Fracture Technology Associates

Automated Fatigue Crack Growth Testing and Analysis
Version 3+.15.12

Users' Steady State Reference Manual

December 2015

Keith Donald
Amy Blair
Fracture Technology Associates
2412 Emrick Boulevard
Bethlehem, PA 18020 USA
610-868-3054
www.FractureTech.com

Table of Contents

1.0 The FTA FCGR Testing and Analysis System

1.1 Introduction

Fracture Technology Associates' fourth-generation **Automated Fatigue Crack Growth (FCGR)** system is an updated hardware and software package designed solely for fatigue crack growth rate testing and analysis. Each system consists of an ADwin Gold signal processor and a computer running the FTA FCGR software.

FTA's basic FCGR (ASTM E647) testing application is designed to run with the ADwin Gold and any closed loop servo-hydraulic mechanical test machine and controller, suitably configured for fatigue crack growth rate 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 (FCGR-C) or DC potential drop (FCGR-D) for steady-state testing with a single crack monitor. The software supports standard crack propagation techniques (including constant load control, K-control and constant Kmax testing) using sine, triangle, and simple user-defined waveforms such as saw-toothed and trapezoidal waveforms. This basic application is the subject of this document.

Three additional FCGR applications are offered separately (additional documentation concerning these applications will be released in due course):

- adjusted compliance ratio capability (FCGR-ACR), including K-max sensitivity and K-residual. Although ACR capability is built into the FCGR-C testing application, the analysis program will not support the resulting data unless FCGR-ACR has been purchased separately
- variable amplitude capability (FCGR-VA) using complex waveforms, including spectrum files and user-defined waveform sequences
- multi crack-monitor capability (FCGR-MM) using either compliance, potential drop, or both in a single load train, with support for up to ten crack monitors on one or multiple specimens

The FTA FCGR 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 Jäeger. 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 and low priority processes, including control; waveform generation; data acquisition; crack length determination; K calculation; and da/dN analysis. 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 fatigue crack growth as well as the American Society for Testing and Materials (ASTM) standard for fatigue crack growth rate testing (E-647) is strongly recommended. Fracture Technology Associates assumes no liability for inappropriate use of its system. It is the user's responsibility to provide back-up verification of the performance and accuracy of the FCGR package, including visual verification of crack length and independent monitoring of applied loads.

All test systems require a software license for each of the three required testing applications. Permission is granted to make copies of the software for back-up purposes. 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 single-monitor steady-state testing and analysis software. The following section describes setup and installation of the ADwin Gold; FTA-DCPD current supply and amplifier; and FTA software. Sections 3.2 and 3.3 provide step-by-step instructions to guide new users through the running of simple da/dN compliance and DCPD tests. 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 and 6 detail use of the analysis software.

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 fatigue crack growth rate 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.*

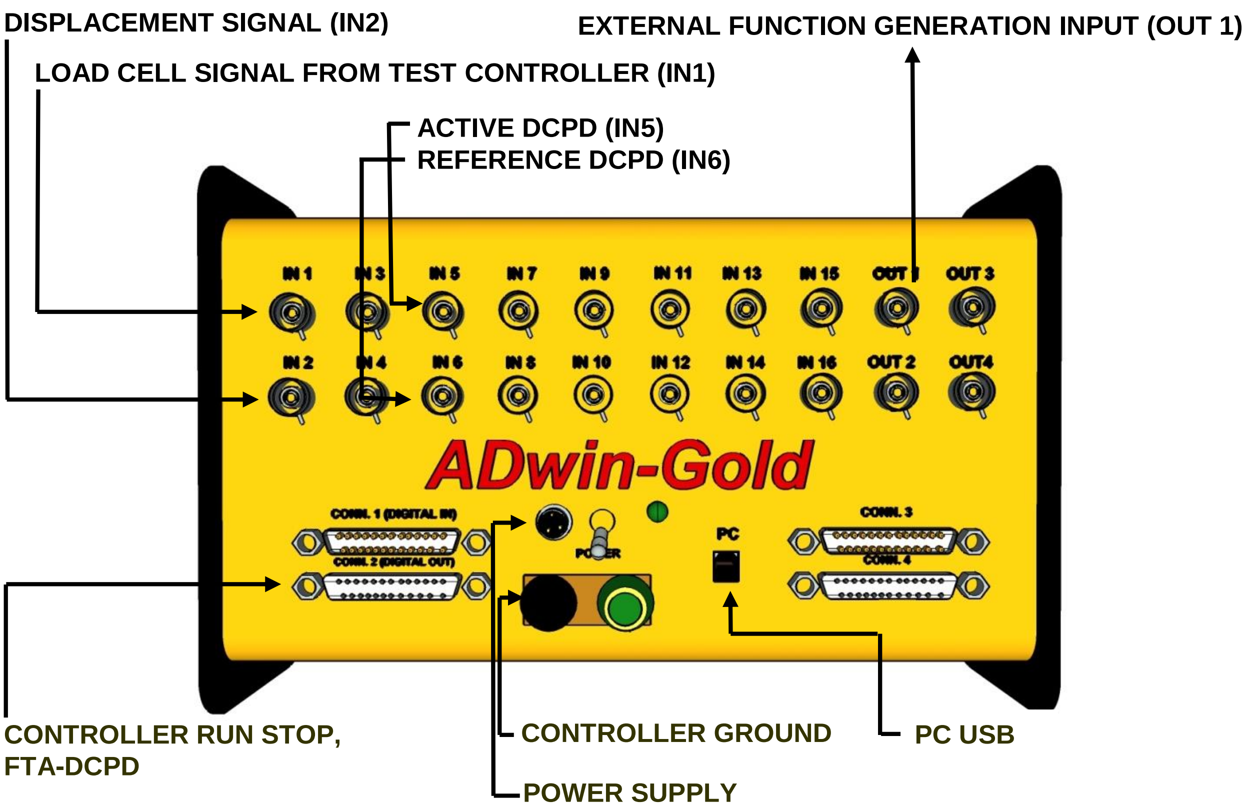
- load cell signal from the test controller: connects to the **IN 1** connector on the ADwin
- external function generator input on the test machine controller: connects to the **OUT 1** connector on the ADwin
- [for compliance] the displacement signal from the test controller or auxiliary instrumentation: 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.

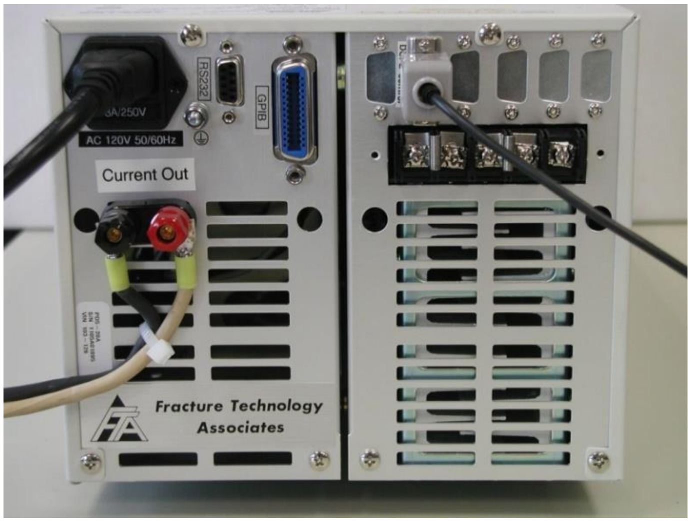
An ADwin connection diagram appears below:



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 test procedure in section 3.3 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-proved current wire from the **Current Out** connector to the test sample or terminal strip. A cable tie for 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 pin1 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-hand 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 **IN 5** on the ADwin-Gold. The channel designated 'reference' by the user connects with **IN 6** 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 amplifier 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 has been provided.

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 test specimen.* In addition, the FTA DCPD testing software must be running 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 3.3 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 two setup files for **Testing** and **Analysis** from their respective folders. It is recommended the software be permitted to create the default directories of c:\Program Files\FCGR Testing and c:\Program Files\FCGR 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 **FCGR 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. Versions for different operating systems are clearly labeled on the FTA CD.

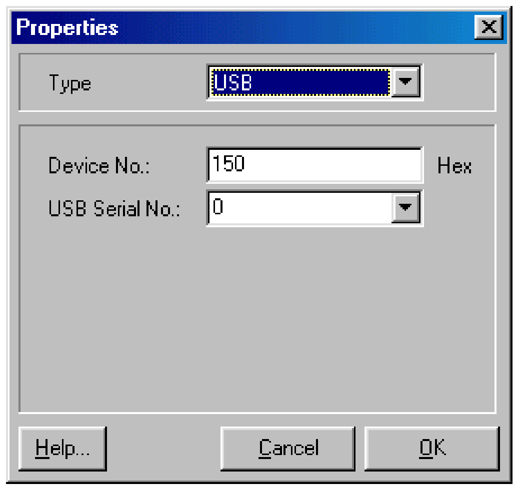
- 32-bit systems, Windows 98 through Windows XP: version3.20.1200
- 32-bit systems, Windows 7: version 5.00.10.00
- 64-bit systems: version 5.00.14.

Drivers can also be found on the web at www.adwin-downloads.de.

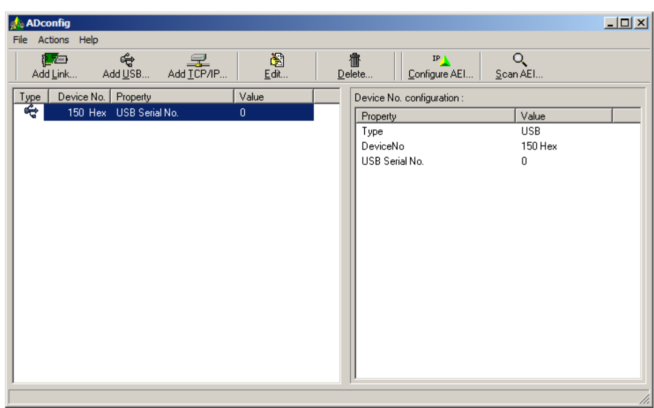
It is very important to copy the entire ADwin folder onto the PC desktop and carry out installation from there. Before installing the drivers, connect the ADwin (powered off) to the computer.

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.

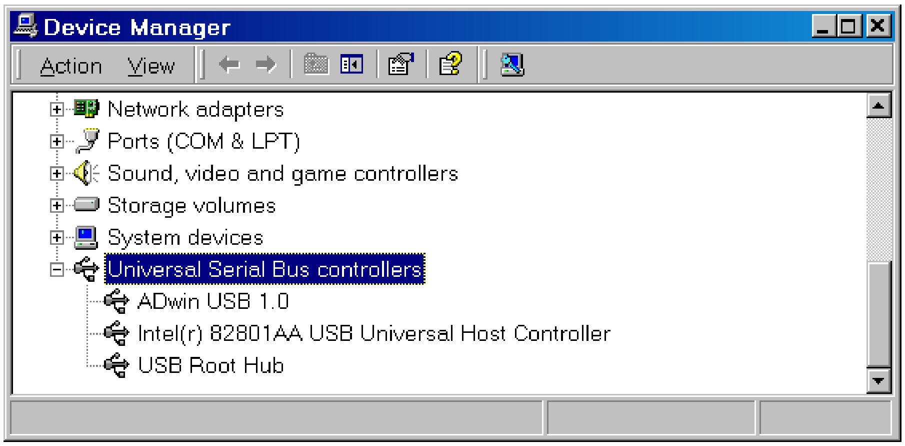


For v. 5.00.10.00, on the ADconfig screen choose ‘Add USB’ from the menu across the top. Choose Device #150 [hex] and USB Serial #0.



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.

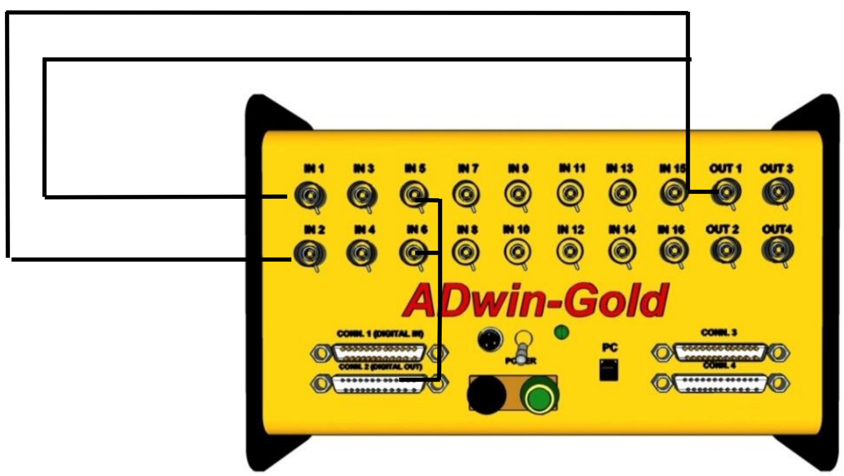
8. Press the red ‘B’ button on the ADbasic screen to boot the ADwin.
9. A flashing green LED on the ADwin-Gold unit means a successful connection has been established. Unless the hardware is changed, booting the system from this point forward will be done automatically when the FTA testing software is 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 FCGR program in simulation mode. Thus, users may familiarize themselves with the FTA software and evaluate custom waveforms and spectrum files without endangering the test machine or expensive specimens. See Sections 3.2 and 3.3 of this manual, below, 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 Sections 3.2 and 3.3 of this manual.



2.6 Tuning

Tune the system independently of the FTA software for the material and specimen geometry to be tested. Then, reduce the controller's proportional (P) gain slightly and set the controller's integral (I) and derivative (D) gain to zero. The FTA system will perform additional signal compensation. Signal quality should be inspected using an external oscilloscope or the FTA-supplied digital scope feature. Consult the controller manufacturer or FTA for additional tuning details.

3.0 Using the FTA FCGR Testing Software (Steady State)

The following section of this manual opens with a discussion of the seven file-types produced by the testing program. Sections 3.2 and 3.3 contain illustrative test procedures, which detail the use of both the compliance and DCPD testing software for simple da/dn testing. Analysis of test results is covered in Sections 5 and 6.

3.1 Understanding Testing Files

Nine different types of file are associated with the testing program, each with their own extensions. 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, below.

- **Analysis** file (.in3 extension): required for FTA's FCGR analysis software (discussed in Sections 5 and 6 of this manual). These files are held in memory until manually saved by the user. Saving analysis files overwrites previously-saved files. See Appendices C2 and C3 for full descriptions of compliance and DCPD analysis files.

- **Back-up** file (no extension): backups of the analysis (.in3) files are automatically saved at specified intervals throughout the test (a two-hour interval is the default). See Appendix E for more information on retrieving lost or unsaved analysis files.

- **Log** file (.txt extension): a detailed record of entire the test including all compliance or DCPD calculations, cycle count, crack length, test parameters and messages. Log files are produced automatically by the testing software. A log file is appended, rather than overwritten, every time it is saved. Lost analysis files may be reproduced using the log files. See Appendix C1 for a description of log files.

- **Hardware Configuration** file (.pr8 extension): information required for configuring the ADwin's analog input channels, including calibration factors and gain settings. Although the information is required, the files themselves are optional, and may be loaded, modified and saved by the user for ease of use.

- **Test Parameter** file (.pr4 extension): key information unique and necessary to the test, such as specimen dimensions and initial test conditions. The information is required but the files themselves are optional: they may be loaded, modified and saved by the user for ease of use. Note that parameter files used with previous versions of the software are not compatible with the current version 3+.15.

- **General Information** file (.gn0 extension): general information not required for testing, but that may be common across tests (such as test temperature and material description). These optional files may be loaded, modified and saved by the user. General information may also be added at analysis time.

- **Channel Scan** file (.chs extension): contains the data stored by optional auxiliary channels 3 and 4 of the Adwin. See Section 4.6.7 for details.

- **Custom [Waveform] Shape** file (.dat extension): see Section 4.5.3 for details about this user-created file, which allows for dwell testing and other simple non-standard waveforms.

- **Matrix** control file (.dat extension): see Section 4.5.4 for details about this user-created file, which allows automation of changes to test conditions.

3.2 Running a Compliance Test Using the FTA FCGR Software

The following is a general outline illustrating use of the FTA software to conduct a four-part steady-state test on a compact tension specimen using a single clip gage for crack and displacement measurement. The four stages of the test are as follows:

- pre-crack (K-control at constant K)
- part A (decreasing K to threshold)
- part B (increasing K to upper regions)
- constant load (to target growth rate)

These steps are meant as guidelines only, in order to demonstrate use of the FTA testing software. For detailed descriptions of the menu and form options referred to below, see Section 4 of this manual.

3.2.1 SETUP

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

*Also note the importance of making sure the program forms always reflect the latest information from the ADwin. To make sure the computer and Adwin are in agreement, it is good practice to press **Receive from ADwin** and **Print to Log** whenever sitting down to a test after a break and before making changes to test conditions.*

1. Turn on power to the Adwin.
2. Open the FCGR testing program. Ensure the green light on the Adwin is blinking, which indicates communication with the computer. If necessary, reboot the Adwin to establish communication. On the initial **Splash Screen**, choose the crack monitor type (*compliance*) and application (*steady state*).
3. Click **New Test**.
4. When the **Main Menu** appears, choose either *English* or *Metric* units (English units are assumed here) and skip to Step 5. *If the program is already open from a previous test, ensure the function generator has been reset by clicking **Reset Max-Min** on the **Full Function Generator Control (FNG)**. This resets the command signal level to zero. Also ensure that the frequency is set to 1 Hz and that **FNG shutdown** is ticked.*
5. From the **Main Menu**, go the **Config** dropdown menu and choose **Hardware** to open the **Hardware Configuration** form. The two tabs on this form are used to calibrate and configure the four analog inputs of the ADwin. On the **Calibration** tab, enter the appropriate calibration factors for **Force** (IN1) and **Displacement** (IN2). The auxiliary channels should be set to zero if inactive. On the **Configuration** tab, the default values are appropriate for C(T) specimens. Press **Send to ADwin** and **Save [the] Hardware Configuration** (.pr8) file for future use. Minimize or close the **Hardware Configuration** form.
6. Return to the **Config** dropdown menu and select **Test** to open the **Test Set-up** form. Note that the form has eight tabs, which are typically addressed from left to right when displayed in a single row. Select the **Initialize** tab. Enter the Test ID with suffix PC (for Precrack).
7. Press **Start Log File,** which establishes the correct file path for the testing and analysis files. It is important that the files *not* be saved in the computer's program directory, since Administrator privileges are sometimes required to retrieve them. FTA recommends establishing a new directory for testing files elsewhere on the C drive.
8. Press **Load Test Parameters** to load a parameter file (.pr4 files for common geometries may be found in the FCGR testing program directory). *If loading a parameter file from an earlier test, note that files from previous versions of the software are **not** compatible with the current version 3+.15.*
9. Still on the **Initialize** tab, tick the following boxes: **Initialize**; **Clear Data Storage Buffer**; **Clear Cycle Count**; and **Clear Elapse Timer** (these are already ticked when the program is opened for the first time). Click the **Send to ADwin** button: this action clears the ADwin's buffer and ready it for the new test.
10. Proceed to the **Calibration** and **Coefficients** tabs, which should have been populated by the parameter file. Ensure the information is correct for the chosen specimen geometry.
11. Go to **Dimensions** tab. Enter correct specimen dimensions and edit other information as necessary. *Note that for a specimen without side grooves, the value **Net Specimen Thickness** must be the same as **Specimen Thickness**.*

At the bottom of the tab, set the **Number of Points for A/D [analog to digital] Data Acquisition** to 800 (for steady-state compliance testing).

12. Go to the **Force** tab. Ensure **Control Type** is set to **Constant Load**. Enter **Maximum Load** (typically a low load for verification of correct operation) and initial **Stress Ratio (R)** (typically = 0.10). *The **K Control Parameters** boxes will be grey and inactive until **Control Type/K Control** is selected later in the procedure.*
13. Go to the **Compliance** tab. The purple **Number of Slopes** text field should be set to 100 and **Enable Slope Number Adjustment** should be checked. Enter the **Modulus** as appropriate. **Slope Measurement** should be set for **Data on Loading** and **Data on Unload**. **Minimum** and **Maximum Slope Level** should be set to 50% and 99% respectively (this ensures the linear part of the slope only is captured). Enable **Crack Closure Measurement** and set **Upper Limit** to 85% (this ensures that only the portion of the load-displacement curve *above* closure is used for crack length determination). **Initial EvB/P for ACR** should be set to 0 and **Initial CR** should be set to 1 (ACR testing is outwith the scope of this manual). Accept all other default values.
14. Go to **Storage** and activate **Crack Length** and **Cycle Count** as triggers for data storage and crack growth-rate calculations. Enter crack length and cycle count values as appropriate (see corresponding sections of this manual for details).
15. Go to the **Limits** tab and enter the final target precrack length in the **Final a** field. The test will stop when this limit has been reached. The default error limits at the bottom of the tab are appropriate for most testing.

16. **Send to ADwin** and **Print to log**.

17. Minimize the **Test Set-Up** form.

18. Press the **Save Test Parameters** button (on the **Limits** or **Initialize** tabs)**,** which saves a .pr4 file for future use.

19. Return to the **Config** dropdown list on the **Main Menu**, and select the **General** form. Load a previous form or enter new values and save the file for future use.

20. Go to the **Control** dropdown list, and open the **Full Function Generator Control (FNG).** No action on this form is necessary, as the default settings are appropriate for most steady-state testing. This form can be minimized. Also open the **Mini Function Generator**.
21. From the **Display** dropdown list, open all required displays, including **Compliance Status** and **Load-Displacement**. Verify that the load and displacement channels are reading correctly on the **Status** display.

22. For good measure, return to the **Hardware** configuration form, press **Receive from ADwin,** and recheck the load range and clip gage calibrations. Also **Receive from ADwin** and verify the settings on the **Test Set-up** form.

23. On the **Status** display, check that the load cell (**Actual Load**) reads zero. Adjust on controller as necessary.
24. Turn on hydraulics
25. Check specimen ID against data sheet and mount specimen with slight preload (using the controller setpoint).
26. On the **Full Function Generator** form, enter the **Pre Load** value in the text box.
27. Attach clip gage and use controller to zero clip gage, observing the clip gage signal on the **Status** display.
28. On controller, enable external command for full scale / 100% ('span' on MTS controllers; 'external auxiliary input' on Instron controllers). Observe load on status screen to ensure it remains stable.

29. On **FNG**, tick the green **RUN** button (to start function generation and ADwin processes). The load will not increase. Immediately tick **Command Control** (under **Control Status**) to enable the command signal and start cycling the specimen. Observe the **Status** screen to ensure correct operation at constant load. *Ignore the 2% load error message, as this is typical at the beginning of a test or when test conditions are purposefully changed. The message disappears after one complete cycle of crack-size determination. Should this message occur at other times during a test, or does not disappear after a crack size interval is concluded, attention should be paid.*
30. On the **FNG**, raise the frequency as required.
31. On the **FNG**, tick **Slope Analysis** (under **Control Status**) to enable crack length measurement.
32. Check crack length on status screen and adjust modulus (**Compliance** tab of the **Test Set-up** form) if necessary. The **Enable Auto E** option may be activated for this purpose (first ensure the correct crack length is entered in the field at the right middle of the screen).
33. Allow several cycles to go by and ensure correct operation.

3.2.2 PRECRACK (K CONTROL AT CONSTANT K)

1. Disable **Command Control** on the **FNG**. This allows correct operation to be verified when changing test conditions: target loads will change, but actual loads will not until **Command Control** has been reactivated.

2. Go to the **Storage** tab and verify correct values:

Next a	=	as required
Delta a	=	as required

3. Go to the **Force** tab and enter:

K type	=	K control (Constant C)
Stress ratio	=	0.1

Initial a	=	as required
Initial Kmax	=	as required for growth rate of 2-4E-7
K-gradient	=	0.0

4. **Send to ADwin**. *Since **Command Control** has been disabled, the operator will observe on the **Status** screen that the target load rises while the actual load is maintained. Disabling **Command Control** allows correct operation to be verified before actual loads are raised, thus ensuring against overload.* Enable **Command Control** when satisfied that operation is as it should be.

5. Examine the **Load Displacement** display for signal quality and lead-lag properties. Adjust phase lag by clicking **Lead Disp** and **Lag Disp** buttons on display. The correlation coefficient on the **Status** screen should be 0.9999 or better and the signal on **Load-Displacement** display should be clean.

6. On **Force** tab, enable **Load Decrease Only**. *With a K-gradient of zero, Pmax will drop as the crack length increases – enabling **Load Decrease Only** is a safety measure that prevents the loads from rising unexpectedly in the event of system malfunction.*

7. During the precrack, periodically check the crack-growth rate on the **Status** screen. Adjust **Initial Kmax** on the **Force** tab as necessary to ensure the required growth rate (typically, 2-4E-7. Don't forget always to **Receive from ADwin** before changing the Kmax value and **Send[ing] to ADwin!** Changes to Kmax may be made while the test is running, although it is a good idea to disable **Command Control** until the correct target load is displayed on the **Status** screen.

8. When the test stops at the **Final a** (**Limits** tab), **Receive from ADwin** and **Print to Log**.

9. Put in a marker band for post-test visual correction. Maintain the current Kmax; change the stress ratio to 0.6; and enter a new **Final a** (**Limits** tab) 0.005 inches longer than the current a.
10. **RUN**
11. When the test stops, **Receive from ADwin** and **Print to Log**.

3.2.3 PART A: DECREASING K THRESHOLD

1. Maintain the precrack frequency unless otherwise required.
2. Deselect **Load Decrease Only** on **Force** tab and **Send to ADwin**.
3. From the **Main Menu**, go to the **Display** dropdown menu and open the **da/dN – delta K** display.
4. On the **Initialize** tab, change the test suffix PC to the suffix A and start a new log file.

5. Tick the **Clear Data Buffer** box *(to clear previously calculated da/dN stored in memory)* and the **Clear Cycle Count** box *(to reset the cycle count to zero)*. **Send to ADwin**.
6. Go to the **Force** tab and enter new K-control parameters:

		Stress ratio	=	as required
		Initial a	=	as required
		Initial Kmax	=	as required
		K-gradient	=	as required (typically ~ –6.0)
Other tabs:	**Compliance**	# of slopes	=	as required (~100)
	Storage	Next a	=	as required
		Delta a	=	as required
		Next N	=	as required (or default)
		Delta N	=	as required (or default)
	Limits	Final a	=	as required
		Final N	=	as required (or default)

7. **Send to ADwin** and **Print to Log**.

8. **RUN** and quickly disable **Command Control** to make sure all is well. Turn it back on when the load looks OK.

9. Tick **Load Decrease Only** (**Force** tab) and **Send to ADwin** *(to prevent unintended load increases under decreasing-K conditions)*.

10. It is a good idea at this point to manually calculate a crack-growth rate before starting to store data. Return to the **Storage** tab, ticking **Enable Calculate (a)** and pressing **Calculate da/dN (a)**. **Send to ADwin**. A new growth rate calculation should appear on the **Status** display in the blue **da/dN** box at the lower right. If it fails to update, repeat the procedure.

11. As an additional check, ensure that the different crack length designations are in sync for storing data at the correct intervals. On the **Status** display, review the values of [current] **a**, **Last a**, and **Next a**. **Last a** should show a lower value than **a** (although not less than the **Delta a** determined on the **Storage** tab) while **Next a** should show a higher value. If necessary, return to the **Storage** tab and manually edit **Next a** until these three values are configured so that **Data Storage** will occur properly.

12. Activate **Data Storage** (**FNG**: **Control Status**) to store data in the analysis file and plot real-time points on the **da/dN – delta K** display. *Note that if **Data Storage** has not been enabled, points will be inactive in the analysis file.*

13. Allow test to run until near-threshold is achieved ~1 x10-9 inches/cycle

14. At completion of test, press **STOP** to stop the FNG.
15. **Receive from ADwin** and **Print to Log**. On the **Main Menu**, go to **File** and **Save [the] Analysis File** for the FTA FCGR analysis software. This file will have the .in3 extension.
16. Disable **Data Storage (FNG)**.
17. Disable **Load Decrease Only** (**Force**).

3.2.4 PART B: INCREASING K TEST

1. Enter new a **TESTID** with the suffix B (**Initialize** tab).
2. **Clear Data Storage Buffer** and **Cycle Count**. Start log file. Toggle **Slope Analysis** (**FNG**) to reset slope # to 0.
3. Maintain frequency.
4. If required, change clip gage calibration (on the controller *and* the **Hardware Config** form) to keep the signal from exceeding full scale towards the end of the test. Use the controller to zero the clip gage.
5. Enter test parameters:

Force	Initial a	=	from **Status**
	Initial Kmax	=	aim for the starting growth rate from part A, reduced by factor of five (ie, if part A started around 3E-7, start part B at 8E-8, for sufficient overlap in curve) or, alternatively, 2/3 initial Kmax for part A
	K-gradient	=	as required
Compliance	# of slopes	=	as required
Storage	Next a	=	current
	Delta a	=	as required
Limits	Final a	=	as required
	Max da/dN	=	~$1x10^{-5}$ in/cycle (or as appropriate for stress ratio)

6. **Send to ADwin** and **Print to log**.
7. **RUN** and turn off **Command Control** to make sure all is well. Turn it back on when load looks OK.
8. Adjust lead and lag (**Load Displacement** display) as necessary.
9. Watch crack length. If it jumps ahead, adjust **Initial a** (**Force** tab) upwards as necessary.
10. Manually calculate the crack-growth rate from the **Storage** tab to record a positive value.
11. Activate **Data Storage**

12. When test stops at target growth rate, **Receive from ADwin** and **Print to Log**. **Save [the] Analysis** file.
13. Continue to the constant load part of the test.

3.2.5 PART C: CONSTANT LOAD

1. Enter a new **TestID** with the suffix C on the **Initialize** tab.
2. **Clear Data Storage Buffer** only and **Start Log File**.
3. Set **Slope Measurement** to **Data on Unload** only (**Compliance** tab).
4. Switch to **Constant Load** (**Force**) and reduce load by 2%.
5. Change maximum da/dN (**Limits**) to required growth rate.
6. Reduce frequency to 5 or 10 Hz.
7. To keep the specimen from overloading (since the maximum load and frequency have been reduced), either press the red **Preset Max-Min** button or manually lower the command signal by pressing the yellow **Lower Max** button several times. Observe the graphical display at the right of the FNG to ensure correct signal levels.
8. **RUN**
9. Turn on **Data Storage**.

10. When the test stops at the maximum growth rate, **Receive from ADwin** and **Print to Log**. **Save** the analysis file.

3.2.6 TEST COMPLETION

1. Disable **Data Storage**.
2. **Reset Max-Min**.
3. Enter new test ID with suffix END.
4. **Start Log File**.
5. Raise frequency to 10-20 Hz.
6. Enter new test conditions:

Force (Constant load)	Max load	=	50% of previous load
	R	=	0.5
Compliance	min slope level	=	85%
	No. of slopes	=	100
Limits	final a	=	current a + 0.0050”

7. **RUN**. Increase load if crack doesn’t seem to be growing.
8. When test stops, **Receive from ADwin** and **Print to Log**.
9. Disable **Slope Analysis**.
10. **Reset Max-Min** and set frequency to 1 Hz.

11. Disable **Command Control**.
12. Disable external command on controller.
13. Pull specimen to failure using the controller setpoint and remove from machine.
14. Measure each marker band at five locations:
    - front surface (FS)
    - ¼ point
    - ½ point
    - ¾ point
    - back surface (BS)
15. Average each marker band: ((FS+BS)/2 + ¼ point + ½ point + ¾ point) / 4
16. Identify the corresponding compliance for use with the FTA FCGR analysis program (see Section 6.2 of this manual details).

3.3 Running a DCPD Test Using the FTA FCGR Software and the FTA-DCPD Instrumentation

The following is a general outline illustrating use of the FTA software to conduct a four-part steady-state test on a compact tension specimen using the DC potential drop method for crack measurement (one pair of active probes only). This procedure also details use of the FTA-DCPD current supply and amplifier. The four stages of the test are as follows:

- pre-crack (K-control at constant K)
- part A (decreasing K to threshold)
- part B (increasing K to upper regions)
- constant load (to target growth rate)

These steps are meant as guidelines only, in order to demonstrate use of the FTA testing software. For detailed descriptions of the menu and form options referred to below, see Section 4 of this manual.

