Fracture Technology Associates

**Non-Linear Fracture Toughness Testing and Analysis
Version 3+.16.01**

Users' Reference Manual

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NLFT Testing - Series 2015 - V3+.16.01

1.0 The FTA NLFT Testing and Analysis System

1.1 Introduction

Fracture Technology Associates' fourth-generation **Non-Linear Fracture Toughness (NLFT)** system is an updated hardware and software package designed primarily for non-linear fracture toughness testing and analysis (ASTM E1820, E1921),), although linear elastic testing and analysis is supported (ASTM E399). Each system consists of an ADwin Gold signal processor and a computer running the FTA NLFT software.

Enhancements to the software include the ability to perform cyclic J and da/dt with a K profile, desirable for accelerated environmentally assisted cracking tests (K_{Ieac}).

Two analysis packages are included with each system: 1) standard analysis and 2) testing playback software, which allows the user to reprocess unloading slopes that may have captured non-linear crack measurement data during testing.

FTA's basic NLFT (ASTM E1820, E1921) testing application is designed to run with the ADwin Gold and any closed loop servo-hydraulic mechanical test machine and controller, suitably configured for non-linear fracture toughness testing. It is important to note that the fourth-generation software requires an ADwin with an integrated USB port: older Adwins are not supported.

1.2 Software

The basic software application uses either compliance (NLFT-C) or DC potential drop (NLFT-D) for non-linear fracture toughness testing with a single crack monitor. The combined application (NLFT-C/D) includes either, independent or simultaneous compliance unloading and DC potential drop monitor of crack size.

The FTA NLFT analysis program runs independently of the Adwin Gold and has been upgraded as well. The analysis program can run analysis files created by the new testing software as well as previous versions.

1.3 The ADwin Gold

The hardware component of FTA's testing system is the ADwin-Gold signal processor, manufactured by the German company Jäger. The ADwin takes over from the test machine controller and performs all function generation, data acquisition, and real-time data processing, using the ADbasic programming language. ADbasic controls both high (such as command control and data acquisition) and low priority processes (such as determination of crack length). The ADwin performs all tasks on a priority basis regardless of the computer's workload and time-critical processes run independently of

the PC operating system. Thus, if the computer running the FTA software crashes, the ADwin continues to maintain control and collect data. When the computer is rebooted, it can access the ADwin process and tests continue uninterrupted.

The ADwin has a dedicated Analog Devices SHARC DSP processor; local memory; and high-speed 16-bit resolution analog input and output. It provides real-time response within one microsecond. Further documentation can be found in the ADwin manuals provided with FTA systems.

1.4   Other Hardware Requirements

Required hardware for the FTA testing package includes the ADwin Gold and a computer running the FTA software. A computer (either 32-bit or 64-bit) with a Pentium 3 processor and 256M memory (or better) and a CD/DVD drive is recommended. Windows versions 98 thru 7 are supported, although ADwin drivers will differ according to the OS used (see section 2.4 of this manual for further details).

For potential drop methods of crack measurement, FTA supplies its own high-quality, DC potential drop instrumentation (FTA-DCPD). The FTA-DCPD was specifically designed for the precise current and amplifier stability necessary for the reversing DC potential drop method of monitoring crack length and consists of two units: a programmable linear DC power supply with built-in solid-state polarity-reversing relays and a two channel precision differential DC amplifier

Please consult FTA for additional details regarding system requirements.

1.5   License Agreement

Familiarization with the background and theory of fracture toughness testing as well as the American Society for Testing and Materials (ASTM) standards for fracture toughness testing (E1820, E1921, E399) is strongly recommended. Fracture Technology Associates (FTA) assumes no liability for inappropriate use of this software and hardware system. It is the user's responsibility to provide back-up verification of the performance and accuracy of this software package (i.e., visual checking of crack length, independent monitoring of the applied loads, and redundant checking of the analysis).

Each test system requires a software license for each of the two required testing applications. Permission is granted to make copies of the software for back-up purposes. The analysis software does not require a license for multiple copies and may be loaded on additional computers for convenience of use. All rights and title to the application software shall remain the sole and exclusive property of FTA. Distribution of this software to another party is prohibited.

1.6   Manual Layout

This manual is intended as a beginning reference for new users of the FTA testing and analysis software. The following section describes setup and installation of the ADwin Gold; FTA-DCPD current supply and amplifier; and FTA software. Section 3.2 provides step-by-step instructions to guide new users through the running of a room temperature E1820 test, including the option of DCPD crack measurement. Section 4 provides detailed descriptions of each of the testing software menus and displays in the order in

which they are typically opened by the user. Sections 5 through 8 detail use of the analysis software, including testing playback.

This manual includes discussion of the E399 and E1820 standards only. Please contact FTA for more details on using the NLFT software for E1921 testing and analysis.

Operation and troubleshooting of laboratory controllers and test frames are outside the scope of this document: for guidance, users are encouraged to contact their equipment manufacturers.

2.0 Installation Guide

2.1 Connecting the ADwin to the Controller and FTA-DCPD

The ADwin-Gold is factory-calibrated and configured for differential inputs, although FTA can provide a calibration procedure upon request. The ADwin must be grounded for use in conjunction with a test machine: it should be grounded to the system console or the common ground of the controller (refer to the ADwin hardware manual *Start Up* section for details).

2.1.1 ANALOG INPUT AND OUTPUT CONNECTIONS

For fracture toughness applications, the following analog BNC connections are required (refer to ADwin hardware manual *Connector* section for details). *Note that these connections are different than those required by FTA's previous testing applications.*

- load cell signal from the test controller: connects to the **IN 1** connector on the ADwin
- external function generator input on the test machine controller: connects to the **OUT 1** connector on the ADwin
- [for compliance] the displacement signal from the test controller or auxiliary instrumentation: connects to the **IN 2** connector on the ADwin.
- [for DC potential drop] active probe amplifier output: connects to the **IN 5** connector on the ADwin.
- [for DC potential drop] reference probe amplifier output (if required): connects to the **IN 6** connector on the ADwin.
- in addition, the ADwin's **IN3** and **IN4** connectors may be used as auxiliary channels for display and/or data logging

The software is configured for a ± 10 volt range. It is therefore recommended that only active inputs be connected to the ADwin, since an unused displacement or DC potential drop signal may have an off-scale output (greater than 10 volts). This condition influences the analog input multiplexer settling time and may affect the readings of the other channels.

2.1.2 DIGITAL INPUT AND OUTPUT CONNECTIONS

With each system, FTA supplies a 25-pin run-stop cable, which connects to **CONN 2** (digital out) of the ADwin. Pins 5 and 13 of this connector (short red and black wires) monitor the run state of the controller (pin 5 connects to 'high' and pin 13 to 'low/ground' of a digital-in logic signal – else, the wires are interchangeable). The nine-pin connector goes to the back of the FTA-DCPD power supply if required. See Section 2.2 for FTA-DCPD hook-up.

An ADwin connection diagram appears below:
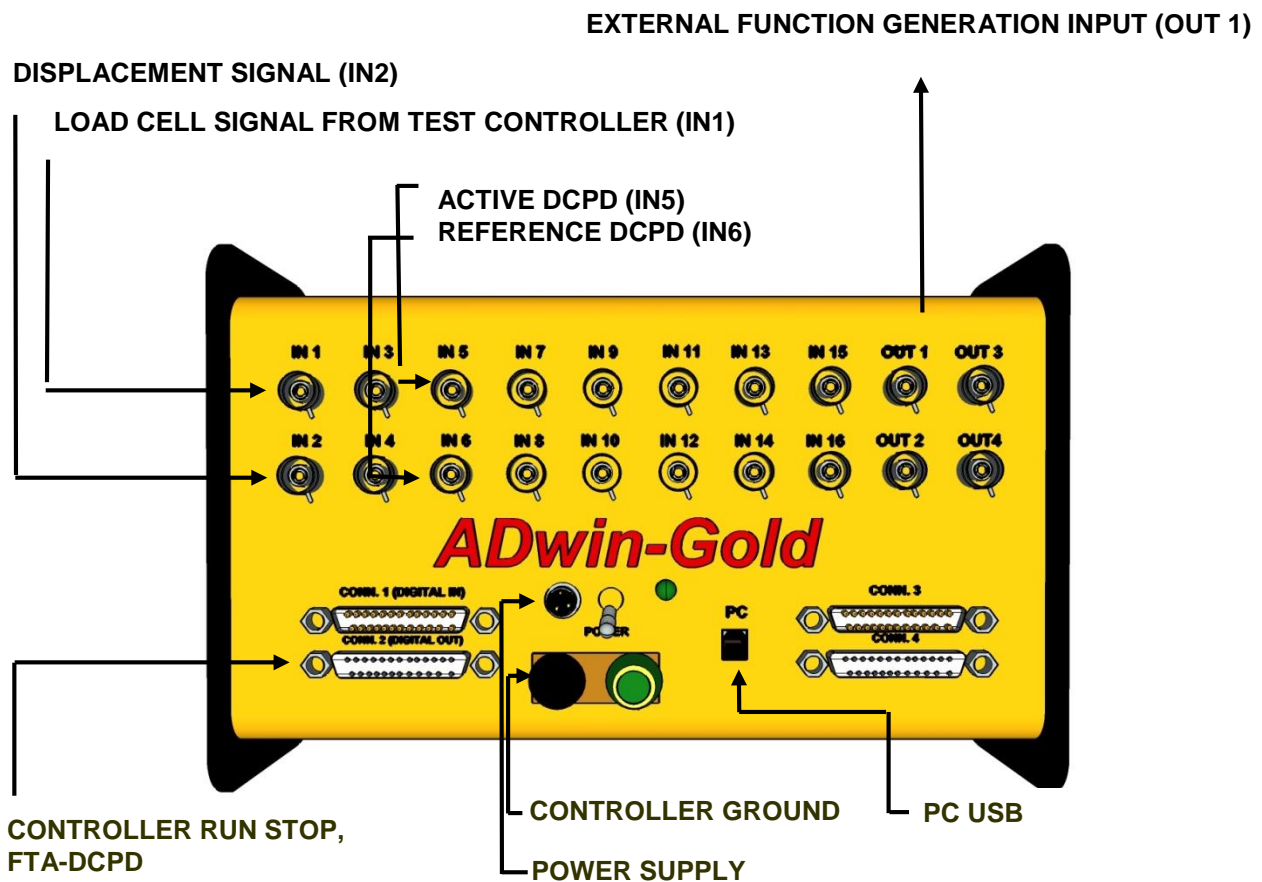
2.2   Connecting the FTA-DCPD Current Supply and Amplifier

The figure below shows the front panel of the power supply. Programming functions are activated by the keypad (see the DCPD options described in the test procedure in Section 3.2 of this manual for details). The voltage/current output on the lower left side has been disabled.

On the back of the unit, the current output is located on the left side beneath the 120 volt AC power cord. Use the FTA-provided current wire from the **Current Out** connector to the test specimen or terminal strip. A cable-tie strain relief is recommended. On the upper right side of the unit is a 9-pin connector labeled **DCPD control**, which is connected to the nine-pin connector from the 25-pin **CONN 2** connector on the cabling to the ADwin-Gold. Note that pin 25 of **CONN 2** goes to pin 1 of **DCPD control**; pin 1 of **CONN 2** goes to pin 3 of **DCPD control**, and pin 14 of **CONN 2** goes to pin 2 of **DCPD control**. *Do not use the voltage/current outputs on the right side below the DCPD control connector.* Grounding of the unit is provided through the AC power cord. However, an additional chassis ground terminal is provided next to the power cord and use of that additional ground is recommended. FTA provides ground cabling in all shipments.
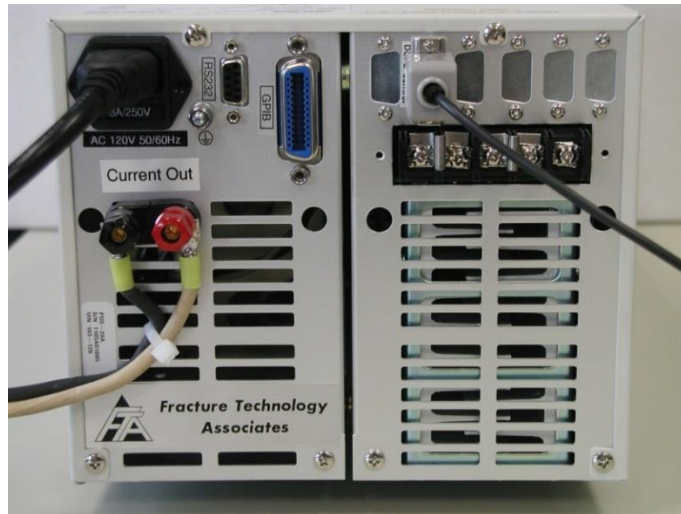
On the FTA DCPD amplifier, gain selection and auto zero are provided using the panel controls on the Ectron modules. The two shielded **Input** connectors above the toggle switches (left and right) connect to the active and reference probes. The active probe senses the voltage drop across the crack while the reference probe senses the voltage drop at a location not significantly affected by crack growth. The left-side Ectron module is linked to the left-side connector and the right-hand module is linked to the right-side connector. Active/reference assignment is at the discretion of the user.

The two **BNC Output** connectors below the toggle switches are the amplified and conditioned voltage outputs for the active and reference probes respectively. They are each paired with the shielded connector above. The channel designated 'active' by the user connects with **IN5** on the ADwin-Gold. The channel designated 'reference' by the user connects with **IN6** on the ADwin-Gold.

The toggle switch between the **Input** and **BNC Output** connectors is the **Filter Switch** for each channel. Filter 'out' is the down position, filter 'in' is the up position.

On the back panel of the amplifer may be found the illuminated power switch; a fuse holder with a 2-amp fuse; and a 12-volt DC power cord. A 120-volt AC to 12-volt DC power supply is provided with the system.

To the left of the DC power cord is a ground terminal. The unit must be connected to ground to function properly: FTA provides ground cabling in all shipments.

Note that the unit is ready for operation only after all the cables have been installed. *This includes attaching the potential drop and current wires to the specimen.* In addition, the FTA DCPD testing software must be open and all test parameters entered before the system's power is turned on. Activation of the FTA software sends a logic signal to the DC power supply enabling the polarity switching relays to start in the forward position. Detailed instructions for use of the FTA-DCPD system are included in the test procedure provided in Section 3.2 of this manual.

2.3   PC Setup and Installation of the FTA Software

1. Deactivate the computer's power saving modes, including standby and hibernation. The settings of the Windows display should be **high color**, **800 by 600** pixels (small fonts) or **1024 by 768** (large fonts). The **Theme/Appearance** should be set to **Windows Classic,** regardless of the computer's OS.
2. From the FTA CD, execute the three setup files for **Testing, Analysis,** and **Testing Playback** from their respective folders. It is recommended the software be permitted to create the default directories of c:\Program Files\NLFT Testing and c:\Program Files\NLFT Analysis.
3. Each program can now be launched from the **Start Programs** menu. To launch the applications from the desktop, right click on their filename in the **Start Programs** menu and **Send** them to the desktop (create shortcut). Icon files FTAlogo3.bmp or FTAlogo4.bmp may be used for customization. These icons can be found in the **NLFT Testing** folder in the **Programs** directory.

2.4   Installing the ADWin Drivers on the PC

Use the ADwin drivers contained on the FTA-provided CD rather than the gold-colored CD provided with the ADwin. Version 3.20.1200 should be used for 32-bit systems with Windows 98 through Windows XP; for Windows 7 use version 5.00.10.00. *Users of older Adwins with ISA-link-to-USB adaptors must use the ADwin driver version 3.00.2332.* Adwin drivers for 64-bit systems can be provided by FTA or found on the web at www.adwin-downloads.de.

Copy the entire ADwin folder onto the PC desktop and carry out installation from there. Before installing the drivers, connect the ADwin (powered off) to the computer.

1. Run the installation program in the ADWin folder. From the ADWin splash screen, execute the complete Driver and ADbasic setup.
2. V. 3.20.1200 users will be prompted to restart the computer at this point. Do not do so. Return to the splash screen, choose Developer-Software setup, and repeat installation. Exit the installation program.
3. Restart the computer with the ADwin powered off.
4. Power up the ADwin. When prompted by the 'new hardware wizard', choose to find the drivers from a specific location. Go the ADwin folder on the desktop and choose to search. Ignore warnings about Windows logo testing and finish the installation.
5. The installation window will reappear when this first stage of installation is complete. Click 'next', choose not to search the internet, and continue with all defaults.
6. Next, go to **Start\Programs\ADwin\ADconfig**. For v. 3.20.1200, remove the two default 'Link' type connections. Add USB from the drop-down menu and click OK to exit the form.
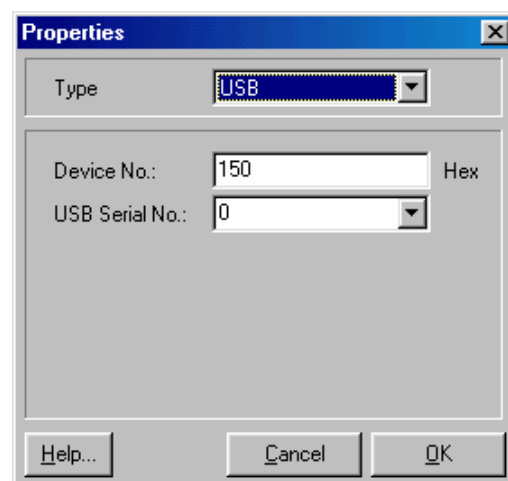
For v. 5.00.10.00, on the ADconfig screen choose 'Add USB' from the menu across the top. Choose Device #150 [hex] and USB Serial #0.
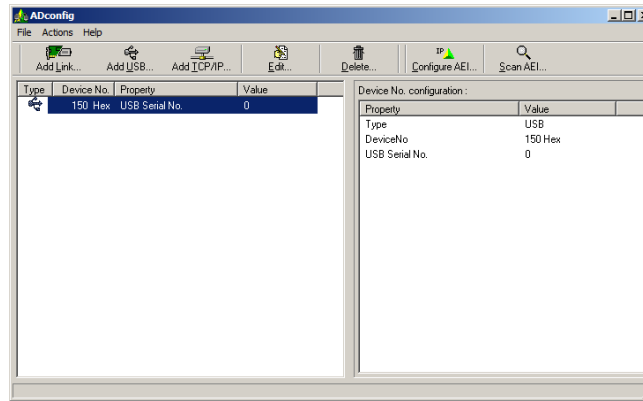
7. Double click on the Adbasic icon on the computer desktop. Leave the license key blank and click 'OK' twice to open the ADbasic program. For v. 3.20.1200, go straight to step 8. For v. 5.00.10.00, go to the 'options' tab at the top of the window and choose 'compiler'. Make sure 'System' = ADwin Gold; 'Processor' = T9; and 'Device No.' = 150 Hex. Close the window.

8. Press the red 'B' button on the Adbasic screen to boot the ADWin.
9. A flashing green LED on the ADwin-Gold unit means a successful connection has been established. Unless the hardware is changed, booting the system from this point forward will be done automatically when the FTA testing software is opened.
10. The final installation may be confirmed by viewing the following form in the Windows' Device Manager.
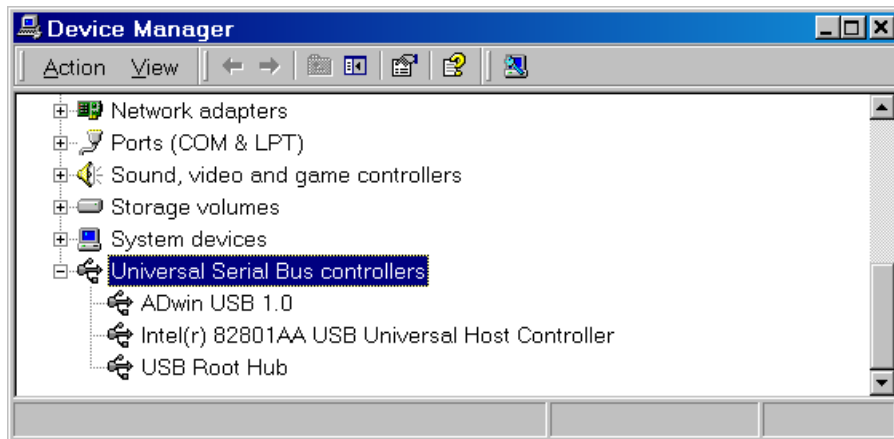
2.5   Testing in Simulation

Note that it is possible to disconnect the ADwin from the test machine and operate the NLFT program in simulation mode. Thus, users may familiarize themselves with the FTA software and evaluate operation of the system without endangering the test machine or expensive specimens. See Section 3.2 of this manual for sample test procedures.

To simulate a compliance test, use BNC cables to jumper the ADwin's **OUT 1** to **IN 1** and **IN 2.** To simulate a DCPD test, jumper **OUT 1** to **IN 1** and connect **PIN 1** of connector 2 to both of the center posts only of [PD active] **IN 5** and [PD reference] **IN 6.** Run the program as normal: new users may benefit from experimenting with the sample test procedures provided in Section 3.2 of this manual.
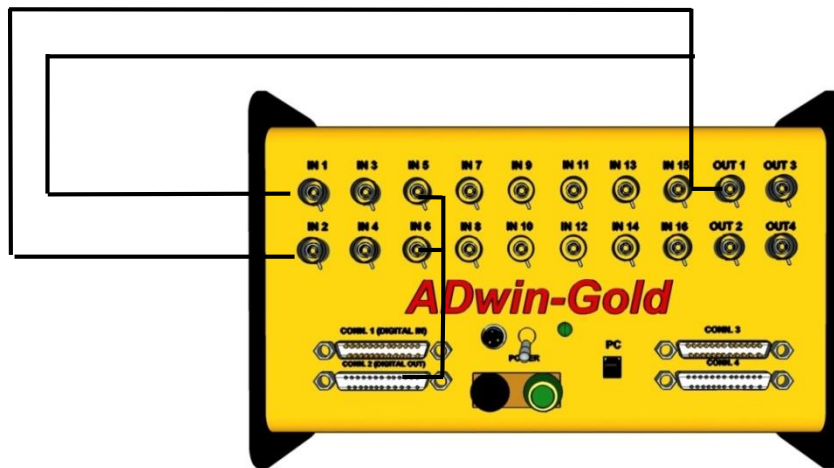
2.6   Tuning

Make sure the machine controller is in displacement (actuator) control. Tune the system as you normally would for a displacement controlled test. Since loading is static, some dither might be required.

3.0   Using the NLFT Testing Software

The following section of this manual opens with a discussion of the six file-types associated with the testing program. Section 3.2 contains an illustrative test procedures, which detail the use of both the compliance and DCPD testing software. Analysis of test results is covered in sections 5 through 8.

3.1   Understanding Testing Files

It is important to note that six different types of file are associated with the testing program, each with its own extension. Some of these files are created automatically during testing, while others must be configured and saved by the user. Several are required by the FTA analysis software. Procedures for using these files are detailed throughout this manual, but a summary of the different files is given briefly, for information, below.

- **Test Parameter** file (.pr5 extension): key information unique and necessary to the test, such as specimen dimensions and initial test conditions. Although the information is required, the files themselves are optional, and may be loaded, modified and saved by the user for ease of use.

- **General Information** file (.gn2 extension): general information not required for testing, but that may be common across tests (such as test temperature or material description). These optional files may be loaded, modified and saved by the user. General information may also be added at analysis time.

- **Log** file (.log extension): details of the test including test parameters and data that are part of the analysis file (.in5). A log file is appended, rather than overwritten, every time it is saved. See Appendix B1 for a description of log files.

- **Analysis** file (.in5 extension): data required for the Windows Visual BASIC analysis software. See Appendix B2.

- **Unloading Data** file (.unl extension): calibration factors and the voltages of the load-displacement unloading slopes. See Appendix B3.

- **Raw Data** file (.raw extension): load-displacement information including elapse time; load; displacement; and auxiliary channel information recorded in engineering units. See Appendix B4.

3.2 Running a Test Using the FTA NLFT Software

The following is a general outline illustrating use of the FTA software to conduct a non-linear fracture toughness test (E1820) at room temperature, using both a clip gage and DC potential drop. These steps are meant as guidelines only in order to demonstrate use of the FTA testing software. For detailed descriptions of the menus and forms referred to below, see Section 4 of this manual. For an analysis procedure, see Section 5.3.

*Note that when data are entered in a text box on a program menu, the data are not transferred to the corresponding variable until another text box or command button (such as **Send to DSP**) is clicked. If data have been entered in a text box but **Send to DSP** has not been clicked, a blinking red reminder message will appear.*

The following step-by step guide to test execution applies both to compliance and DCPD testing. Where the process differs, directions for compliance testing appear in blue and directions for DCPD testing appear in red. These steps are a guideline only: a thorough knowledge of governing ASTM standards is essential.

3.2.1 SETUP

1. Turn on power to the ADwin.

2. Power to the FTA-DCPD amplifer and power supplies should be on, but the power supply's **Output** (number 1 on keypad) should be toggled to **Off** (the front LED panel on the power supply should display 'Output Off'). The unit will start with a default voltage of 5 volts, which is recommended for most applications. The default current is 1 amp. With **Output** set to off, the current may be changed using the keypad. To input a current of 10 amps, for example, press **CURR** (number 8 on the keypad) to bring up a new menu. Press the numbers 1 and 0. Press the blue **ENTER** key to confirm the new setting.

3. On the FTA-DCPD amplifer, set the desired gain with the black dial on the appropriate Ectron module (left module for left channel, right module for right channel). Remember that the actual gain is 10 times that displayed on the module. Also ensure that the amplifier's **VERN** toggle switch is in the **OUT** position and the left-hand toggle switch is in the **X1** position. Note that the toggle switch for the excitation has been locked in the 5 volt position. *Do not tamper with this lockout.*

4. Open the NLFT testing program. *If the program is already open from a previous test, skip straight to step 7 of this procedure*. Ensure the green light on the Adwin is blinking, which indicates communication with the computer. Reboot the Adwin to establish communication, if necessary. On the initial **Splash Screen**, choose the crack monitor type: **Compliance** (for clip gage

measurement of crack length and J) or **DC Potential Drop** (for DCPD measurement of crack length and clip gage measurement of J).

5. Select **New Test** (select **Resume** only if restarting a test, for example, after a system crash).

6. The **Main Menu** appears: select **Unit Type** (English or Metric).

7. From the **Input** menu, select **Data** from the dropdown list. The **Data Input** form appears, with the **Initialize** tab foremost. *Note that the form has six tabs, which are typically addressed from left to right.*

> *If the program is already open from a previous test, ensure **FNG OUT** on the **Status** screen reads zero. Ensure **STOP** is active on the **Ramp Generator** and that the three boxes under **Data Acquisition Status** are unticked. On the **Initialize** tab of the **Data Input** form, **Initialize** the new test by ticking **Set Delta a to Zero** and **Clear Data Storage Buffer**. Press **Send to DSP** to clear the Adwin of data from the previous test.*

8. Select the **Initialize** tab of the **Data Input** form and enter the **Test ID**.

9. Press **Start Data Files**: this enables you to save .log files; .unl files (compliance only); and .raw files as well as specify their data storage path.

10. Press **Load Test Parameters** (.pr2 files for common specimen geometries may be found in the NLFT testing program directory).

11. Ensure the **K-Calibration Type** and **PD Calibration Type** are appropriate for the application.

12. The **Send to DSP** button will blink when changes are made, reminding you to send the changes to the ADwin by pressing **Send to DSP**. As an option, press **Print to Log** to send data input to the .log file.

