab. Base 6x8 in","Gran. Base 6x8 in","Subgrade 6x8
in","PCC 4x8 in"
PCC 3x6 in=0,20000,25,D_,0.0762,0.1524,2300,40,1,1,0,0,5,1
PCC 4x8 in=0,15000,25,D_,0.1016,0.2032,2300,40,1,1,0,0,5,1
PCC 6x12 in=0,10000,25,D_,0.1524,0.3048,2300,40,1,1,0,0,5,1
Cem. Stab. Base 6x8 in=0,10000,25,D_,0.1524,0.2032,2100,10,0,0,0,0,5,1
Cem. Stab. Base 6x12 in=0,8000,25,D_,0.1524,0.3048,2100,10,0,0,0,0,5,1
Stab. Base 6x8 in=0,10000,25,D_,0.1524,0.2032,2100,2.5,0,0,2,0,5,1
Stab. Base 6x12 in=0,8000,25,D_,0.1524,0.3048,2100,2.5,0,0,2,0,5,1
Gran. Base 6x8 in=0,4000,10,D_,0.1524,0.2032,2100,0.7,0,0,7,0,5,2
Gran. Base 6x12 in=0,3000,10,D_,0.1524,0.3048,2100,0.7,0,0,10,0,5,2
Subgrade 4x6 in=0,3000,5,D_,0.1016,0.1524,1800,0.2,0,0,10,0,5,2
Subgrade 4x8 in=0,2000,5,D_,0.1016,0.2032,1800,0.2,0,0,10,0,5,2
Subgrade 6x8 in=0,2000,5,D_,0.1524,0.2032,1800,0.2,0,0,10,0,5,2
Asphalt 4x6 in=4000,14000,10,D_,0.1016,0.1524,2100,15,0,0,5,0,5,1
Default=0,10000,50,D_,0.152,0.203,1800,10,0,0,0,0,5,1
LastMaterial=Gran. Base 6x8 in
```

The file has three sections. The first line gives a list of the material definitions that will be displayed in the FFRC user interface. The last line contains the name of the last-used material. Each of these lines has a label, followed by the equals sign, followed by the parameter list. These two labels are fixed in the code, and will disable the table if they are changed.

The intervening lines contain the default material types and core sizes. Each is also composed of a label followed by the list of parameters. If you have a special need for a routine type of sample, you can create a name with a set of parameters, put the name in the material list, and it will become available to the user.

Material List

The Material list sample follows. The list of material names is stored in a “comma-text” format. Names in the list can be separated by spaces or commas. If you wish to have a name that contains spaces, it is necessary to place the name in double quotes.

```
Materials="PCC 3x6 in","Stab. Base 6x8 in","Gran. Base 6x8 in","Subgrade 6x8 in"
```

If the name you’ve placed in the Materials list does not exist in the following lines, the software will attempt to load the material named “Default”. If this does not exist, values will be left unchanged.

Materials

A material description entry has the name followed by an equals, followed by 14 arguments that control the software. A list of the control arguments follows.

```
PCC 6x12 in=0,10000,25,D_,0.1524,0.3048,2300,40,1,1,0,0,5,1
```

Graphs

1) Minimum frequency for display and resonance peak searches. It should be set greater than zero and less than the maximum frequency.
2) Maximum frequency for display and resonance peak searches. It should be set greater than the minimum, and less than 45 kHz. The maximum should also be greater than the resonant frequency arising from the maximum expected modulus and minimum core length for that class of sample.
3) Frequency interval used in display and analysis. In general this value should be less than 1/1000 the maximum frequency. Making this number large decreases computation time, but reduces the precision of the modulus measurement.

Material Defaults

4) Default sample ID. This is the starting ID value initialized in the ID display.
5) Default core diameter in meters.
6) Default core length in meters.
7) Default core density in kg/m^3.
8) Typical core modulus in GPa. This localizes the resonant peak search in core with multiple peaks.
9) Measurement mode: (0) analyzes the compression resonance peak, (1) analyzes for both compression and shear resonances.
10) Enable selection of measurement mode: (0) disables the measurement mode selection box, (1) enables the selection of measurement mode.

Hardware Settings

11) Time record sample rate. A value of (0) gives the fastest sample rate, and should be suitable for all pavement core samples. Increasing this value introduces a linear delay in the sample time. The faster you sample, the better the quality of the peak measurement should be. You might need to slow down sampling if your samples

continue strongly resonating past the end of the time record. Values of (10) or less should be adequate for the typical base or soil samples.

12) Preamp gain: (0) gives a gain of 1, (1) gives a gain of 10.
13) Starting gain: a value of 5 is a reasonable start for all samples. We test hit to optimize gain levels, and this simply provides a starting point to simplify the search.
14) Filter bank; (0) 10 kHz- 40kHz: (1) 4 kHz-20 kHz: (2) 500 Hz- 5 kHz: (3) 50 Hz to 500 Hz.

Last Material

This entry records your last setting, and restores that setting when you restart start up the software.

```
LastMaterial=Subgrade 6x8
```

USB Startup and Software Installation Instructions

V3.3.1: 5/2006

1) Insert the software installation CD into the optical drive on your computer.
2) Run the Setup.exe file, and follow the InstallShield installation instructions.
3) Exit the setup program.
4) Make a desktop shortcut to C:\Program Files\FfrcA\FfrcTest.exe: we generally name it FFRC.
5) Make a desktop shortcut to C:\ Program Files\FfrcA\FfrcUser Documentation.pdf. We generally name it Ffrc Documentation.
6) Connect the supplied USB cable to the FFRC and then to the computer USB port, on which you would like to run the FFRC. The “Found New Hardware” wizard should start up. If you let the wizard search automatically for a driver, it should find the FTD2XX information file on the optical drive. If it does not find this file automatically, please direct to wizard to look on the root directory of the optical drive with the installation CD-ROM. It should complete the driver installation without further fuss. If you do not have the CD available, direct the wizard to look in the installation directory, C:\Program Files\FfrcA, where we've left an additional copy.
7) We recommend making a copy of the CD-ROM install disk into a subdirectory of the C:\ drive. For future support calls, we may ask you to compare configuration files or executable dates. You can reinstall the software from this backup directory at any time as well.