3.3.1 SETUP

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

*Also note the importance of making sure the program forms always reflect the latest information from the ADwin. To make sure the computer and Adwin are in agreement, it is good practice to press **Receive from ADwin** and **Print to Log** whenever sitting down to a test after a break and before making changes test conditions.*

1. Turn on power to the Adwin.
2. Power to the FTA-DCPD amplifier 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 amplifier, 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 FCGR testing program. 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 (DC potential drop) and application (steady state).
5. Click **New Test**.
6. When the **Main Menu** appears, choose either *English* or *Metric* units (English units are assumed here) and skip to Step 7. *If the program is already open from a previous test, ensure the function generator has been reset by clicking* ***Reset Max-Min*** *on the* ***Full Function Generator Control (FNG)****. This resets the command signal level to zero. Also ensure that the frequency is set to 1 Hz and that* ***FNG shutdown*** *is ticked.*
7. From the **Main Menu**, go the **Config** dropdown menu and choose **Hardware** to open the **Hardware Configuration** form. The two tabs on this form are used to calibrate and configure the four analog inputs of the ADwin. On the **Calibration** tab, enter the appropriate calibration factors for **Force** (IN1) and **DCPD Active** (IN5). **DCPD Ref** (IN6) should be set to zero. The auxiliary channels should also be set to zero, if inactive. On the **Configuration** tab, the default values are appropriate for C(T) specimens. Press **Send to ADwin** and **Save [the] Hardware Configuration** (.pr8) file for future use. Minimize or close the **Hardware Configuration** form.
8. Return to the **Config** dropdown menu and select **Test** to open the **Test Set-up** form. Note that the form has eight tabs, which are typically addressed from left to right when displayed in a single row. Select the **Initialize** tab. Enter the Test ID with suffix PC (for Precrack).
9. Press **Start Log File,** which establishes the correct file path for the testing and analysis files. It is important that the files *not* be saved in the computer's program directory, since Administrator privileges are sometimes required to retrieve them. FTA recommends establishing a new directory for testing files elsewhere on the C drive.
10. Press **Load Test Parameters** to load a parameter file (.pr4 files for common geometries may be found in the FCGR testing program directory). *If loading a parameter file from an earlier test, note that files from previous versions of the software are* ***not*** *compatible with the current version 3+.15.*
11. Still on the **Initialize** tab, tick the following boxes: **Initialize**; **Clear Data Storage Buffer**; **Clear Cycle Count**; and **Clear Elapse Timer** (these are already ticked when the program is opened for the first time). Click the **Send to ADwin** button: this action clears the ADwin's buffer and ready it for the new test.
12. Proceed to the **Calibration** and **Coefficients** tabs, which should have been populated by the parameter file. Ensure the information is correct for the chosen specimen geometry.
13. Go to **Dimensions** tab. Enter correct specimen dimensions and edit other information as necessary. *Note that for a specimen without side grooves, the*

*value **Net Specimen Thickness** must be the same as **Specimen Thickness**.* At the bottom of the tab, set the **Number of Points for A/D [analog to digital] Data Acquisition** to 500 (for steady-state DCPD testing).

14. Go to the **Force** tab. Ensure **Control Type** is set to **Constant Load**. Enter **Maximum Load** (typically a low load for verification of correct operation) and initial **Stress Ratio (R)** (typically = 0.50). *The **K Control Parameters** boxes will be grey and inactive until **Control Type/K Control** is selected later in the procedure.*
15. Go to the **DCPD** tab. The purple **Number of PD Cycles** text field should be set to 50 and **Enable DCPD Number Adjustment** should be checked. In the PD **Initial Crack Length** text box enter the nominal notch depth of the specimen. **Initial PD** should be set to zero (**Initial Reference PD** should be grey and inactive, since **Enable Reference Probe** has not been checked). **Minimum PD Level** should be set to -5% (to ensure readings are taken over the entire cycle). **Current Switching Interval** should be set to 5 and the **Current Delay Factor** to 0.5. Accept all other default values.
16. Go to **Storage** and activate **Crack Length** and **Cycle Count** as triggers for data storage and crack growth-rate calculations. Enter crack length and cycle count values as appropriate (see corresponding sections of this manual for details).
17. Go to the **Limits** tab and enter the final target precrack length in the **Final a** field. The test will stop when this limit has been reached. The default error limits at the bottom of the tab are appropriate for most testing.

18. **Send to ADwin** and **Print to log**.

19. Minimize the **Test Set-Up** form.

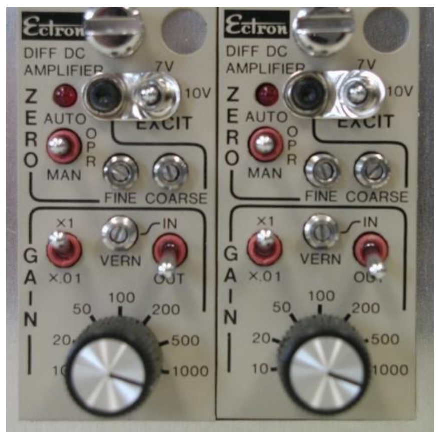
20. Press the **Save Test Parameters** button (on the **Limits** or **Initialize** tabs)**,** which saves a .pr4 file for future use.

21. Return to the **Config** dropdown list on the **Main Menu**, and select the **General** form. Load a previous form or enter new values and save file for future use.

22. Go to the **Control** dropdown list, and open the **Full Function Generator Control (FNG).** No action on this form is necessary, as the default settings are appropriate for most steady-state testing. This form can be minimized. Also open the **Mini Function Generator**.
23. From the **Display** dropdown list, open all required displays, including **Status–DC Potential Drop** and **Load-Displacement**. Verify that the load channel is reading correctly on the **Status** display.

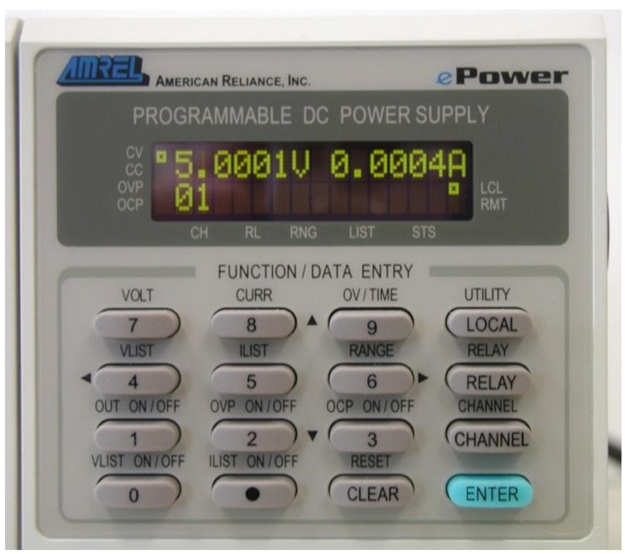
24. For good measure, return to the **Hardware** configuration form, press **Receive from ADwin,** and recheck load range and DCPD active gain**.** Also **Receive from ADwin** and verify the settings on the **Test Set-up** form.

25. On the **Status** display, check that the load cell (**Actual Load**) reads zero. Adjust on controller as necessary.
26. Turn on hydraulics.
27. Check specimen ID against data sheet and mount specimen with slight preload (using the controller setpoint).
28. On the **Full Function Generator** form, enter the **Pre Load** value in the text box.
29. Attach specimen lead wires to terminal strips.
30. 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 FCGR testing software's **Status** screen.



31. 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.

32. 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.



33. Using the black knob on the amplifier’s Ectron module(s), adjust the gain setting such that the amplified signal displayed on the FCGR 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 **Dimensions** 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. As the test proceeds, it is important not to

reach the ±10 volt amplifier output limit as this is considered an error limit and shuts down the test). 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.

34. On the controller, enable external command for full scale / 100% ('span' on MTS controllers; 'external auxiliary input' on Instron controllers). Observe load on status screen to ensure it remains stable.

35. On **FNG**, tick the green **RUN** button (to start function generation and ADwin processes). The load will not increase. Immediately tick **Command Control** (under **Control Status**) to enable the command signal and start cycling the specimen. Observe the **Status** screen to ensure correct operation at constant load. *Ignore the 2% load error message, as this is typical at the beginning of a test or when test conditions are purposefully changed. The message disappears after one complete cycle of crack size determination. Should this message occur at other times during a test, or does not disappear after a crack size interval is concluded, attention should be paid.*
36. On the **FNG**, raise the frequency as required.
37. On the **FNG**, tick **DCPD Analysis** (under **Control Status**) to compute in micro-volts the potential drop between the active leads. This value is displayed as **DCPD Active** at the lower left-hand corner of the **Status Screen**. Let run for a few minutes so readings may stabilize.
38. Enter the **DCPD Active** value in the **Initial PD** box on the **DCPD** tab (**Test Set-up** form). Verify that the correct crack length (a) has been computed in the display box to the right of **PD Initial Crack Length**.
39. Allow several cycles to go by and ensure correct operation.

3.3.2 PRECRACK (K CONTROL AT CONSTANT K)

1. Disable **Command Control** on the **FNG**. This allows correct operation to be verified when changing test conditions: target loads will change, but actual loads will not until **Command Control** has been reactivated.

2. Go to the **Storage** tab and verify correct values:

Next a	=	as required
Delta a	=	as required

3. Go to the **Force** tab and enter:

K type	=	Kcontrol (Constant C)
Stress ratio	=	0.1
Initial a	=	as required
Initial Kmax	=	as required for growth rate of 2-4E-7
K-gradient	=	0.0

4. **Send to ADwin**. *Since **Command Control** has been disabled, the operator will observe on the **Status** screen that the target load rises while the actual load is maintained. Disabling **Command Control** allows correct operation to be verified before actual loads are raised, thus ensuring against overload.* Enable **Command Control** when satisfied that operation is as it should be.

5. On **Force** tab, enable **Load Decrease Only**. *With a K-gradient of zero, Pmax will drop as the crack length increases – enabling **Load Decrease Only** is a safety measure that prevents the loads from rising unexpectedly in the event of system malfunction.*

6. During the precrack, periodically check crack growth rate on the **Status** screen. Adjust **Initial Kmax** on the **Force** tab as necessary to ensure the required growth rate (typically, 2-4E-7. Don't forget always to **Receive from ADwin** before changing the Kmax value and **Send[ing] to ADwin!** Changes to Kmax may be made while the test is running, although it is a good idea to disable **Command Control** until the correct target load is displayed on the **Status** screen.

7. When the test stops at the **Final a** (**Limits** tab), **Receive from ADwin** and **Print to Log**.

8. Put in a marker band for post-test visual correction. Maintain the current Kmax; change the stress ratio to 0.6; and enter a new **Final a** (**Limits** tab) 0.005 inches longer than the current a.
9. **RUN**
10. When the test stops, **Receive from ADwin** and **Print to Log**.

3.3.3 PART A: DECREASING K THRESHOLD

1. Maintain the precrack frequency unless otherwise required.
2. Deselect **Load Decrease Only** on **Force** tab and **Send to ADwin**.
3. From the **Main Menu**, go to the **Display** dropdown menu and open the **da/dN – delta K** display.
4. On the **Initialize** tab, change the test suffix PC to the suffix A and start a new log file.
5. Tick the **Clear Data Buffer** box *(to clear previously calculated da/dN stored in memory)* and the **Clear Cycle Count** box *(to reset the cycle count to zero)*. **Send to ADwin**.
6. Go to the **Force** tab and enter new K-control parameters:

Stress ratio	=	as required
Initial a	=	as required
Initial Kmax	=	as required

		K-gradient	=	as required (typically ~ –6.0)

7. Note the current DCPD value on the **Status** screen. Enter this new number in the **Initial PD** box on the **DCPD** tab, together with the new assumed crack length (**PD Initial Crack Length**). *The computed crack length at the end of the pre-crack, using Johnson's formula on a C(T) specimen, will be shorter than the actual crack length. Adjustments are therefore made at this time. These values will not change for the remainder of the test.* Also on the **DCPD** tab, change the **Number of PD Cycles** to 25.

8. Other tabs	**Storage**	Next a	=	as required
		Delta a	=	as required
		Next N	=	as required (or default)
		Delta N	=	as required (or default)
	Limits	Final a	=	as required
		Final N	=	as required (or default)

9. **Send to ADwin** and **Print to Log**.

10. **RUN** and quickly disable **Command Control** to make sure all is well. Turn it back on when the load looks OK.

11. Tick **Load Decrease Only** (**Force** tab) and **Send to ADwin** *(to prevent unintended increases in load under decreasing-K conditions)*.

12. It is a good idea at this point to manually calculate a crack-growth rate before starting to store data. Do this by returning to the **Storage** tab, ticking **Enable Calculate (a)** and pressing **Calculate da/dN (a)**. **Send to ADwin**. A new growth rate calculation should appear on the **Status** display in the blue **da/dN** box at the lower right. If it fails to update, repeat the procedure.

13. As an additional check, ensure that the different crack length designations are in sync for storing data at the correct intervals. On the **Status** display, review the values of [current] **a**, **Last a**, and **Next a**. **Last a** should show a lower value than **a** (although not less than the **Delta a** determined on the **Storage** tab) while **Next a** should show a higher value. If necessary, return to the **Storage** tab and manually edit **Next a** until these three values are configured so that **Data Storage** will occur properly.

14. Activate **Data Storage** (**FNG**: **Control Status**) to store data in the analysis file and plot real-time points on the **da/dN – delta K** display. *Note that if **Data Storage** has not been enabled, points will be inactive in the analysis file.*

15. Allow test to run until near-threshold is achieved ~1 x10-9 inches/cycle

16. At completion of test, press **STOP** to stop the FNG.
17. **Receive from ADwin** and **Print to Log**. On the **Main Menu**, go to **File** and **Save [the] Analysis File** for the FTA FCGR analysis software. This file will have the .in3 extension.
18. Disable **Data Storage (FNG)**.
19. Disable **Load Decrease Only** (**Force**).

3.3.4 PART B: INCREASING K TEST

1. Enter a new **TESTID** with the suffix B (**Initialize** tab).
2. **Clear Data Storage Buffer** and **Cycle Count**. Start log file. Toggle **DCPD Analysis** (**FNG**) to reset cycle # to 0.
3. Maintain frequency.
4. Enter test parameters:

Force	Initial a	=	from **Status**
	Initial Kmax	=	aim for starting growth rate from part A, reduced by factor of five (ie, if part A started around 3E-7, start part B at 8E-8, for sufficient overlap in curve) or, alternatively, 2/3 initial Kmax for part A
	K-gradient	=	as required
DCPD	# of PD cycles	=	as required
Storage	Next a	=	current
	Delta a	=	as required
Limits	Final a	=	as required
	Max da/dN	=	~$1x10^{-5}$ in/cycle (or as appropriate for stress ratio)

5. **Send to ADwin** and **Print to log**.
6. **RUN** and turn off **Command Control** to make sure all is well. Turn it back on when load looks OK.
7. Watch crack length. If it jumps ahead, adjust **Initial a** (**Force** tab) upwards as necessary.
8. Manually calculate the crack-growth rate from the **Storage** tab to record a positive value.
9. Activate **Data Storage**

10. When test stops at target growth rate, **Receive from ADwin** and **Print to Log**. **Save [the] Analysis** file.
11. Continue to the constant load part of the test.

3.3.5 PART C: CONSTANT LOAD

1. Enter a new **TestID** with the suffix C on the **Initialize** tab.
2. **Clear Data Storage Buffer** only and **Start Log File**.
3. Switch to **Constant Load** (**Force**) and reduce load by 2%.
4. Change maximum da/dN (**Limits**) to required growth rate.
5. Reduce frequency to 5 or 10 Hz.
6. To keep the specimen from overloading (since the maximum load and frequency have been reduced), either press the red **Preset Max-Min** button or manually lower the command signal by pressing the yellow **Lower Max** button several times. Observe the graphical display at the right of the FNG to ensure correct signal levels.
7. **RUN**
8. Turn on **Data Storage**.

9. When the test stops at the maximum growth rate, **Receive from ADwin** and **Print to Log**. **Save** the analysis file.

3.3.6 TEST COMPLETION

1. Disable **Data Storage**.
2. **Reset Max-Min**.
3. Enter new test ID with suffix END.
4. **Start Log File**.
5. Raise frequency to 10-20 Hz.
6. Enter new test conditions:

Force (Constant load)	Max load	= 50% of previous load
	R	= 0.5
DCPD	Number of PD cycles	= 50
Limits	final a	= current a + 0.0050”

7. **RUN**. Increase load if crack doesn’t seem to be growing.
8. When test stops, **Receive from ADWIN** and **Print to Log**.
9. Disable **DCPD Analysis**.
10. **Reset Max-Min** and set frequency to 1 Hz.
11. Disable **Command Control**.
12. Disable external command on controller.
13. Pull specimen to failure using the controller setpoint and remove from machine.
14. Measure each marker band at five locations:
    - front surface (FS)
    - ¼ point
    - ½ point
    - ¾ point

- back surface (BS)

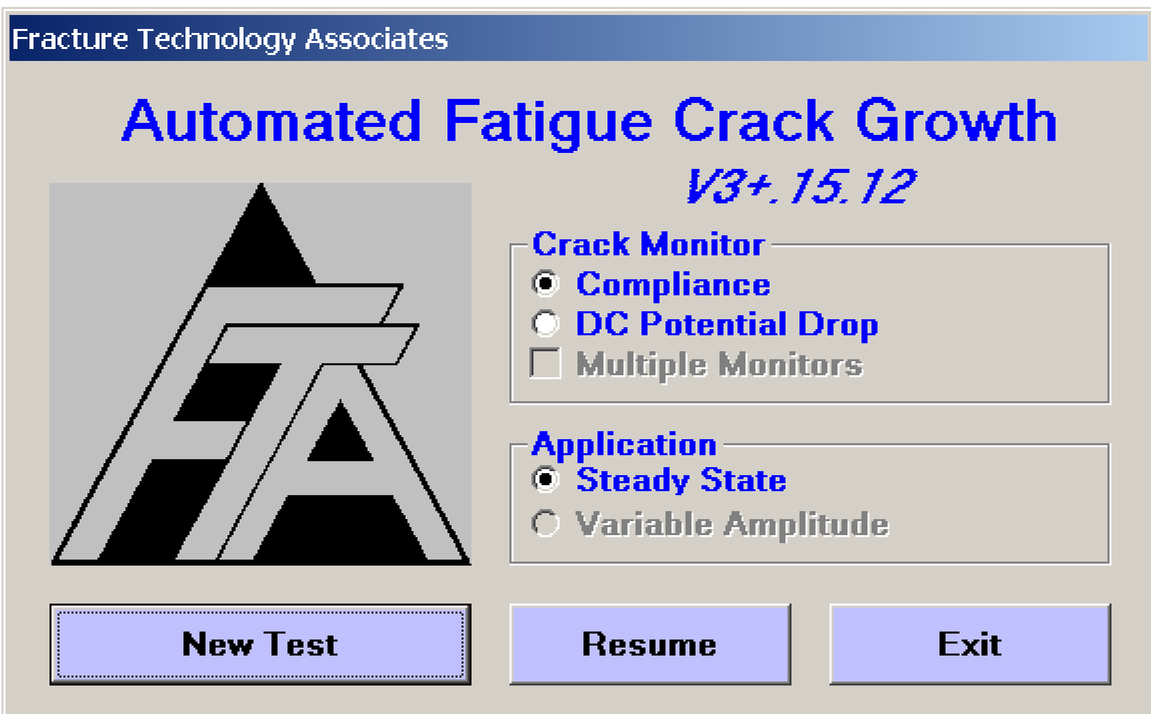
15. Average each marker band: ((FS+BS)/2 + ¼ point + ½ point + ¾ point) / 4
16. Identify the corresponding compliance for use with the FTA FCGR analysis program (see Section 6.2 of this manual details).

4.0 FTA Testing Software: Description of Menus and Tabs (Steady State)

The following section of the manual offers a complete description of the menus and tabs for both the compliance and DCPD versions of the steady-state testing application. The menus are presented in the order in which they would normally be opened during program startup.

For step-by-step procedures detailing how the software may be used for running steady-state tests, see preceding Sections 3.2 and 3.3.

4.1 Splash Screen

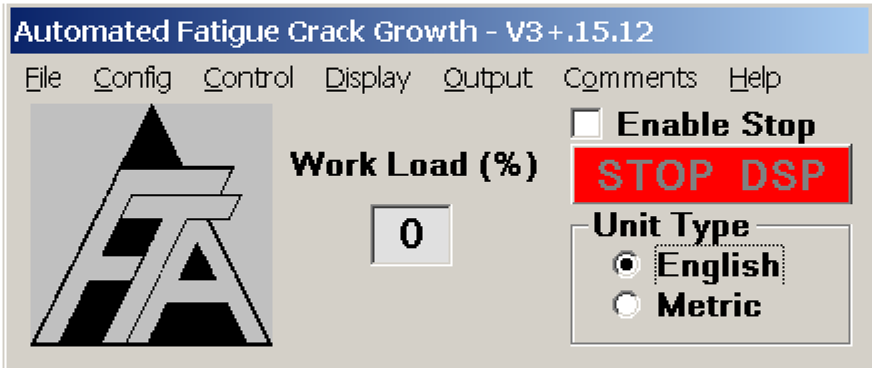


When the FCGR testing program is first opened, the **Splash Screen** is displayed. The application title and version number are identified at the top of this form.

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. **Multiple Monitors** and **Variable Amplitude** capability are not available with the basic program.

Once the test selection has been made, **New Test** or **Resume** options allow either the beginning of a new test from scratch or the resuming of a test that may already have been in progress (for example, after a system crash or power outage: see Appendix A for the **Resume** procedure). Upon clicking the **New Test** command button, the green LED on the Adwin will begin to flash, confirming its link to the PC.

4.2 Main Menu



The **Main Menu** is always displayed while the program is running: its default position is in the upper left-hand 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 but this requires closing and reopening all 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 ADwin processes, in effect rebooting the ADwin in the event that it appears to have stopped responding or is behaving sluggishly. To reboot the ADwin, it is essential to make sure the test is not running by pressing **Stop** on the **Function Generator** and **Reset[ing] Max / Min**, thus returning the specimen to its setpoint load. Next, tick the **Enable Stop** box on the **Main Menu** and press the red **Stop DSP** button. When **RUN** is pressed on the **Function Generator**, all ADwin processes are restarted as normal.

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 .in3 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.

Although it is important to remember to save the analysis file at the end of the test (before the data storage buffer has been cleared), two options are available for reconstructing the file if this step has been forgotten. The first method makes use of the backup file that is automatically saved every two hours during the test: this file has no extension but can be read by the analysis program when the [.in3] extension is added to the filename by the user. Any missing lines of data from the end of the test may be manually extracted from the log file, a text document that automatically records all data taken during the test. If for some reason the automatic backup file is missing, an entire.in3 file can be constructed from the log file using a text editor and Excel (see Appendix E of this manual for details).

4.3.2 EXIT

When **Exit** is chosen, the user is prompted to save the analysis file even if it has been previously saved. If **Exit** is selected inadvertently and the ADwin keeps running, the test can be continued without interruption by restarting the program and selecting the **Resume** option on the **Splash Screen** (see Appendix A of this manual for a recovery procedure).

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**.*

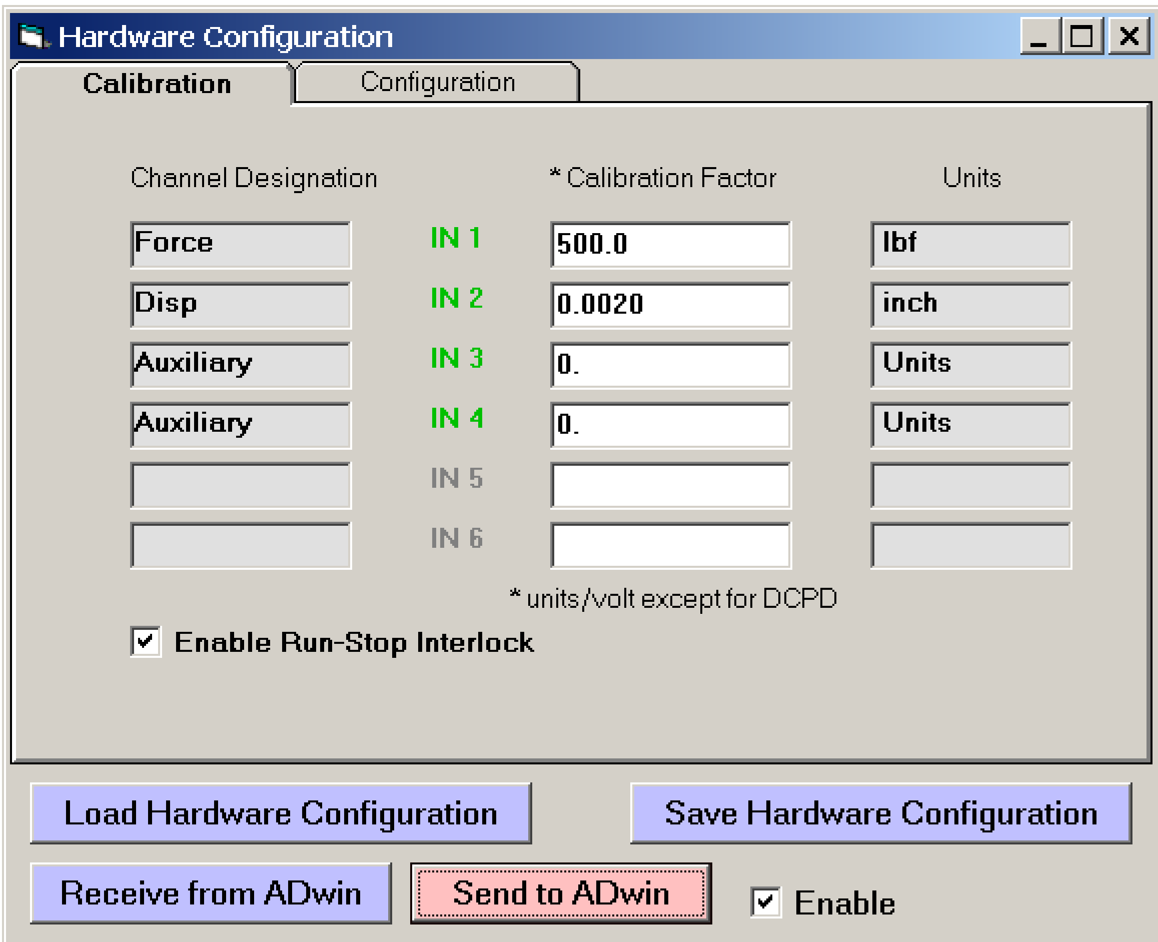
4.4.1 HARDWARE CONFIGURATION

The **Hardware Configuration** form is used to assign and configure the ADwin's analog input channels, although for the steady-state single-monitor application all channels except auxiliaries 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

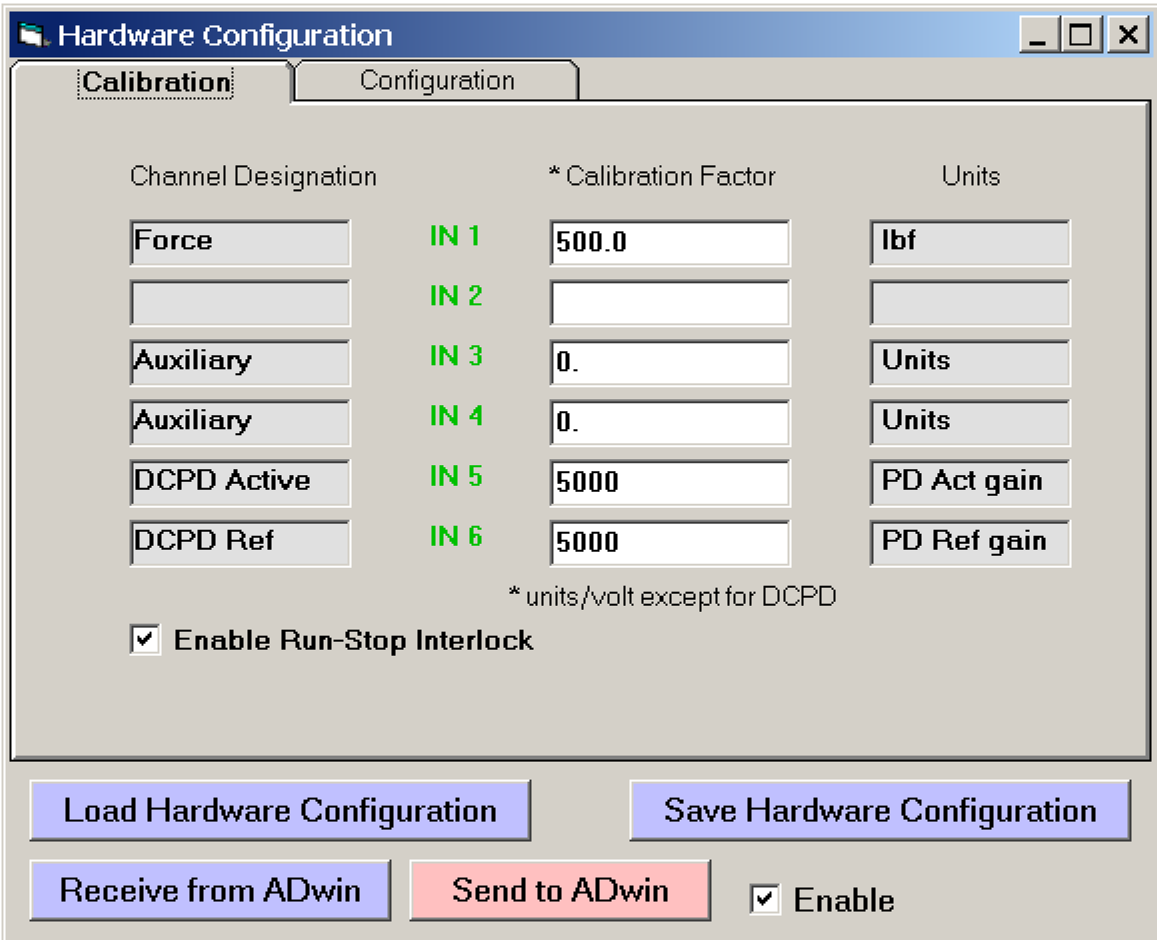


The **Calibration** tab displays the active ADwin analog input compliance channels IN1 through IN4 and their function under the **Channel Designation** heading. These assignments may not be changed by the user in the steady state single-monitor application. The two auxiliary channels (IN3 and IN4) are 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

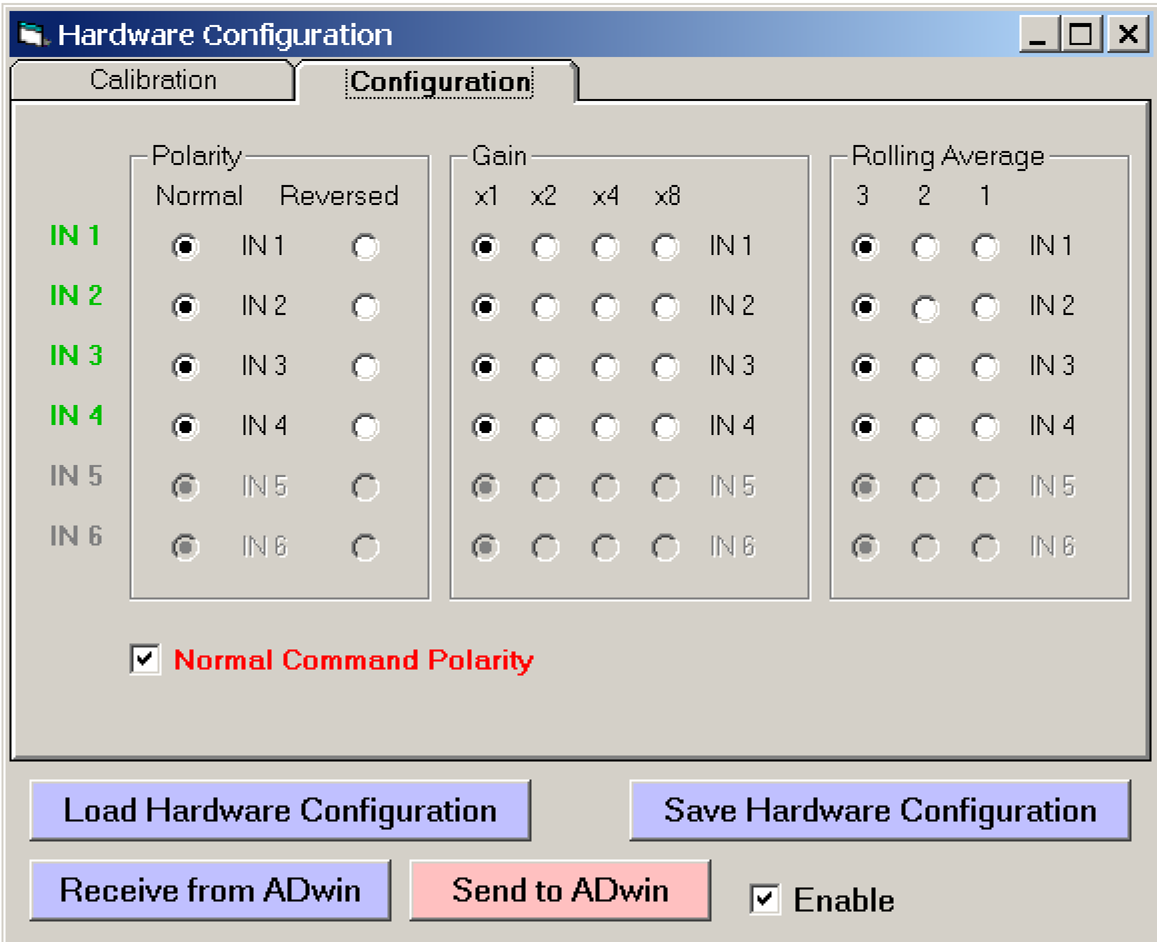


The **Calibration** tab displays the active ADwin analog input DCPD channels IN1 through IN6 and their function under the **Channel Designation** heading (note that IN2 is used only by the compliance application). Channel assignments may not be changed by the user in the steady state single-monitor application. 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



For each of the ADwin input channels, the **Configuration** tab allows designation of **Polarity**, programmable **Gain**, and **Rolling Average** for peak reading. 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.