13. Address the remaining five tabs on the **Data Input** form (details may be found in Section 4 of this manual). Go first to the **Coefficients** tab and confirm correct values.

14. Go to the **Dimensions** tab. Ensure values are correct and change as necessary. *The program will automatically calculate limit load based upon the values entered. The limit load is based on the plastic limit derived from the specimen's yield strength and geometry and is useful for determining the maximum load range for the test.*

15. Address the **Calibration** tab. Review and adjust values as required. *It is important to note that values in red must correspond to settings on the controller and PD instrumentation. A full scale of 10 volts is assumed for all controller settings and entry must be 10% of full-scale range. For a load range*

of 25,000 lbs, for example, the entry in the **Load Cell Calibration** *text box should be 2500.* **PD gain** *(if running a DCPD test) should be the same as the gain set on the FTA amplifier x10 (a gain of 500 on the amplifier should be entered as 5000 on the* **Calibration** *tab).* **Initial PD** *should be set to zero.*

16.   Select the **Data Acquisition** tab, on which criteria for and characteristics of automatic unloading slopes or DCPD crack length measurements are determined. *For example, if* **Load** *under* **Unloading Slope**/**DCPD Acquisition Interval** *is set to 500 pounds, then that action will be taken every time the load increases by 500 pounds. Please see Section 4.4.1.5 for more details on the* **Data Acquisition** *tab.*

17.   *Go to the* **Limits** *tab. The parameters on this tab specify the limits (***Transducer Limits, Load Drop Limit***) at which the command signal will go to* **STOP** *or the test will be terminated (***Delta a Limit***).*

- **Load Limit Hold** determines the initial ramp-up load level (which in most cases should not exceed the Pmax of the precrack), at which point the system can be tested for signal quality and correct crack-length reading before the start of the test proper.

- **Ramp Down Amount** specifies how much the load will ramp down upon test termination (before going into **Hold** mode).

- **Automatic Preload** is a useful alternative to the controller setpoint and applies a [typically low] constant load to the specimen when, for example, it is coming to test temperature or being held steady for other purposes before testing commences.

18.   Press **Send to DSP** to send all changes on the **Data Input** form to the ADwin. **Print to Log**.

19.   Return to the **Initialize** tab and press **Save Test Parameters**. This updates the .pr2 file for future use.

20.   Minimize the **Data Input** form, but do not close it.

21.   Return to the **Main Menu** and select the **Options** form from the **Input** dropdown list. The default settings are appropriate for most applications. **Apply Rotation Correction to Delta a** should always be ticked when compliance-testing a C(T) specimen. For bend-bar testing, **Normal Load Cell Polarity** and **Normal Stroke Polarity** should be unticked. See Section 4.4.2.2 for more details on the **Options** menu.

22.   Press **Send to DSP** regardless of whether any changes have been made. Minimize but do not close the **Options** menu.

23.   Return to the **Main Menu** and select **General Information** from the **Input** dropdown list. Load a previously-saved .gn2 file or input new values and save the file for future use. Information about both the test and precracking regime

can be recorded. *Note that some precracking parameters are necessary for fulfilling validity requirements during analysis.* The **General Information** form may be closed before proceeding.

24. Return to the **Main Menu** and open the **Ramp Generator** from the **Control** drop-down list. The **Ramp Generator** is the form from which the test is controlled and must not be closed while the test is running. Changes on this form are sent immediately to the ADwin.

25. On the **Ramp Generator**, verify the **Ramp** and **Data Acquisition Rates** and change as appropriate (see details in Section 4.5). These rates may also be changed on-the-fly while the test is running, if necessary. Ensure once again that none of the check-boxes is selected and that the program is in **STOP** mode. Minimize but do not close the **Ramp Generator**.

26. Return to the **Main Menu** and open the **Status**; **Load-displacement**; and **J-da (J-delta a)** forms from the **Display** drop-down list.

27. Observe the **Status** display. Verify that the load and displacement channels are active and reading correctly. **FNG Out** should read zero. **Load** should also indicate zero.

28a. **COMPLIANCE ONLY**. Set the test controller to stroke control. Turn on the test machine hydraulics. Enable the external command for full-scale input. Mount the specimen in the test machine. Attach the clip gage and use the controller to adjust the signal to read zero (**Disp 1** on the FTA testing software's **Status** display). If more than 10v will be required for the test, adjust the signal for a negative voltage.

28b. **DCPD ONLY**. Set the test controller to stroke control. Turn on the test machine hydraulics. Enable the external command for full-scale input. Mount the specimen in the test machine. Attach the clip gage and use the controller to adjust the signal to read zero (**Disp 1** on the FTA testing software's **Status** display). If more than 10v will be required for the test, adjust the signal for a negative voltage.

Attach current and potential drop leads to the specimen.

With the FTA-DCPD power supply **Output** still **Off**, zero the volts on the **Status** screen by toggling up the 'auto/man zero' switch at the top left of the amplifier's Ectron module. When the red light has activated, return the switch to its central position. Voltage should now read zero on the NLFT testing software's **Status** screen (**DCPD volts**).
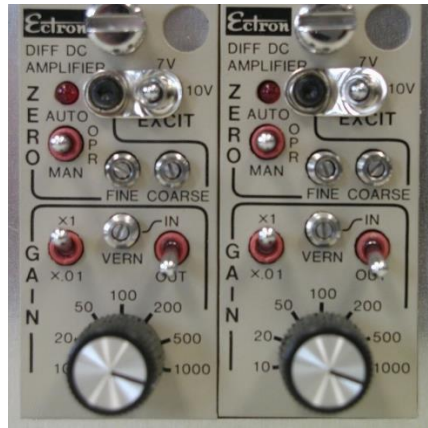
Activate the current output, (**OUT ON/OFF** or keypad number **1** on the power supply). If the FTA software is running and the sample installed correctly, the LED display should appear similar to the figure below, in which a 10 amp current has been selected. In this figure, the voltage of 0.8686 volts is due almost entirely to the voltage drop through the 10-12 AWG wire from the DC power supply to the test sample. Constant current is assured as long as the display voltage is less than the default setting of 5 volts. Note that in addition to displaying the designated current of ~10 amps, the left side of the display shows a square symbol next to the letters 'CC', indicating the constant current mode.
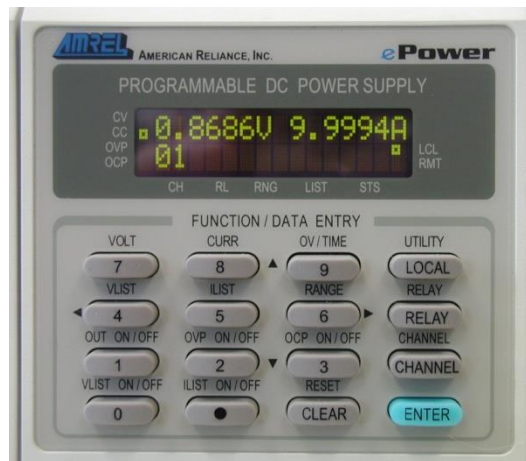
The figure below shows the power supply display if the current wires are not hooked up to the specimen or the FTA software is not running. Note that the left side of the display shows a square symbol next to the letters 'CV', indicating the constant voltage mode. If the system cannot maintain constant current due to the resistance of the current loop then it defaults to the constant voltage mode. The constant voltage mode with a current value lower than desired is most likely due to insufficient wire size in the current path. A current value near zero

indicates an open current path or a low logic signal state on pins 2 and 3 of the DCPD control connector.
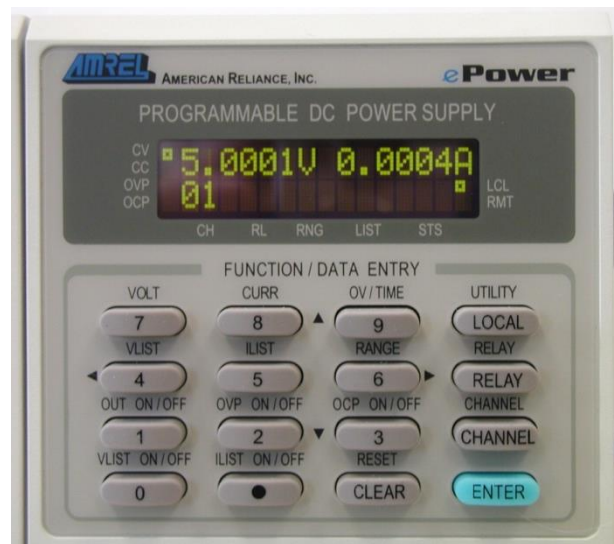
Using the black knob on the amplifier's Ectron module(s), adjust the gain setting such that the amplified signal displayed on the NLFT testing software's **Status** screen is between 0.5 and 1.0 volts. Be sure to enter the final gain setting in the FTA software on the **Calibration** tab, remembering to multiply the selected amplifier gain by 10. (Note that the proper gain setting is also a function of the applied current and must take into account the actual PD calibration and range of crack size. It is important not to reach the ±10 volt amplifier output limit during a crack growth rate experiment). For gains above 10,000, select the **VERN IN** position of the toggle switch. The vernier adjustment can be used to increase the gain to ~25,000.

3.2.2 RUNNING THE TEST

1. Press **Reset MAX** on the **Status** form to reset the **FNG Out** and **Load** on the **Status** display.

2. Return to the **Ramp Generator** and **Clear Message** if necessary.

3. Press **Run** on the **Ramp Generator** to activate the command signal.

4. Press **Load Limit Hold** to ensure that loading will stop when the load limit (set on the **Limits** tab of the **Data Input** form) is reached.

5. Press **Load-Displacement** to begin data acquisition and ensure real-time plotting of load on the **Load-Displacement Display**.

6. Press **Ramp Up** to begin loading the specimen to the load limit hold level.

7. Observe the **Load-displacement** display and **Status** screen (**Load**) to ensure loading stops at the load limit hold. The **HOLD** indicator on the **Ramp Generator** will flash when the load limit has been reached. The **Load-displacement** display may be scaled using the blue buttons.

8a. **COMPLIANCE ONLY**. Return to the **Ramp Generator**. Press the blue **Unload Slope** button once to apply an unload slope to the specimen (the characteristics of the unload slope were determined on the **Data Acquisition** tab of the **Data Input** menu). Observe the green trace on the **Load-displacement** display to verify correct operation:

- the correlation coefficient should 0.9999 or better
- the crack length should be accurate

Repeat unloading slopes as necessary to ensure repeatability of crack length and quality of signal. Scale the unloading slopes as necessary (using the pink buttons). Press **Refresh** to bring up the full display. Delta a should be within ± 0.001 inches and there should be no change in Ci/Co greater than 0.003. When the system is stable, tick **Set Delta a to Zero** on the **Initialize** tab of the **Data Input** form. **Send to DSP**.

Activate **Unloading Slope** on the **Ramp Generator (Data Acquisition Status)** and apply one more unload slope to the specimen. This will be the first active data point in the .in5 file.

8b. **DCPD ONLY**. Return to the **Ramp Generator**. Press the blue **DCPD Acqu.** button once to take a DCPD reading (the characteristics of the acquisition were determined on the **Data Acquisition** tab of the **Data Input** menu). Observe the green trace on the **Load-displacement** display to verify correct operation.

Press **DCPD Acqu**. several more times. Observe the **DCPD Active Voltage** on the **Load-Displacement Display** form. Readings should be consistent within 0.1%. Compute the mean of the final three readings and enter the value as **Initial PD** on the **Calibration** tab of the **Data Input** form. **Send to DSP**.

Activate another DCPD acquisition cycle. The **Load-Displacement Display** should now indicate the correct crack length. Apply at least two more cycles and observe changes in crack length. Verify that the variation in delta a is consistently within ±0.001 inches.

Activate **DCPD Data** on the **Ramp Generator** (**Data Acquisition Status**) and press **DCPD Acqu.** once more. This will be the first active data point in the .in5 file.

9.   When the quality of the signal and repeatability of crack length readings is satisfactory, it is time to start the test. On the **Ramp Generator** disable **Load Limit Hold**. Enable **Auto Unloading** [compliance] [or] Enable Auto DCPD Acq. [DCPD] and press **Clear Message**.

10.   Press **Ramp Up** to start the test. Unload slopes/DCPD acquisition cycles will occur at the intervals and durations set on the **Data Acquisition** tab of the **Data Input** form. View the **Load-Displacement** trace to verify correct operation.

11.   Observe the **J-da (J-delta)** display from the **Display** and adjust the scale as required.

12.   When the final test limit has been achieved (typically the **Delta a Limit** specified on the **Limits** tab of the **Data Input** form), the test is complete. The machine will automatically ramp down to the load specified under **Ramp Down Amount** on the **Limits** tab. When this load is reached, the test will **HOLD**.

13.   On the **Ramp Generator**, disable Unloading Slope and Auto Unloading/DCPD data and Auto DCPD Acqu. On the **Limits** tab of the **Data Input** form, disable **Displacement 1 Limit** and **Send to DSP**.

14.   Press **Run** and then **Ramp Down** to ramp the load to zero. When the load reaches zero press **Hold**. Disable Load-Displacement and remove the specimen from the test machine (if DCPD, turn off the current before removing the specimen). If necessary, press **Ramp Down** again until **FNG Out** reads zero on the **Status** display.

15.   Press **Stop**.

16.   Return to the **Main Menu**. Using the **File** drop-down list, save the analysis (.in5) file in **Version 3 Format**. Also save the load-displacement (.raw) data file and the unload (.unl) data file.

17. Choose **Exit** if you wish to quit the program. For a new test, return to the **Initialize** tab on the **Data Input** form. Enter a new **Test ID** and go straight to step 7 of the preceding section, **Setup**.

4.0   NLFT Testing Software: Description of Menus and Tabs

The following section of the manual offers a complete description of the menus and tabs comprising both the compliance and potential drop NLFT testing applications. The menus are presented in the order in which they would normally be opened during test setup.

For a step-by-step procedure detailing how the software may be used for running an E1820 test, see preceding Section 3.2.

4.1   Splash Screen
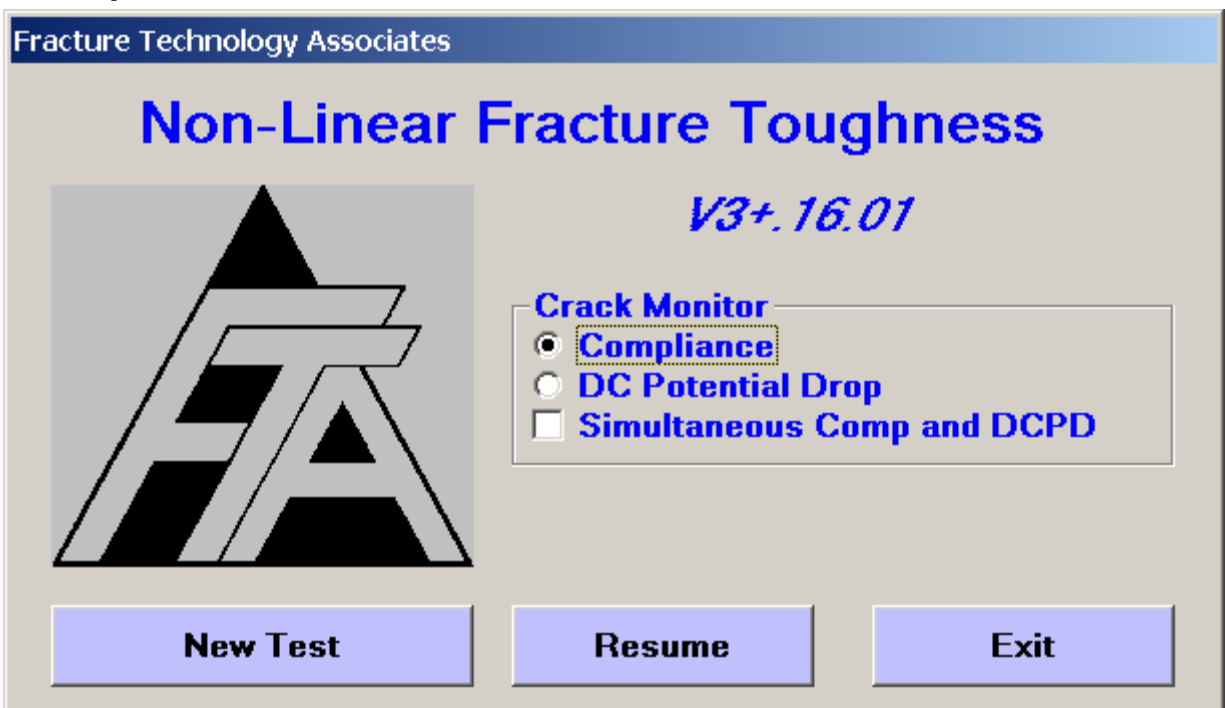
The splash screen is displayed upon start-up. The application title and version number are identified at the top of this form. From this form the **Crack Monitor** type (**Compliance** or **DC Potential Drop)** is selected. If a different crack monitor type is required for subsequent tests, the program must be shut down completely and restarted. Simultaneous **Compliance** and **DC Potential Drop** if desired.

Once the test selection has been made, select **New Test** to call up the **Main Menu** and begin a test from scratch. The **Resume** options allows the operator to resume a test that may already have been in progress (for example, after a system crash or power outage). See Appendix A for details. The establishment of a successful link between the PC and the ADwin is confirmed when the green LED on the Adwin begins to flash.

4.2   Main Menu
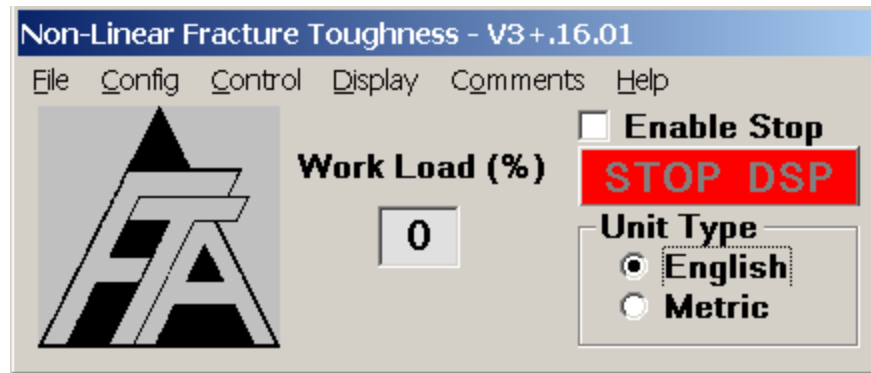
The **Main Menu** is always displayed while the program is running: its default position is in the upper left-corner of the computer screen. The **Unit Type** (**English** or **Metric**) must be selected before other forms may be opened. The **Unit Type** can be changed while the test is in progress or the program is open, but such a change requires closing and reopening all of the other forms. Note that all processing and data storage are done in English units, even if the Metric option is chosen: the unit conversion takes place as data are entered or displayed.

The **Work Load** displays the ADwin workload in % for both high and low priority processes and is for reference only.

Pressing the red **STOP DSP** button terminates all DSP processes. This is not recommended for normal operation and the button is disabled by default. To activate, tick the **Enable Stop** box. Sometimes, if the ADwin does not appear to be responding, enabling stop can reset the Adwin so normal functioning can resume. All DSP processes are then restarted when the **Run** Button is pressed on the **Main Function Generator**. Use with caution.

4.3   File

The first drop-down menu on the **Main Menu** is **File**. See Section 3.1 of this manual for a full discussion of the files produced by the testing software.

4.3.1 SAVE ANALYSIS FILE

Analysis files with the .in5 extension **must** be saved manually, although they are held in memory until the data buffer has been cleared. The user may save the analysis file at any time during the test, noting that saving an analysis file overwrites any previous versions.

Analysis files contain the header and raw test data that will be processed using the analysis program. In addition to the analysis file (which is not saved automatically), the program produces a .raw file containing load-displacement data and time data in engineering units; a .unl file containing unloading slope data in volts; and a .log file that automatically records all data taken during the test. It is nonetheless good practice to save the .raw and .unl files at test completion using the **Save As** feature. Log files are automatically produced and saved as long as this process is activated on the **Options** form. It is also possible to save the analysis file in the FCGR format for da/dt analysis using the FCGR analysis software.

Saving an analysis file overwrites the previous file. Analysis files are held in memory until manually saved or the data buffer is cleared. Log files are saved automatically: however, data dumps between automatic saving intervals (determined on the Options form) must be done manually by pressing Print to Log on the Data Input form.

4.3.2 EXIT

When **Exit** is chosen, the user is prompted to save the analysis files even if they have been previously saved. If **Exit** is selected inadvertently and the ADwin system power remains on, the test can be continued without losing data by selecting **Resume** on the splash screen.

4.4   Config

From the **Main Menu**, the **Config** dropdown menu accesses the **Hardware Configuration** form; the **Test Set-up** form; and the **General Information** form. These forms are addressed in sequence during test setup. All testing configuration (but not function generation or control) is determined on the **Config** forms. Entries are transferred between the PC and the ADwin when the **Send to ADwin** and **Receive from ADwin** buttons are pressed. When a change is made to the input forms, the **Send to ADwin** button will flash indicating that the change has not yet been sent to the ADwin. When the **Receive from ADwin** button is pressed, the user will notice that all fields in blue will be updated with the latest information from the ADwin. Pressing **Receive from ADwin** does not alter test conditions and may be done at any time during a test. All **Config** entries can be dumped to the .log file using the **Print to Log** button on each of the three forms.

NB Text box entries are not transferred to the corresponding variable until you click on another text box or command button such as Send to ADwin.

4.4.1 HARDWARE CONFIGURATION

The **Hardware Configuration** form is used to assign and configure the ADwin's analog input channels. All channels are pre-assigned and cannot be changed by the user. Channels one through six are used, as detailed in the following sections.

The form consists of two tabs: **Calibration** and **Configuration**. These tabs are slightly different depending on whether the compliance or DCPD application is in use, as detailed below.

Hardware configuration entries are not transferred between the ADwin and computer until the **Send to ADwin** or **Receive from ADwin** buttons are pressed. Hardware configuration files (.pr8 extension) may be saved and loaded for subsequent tests using the blue buttons at the bottom of the form.

4.4.1.1 Calibration (compliance)

The **Calibration** tab displays the active ADwin analog input compliance channels IN1 through IN4 and their function under the **Channel Designation** heading. These assignments may not be changed by the user in the steady state single-monitor application. The two auxiliary channels (IN3 and IN4) are optional and should be set to zero when not in use (in this case, the BNC connectors on the ADwin should be empty). IN5 and IN6 are used by the DCPD application only.

The channels are calibrated by the user using the text boxes under **Calibration Factor**, using units/volt.

Enable Run-Stop Interlock is ticked by default and may not be changed.

### 4.4.1.2   Calibration (DCPD)

The **Calibration** tab displays the active ADwin analog input DCPD channels IN1 through IN6 and their function under the **Channel Designation** heading. Channel assignments may not be changed by the user. The two auxiliary channels and DCPD

Ref[erence] (IN3, IN4, and IN6) are optional and should be set to zero when not in use (in this case, the BNC connectors on the ADwin should be empty).

The channels are calibrated by the user using the text boxes under **Calibration Factor**. All calibration factors are in units/volt except **DCPD Active** and **DCPD Ref[erence]**, which relate directly to the proportional gain selected on the amplifier. When using the FTA DCPD system, the number entered for IN5 and IN6 must be 10X that selected on the associated Ectron module: that is, if a gain of 500 is selected on the amplifier, then a gain of 5000 should be entered on the **Calibration** tab).

Enable Run-Stop Interlock is ticked by default and may not be changed.

4.4.1.3   Configuration (Compliance and DCPD)
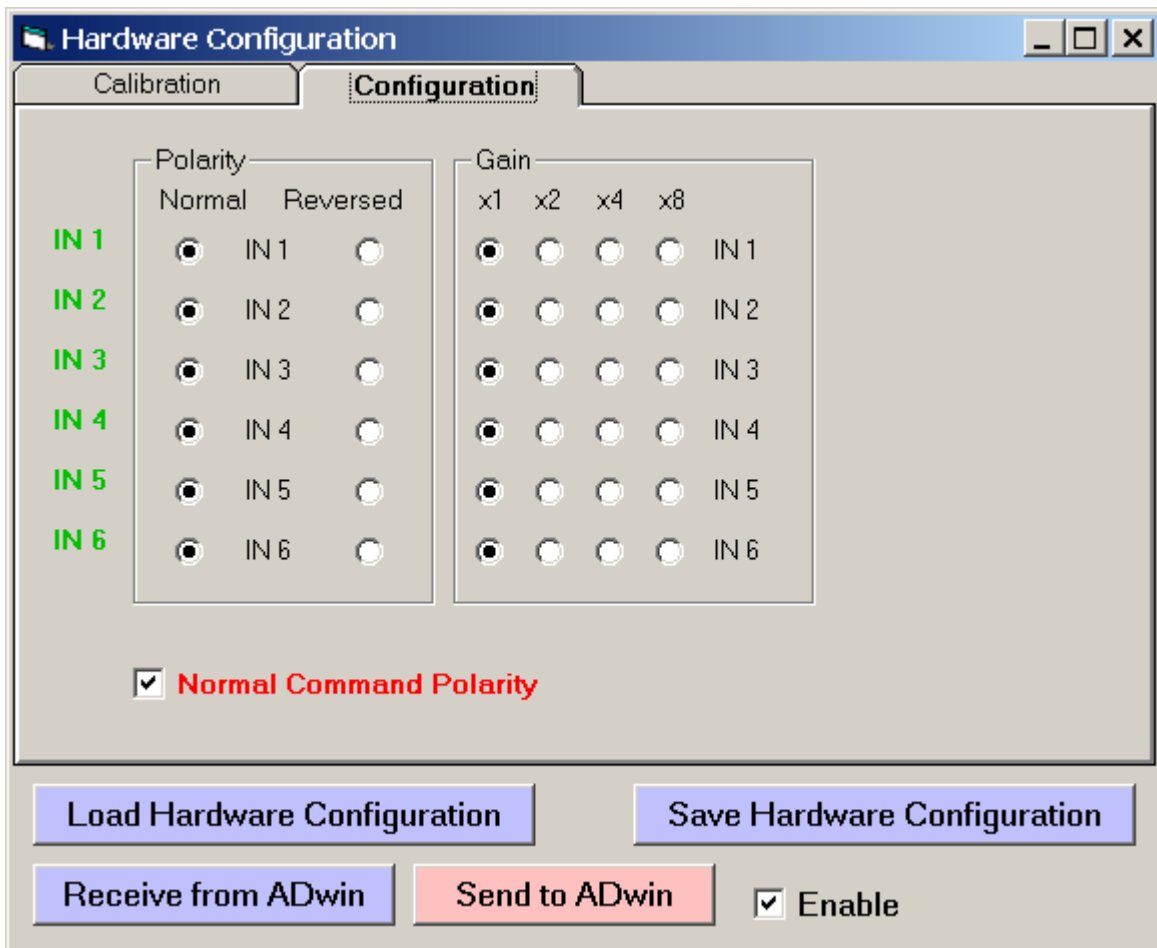
For each of the ADwin input channels, the **Configuration** tab allows designation of **Polarity** and programmable **Gain**. Default selections are appropriate for most applications with the following exceptions:

- **Polarity**

    IN1: increasing voltage with increasing load is the default setting for most geometries with the exception of the compressive loading of bend bars, for which polarity should be reversed. If the **IN1** polarity is reversed, then the load cell polarity must also be reversed by unticking the **Normal Command Polarity** option below it. *Use this option with caution. Do not change the polarity while the ADwin is in control. The polarity cannot be changed while the function generator is running.*

    IN2: increasing voltage with increasing displacement is the default setting and appropriate for most applications.