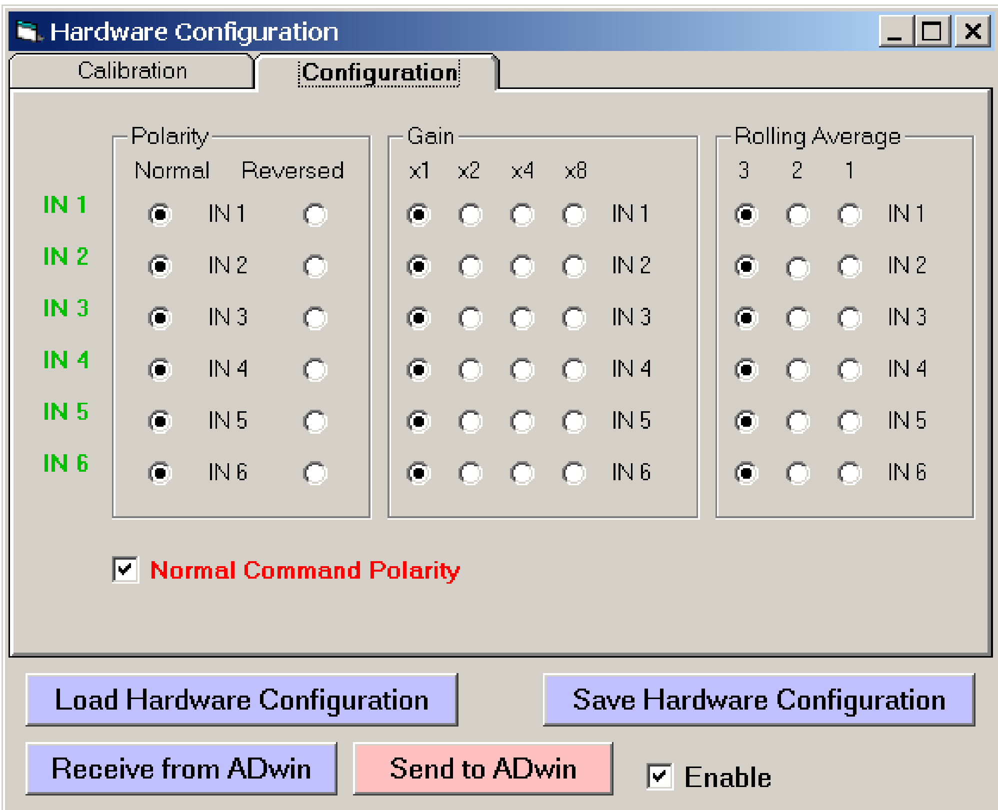
IN3: normal polarity is chosen by default

IN4: normal polarity is chosen be default

- **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.

- **Rolling Average**: for peak reading of sine waves, the three point rolling average will provide the most accurate noise-free peaks and is appropriate for most applications.

4.4.1.4 Configuration (DCPD)



For each of the ADwin input channels, the **Configuration** tab allows designation of **Polarity**, programmable **Gain**, and **Rolling Average** for peak reading. 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.

- **Rolling Average**: for peak reading of sine waves, the three point rolling average will provide the most accurate noise-free peaks and is appropriate for most applications.

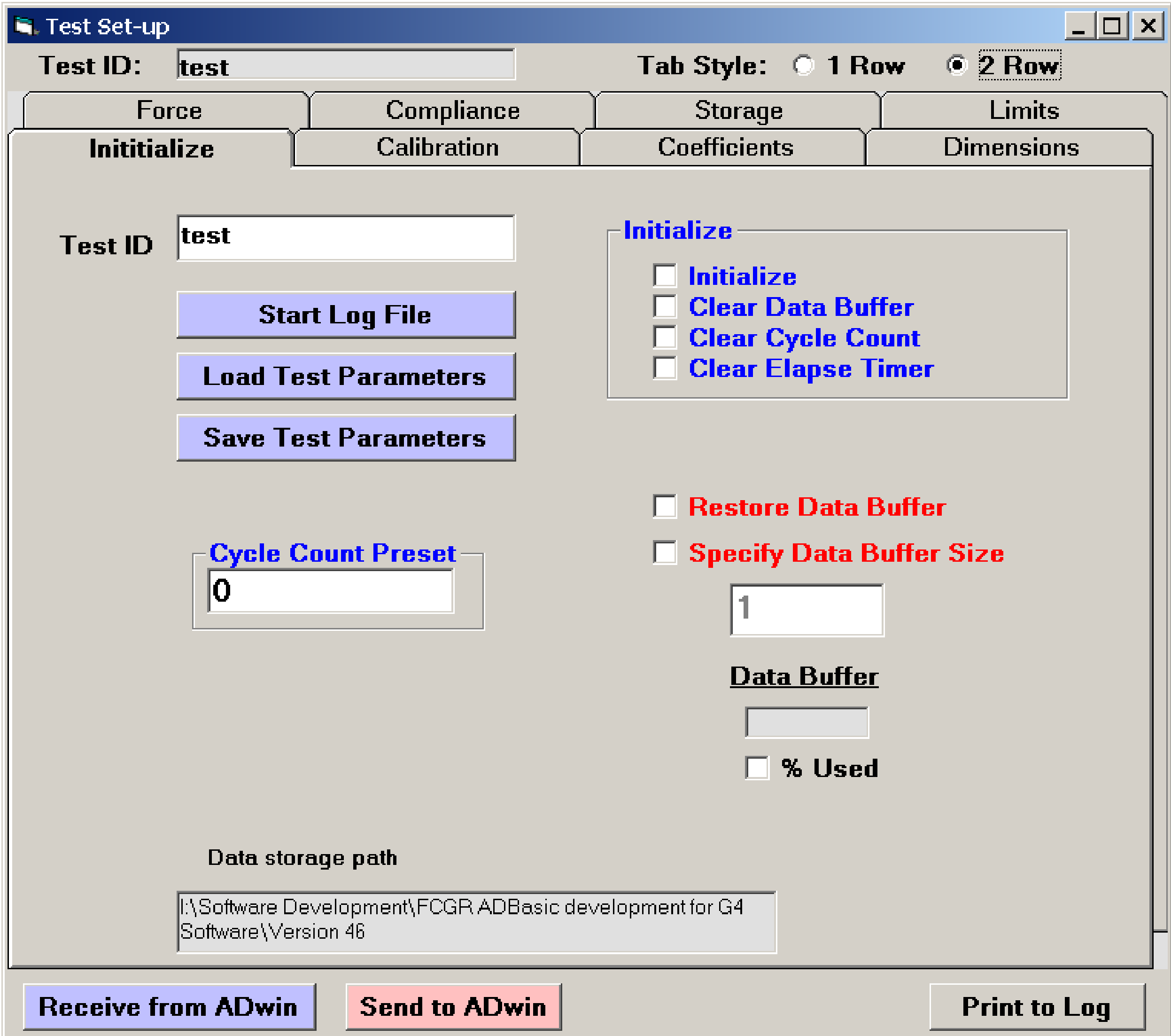
4.4.2 TEST SET-UP

The **Test Set-up** form consists of eight tabs: **Initialize; Calibration; Coefficients; Dimensions; Force; Compliance** or **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.

Cyan-shaded fields indicate values that are changed by the ADwin as the test is running (such as P_{MAX} during K-control testing or stress ratio during constant Kmax testing). These fields are not updated on the computer screen until the **Receive from ADwin** button is pressed, thus retrieving the current data from the ADwin.

*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 (extensions are appended automatically to filenames and are not necessary in the **Test ID** field). It is recommended to use suffixes (e.g. TestA, TestB) if more than one test is to be conducted on the same specimen, providing a means of distinguishing by name the analysis and log files. 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 (.pr4) 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+.15.*

  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 E399 and E647 test standards for corresponding formulas and coefficients. Test parameter files supplied by FTA include:

  - C(T) FF.pr4: compact tension with front face clip gage
  - C(T) LL.pr4: compact tension with load line clip gage
  - M(T) 4W.pr4: middle crack tension, 0.6" gage length, 4" panel width
  - SE(B).pr4: single edge 3-point bend
  - SE(T) PIN LOADED.pr4: single edge tension (pin loaded)
  - SE(T) RIGID.pr4: single edge tension (rigid grip)
  - ESE(T).pr4: eccentrically load single edge tension
  - SF.pr4: surface flaw tension
  - CC.pr4: 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 four 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 da/dN data stored in memory. This is typically used when starting a new test. It may also be used when the user deliberately wants to discard initial, scattered data produced before steady state conditions have been achieved. Ticking **Clear Data Buffer** automatically issues a prompt to store the data to an analysis file.

- **Clear Cycle Count**: resets the cycle count to zero. If not ticked, the previous cycle count will be maintained.
- **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.

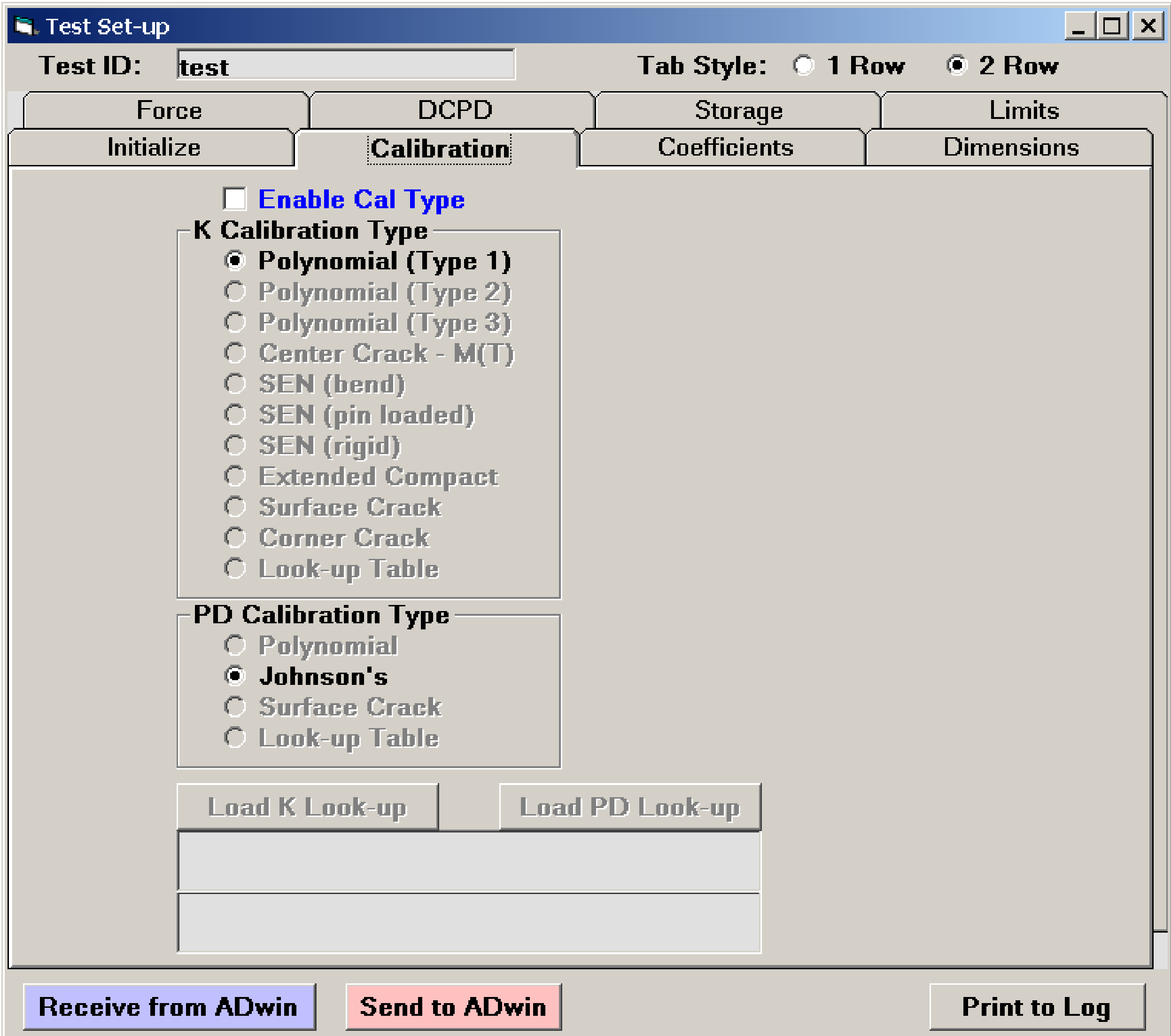
If the data buffer has been cleared unintentionally (or the operator has second thoughts!) it may be restored using the **Restore Data Buffer** checkbox. This is particularly useful if the analysis file was not manually saved before the buffer was cleared.

The **Data Buffer** display shows the current status of the buffer, either as an absolute value or **% Used**. Data stored include normalized compliance; DCPD active; DCPD reference; DCPD normalized; maximum force; cyclic force; cycle count; elapsed time; compliance ratio; crack closure levels; displacement at zero load; crack length; da/dN; da/dt; delta K; and Kmax. The buffer allows for a maximum of 50,000 lines of data in the analysis (.in3) 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.

If the cycle count has been accidentally reset to zero (by activating the **Clear Cycle Count** box in the **Initialize** frame) the operator may enter a number (which can be retrieved from the log file) in the **Cycle Count Preset** field, which will assign a non-zero cycle-count value to the first data point.

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 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:

$$a/W = B_0+B_1(V_a/V_{0,a} \bullet V_{0,r}/V_r) + B_2(V_a/V_{0,a} \bullet V_{0,r}/V_r)^2 + B_3(V_a/V_{0,a} \bullet V_{0,r}/V_r)^3 + B4(V_a/V_{0,a} \bullet V_{0,r}/V_r)^4$$

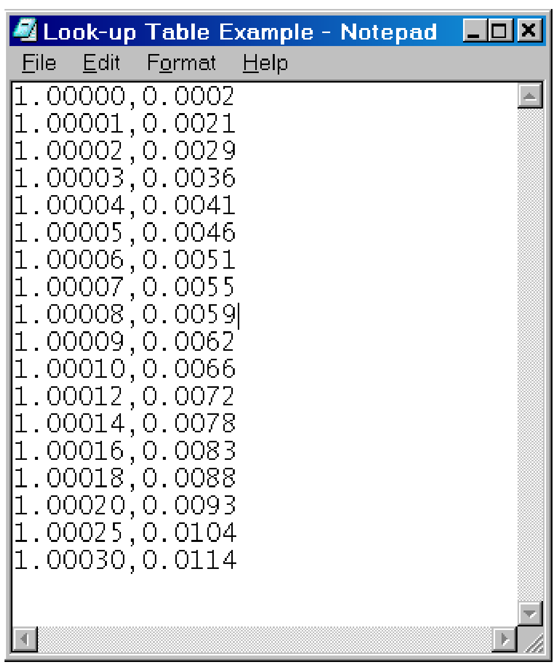
Where:

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.

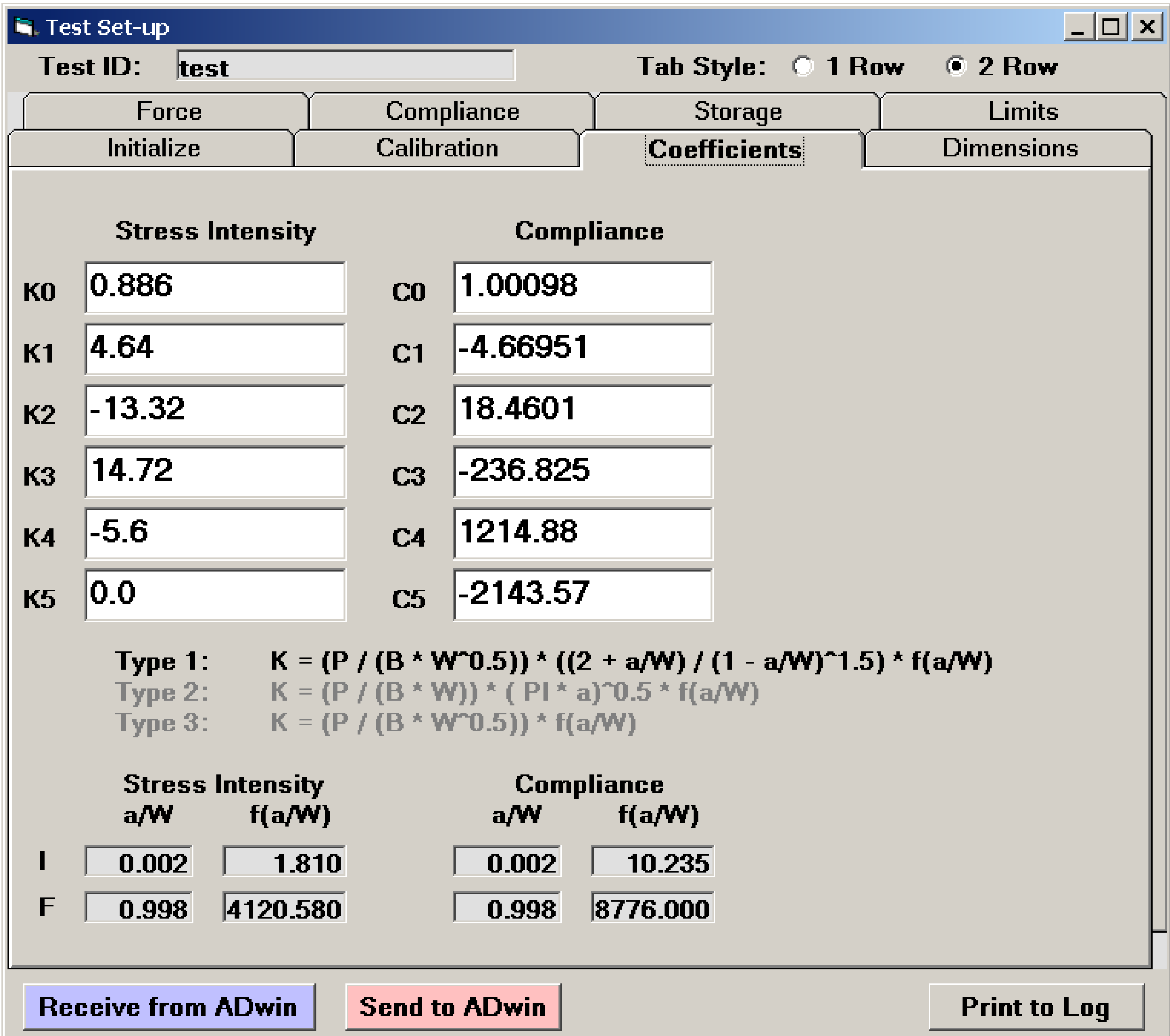
- **Look-up Table**: for situations where a polynomial expression or Johnson's formula are not sufficiently accurate. The data pairs are entered in a file with the .dat extension in tabular form as shown in the example below:




```
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)**.

4.4.2.3 Coefficients

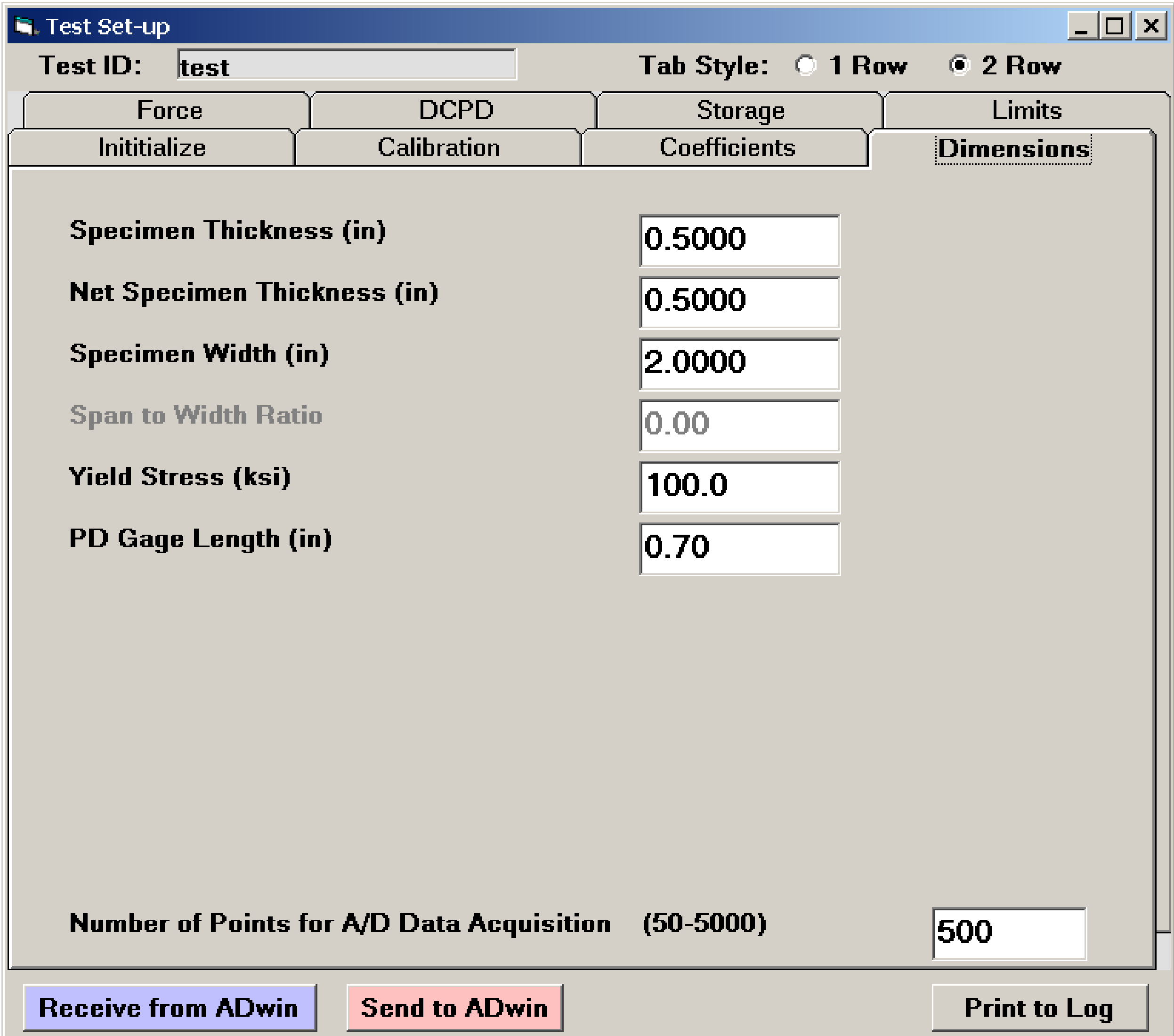


This tab displays the coefficients of fifth-order polynomial expressions used to calculate stress intensity and crack length. When a selection other than **Polynomial** is made on the **Initialize** tab, the coefficient fields on this tab are disabled and appear in gray. Compliance coefficients are required 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-front face.pr4).

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



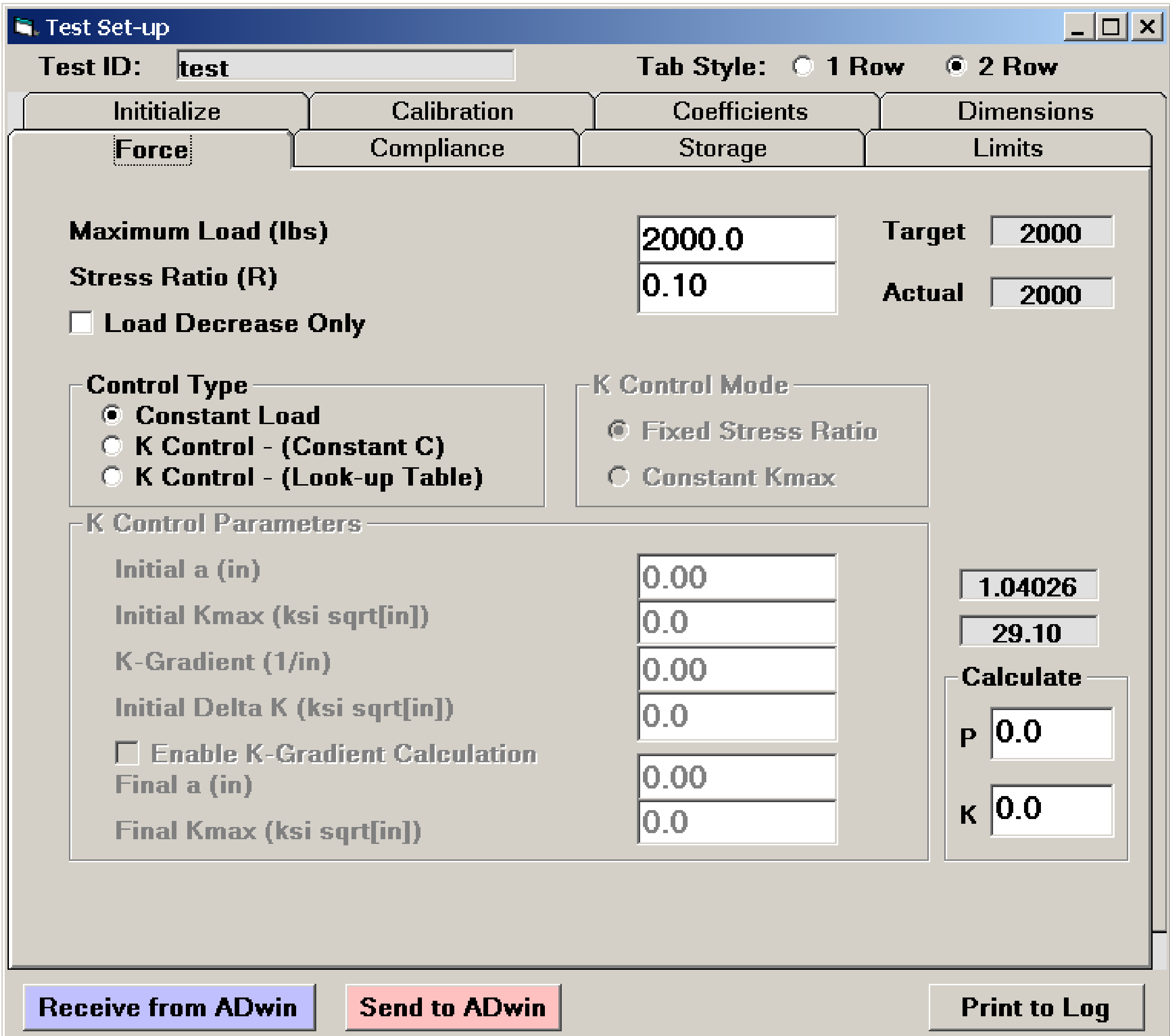
The following values must be entered by the user:

- **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)
- **P[otential] D[rop] Gage Length** (Johnson's Formula): the distance in inches between the active potential-drop probes.

In addition, the **Number of Points for A/D (analog to digital) Data Acquisition** must be specified at the bottom of the tab. This value corresponds to the number of compliance or DCPD readings taken over a single loading cycle. The default value of 500 is recommended for DCPD testing. A value of 800 is recommended for compliance testing. For dwell testing and other non-standard waveform shapes at very low frequency, the maximum value of 5000 is appropriate. It is also possible to change this value on the **Matrix** (Section 4.5.4) when automating changes to test conditions.

4.4.2.5 Force

The **Force** tab is used to determine loading and control parameters. Three control types are possible using the steady state software: **Constant Load**, **K control (Constant C)**, and **K control (Look-up Table)**.



If **Constant Load** is selected, **Maximum Load** and **Stress Ratio** (ratio of minimum to maximum cyclic load) must be entered by the user in the boxes at the top of the tab.

If **K Control (constant C)** is selected, the **K Control Mode** (**Fixed Stress Ratio** or **Constant Kmax**) must also be selected, as follows:

- **Fixed Stress Ratio**: the **Initial a**, **Initial Kmax**, and **K-gradient** (C) must be entered under **K Control Parameters.** The maximum load will be adjusted as a function of crack length. See the preceding test procedures for order of operations. *In DCPD testing, particularly, it is important not to choose K-control until a crack length has been established and is visible on the **Status** form.*

Under K control, the relationship for K as a function of crack length is:

$$K = K_i \cdot e^{C(a-a_i)}$$

where:

K = ΔK or K_{max}
K_i = Initial ΔK or K_{max}
C = K-gradient
a = Crack length
a_i = Initial crack length

Note that a positive value (6, for example) entered in the K-gradient text box increases the stress intensity and a negative value (-6, for example) decreases K. Choose a K-gradient of zero for constant ΔK testing.

- **Constant Kmax**: the initial ΔK must be entered by the user. In this case, Kmax remains constant and ΔK is modified by the above expression. Both the maximum load and the stress ratio will be adjusted as a function of crack length.

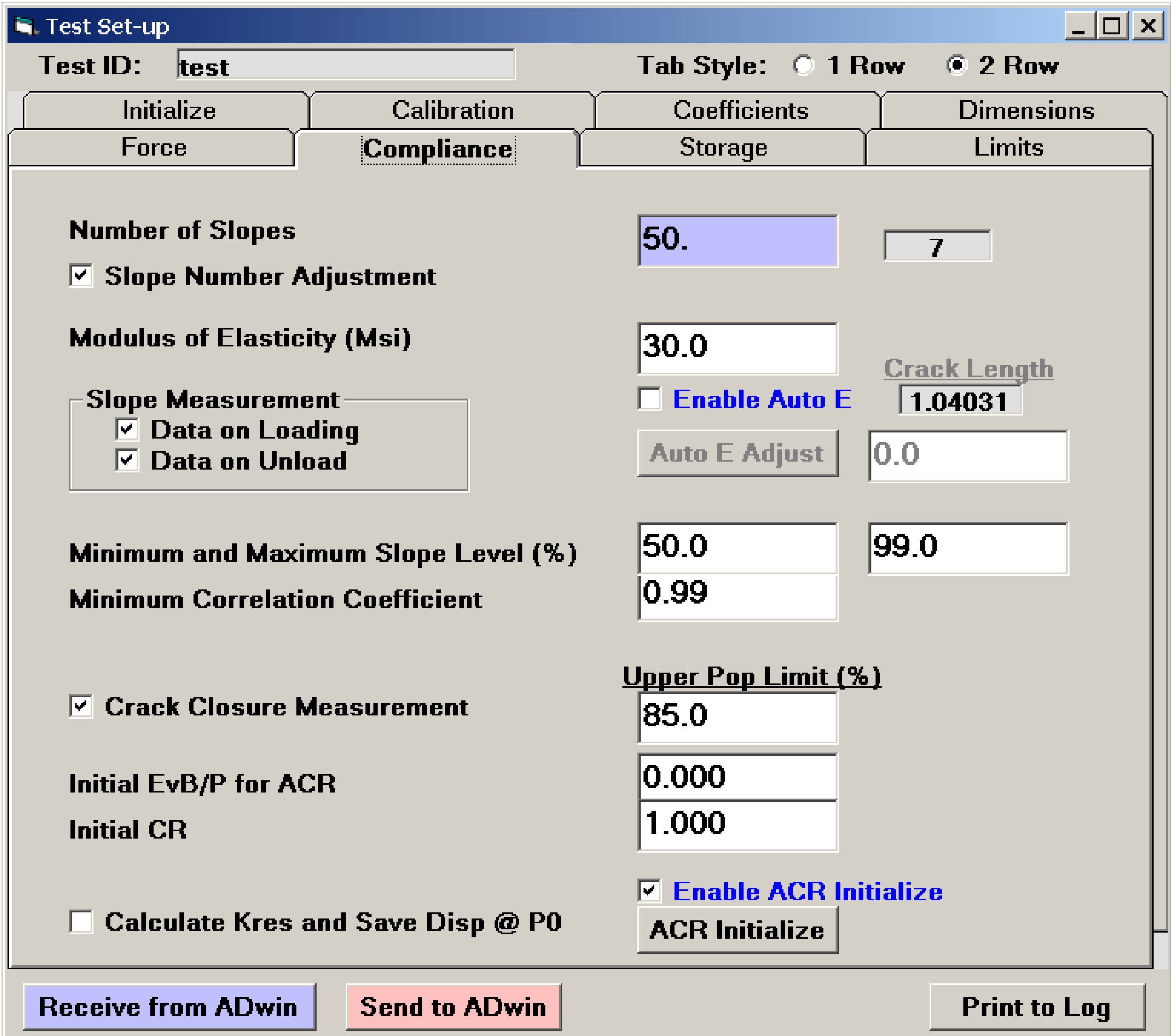
If non-zero values are entered for **Final a** and **Final Kmax,** the software computes the K-Gradient required to achieve those final boundary conditions.

K Control (look-up table) allows the user to employ a K profile according to the parameters of a look-up table, whereby the first column is a/W and the second column is K in units of ksi-sqrt(in). The **Load K Profile** button is used to load the file, which can include header text for documentation purposes. The line prior to the two columns of data must contain the text [Start Data] (case sensitive). Since actual maximum and cyclic loads are passed to the analysis software, the K profile is not required by the analysis software.

To enable the operator to monitor loads, crack length, and K levels without referring to the **Status** screen, these values are displayed in real time on the right-hand side of the tab.

Note the **Load Decrease Only** checkbox at the top of the tab**.** Ticking this box prevents unwanted increases in load. This is useful under decreasing-K conditions when a high closure level could cause a decrease in crack length and a subsequent rise on load. It is also a good safety feature in case of system malfunction. When this option is selected, the **Target Load** (max) value on the **Status Screen** flashes red as a reminder.

4.4.2.6 Compliance



The **Compliance** tab defines the parameters related to crack measurement, including slope characteristics and values associated with crack closure and ACR. Note that although it is possible to gather ACR data using the basic compliance application, the data cannot be interpreted by the analysis program unless the FTA FCGR-ACR package is purchased separately. Discussion of the ACR options at the bottom of the tab are beyond the scope of this document and users of the basic application are advised to use the default values shown above.

The following values must be entered by the user:

Number of Slopes: … required to determine crack length. A large number gives greater crack-length precision but does not update the crack length as often. If the **Enable Slope Number Adjustment** box is ticked, this value is automatically modified as the test proceeds, so that the optimum number is used for a given crack growth rate.

A value of 50 is appropriate for test start-up. It is recommended to leave this option turned on, although in certain cases where a runaway crack is expected after slow growth it can be a good idea to turn this option off and enter a very small number in the text field. When this option is turned off, the **Slope#** field on the **Status** screen flashes red as a reminder.

Modulus of Elasticity: This value may be changed on the fly to achieve the correct crack length at test startup. Pressing the **Auto E Adjust** button calculates automatically the effective modulus based on the measured compliance. The **Enable Auto E** checkbox must be ticked to activate the command button and the crack length manually entered in the text field to its right. The iteration process will adjust the modulus up to ±10% from the original modulus and may be repeated several times, if required. The real-time crack-length display above allows the user to monitor the crack length without referring to the **Status** screen.

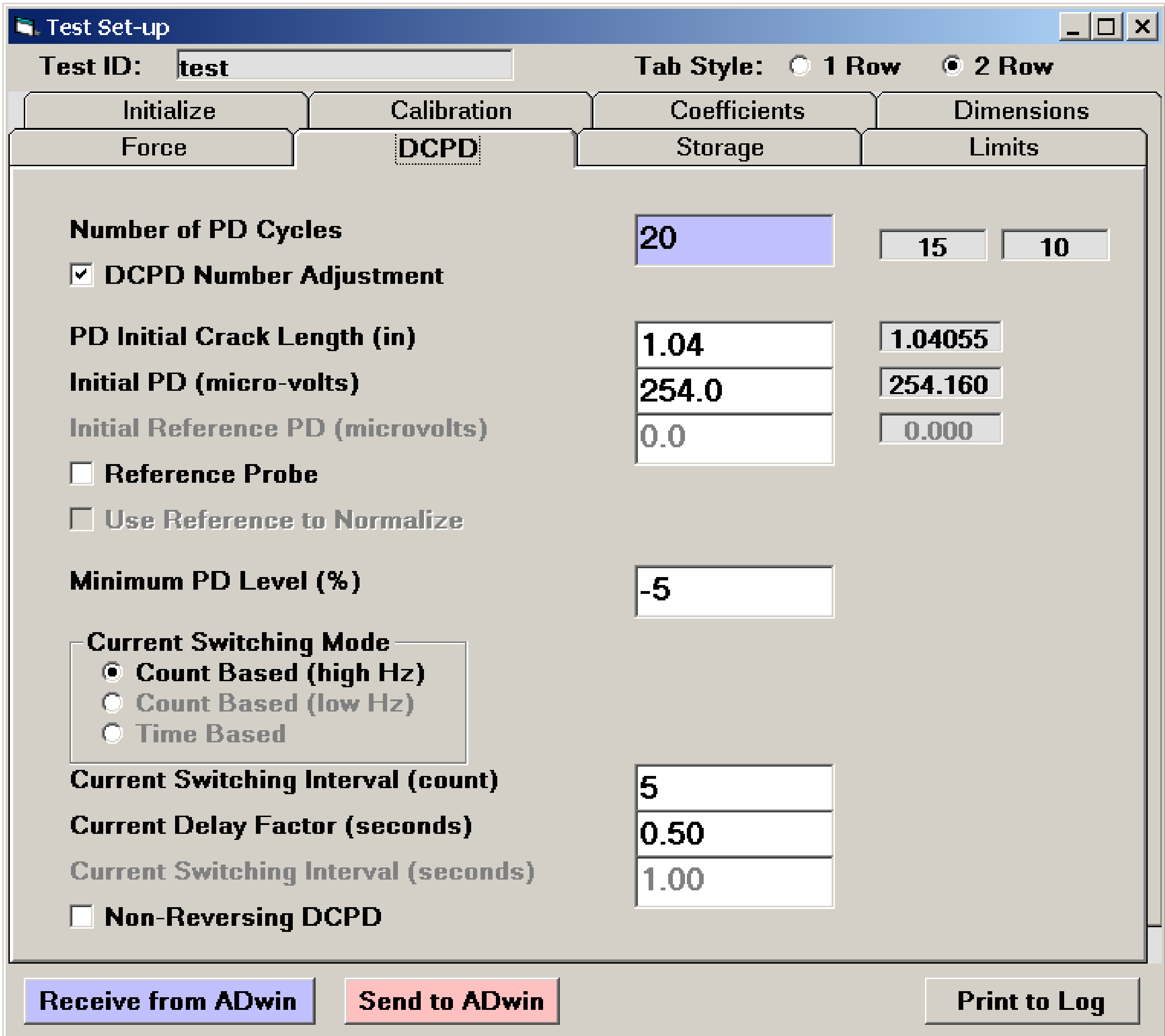
Slope Measurement: selects whether to use data on the loading and/or unloading portion of the load-displacement curve. Select both the **Data on Loading** and **Data on Unload** boxes for most applications.

Minimum and Maximum Slope Level (percent of the maximum load): these values define the lower and upper windows for slope measurement and are used to ensure that data for slope measurement are above the effects of crack closure. A minimum value of 50 and a maximum value of 99 are recommended to start with. *Even if the **Enable Crack Closure Measurement** option is activated, the minimum slope level will still be maintained; however, if closure is detected above this setting, only the slope above closure will be used in crack length determination.*

Minimum Correlation Coefficient: used to reject slope measurements with correlation coefficients below the minimum value. A value of 0.99 is recommended for most applications. Cycling will stop automatically if it falls below the minimum value, unless **FNG Shutdown** is disabled on the **Full Function Generator**.

Enable Crack Closure Measurement: this option is active by default and is recommended for most applications. When active, only the portion of the load-displacement curve above closure (and above the **Minimum Slope Level**) will be used in the crack length determination. The **Upper pop limit %** text field allows the user to specify the upper limit for the linear part of the load-displacement curve when **Enable Crack Closure Measurement** is selected. The default value is 85%.

4.4.2.7 DCPD



The **DCPD** tab defines the parameters related to crack measurement, including calibration of the PD signal and signal-switching characteristics.

The following values must be entered by the user:

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 50 is appropriate for test start-up. If the **Enable DCPD Number Adjustment** box is ticked, this value is automatically modified as the test proceeds, so that the optimum number is used for a given crack growth rate. It is recommended to leave this option turned on, although in certain cases where a runaway crack is expected after slow growth it can be a good idea to turn this option off and enter a very small number in the text field. When this option is turned off, the **PD#** field on the Status screen flashes red as a reminder.

PD Initial Crack Length: the nominal starting crack length of the specimen, used for calibrating the PD signal in the text field directly below.

Initial [Active] PD: at test startup, this value is set to zero. After the specimen has been cycled and PD readings are deemed repeatable, the DCPD value from the **Status** screen (in microvolts) is entered here so the crack length can be calculated by the program. See Section 3.3 of this manual for the order of operations. If the reference probe has been enabled using the checkbox below, this procedure must be repeated for the reference probe using the **Initial Reference PD** text field.

If the reference probe has been activated, readings are recorded in the log and analysis files but are not used to compute crack length during the test. To employ the reference probe for crack length measurement, **Use Reference to Normalize** must also be ticked. If post-test normalization is required, this option can also be activated in the analysis program.

Minimum PD Level (percent of cyclic load): the program averages PD signals above the minimum level if crack shorting is suspected. Typically, this value is set to –5 % to ensure the entire signal is averaged.

Three current-switching modes are available to the user. They may be assigned on the **DCPD** tab as follows or on the **Matrix** (Section 4.5.4) when automating changes to test conditions.

- The **Count Based (high Hz)** option is recommended for cyclic test frequencies of 0.5 Hz and higher. When using this option, two additional parameters must be specified:
    - **Current Switching Interval:** the number of PD cycles after which the current is reversed. A value of 5 is recommended for most applications.
    - **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. Regardless of the specified delay, the crack size will not be updated until the beginning of the subsequent cycle.
- The **Count Based (low Hz)** option is recommended for cyclic test frequencies of 0.5 Hz and slower and starts reading DCPD data immediately after the **Current Delay Factor** has passed, without waiting for the subsequent cycle in the manner of the **high Hz** option above. This allows the crack size to be updated

every other cycle, thus reducing crack size variability due to thermally-induced signal drift. A value of one [cycle] should be entered in the **Current Switching Interval** box.

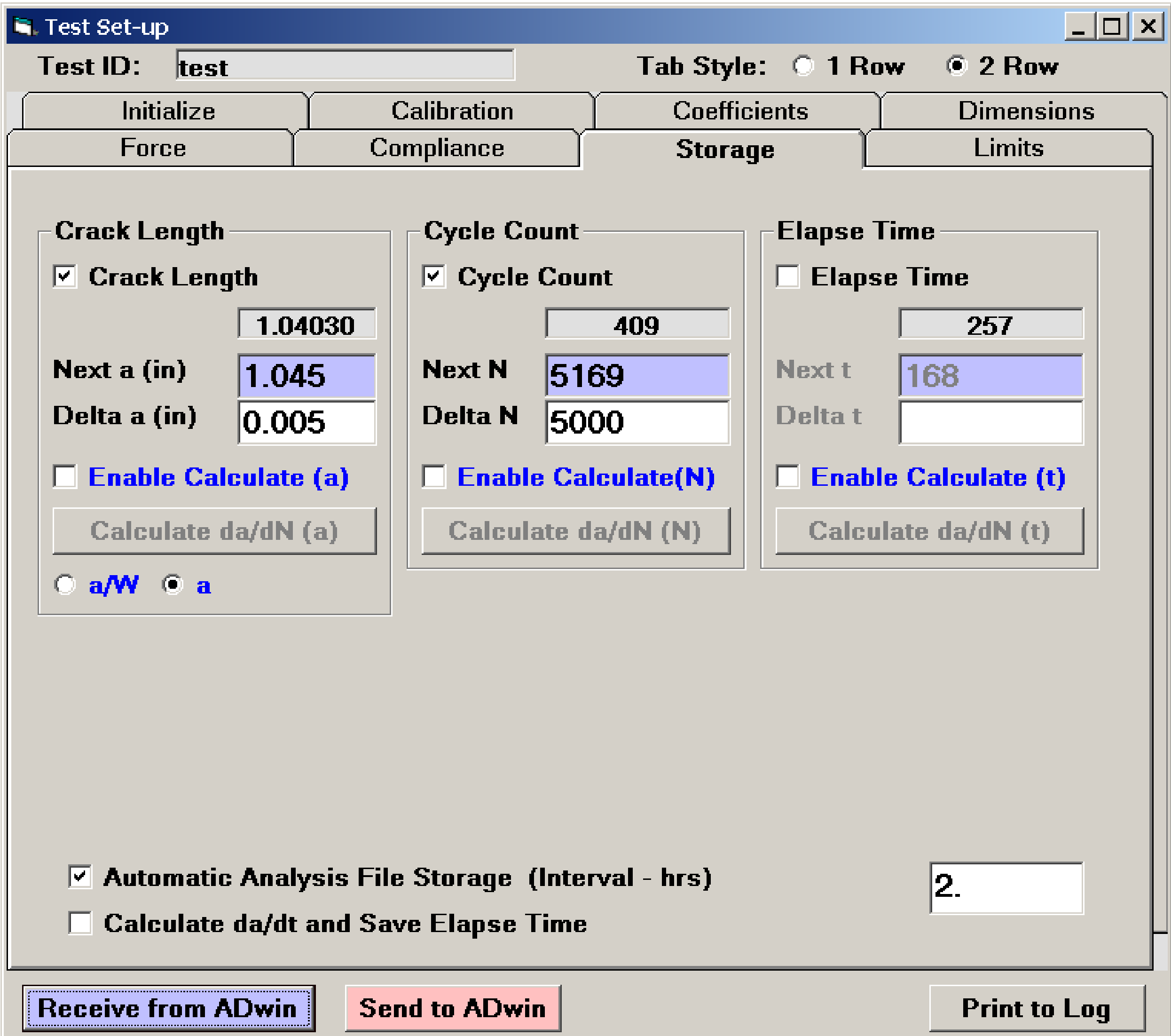
- The **Time Based** option should be used for exceptionally low frequencies, allowing updating of the crack size at user-defined timed intervals within a single cycle. When using the time-based option, the **Current Switching Interval (seconds)** must be specified. Current switching intervals greater than one minute are not recommended. Note that time-based current switching continues even if cycling has stopped.

Enable Non-Reversing DCPD: when ticked, this option turns off current switching and the reversing DCPD averaging logic, thus allowing the system to monitor a direct analog output system such as an AC potential drop power source. By default, this option is deselected.

Real-time displays of the PD tally in the current-forward and current- reversed direction; the current crack size; and the current DCPD value (active and reference) may be found on the right-had side of the tab, adjacent to the applicable text boxes. These fields provide a useful aid when initializing DCPD for crack length without having to refer to the **Status** screen.

4.4.2.8 Storage

The **Storage** tab is used to determine the intervals at which data are used to calculate growth rates and subsequently stored in the analysis file. Storage intervals may be based upon **Crack Length**, **Cycle Count** and/or **Elapse Time** as selected using the boxes at the top of the form. Options that are not chosen will be inactive. If more than one option is selected, then crack lengths will be calculated on a first-past-the-post basis.



Crack length: may be expressed as either **a** or **a/W,** by selecting the desired option in the **Crack Length** frame. The default is **a**. If active, the following values (in or mm) must be entered by the user:

- **Next a**: crack length at which the next crack growth rate will be calculated.

- **Delta a**: increase in crack length at which the next crack growth rate will be calculated (when the [current] reaches the **Next a**, a growth-rate calculation is made and then **Next a** is incremented by **Delta a,** *ad infinitum*). Optimum values of **Delta a** are a function of crack-length measurement precision, specimen size, specimen geometry and K-gradient. Typical values of **Delta a** range between 0.001 and 0.005 inches, with 0.0025 to 0.005 inches being appropriate for a one-inch C(T) specimen.

Cycle Count: it is often desirable to select a cycle-count increment for near-threshold testing. This guarantees that data will be stored periodically as a function of cycle count, even if the crack length increment has not been achieved due to very slow crack growth. If **Cycle Count** is active, two values must be entered by the user:

- **Next Count**: typically start at 50,000 for room temperature tests and 100,000 for elevated temperature tests. Else, choose a value slightly higher than the current value on the **Status** screen.
- **Delta n**: crack growth rates are calculated and recorded when the cycle count advances by the increment specified. Optimum values are a function of specimen size, specimen geometry and K-gradient. Typical values are 50,000 (elevated temperature) and 100,000 (room temperature).

Elapse time: this option is not typically used for standard FCGR testing, although it can be appropriate for static loading and stress corrosion testing.

Crack growth rates may also be calculated manually using the **Calculate da/dN** buttons at the bottom of each frame. Pressing these buttons causes **Next a, Next N**, or **Next t** to be decreased by the specified increment, thus triggering a growth-rate calculation. In most cases, it is best to use the button in the **Crack Length** frame for this purpose, although at very low growth rates, the button in the **Cycle Count** frame may provide a quicker result. See the test procedures in Sections 3.2 and 3.3 for the order of operations and use of these buttons.

At the bottom of the tab, **Enable Automatic Analysis File Storage** is activated by default. As long as this option is ticked, a backup analysis file (no extension) is automatically saved to the test directory. These files are saved every two hours by default, although this interval can be changed by the user. See Appendix E1 for more information on these backup files. Note that if this option is deselected, no backup files will be created. See Appendix E2 for instructions on reconstructing an analysis file from a log file in the event that a backup file cannot be found.

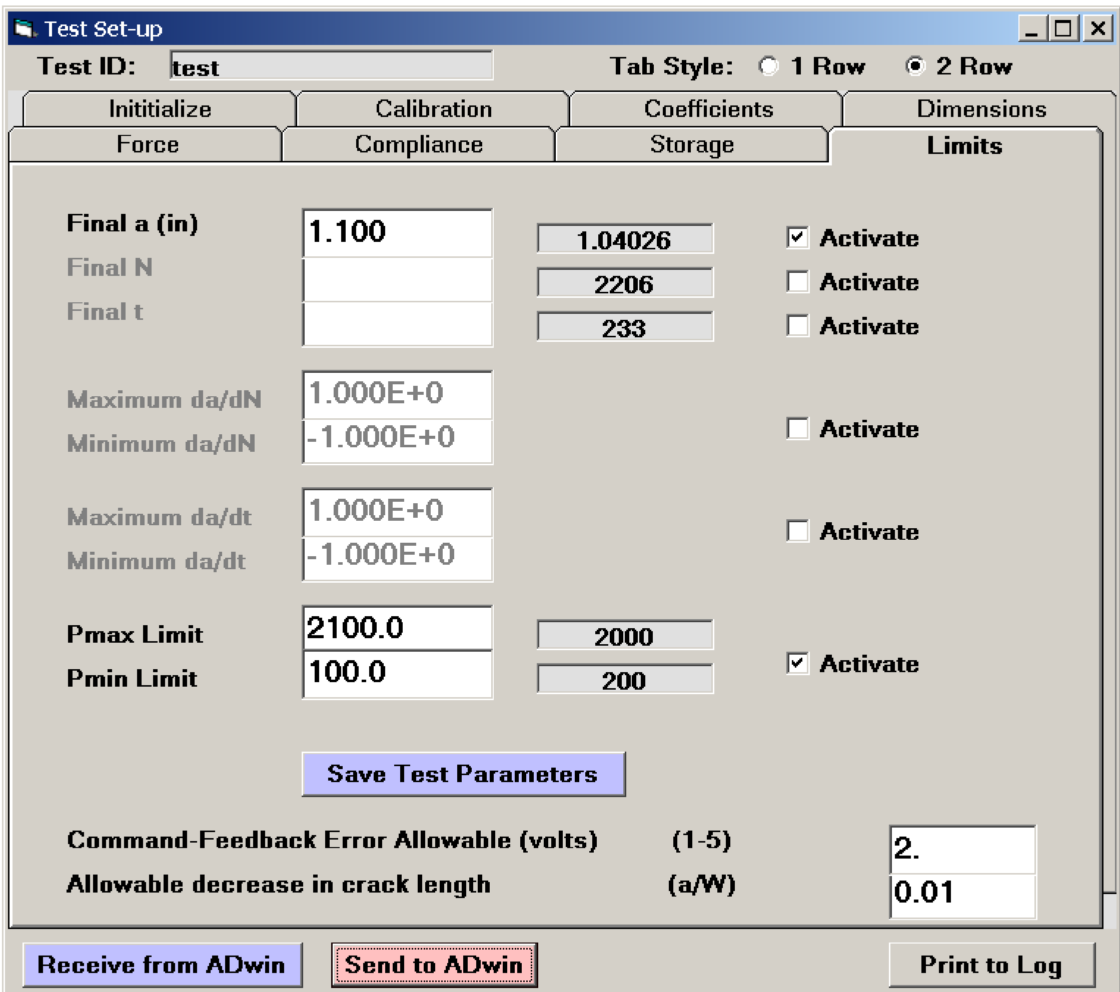
The **Calculate da/dt and Save Elapse Time** option is inactive by default. When checked, an additional field appears on the **Status** display and the elapsed test time (in seconds) is stored as an extra column in the analysis file.

4.4.2.9 Limits

The **Limits** tab is used for defining the conditions under which the function generator will stop the test. Stopping conditions include achieving targets such as maximum crack length or crack growth rate as well as error limits defined by the user. When a limit has been reached, the specimen will stop cycling and the load will return to its mean level (if a hold level has not been specified on the function generator) or hold level (if it has).

Any limit may be active or inactive as appropriate.

Since this is the final tab addressed by the user during test setup, test parameter files may also be saved from here.



The limits are self-explanatory: if a limit is active, then function generation will stop when a target (**Final**) crack length **a**; cycle count **N**; elapse time **t**; growth rate **da/dN**; or load **P** limit has been reached. If more than one limit is active, the test will stop on a first-past-the-post basis.

In addition, two error limits are specified at the bottom of the tab:

Command-Feedback Error: the maximum-allowable error between peak command voltages and peak feedback voltages. The test stops when this error is exceeded. The default value of two volts is appropriate in most cases.

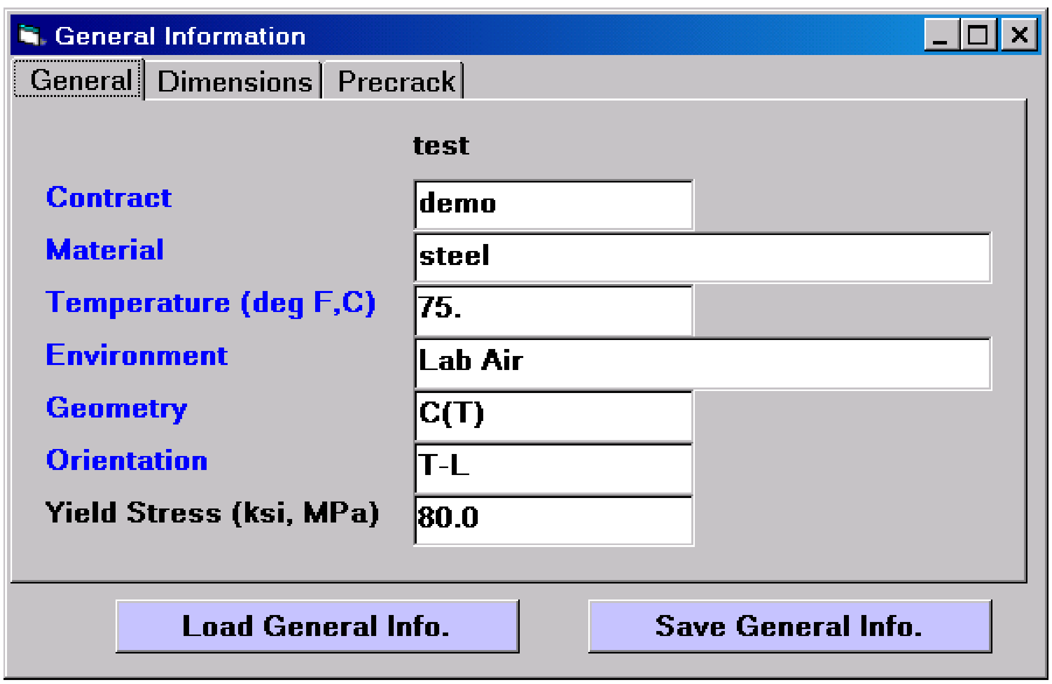
Allowable decrease in crack length: the test stops when the decrease in crack length between two calculations exceeds the limit specified by the user. The default value of 0.01 times **W** is appropriate in most cases.

4.4.3 General Information

Non-critical **General Information** may be saved and loaded into the testing program at any time, thus avoiding repetitive data entry during analysis. Use of [.gn0] files also minimizes the risks of mistakes and typographical errors at analysis time. Three tabs are available for input: **General Information**; [specimen] **Dimensions**; and **Precrack**[ing information]. Although this information is not required for running a test, it does appear on the cover page of the analysis program output (see Sections 5 and 6 of this manual for further details).

4.4.3.1 General

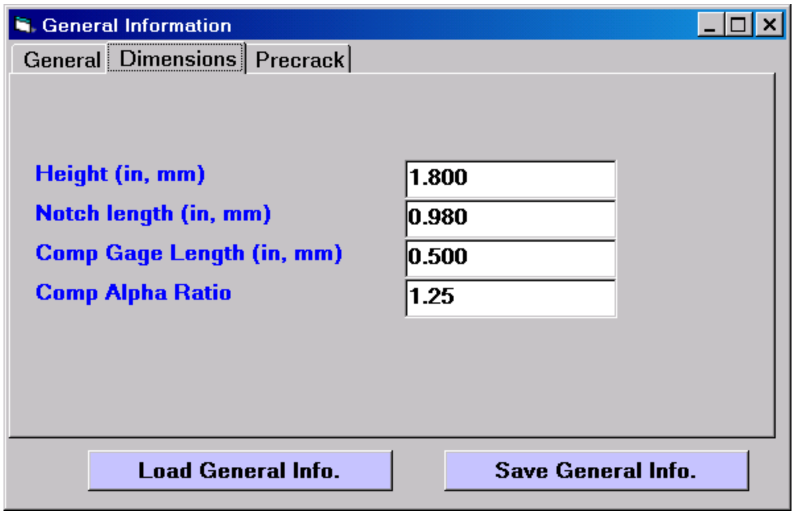
Load General Info: this button calls up a dialogue box requesting selection of the correct [.gn0] file for loading. Selecting the appropriate file populates the three tabs of the **General Information** screen. This [.gn0] file is created through the **Save General Info** button.



Save General Info: after the fields of the three **General Information** tabs have been populated, the input values may be saved as a [.gn0] file and loaded during subsequent tests. The user is prompted for an appropriate file name and file path.

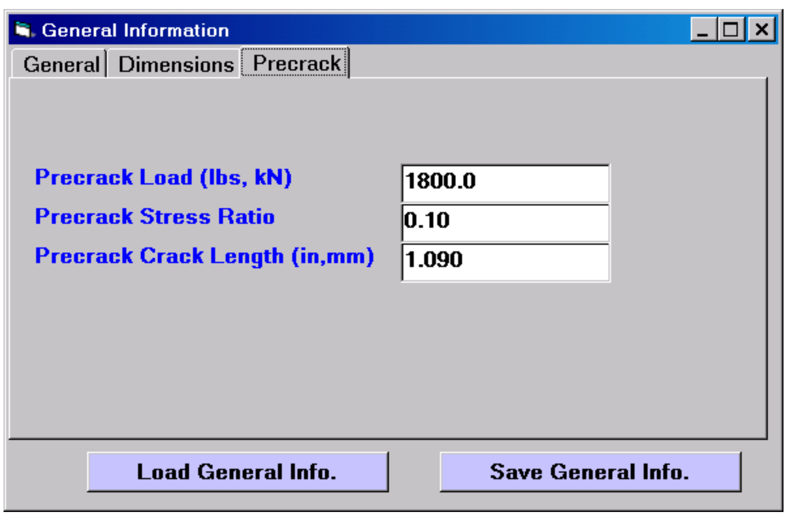
4.4.3.2 Dimensions

Additional dimensions not critical to testing may be entered by the user.



4.4.3.3 Precrack

Precrack parameters may also be provided by the user (although often the final **Precrack Load** is not known until precracking is complete).



4.5 Control

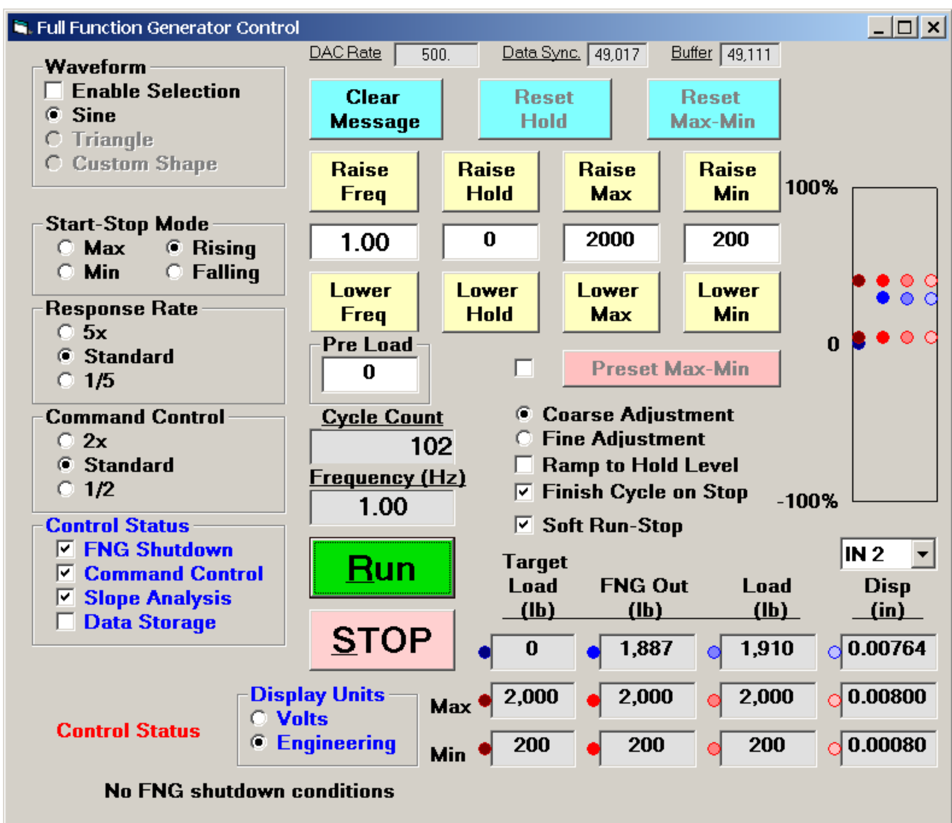
4.5.1 FULL FUNCTION GENERATOR CONTROL (FNG

The **Full Function Generator Control (FNG)** is the heart of the FTA/ADwin control system. Waveform shape, test frequency, hold levels, and other command and control parameters are specified using this form.

Changes on the **FNG** are immediately sent to the ADwin, unlike changes on the **Data Input** form, which must be sent manually. Text boxes with white backgrounds are both for display and entry purposes, while text boxes with gray backgrounds (appearing in the lower right of the form) are for display only.

Values may be displayed in volts or engineering units (**Display Units**). Function generation and feedback signals are updated five times per second.

In addition to the **Full FNG**, a **Mini** version is available. The full version must be accessed first and is used during the setup of a test. This form must be open to activate the **Status** and **Load-Displacement** displays. After the test has begun, the **FULL FNG** may be minimized and the **Mini FNG** displayed to minimize computer screen usage*. An **FNG** form must be active at all times during testing.*



A variety of FNG control choices appears on the left of the screen, as follows:

- **Waveform**: **Sine**, **Triangle** or **Custom Shape** can be selected. **Sine** is active by default. The **Custom Shape** selection allows the construction of simple non-standard waveforms, such as saw-tooth and trapezoid. The **Custom Shape** mode cannot be activated until the **Custom Waveform Shape** form is selected from the **Control** menu and the custom waveform [.dat] file created or loaded (discussed in Section 4.5.3, below). It is possible to change the waveform while the **FNG** is running. It is also possible to automate changes to the waveform using the **Matrix** (Section 4.5.4).

- **Start-Stop Mode**
  - **Max**: starts and finishes the waveform at maximum load.
  - **Min:** starts and finishes the waveform at minimum load.
  - **Rising:** starts the waveform at mean load, then goes to maximum load followed by minimum load. The waveform finishes on mean load. This is the default value.
  - **Falling:** starts the waveform at mean load, then goes to minimum load, followed by maximum load. The waveform finishes on mean load.

- **Response Rate**: the rate of frequency change; soft run-stop; and ramp-to-hold level. **Medium** is the optimum / default for steady-state testing. The **5x** rate is five times faster and the **1/5** rate is five time slower than the **Medium** rate.

- **Command Control:** it is possible to adjust the aggressiveness of the function generator compensation in response to errors between the target / actual maximum and minimum loads. The **Standard** default setting adjusts the function generator by 1/4 the load error. This value can be increased or decreased by a factor of two (**2x** and **½**, respectively). In addition, there are voltage limits imposed on these values that vary as a function of test frequency, thus preventing over-compensation and instability at higher frequency.