    IN3: normal polarity is chosen by default

    IN4: normal polarity is chosen be default

    IN5: specifies the polarity of the **active DCPD signal.** This option should be **Reversed** if the potential signal is negative when the current is in the forward direction (for example, if the hardware configuration has been accidentally reversed)

    IN6: specifies the polarity of the **Reference DCPD signal.** This option should be **Reversed** if the potential signal is negative when the current is in the forward direction (for example, if the hardware configuration has been accidentally reversed)

- **Gain:** the default gain of x1 provides + to -10 volt inputs, which is appropriate for most steady-state testing. Higher gains allow for greater resolution but offer less range: lower-level signals could benefit from gains of **x2** (+ to -5 volts), **x4** (+ to -2.5 volts) or **x8** (+ to -1.25 volts). Changes to the **Gain** on the **Configuration** tab do not require any alterations on the **Calibration** tab.

4.4.2 TEST SET-UP

The **Test Set-up** form consists of eight tabs: **Initialize; Calibration; Coefficients; Dimensions; Compliance; DCPD; Storage;** and **Limits.** When organized in a single row, these tabs appear in the logical order in which parameters would be entered to start a test. Inactive data fields are displayed in gray.

*NB It is important to remember that entries are not automatically transferred between the PC and the ADwin, but must be sent manually using the **Send to ADwin** and **Receive from ADwin** buttons at the bottom of the form. Once a test has been started, it is extremely important, before changing any test conditions, to **Receive from ADwin** in order to ensure the PC and ADwin are in agreement.*

4.4.2.1   Initialize

The tabs of the **Test Set-up** form are organized logically and, when displayed in a single row, addressed from left to right by the user. Initial test setup is accomplished on the **Initialize** tab. First, the **Test ID** must be entered, establishing the name of all the test's associated files (analysis files (.in5), log files (.log), load-displacement files (.raw) and unloading slope files (.unl)). An extension is not entered in this field because it will be automatically appended by the software. When changing the **Test ID**, the user will be prompted to save the current analysis file. The **Send to ADwin** button must be pressed a second time to confirm the name change.

Three blue buttons at the top of the tab establish the data storage path and allow creation and saving of parameter files:

- **Start Log File:** starting a log file also establishes the data storage path (prompted by a pop-up window when the button is pressed) for all files created by the testing program. It is recommended that users create discreet storage folders out with the PC's program directory, since some computers require administrator privileges to access such files later on. Once initiated, log files are saved and updated automatically by the program.

- **Load Test Parameters**: loading a parameter (.pr5) file populates the **Data Input** form with all the information necessary to start a test (except the **Test ID)**, edited as required. Parameter files contain geometry designations, specimen dimensions, initial Pmax values, and other specific test information. Use of parameter files can save time and reduce the risk of errors when entering repetitive information. FTA supplied parameter files can be used for either **Compliance** or **DC Potential Drop**. However, once these files are saved, they become unique to the crack monitor type. *Note that .par files from previous versions of the software are **not** compatible with the current version 3+.16.*

  Several parameter files for commonly-used specimen geometries are supplied in the program directory for the testing software. These files may be modified for users' particular needs. Refer to the latest ASTM E1820 and E647 test standards for corresponding formulas and coefficients. Test parameter files supplied by FTA include:

  - C(T) FF.pr5: compact tension with front face clip gage
  - C(T) LL.pr5: compact tension with load line clip gage
  - M(T) 4W.pr5: middle crack tension, 0.6" gage length, 4" panel width
  - SE(B).pr5: single edge 3-point bend
  - SE(T) PIN LOADED.pr5: single edge tension (pin loaded)
  - SE(T) RIGID.pr5: single edge tension (rigid grip)
  - ESE(T).pr5: eccentrically load single edge tension
  - SF.pr5: surface flaw tension
  - CC.pr5: corner crack tension

- **Save Test Parameters**: pressing this button saves the current information with the Test ID for future reference and/or loading. Parameter files may also be saved from the **Limits** tab when all test setup fields are complete.

The **Initialize** tab also includes the following three check boxes at the upper right:

- **Initialize**: sets to zero the values of crack length and current a/W (used only at the start of a new test, after the previous test's data have been saved).

- **Clear Data Buffer**: clears all previously calculated data stored in memory. This is typically used when starting a new test. Ticking **Clear Data Buffer** automatically issues a prompt to store the data to an analysis file.
- **Clear Elapse Timer**: resets the hour and day-elapse timer on the **Status** display.

After a box is ticked, the **Send to ADwin** button must be pressed to communicate the change to the ADwin. The box is then cleared automatically so the action is not repeated accidentally. All of these selections may be made without stopping a test and may be carried out individually or in combination.

If the data buffer has been cleared unintentionally (or the operator has second thoughts!) it may be restored using the **Restore Data Buffer** checkbox. This is particularly useful if the analysis file was not manually saved before the buffer was cleared.

The **Data Buffer** display shows the current status of the buffer, either as an absolute value or **% Used**. Data stored include elapsed time; force; displacement; auxiliary1; auxiliary2; crack size; unloading compliance; DCPD active; DCPD reference; and DCPD normalized. The buffer allows for a maximum of 50,000 lines of data in the analysis (.in5) file.

If the data buffer has been cleared accidentally (by activating the **Clear Data Buffer** box in the **Initialize** frame), it may be restored by activating the **Restore Data Buffer** box and sending to the ADwin. If too few data points reappear, more may restored by entering the total desired number in the **Specify Data Buffer Size** field. Caution should be exercised when using this capability, however, as it is possible to include data from previous tests if too many points are specified.

4.4.2.2   Calibration

The **K Calibration Type** is selected automatically when the appropriate test parameter file is loaded. It may be changed, however, when the user is testing a specimen geometry for which a test parameter file does not exist or when creating a new test parameter file from scratch. To change a K calibration, tick the **Enable Cal Type** box, make the desired selection, then untick the **Enable Cal Type** box. **Send to ADwin**. Do not forget to untick the **Enable Cal Type** box once all changes are made!

See Appendix G of the FCGR manual for the stress intensity solutions used by the FTA software.

- **Polynomial (Type 1)**: allows the user to enter coefficients of a polynomial expression up to the 5th order. The form of the expression is taken from the ASTM E647 stress intensity (K) solution for the compact tension, C(T), geometry. However, the user can apply other coefficients for different geometries such as the disk-shaped compact tension, DC(T), as long as the K expression is of the same form. Type 1 Type 1 is the form suitable for the compact tension sample as follows:

$$K = (P /(B\sqrt{W})) \bullet ((2+a/W)/(1-a/W)^{1.5}) \bullet f(a/W)$$

- **Polynomial (Type 2):** a more general form suitable for custom K calibrations:

$$K = \sigma\sqrt{\pi a} \bullet f(a/W) = (P/(BW)) \bullet \sqrt{\pi a} \bullet f(a/W)$$

- **Polynomial (Type 3):** an alternative form suitable for custom K calibrations:

$$K = (P /(B\sqrt{W})) \bullet f(a/W)$$

- **Center Crack**, M(T): the K solution is taken from ASTM E 647
- **Single Edge Crack**, SE(T): assumes a pin-loaded specimen with the K solution taken from: H. Tada, P. Paris, G. Irwin, Stress Analysis of Cracks Hankbook, Second Edition, 1985.
- **SEN rigid** for a rigidly gripped single edge notch
- **Bend**, SE(B): K solution is taken from ASTM E399
- **Extended Compact**, ESE(T): K solution is taken from ASTM E 647.
- **Surface Crack** the solution assumes an aspect ratio of 1.
- **Corner Crack** the solution assumes an aspect ratio of 1.
- **Look-up Table** (see further details below)

The DCPD version of the **Test Set-up** form (shown at the beginning of this section) includes **PD Calibration Type** options. When a standard test parameter file is loaded, the selection of PD calibration type is automatic. However, when creating a unique parameter file, the user may change the PD calibration. To change a PD calibration, tick **Enable Cal Type**, make the desired selection, then untick the **Enable Cal Type** box. **Send to ADwin**. Do not forget to untick the **Enable Cal Type** box once all changes are made!
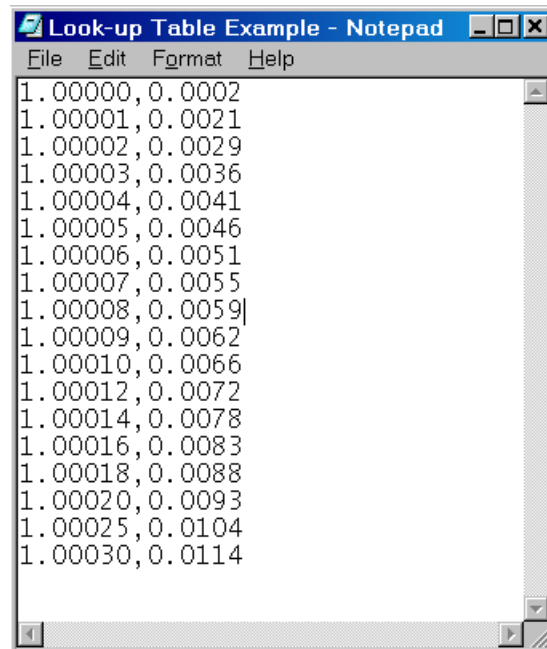
- **Polynomial**: requires the input of user-supplied coefficients. The form of the equation in terms of a/W is:

$$a/W = B_0 + B_1(V_a/V_{0,a} \bullet V_{0,r}/V_r) + B_2(V_a/V_{0,a} \bullet V_{0,r}/V_r)^2 +$$

$$B_3(V_a/V_{0,a} \bullet V_{0,r}/V_r)^3 + B4(V_a/V_{0,a} \bullet V_{0,r}/V_r)^4$$

Where:

V_a = instantaneous active voltage

$V_{0,a}$ = starting active voltage

V_r = instantaneous reference voltage (equal to 1 when reference probe is not used)

$V_{0,r}$ = starting active voltage (equal to 1 when reference probe is not used)

- **Johnson's formula:** may be selected for most specimen geometries. This is a closed form solution for crack length and can be found in ASTM E647. It should be noted that when applying Johnson's formula to the C(T) geometry, a starting a/W > 0.3 and a probe spacing to width ratio of 0.35 gives the most accurate result.

- **Surface Crack**: for a surface crack or corner crack. The solution assumes an aspect ratio of 1.0.

- **Look-up Table**: for situations where a polynomial expression or Johnson's formula are not sufficiently accurate. The data pairs are entered in a file with the .dat extension in tabular form as shown in the example below:

```
Look-up Table Example - Notepad
File  Edit  Format  Help
1.00000,0.0002
1.00001,0.0021
1.00002,0.0029
1.00003,0.0036
1.00004,0.0041
1.00005,0.0046
1.00006,0.0051
1.00007,0.0055
1.00008,0.0059
1.00009,0.0062
1.00010,0.0066
1.00012,0.0072
1.00014,0.0078
1.00016,0.0083
1.00018,0.0088
1.00020,0.0093
1.00025,0.0104
1.00030,0.0114
```

The first column is the normalized DCPD reading and the second column is the corresponding crack-length to width ratio **(a/W)**.

The **Geometry Type** is selected automatically when the appropriate test parameter file is loaded. It may be changed, however, when the user is testing a specimen geometry for which a test parameter file does not exist or when creating a new test parameter file from scratch. To change a Geometry calibration, tick the **Enable Cal Type** box, make the desired selection, then untick the **Enable Cal Type** box. **Send to ADwin**. Do not forget to untick the **Enable Cal Type** box once all changes are made!

The **Geometry Type** is necessary to assign eta and gamma functions for non-linear fracture toughness. It is not necessary to assign a geometry for linear elastic fracture toughness.

- **C(T):** compact of similar type
- **M(T):** center crack
- **SEN(B):** single edge crack bend
- **SEN(pin):** single edge crack tension (pin loaded)
- **SEN(rigid):** single edge crack tension (clamped)
- **Neutral:** no geometry adjustment

4.4.2.3 Coefficients

Test Set-up

Test ID:	test	Tab Style: ○ 1 Row ◉ 2 Row

Tabs: Compliance | DCPD | Storage | Limits
Inititialize | Calibration | **Coefficients** | Dimensions

Stress Intensity

K0	0.886
K1	4.64
K2	-13.32
K3	14.72
K4	-5.6
K5	0.0

Compliance

C0	1.0002
C1	-4.0632
C2	11.242
C3	-106.04
C4	464.33
C5	-650.68

Type 1: $K = (P / (B * W^{0.5})) * ((2 + a/W) / (1 - a/W)^{1.5}) * f(a/W)$
Type 2: $K = (P / (B * W)) * (PI * a)^{0.5} * f(a/W)$
Type 3: $K = (P / (B * W^{0.5})) * f(a/W)$

Stress Intensity

	a/W	f(a/W)
I	0.002	1.810
F	0.998	4120.580

Compliance

	a/W	f(a/W)
I	0.002	3.804
F	0.998	3756.000

[Receive from ADwin] [Send to ADwin] [Print to Log]

This tab displays the coefficients of fifth-order polynomial expressions used to calculate stress intensity and crack length. When a selection other than **Polynomial** is made on the **Initialize** tab, the coefficient fields on this tab are disabled and appear in gray. Compliance coefficients are required in all cases for the compliance method of crack-length determination. DCPD applications using polynomial expressions for crack length will require input of user-supplied coefficients.

The **Coefficients** tab shown displays the correct values for a C(T) specimen with a front-face mounted clip gage (CT-comp-load line.pr5).

When using an FTA-provided parameter file, the **Stress Intensity** and **Compliance** ranges displayed at the bottom of the tab are for information only. Consult FTA for more information on user-generated look-up tables.

4.4.2.4 Dimensions

The following values must be entered by the user:

- **Specimen Thickness**, B *(NB When testing surface-crack or corner-crack specimens, width and thickness dimensions are reversed)*
- **Net Specimen Thickness**, B_{net}, for side-grooved samples. If there are no side-grooves, **Net Specimen Thickness** must equal **Specimen Thickness**, as in the example above.
- **Specimen Width**, W. For center-crack specimens enter half the full panel width. *(NB When testing surface-crack or corner-crack specimens, width and thickness dimensions are reversed)*
- **Span to Width Ratio**(bend bars)

- **Pin Spacing.**

- **Modulus of Elasticity**, E.

- **Yield Stress** σ_{ys}.

- **Tensile Stress** σ_{ult}.

- **Crack Length**

Limit Load is automatically calculated by the program in reference to the other dimensions entered by the user.

The **ADC Data Burst Count** parameter specifies the number of analog-to-digital conversions that are averaged for each data point. A value of 83 is recommended since this number cancels 60 Hz AC noise.

4.4.2.5   Compliance

The **Compliance** tab defines the parameters related to crack measurement using unloading slopes.

The following values must be entered by the user:

- **Comp[liance] Gage Length.**

- **Comp[liance] Alpha Ratio**: the ratio between the gage location to back edge distance divided by the specimen width. For example, when testing a C(T) specimen with displacement measured on the load line, alpha = 1. If a front-face displacement measurement is made, alpha = 1.25.

- **Load Drop for Unloading Slopes:** the load drop value, expressed in pounds, should not exceed 20% of the limit load. If no unloading slopes are required during the test, enter zero.

- **Upper Window for Slope:** specifies the upper cutoff for unloading compliance slope measurement based upon percentage of load drop. The excluded portion of the slope is displayed in red on the **Load-displacement Display**. During a long test, it can be useful to decrease this window to capture the linear part of the slope only. The default value of 90% (corresponding to the lower 90% of the slope) is recommended at the start of tests, but this window can be decreased to as much as 50% if the specimen undergoes severe deformation (it is good practice to increase the **Load Drop** in this case). Slopes can also be reprocessed during analysis using the **Testing Playback** software (discussed in Section 8 of this manual).

- **Lower Window for Slope:** specifies the lower cutoff for unloading compliance slope measurement based upon percentage of load drop. The excluded portion of the slope is displayed in red on the **Load-displacement Display**. Generally a value of 0% is recommended.

- **Unloading Slope Delay**: specifies the time interval between holding the command signal at load and starting the unloading slope. The default value of 1 second is recommended for most applications where no creep effect is expected

- **Unloading Options**: allows optional displacement limits for unloading slopes. This is used for cyclic J and is beyond the scope of this manual.

4.4.2.6 DCPD

The **DCPD** tab defines the parameters related to crack measurement using DC potential drop.

The following values must be entered by the user:

- **PD Number of PD Cycles:** … required to determine crack length. A large number gives greater crack length precision but does not update the crack length as often. A value of 2 to 5 is appropriate for most applications.
- **PD Initial Crack Length**: the specimen's starting crack length
- **Initial PD**: this value is initially set to zero, then changed after DCPD data acquisition to calculate crack length. See the test procedure in Section 3.2 of this manual for the order of operations.

- **Initial Reference PD** (if enabled): this value is initially set to zero, then changed after DCPD data acquisition to calculate crack length.
- **Current Delay Factor:** the delay in seconds that the program waits after the current is reversed to allow the voltage to stabilize. A value of 0.5 seconds is recommended for most applications when using a solid-state current source.
- **DCPD Data Buffer Size** specifies the number of DCPD readings between each current reversal. A data buffer size of 50 is recommended.

4.4.2.7 Storage

The **Storage** tab is used to determine the intervals at unloading slopes or DC potential drop measurements are to be taken.

Three text boxes specify conditions at which unloading will occur. Unloading is triggered by whichever condition is met first:

- **Load:** in the example above, unloading slopes will occur every 1000-lb increase in load
- **Displacement:** in the example above, unloading slopes will occur every 0.0002" increase in displacement.
- **Time:** specifies the time interval between unloading slopes.

Four additional check boxes determine which channels, in addition to elapse time, are saved in the .raw file. Only active channels should be selected.

- **Store Load:** must always be selected!

- **Store Disp:** select if a displacement signal is fed into BNC IN2 on the ADwin.

- **Store Aux 1:** select if a signal is fed into BNC IN3 on the ADwin.

- **Store Aux 2**: select if a signal is fed into BNC IN4 on the ADwin.

- **Automatic Zero of Displacement** sets displacement to zero when data acquisition is started. This allows the operator to begin a test with negative voltage at zero displacement, ensuring that the full range is not exceeded during the test.

- **Apply Rotation Correction to Delta a** should always be ticked when compliance-testing a compact tension C(T) specimen.

- **Enable Automatic Analysis File Storage** allows a backup analysis file (no extension) to be automatically saved to the test directory. These files are saved every two hours by default, although this interval can be changed by the user.

4.4.2.8 Limits

The **Limits** tab allows the user to specify conditions outside which the program goes into **HOLD** mode or ends the test. Additionally, the tab is used to automate certain actions that occur at the beginning of a test or when the test is finished.

When **Transducer** Limits are exceeded, the program goes into **HOLD** mode:

- **Load Limit**

- **Displacement Limit**

- **DCPD Active**

- **DCPD Reference**

Other Limits and Actions include the following:

- **Load Limit Hold**: the load at which the command goes to hold. A useful feature at the beginning of tests for applying low loads and evaluating signal quality and repeatability of crack length readings.

- **Load Drop Limit**: the drop in load that triggers the **HOLD** mode.

- **Delta a Limit**: the value of Delta a that, when achieved, will cause test termination and a ramping down of load, as specified by the **Ramp Down Amount**.

- **Ramp Down Amount**: specifies the drop in load after which the command signal goes to hold, typically at the end of a test (when the specified Delta a has been reached).

- **Automatic PreLoad**: typically a low load, applied while a specimen is coming to test temperature. *Enable **Automatic PreLoad** only when the three **Data Acquisition** items on the **Ramp Generator** deselected!* When **Automatic Preload** and **RUN** on the **Ramp Generator** are pressed, the command signal will change so the automatic preload is achieved. Pressing **Ramp Up** is *not* required**.** The load level for the preload may be determined here or on-the-fly on the **Ramp Generator.**
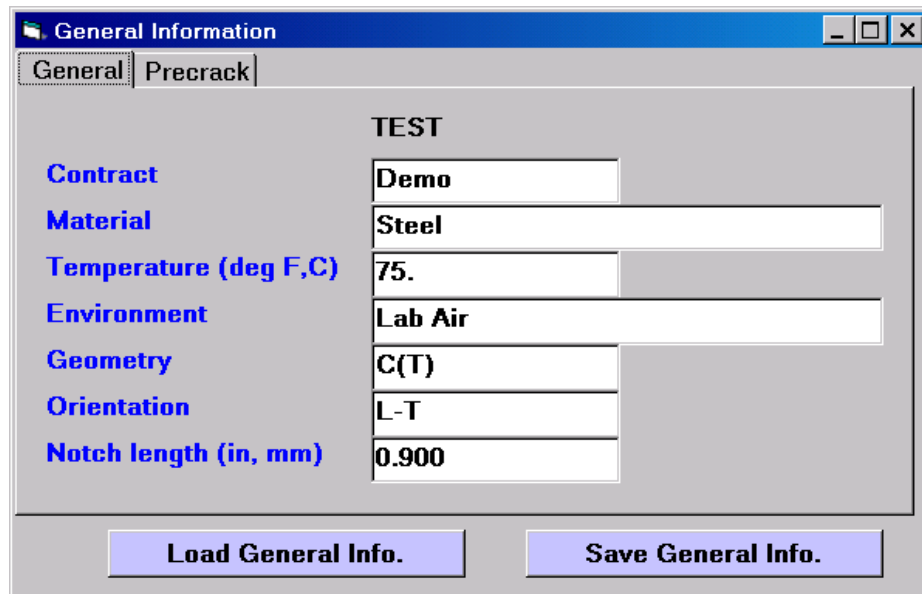
Since this is the final tab addressed by the user during test setup, test parameter files may also be saved from here.

4.4.3 GENERAL INFORMATION

General information may be saved and loaded before or during testing, thus avoiding the entering of repetitive data during analysis and the risk of mistakes. This information is not required to run a test, but is necessary for the cover page of the analysis program output and some validity checks (discussed more fully Section 7 of this manual).

4.4.3.1   General

Load General Info: this button calls up a dialogue box requesting selection of a .gn2. Selecting the appropriate file populates the two tabs of the **General Information** screen. This .gn2 file is created through the **Save General Info** button.

```
General Information                                    _ □ ✕

 General │ Precrack

                          TEST

   Contract              Demo

   Material              Steel

   Temperature (deg F,C) 75.

   Environment           Lab Air

   Geometry              C(T)

   Orientation           L-T

   Notch length (in, mm) 0.900


       Load General Info.          Save General Info.
```

Save General Info: after the fields of the **General Information** tabs have been populated, the input values may be saved as a .gn2 file and loaded during subsequent tests. The user is prompted for an appropriate file name and file path.

4.4.3.2 Precrack

Precrack parameters may also be provided by the user:

General Information

General | Precrack

Precrack Yield Stress (ksi, MPa)	100.0
Precrack Tensile Stress (ksi, MPa)	120.0
Precrack Modulus (Msi, GPa)	30.0
Precrack Load (lbs, kN)	2000.0
Precrack Stress Ratio	0.10
Precrack Crack Length (in,mm)	1.000

Load General Info.   Save General Info.

4.5   Control

4.5.1   RAMP GENERATOR: COMPLIANCE AND DCPD

The **Ramp Generator** is at the heart of a test's control. The **Ramp Generator** *must* be open to activate the **Status** and **Load-Displacement** display forms and must remain open for the duration of the test. Ramp generation and feedback signals are updated three times per second. Unlike the **Data Input** and **Options** forms, changes on this form are sent immediately to the ADwin-Gold. Text boxes with white backgrounds are both for display and entry purposes; text boxes with gray backgrounds are used for display only.

Ramp and **Data Acquisition** rates are displayed in/determined by seven text boxes at the top of the form. They may be changed on the fly as the test progresses. The values shown in the example above are typical for a steel 1T C(T) specimen. Changes in material or specimen geometry will require adjustments to these rates.

Ramp Rate (units are inches per minute):

- **Ramp Up** controls the speed of the monotonic loading between unload slopes.

- **Unload** controls the rate of the unload slopes. This is typically set faster than the ramp rate to save time for unloading slopes

- **Ramp Down** is the ramp rate when the ramp down button is pressed

Data Acquisition Rate (units are points per second):

- **Normal**: the data acquisition rate when the program is not in **HOLD**.

- **Hold:** the data acquisition rate during the **HOLD** mode.

- **Unloading slopes:** the data acquisition rate during unloading slopes.

- **DCPD (if enabled):** the DCPD data acquisition rate during crack length determination (points per second).

Five boxes in the middle of the form determine the status of **Data Acquisition.**

- **Load-Displacement Storage:** when selected**,** load-displacement data are stored in the .raw data file and traced in real-time on the **Load-Displacement Display.**

- **Unloading Slope Storage:** when selected, the unloading slope data that are stored in the .in5 analysis file are included instead of excluded. Typically, this option is not activated until signal quality and crack length repeatability have been verified at a relatively low load (unloading slope data can also be included or excluded at analysis time).

- **Enable Auto Unloading:** when selected**,** then automatic unloading slopes are enabled according to the specifications determined on the **Data Acquisition** tab of the **Data Input** form. Auto-unloading should not be enabled until initial unloading slopes have been applied to verify set up and crack length (see above). Auto unloading will not occur if **Load Limit Hold** is activated. If no unloading slopes are required, the value **Load Drop for Slopes** should be set to zero on the **Data Acquisition** tab.

- **DCPD Data (if enabled):** when selected, DCPD readings that are stored in the .in5 analysis file are included instead of excluded. T. Typically, this option is not activated until signal quality and crack length repeatability have been verified at a

relatively low load (DCPD data can also be included or excluded at analysis time).

- **Enable Auto DPCD (if enabled):** when selected, then automatic DCPD data acquisition is enabled according to the specifications determined on the **Data Acquisition** tab of the **Data Input** form. Auto-acquisition should not be enabled until initial DCPD readings have been taken to verify set up and crack length (see above). Auto acquisition will not occur if **Load Limit Hold** is activated.

Load Limit Hold specifies the level at which command signal will hold (specified on the **Limits** tab of the **Data Input** form) during initial ramping-up. The load limit is usually set to the precrack Pmax for the purpose of applying manual unloading slopes before the test proper has begun.

Automatic Preload adjusts the command signal to ensure a stable preload according to the value specified on the **Limits** tab of the **Data Input** form. This is typically used to hold a specimen at a constant load while it is brought to test temperature. Selecting the **Automatic Preload** box will cause the load to increase *without* pressing **Ramp Up** on the **Ramp Generator** and should be used with some caution.

Run must be selected for the command signal to change and the test to begin. Transducer limits and other limit conditions will set the button to **STOP** or HOLD.

Pressing **Clear Message** clears all displayed error or limit messages, provided the cause of the error has been rectified.

Pressing **Reset Max** resets the display of **FNG Out (max)** and **Load (max)** on the **Status** display.

Five blue buttons at the right top of the **Ramp Generator** allow for manual control of certain aspects of the test and indicate the test's status during auto unloading:

- **Ramp Up**: pressing **Ramp Up** ramps the command signal in the positive direction (dependent on the polarity setting on the **Options** screen). The button turns dark blue when the machine is ramping up in auto-unloading mode.

- **Ramp Down**: pressing **Ramp Down** ramps the command signal in the negative direction (dependent on the polarity setting on the **Options** screen). The button turns dark blue when the machine is ramping down in auto-unloading mode.

- **Hold:** pressing **Hold** stops the command signal from ramping up or down and holds the actuator at its current position. The button turns dark blue when the

machine goes into **Hold** mode - for example, after completion of a manually-applied unloading slope or when limits have been reached.

- **Unload Slope**: pressing **Unload Slope** applies a manual unloading slope to the specimen. Use this for initial unloading slopes, before enabling **Auto-Unloading** and commencing the test proper. When **Auto-Unloading** is enabled, the **Unload Slope** button turns dark blue during automatic unload slopes.

- **DCPD (if enabled)**: pressing this blue button at the top right of the form initiates DCPD data acquisition for determining crack length, *before* enabling **Auto DCPD** (above) and commencing the test proper. When **Auto DCPD** is enabled, the **DCPD** button turns dark blue during automatic data acquisition.

Status displays whether the command signal is in the UP, HOLD, or DOWN mode.

Nine boxes on the right side of the **Ramp Generator** display the current status of the test and command signal. These boxes are for information only and not available for editing:

- **% Used:** toggles between absolute and percent of memory used up in data storage. The limit is 100%. If this value is exceeded, the test will stop. Therefore, judgement must be exercised in selecting data acquisition rates. For normal operation, only a few percent will be required. Note that at 20% of memory usage, the program displays tend to become sluggish.

- **Data Count** displays the number of load-displacement data pairs recorded up to that point in the test

- **Unload Count** displays the number of unloading load-displacement data pairs recorded up to that point in the test

- **DCPD Count (if enabled)** displays the number of DCPD measurements recorded for each DCPD crack size determination

- **A Count** displays the number of crack length determinations from both unloading slopes and DC potential drop recorded up to that point in the test

- **Time (sec)** displays the elapsed time of the test

- **Unload (sec)** displays the elapse time of each unloading slope.

- **DCPD (if enabled) (sec)** displays the elapse time of each DCPD measurement.

- **FNG max** displays the maximum value of the command signal output.

- **FNG Out** displays the current command signal output.

- **RC@0:** (rate change at zero load) When doing cyclic J, it is useful to activate this when going through zero load. This feature shifts the rate to the ramp down rate when going through zero load.
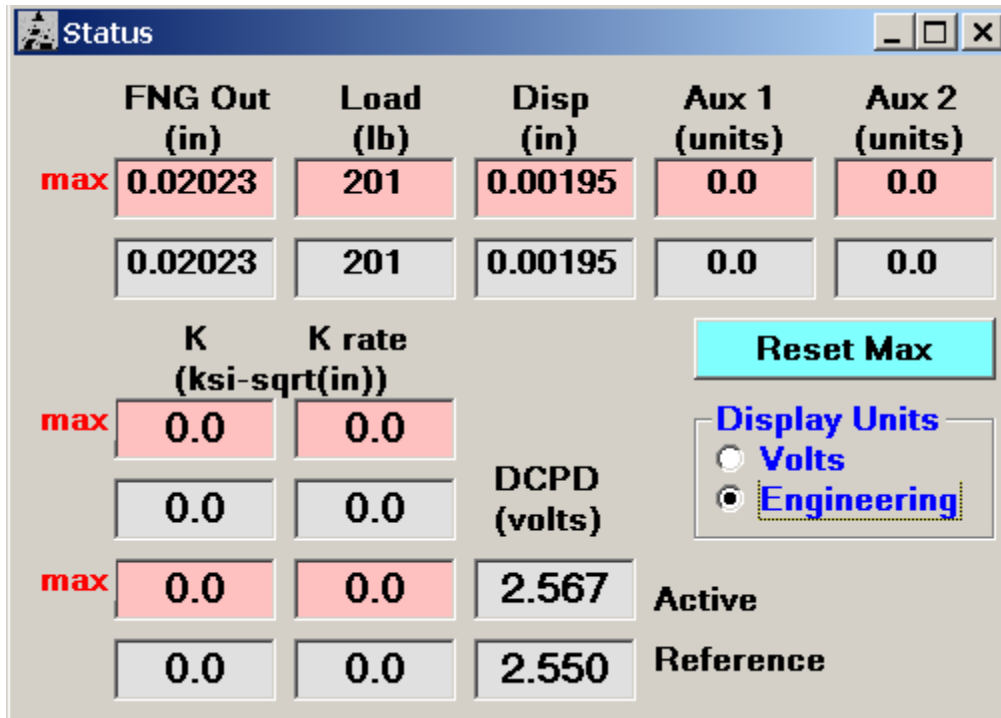
When an error or limit condition occurs, the error is displayed in blinking red letters in place of the **No FNG shutdown conditions** label shown. A list of possible self-explanatory error messages follows:

- 'Command output exceeded full scale'
- 'Load reached full scale or limit setting'
- 'Displacement reached full scale or limit setting'
- 'Auxiliary channel reached full scale or limit setting'
- 'Active PD signal reached full scale or limit setting'
- 'Reference PD signal reached full scale or limit setting'
- 'Load limit hold'
- 'Load drop limit'
- 'Delta a limit'
- 'Data storage buffer overload'

4.6 Display

The **Display** drop down list on the **Main Menu** allows the user to open the **Status, Load-Displacement,** and **J-Δa** displays. These displays may not be accessed until a test has been initialized and the **Ramp Generator** is open.

4.6.1 STATUS

	FNG Out (in)	Load (lb)	Disp (in)	Aux 1 (units)	Aux 2 (units)
max	0.02023	201	0.00195	0.0	0.0
	0.02023	201	0.00195	0.0	0.0

	K (ksi-sqrt(in))	K rate			
max	0.0	0.0		Reset Max	
	0.0	0.0	DCPD (volts)	Display Units ○ Volts ● Engineering	
max	0.0	0.0	2.567	Active	
	0.0	0.0	2.550	Reference	

The **Status** screen displays both the maximum and current signals for **FNG Out, Load, Displacement, Auxiliary** and **Potential Drop** in either volts or engineering units.

The **Stress Intensity** and **Stress Intensity Rate** per minute are also displayed.

4.6.2 LOAD-DISPLACEMENT
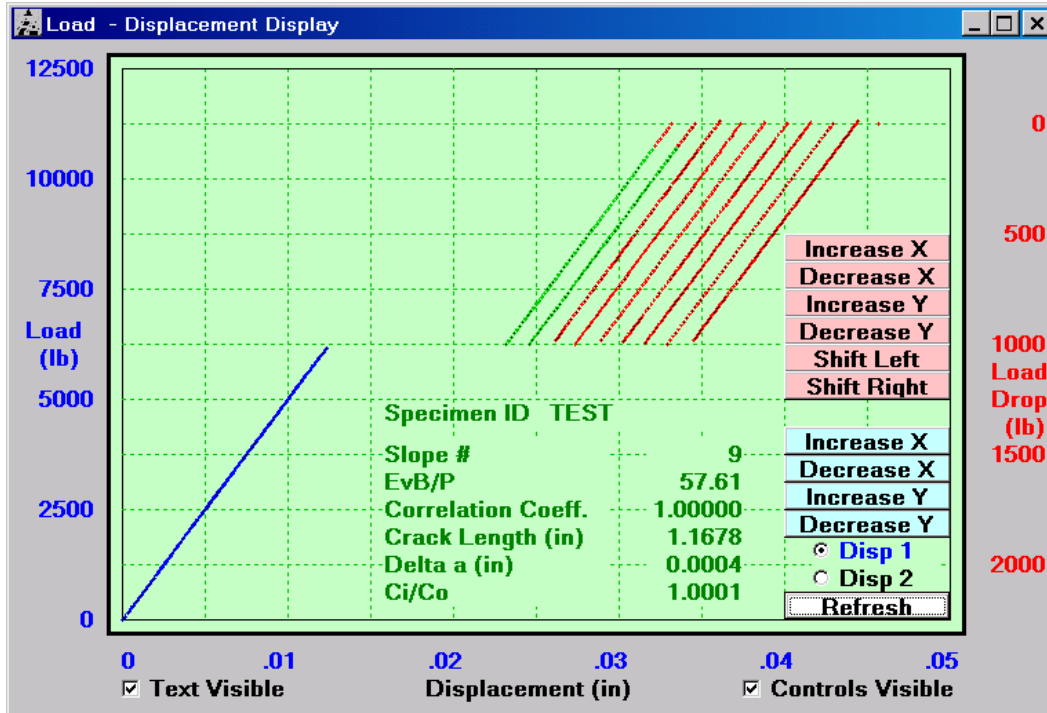
When **Load-displacement** has been activated under **Data Acquisition** on the **Ramp Generator**, real-time traces of load-displacement (blue) and unloading slopes (green and red) are plotted on this display. The green portion of the active unloading slopes indicates the data that are used for slope determination: this 'window' is determined on the **Data Acquisition** tab of the **Data Input** form (these data may be edited during analysis using the Testing Playback software). Note that the unloading slope traces turn completely red when the pink scaling or **Refresh** buttons are deployed. This in no way affects that data that are used in slope determination.

The **Disp 1** and **Disp2 (Aux 1)** selectors allow the user to choose which displacement channel is displayed.

A variety of scaling and display buttons are available for adjusting the plots in real time:

- **Increase X** increases the full scale of the unloading slopes in the X direction.

- **Decrease X** decreases the full scale of the unloading slopes in the X direction.

- **Increase Y** increases the full scale of the unloading slopes in the Y direction.

- **Decrease Y** – Decrease the full scale of the unloading slopes in the Y direction.
- **Shift Left** shifts the unloading slopes to the left.
- **Shift Right** shifts the unloading slopes to the right.

- **Increase X** increases the full scale of the load-displacement trace in the X direction.
- **Decrease X** decreases the full scale of the load-displacement trace in the X direction.
- **Increase Y** increases the full scale of the load-displacement trace in the Y direction.
- **Decrease Y** decreases the full scale of the load-displacement trace in the Y direction.

4.6.3 J – DELTA A
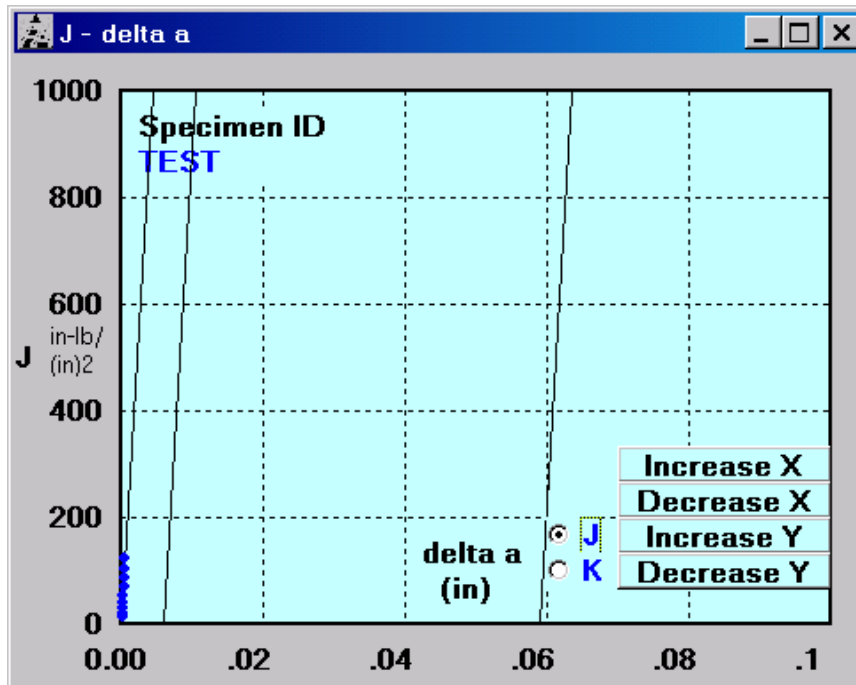
The **J-delta a** display plots a new point after every unload slope or DCPD data acquisition cycle. Either J or K may be displayed

The three parallel and slanted vertical lines represent the crack tip blunting line and the minimum and maximum data exclusion limits.

Four options for rescaling the plot are available:

- **Increase X** increases the full scale of the J-Δa data in the X direction.

- **Decrease X** decreases the full scale of the J-Δa data in the X direction.

- **Increase Y** increases the full scale of the J-Δa data in the Y direction.

- **Decrease Y** decreases the full scale of the J-Δa data in the Y direction.

4.7 Comments

This form allows comments to be entered during the test. These comments are stored in the .in5 analysis file and can be changed during analysis, although they do not appear in the final Excel workbook.

4.8 Help

A PDF file of this manual is available under the **Help** menu.

5.0   USING THE FTA ANALYSIS SOFTWARE

The analysis software is a Visual Basic/Excel editing and analysis package that uses the raw data from testing and visual crack length observations to perform three fracture toughness analyses with both tabular and graphical output:

- ASTM E1820
- E399
- E1921 (with an Excel utility for master curve generation)

The following Sections 5.1 through 5.5 provide an explanation of the VB analysis program's structure; descriptions of the analysis files; and analysis procedures for each of the three ASTM standards. Section 6 details the analysis program's structure, including a complete description of its menus and tabs. Section 7 describes the Excel post-processing utility and Section 8 the Testing Playback program.

Only E1820 and E399 analyses are considered here. For details on E1921, please contact FTA.

5.1   How the NLFT Analysis Program Works

The analysis program is constructed in two distinct parts. Raw data from the test are first edited, pre-processed, and analyzed by the Visual Basic program. The user then selects a post-processing option, which calls up a Microsoft Excel utility for data reduction; calculation of JQ; validation; and plotting. Microsoft Excel v. 2007 or 2010 must have been previously loaded onto the PC for the program to function correctly. The workbook templates necessary for the utility (nlft.xls and nlft_timed data.xls) are included with the FTA software.

The Excel utility functions through a combination of four elements.

- Visual Basic ActiveX Control is used by the VB program to start Excel and call the file nlft.xls or nlft_timed data.xls. These files have been extensively customized for the sole purpose of fracture toughness analysis post-processing. The worksheets' cells are populated with information and formatting statements from the VB analysis program via a one-way communication link. The Excel utility must be exited before a new file can be analyzed in the main VB program.

- VBA (Visual Basic for Applications) enables the use of macros within Excel to expand the capability of basic worksheet features and automate repetitive tasks. The macros are invoked by pressing the analysis button on the **Raw Data** sheet in the Excel file. The macros used for the various analysis types can be viewed using the **Tools** menu in Excel.

- Excel worksheets are used to display tabular data, hold variables, perform calculations, and make logic decisions. The nlft.xls workbook contains from five

to seven worksheets, depending upon the analysis type (E1820 or E1921). The user may view all the worksheets by opening the nlft.xls file. The nlft.xls file should never be overwritten by the user but always saved under a new name (usually the **TEST ID**).

- Excel file: one standard Excel file is dedicated to each analysis option or test.

5.2   Understanding the Files Used by the Analysis Program

At the end of a test, analysis (.in5) files must be saved from within the testing program using the **Save Analysis File As Version 3** command. This .in5 file is loaded into the analysis program for editing and processing. Once edited within the VB program, it is saved as an .in6 file, thus preserving the unedited .in5 file. Initial processing produces a .dat file, which is subsequently called (together with the .raw file) by the Excel utility for final processing. The analysis program's final output consists of an Excel workbook including a cover page; tabular data, and plots.

A review of the files required and produced by the analysis program follows:

- **Analysis** file (.in5 extension): data produced by the testing program and required for the NLFT analysis program. This file remains unchanged by analysis, thus preserving the unedited data.

- **Edited** analysis file (.in6 extension): edited .in5 files are saved by the analysis program with the new .in6 extension. These files will include visual crack length measurements, edited data points, and initial choices for analysis and data reduction.

- **General Information** file (.gn2 extension): general information not required for testing, but that may be common across tests (such as test temperature or material description). These optional files may be loaded, modified and saved by by the analysis program as well as the testing program.

- **Log** file (.log extension): details of the test including test parameters and data that are part of the analysis file (.in5).

- **Load-displacement Data** file (.raw extension): elapse time; load; displacement; and auxiliary channel information recorded engineering units.

- **Unloading Data** file (.unl extension): calibration factors and the voltages of the load-displacement unloading slopes. These files are typically only required when using the Playback software.

In addition, two customized Excel templates are provided, which are called up by the **Post Processing** option in the VB software. These files should never be altered but always saved under a new name after data analysis (typically the **Test ID**):

- **Non-Linear Toughness Report Template** (nlft.xls): used for non-linear J-R analyses, production of test reports and graphs, and performance of validity checks
- **Load Disp and Linear Toughness Report Template**: (nlft_timed data.xls) used for linear K_{IC} analysis and the production of load-time and load-displacement plots for E1820 and E1921 analyses.

The following sample analysis files are included with FTA's analysis software so users may practice when no actual test data are present:

- TEST1.IN5: an unedited data file based on an E1820 compliance test
- TEST1.IN6: the above data file edited to include visual measurements and edited data points.
- TEST1.DAT: the analysis program's E1820 output from the above test
- TEST1.RAW: the load-displacement data file associated with the above test
- TEST1.UNL: the unloading data file associated with the above test
- TEST1KIC.IN6: the TEST1.IN5 data file edited for E399 analysis.
- TEST1KIC.DAT: the analysis program's E399 output from the above test

Each of these files may be opened for editing/analysis and saved under a different name.

5.3   E1820 Analysis Procedure

1. Start the program **NLFT Analysis** and press **Continue** on the **Splash Screen**. Note the **Main Form** with its eight tabs of information (see Section 6 of this manual for a full discussion of the menus and forms associated with the analysis software). The **Control** tab is foremost.

2. On the **Control** tab, select the **Unit Type.**

3. From the **File** menu select **Open → Analysis Input File**.

4. Open the file **Test1.in6**, which may be found in the NLFT program directory.

5. Return to the **File** drop own list and **Open** the **Load-displacement Data** (.raw) file **Test1.raw**, which also may be found in the NLFT program directory.

6. On the **Control** tab, select the **Analysis Option** (eg ASTM 1820) appropriate for the test. If a general file already existed, that could also be loaded from the **Control** tab.

7. Go to the **Coefficients** tab. Note that these values are part of the analysis file and should not be changed.

8. Go to the **General** tab. Check general information (labeled in blue) and edit as required. Note that values in red will affect the analysis results and should only be changed with caution. Some general information (such as precrack load, for example) is required for the Excel utility to generate validity statements.

9. Go to the **Dimensions** tab. The only dimension that may be changed is notch length, which is part of the general file.

10. Address the **Visuals** tab. Here is where visually-measured crack lengths (**Precrack** and **Final** crack) are entered. For E1820 and E1921 analyses, nine measurements are required for each and the number nine must be entered in the text box at the top of each column. If no crack extension is visible on the specimen, the precrack measurements should be entered in the final visuals fields. The Test1.in6 file already contains visual measurements.

   Also on the **Visuals** tab, evaluate the two corrections options. Recall that for E1820 the **improved a$_{oq}$** correction is mandatory. For an E813 analysis, an improved aoq is not used, however, the **effective modulus** is required. Be sure to consult the correct standard before selecting options.

11. Additional notes may be entered on the **Comments** tab, although these will not appear on the Excel output.

12. On the **Data** tab, note that the characteristics of each data point may be examined by scrolling through the file using the **Back** and **Forward** buttons. This tab has limited use before the data are pre-processed.

13. Finally, address the **Load-Disp Data** tab, where the .raw data may be filtered and the pre-processing results displayed. This tab also has little meaning before pre-processing.

14. Return to the **File** drop down list and **Save the Edited Input Analysis File**. This gives the edited file a .in6 extension, thus preserving the original .in5 file. It is wise to work subsequently with the .in6 file to save the time required by re-editing.

15. The general (.gn2) file may be saved or updated at this point by pressing the blue **Save General Info** button on the **Control** tab.

16. It is time for pre-processing the data. Press the **Run Non-Linear Analysis** button at the bottom of the **Main Form**. A message will appear prompting the user to save the resulting .dat file. The .dat file must be saved or the program will crash!

17. The **J-delta a** plot will appear in a new window. Note that each point on the plot can be selected by scrolling through the indeces on the **Data** tab of the **Main Form**. Selected points are shown in green on the **J-delta** a plot. Errant points may be excluded from analysis by activating the **Exclude Data** box on the **Data** tab. The point can be reintroduced into the analysis by deactiving the box. Use of the **Delete** option is not recommended, as this deletes the point entirely from the file.

18. Go to the **Visuals** tab and ensure the **Actual delta a** (which was calculated from the manually-entered visuals) corresponds with the **Predicted delta a**

(determined from compliance or DCPD measurements during testing). This check helps ensure no typos occurred during data entry.

19. The contents of the .dat file produced during pre-processing may be viewed in the **Output** window.

20. Further editing may be required after the pre-processing results have been inspected. This may be done as before, remembering that the updated file must always be saved with its .in6 extension. The **Run Non-Linear Analysis** button should be pressed after each iteration to ensure the most recent .dat file is sent to the Excel utility.

21. To pre-process the load-displacement data (for the production of **Load-displacement** or **Load Time** plots later on), press the blue **Process Load-Disp Data** button at the bottom of the **Main Form**. The results will be shown on the **Load-Disp Data** tab and the data filter accordingly. See Section 6.3.8 for a discussion of the **Load-Disp Data** tab.

22. When the pre-processed results are satisfactory, call up the Excel utility to finish the analysis. Go to the **Post Processing** drop down list at the top of the **Main Form** and choose **Non-Linear Report**. This calls up the Excel workbook nlft.xls and populates it with the .dat file.

23. After a few seconds, the Excel workbook will appear. Press the grey button **ASTM 1820 JIC** to perform the regression analysis. A complete seven-worksheet record of the test will appear.

24. This file must be saved with a new file name, typically the TEST ID. The original template nlft.xls must be preserved. Resist all prompts to save the changes to the original file!

25. After saving the new Excel file, examine the worksheets in turn to view their contents, which include a cover page, program output, and a plot. These worksheets are not usually edited, although plots may be scaled as required. This file serves as the printable record of the test. See Section 7.1 of this manual for a full discussion of the Excel workbooks' worksheets.

26. If a Load-Displacement and/or Load Time plot is required, return to the main VB program and the **Post Processing** drop down list. Choose **Load-Disp and Linear Report**, which calls up the nlft-timed data.xls Excel workbook. The required plots may be found among the worksheets of the resulting populated workbook and saved under a new name as before (see Section 7.2 for full details).

5.4   E399 Analysis Procedure

NB The sample data files included in the NLFT Analysis program directory (Test1.in6 and Test1.raw) are drawn from the same test provided for the E1820 sample analysis session and will not produce a valid K_{IC} result.

1. Start the program **NLFT Analysis** and press **Continue** on the **Splash Screen**. Note the **Main Form** with its eight tabs of information (see Section 6 of this manual for a full discussion of the menus and forms associated with the analysis software). The **Control** tab is foremost.

2. On the **Control** tab, select the **Unit Type.**

3. From the **File** menu select **Open → Analysis Input File**.

4. Open the file **Test1.in6** and select the **ASTM E399** analysis option.

5. Treat the first seven tabs as in the E1820 sample analysis session described in Section 5.3.

6. Go to the **Load-Disp Dat** tab and activate the **3 Column Raw Data File Format** at the lower right.

7. Return to the **File** drop own list and **Open** the **Load-displacement Data** (.raw) file **Test1.raw**, which may be found in the NLFT program directory.

8. It is not necessary to press the **Run Non-Linear Analysis** button.

9. Press the **Process Linear Data**. The KIC Utility tab should look like the one below.

NLFT Analysis - V3.16.01

File   Display   Post Processing   Help

Control | Coeff's | General | Dimensions | Visuals, Etc | Comments | Data | Load-Disp Data

Number of Time-Based Data
```
1236
```

Number of False Starts
```
0
```

Data Filter Options
☑ Remove False Starts
☐ Remove Unload Slopes

Max Load (lbf, kN)
```
1489.75
```

Disp (in, mm) at Max Load
```
0.02679
```

Data Reduction Factor
```
1
```

Time (sec) at Max Load
```
510.7
```

# of points after Reduction
```
1220
```

Raw Data File Format
○ 3 Column
○ 4 Column
◉ 5 Column

Analysis File Name: I:\Software Development\NLFT ADBasic development for G4 Software\NLFT Analysis

Load-Disp File Name: I:\Software Development\NLFT ADBasic development for G4 Software\NLFT Analysis

Run Non-Linear Analysis | **Process Load-Disp Data** | **English** | **Quit**

10. From the **Display** menu select **Load-Displacement**, where the pre-processing result may be viewed. Select the **Filter** option on the plot to see what effect changing the **Data Filter Options** or changing the **Data Reduction Factor** has on the display, pressing the **Process Load-Disp Data** button after each change.

11. When satisfied, call up the Excel utility by going to the **Post Processing** drop down list and selecting **Load Disp and Linear Report**. Wait a few seconds while the workbook is populated with the pre-processed data.

12. On the **User Input** sheet select the **Upper** and **Lower** limits for the regression and press **Calculate KIC.** At the completion of this step, return to the **User Input** sheet. It should look like this:

User Input Information

Specify Upper and Lower Regression Limits ONLY and Calculate KIC.

70	Upper Regression Limit, %Pmax	Slope of Line OA
		80775.76 lbf/in
20	Lower Regression Limit, %Pmax	
		Y Intercept of Line 0A
379	# of Data Points, Total	49.37765 lbf
88	# of Data Points used	Slope, 95% Secant
	for Regression	76736.97 lbf/in
		Coord's of Secant Line
		x's y's
		1 -0.00061 0
KQ		2 0.018802 1489.75
90.1	ksi sqrt (in)	
		Load at PQ
Rate		1189.2 lbf
355.45	lbf/min	
26.92	ksi sqrt (in)/min	Disp at PQ
		0.015 in
1489.75	Pmax (lbf) from Raw File	
0.027	Disp (in) at Pmax	Crack Length
510.7	Time (sec) at Pmax	0.625 in

X Intrcpt of Line 0A: -0.00061 in

Coord's of Line OA:
x's   y's
1 0.003077   297.95
2 0.012299   1042.825

Y Intrcpt of Secant Line: 46.90877 lbf

Calculate KIC

Worksheet tabs: User Input | E399 Cover Page | Load Disp | Load Time | K-plot | Timed Data | Reg Data | Variables

13. Other worksheets such as the **Cover Page** appear much as the E1820 worksheets.

14. If the linear fit of the **K-plot** is improper, return to the **User Input** sheet and select different regression limits. Press **Calculate KIC** again .
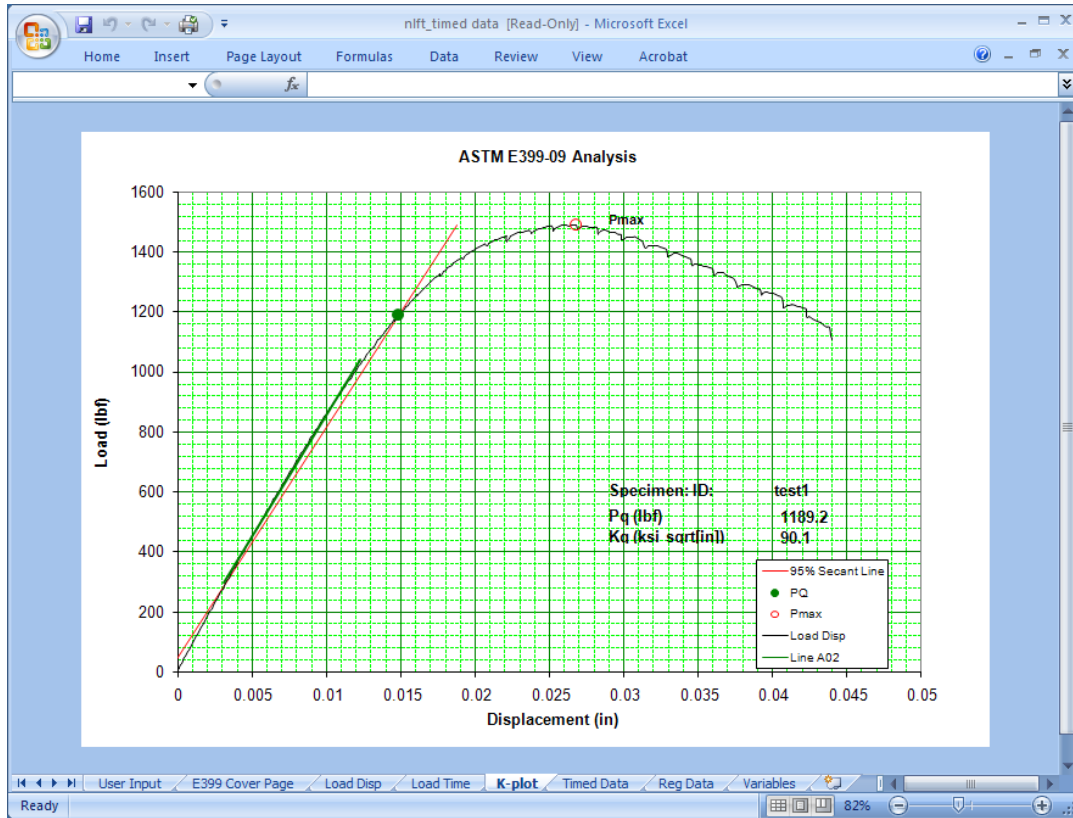
15. The finished file must be saved with a new file name, typically the TEST ID. The original template nlft_timed data.xls must be preserved. Resist all prompts to save the changes to the original file!