In the lower left of the FNG, four commands appear under the heading **Control**: **FNG Shutdown**; **Command Control**; **Slope (compliance) / DCPD Analysis**; and **Data Storage**. See the preceding test procedures for the order of operations of these commands. *Note: the reminder of **Control Status** will flash on the **FNG** screen until all four of these boxes have been ticked.*

- **FNG Shutdown**: when selected, the function generator will shut down in response to error or limit conditions and the test will stop. *FTA recommends **FNG Shutdown** be selected at all times as a safety precaution. If FNG shutdown is disabled by the user, it will automatically reactivate after five minutes have elapsed.*

- **Command Control**: when selected, the function generator will adjust the command signal (FNG Out) in response to errors between target load and actual load. Until this box is selected, actual test conditions will not be affected despite changes made on the **Data Input** form. *FTA recommends this command be deselected whenever test conditions are changed by the user.* ***Command Control*** *may then be activated when proper operation is verified.*

- **Slope/DCPD Analysis**: when selected, load-displacement or DCPD data are analyzed to determine crack length.

- **Data Storage**: this box must be ticked for data to be stored in memory for the analysis file (although the log file will always continue to store data). The user may opt not to activate this command while warming up the test machine or for the first few data points of a test, which may not be indicative of true material behavior. Points will not be plotted on the da/dN display during the test unless **Data Storage** is ticked.

Three blue buttons appear at the top of the FNG display:

- **Clear Message** clears all displayed error or limit messages on the FNG.

- **Reset Hold** returns the hold level to the setpoint value (discussed more fully below). *This command cannot be activated while the function generator is running.*

- **Reset Max/Min** resets the maximum and minimum command signal level to the setpoint value but does not reset a non-zero **Hold** value.

Use of the **Pre-Load** text entry box removes the bias from all control algorithms by allowing manual entry of the preload as determined using the machine controller. If the setpoint preload is set at 50 lbs, for example, the operator should enter a 50 in the box. Use of the **Pre-Load** feature is highly recommended.

Preset Max-Min is a useful function at test startup, particularly at low frequencies and during hold tests. Pressing this button while the function generator is not running presets the maximum and minimum loads to slightly less than their target values. Mean load will be reached *immediately* when the **Preset Max-Min** button is pressed; maximum load after cycling begins. Selecting the **Fine Adjustment** option will result in preset values being much closer but still shy of target values.

Four pairs of yellow command buttons appear in the middle of the **FNG** display. Gradual changes may be made by pressing the **Raise** or **Lower** buttons (the rate of change when using this buttons is set by the **Coarse** and **Fine** adjustment options that appear directly below). Changes may also be made by typing new values in the text boxes.

- **Raise/Lower Freq.**: raises or lowers the frequency, which is displayed in the text box.

- **Raise/Lower Hold**: raises or lowers the hold level, which is displayed in the text box (**Ramp to Hold Level** must be checked to activate this feature).

- **Raise/Lower Max:** raises or lowers the maximum level of the command signal.

- **Raise/Lower Min**: raises or lowers the minimum level of the command signal.

Five additional options appear below:

- **Coarse Adjustment**: sets the rate of change for the yellow command buttons discussed above. If this option is selected, the frequency is changed by 2 Hz above 10 Hz or by 20% below 10 Hz. The hold, mean and amplitude levels are changed by 0.2 volts.

- **Fine Adjustment**: sets the rate of change for the yellow command buttons discussed above. If this option is selected, the frequency is changed by 0.2 Hz above 10 Hz or by 2% below 10 Hz. The hold, mean and amplitude levels are changed by 0.02 volts.

- **Ramp to Hold Level**: if enabled, the function generator, when stopped, will hold at the **Hold** level determined by the yellow command button, above.

- **Finish Cycle on Stop**: see **Stop**, below.

- **Soft Run-Stop**: if selected, the amplitude of the waveform is changed such that the cyclic loading is not instantaneously stopped or started when the FNG is stopped or started. The rate of stop-start can be adjusted by the **Response Rate** (described above).This feature minimizes the possibility of over-shoot during stopping and starting. Cycle counting commences only when the full amplitude is reached.

Two additional buttons are prominent on the FNG:

- **Run**: starts the function generator and all the ADwin processes.

- **Stop**: stops the function generator but does not stop the ADwin processes. Data acquisition continues and the analog output process remains active, to respond to changes in mean level or hold level. If the **Finish Cycle on Stop** option is selected, the function generator is stopped at completion of the current cycle.

Under normal test operation, the message **No FNG Shutdown Conditions** appears at the bottom of the **FNG**. When a limit condition is reached or an error occurs, the test will stop and the cause displayed in blinking red letters, as follows

- Final crack length exceeded
- Final cycle count exceeded
- Crack growth rate limit exceeded
- Target load exceeded full scale
- Command output exceeded full scale
- Actual Load exceeded full scale
- Actual displacement exceeded full scale
- Active PD signal reached full scale
- Reference PD signal reached full scale

Error messages include the following:

- Correlation coefficient less than minimum allowed
- Crack length decreased by > than allowable
- Test machine Run-Stop interlock
- Data storage buffer overflow
- Command feedback error limit exceeded

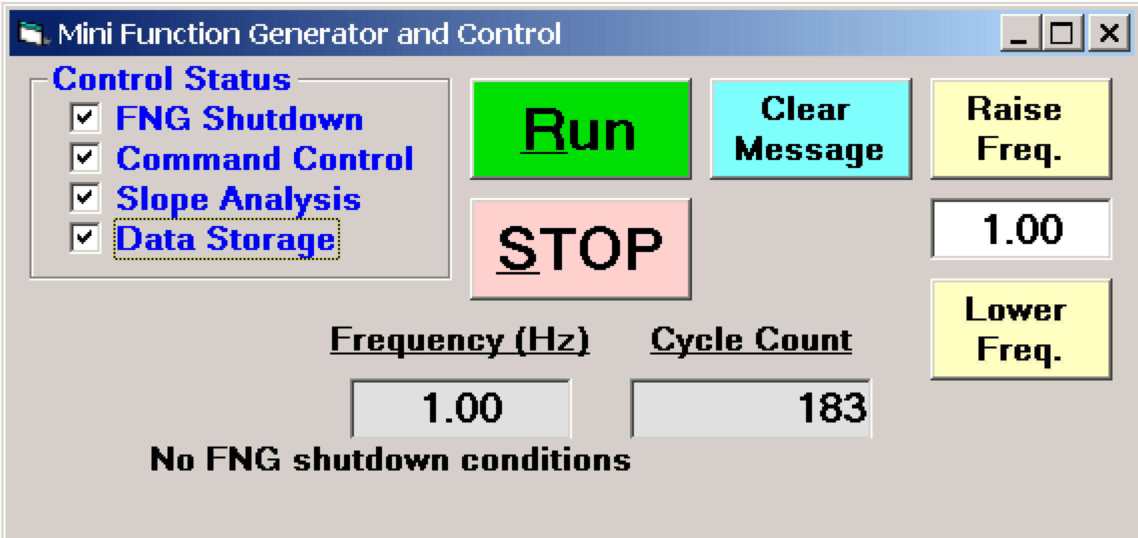
Aux.: The lower right hand corner of the form is devoted to displaying (in volts) the instantaneous, maximum and minimum values of any analog input channel. These values are also graphically represented by the red and blue dots shown above the digital display.

The lower right hand corner of the **FNG** is devoted to the display of the instantaneous, peak and valley function generator output, load feedback and auxiliary feedback signals. This display is updated three times per second. A color-coded graphical display is also included to provide a visual representation of the signal levels: a color key is provided next to each display field.

Across the top of the FNG are useful tracking parameters as follows:

- DAC Rate: the analog input data acquisition rate in readings per second.
- Data Sync: the starting location of data acquisition cycle in 100,000 word circular buffer.
- Buffer: the current location of data acquisition cycle in 100,000 word circular buffer.

4.5.2 Mini Function Generator

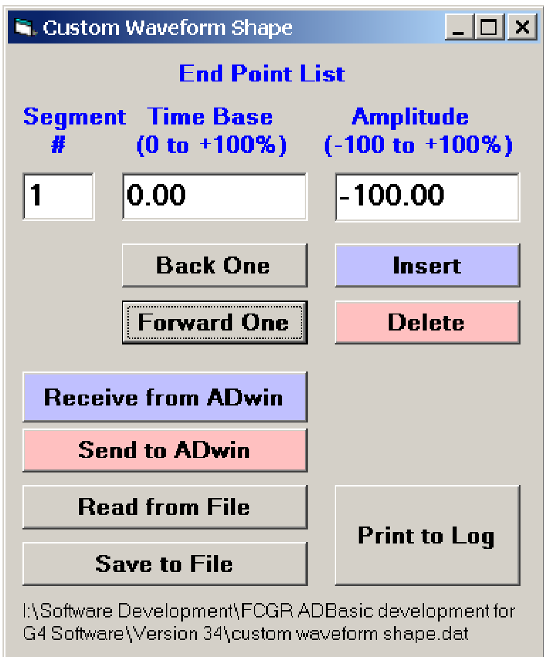


This form provides a condensed version of the **Full Function Generator**. Once a test has been set up and the **Full FNG** minimized, this form is generally sufficient for running the test. The buttons work in the same way as in the **Full FNG.**

4.5.3 Custom Waveform Shape

A **Custom Waveform Shape** option exists under the **Control** menu for creating user-defined single-cycle constant-amplitude waveforms. Simple shapes expressed by a maximum of100 end points may be generated, with custom ramp rates and hold times, saved as a .dat file. Waveforms can be created using the form shown below or in a text editor. See Appendix B for a description of how to construct a simple dwell waveform and use it for running a test. Complex waveforms and custom waveform sequences can only be created with the FTA variable amplitude software.

A **Custom Waveform Shape** may be used only if **Custom Shape** has been selected from the **Waveform** options on the **FNG**.



Three display boxes appear at the top of the **Custom Waveform** screen.

- **Segment #** is the index for the individual segment of the waveform, starting with 1.

- **Time Base** is the percent of total cycle time elapsed from the beginning of the waveform. The time associated with Index 1 is zero, which defines the starting point. The total cycle time or period of the waveform is defined as the inverse of the frequency set in the **Full Function Generator** (see Appendix B).

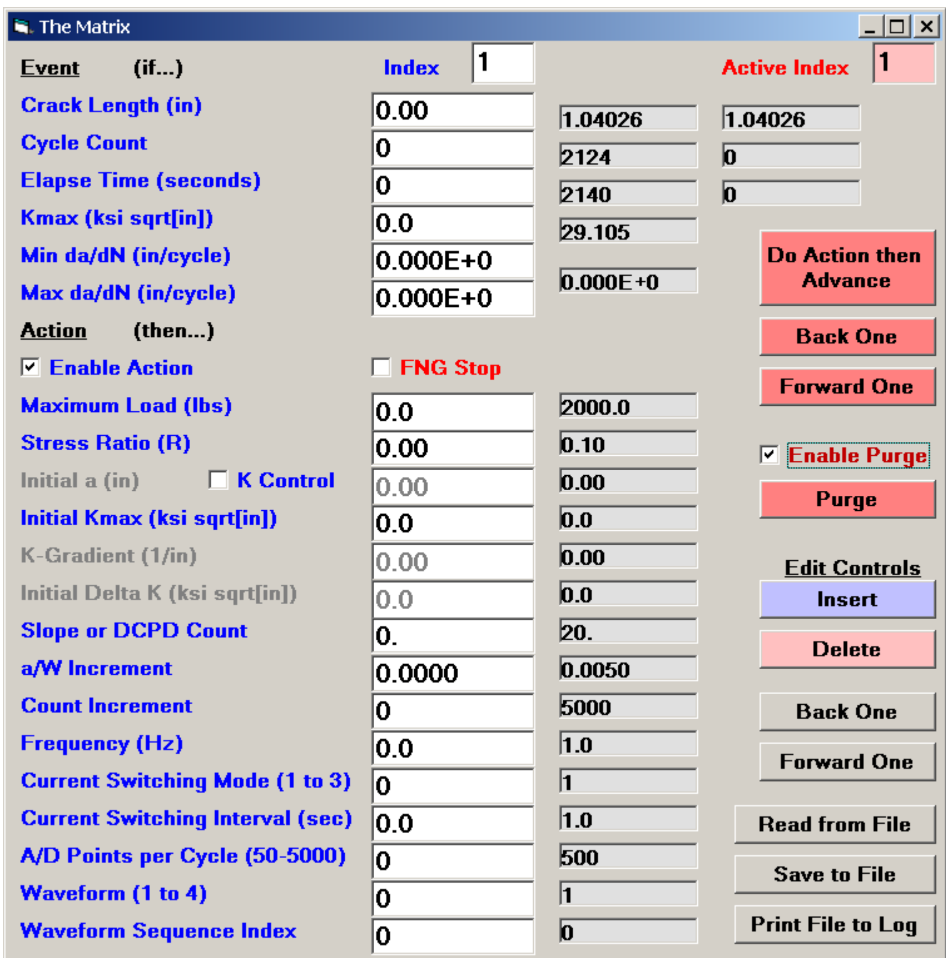
- **Amplitude** is the scaling factor. The maximum peak or valley in the waveform should be set as 100% and -100% respectively. Any peaks or valleys less than the max and min values must be scaled in relative percent to the max and min.

*NB It is recommended that the number of points for A/D Data Acquisition (**Dimensions** tab of the **Test Set-up** form) be set to 5000 when using this option (See Section 4.4.2).*

4.5.4 THE MATRIX

The Matrix is the final menu choice under **Control**. **The Matrix** allows the user to automate changes in test conditions by specifying an **Action** (such as a change in stress ratio or frequency) for a corresponding **Event** (such as the reaching of a target crack length or cycle count). Any non-zero **Event** triggers a corresponding non-zero **Action** (except **K-gradient,** which may be set to zero). The **Matrix** form must be open to be active, but may be minimized. See the end of this section for important tips on setting up the **Matrix**.

NB A positive value entered in the **crack length** or **cycle count** fields signifies an absolute value. A negative entry signifies Δa or ΔN.



Up to 600 events and actions can be programmed (by pressing the **Insert** button for each) and **Save**[d] in a file for future reference. In order for an action to occur, the

Enable Action checkbox must be checked (it is checked by default). When an **Event** is triggered, the **Active Index** is automatically incremented to the next command line. Alternatively, by pressing **Do Action then Advance**, the user can trigger an **Action** before its corresponding **Event** has occurred. This **Action** also increments the command line index by one.

The command lines can be stepped up and down and edited by using the **Edit** controls **Back One/Forward One, Insert/Delete**. The **Active Index** may also be manually stepped up or down by using the red buttons at the top of the form. The **Active Index** sets the condition (**Event**) at which the next **Action** will occur.

The grey boxes display the test's real-time status and are updated continuously.

The library of **Events** and **Actions** is (it is hoped) self-explanatory, with perhaps a few exceptions:

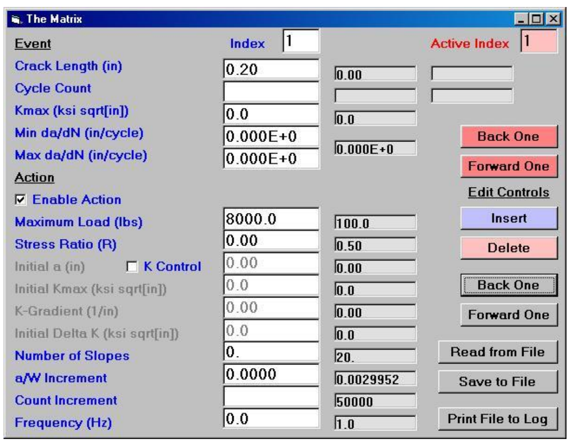
- Choosing **FNG Stop** as an action stops the specimen from cycling and returns the load to its preset hold level. Thus, a test can finish when (for example) the desired crack length or growth rate has been achieved.
- When in constant load (that is, when the **K Control** option under **Actions** is unticked) selecting a non-zero value for **Initial Kmax**, combined with a zero value for **Maximum Load**, automatically computes and applies a constant value of **Maximum Load** for the duration of the **Event**.
- Remember to change the **A/D Points per Cycle** when switching between frequencies and waveforms. Any such choice made on the **Matrix** will override the entry on the **Dimensions** tab of the **Test Set-up** form.
- It is possible to change the **Current Switching Mode** automatically using the **Matrix**. To designate the mode, enter the number 1 (count based, High Hz), 2 (count Based, low Hz), or 3 (time based) in the **Current Switching Mode** field. If the time-based option has been selected, the interval (in seconds) can be designated in the **Current Switching Interval** field. Any such choice made on the **Matrix** will override the entry on the **DCPD** tab of the **Test Set-up** form.
- It is possible to change the **Waveform [Shape]** automatically using the **Matrix**. To define the waveform, enter the numbers **1** (Sine), **2** (Triangle), or**3** (Custom Shape) in the **Waveform** field. Note that the **Waveform Sequence [4]** option at the bottom of the **Matrix** is available only in the Variable Amplitude application and is inactive on the Steady State version.
- Enabling the **Purge** command sets all the command lines in the **Matrix** to zero. It is good practice to purge the **Matrix** before closing down the menu or when starting a new test.

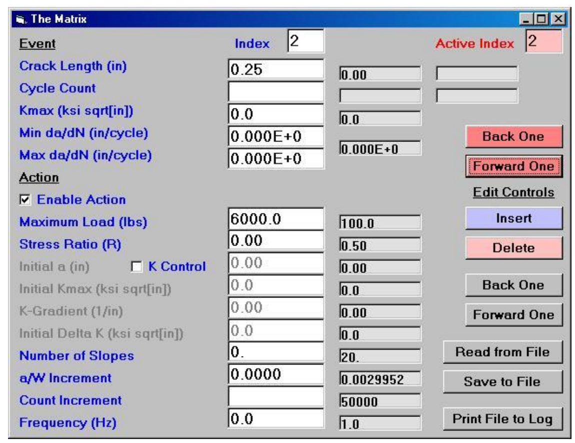
If the user closes the **Matrix**, the FNG is halted and a message box is displayed. This prevents the test from continuing if the **Matrix** is accidentally disabled.

Tips for setting up the Matrix:

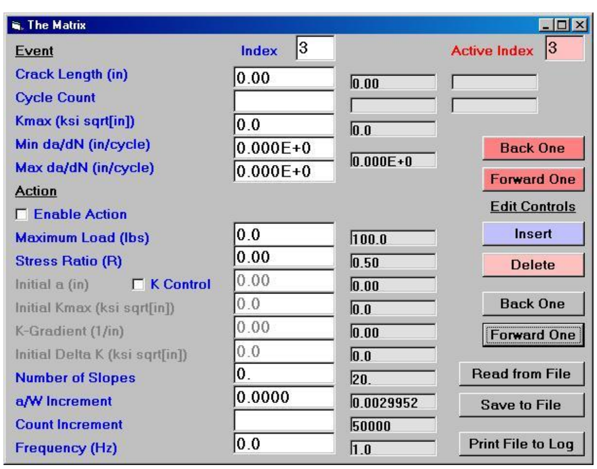
Initial test conditions should be entered on the **Stress Parameters** tab of the **Data Input** form as usual. Set **Index 1**of the **Matrix** to correspond to the first required change to test conditions (the **Event** at top of form determines the **Action** below). In the simple example below, where the test is running at constant load, Pmax will drop to 8000 lbs when the crack length reaches 0.20 inches and drop again to 6,000 pounds when the crack length reaches 0.25 inches. **Enable Action** must be ticked for the **Matrix** to function properly.

Before minimizing the **Matrix** and starting the test, make sure that the red **Active Index** is set to **1** (use the red **Forward One** button to set the **Active Index**), as shown at left, below (note that these forms are not identical to those in the latest software version, although functionality is the same):





If the final action is *not* **FNG Stop**, then insert a final, blank index page at the end to ensure the test continues after the final change has occurred. **Enable Action** does not need to be ticked on this page:



The test will stop as usual when either 1) the final conditions on the **Limits** tab of the **Test Set-up** form have been reached or 2) if the **FNG Stop** action has been activated on the **Matrix** itself and triggered by the corresponding **Event**.

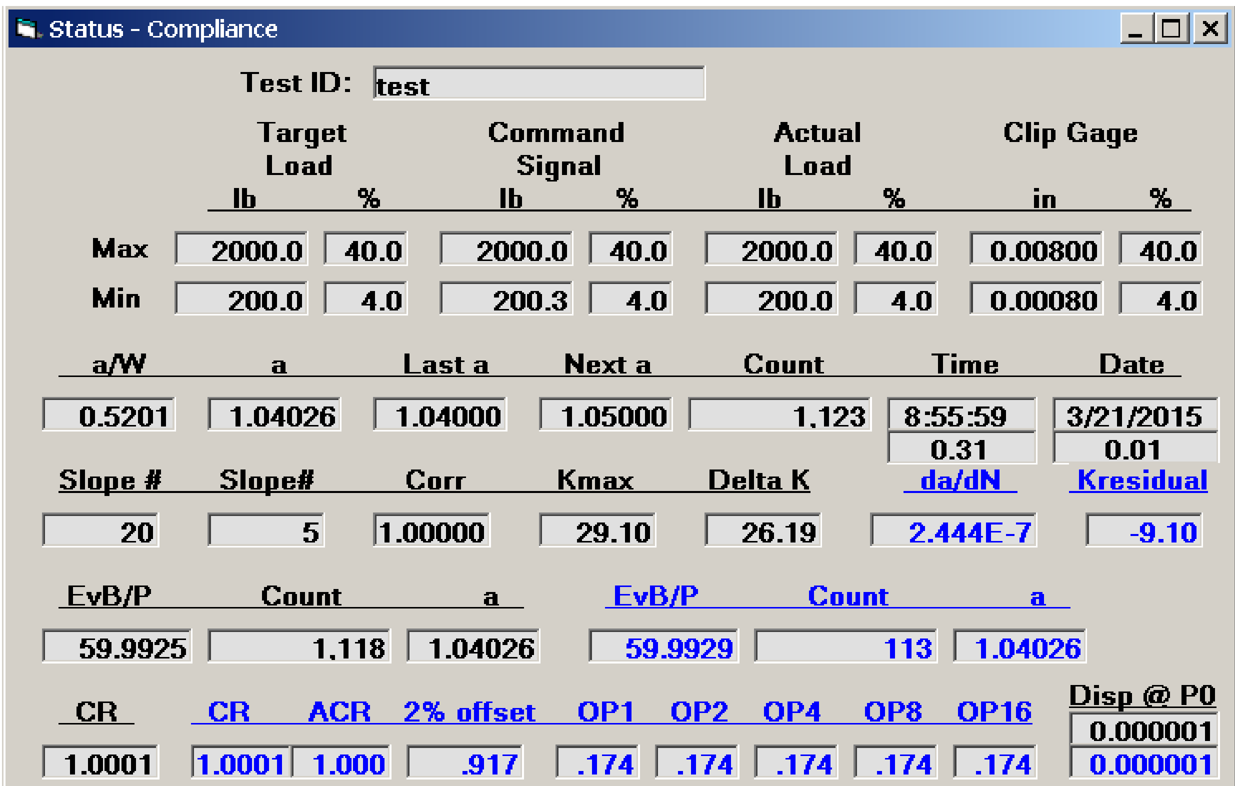
It is good practice to purge the **Matrix** and close it before starting a new test where the **Matrix** is not required for control.

4.6 Display

The **Display** dropdown menu (accessed from the **Main Menu**), selects the **Status** display; the **Load Displacement** display; the **Load DCPD** display(DCPD only);**Load Scan**; the **da/dN - ΔK** (crack growth rate vs. cyclic stress intensity) display; **Channel Scan**; and **Data Plot**. The **Full Function Generator** must be open for these displays to be updated properly.

The following descriptions are for the steady-state **Status** displays.

4.6.1 Compliance Status



The four parameters across the top of the **Status** display are updated five times per second. They are expressed both as engineering units and percent of full scale:

- **Target Load**: the maximum and minimum target load
- **Command Signal**: the maximum and minimum analog output of the ADwin
- **Actual Load**: the actual load, as measured by the analog inputs of the ADwin. This value should be within 0.1 % of the target load.
- **Clip Gage**: the actual displacement, as measured by the analog inputs of the ADwin

The remaining display boxes on the **Status** screen contain the following information in black or blue text. Data fields in blue are stored, averaged values that are updated at every data storage interval, and sent to the log file as a line of data (see Appendix C for a full explanation of log files). In addition, these values are held in memory for saving to the analysis file. The fields pertaining to ACR and crack closure may be ignored by new users.

- **a/W**: current crack length to width ratio
- **a**: current crack length
- **Last a**: crack length as of the previous data storage interval (also saved in blue as **a**)
- **Next a**: crack length at which data storage will next occur
- **Count**: current cycle count
- **Time**: time of day and elapsed test time in hours
- **Date**: date (month/day/year) and elapsed test time in days
- **Slope** #[left]: total number of slope calculations required for next crack length determination
- **Slope** #[right]: current count of slope calculations
- **Corr**: Correlation coefficient of load-displacement linear fit. Expect 0.99990 for good quality signals and 0.99999 for great signals (FTA recommends four nines or better!)
- **Kmax**: current maximum stress intensity
- **Delta K:** current cyclic stress intensity
- **EvB/P**: current normalized compliance (non-dimensional, where E = Elastic modulus; v = displacement; B = thickness; P = load)
- **Count**: cycle count corresponding to last crack length determination
- **a**: current crack length
- **CR**: compliance ratio used for ACR closure technique.

- **da/dN**: crack growth rate in engineering units per cycle (updated every data storage interval: the value shown at any given time is the previous value saved for the analysis file)

- **Elapse time** (in seconds) and **da/dt** are displayed in red if **Calculate da/dt and Save Elapsed Time** have been enabled on the **Storage** tab of the **Data Input** form.

- **Kresidual:** Kresidual calculation using the crack-compliance technique.

- **EvB/P**: normalized compliance averaged over a data storage interval (stored value).

- **Count**: cycle count averaged over a data storage interval (stored value)

- **A**: crack length averaged over a data storage interval (stored value)

- **CR**: Compliance ratio normalized by the initial compliance ratio (stored value)

- **ACR**: Adjusted Compliance Ratio

- **2% offset***:* equivalent factor using ASTM 2% opening load technique

- **OP1**: ratio of opening load to maximum load based on 1% compliance offset

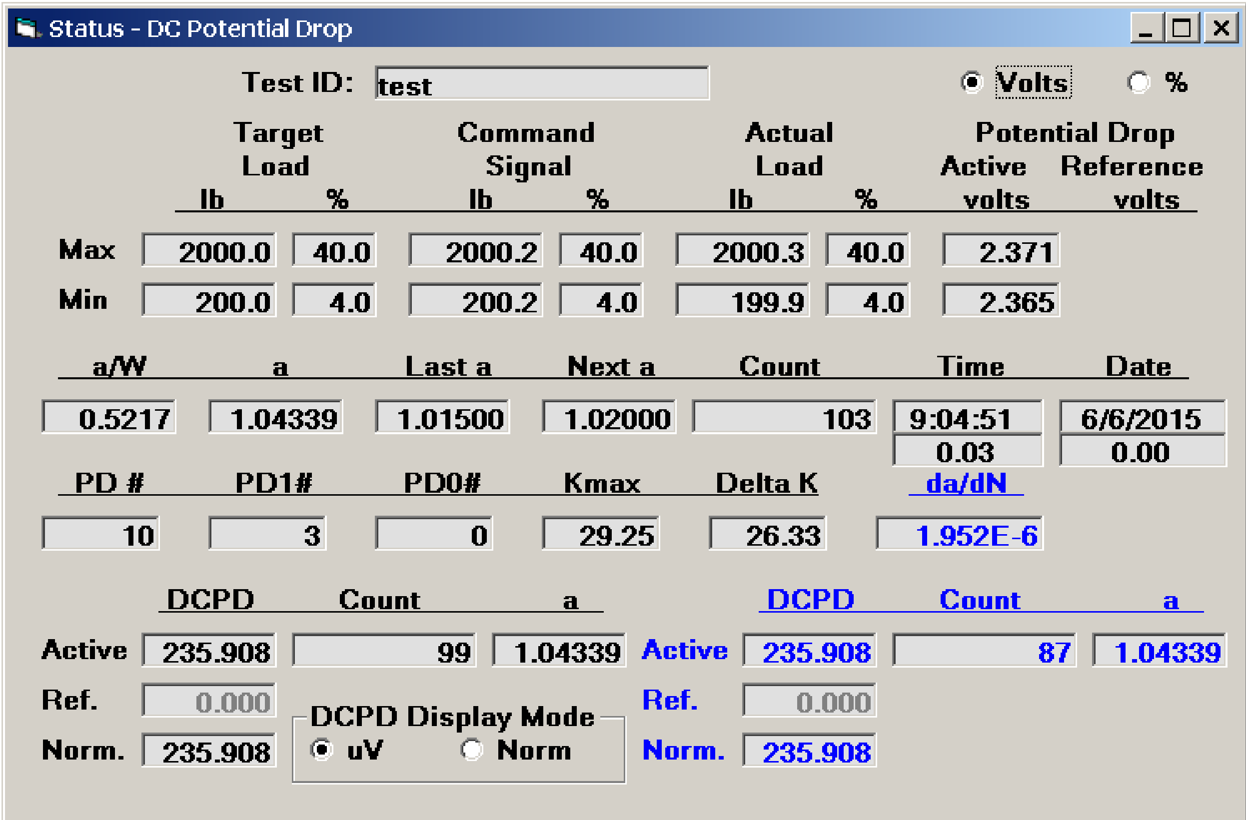
- **OP2**: ratio of opening load to maximum load based on 2% compliance offset

- **OP4**: ratio of opening load to maximum load based on 4% compliance offset

- **OP8**: ratio of opening load to maximum load based on 8% compliance offset

- **OP16**: ratio of opening load to maximum load based on 16% compliance offset

4.6.2 STATUS - DC POTENTIAL DROP



The DCPD **Status** screen can be displayed in either micro-volts or normalized voltage by choosing the appropriate display mode check box.

The four parameters across the top of the display are updated five times per second. The first three are expressed both as engineering units and percent of full scale:

- **Target Load**: the maximum and minimum target load
- **Command Signal**: the maximum and minimum analog output of the ADwin
- **Actual Load**: the actual load, as measured by the analog inputs of the ADwin. This value should be within 0.1 % of the target load.
- **Potential Drop**: the actual voltage change with crack length expressed in volts.

The remaining display boxes on the **Status** screen contain the following information in black or blue text. Data fields in blue are stored, averaged values that are updated at every data storage interval, and sent to the log file as a line of data. In addition, these values are held in memory for saving to the analysis file.

- **a/W**: current crack length to width ratio

- **a**: current crack length
- **Last a**: crack length as of the previous data storage interval
- **Next a**: crack length at which data storage will next occur
- **Count**: current cycle count
- **Time**: time of day and elapsed test time in hours
- **Date**: date (month/day/year) and elapsed test time in days
- **PD #**: total number of PD calculations required for the next crack length determination
- **PD1 # and PD0 #**: current count of DCPD calculations for forward (PD1) and reversed (PD0) current directions
- **Kmax**: current maximum stress intensity
- **Delta K**: current cyclic stress intensity
- **DCPD** -**Active**: the voltage between the active leads(μV)
- **DCPD -Ref:** the voltage between the reference leads (if selected on the **Options** menu)(μV)
- **DCPD -Norm:** the voltage of the active corrected by the reference for temperature compensation(**Norm**= **Active** if reference leads are not being used)(μV)
- **Count**: cycle count corresponding to last crack length determination,
- **a**: current crack length
- **da/dN**: crack growth rate in engineering units per cycle, updated every data storage interval (stored value)
- **Elapse time** (in seconds) and **da/dt** are displayed in red if **Calculate da/dt and Save Elapsed Time** have been enabled on the **Storage** tab of the **Data Input** form.
- **DCPD(μV**) – **Active**: the voltage between the active leads averaged over a data storage interval (stored value)

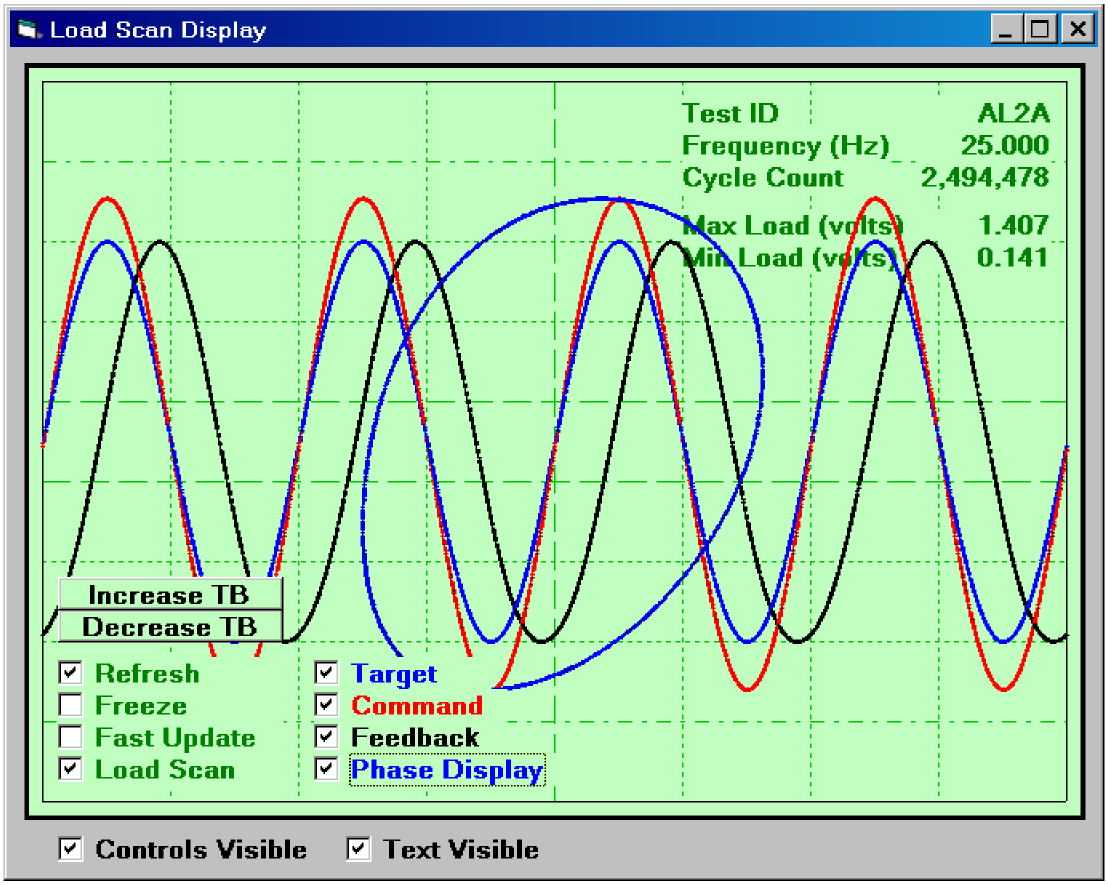
- DCPD – **Ref:** the voltage between the reference leads (if selected on the **Options** menu),averaged over a data storage interval (stored value)

- DCPD – **Norm:** the voltage of the active corrected by the reference for temperature compensation. (**Norm** = **Active** if reference leads are not being used), averaged over a data storage interval (stored value)

- **Count** - cycle count averaged over a data storage interval (stored value)

- **a** – Crack length averaged over a data storage interval (stored value)

4.6.3 Load Scan Display



The **Load Scan** display allows the user to evaluate signal quality. There are four display options, which may be selected as appropriate:

- **Target:** the computed value of full amplitude. Displayed in blue.
- **Command**: the command signal from the ADwin **OUT 1** connector. Displayed in red.