6.0 NLFT Analysis Software: Description of Menus and Tabs

6.1 Splash Screen
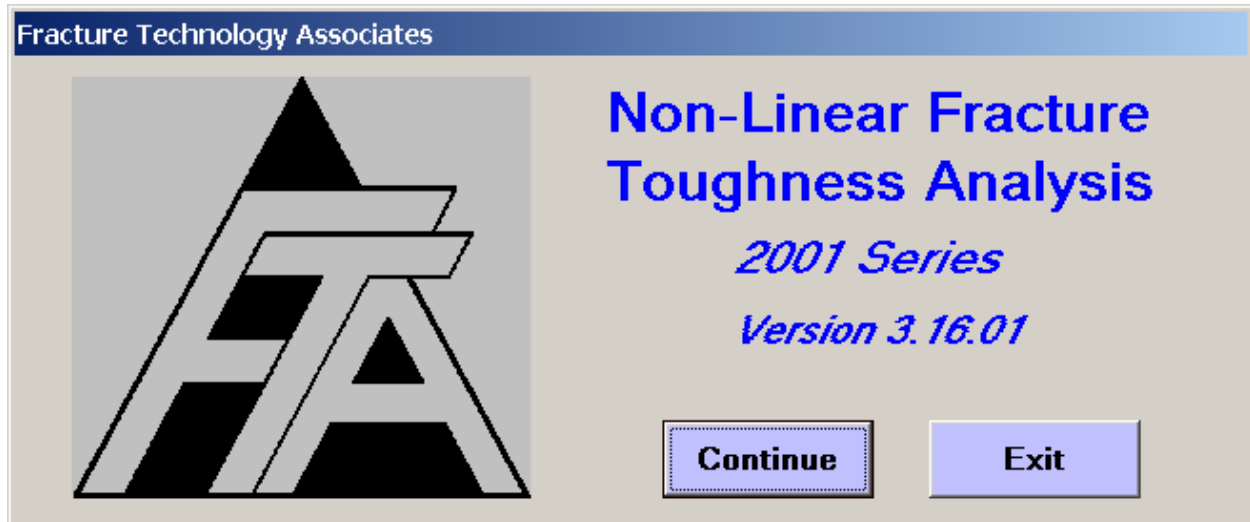
The Splash Screen is displayed upon start-up. The application and version number are displayed on this screen. Click **Continue** to proceed to the **Main Menu**.

6.2 Main Form: Menu Items

Data are edited, preprocessed, and prepared for export into the Excel utility using the **File** options and eight tabs of the **Main Form**. The **Post Processing** routine accessed from the drop down list at the top of the form is not discussed until the end of this section, since it is the last step before calling up the Excel utility.
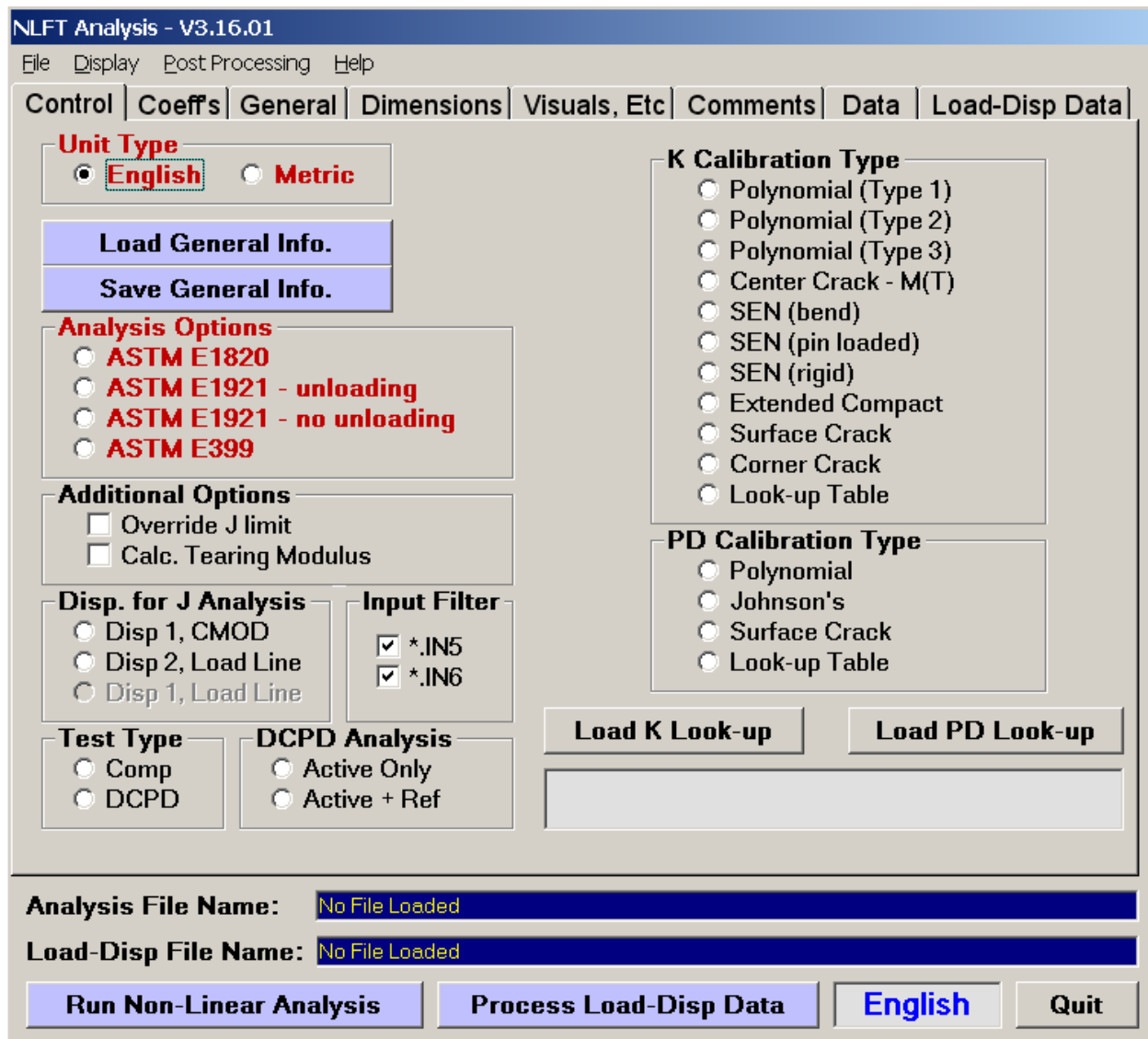
6.2.1 FILE

The **File** drop down list allows the opening and saving of **Input** (.in5) files as well as the saving of .dat files in English or metric units. One may also **Exit** the analysis program from the **File** menu.

Both input and output files are standard ASCII files that may be examined and modified with a Windows-based text editor such as NotePad. When editing files with an editor, be sure to save the file with the correct extension (.in6 or .dat). Choosing the 'All Files' type when saving preserves the current extension even if the name has been changed. Otherwise, the modification may render the extension incompatible with the analysis software.

6.2.1.1 Open

This menu option allows both opening of **Analysis Input** (.in5 or .in6) files and **Load-displacement Data** (.raw files). Before opening a file, the user must select the **Unit Type.** This selection is independent of how the test was run.

- **Open Analysis Input Files**: only files with .in5 or .in6 extensions are recognized by the analysis program. Analysis files with the .in5 extension are created by the testing software. The .in6 extension is used for files that have already been edited with the analysis software.

- **Open Load-displacement Data**: load-displacement (.raw) files are only needed for the creation of **Load-Displacement** or **Load-Time** plots and K_{IC} analyses. Only files with the .raw extension are recognized by the analysis software.

6.2.1.2   SAVE

- **Save Edited Input Analysis Files** saves the edited analysis files with the .in6 extension. This distinguishes the new edited file from the original .in5 file produced by the test software. Each time an input file is edited, the previous file is overwritten unless the name is changed.

- **Save Output As:** after pre-processing, output files are stored with the .dat extension for use by the Excel utility. Used if default output (**English** or **Metric)** is not desired. Output (.dat) files are also saved automatically when the user presses the **Run Non-Linear Analysis** button at the bottom of the menu.

6.2.2 DISPLAY

This menu option selects the **J vs. Δa**; **Output**; and **Load-displacement** screens. These screens appear after the data have been pre-processed, but if they are accidentally closed by the user, they can be reopened using this menu.

6.2.3 HELP

A .pdf version of this manual appears under the **Help** menu.

6.2.4 QUIT

In addition, the user may exit the analysis program at any time, by pressing the **Quit** button at the bottom of the **Main Form**. This button is visible from any of the **Main Form** tabs. The user will be prompted to save input and output as appropriate.

6.3   Main Form: Tabs

Analysis (.in5 and .in6) files are examined and edited on the eight **Main Form** tabs. In some cases, editing will be necessary after the first pre-processing routine and examination of results. For example, if some early data pairs are shown not to be appropriate, they may be excluded from subsequent analysis. Editing procedures are explained in the following sections.

On the **Main Form** tabs, labels in blue indicate areas where user modification is expected. Changes to text boxes labeled in red will affect the test results.

6.3.1   CONTROL

The **Contro**l tab is foremost on the **Main Form** and is the first to be addressed when the form is opened.

The selection of **Unit Type** is mandatory before loading a file and is independent of the units selected during the test.

An **Analysis Option** must be selected before running an analysis, as it determines the equations that will be applied to the data set.

- **ASTM E1820** is based on the 2010 standard
- **ASTM E1921** is based on the 2009 standard. The user must specify whether or not unload slopes were used during the particular E1921 test being analyzed.
- **ASTM E399** is based on the 2009 Standard.

Additional Options:

- **Override J Limit** allows data that exceeds J_{limit} (E1820) to be used in the regression analysis of the J-R curve to determine a provisional J value. However, data outside the exclusion lines are not used.
- **Calc[ulate] Tearing Modulus** performs a tearing modulus calculation by linearly fitting the data used for the J regression. This includes only the data between the exclusion lines, but may include data that exceeds J_{Limit} if **Override J Limit** is activated.

The **Input Filter** allows the user to discriminate between .in5 and .in6 extensions when searching for an analysis file. This is particularly useful when re-analyzing data, where the user might accidentally load an .in5 file that doesn't include visual measurements and edited data pairs. If neither box is selected, both file types will be displayed.

The right-hand side of the form indicates the **K-Calibration Type, PD calibration Type,** and **Test Type.** These characteristics were established during test time and are part of the analysis file. These options cannot be changed.

The Load PD Look-up [table] option at the bottom of the form is used for non-standard geometries. When pressed, the same user-defined DCPD – crack length calibration file (.dat extension) that was used during testing may be loaded into the analysis program.

For DCPD tests that used a reference probe, the user may run the **DCPD Analysis** with or without including the reference probe data.

The **Disp[lacement] for J Analysis** option allows the user to select data collected from either displacement channel (I**N2** or **IN3** on the ADwin, identified as **Disp 1** and **Disp 2** in the testing software).

- **Disp 1, CMOD** is the standard setting for testing C(T) specimens using compliance as the crack monitor. Also, it can be used for the special case of SEN(B) testing when the crack mouth opening displacement is measured with a clip gage on the specimen and converted to a theoretical load line displacement.

- **Disp 2, Load line** is the typical setting for a bend bar SEN(B) test. It should be selected if the displacement from the LVDT is fed into Input 3 on the ADWIN Gold and used as the primary displacement for J analysis.

- **Disp 1, Load Line** is a special case for SEN(B) tests. This is used when the crack monitor type is DCPD. Also the load line displacement signal is fed into Input 2 on the ADWIN Gold and used as the primary displacement for J analysis.

The user can also make use of general information (.gn2) files at analysis time:

- By pressing **Read General Info.** the user can load a general information (.gn2) file , which populates the input fields with contract and test condition information common to all specimens in a test group (the blue labels on the **General** tab). Although this information is not critical to the analysis, time can be saved by loading repetitive information in this way. The .gn2 file can be created during the test or by completing the input fields in the analysis program.

- By pressing **Save General Info.** after filling in the blue input fields, the user may save or update the .gn2 file at analysis time. Subsequently, the information can be read into further analyses in the same test group to streamline input (see above).

6.3.2 COEFF[ICIENT]S

NLFT Analysis - V3.16.01

File   Display   Post Processing   Help

Control | Coeff's | General | Dimensions | Visuals, Etc | Comments | Data | Load-Disp Data |

K, Stress Intensity		a/W, Compliance		a/W, DCPD	
K0	.886	C0	1.0002	PD0	0
K1	4.64	C1	-4.0632	PD1	0
K2	-13.32	C2	11.242	PD2	0
K3	14.72	C3	-106.04	PD3	0
K4	-5.6	C4	464.33	PD4	0
K5	.	C5	-650.68	PD5	0

Type 1: $K = (P / (B * W^{0.5})) * ((2 + a/W) / (1 - a/W)^{1.5} * f(a/W)$
Type 2: $K = (P / (B * W)) * (PI * a)^{0.5} * f(a/W)$
Type 3: $K = (P / (B * W^{0.5})) * f(a/W)$

Geometry Type
- ● C(T)
- ○ M(T)
- ○ SEN (bend)
- ○ SEN (pin)
- ○ SEN (rigid)
- ○ Neutral

Analysis File Name: I:\Software Development\NLFT ADBasic development for G4 Software\NLFT Analysis

Load-Disp File Name: I:\Software Development\NLFT ADBasic development for G4 Software\NLFT Analysis

| Run Non-Linear Analysis | Process Load-Disp Data | English | Quit |

The **Coefficients tab** of the **Main Form** allows examination of **K, Stress Intensity**; **a/W, Compliance**; and, if applicable, **a/W, DCPD** coefficients. None of these values should be changed unless an incorrect coefficient is detected. Although errors may be remedied here, the user should perform a cause-and-effect analysis of any such alteration to the data.

When analyzing fracture-toughness test data collected using the potential drop technique, compliance is back-calculated from known values of a/W. For ASTM-recommended geometries, the equations are embedded in the code. See ASTM E1820 for more detail.

6.3.3 GENERAL

The **General** tab contains information that will appear on the cover page of the Excel analysis spreadsheet. Blue labels indicate information that may need to be entered by the user if it was not entered at test time. These fields can be automatically populated by reading in an existing .gn2 file.

Many of these data are for information purposes and do not affect the analysis. The **Test Modulus**, however, does affect the analysis, and so is shown in red. Also, **Tensile Stress** and **Yield Stress** are required to calculate flow stress and determine limit loads. Although estimates may have been used during testing, these values may be changed at analysis time.

Precrack Load, **Precrack Stress Ratio**, and **Precrack Length** are used to determine the final K level attained during precracking. These are also used for validity checks. K will be calculated based on B_{eff}.

6.3.4 DIMENSIONS

```
NLFT Analysis - V3.16.01

File   Display   Post Processing   Help

Control | Coeff's | General | Dimensions | Visuals, Etc | Comments | Data | Load-Disp Data


        Thickness, B (in, mm)                  0.230
        Net Thickness, Bnet (in, mm)           0.1746
        Width, W (in, mm)                      0.9987
        Span to Width Ratio (bend)             0
        Notch length (in, mm)                  0.550
        Pin Spacing (in, mm)                   0.750
        Comp Gage Length (in, mm)              0.170
        Comp Alpha Ratio                       1.000
        DCPD Gage Length (in, mm)              0
        DCPD Initial a (in, mm)                0
        DCPD Initial PD (micro-volts)          0
        Load line compliance corr. (in/lb, mm/kN)   0.000E+0
        Load line displacement corr. (in, mm)  0.000
        Poisson's Ratio                        0.300


Analysis File Name:   I:\Software Development\NLFT ADBasic development for G4 Software\NLFT Analysis
Load-Disp File Name:  I:\Software Development\NLFT ADBasic development for G4 Software\NLFT Analysis

  Run Non-Linear Analysis      Process Load-Disp Data      English      Quit
```

Most of the information on the **Dimensions** tab was entered at test time and may not be changed. An exception is specimen notch length, which is part of the .gn2 file.

6.3.5 VISUALS, ETC.

Visual measurements of precrack and final crack length (after heat tinting or specimen failure) are added manually by the user on the **Visuals** tab. Up to eighteen measurements for E 1820 and E1921 analysis may be entered (nine **Precrack** and nine **Final** crack), but the user must be sure to enter the total **Number of Measurements** for each column, as above. Five measurements only are required for E399 analysis so most of the text boxes are inactive when this option is chosen on the **Control** tab. The **a1** and **a9** values are weighted 50% compared to the others.

Two additional operations for data pre-processing are available:

- **Calculate improved aoq** is required for E1820 analysis. When the box is activated, J-da pairs from 0 to Pmax are shifted about the blunting line by

adjusting the starting crack length, a_{oq}. The value of a_{oq} is found by solving the equation:

$$a = a_{oq} + J/(2\sigma_y) + BJ^2 + CJ^3$$

- **Calculate effective modulus** calculates an effective modulus that corrects the crack lengths measured at test time with the visually-measured post-test values. This effective modulus is displayed in the Excel Report after post-processing.

Three Intermediate Results are displayed when the data have been pre-processed (by pressing the **Run Non-Linear Analysis** button at the bottom of the form). These values provide an initial indication of the validity of the test and help ensure all entered values are correct.

- **Initial Crack Length Correction Factor**: a multiplier used to adjust the effective modulus so that compliance-measured crack length equal the visually-measured values. Values are typically between 0.9 and 1.1.

- **Actual delta a**: the difference between the initial and final crack length measurements as visually-measured after the test.

- **Comp or DCPD predicted delta a**: the difference between the initial and final crack length measurements as determined during the test by compliance unloading slopes or by DCPD data acquisition.

6.3.6 COMMENTS
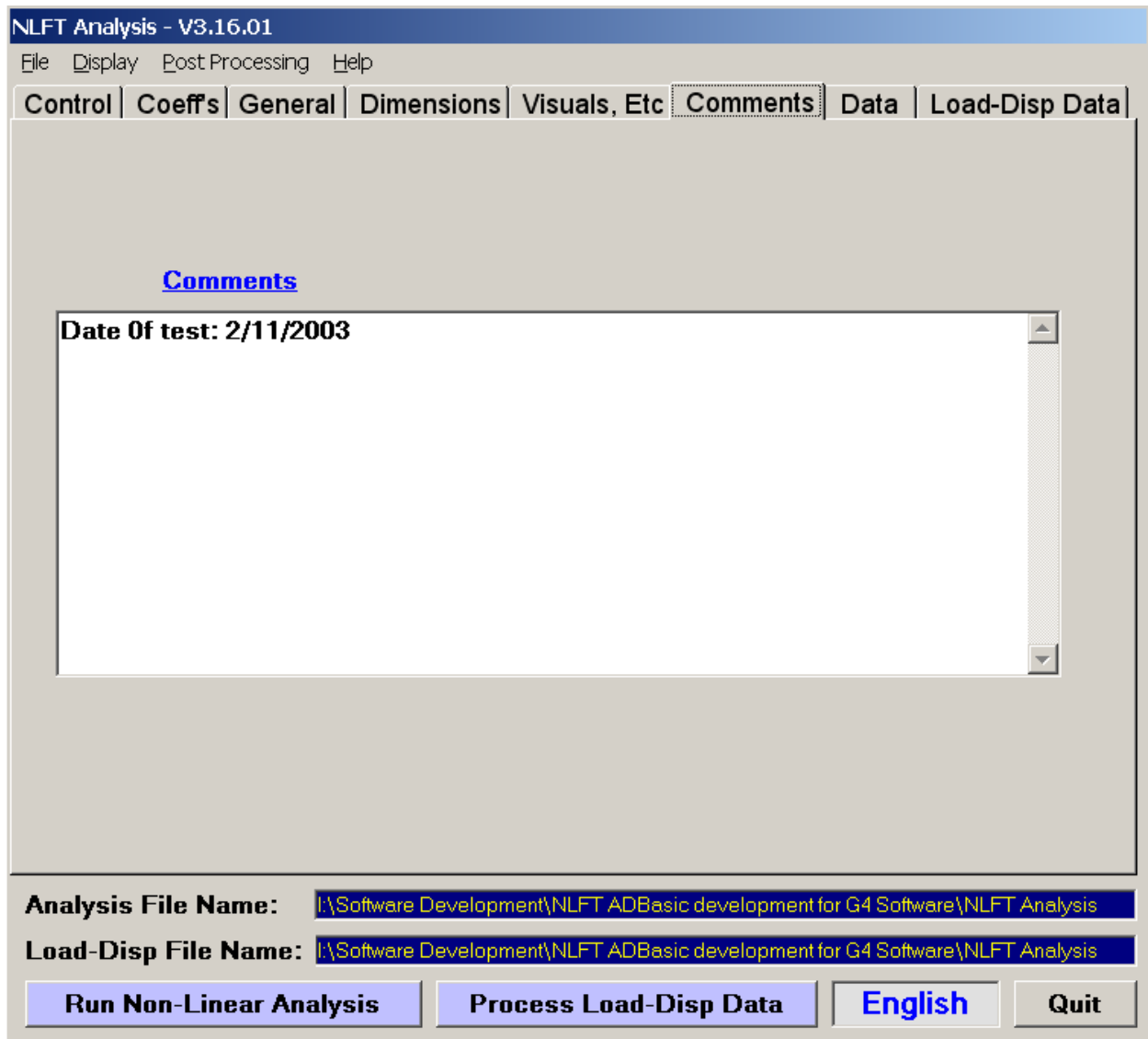
Comments may be added to the analysis file on the **Comments** tab, although the comments will not appear in the final Excel workbook or cover page of the test.

6.3.7 DATA

The **Data** tab is used for viewing and editing the data points in the analysis file. Characteristics of each point are displayed in the white text boxes with its assigned index at the top.

It is usually necessary to pre-process the data to determine whether editing is appropriate: after pressing the **Run Non-Linear Analysis button**, the points may be viewed on the **J - Δa Display**. The active point is shown in green on the display of blue data points.

Use the command buttons **Back One/Ten** and **Forward One/Ten** to examine the contents of each text box. The **Insert/Delete** check boxes, in combination with the **Activate Ins/Del** command button, may be used to remove data points from the analysis file. However, it is safer to merely *exclude* the points from the analysis (rather

than the file itself) by using the **Exclude Data** feature: this way, points are easily re-introduced into the analysis by deactivating the **Exclude** feature. Ticking the **Carry** checkbox allows actions such as **Delete** or **Exclude** to be carried across data points by pressing **Back One/Ten** or **Forward One/Ten**.

6.3.8 Load-Disp Data

```
NLFT Analysis - V3.16.01
File   Display   Post Processing   Help

Control | Coeff's | General | Dimensions | Visuals, Etc | Comments | Data | Load-Disp Data

    Number of Time-Based Data          Number of False Starts
    ┌──────────────────────┐           ┌──────────────────────┐
    │ 1236                 │           │ 0                    │
    └──────────────────────┘           └──────────────────────┘

    Data Filter Options                Max Load (lbf, kN)
    ☑ Remove False Starts              ┌──────────────────────┐
    ☐ Remove Unload Slopes             │ 1489.75              │
                                        └──────────────────────┘

                                        Disp (in, mm) at Max Load
                                        ┌──────────────────────┐
                                        │ 0.02679              │
                                        └──────────────────────┘

    Data Reduction Factor              Time (sec) at Max Load
    ┌──────────────────────┐           ┌──────────────────────┐
    │ 1                    │           │ 510.7                │
    └──────────────────────┘           └──────────────────────┘

    # of points after Reduction        ┌─ Raw Data File Format ─┐
    ┌──────────────────────┐           │  ○ 3 Column            │
    │ 1220                 │           │  ○ 4 Column            │
    └──────────────────────┘           │  ◉ 5 Column            │
                                        └────────────────────────┘

Analysis File Name:   I:\Software Development\NLFT ADBasic development for G4 Software\NLFT Analysis
Load-Disp File Name:  I:\Software Development\NLFT ADBasic development for G4 Software\NLFT Analysis

  Run Non-Linear Analysis      Process Load-Disp Data      English      Quit
```

The **Load-Disp Data** tab displays the pre-processing results of the load-displacement analysis, achieved by pressing the **Process Load-Disp Data** button at the bottom of the form. These results should be examined and filtered before post-processing the data and producing the Excel **Load-Disp Linear Toughness Report**.

Pre-processing results can be viewed in the text boxes **Number of Time-Based Data**; **Number of False Starts**; **Max Load**; **Disp[lacement] at Max Load;** and **Time at Max Load.**

A number of **Data Filter Options** enable editing of the load-displacement data:

Remove False Starts: when activated, this option filters any restarts from the the load-displacement (.raw) file. For example, if the elapse time in the file shows a decrease, this is an indication that the test was restarted and any previous data are ignored.

Remove Unload Slopes: when activated, only increases in displacement are processed, thus removing unloading slopes from the load-displacement curve.

Data Reduction Factor: the total number of load-displacement pairs to be processed can be reduced by the factor entered.

Recent releases of this software are formatted for five columns in the .raw file (elapsed time, load, disp1, disp2, auxiliary) even if storage of less than five columns was indicated when the test was run and the data collected. The unused columns are separated by commas. However, earlier versions may only have three or four columns. For this reason, the number of columns in the file can be selected under **Raw Data File Format**. If the number is unknown, the file should be opened with a text editor or Excel to determine the correct option. If the data do not process with the default setting of five columns, running it with three or four columns may prove more successful.

6.4 Processing The Data

6.4.1 Run Non-Linear Analysis

The **Run Non-Linear Analysis** button is located at the bottom of the **Main Menu** and is visible on all the tabs. When this button is pressed, the loaded .in5 or .in6 file is pre-processed and a non-linear fracture toughness analysis performed, producing a .dat file and populating the **J-Δa** display. For a complete J_{IC} analysis and associated printout, the **Post Processing** option on the **Main Form** must be deployed, sending the .dat file to the Excel utility.

After pre-processing (but before post-processing), it is useful to examine the **J-Δa** display for any errant data points, which may be edited using the **Exclude Data** option on the **Data** tab. It is also a good idea to review the predicted and actual Δa values on the **Visuals** tab to ensure the manual entries in the **Precrack** and **Final Visuals** columns make sense. If any changes are made, it is important to resave the file and run the pre-processing routine again before calling up the Excel utility.

6.4.2 Process Load-Disp Data

The **Process Load-Disp Data** button is located at the bottom of the **Main Menu** and is visible on all the tabs. When this button is pressed, the load-displacement (.raw) data are filtered according to the options chosen on the **Load-Disp Data** tab. For a complete analysis and associated printout, the **Post Processing** option on the **Main Form** must subsequently be pressed, sending the .dat file to the Excel utility.

6.5 Display

Two displays appear when the **Run Non-linear Analysis** button is pushed: the **J-delta a** display and the **Output** display. If either of these displays is closed after pre-processing, they can be reopened using the drop-down list under **Display** on the **Main Form**.

6.5.1 J – DELTA A DISPLAY
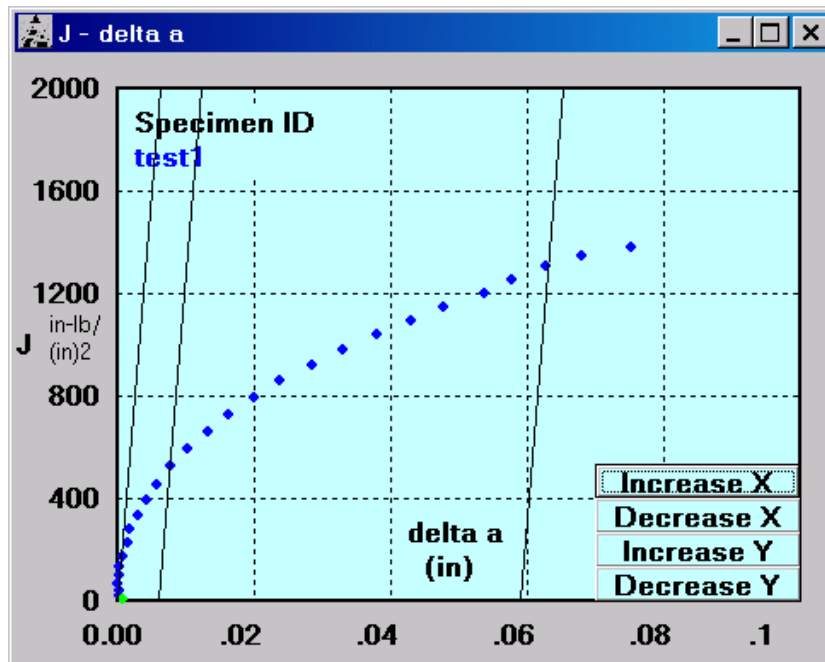
The results of the pre-processing analysis are based upon the test standard **Analysis Option** selected on the **Contro**l tab of the **Main Form**.

The axes of the **J-delta a** plot are auto-scaled, but can be adjusted by using the **Increase/Decrease X/Y** buttons.

The characteristics of each data point may be examined using the **Forward/Back** buttons on the **Data** tab of the **Main Form**, with the active point appearing in green on the **J-delta a** display.

The plot will be available for printing after post-processing in the Excel utility has taken place.

6.5.2 OUTPUT DISPLAY

```
Test ID I:\Software Development\Current Software Development\NLFT Analysis V3.11.07\test1.dat    _ □ ×

Index,Time,Force,Disp1,Disp2,CrackLength, Delta-a,CTOD,K-E561, K-E1820,J-E1820,KJ-E1820, K-E1921,J-E1921,KJ-E1921
1, 32.8, 239.4, 0.00260, 0.09705, 0.6219, 0.0006, 0.000034, 18.05, 17.89, 9.74, 17.92, 0.00, 0.00, 0.00,
2, 52.6, 235.7, 0.00255, 0.09583, 0.6219, 0.0006, 0.000032, 17.77, 17.62, 9.41, 17.61, 0.00, 0.00, 0.00,
3, 68.4, 239.3, 0.00259, 0.09705, 0.6218, 0.0005, 0.000034, 18.03, 17.88, 9.73, 17.91, 0.00, 0.00, 0.00,
4, 101.1, 240.2, 0.00260, 0.09766, 0.6218, 0.0005, 0.000034, 18.10, 17.95, 9.77, 17.94, 0.00, 0.00, 0.00,
5, 219.6, 369.9, 0.00407, 0.14893, 0.6213, 0.0000, 0.000081, 28.15, 27.58, 23.37, 27.76, 0.00, 0.00, 0.00,
6, 240.9, 500.0, 0.00557, 0.20142, 0.6214, 0.0001, 0.000149, 38.72, 37.30, 43.33, 37.79, 0.00, 0.00, 0.00,
7, 261.8, 628.4, 0.00709, 0.25360, 0.6211, -0.0002, 0.000240, 49.66, 46.81, 69.55, 47.88, 0.00, 0.00, 0.00,
8, 282.4, 751.4, 0.00861, 0.30243, 0.6215, 0.0001, 0.000350, 61.08, 56.06, 101.42, 57.82, 0.00, 0.00, 0.00,
9, 302.8, 867.6, 0.01011, 0.34790, 0.6216, 0.0002, 0.000478, 72.68, 64.75, 138.65, 67.61, 0.00, 0.00, 0.00,
10, 323.1, 973.8, 0.01157, 0.39215, 0.6219, 0.0006, 0.000621, 84.37, 72.79, 179.99, 77.03, 0.00, 0.00, 0.00,
11, 342.8, 1080.9, 0.01313, 0.43396, 0.6226, 0.0012, 0.000790, 97.56, 81.02, 229.02, 86.89, 0.00, 0.00, 0.00,
12, 362.6, 1173.2, 0.01463, 0.47211, 0.6229, 0.0016, 0.000971, 110.00, 88.07, 281.59, 96.35, 0.00, 0.00, 0.00,
13, 381.9, 1257.0, 0.01617, 0.50537, 0.6241, 0.0028, 0.001169, 123.22, 94.83, 338.96, 105.71, 0.00, 0.00, 0.00,
14, 401.1, 1320.3, 0.01762, 0.53070, 0.6253, 0.0040, 0.001370, 134.63, 100.11, 397.03, 114.41, 0.00, 0.00, 0.00,
15, 419.8, 1374.6, 0.01914, 0.55145, 0.6269, 0.0055, 0.001588, 145.97, 104.91, 460.22, 123.18, 0.00, 0.00, 0.00,
16, 438.3, 1421.4, 0.02072, 0.57190, 0.6289, 0.0076, 0.001821, 157.72, 109.43, 527.88, 131.92, 0.00, 0.00, 0.00,
```

The .dat file produced by the pre-processing routine appear on the **Output** display. This is for information only: the .dat file will be available for printing after post-processing has occurred.

6.5.3 LOAD-DISPLACEMENT DISPLAY
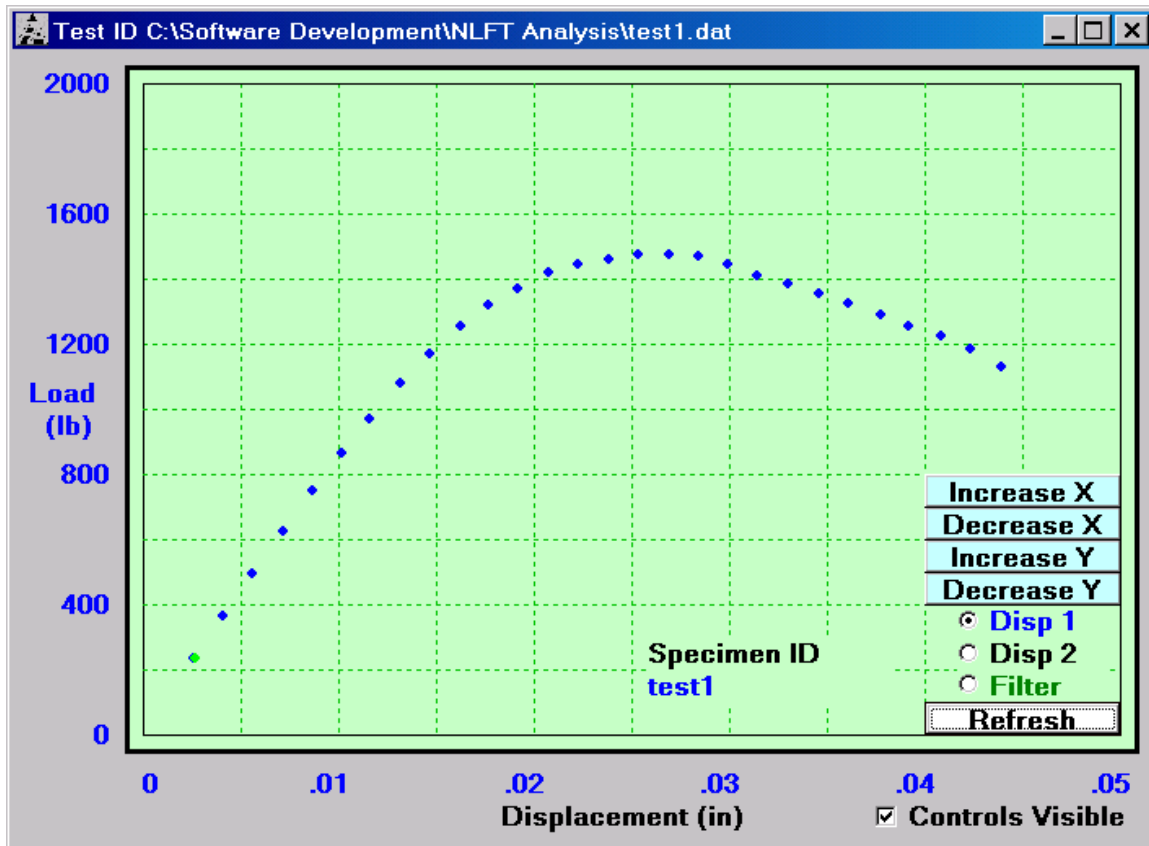
After pre-processing a third display, **Load-Displacement**, may be viewed by selecting **Load-displacement** from the **Display** drop down list on the **Main Form**. The **Increase/Decrease X/Y** buttons may be used to change the scale.

If the load-displacement data file (.raw extension) is loaded, this can also be displayed as seen below. When the **Filter** option on the plot is selected, the **Data Filter Options** from the **Kıc Utility** tab are displayed.

NLFT Testing - Series 2015 - V3+.16.01
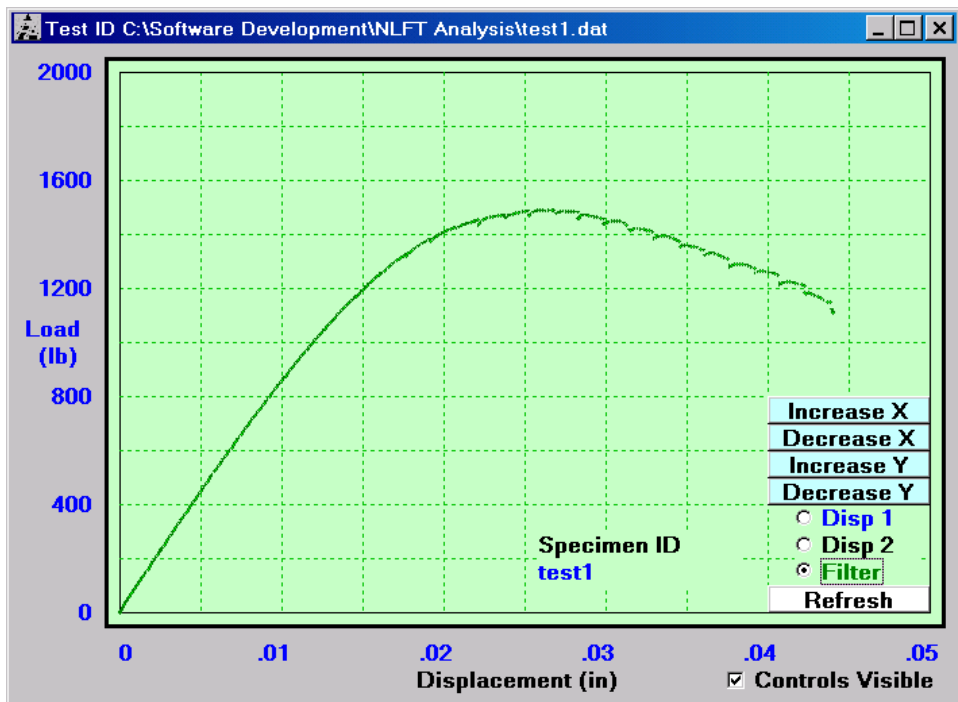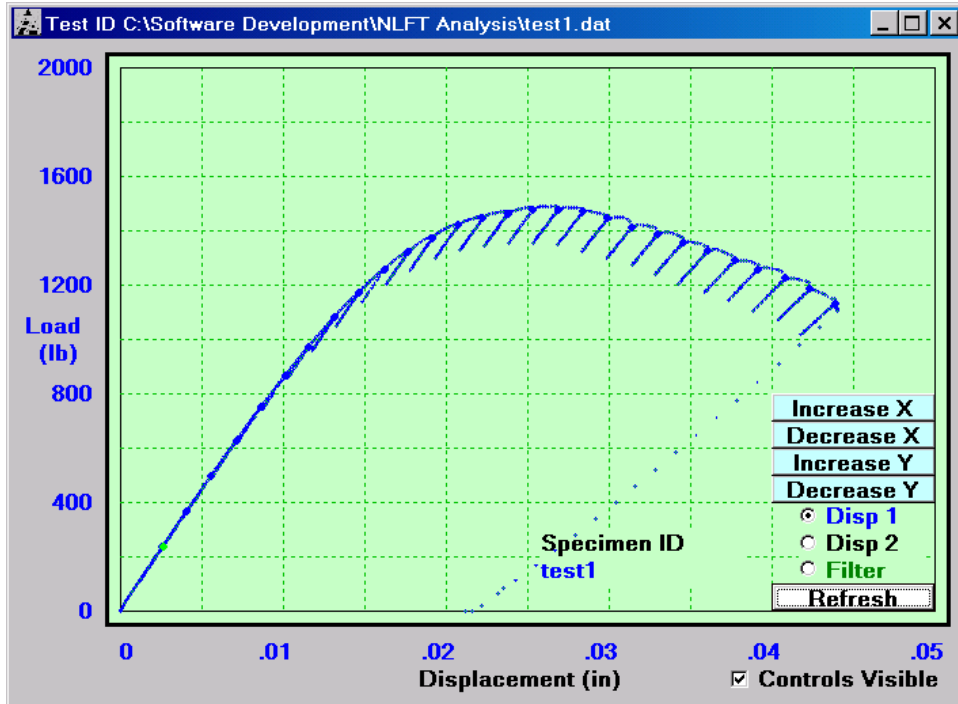
6.6   Post Processing

This menu option launches the post processing Microsoft Excel utilities by calling and populating two Excel templates from the **Post Processing** drop down list on the **Main Form**:

- **Non-Linear Toughness Report** (nlft.exe) for E 1820 or E1921 analyses. Designed for non-linear J-R analyses; production of test reports and graphs; and performance of validity checks

- **Load Disp and Linear Toughness Report** (nlft_timed data.xls) for E399 analysis (or the production of Load-displacement and Load-Time plots for other tests). Designed for linear K_{IC} analysis and the production of **Load Time** and **Load-displacement** plots for other tests.

Selecting either of these options from the drop-down list calls up the Excel post-processing utility, which is described in detail below. It is important that all data be pre-processed (using the blue **Run Non-Linear Analysis** and **Process Load-Disp Data** buttons at the bottom of the **Main Form**) and viewed for anomalies before proceeding with the post-processing routine.

7.0 Analysis Utility

After analyzing data in the FTA analysis main program, the post-processing and validation of data are accomplished using the Microsoft Excel utility described herein. Microsoft Excel 2007 or 2010 must be previously loaded on the user's PC. The intent is to provide an Excel file that contains all necessary output in a convenient location and file format. Once the analysis is completed, the user must save the Excel file under a different name and directory for data archiving. The user may modify the appearance (color, title, scale, etc.) of the Excel workbook as usual.

The macros used for the various analysis types can be viewed using the **Tools** menu in Excel.

7.1. Non-Linear Report

After the data have been preprocessed using the blue **Run Non-Linear Analysis** button at the bottom of the **Main Form,** the Excel utility is initiated by choosing **Non-Linear Report** from the **Post Processing** drop down menu. The unit type will be carried over from pre-processing. The following example uses English units.

Launching the post-processing procedure will result in a pause while Excel is started and the cells of the nlft.xls workbook are populated with the .dat file's raw data. To reduce wait time, Excel is kept invisible until all data have been transferred, although a flashing message on the VB program's **Control** tab (**Main Form**) indicates its progress. Once the data transfer is complete, the Excel workbook will appear in a standard window.

If **ASTM E1820** was chosen on the **Control** tab of the VB program's **Main Form**, it will be necessary to press the **ASTM E1820 JIC** button on the topmost page of the Excel workbook (the **Raw Data** worksheet) to complete the regression analysis. A new seven-worksheet report will appear.

If **ASTM E1921** was chosen on the **Control** tab of the VB program's **Main Form**, it will be necessary to press the **ASTM E1921 KJIC** button on the topmost page of the Excel workbook (the **Raw Data** worksheet) to complete the regression analysis. A new five-worksheet report will appear.

The workbooks should be saved with a new name (usually the **TEST ID**) before viewing and printing. Each of the worksheets in the workbooks is discussed in detail, below, as they appear in the workbook from left to right in the 2007 version of the program.

7.1.1 USER INPUT
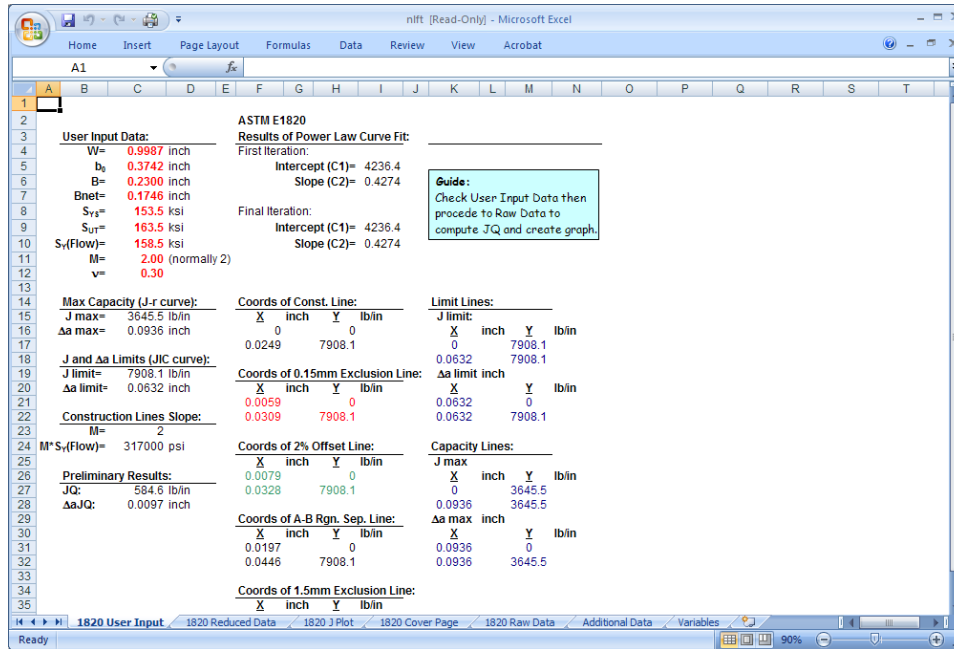
The **User Input** worksheet holds data used for plotting purposes and should not be modified. However, when running an E1820 analysis, the user has the option of changing the value of M (slope of the blunting line). See ASTM E1820 for details and limitations.

User Input is not necessary for an E1921 analysis and is therefore not displayed in an E1921 workbook.

7.1.2 REDUCED DATA

First Iteration Data Set		Second Iteration Data Set	
Δa	J1820	Δa	J1820
0.00757441	527.8811646	0.00757441	527.8811646
0.0101749	593.6184082	0.0101749	593.6184082
0.013142556	660.5320435	0.013142556	660.5320435
0.01603511	727.5093994	0.01603511	727.5093994
0.019822747	795.2597656	0.019822747	795.2597656
0.02357319	861.4018555	0.02357319	861.4018555
0.028335541	922.4325562	0.028335541	922.4325562
0.032954365	980.6972656	0.032954365	980.6972656
0.037784904	1041.176758	0.037784904	1041.176758
0.042875081	1096.873047	0.042875081	1096.873047
0.047517151	1151.717896	0.047517151	1151.717896
0.053614765	1202.566772	0.053614765	1202.566772
0.057519764	1255.595459	0.057519764	1255.595459
0.062505752	1307.883057	0.062505752	1307.883057

When running an E1820 analysis, the **Reduced Data** worksheet is populated after the **E1820 JIC Analysis** button on the **Raw Data** worksheet was pressed. Data are excluded based on location relative to exclusion lines; J limit; and Δa Limit lines. If before post-processing, the **Override J Limit** was activated on the **Control Worksheet** of the VB program's **Main Form**, then J_{limit} is ignored in the exclusion decision. Two reductions are applied, labeled **First Iteration Data Set** and **Second Iteration Data Set** (above). It is possible for no difference to exist between the first and second iteration data sets. A power law fit is applied to the first data set to qualify data in the second. A final power law fit is applied to the second to determine J_Q. The coefficients of these regression analyses are shown on the **User Input** worksheet.

The **Reduced Data** sheet is intended for information purposes only and does not appear in E1921 analyses.

7.1.3 J-PLOT
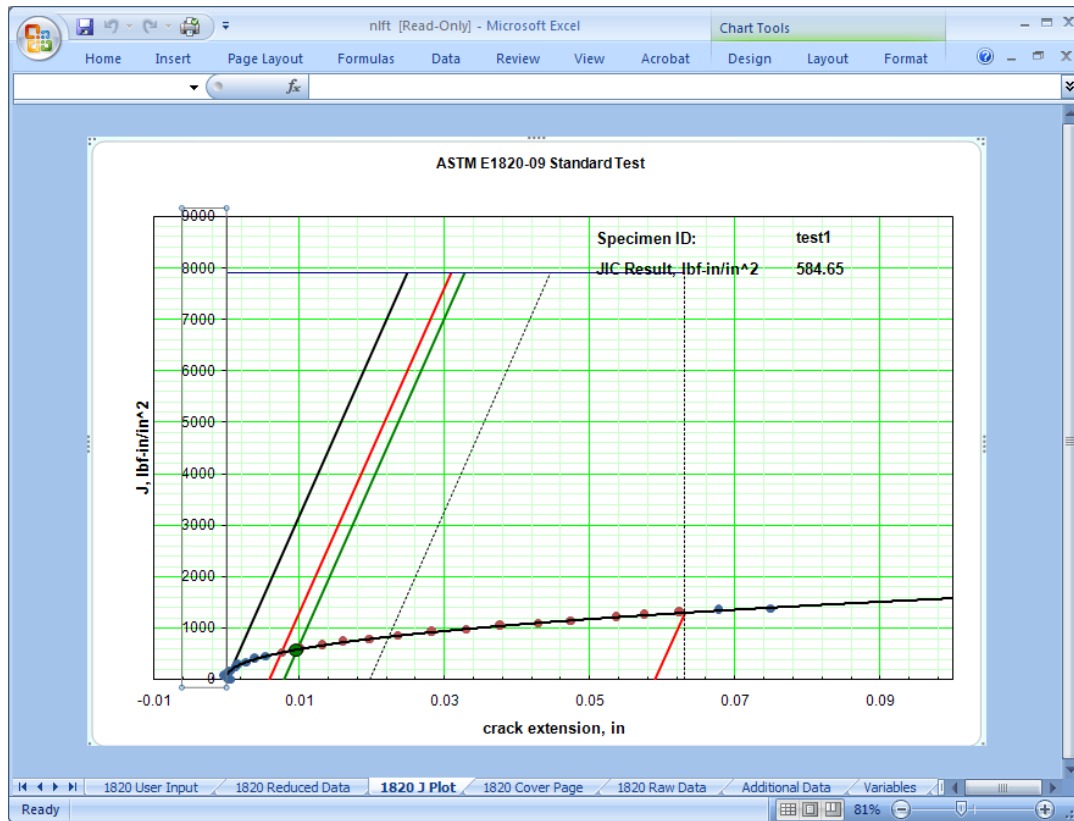
In addition to populating the **Reduced Data** worksheet, pressing **E1820 JIC Analysis** generates a **J plot.** Raw data appear as hollow circles while red-filled circles are data from the **Reduced Data** second iteration. Red circles should only appear between the red exclusion lines. The slanted lines from left to right are **construction** (black); **0.15mm exclusion** (red); **0.2mm offset** (green); **A-B region separation** (dashed); and **1.5mm exclusion** (red). The blue horizontal and vertical lines are the J_{limit} and Δa_{limit} lines, respectively. These lines are linked to the information on the **User Input** worksheet and may not be visible before the analysis button is pressed. The equation of the regression line is also shown. A legend may be added as shown above using standard MS Excel commands. The data and time are included as an Excel custom header. The title is accessed and edited by clicking on it.

For an E1921 test with unloading slopes, the **J-plot** is replaced with a **K Plot**.

7.1.4 COVER PAGE

The **Cover Page** is intended to serve as a hardcopy test report. It is populated through absolute referencing of the **Variables** and **User Input** worksheets. The definitions of the qualification and validity checks are available in the relevant ASTM standard. An **x** appearing below a visually-measured crack length, flags it as invalid in terms of straightness. Also, J_{IC} and K_{JIC} are only valid according to the standard if all validity conditions on this sheet are met.