- **Feedback**: the incoming load cell signal from the controller (ADwin **IN1**) indicating the true load cell response to the command signal. The command is adjusted automatically so that the feedback matches the target loads displayed on the status screen. Displayed in black.
- **Phase Display**: plot of command (vertical axis) vs. feedback (horizontal axis). Displayed in blue.
- **Load Scan**: chooses the **Load Scan** display in the compliance software: on the DCPD software, the **Load Scan** display is always active.

- **IncreaseTB/DecreaseTB**: allows increasing or decreasing the horizontal time by a factor of two allowing 1, 2, 4, 8, 16 or more cycles to be displayed.

A variety of additional options allow manipulation of the display:

- **Refresh**: each sweep is recorded and remains displayed until **Refresh** is ticked. Once selected, the display is refreshed once per second.

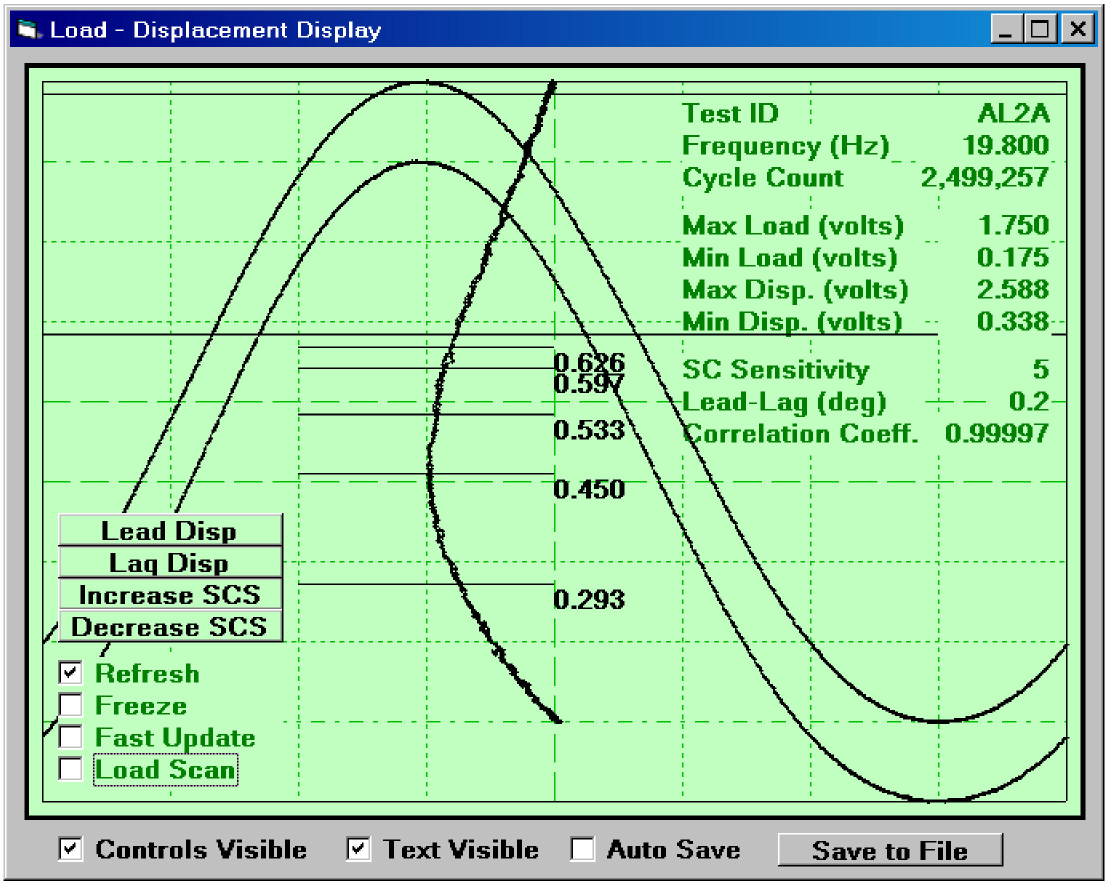
- **Freeze**: freezes the last display, which can be captured by pressing Alt/Print Screen on the computer keyboard. Deselected by default.

- **Fast Update**: increases the update rate to a maximum of ten per second. The actual update rate is governed by the number of data points per cycle and the cyclic frequency. This rate has no effect on data analysis. Deselected by default.

- **Controls Visible**: when selected, the controls are visible on the Load - Displacement Display

- **Text Visible:** when selected, the text is visible on the Load - Displacement Display

4.6.4 Load – Displacement Display



Load (top curve) and displacement (bottom curve) versus time are displayed for one cycle. Each signal is automatically scaled to the same relative amplitude. The voltage of each signal is displayed in the upper right hand corner.

The vertical trace is a signal cancellation signal that has been expanded to exaggerate non-linear effects due to crack closure. The vertical axis is load, with deviation in linearity between load and displacement shown on the horizontal axis. The five offset values due to crack closure are clearly indicated. The thin black horizontal lines show the upper and lower limits for slope measurement. Both the text and controls can be made visible or hidden from view.

Two pairs of command buttons are available for on-the-fly adjustment:

- **Lead Disp/Lag Disp**: the phase of the displacement signal with respect to load can be shifted in either direction in increments of 1/3 of a data point. For the default value of 500 points per cycle, this represents about 0.25 degrees per click of the command buttons. This feature can be useful if the elastic characteristics of the load-displacement curve do not match one another due to differing filter characteristics of the transducers or dynamic characteristics. An in-phase response will show the highest correlation coefficient. Phase shifting is not intended to cancel phase differences due to material plasticity at higher stress intensities. The default value is 0.

- **Increase SCS/Decrease SCS**: this command changes the horizontal sensitivity of the signal cancellation curve. This setting has no effect on data analysis, since only the visual representation is affected. The default value is a multiplier of 5.

A variety of additional options allow manipulation of the display:

- **Refresh**: each sweep is recorded and remains displayed until **Refresh** is ticked. Once selected, the display is refreshed once per second.

- **Freeze**: freezes the last display, which can be captured by pressing Alt/Print Screen on the computer keyboard. Deselected by default.

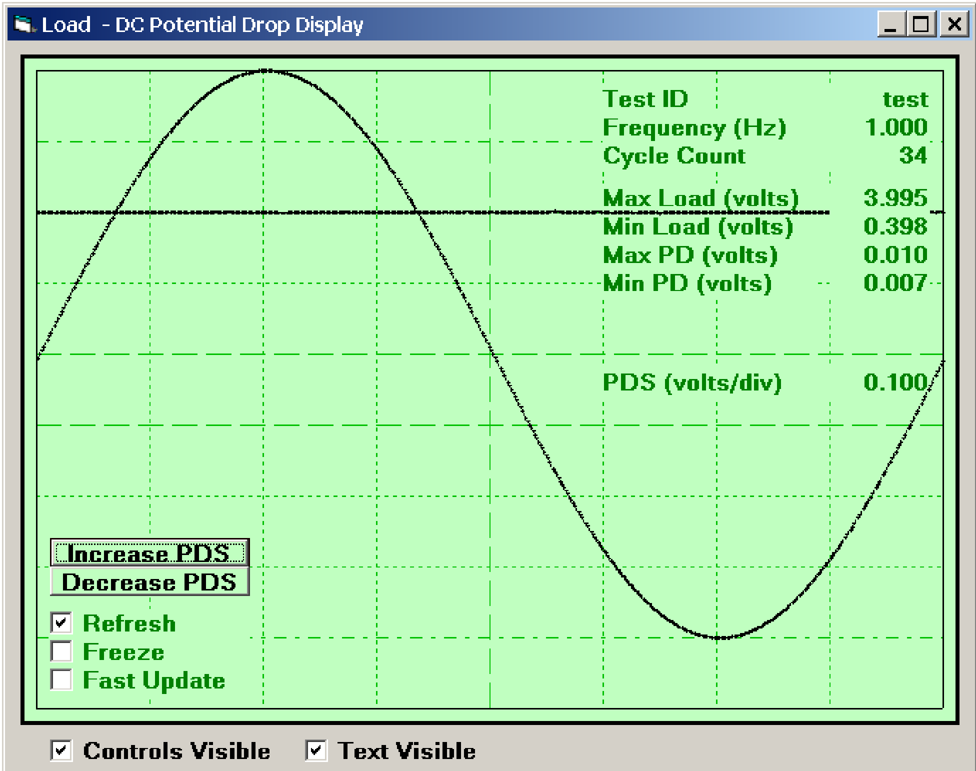
- **Fast Update**: increases the update rate to a maximum of ten per second. The actual update rate is governed by the number of data points per cycle and the cyclic frequency. This rate has no effect on data analysis. Deselected by default.

- **Controls Visible**: when selected, the controls are visible on the Load - Displacement Display

- **Text Visible:** when selected, the text is visible on the Load - Displacement Display

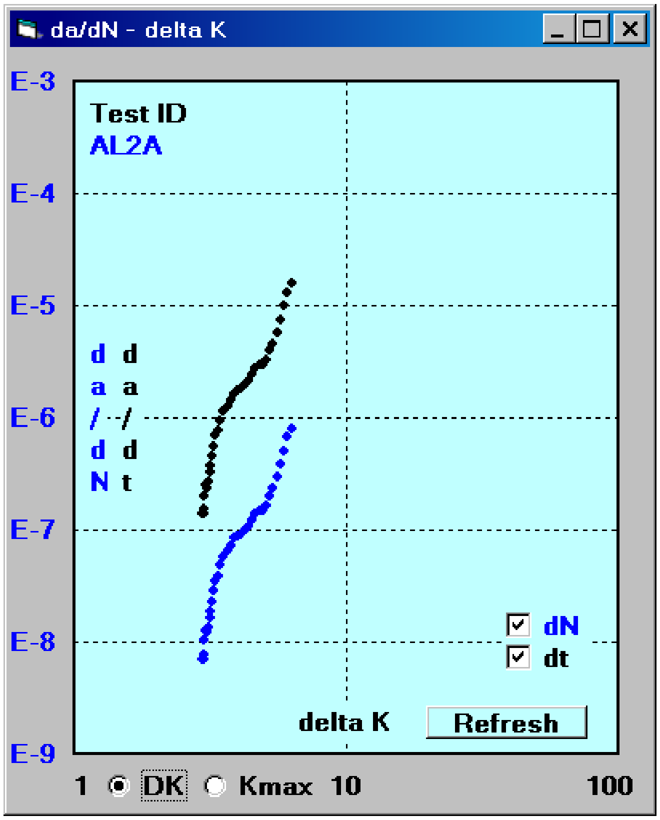
To save the load displacement record, press **Save to File** to establish the file path. Then tick **Auto Save** to store the record at every crack growth rate storage interval.

4.6.5 Load – DCPD Display



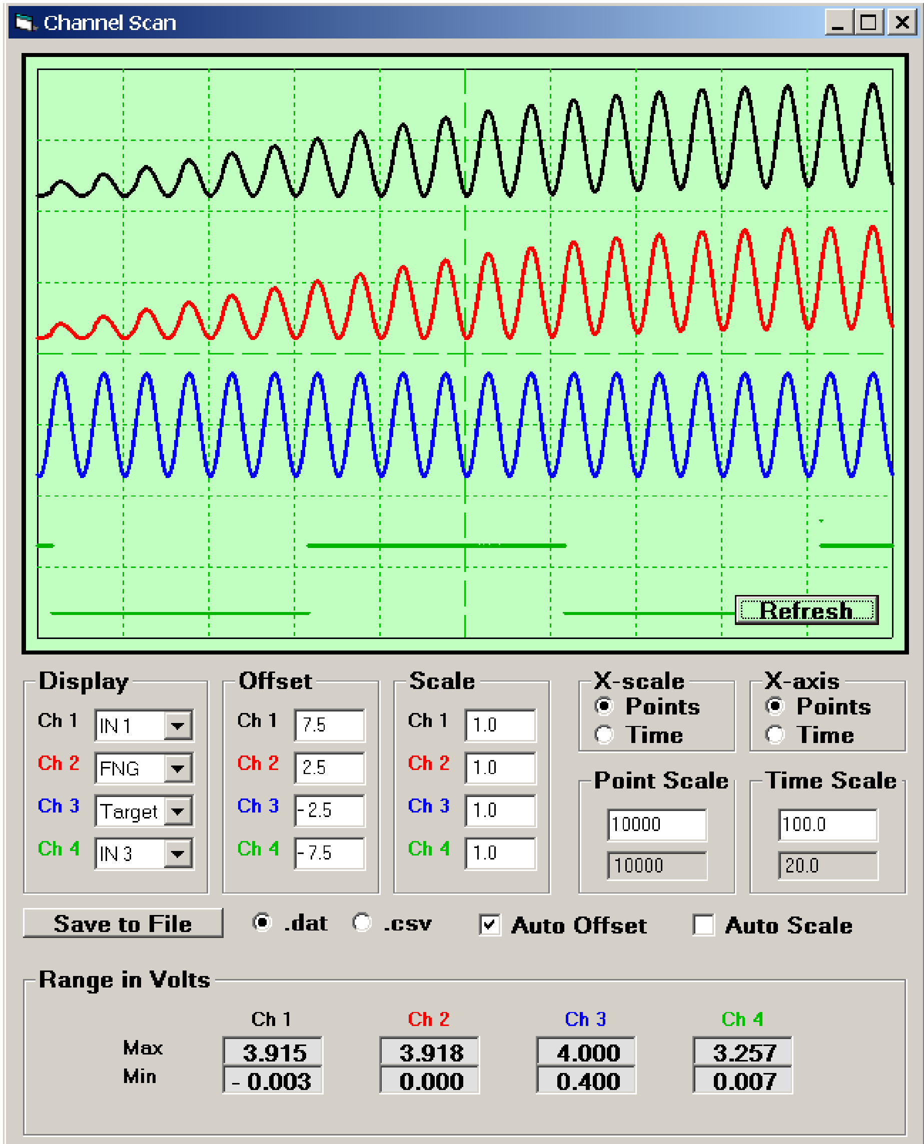
This display differs from the **Load-Displacement Display** (discussed in the previous section of this manual) in that the DCPD signal (**Active** on top, **Reference** on the bottom) replaces displacement. The display sensitivity of the potential drop signal can be changed using the **Increase PDS/Decrease PDS** buttons. All other options (**Refresh**, **Freeze**, etc.) operate identically to those of the **Load-Displacement Display.**

4.6.6 DA/DN-ΔK DISPLAY



The raw crack growth rate data are displayed on log-log scales with the crack growth rate (da/dN) in engineering units per cycle, as a function of the cyclic stress intensity. A da/dt trace may also be plotted, as shown above. This display will only be updated in real time during a test if **Data Storage** is selected on the **FNG**.

4.6.7 CHANNEL SCAN



The **Channel Scan** display allows display and storage of four analog input channels; the FNG signal; and target load for the most recent 100,000 data points of each channel.

For viewing purposes, each channel can be individually scaled and offset. It is recommended to start with the **Auto Offset** and **Auto Scale** features activated: these may be adjusted later as required.

The horizontal axis can display either time (in seconds) or the number of points. The data can be saved to a file in a comma-delimited format. The first column is FNG clock cycles for timing purposes (10000 clock cycles per second). The remaining columns are channels one through four. The analog data are stored in volts.

Additional attributes of each channel are outlined in the following example:

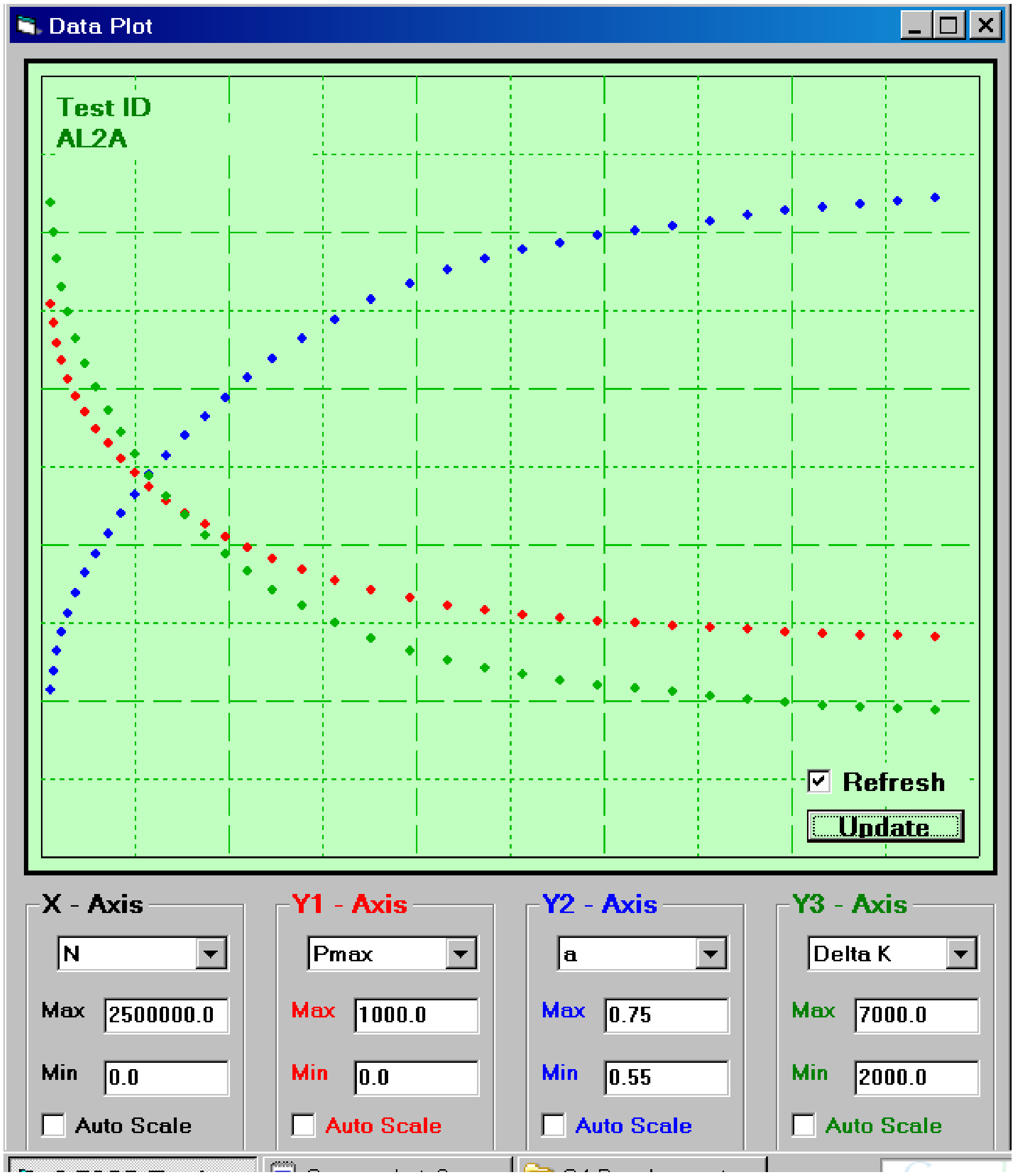
Channel #	,IN 1	,FNG	,Target	,IN 3
Data Count	, 11495	, 11495	, 11495	, 11495
Cycle Count	, 25	, 25	, 25	, 25
Elapse Time	, 1344	, 1344	, 1344	, 1344
Polarity	, 0	, 0	, 0	, 0
Gain Factor	, 1	, 1	, 1	, 1
Rolling Ave	, 3	, 3	, 3	, 3
Channel Type	, 1	, 1	, 1	, 4
Cal. Factor	, 500.0	, 500.0	, 500.0	, 10000.0
0	, 0.0006	, 0.0	, 0.4184	, 2.3666
200	, 0.0003	, 0.0	, 0.4153	, 2.3642
400	, 0.0	, 0.0	, 0.4123	, 2.3654
600	, 0.0	, 0.0	, 0.4099	, 2.3679
800	, 0.0006	, 0.0	, 0.4077	, 2.3666
1000	, 0.0009	, 0.0	, 0.4056	, 2.3672
1200	, 0.0	, 0.0	, 0.4041	, 2.3672
1400	, 0.0006	, 0.0	, 0.4025	, 2.3669
1600	, 0.0006	, 0.0	, 0.4016	, 2.3676

Where:

Channel #:	Channel designation (!N 1 - !N 16, FNG Output, Target Force)
Data Count:	Array number of most recent data point
Cycle Count:	Most recent cycle count
Elapse Time:	Most recent elapse time in seconds
Polarity:	0 = normal, 1 = reversed
Gain factor:	Programmable gain (1, 2, 4 and 8 available)
Rolling Ave.:	Rolling average of peak reading (1, 2 and 3 available)
Channel Type:	1 = force, 2 = displacement, 4 = DCPD, 5 = DCPD ref, 6 = Auxiliary
Cal. Factor:	Calibration factor in units/volt (except DCPD, which is the gain factor)

Data:	Column 1	=	FNG clock cycles (10,000/sec)
	Columns 2 – 5	=	volts for each channel

4.6.8 Data Plot

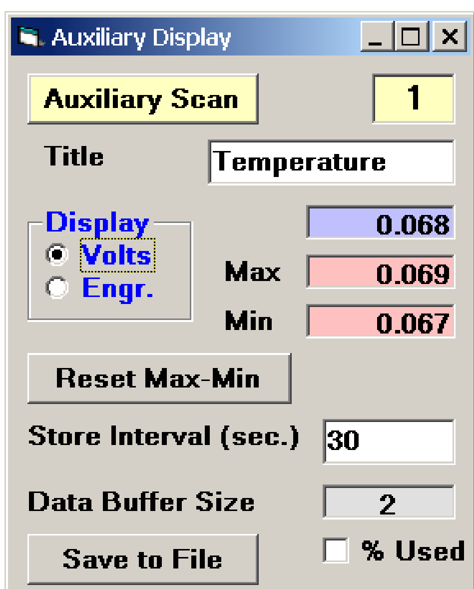


It is recommended to start with the **Auto Scale** feature activated: axes may then be manually adjusted as required.

The **Data Plot** allows plotting any combination of the following variables:

Pmax	
Delta P	
EvB/P	
CR	(compliance ratio)
OP1	(opening load levels)
OP2	(opening load levels)
OP4	(opening load levels)
OP8	(opening load levels)
OP16	(opening load levels)
Disp @ P0	(displacement at zero load)
PD Act	
PD Ref	
PD norm	
a	(crack length)
N	(cycle count)
t	(elapse time)
da/dN	
da/dt	
Kmax	
Delta K	

4.6.9 Auxiliary Display



The **Auxiliary Display** allows display of the instantaneous, maximum and minimum values recorded by the auxiliary channels determined under **Hardware Configuration**.

If the **Store Interval** is zero, then data storage is triggered by a crack increment or a cycle count increment data storage interval. Otherwise, data storage is determined by the **Store Interval**. The data are stored in the PC memory until transferred to a file using the **Save to File** command button. The data buffer is cleared using the **Clear Data Storage Buffer** checkbox under the **Initialization** tab of the **Data Input** form. The output file may contain a maximum of 50,000 lines of data.

An example of the auxiliary channel file is shown below (.chs extension):

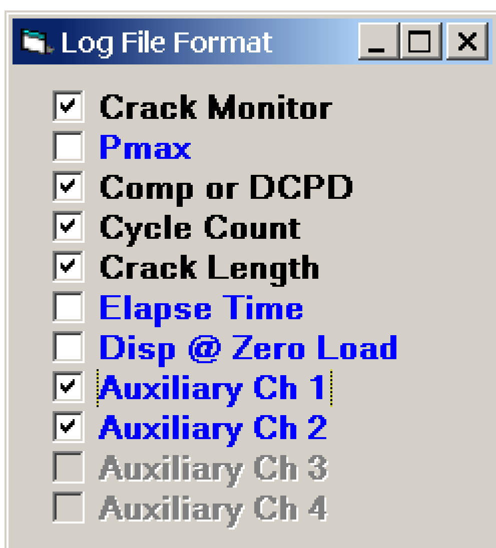
Cycle Count	Elapse Time	Aux 1	Max	Min	Aux 2	Max	Min
27	,3017	,0.00741	,0.01831	,0.000	,10.2114	,0.11292	,0.000
30	,3048	,0.00244	,0.01831	,-0.00916	,23.88905	,23.71826	,0.000
34	,3083	,0.00284	,0.02136	,-0.00916	,21.56455	,23.71826	,0.000
37	,3114	,0.01049	,0.02136	,0.00305	,0.09832	,23.70911	,0.07935
40	,3145	,0.00681	,0.02136	,-0.0061	,11.05777	,23.71826	,0.07629
43	,3177	,0.00209	,0.01526	,-0.00916	,23.70204	,23.71826	,0.0946

NB The **Auxiliary Display** form *must* remain open for data storage to take place.

4.7 Output

Two selections appear under the **Output** dropdown menu on **the Main Menu**, allowing users to customize the log and analysis (.in3) files.

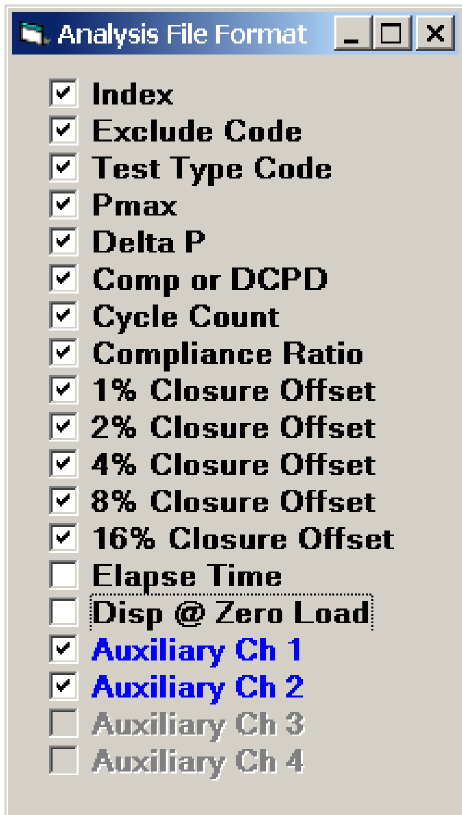
4.7.1 Log File Format



The **Log File Format** form allows selection of columns to be printed every time a crack size calculation occurs. Check boxes with a black label are the default choices and cannot be deselected. Check boxes in blue are user-selectable. The example above shows two auxiliary channels available as selected by the **Hardware Configuration** form.

See Appendix C1 for a full description of log files.

4.7.2 ANALYSIS FILE FORMAT



The **Analysis File Format** form allows selection of columns to be saved in the analysis [.in3] file based on a crack size or cycle increment. The first seven check boxes with a black label are default choices and cannot be deselected. The remaining black check boxes are indicated here but are selected on the **Compliance** and **Storage** tabs of the Test Set-up form. Check boxes in blue are user-selectable. The example above shows two auxiliary channels available as selected by the **Hardware Configuration** form.

See Appendices C2 and C3 for a full description of compliance and potential drop analysis files.

4.8 Comments

This form allows comments to be entered during the test. These comments are stored in the analysis file and can be changed in an editor and the FTA Analysis Program.

5.0 Using the FTA FCGR Analysis Software

The **Fatigue Crack Growth Rate Analysis Software** processes the data provided by FTA's Windows-based FCGR testing program discussed previously. This Visual Basic analysis package produces a printout record of the test and a data (.dat) file suitable for spread sheet plotting in applications such as Excel or Grapher.

Key features of the analysis software include:

- provision for post-test crack length corrections
- full ability to edit data
- choice of data columns for plotting
- options for crack closure measurement (beyond the scope of the document)
- options for Kmax sensitivity (beyond the scope of the document)
- options for Kresidual using crack-compliance (beyond the scope of the document)
- options for variable amplitude processing(beyond the scope of the document)

The following sections of this manual explain analysis files in some detail; provide step-by-step instructions to guide new users through the analysis of a test; and offer detailed descriptions of each of the analysis software menus and displays. Appendix C considers the construction of the analysis files produced by the testing program and provides examples. A glossary of terms is provided in Appendix D. Appendix E provides instructions for reconstructing analysis files that were not saved at the end of the test.

5.1 Understanding the Files Used by the Analysis Program

At the end of a test, analysis files must be saved with the [.in3] extension using the **Save Analysis File** command (see Appendix E for instructions for reconstructing an analysis file that has not been saved or has been lost). This [.in3] file is loaded into the analysis software for editing and processing. Once edited, it is saved as an [.in4] file, thus preserving the unedited [.in3] analysis file.

The output of the analysis program may be 1) printed or 2) saved as a **.prn** file. In addition, the analysis program produces a data (.dat) file that may be exported to a spreadsheet or plotting application such as Excel or Grapher.

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

- TEST4A.IN3: unedited data file, decreasing K test
- TEST4B.IN3: unedited data file, increasing K test
- TEST4C.IN3: unedited data file, constant load test
- TEST4.IN4: edited data file, combining TEST4A, TEST4B, and TEST4C

Each of these files may be opened for editing/analysis and saved (under a different name) with the [.in4] extension.

In addition, the testing program produces log files and backup analysis files, which can be helpful during analysis – especially if an [.in3] file was not saved or is lost (see Appendix E).

5.2 Analysis Procedure

The following example is intended to guide a new user through the editing and processing of an analysis file. Use of the software's options for crack closure measurement, Kmax sensitivity and Kresidual is outside the scope of this manual.

The FCGR analysis software may be loaded onto any Windows PC and need not reside on the computer used for testing.

1. Start the **FCGR Analysis** program.

2. Press **Continue** on the **Splash Screen**. The eight-tabbed analysis menu will appear, with the **Control** tab on top. Select the appropriate **Unit Type** (English or Metric) for analysis.

3. From the **File** menu at the upper left of the screen, select **Open, New Test**.

4. Navigate to an appropriate analysis (.in3) file and select it. This will load the test data into the analysis program. By selecting different tabs, it will be noticed that most box-fill (such as Test ID and specimen dimensions) and selections (such as K-calibration type) are automatic.

5. Select the **Coefficients** tab: note that the appropriate coefficients have been entered with the analysis file.

6. Select the **General** tab. Much of this box-fill will be complete, although missing information may be added manually at this time. Any alterations may be saved using the **Save General Info** button on the **Control** tab. This produces a [.gn1] file for future loading, thus saving the entering of repetitive information during subsequent analyses. Information entered on the **General** tab appears at the top of the cover page output.

7. Select the **Dimensions** tab, which should have been populated by the [.in3] file. These values will appear at the top of the cover page output when the data have been processed.

8. Select the **Stress** tab, which displays the final conditions under which the test was run. If conditions were altered earlier in the test (a change in frequency or load, for example), these may be recorded as lines of data here. Use the **Insert** button to insert empty lines that may be populated using the boxes provided. These lines appear under the heading **Test Parameters** on the cover page output.

9. Select the **Visuals** tab. Here, visual measurements are entered for post-test compliance or PD corrections. Use the **Insert** button to insert empty lines and enter each measured crack length and its corresponding compliance or PD

value. Choose **Constant** if one correction is entered and **Linear** if more than one correction is entered. **Visual Corrections** are saved in the [.gn1] file and appear at the bottom of the cover page output.

10. Select the **Data** tab. Lines of data may be reviewed visually by clicking **Back** and **Forward**. These data were collected when Data Storage was ticked on the FNG and appeared in blue on the Status Screen after each data storage interval.

11. Select the **Da/dN Fit** tab and enter the appropriate parameters for a straight line fit of the Da/dN vs. ΔK data. Fit parameters are saved in the [.gn1] file.

12. Return to the **Control** tab and go to the dropdown **File** menu. Choose to **Save** the **Input as …Version 3 format**. This saves the edited data in a file with the [.in4] extension. Remember to save the input whenever any changes are made to the analysis file*. It is wise to work subsequently on the .in4 file only. By choosing the .in4 **Input Filter** on the **Control** tab, only [.in4] files will appear for selection under the **Open New Test** dropdown menu.*

13. On the **Format Output** menu window, which appears separate from the tabbed menu, choose the data columns to be saved in the [.dat] file and used for plotting. FTA recommends that the following nine options be selected for typical applications: **Index; Pmax; Delta P or Damage; Comp or DCPD; Crack Length; Cycle Count; da/dN; Kmax;** and **Delta K**.

14. Process the data by pressing the blue **Run Analysis** button, available on any of the tabs. When this button is pressed, a number of things happen:

    - a [.dat] file is produced (always choose to **Save** when this menu option appears)
    - a new window appears showing the contents of the [.dat] file
    - a new window appears containing the da/dN plot
    - output is sent to a printer (if **Cover Page** and/or **Tabular Results** are selected under **Print Mode** on the **Control** tab: see below). Note that the output format is fixed and may not be changed by the user: T1 is the default style.
    - output is saved in a .prn file (if **Print to File** is selected under **Print Mode** on the **Control** tab). Note that the output format is fixed and may not be changed by the user: T1 is the default style.

15. Note that by clicking **Back** and **Forward** on the **Data** tab, the data point corresponding to each line of data is highlighted in green on the da/dN plot. Errant points may be deleted from analysis using the **Exclude Data** and **Skip da/dN** options.

5.3 Plotting the Data

Plots cannot be printed directly from the FTA analysis software. The [.dat] files can be exported into most spreadsheet or plotting programs such as Excel or Grapher. A Grapher plot of the Test4.dat sample file is shown below:

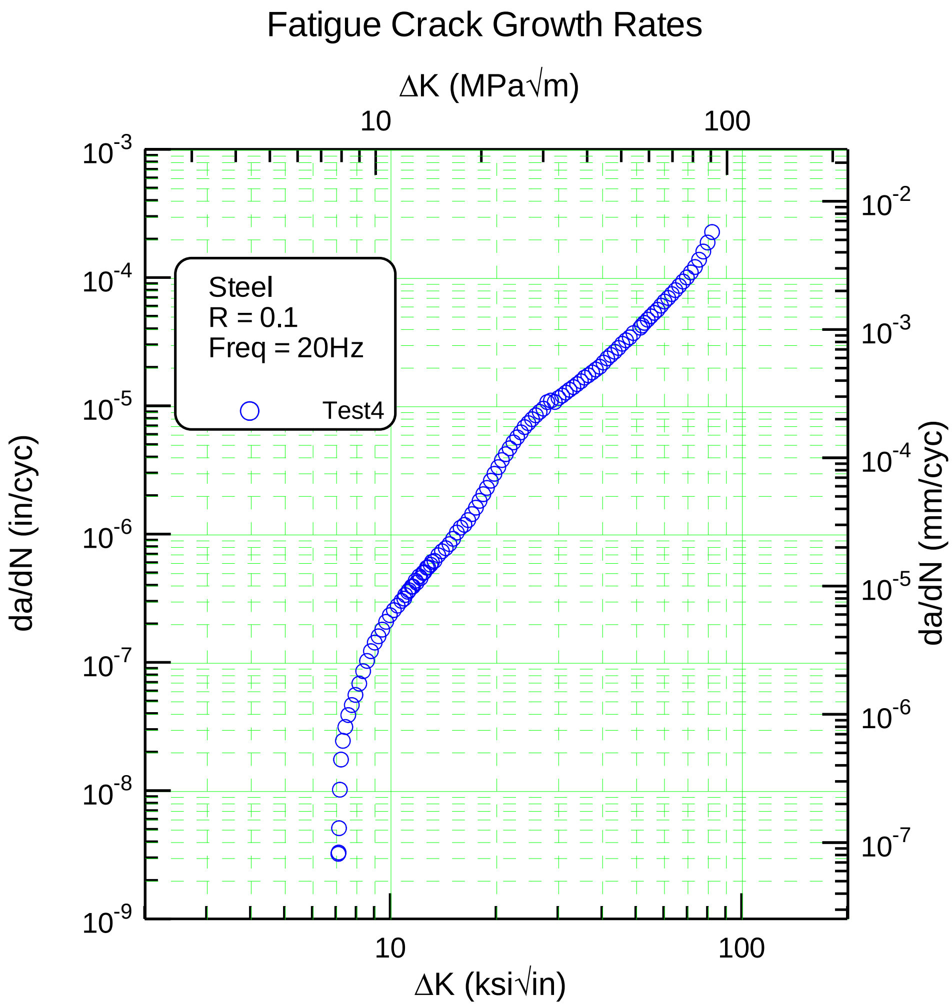


Figure 1 - Plot of FCGR response.

5.4 Output: Cover Page

When the **Cover Page** box of the **Print Modes** menu on the **Control** tab is selected, the following T1 output page is sent to the printer when the analysis is run.

Automated Fatigue Crack Growth Rate Analysis

Test ID	TEST4	Geometry	C(T)
Contract	ADwin-Gold	Orientation	T-L
Material	Steel	Yield (ksi)	80.0
Temperature (F)	75	Modulus (Msi)	29.5
Environment	Lab Air		

Specimen Dimensions (in)

Thickness	0.500	Height	1.800
Net Thickness	0.500	Notch Depth	0.980
Width	2.980	Gage Length	0.500

Precrack Parameters

Pmax (lbs)	1800.0	Stress Ratio	0.10
Final a (in)	1.090	Kmax (ksi sqr[in])	13.88

Test Parameters

EvBP	Freq	Pmax	R	Ai	Kmaxi	C	DKi
31.760	20.00	0	0.10	1.090	15.00	-5.00	0.00
37.530	20.00	0	0.10	1.220	12.00	5.00	0.00
59.400	5.00	4900	0.10	0.000	0.00	0.00	0.00

K Coeff	C Coeff	da/dN Fit Parameters	
.886	1.00098	Upper da/dN limit	3.937E-8
4.64	-4.66951	Lower da/dN limit	3.937E-9
-13.32	18.4601	da/dN intercept (C)	5.247E-50
14.72	-236.825	da/dN slope (m)	48.236
-5.6	1214.88	da/dN for delta K	3.937E-9
.	-2143.57	delta K	7.037

Visual Observations

EvB/P	Crack(EvB/P)	Crack(visual)	Error	CAF
31.581	1.079	1.080	0.001	0.991
36.761	1.192	1.185	-0.007	0.984
37.403	1.204	1.210	0.006	0.983
39.937	1.251	1.250	-0.001	0.980
42.807	1.301	1.300	-0.001	0.977
49.136	1.396	1.400	0.004	0.972
58.906	1.515	1.510	-0.005	0.965
80.590	1.704	1.705	0.001	0.954

Comments

Date of test: 10/7/2000
Decreasing K control to crack length of 1.25 inches
Increasing K control to crack length of 1.41 inches
Constant load control to completion of test

5.5 Output: Tabular Results

When the **Tabular Results** box of the **Print Modes** menu is ticked, the following columns of data are sent to the printer (T1 output):

Test ID TEST4 Page 1

Pmax (lb)	EvB/P	a (in)	N	da (in)	dN	da/dN (in/cyc)	Kmax (ksi[in]^.5)	deltaK
	31.76	1.0830	10300					
1886	31.96	1.0878	17596	0.0095	15459	6.170E-7	14.525	13.073
1832	32.16	1.0925	25759	0.0095	16966	5.600E-7	14.169	12.752
1780	32.37	1.0973	34562	0.0094	18371	5.124E-7	13.817	12.435
1729	32.57	1.1019	44130	0.0094	20256	4.618E-7	13.483	12.134
1680	32.77	1.1066	54818	0.0095	22261	4.248E-7	13.149	11.834
1632	32.98	1.1114	66391	0.0095	23943	3.964E-7	12.828	11.545
1585	33.19	1.1161	78761	0.0097	26239	3.705E-7	12.504	11.253
1537	33.41	1.1211	92630	0.0097	28333	3.406E-7	12.197	10.977
1494	33.62	1.1258	107094	0.0092	29919	3.065E-7	11.894	10.705
1453	33.83	1.1303	122549	0.0094	33283	2.810E-7	11.602	10.441
1411	34.05	1.1351	140377	0.0098	37778	2.594E-7	11.314	10.183
1368	34.28	1.1401	160327	0.0098	41450	2.372E-7	11.031	9.928
1328	34.50	1.1450	181827	0.0094	44872	2.102E-7	10.756	9.681
1291	34.72	1.1495	205199	0.0092	50434	1.826E-7	10.492	9.443
1255	34.94	1.1542	232261	0.0094	58218	1.622E-7	10.235	9.211
1218	35.16	1.1590	263417	0.0096	65965	1.448E-7	9.987	8.988
1184	35.39	1.1637	298226	0.0095	76192	1.243E-7	9.737	8.763
1149	35.62	1.1684	339609	0.0096	91898	1.043E-7	9.495	8.545
1116	35.86	1.1733	390124	0.0097	112128	8.664E-8	9.258	8.333
1083	36.09	1.1781	451737	0.0096	138619	6.931E-8	9.027	8.124
1052	36.33	1.1829	528743	0.0096	170291	5.657E-8	8.800	7.920
1021	36.57	1.1878	622028	0.0093	195779	4.725E-8	8.591	7.732
994	36.79	1.1922	724522	0.0081	206545	3.943E-8	8.397	7.557
971	36.98	1.1959	828573	0.0066	208130	3.184E-8	8.236	7.413
954	37.13	1.1988	932652	0.0052	208045	2.481E-8	8.103	7.293
940	37.25	1.2011	1036618	0.0037	209020	1.775E-8	8.009	7.208
931	37.32	1.2025	1141672	0.0021	204687	1.033E-8	7.944	7.150
927	37.35	1.2032	1241305	0.0011	204693	5.182E-9	7.905	7.115
925	37.37	1.2036	1346365	0.0007	210158	3.340E-9	7.882	7.094