It is recommended that the **Cover Page** be viewed in Print Preview mode (shown below) to ensure proper format:

Next | Previous | Zoom | Print... | Setup... | Margins | Page Break Preview | Close | Help

File Name : nlft.xls   Date: 2/11/2003

Elastic-Plastic Fracture Toughness Analysis

Specimen ID	test1	Geometry	C(T)
Contract	Demo	Orientation	Unknown
Material	Steel	Yield (ksi)	153.5
Temperature(F)	75.0	Tensile (ksi)	153.5
Environment	Lab Air	Modulus (Msi)	30.0

Specimen Dimensions

Thickness (in)	0.230	Notch Depth (in)	0.550
Net Thickness (in)	0.175	Gage Length (in)	0.170
Width (in)	0.999	Alpha Ratio	1
Pin Spacing (in)	0.750		

Precrack Parameters

Pmax (lbf)	320.0	Stress Ratio	0.1
Final a (in)	0.620	Kmax (ksi sqrt(in))	21.1
Pf (lbf)	77.9		

Initial measured crack lengths (in)

0.623	0.624	0.625	0.625	0.625	0.625	0.626	0.624	0.624

Final measured crack lengths (in)

0.669	0.698	0.696	0.700	0.702	0.702	0.697	0.692	0.669
0	0	0	0	0	0	0	0	0

Ave. initial crack length (in)	0.624	aoq (in)	0.621
Ave. final crack length (in)	0.695	Compliance Adj. Factor	1.000
Delta a measured (in)	0.070	Effective Modulus (Msi)	30.0
Delta a predicted (in)	0.074		

Results

J_Q (E1820)	584.6 lbf-in/in^2
$K_{JIc}(E^*JQ)^{1/2}$	138.8 ksi sqrt(in)

Qualification of Data		**Qualification of J_Q an J_{Ic}**	
7.4.2 : precrack length	valid		
9.1.4.1; precrack	valid	A9.3.1; thickness	valid
9.1.4.2; final crack	valid	A9.3.2; ligament	valid
9.1.5.1; Aa mea s	invalid	A9.3.3 ; slope	valid
9.1.5.2; Aa pred	valid		
A9.6.4; # of pnts in reg. A	valid		
A9.6.4; # of pnts in reg. B	valid		
A9.8.1; Cx<1	valid		
A9.8.2.1; aoq<ac	valid		
A9.8.2.2; # of pnts for J_Q	valid		
A9.8.2.2; # of pnts < J_Q	valid		
A9.3.3.1; correlation	valid		

Preview: Page 1 of 1

7.1.5 RAW DATA

The **Raw Data** worksheet displays the .dat file. Data excluded in the main program are not transferred to the utility. The button for completing analyses is located in the middle of the sheet for easy access but is not visible when printing.

When printed, this page serves as a hardcopy record of the data. Special formatting and naming have been applied to the columns; therefore *columns cannot be deleted*. If a printout is desired with less information, the user may hide or show the un/wanted columns using basic Excel procedures. Excel-related information and help can be accessed through the program.

7.1.6 ADDITIONAL DATA

FTA has no comment to make on this worksheet. It is possibly non-functional.

7.1.7 VARIABLES

The **Variables** worksheet is populated by the main program and the analysis macro. *It must not be edited by the user.* Cells cannot be moved as this will cause an error in the utility's operation. Since this sheet is cleared automatically with each new run, it is not necessary to clear it manually.

7.2. Load-Disp and Linear Report

After the load-displacement (.raw) data have been pre-processed using the blue **Process Load Disp** button at the bottom of the **Main Form,** the Excel utility is initiated by choosing **Load-Disp and Linear Report** from the **Post Processing** drop down menu. The unit type will be carried over from pre-processing. The following example uses English units.

Launching the post-processing procedure will result in a pause while Excel is started and the cells of the workbook are populated with the output from the VB program. To reduce wait time, Excel is kept invisible until all data have been transferred, although a flashing message on the VB program's **Control** tab (**Main Menu**) indicates its progress. Once the data transfer is complete, the Excel workbook will appear in a standard window.

If **ASTM E1820** or **ASTM 1921** was chosen on the **Control** tab of the VB program's **Main Form**, only two worksheets of the resulting Excel workbook will be of interest: the load-displacement plot and the load-time plot.
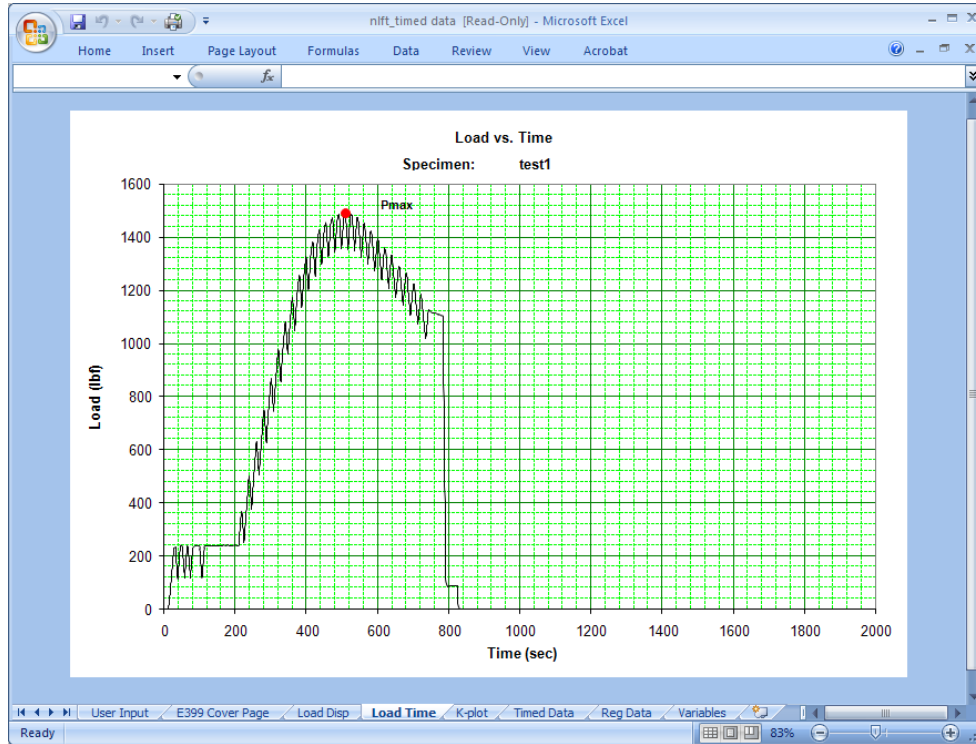
7.2.1 LOAD DISP

For non-linear analysis, a typical load-displacement display is shown below.
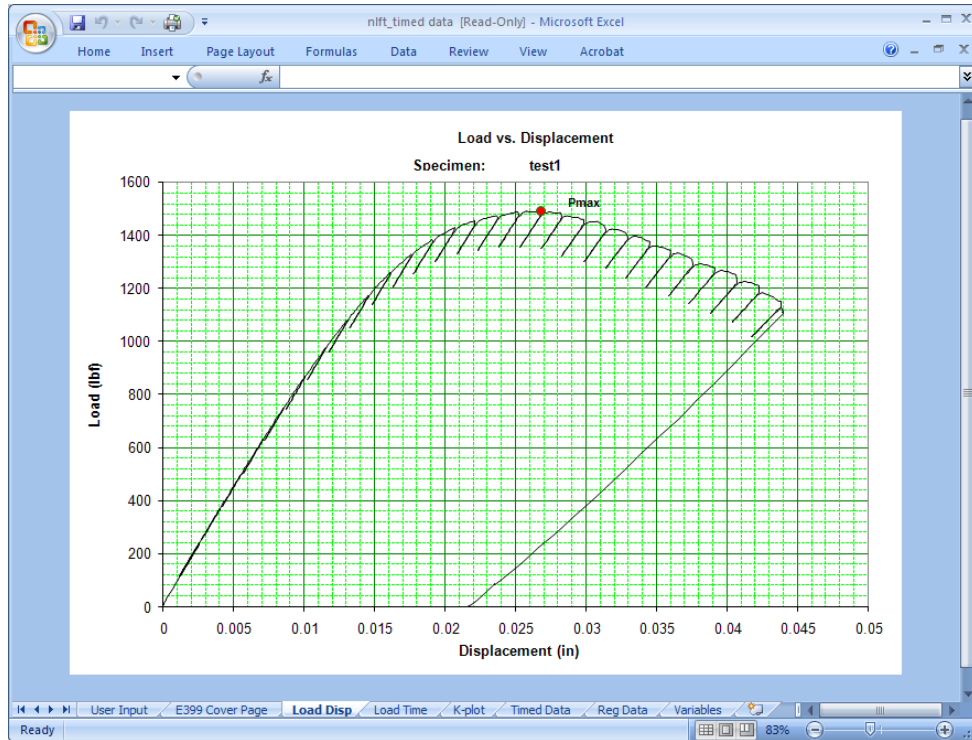
7.2.2 LOAD TIME

For non-linear analysis, a typical load-time display is shown below.

7.2.3 USER INPUT

For linear elastic analysis, the upper and lower limits of linear fit may be modified.

User Input Information				
Specify Upper and Lower Regression Limits ONLY and **Calculate KIC**.				
70	Upper Regression Limit, %Pmax		Slope of Line 0A	X Intrcpt of Line 0A
			80775.76 lbf/in	-0.00061 in
20	Lower Regression Limit, %Pmax			
			Y Intercept of Line 0A	Coord's of Line 0A
379	# of Data Points, Total		49.37765 lbf	x's y's
				1 0.003077 297.95
88	# of Data Points used		Slope, 95% Secant	2 0.012299 1042.825
	for Regression		76736.97 lbf/in	
			Coord's of Secant Line	Y Intrcpt of Secant Line
			x's y's	46.90877 lbf
			1 -0.00061 0	
	KQ		2 0.018802 1489.75	
	90.1 ksi sqrt (in)			
			Load at PQ	
	Rate		1189.2 lbf	**Calculate KIC**
	355.45 lbf/min			
	26.92 ksi sqrt (in)/min		Disp at PQ	
			0.015 in	
	1489.75 Pmax (lbf) from Raw File			
	0.027 Disp (in) at Pmax		Crack Length	
	510.7 Time (sec) at Pmax		0.625 in	

Sheet tabs: User Input / E399 Cover Page / Load Disp / Load Time / K-plot / Timed Data / Reg Data / Variables

7.2.4 COVER PAGE

For linear elastic analysis, the cover page can be displayed.

7.2.5 K-PLOT

For linear elastic analysis, the plot and K_Q as per secant offset is displayed.

NLFT Testing - Series 2015 - V3+.16.01
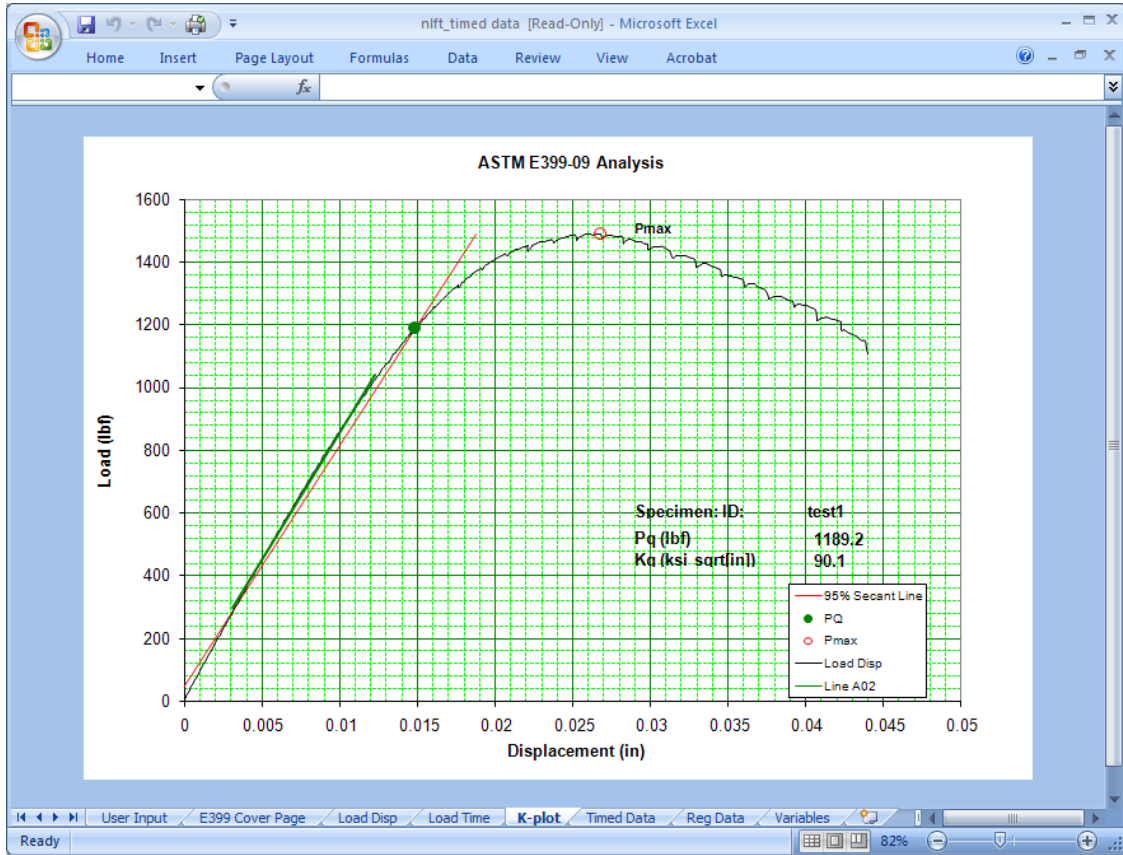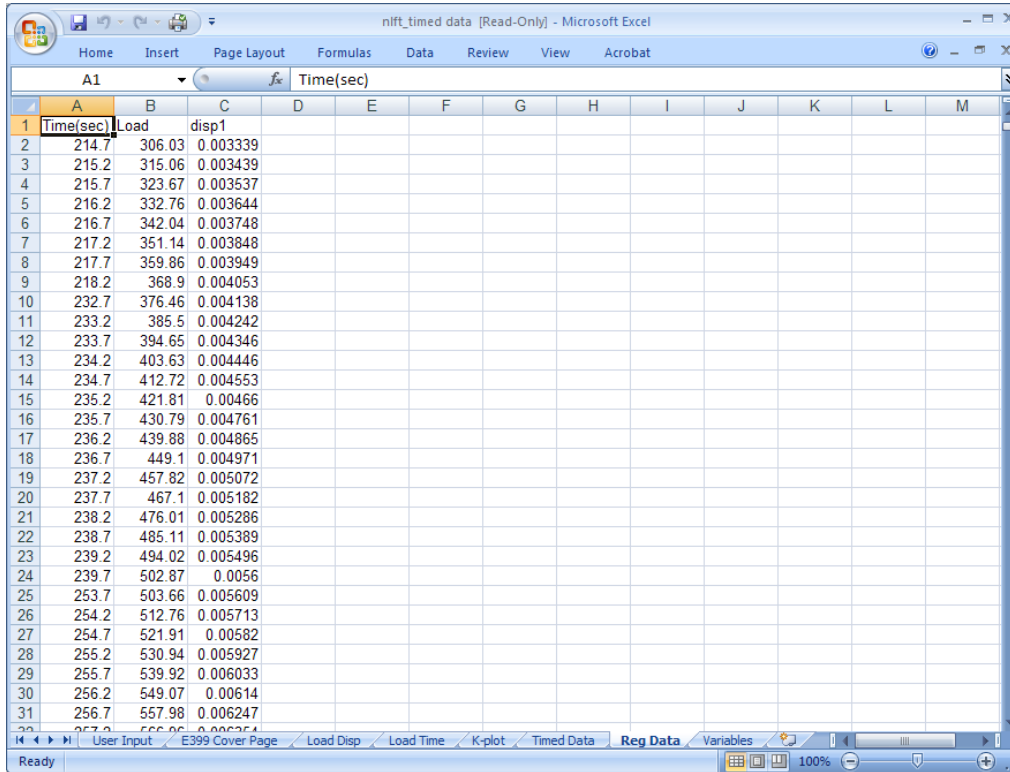
7.2.6 TIMED DATA

Raw load-displacement with time stamp can also be displayed.

7.2.7 REG DATA

The load-displacement selected for linear fit can also be displayed.

7.2.8 VARIABLES

Excel spreadsheet "nlft_timed data [Read-Only] - Microsoft Excel", cell A1: Single Variables (From VBA)

	A	B	C	D	E	F	G	H	I	J	K
1	Single Variables (From VBA)					Array Variables					
2											
3	Value	Var. Name									
4	0.998700023	W(in,mm)			precrack(in,)	0.6227	0.6247	0.6246	0.6257	0.624	
5	0.373700023	b0(in,mm)									
6	0.230000004	B(in,mm)									
7	0.174600005	Bnet(in,mm)									
8	153.5	yield stress(ksi,Mpa)		Validity Values	Validity Check Variables:						
9	163.5	tensile stress(ksi,Mpa)		0.0008	1	section A833a					
10	31	Buffersize2		24.23217583	1	section A833b					
11	test1	testID		0.100000001	1	section A842					
12	Demo	Contract		0.625813544	0	section 7321					
13	Steel	Material		0.072699964	1	section 7322					
14	75.0	temperature		0	1	section 8.2.2 (1)					
15	Lab Air	Environment		0	0						
16	C(T)	Geom		0	1	section 8.2.2 (3), three parts					
17	Unknown	Orientation				section 8.2.3		Visual Observation			
18	158500	Flow Stress(psi,KPa)		26.91632271	0	section 8.3					
19	30	E(Msi,Gpa)		1.252722383	0	section 9.1.2					
20	0.02	Ramp Rate		0.860449195	0	section 9.1.3					
21	0.75	H(in,mm)									
22	0.550000012	Notch(in,mm)			24.23	Precrack K					
23	0.170000002	GL(in,mm)									
24	1	Alpha			0.625	aAve					
25	320.0	PrecrackP			0.626	a/W					
26	0.620000005	PrecrackA(in,mm)			0.860	Minimum Size					
27	0.100000001	PrecrackR			2.088	Crack Strength ratio					
28	21.11303329	PrecrackK									
29	0.625	a0average(in,mm)			1189.21	PQ					
30	1489.75	Pmax (raw file) lbf,kN			1489.75	Pmax					
31	0.026794	Disp at Pmax, in, mm			1.253	Pmax/PQ Ratio					

Sheet tabs: User Input, E399 Cover Page, Load Disp, Load Time, K-plot, Timed Data, Reg Data, **Variables**

8.0 The NLFT Testing PLAYBACK Software

The **Non-Linear Fracture Toughness Playback** software provides a means of re-processing a test's unloading slopes using a different window for the linear part of the slope. This routine is useful if the window was not adjusted during testing and crack length data were collected during non-linear portions of the slope. The new file is a .in5 file with the letter **X** appended to the test ID in the filename.

8.1 Using the Testing Playback Software

1. Start the **NLFT Testing Playback** program from the desktop or the program menu.

2. When the **Splash Screen** appears, press **Start**.

3. The **Main Menu** appears: select **Unit Type** (English or Metric).

4. From the **File** menu, select **Open → Load-Displacement File (.raw)**. After loading the file the **Data Count** should be displayed in the text box on the **Main Menu**.If the box is empty, the file is not compatible with the five-column default determined on the **Options** form. On the **Main Menu**, go to **Input** drop down list and select **Data Input** and **Options**. On the **Options** form, choose only the stored data columns consistent with those in the load-displacement (.raw) file. When experimenting with the practice files provided with the FTA software, for example, choose **Store Load** and **Store Disp 2** only on the **Options** form.

5. From the **File** menu, select **Open →Unloading Data File (.unl)**. The **Unload Count** should be displayed.

6. From the **File** menu, select **Open → Analysis File (.in5)**. The **Slope Count** should be displayed.

7. If not already open, open the **Data Input** and **Options** forms from the **Input** drop down list.

8. From the **Display** drop down menu, select the **Load-Displacement** display.

9. From the **Display** drop down menu, select the **J-da** display.

10. Press the **Activate** button on the **Initialize** tab of the **Data Input** form.

11. Press **Refresh** on the **Load-Displacement** display. The unloading slopes will appear in red.

12. Observe the text box under the **Compute** buttons. The number already appearing in the box is the slope window (expressed as % of slope) that was specified on the **Data Acquisition** tab (**Upper Window for Slope**) of the **Data Input** menu during testing. The default was 90%. Enter a new lesser value that will capture the linear part of the slope only.

13. Use the **Compute +/Compute** buttons to step forward or back through the slopes, which are reprocessed according to the new window specified above. View the results on the **J-da** display and adjust the window for each slope as necessary.

14. When you are satisfied with the results, you may save the re-processed analysis file (.in5 extension) with **Save Analysis File As → Version 3**. An **X** will be appended to the Test ID in the filename to avoid overwriting the original .in5 file.

8.2 Description of Menus and Tabs

8.2.1 SPLASH SCREEN

The **Splash Screen** is displayed upon start-up. The application title and version number are identified at the top of this form. Only unloading compliance data may be reprocessed.

8.2.2 Main Menu
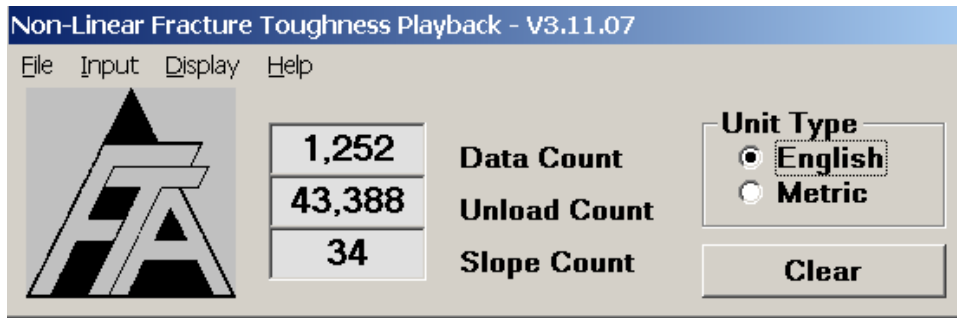
The **Main Menu** is always displayed while the program is running: its default position is in the upper left-corner of the computer screen. The **Main Menu** cannot be minimized or closed, but it can be moved. Select the **Unit Type** prior to opening other forms.

Three text boxes provide information about the data files:

- **Data Count** indicates the number of load-displacement pairs in the load-displacement (.raw) file. If the stored data columns in the .raw file do not match those specified on the **Options** tab of the **Testing Playback** software, this text box will remain blank. Adjust as required on the **Options** tab.

- **Unload Count** indicates the number of load-displacement pairs in the unloading (.unl) file

- **Slope Count** indicates the number of unloading slopes in the analysis (.in5) file

Each of the **Main Form** drop down lists, **File, Input, Display,** and **Help,** is described below.

8.2.2.1   FILE
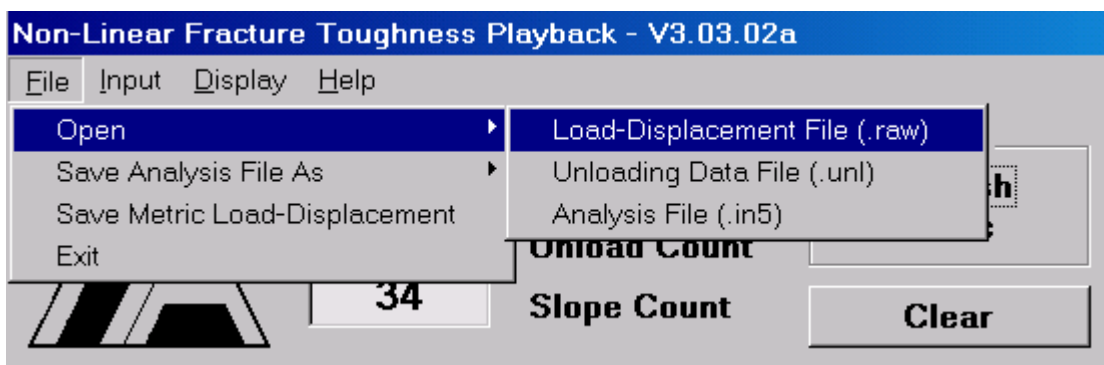
8.2.2.2   Open

The **Open** drop down list allows the user to load the three files associated with the **Testing Playback** program:

- **Open Load-Displacement File:** the load-displacement (.raw) file may be opened for viewing or, if necessary, saving in Metric units. The default setting for reading this file is a five column format. If the file to be read has less than five columns, it is necessary to open the **Options** form (**Input** drop down list), then select the data columns consistent with the .raw file. It is not necessary to open this file to reprocess unloading slopes.

- **Open Unloading Data File:** the unloading slope (.unl) file must be opened for reprocessing.

- **Open Analysis File**: the analysis (.in5) file must be opened for reprocessing.

8.2.2.3   Save Analysis File As

The reprocessed file is saved with a .in5 extension. An **X** is appended to the file name to avoid overwriting the original file.

8.2.2.4   Save Metric Load-Displacement

The load-displacement (.raw) file may be saved in Metric instead of English units. An M is appended to the file name to avoid overwriting the original file.

8.2.3 INPUT

The **Input** drop down list allows access to the **Data Input** form and the **Options** form.

8.2.3.1 Data

The **Data Input** form includes four tabs for viewing data: **Initialize**, **Coefficients**, **Dimensions**, and **Calibration.** These data may not be changed.

8.2.3.1.1 Initialize

When the analysis (.in5) file is loaded the fields will be populated automatically.

The initialize frame allows restarting the re-processing with the first slope. The delta a can be set to zero at any slope.

8.2.3.1.2 Coefficients

The stress intensity and compliance coefficients are part of the .in5 file and can be examined but not changed.

8.2.3.1.3 Dimensions

Data Input

Initialize | Coefficients | Dimensions..... | Calibration

Specimen Thickness (in)	0.230
Net Specimen Thickness (in)	0.1746
Specimen Width (in)	0.9987
Span to Width Ratio	0.00
Crack Length (in)	0.6227
Pin Spacing (in)	0.750
Comp Gage Length (in)	0.170
Comp Alpha Ratio	1.000
Modulus of Elasticity (Msi)	30.0
Yield Stress (ksi)	153.5
Tensile Stress (ksi)	163.5
Limit Load (kN)	0.0

Dimensions and material properties are part of the .in5 file and can be examined but not changed.

8.2.3.1.4   Calibration

The calibration factors must be entered consistent with the ones used to run the test.

8.2.3.2   Options
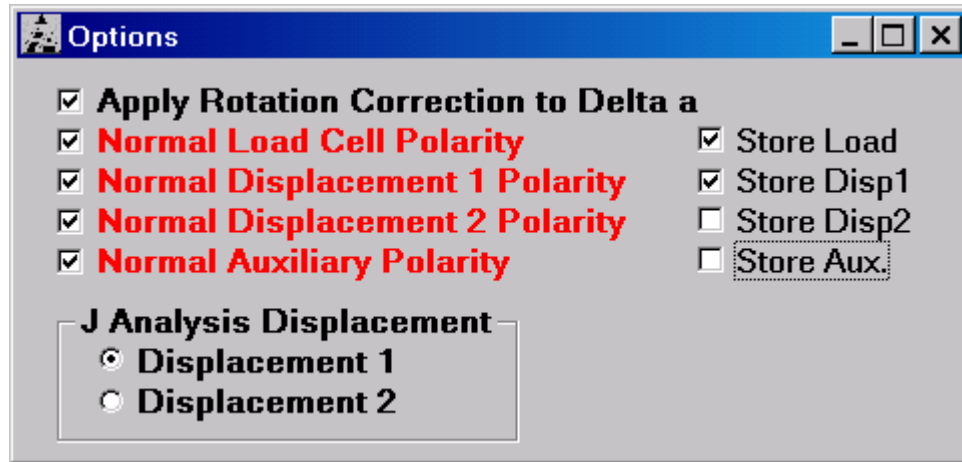
It is critical that the stored data check boxes match those in the .raw file to be re-processed.

8.2.4 DISPLAY

This main menu drop down list is used to open the **Load-Displacement** display and the **J-Δa** display.

8.2.4.1   Load-Displacement
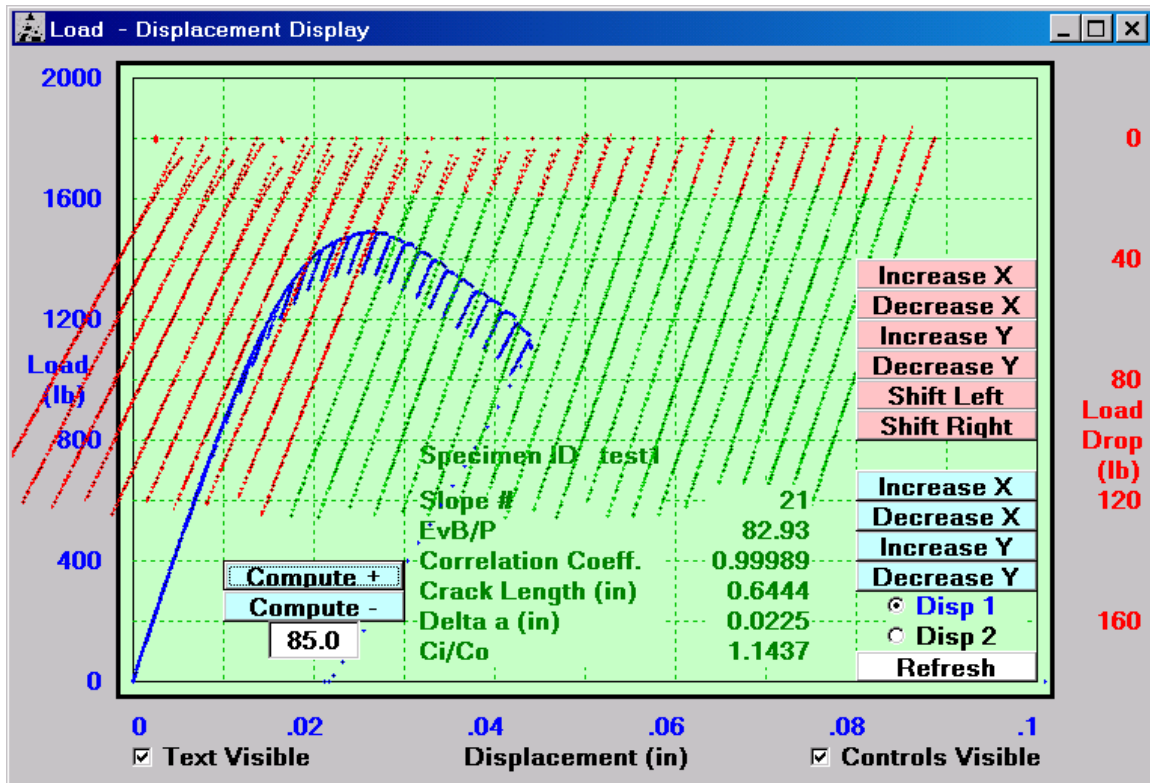
Load-displacement and unloading slopes are shown on the **Load-displacement** display, scaled with red and blue buttons as with the testing program. **Disp 1/Disp2** and **Refresh** also work in the same manner as the testing program.

The data used for crack length determination are shown as green portions of the unloading slopes. Data in red are excluded from analysis.

COMPUTE + : when pressed, the slope to the left of the current slope is re-processed.

COMPUTE - : when pressed, the slope to the right of the current slope is re-processed.

White Text Box: specifies the cutoff (as a % of total unloading compliance slope) below which crack length is determined. The user enters the desired slope window in this box.

8.2.4.2   J – Delta a
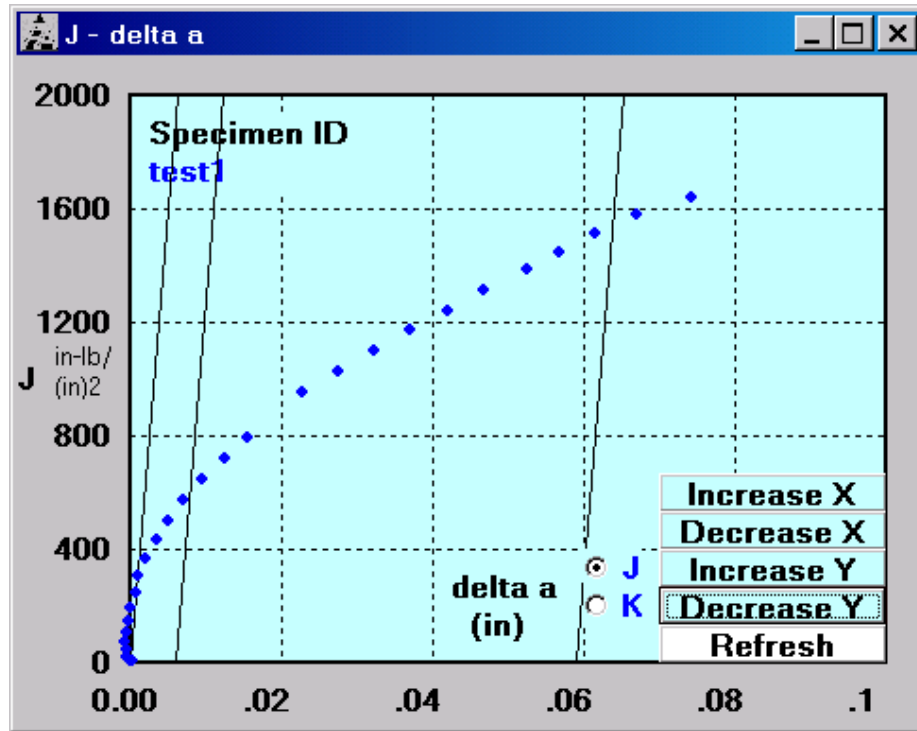
The **J- delta a** plot functions in the same way as the J-delta a plot in the main VB analysis program.

8.2.5 HELP

A PDF file of this manual is available under the **Help** menu

Appendix A: Recovery from System Crash

In the event of a fatal error, system crash or accidental exit from the program, it is possible to resume the test without test interruption, loss of control, or data. All key variables are stored in the ADwin-Gold system.

1. Reboot the computer if necessary. Be sure the green light on the ADwin-Gold continues blinking.

2. Restart the program from the desktop or the program menu.

3. The compliance or DCPD potential drop choice should already be displayed. Press **Resume** on the Splash Screen.

4. Select **Data** under the **Input** menu.

5. Re-enter the test identification.

6. Press **Start Data File** and save.

7. Inspect the remaining tabs for proper input parameters.

8. Open the remaining forms. Remember that the **Ramp Generator** must be open for the display forms to update properly.

9. Breathe a sigh of relief!

Appendix B: Descriptions of Analysis Files

B1:   Log file

Log files are saved automatically by the testing software and contain one line of key test parameters whenever a crack size calculation is made. In addition, all date input parameters are stored to the log file every time **Print to Log** is pressed on the **Data Input** form. When data storage limits are reached (final crack length, for example), a record of this stopping condition is also recorded in the file. Any error messages that appeared on the FNG are also recorded. Examples of a compliance and DCPD log file appear below.

B1A: COMPLIANCE

```
Test ID              test527
Unit Type            English
K Calibration Type        Polynomial

Coeff K0             0.886
Coeff K1             4.64
Coeff K2             -13.32
Coeff K3             14.72
Coeff K4             -5.6
Coeff K5             0

Coeff C0             1.0002
Coeff C1             -4.0632
Coeff C2             11.242
Coeff C3             -106.04
Coeff C4             464.33
Coeff C5             -650.68

Specimen Thickness (in)      1
Net Specimen Thickness (in)   0.8
Specimen Width (in)        2
Crack Length (in)        1.2
Pin Spacing (in)         1.1
Gage Length (in)         0.2
Alpha ratio          1
Modulus of Elasticity (Msi)    30
Yield Stress (ksi)        100
Tensile Stress (ksi)       120

Load Cell Calibration (lb/volt)  2500
Disp. 1 Calibration (in/volt)   0.005
Disp. 2 Calibration (in/volt)   0.005
Auxiliary Calibration (unit/volt) 1
Stroke Calibration (in/volt)   0.025
PD Gage Length (in)        0
PD Initial Crack Length (in)   0
Initial PD (micro-volts)     0
```

```
PDGain (Active)               0

Storage Interval (Active only)
Load (lb)          500
Disp. 1 (in)       0.001

Load Drop for Unloading Slopes (lb) 1000
Upper Window for Slope (%)      90
Data Interval Delay (seconds)    1

Transducer Limits (Active only)
Load (lb)          -100          20000
Disp. 1 (in)       -0.01          0.05

Other Limits (Active only)
Load Drop Limit (lb)  2000

Ramp Rate
Ramp Up (in/min)        0.05
Unloading Slope (in/min)  0.1
Ramp Down (in/min)       0.2

Data Acquisition Rate
Normal (pts/sec)       2
Hold (pts/sec)         0.2
Unload (pts/sec)       10

Time               2:03:37 PM
Date               5/27/2013

Index Time Load Disp1 Disp2 Aux v/P EvB/P Corr CiC0  A  dA


1, 42.5, 1496.1, 0.003, 0.00025, 0.02136, 2.00069E-6, 57.62, 0.999999, 0.000000, 1.1674, 0.0000
2, 56.8, 1503.8, 0.00301, 0.00024, 0.02167, 2.00032E-6, 57.609, 0.999999, 1.000000, 1.1674, 0.0000
3, 74.1, 1503.8, 0.00301, 0.00025, 0.02167, 2.00070E-6, 57.62, 0.999999, 1.000188, 1.1674, 0.0001
4, 101.6, 2005.8, 0.00402, 0.00033, 0.03784, 2.00186E-6, 57.653, 0.999999, 1.000767, 1.1677, 0.0003
5, 120.7, 2507.0, 0.00502, 0.00041, 0.05402, 2.00121E-6, 57.635, 0.999999, 1.000442, 1.1676, 0.0002
8, 177.9, 4023.0, 0.00805, 0.00065, 0.10284, 2.00091E-6, 57.626, 0.999999, 1.000296, 1.1677, 0.0003
9, 197.2, 4513.6, 0.00903, 0.00074, 0.11963, 2.00030E-6, 57.609, 0.999999, 0.999989, 1.1676, 0.0003
10, 216.2, 5032.3, 0.01007, 0.00082, 0.13519, 2.00107E-6, 57.631, 0.999999, 1.000373, 1.1678, 0.0005
```

B1B: POTENTIAL DROP

```
Test ID              test2
Unit Type            English
K Calibration Type        Polynomial
PD Calibration Type       Johnson's

Coeff K0             0.886
Coeff K1             4.64
Coeff K2             -13.32
Coeff K3             14.72
Coeff K4             -5.6
Coeff K5             0

Coeff C0             1.0002
Coeff C1             -4.0632
Coeff C2             11.242
Coeff C3             -106.04
Coeff C4             464.33
Coeff C5             -650.68

Specimen Thickness (in)      0.5
Net Specimen Thickness (in)    0.4
Specimen Width (in)         1
Crack Length (in)          0.5
Pin Spacing (in)          0.55
Gage Length (in)          1.135
Alpha ratio             1
Modulus of Elasticity (Msi)    30
Yield Stress (ksi)         48
Tensile Stress (ksi)        109

Load Cell Calibration (lb/volt)  500
Disp. 1 Calibration (in/volt)   0.02
Disp. 2 Calibration (in/volt)   0.02
Auxiliary Calibration (unit/volt) 1
Stroke Calibration (in/volt)   0.1
PD Gage Length (in)        0.35
PD Initial Crack Length (in)   0.5
Initial PD (micro-volts)     0
PDGain (Active)          5000

Storage Interval (Active only)
Load (lb)        200
Disp. 1 (in)      0.002

Number of PD Cycles       2
Current Delay Factor (seconds)  0.5

Transducer Limits (Active only)
Load (lb)        -100       5000
Disp. 1 (in)      -0.01       0.2
DCPD Active (volts) -9.9        9.9

Other Limits (Active only)
```

```
Load Limit Hold (lb)   500
Delta a Limit (in)    0.08

Ramp Rate
Ramp Up (in/min)       0.05
Unloading Slope (in/min)  0.01
Ramp Down (in/min)      0.2

Data Acquisition Rate
Normal (pts/sec)       2
Hold (pts/sec)        0.2
Unload (pts/sec)       50


Time            2:16:38 PM
Date            1/24/2012


Index Time Load Disp1 Disp2 Aux PD PDref PDnorm  A  dA


Load limit hold

1, 139.2, 500.0, 0.01999, 0.00165, 0.05463,249.678,0.000,0.000, 0.0000, 0.0000
2, 168.7, 500.0, 0.01999, 0.00165, 0.05463,249.687,0.000,249.687, 0.5000, 0.0000
3, 188.6, 500.0, 0.01999, 0.00165, 0.05463,249.698,0.000,249.698, 0.5000, 0.0000
4, 202.1, 500.0, 0.01999, 0.00165, 0.05463,249.682,0.000,249.682, 0.5000, 0.0000
5, 263.0, 500.0, 0.01999, 0.00165, 0.05463,249.692,0.000,249.692, 0.5000, 0.0000
6, 372.1, 550.2, 0.02199, 0.00182, 0.06348,249.689,0.000,249.689, 0.5000, 0.0000
7, 389.6, 604.9, 0.02418, 0.00198, 0.07172,249.731,0.000,249.731, 0.5001, 0.0001
8, 407.2, 659.6, 0.02637, 0.00216, 0.08026,249.699,0.000,249.699, 0.5000, 0.0000
9, 424.9, 714.4, 0.02856, 0.00234, 0.09003,249.724,0.000,249.724, 0.5000, 0.0001
10, 442.5, 769.0, 0.03076, 0.00251, 0.09796,249.745,0.000,249.745, 0.5001, 0.0001
11, 460.1, 824.1, 0.03295, 0.00269, 0.10681,249.677,0.000,249.677, 0.5000, 0.0000
12, 477.7, 878.9, 0.03515, 0.00286, 0.11566,249.733,0.000,249.733, 0.5001, 0.0001
13, 495.4, 933.8, 0.03735, 0.00304, 0.12451,249.705,0.000,249.705, 0.5000, 0.0000
14, 513.0, 988.6, 0.03954, 0.00322, 0.13336,249.706,0.000,249.706, 0.5000, 0.0000
15, 530.6, 1043.5, 0.04174, 0.00339, 0.1416,249.739,0.000,249.739, 0.5001, 0.0001
16, 548.3, 1098.3, 0.04393, 0.00358, 0.15045,249.687,0.000,249.687, 0.5000, 0.0000
```

B2: Compliance .in5 file

Analysis files consist of header information and data, which differ according to the type of test that has been run. A compliance analysis file ([.in5] or [.in6]) with field descriptors appears below:

```
0
 0 , 0 , 9 , 9 , 2 , 0 , 0 , 0 , 0
 0.886 4.64 -13.32 14.72 -5.6 0
 1.0002 -4.0632 11.242 -106.04 464.33 -650.68
 0 0 0 0 0 0
test1,Demo,Steel, 75 ,Lab Air
 0.02 ,C(T),Unknown, 153.5 , 163.5 , 153.5 , 163.5 , 30 , 30
 320 , 0.1 , 0.62
 0.23 , 0.1746 , 0.9987 , 0.75 , 0 , 0.55
 0 , 0.17 , 1 , 0 , 0 , 0
 0.6227 , 0.62363 , 0.6247 , 0.6246 , 0.6246 , 0.6254 , 0.6257 , 0.624 , 0.624
 0.6693 , 0.6985 , 0.6961 , 0.6999 , 0.7023 , 0.7017 , 0.6975 , 0.6922 , 0.6691
Date 0f test: 2/11/2003
EOT
,0,0,0.0,0.00,0.000,0.000,0.000,0.000,0.00000E+0,00.0000,00.0000,00.0000
1,0,0,32.8,239.38,0.002597,0.097046,-0.043945,0.000,1.11581E-5,00.0000,00.0000,00.0000
2,0,0,52.6,235.72,0.002551,0.095825,-0.04425,0.000,1.11569E-5,00.0000,00.0000,00.0000
3,0,0,68.4,239.32,0.002594,0.097046,-0.04425,0.000,1.11501E-5,00.0000,00.0000,00.0000
4,0,0,101.1,240.17,0.0026,0.097656,-0.043945,0.000,1.11501E-5,00.0000,00.0000,00.0000
5,0,0,219.6,369.87,0.004065,0.148926,-0.032349,0.000,1.11119E-5,00.0000,00.0000,00.0000
6,0,0,240.9,500.00,0.005573,0.201416,-0.020447,0.000,1.11117E-5,00.0000,00.0000,00.0000
7,0,0,261.8,628.36,0.007092,0.253601,-0.00824,0.000,1.10828E-5,00.0000,00.0000,00.0000
8,0,0,282.4,751.40,0.008609,0.302429,0.003662,0.000,1.11026E-5,00.0000,00.0000,00.0000
9,0,0,302.8,867.55,0.010107,0.3479,0.015564,0.000,1.11026E-5,00.0000,00.0000,00.0000
10,0,0,323.1,973.82,0.011569,0.392151,0.027466,0.000,1.11203E-5,00.0000,00.0000,00.0000
11,0,0,342.8,1080.93,0.013126,0.43396,0.039673,0.000,1.11604E-5,00.0000,00.0000,00.0000
12,0,0,362.6,1173.16,0.014627,0.472107,0.05188,0.000,1.11803E-5,00.0000,00.0000,00.0000
13,0,0,381.9,1256.96,0.016165,0.505371,0.064087,0.000,1.12545E-5,00.0000,00.0000,00.0000
14,0,0,401.1,1320.31,0.017621,0.530701,0.075378,0.000,1.13332E-5,00.0000,00.0000,00.0000
15,0,0,419.8,1374.57,0.019138,0.551453,0.08728,0.000,1.14358E-5,00.0000,00.0000,00.0000
16,0,0,438.3,1421.39,0.020718,0.571899,0.100098,0.000,1.15764E-5,00.0000,00.0000,00.0000
17,0,0,456.8,1447.75,0.022232,0.582581,0.112,0.000,1.17606E-5,00.0000,00.0000,00.0000
18,0,0,475.2,1464.72,0.023764,0.587769,0.123901,0.000,1.19767E-5,00.0000,00.0000,00.0000
19,0,0,493.6,1476.44,0.025278,0.591431,0.135498,0.000,1.21926E-5,00.0000,00.0000,00.0000
20,0,0,507.9,1490.42,0.025867,0.599976,0.000,0.000,0.00000E+0,00.0000,00.0000,00.0000
20,0,0,511.9,1480.10,0.026855,0.596619,0.148926,0.000,1.24855E-5,00.0000,00.0000,00.0000
```

```
21,0,0,530.3,1473.51,0.028394,0.592651,0.160828,0.000,1.27854E-5,00.0000,00.0000,00.0000
22,0,0,548.6,1447.39,0.02991,0.58075,0.172119,0.000,1.31831E-5,00.0000,00.0000,00.0000
23,0,0,567.3,1414.49,0.031387,0.566101,0.1828,0.000,1.35855E-5,00.0000,00.0000,00.0000
24,0,0,586.1,1389.10,0.032971,0.559387,0.196533,0.000,1.40248E-5,00.0000,00.0000,00.0000
25,0,0,605.5,1359.50,0.034515,0.54718,0.208435,0.000,1.45103E-5,00.0000,00.0000,00.0000
26,0,0,625.1,1326.66,0.036032,0.531006,0.219116,0.000,1.49733E-5,00.0000,00.0000,00.0000
27,0,0,644.6,1293.34,0.037665,0.521851,0.23407,0.000,1.56159E-5,00.0000,00.0000,00.0000
28,0,0,665.0,1259.46,0.039139,0.506897,0.244751,0.000,1.60454E-5,00.0000,00.0000,00.0000
29,0,0,685.6,1225.77,0.040771,0.492554,0.256958,0.000,1.66201E-5,00.0000,00.0000,00.0000
30,0,0,706.6,1188.66,0.042328,0.479431,0.270081,0.000,1.72580E-5,00.0000,00.0000,00.0000
31,0,0,727.6,1134.89,0.043854,0.455322,0.280151,0.000,1.82142E-5,00.0000,00.0000,00.0000
-1,0,0,0.0,0.00,0.000,0.000,0.000,0.000,0.00000E+0,00.0000,00.0000,00.0000
```

B2A: FIELD DESCRIPTORS

```
DCPD&
KType&,PDType&,NInitialCrack&,NFinalCrack&,NComments&,JDisp&,GType&,Spare2&,PDRef&
KCoeff(1), KCoeff(2), KCoeff(3), KCoeff(4), KCoeff(5), KCoeff(6)
CCoeff(1), CCoeff(2), CCoeff(3), CCoeff(4), CCoeff(5), CCoeff(6)
PDCoeff(1), PDCoeff(2), PDCoeff(3), PDCoeff(4), PDCoeff(5), PDCoeff(6)
TestID$,Contract$,Material$,Temperature,Environment$
RampRate,Geometry$,Orientation$,YieldPre,TensilePre,Yield.Tensile,E,EPre
PrecrackP,PrecrackR,PrecrackA
B,Bnet,W,H,SOW,Notch
LLvP,GL,Alpha,PDGL,PDA0,PD0
a0(1),a0(2),a0(3),a0(4),a0(5),a0(6),a0(7),a0(8),a0(9)
aF(1),aF(2),aF(3),aF(4),aF(5),aF(6),aF(7),aF(8),aF(9)

Test Date (Comment 1)
End of Input indicator (Comment 2)
[lines of data, as follows]
Index(1),Exclude(1),Skip(1),Time(1),Force(1),Disp1(1),Disp2(1),Aux(1),CrackLe
ngth(1),VP(1),PDSum(1),PDRefSum(1),PDNormSum(1)
```

B2B: GLOSSARY OF VARIABLES

Alpha	'Ratio of displacement location to W
B	'Specimen thickness
Bnet	'Net specimen thickness
Contract$	'Contract
Comments$	'Text containing comments

DCPD&	'0 = compliance, 1 = DCPD
E	'Modulus of elasticity (at test temperature)
EPre	'Modulus of elasticity (at precrack temperature)
Environment$	'Environment
GL	'Gage length for compliance
Geometry$	'Geometry
GType&	'Geometry type
H	'Specimen height
JDisp&	'Displacement channel (0= IN2, 1 = IN3)
Ktype&	'Type of K, 0=Polynominal
	, 1=Center crack
	, 2=Bend
	, 3=Single edge notch
Material$	'Material
Notch	'Notch depth
NInitialCrack&	'Number of initial crack size measurements
NFinalCrack&	'Number of final crack size measurements
NComments&	'Number of comments
Orientation$	'Orientation
PDGL	'Gage length for potential drop
PDRef&	'If 1 then reference probe active
PDType&	'0 = polynomial, 1 = Johnsons, 2 = look-up table
PDA0	'Initial crack length for potential drop
PD0	'Initial potential drop

PDfilename$ 'PD look-up table filename

PrecrackP   'Precrack load

PrecrackR   'Precrack stress ratio

PrecrackA   'Precrack crack length

RampRate   'Ramp rate

SOW   'Span to width ratio

Spare1&   'Dummy variable

Spare2&   'Dummy variable

TestID$ 'Filename

Temperature   'Temperature

Tensile   'Tensile strength (at test temperature)

TensilePre   'Tensile strength (at precrack temperature)

W   'Specimen width

Yield   'Yield strength (at test temperature)

YieldPre   'Yield strength (at precrack temperature)

Arrays:

KCoeff(10)   'Stress intensity coefficients

CCoeff(10)   'Compliance coefficients

PDCoeff(10)   'PD Coefficients

a0(10)   'Initial crack size measurements

aF(10)   'Final crack size measurements

Index&(5000)   'Index

Exclude&(5000)   'If 1 then exclude line of data

Skip&(5000)   'If 1 then skip next da/dN data point

Time&(5000)   'Elapse time

Force(5000)   'Force channel (IN 1)

Disp1(5000)   'Displacement 1 channel (IN 2)

Disp2(5000)   'Displacement 2 channel (IN 3)

Aux(5000)   'Auxiliary channel (IN 4)

CrackLength(5000)   'Crack Length

VP(5000)   'Compliance slope

PDSum(5000)   'Active PD

PDRefSum(5000)   'Reference PD

PDNormSum(5000)   'Normalized PD

B3: RAW file

RAW files consist of five columns: elapse time (seconds); force channel (IN 1 in lbf); displacement 1 (IN 2 in inches); displacement 2 (IN 3 in inches); and the auxiliary channel (IN 4 in user-defined units).

An example of a raw data file ([.RAW]) appears below:

```
1.7,-0.61,.,0,0
4.7,-0.61,.,0,0
5.2,-0.49,0.000001,0,0
5.7,-0.55,0.000001,0,0
6.2,-0.55,0.000001,0,0
6.7,-0.61,0.000001,0,0
7.2,-0.55,0.000001,0,0
7.7,-0.55,0.000001,0,0
8.2,-0.55,0.000001,0,0
8.7,-0.55,0.000001,0,0
9.2,-0.55,0.000001,0,0
9.7,-0.24,0.000001,0,0
10.2,-0.18,0.000003,0,0
10.7,-0.12,0.000003,0,0
11.2,0.24,0.000006,0,0
11.7,0.73,0.000009,0,0
12.2,1.46,0.000015,0,0
12.7,2.62,0.000024,0,0
13.2,4.82,0.000043,0,0
13.7,8.42,0.00007,0,0
14.2,13.37,0.000113,0,0
14.7,18.92,0.000159,0,0
15.2,25.15,0.000214,0,0
15.7,31.25,0.000272,0,0
16.2,37.05,0.00033,0,0
16.7,43.03,0.000397,0,0
17.2,49.07,0.000461,0,0
17.7,55.3,0.000531,0,0
18.2,61.83,0.000604,0,0
18.7,68.73,0.000681,0,0
```

B4: UNL file

UNL files contain unloading slope data consisting of two columns (force and displacement) and additional parameters as shown below:

`10.00000E+6,10.00000E+6`	first line of file and unloading slope terminator
`10.00000E-1,20.00000E-1`	unload number, .unl data storage count
`50.00000E+0,00.00000E+0`	.raw data storage count, zero
`20.62988E-2,11.96899E-1`	FNG Out (volts), Force (volts)
`16.57104E-2,34.48486E-3`	Displacement 1 (volts), Displacement 2 (volts)
`-43.94531E-3,32.80000E+1`	Aux channel (volts), Elapse time (1 unit = 0.1 second)
`20.00000E+1,10.00000E-3`	Load cell cal factor (lb/volt), Displacement 1 cal factor (inch/volt)
`11.96899E-1,16.57104E-2`	first line of unloading slope data - Force (volts), Disp1 (volts)
`11.96289E-1,16.57104E-2`	
`11.80725E-1,16.20483E-2`	
`11.67603E-1,15.93018E-2`	
`11.58752E-1,15.71655E-2`	
.	
.	
.	
`10.93140E-1,14.22119E-2`	
`11.02295E-1,14.43481E-2`	
`11.11145E-1,14.61792E-2`	
`11.20605E-1,14.83154E-2`	
`11.29456E-1,15.04517E-2`	
`11.37695E-1,15.22827E-2`	
`11.47156E-1,15.41138E-2`	
`11.55701E-1,15.59448E-2`	
`11.65466E-1,15.80811E-2`	
`11.74927E-1,16.02173E-2`	
`11.84082E-1,16.23535E-2`	
`11.91711E-1,16.41846E-2`	last line of unloading slope data - Force (volts), Disp1 (volts)
`10.00000E+6,10.00000E+6`	unloading slope terminator

Acknowledgement
Thanks to Pete Blair for the ADwin art

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