923	37.39	1.2039	1451463	0.0006	183702	3.269E-9	7.869	7.082
	37.40	1.2042	1530067					
	37.53	1.2067	1576370					
1412	37.77	1.2112	1591438	0.0093	29107	3.193E-7	12.120	10.908
1440	38.02	1.2160	1605477	0.0097	26910	3.605E-7	12.416	11.174
1470	38.28	1.2209	1618348	0.0098	24842	3.958E-7	12.726	11.453
1501	38.54	1.2258	1630319	0.0099	22442	4.395E-7	13.052	11.747
1533	38.80	1.2308	1640790	0.0095	19946	4.768E-7	13.371	12.034
1563	39.05	1.2353	1650265	0.0093	18351	5.058E-7	13.711	12.340
1595	39.31	1.2400	1659141	0.0098	17654	5.553E-7	14.054	12.649
1630	39.59	1.2451	1667919	0.0098	16757	5.862E-7	14.402	12.962
1663	39.85	1.2499	1675898	0.0095	15077	6.279E-7	14.772	13.294
1697	40.12	1.2546	1682996	0.0096	13795	6.947E-7	15.140	13.626
1732	40.39	1.2594	1689693	0.0095	12758	7.464E-7	15.512	13.961

6.0 FTA Analysis Software: Description of Menus and Tabs

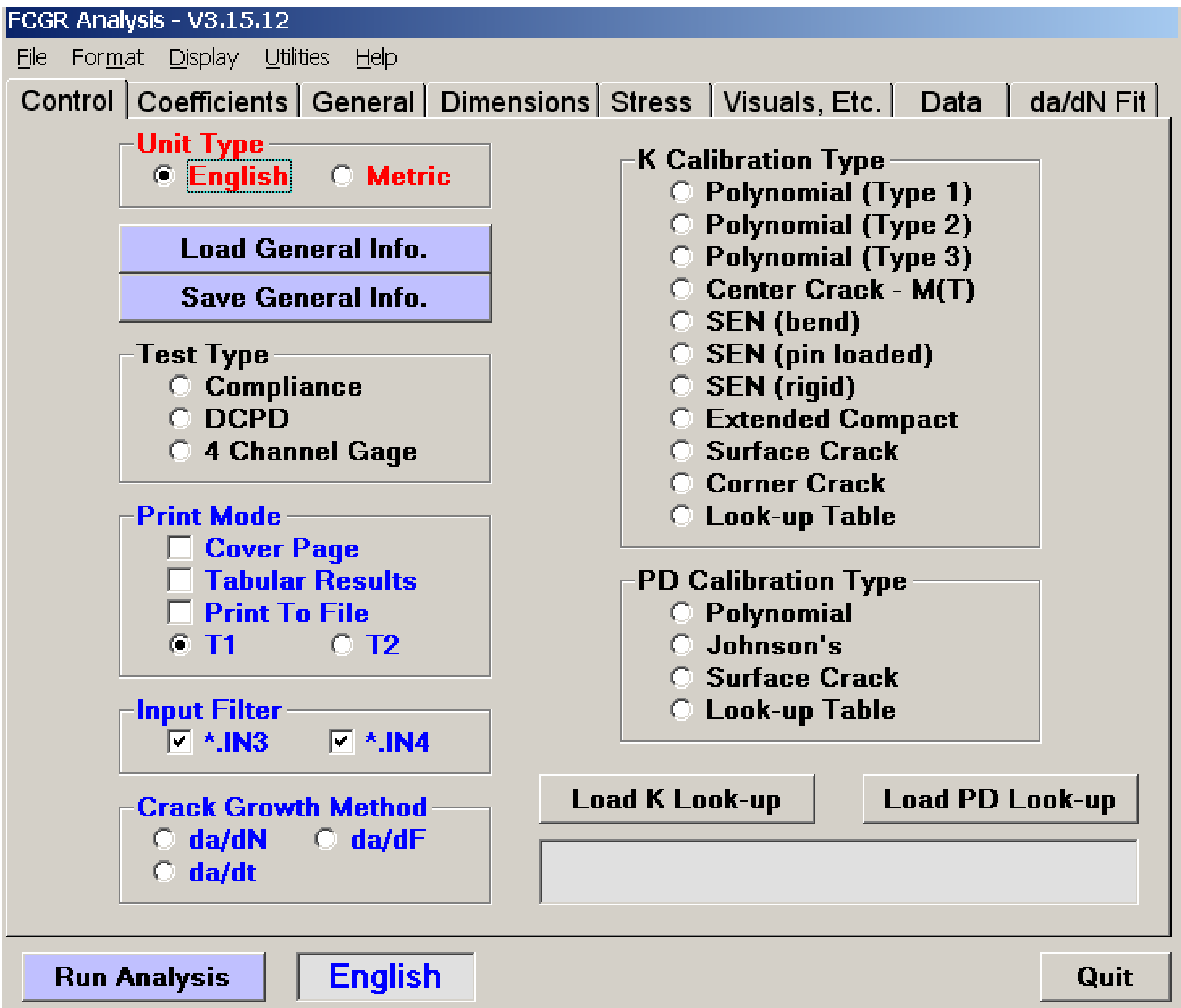
6.1 Splash Screen

The **Splash Screen** is displayed upon start-up. The application and version number are displayed on this screen. Press **Continue** (to proceed to the **Main Menu**) or **Exit**.

6.2 Main Menu: General

The eight-tabbed main menu is where most data editing takes place. Although many boxes are populated and selections made automatically when an analysis file is loaded, a number of options are available to the user.

*Text boxes labeled in blue (such as those on the **General** tab) indicate areas where user modification is appropriate. Text boxes where input is shown in red (such as those on the **Coefficients** tab) should only be changed with extreme caution as changes will affect the test results. Note that in the testing software, the label is in red, too.*



Across the top of the **Main Menu** there are four dropdown menus: **File**, **Format**, **Display** and **Help**.

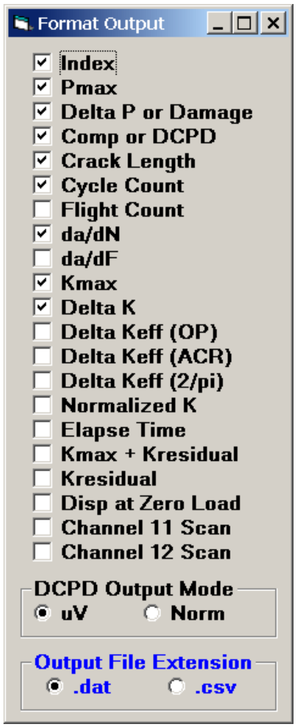
6.2.1 File

The **File** menu contains a number of options for opening and saving analysis files. Note that these files are standard ASCII files that may be examined and modified with a text editor such as NotePad. However, incorrect modification may render the file incompatible with the FTA analysis software, and is not recommended.

- **Open**
    - **New Test**: loads [.in3] or [.in4] files for analysis
    - **Add to Existing Test**: loads multiple [.in3] or [.in4] files for merging into a single file
- **Save**
    - **Input** saves the edited analysis file with a [.in4] extension.
    - **Output** saves the .dat output file in **English** or **Metric** units. The user is also prompted to save output files after running an analysis.

6.2.2 Format

The **Format Output** window is separate from the **Main Menu** and appears automatically when the program is opened.



This option allows the selection of the data columns that will be saved in the [.dat] file when analysis is run. Typical selections for most steady state analyses are shown above.

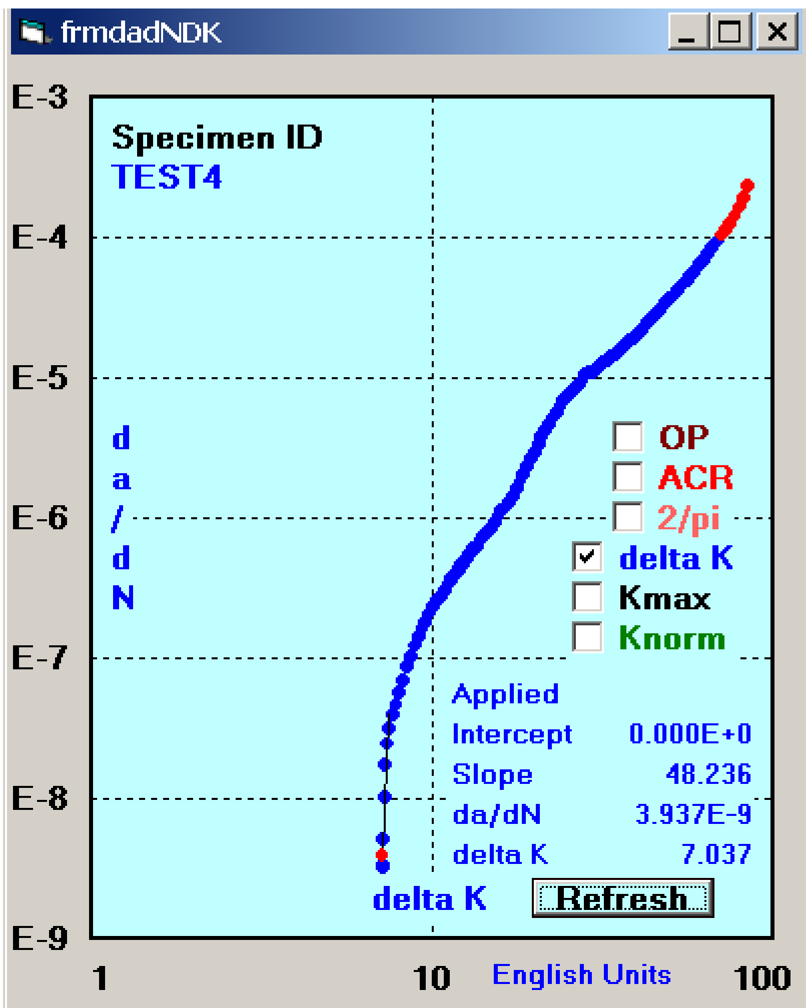
DCPD output may be displayed in micro-volts or normalized voltage. The analysis output file may be given either a .dat or .csv extension.

Note that some specialist options, such as Damage; Flight Count; da/dF; Delta Keff; and Kresidual are outside the scope of this manual.

6.2.3 Display

Two additional windows appear when the **Run Analysis** button is pressed: these are also available under **Display** on the main menu, but will be empty if the analysis has not yet been run.

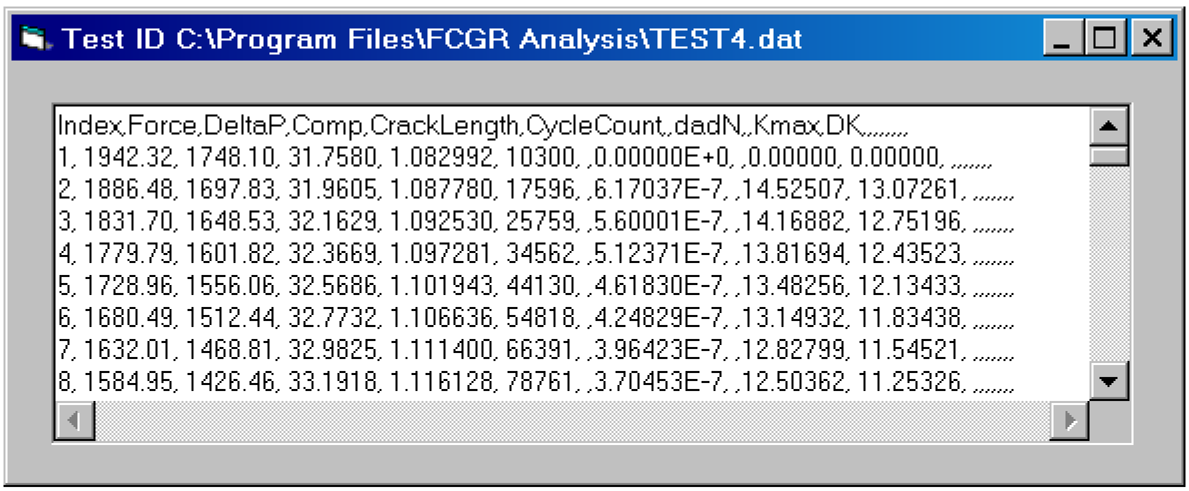
- da/dN - dK: selects the crack growth rate vs. cyclic stress intensity (da/dN - ΔK) display window. The results are displayed in a new window when the **Run Analysis** button is pressed.



The crack growth rate data are displayed on log-log scales with the crack growth rate (da/dN) in engineering units per cycle as a function of the cyclic stress intensity.

In the above display, threshold fitting parameters are displayed. Symbols plotted in red are invalid due to exceeding ASTM size requirements. Additional checkboxes allow displaying Kmax, Knormalized, and three methods of delta K effective, which are not covered here.

- Output: displays the contents of the .dat files, the columns of which are determined by the choices made on the **Format Output** menu. The .dat file is displayed in a new window when the analysis is run: an example is shown below.

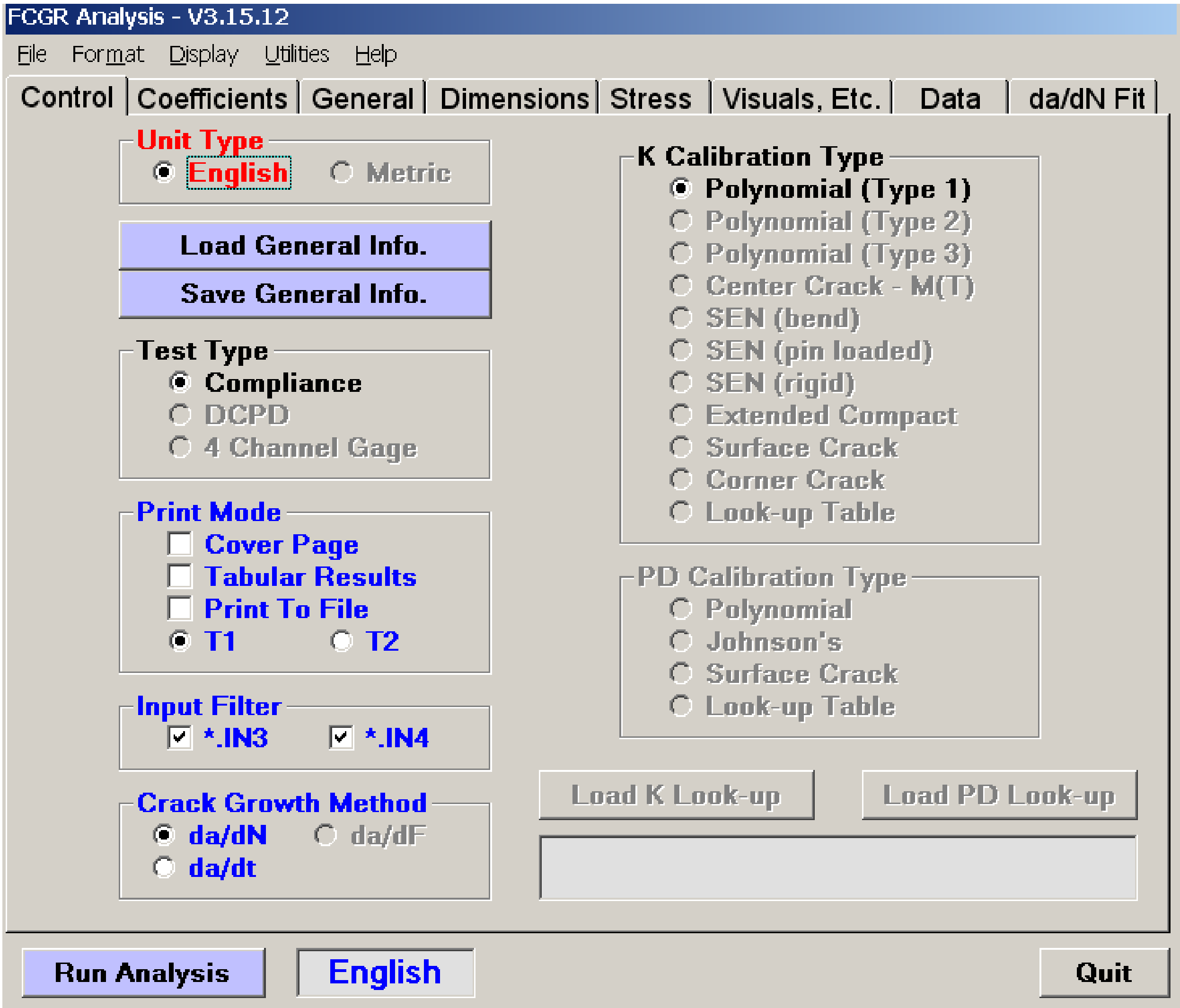


These data may be exported to spreadsheet or plotting applications for graphical display.

6.2.4 Utilities

Three utilities available for variable amplitude testing, Kmax sensitivity, and K residual functions are outside the scope of this manual.

6.3 Main Menu: Control Tab



The first tab on the **Main Menu**, and the one that appears on top by default when the program is opened, is the **Control** tab.

- **Unit Type (English or Metric):** must be selected prior to loading analysis files. Note that all analysis files are stored in English units. If metric units have been chosen for analysis, the [.dat] file will show an **M** appended to the Test ID.

- **Test Type**: **Compliance**, **DCPD**, or **4 Channel Gage**. Selected automatically when an analysis file is loaded into the program and cannot be changed by the user

- **K Calibration Type:** selected automatically when a file is loaded into the program and cannot be changed by the user

- **PD Calibration Type:** selected automatically when a file is loaded into the program and cannot be changed by the user.

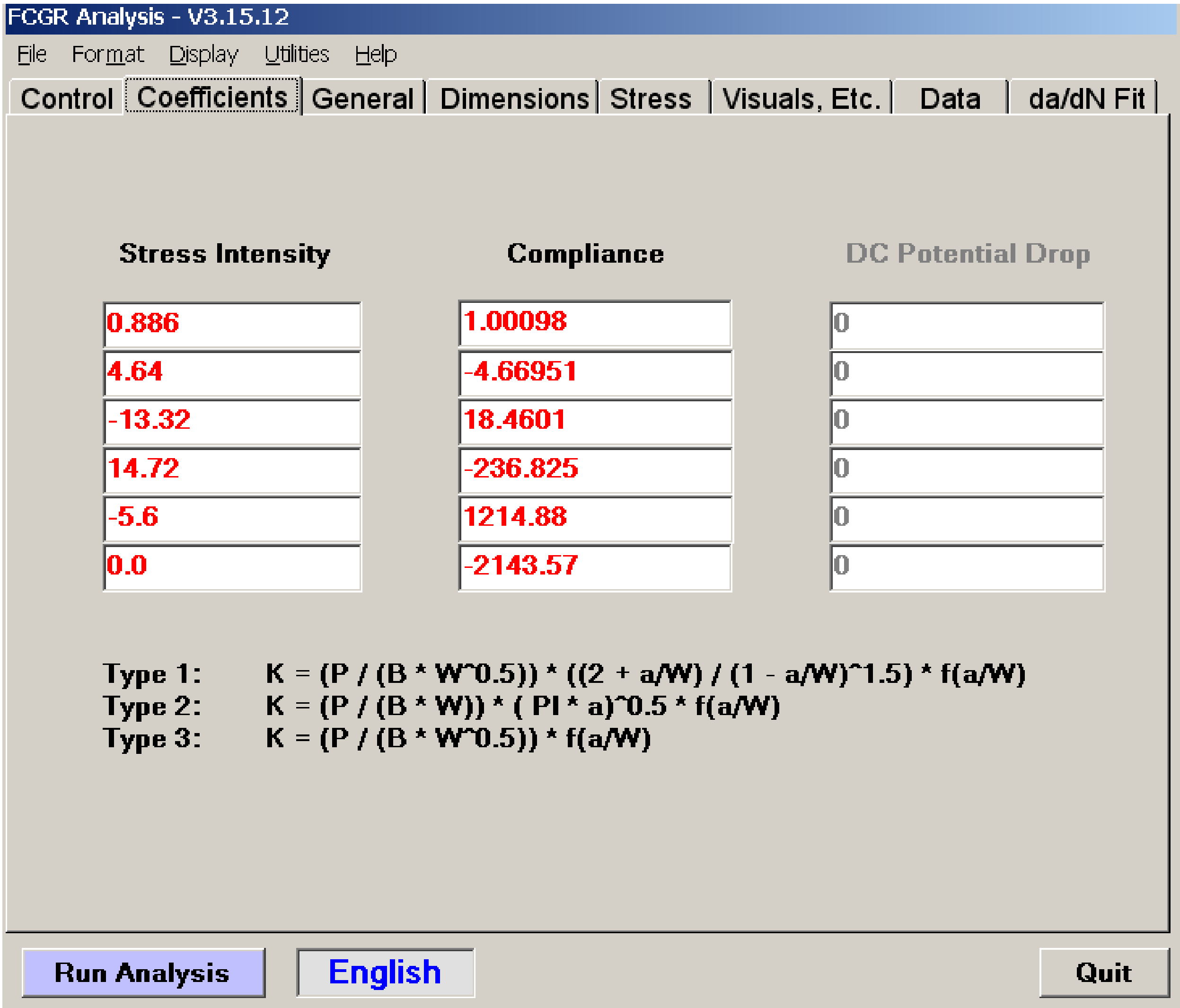
- **Print Mode**: selects what information is sent to the printer. If the **Print To File** check box is selected, both the cover page output and tabular output will be sent to a file with the TestID filename and the .prn extension. The T2 print format is not recommended for most users.

- **Input Filter:** allows the user to select the types of analysis files (unedited [.in3] or edited [.in4]) to be imported into the analysis program.

- **Crack Growth Method:** allows selection of da/dN (default), da/dF (for special case of variable amplitude analysis) or da/dt.

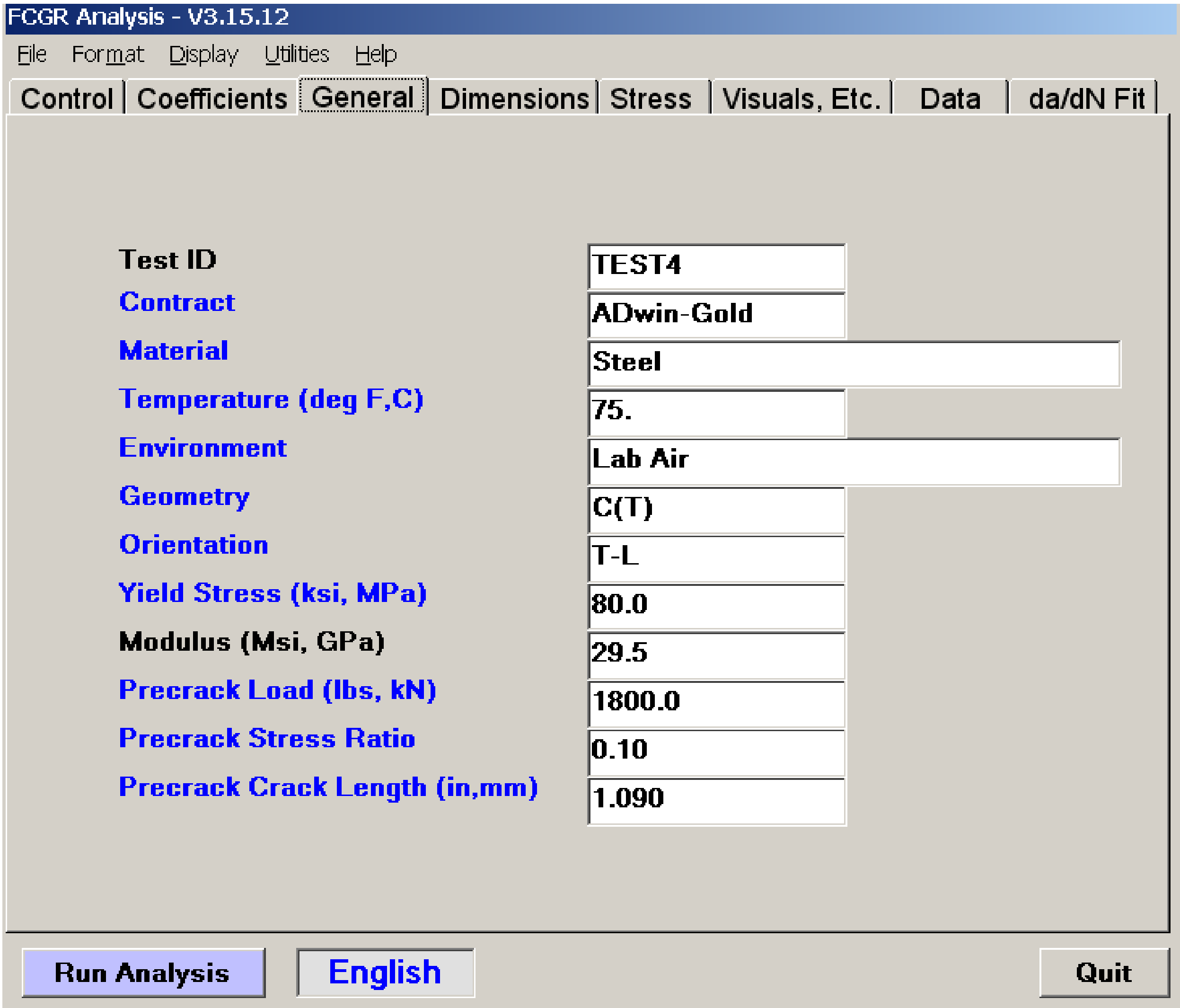
- **Load/Save General Info:** these buttons allow the creation (**Save**) and calling (**Load**) of a [.gn1] file. This file contains test information that may not be contained in the analysis files, such as test temperature and specimen geometry. Selecting **Save General Info** will save all the data in the blue boxes on the **General**, **Dimensions**, and **da/dn Fit** tabs. The **Crack Length** (visual corrections) data on the **Visuals** tab are also saved. General files are optional and may be used to save time when entering repetitive data for large test programs: after the [.gn1] file has been saved once, it may be loaded during the analysis of additional tests. General info files may also be created during testing, as [.gn0] files (see section 3.1 for details about .gn0 files).

6.4 Main Menu: Coefficients Tab



Red values on the **Coefficients** tab are automatically loaded with the analysis file, allowing examination of the stress intensity, compliance, and DC potential drop coefficients. These should not be changed unless an error is detected.

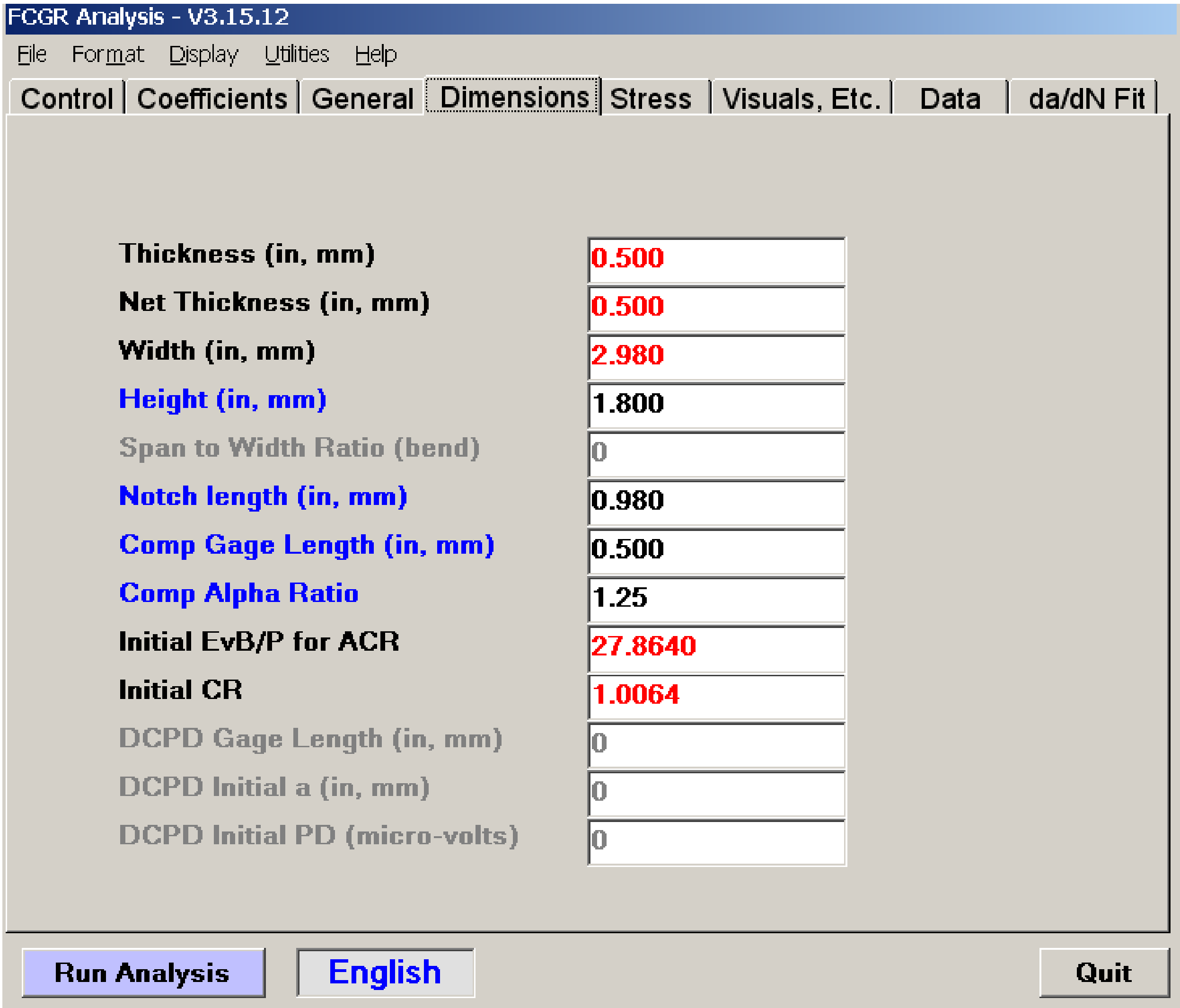
6.5 Main Menu: General Tab



On this tab, blue labels indicate information that may or may not have been entered/saved at test time as a [.gn0] file. Editing this information does not affect analysis, with the exception of **Yield Stress** (see below). If a general (.gn1) file has been created during analysis, these boxes may be populated by **Load[ing] General Info** from the **Control** tab**.**

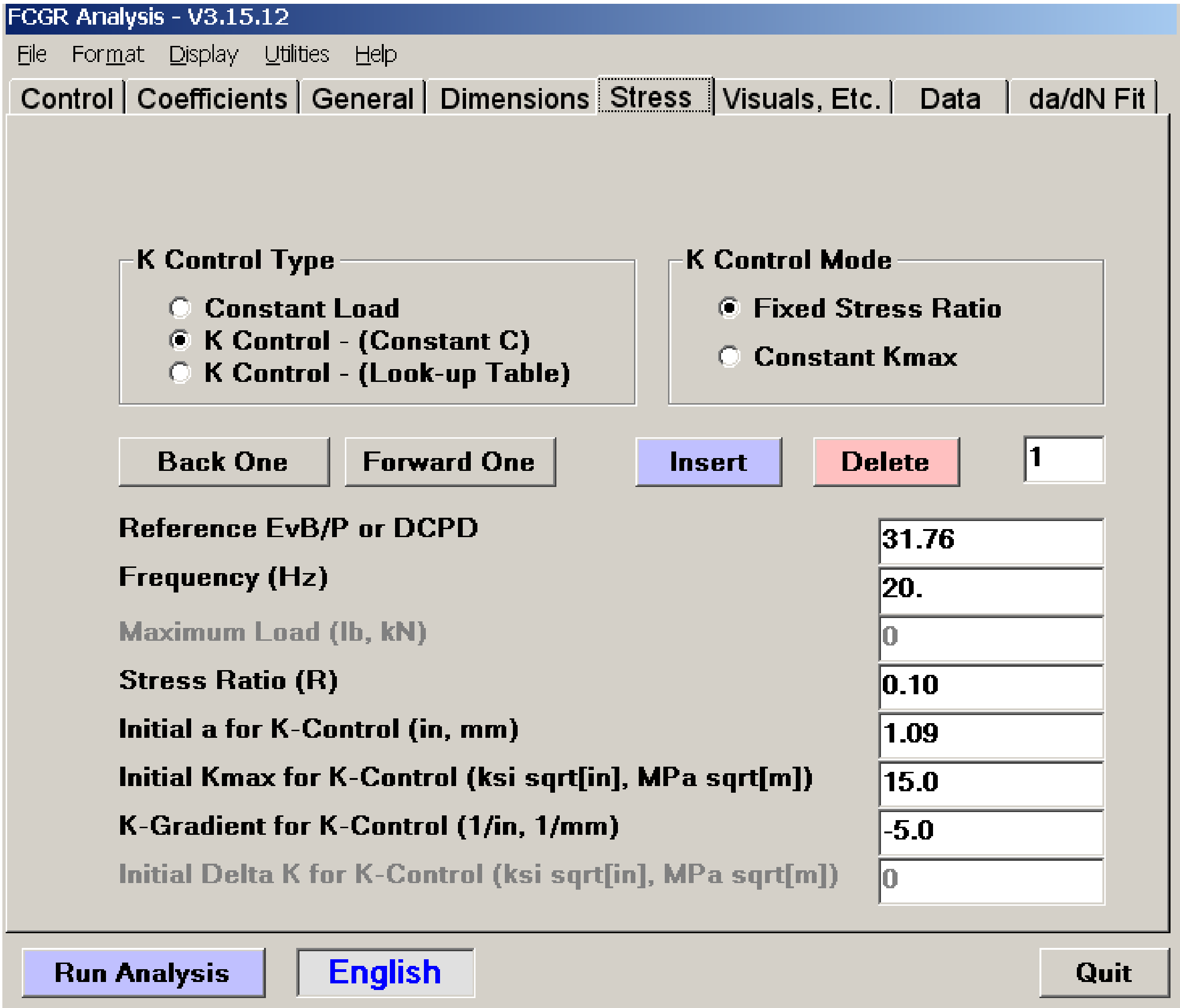
Validity criteria are affected by **Yield Stress**, so editing this information should be done with care. If **Yield Stress** has been entered for a particular material, data that exceed the size requirement determined by the E647 standard appear with an asterisk on the tabular results and are shown in red on the da-dN plot, (see the example in Section 6.2.3).

6.6 Main Menu: Dimensions Tab



The specimen **Thickness** and **Width** values are critical, and are loaded with the analysis files. The **Initial EvB/P** and **Initial CR** affect the ACR closure analysis, which is not covered here. For most applications, these values will be set to zero and one, respectively.

6.7 Main Menu: Stress Tab



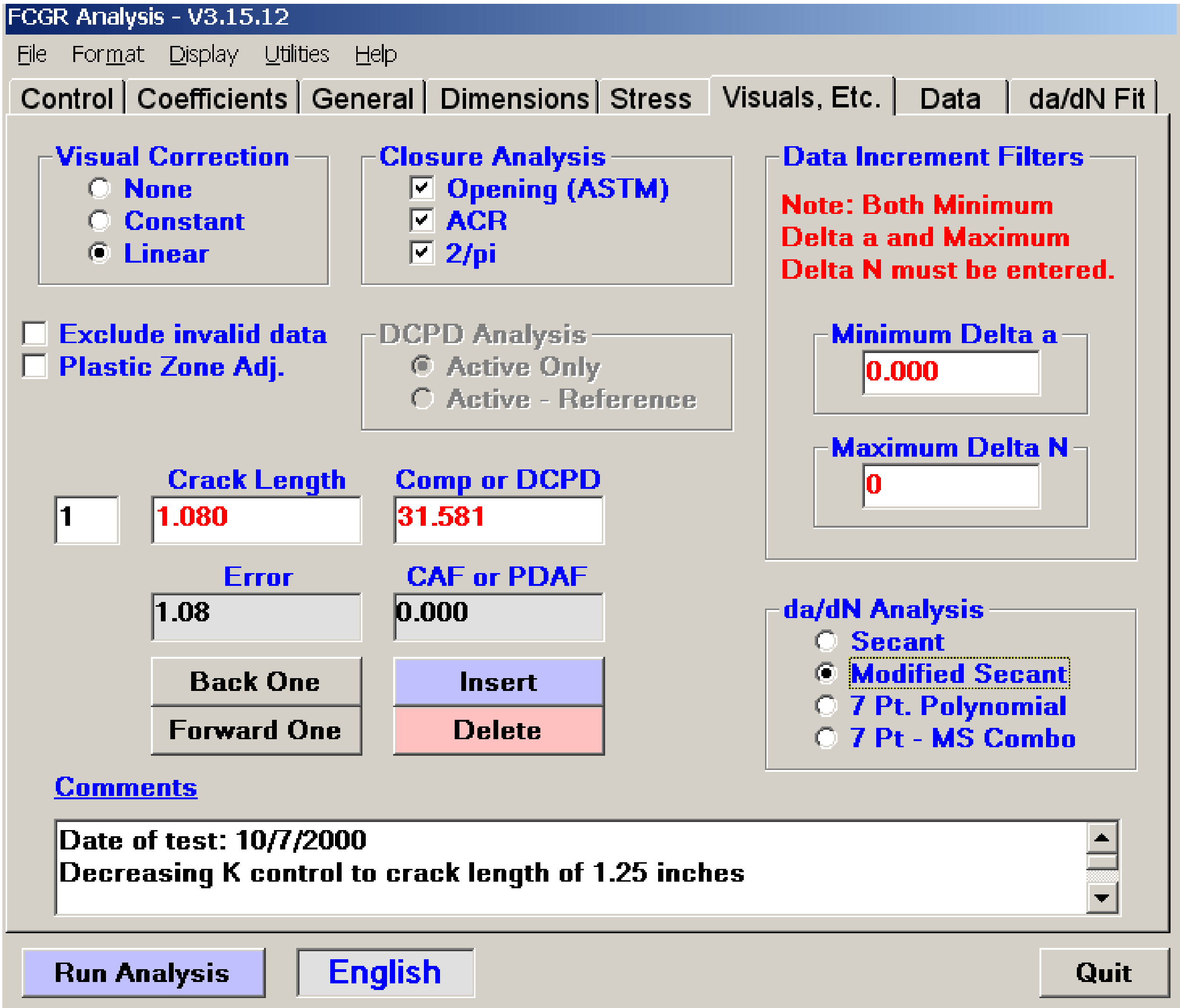
The **Stress** tab displays the conditions under which the test was run. This information appears under the heading **Test Parameters** on the cover page output.

If only one analysis file has been loaded into the analysis program, one line of information, displaying the final conditions under which the test was run, will appear. If conditions were altered earlier in the test (a change in frequency or load, for example), these may be recorded as additional lines of data here. Use the **Insert** button to insert empty lines that are populated using the text entry boxes provided.

If two or more data files have been combined (using the **File Open … Add to Existing Test** dropdown menu) one line of data will exist for each. To examine each, use the **Back One** or **Forward One** command buttons. Lines may be deleted using the **Delete** button.

Note that these records are for information only, since the actual maximum and cyclic load are included in the analysis file for each data point.

6.8 Main Menu: Visuals, Etc. Tab



The **Visuals** tab of the **Main Menu** has two main purposes: user entry of visual measurements for post-test corrections; and user choice of analysis options.

6.8.1 VISUAL CORRECTION

When the test specimen has been broken open and marker bands have been measured, or when surface visuals have been recorded during the test, the results are entered under Crack Length and Comp or DCPD. Since more than one visual observation is expected, the editor is configured to handle multiple entries. To add a measurement, press Insert. Then enter the crack length and corresponding compliance or DCPD value. To examine each resulting record, use the Back One or Forward One command buttons. To remove entries, press Delete

Visual observations may be partitioned by entering a crack length of **zero** and the compliance or DCPD corresponding to where the partition is to occur. Visual observations on each side of a partition are handled and corrected separately.

The cover page output values show the errors after corrections have been applied. The C[PD]AF (Compliance [Potential Drop] Adjustment Factor) is the value by which EvB/P or DCPD must be multiplied to minimize errors.

There are three modes of **Visual Correction**.

- **None:** select if there are no visual measurements orno correction is desired. If visual observations are entered, the output cover page will still include a listing of the errors between the crack length observation and the uncorrected calculated crack length. On the cover page output, the value C[PD]AF (Compliance [Potential Drop] Adjustment Factor) is [1].

- **Constant**: select if only one visual observation is made, or if the observations do not follow a systematic trend from the initial to final crack length. The C[PD]AF is a constant value to minimize errors.

- **Linear:** select if there are two or more measurements and it is desirable to do a linear correction to the observations as a function of crack length. The resulting linear fit results in a variable C[PD]AF value.

It is suggested that the sample data (TEST4) supplied with the software be reprocessed with each of these modes to fully comprehend the impact of these choices.

6.8.2 ANALYSIS OPTIONS

- **Closure Analysis**: for most analyses, these options are not activated.

- **Data Increment Filters**: prudent use of these filters can optimize the number of points for graphical representation of the data, particularly if too many data were recorded during the test. Both filters must be used in combination, if they are used at all.

    - **Minimum Delta a**: if the Δa increment for data storage selected during the test was too small, a larger increment can be chosen for the analysis. A maximum ΔN increment must be selected for this filter to work.
    - **Maximum Delta N**: allows adjusting the Δa increment to a smaller size for near-threshold data. However, if this value were to remain at zero, then no Δa increment filtering can be done. Therefore, to filter based on Δa increment only, a large value for ΔN must be chosen.

- **da/dN Analysis**: four methods of performing the da/dN analysis are available at the bottom right of the Visuals tab. When the Run Analysis tab is pressed, the da/dN plot will appear in a new window and the results can be examined. It can be a useful exercise to run the same data file using different options, while observing the changes to the da/dN plot.

    - **Secant**: performed by reading in the raw analysis file data and performing a secant computation as follows.

      $$da/dN = (a_{i+1}-a_i)/(N_{i+1}-N_i)$$
      $$a_{average} = (a_{i+1}+a_i)/2$$

    - **Modified secant**: the default analysis method, and particularly useful for threshold tests with steep curves.

      $$da/dN = (a_{i+2}-a_i)/(N_{i+2}-N_i)$$
      $$a_{average} = (a_{i+2}+a_i)/2$$

    - **7-point polynomial:** this method is thoroughly described in Appendix X1 of ASTM E647. The method smoothes the data but misses two points at the beginning and two points at the end, as compared to the modified secant method.

    - **7 point-MS combo**: this method uses the 7-point incremental polynomial technique, with the modified secant method used for the missing points. FTA recommends this method for most analyses.

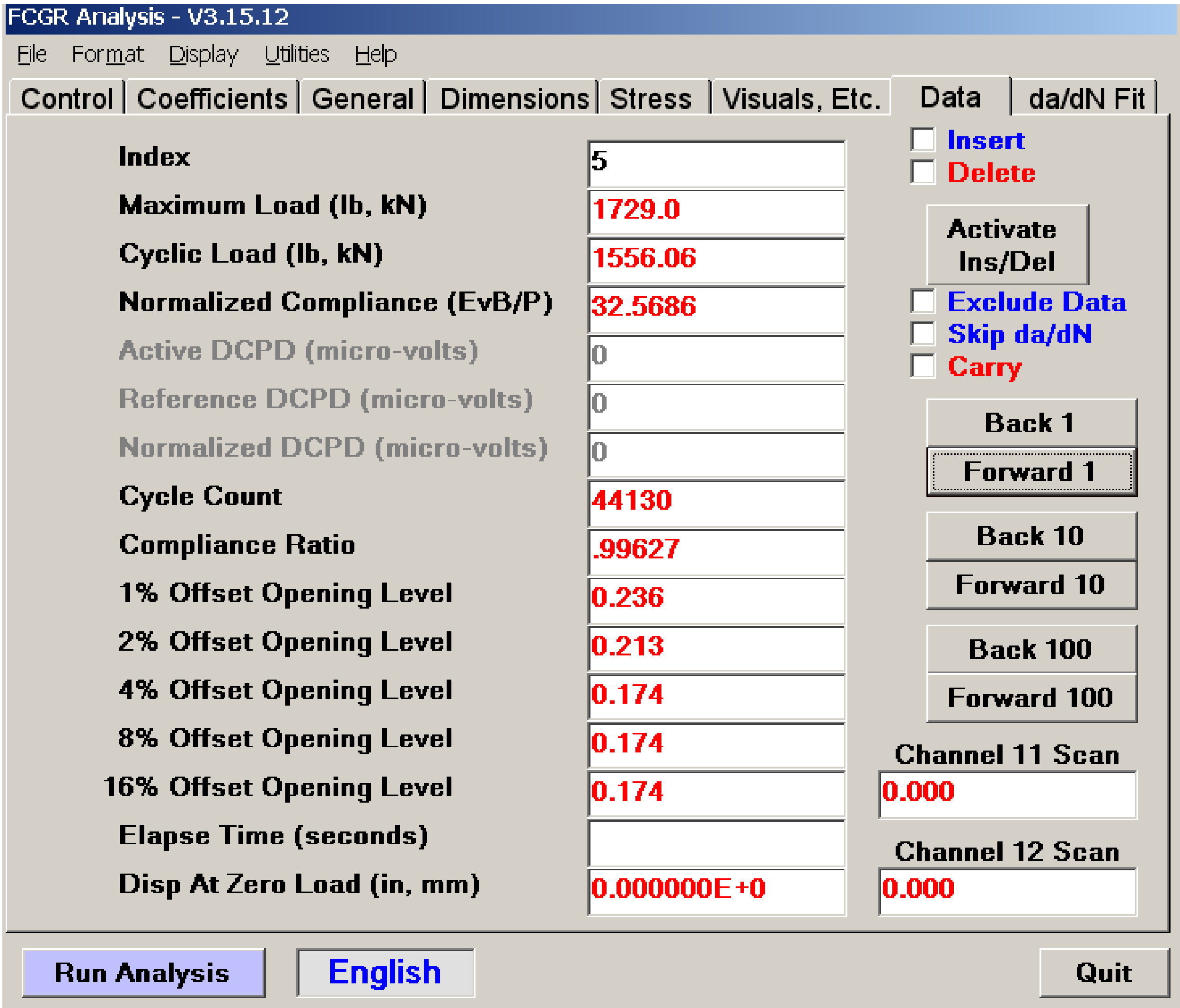
- **Exclude Invalid data** checkbox: If checked then data are excluded from output if the ASTM size requirement is exceeded.

- **Plastic Zone Adjustment** checkbox: If checked then K is computed based upon plastic zone size correction to the crack length. Not recommended for new users.

6.8.3 COMMENTS

At the bottom of the **Visuals** tab, the user may input comments about the test. These comments appear at the bottom of the cover page output.

6.9 Main Menu: Data Tab



The **Data** tab allows the user to examine and edit each data point of the analysis file, by proceeding **Back One/Ten** and **Forward One/Ten** through the indexed lines. It is usually necessary to run the analysis first to determine whether editing is appropriate. Each selected data point is shown in green on the da/dN plot in its new window.

Three methods exist for removing errant data from the analysis:

- **Delete**: in combination with the **Activate Ins/Del** command button, ticking the **Delete** box removes the selected line of data from the [.in4] file. FTA does not recommend this method, since such removal is a permanent change to the file.

- **Exclude Data:** when this box is ticked, the selected line of data is excluded from the analysis run, but not deleted from the analysis file. FTA recommends this approach, as data excluded thusly are easily reintroduced into the analysis when the box is deselected.

- **Skip da/dN:** when this box is ticked, no da/dN calculation occurs between the selected point and the next point. This option is invoked automatically for the last data point in a file if another test file is added to it. **Skip** is a useful option for test interruptions, or if the cycle count has been re-zeroed during a test.

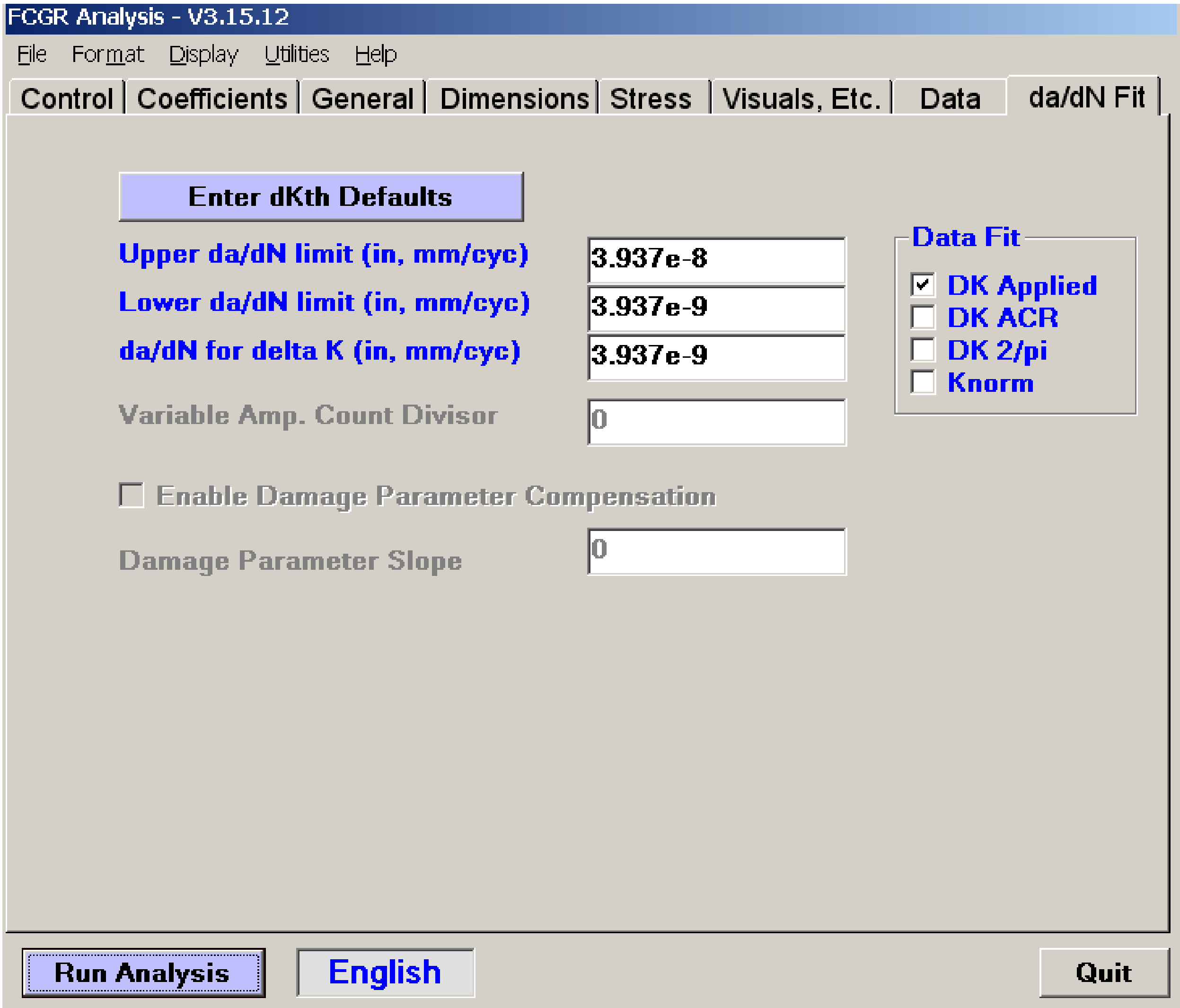
Data can also be added to the file if, for example, **Data Storage** was not activated during testing and the only record is in the log file. Use the **Insert** button in combination with the **Activate Ins/Del**to add additional lines of data to the analysis file. FTA does not recommend this approach, as it is often more convenient to edit analysis files in a text editor such as NotePad. See the appendices for more information on editing analysis files.

Channel 11 Scan: this box will be populated if the channel scan option was chosen during testing to record temperature.

Channel 12 Scan is not used during analysis.

The fields related to ACR and crack closure are not covered in this document and may be ignored by most new users.

6.10 Main Menu: da/dN Fit Tab



In this form, the parameters for a straight line fit of the da/dN vs. ΔK data can be specified including the parameters for determining ΔK_{th}. The ASTM E647 definition of threshold employs the values shown above:

- **Upper da/dN limit:** 3.937E-8 inch/cycle (1E-6 mm/cycle)
- **Lower da/dN limit:** 3.937E-9 inch/cycle (1E-7 mm/cycle)
- **Da/dN for delta K:** 3.937E-9 inch/cycle (1E-7 mm/cycle)

The default value for **Data Fit** is **DK Applied**.

Additional options appear for variable amplitude analysis.

6.11 Run Analysis

The **Run Analysis** button is located at the bottom of the **Main Menu** and is visible on all the tabs. When this button is pressed, a number of things happen:

- A data[.dat] file is produced (always choose to **Save** when this menu option appears)
- a new window appears showing the contents of the .dat file
- a new window appears containing the da/dN plot
- output is sent to a printer (if **Cover Page** and/or **Tabular Results** are selected under **Print Mode** on the **Control** tab: see below)
- output is saved to a [.prn] file (if **Print to File** is selected under **Print Mode** on the **Control** tab)

Analyses may be run at any time, although if an analysis file has not yet been imported into the program, an error message appears prompting the user to open one. It is important to remember that [.in3] files remain unchanged by the analysis program.

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

Appendix A: Recovery from System Crash

In the event of a computer crash or accidental exit from the FTA program, it is possible to resume the test without loss of any data as long as the ADwin itself has not lost power. All key variables are stored in the ADwin until retrieved by the FTA testing program.

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

2. Start FTA's FCGR testing program.

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

4. Choose the correct unit type.

5. Open the **Hardware Configuration** tab and confirm the correct settings.

6. Open the **Test Set-up** form. On the **Initialize** re-enter the **Test ID** and confirm the correct settings on all tabs.

7. **Receive from ADwin**; **Send to ADwin**; and **Print to Log**.

8. Open the FNG and the remaining displays. Remember that the **FNG** must be open for the display forms to update properly.

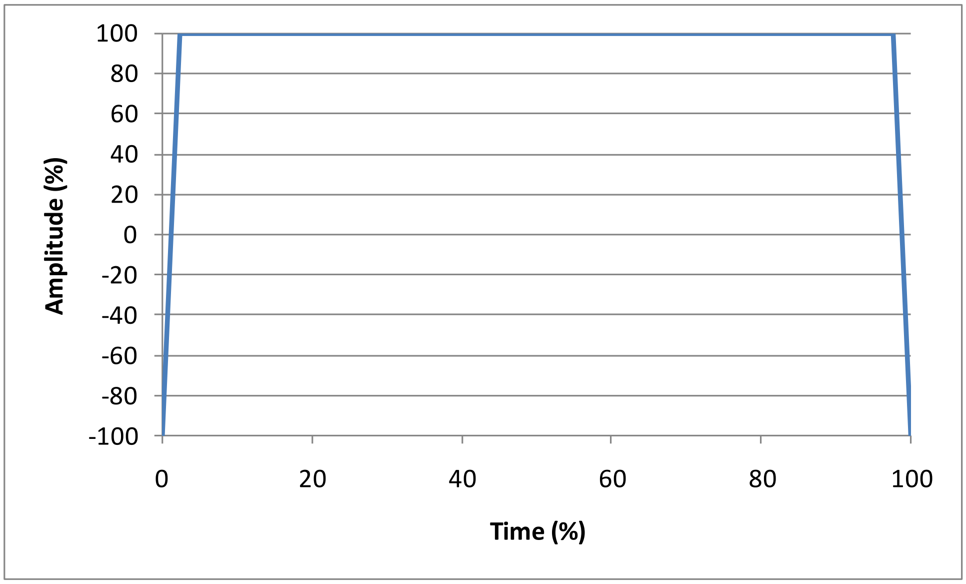
9. Breathe a sigh of relief!

Appendix B: Custom Waveform Example (Dwell Waveform)

Consider a waveform with the following characteristics:

Frequency, f	=	*0.0079365 Hz (Period, τ = 126 sec)*
Ramp time	=	*3 sec (unload or reload)*
Dwell time	=	*120 sec (hold at maximum load)*

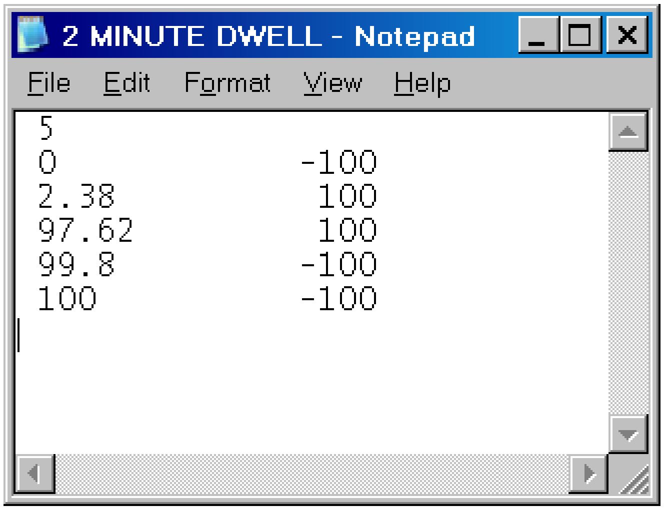
First, construct the base waveform. This three segment waveform will begin at a specified starting level (in this case, the lowest level, or -100%); rise to max load (100%); hold for a given time period; then drop to the starting level. A small increment of time at minimum load is recommended so that the software accurately captures the minimum load during testing. The period of the waveform corresponds to 100% of time.



Calculate the cumulative % time attained by the end of each segment:

- % time from starting point to hold level: 3 sec / τ •100 = 2.38
- % time from starting point to end of hold period: 3 +120 sec / τ• 100 = 97.62
- % time from starting point to end of cycle: 3 +120 +3 sec / τ• 100 = 100

If a small increment of time is desired at minimum load, then the third segment should stop short of the 100% time base and a fourth segment added as shown in the 2 Minute Dwell.dat file.



The number at the beginning of the file (in this case, 5) is the total number of lines in the file.

This is the custom waveform that needs to be loaded into the FCGR program using **Read from File** on the **Custom Waveform Shape** screen (**Control** menu).

Use the **Force** tab to establish the actual loads. The maximum load will correspond to the 100% amplitude of the waveform and the minimum load will correspond to the -100% amplitude for the waveform. Use the appropriate stress ratio to achieve minimum load.

The cyclic frequency of the **Function Generator** must be set to 0.0079365 Hz for this waveform to provide a 10 cycle per minute (CPM) unload-reload and a 2 minute hold at maximum load.

The user is encouraged to verify that the waveform has been constructed properly by observing the Status Screen, Load Displacement plot, or oscilloscope output.

*NB It is recommended that the number of points for A/D Data Acquisition (**Options** tab) be set to the maximum of 4000 when using this option (See Section 4.4.2).*

Appendix C: Examples of Analysis Files

C1: Log Files

Log files are saved automatically by the testing software and contain a complete record of the test. An abbreviated potential drop log file appears below, including test parameters and conditions (shown in red text for illustrative purposes); crack lengths and associated DCPD [EvB/P in compliance files] values (blue) and stored data points (green). See Appendix E for a procedure using log files to recreate lost analysis files.

Test Parameters: this record of the box-fill on the **Test Set-up** form is logged to the file every time **Print to Log** is pressed. This self-explanatory information is clearly labeled in the file, as shown below. When data storage limits are reached (final crack length or crack growth rate, for example), a record of this stopping condition is also recorded in the file. Any error messages that appeared on the FNG are recorded as well.

Crack lengths and associated information: these lines of data include all the critical data associated with each calculated crack length. The five comma-delineated values shown in the file below are (in order): Active DCPD; Reference DCPD; Normalized DCPD; Cycle count; and Calculated crack length:

```
60.4884,469.4655,59.1915,7729659,0.19719
```

For a DCPD test where no reference lead is used, the comma-delineated values are (in order): Active DCPD; Cycle count; Calculated crack length. For a compliance test, the comma-delineated values are (in order): EvB/P; Cycle count; Calculated crack length; Displacement at zero load (if activated on the **Compliance** tab of the testing software).

Data points: during testing, the blue stored values on the **Status Screen** are updated every data storage interval; that is, whenever data storage is prompted by the crack length or cycle count interval determined on the **Data Storage** tab of the testing software. It can be seen clearly below where the data storage intervals occur. These values are the average of all the preceding blue lines of data in the associated storage interval, and are held in memory and saved manually to the analysis file at the end of the test.

The first line associated with data storage is self-explanatory.

```
Load       R       a/W      a       Pdnum   dK      da/dN       Time         Date
004400.0  0.700  0.5656  0.1980  00013  006.55  9.385E-7  1:45:40 PM  11/4/2007
```

The second line, which is saved to the analysis file, appears as follows:

```
1,0,0,4399.99,1319.99,60.6162,469.5159,59.3102,7730056
```

In order, these values represent the **Index** of each data point (1 until saved as an [.in3] file); whether the point will be **excluded** from the analysis file (1 for 'exclude'); whether the da/dn calculation will be **skipped** during analysis (1 for 'skip'); **P**$_{max(ave)}$; **P**$_{delta(ave)}$; **active DCPD** (ave); **reference DCPD** (ave); **normalized DCPD** (ave); and **cycle count** (ave).

Example of a DCPD Log File

```
Test ID                             102A
Unit Type                           English
K Calibration Type                  Corner Crack
PD Calibration Type                 Surface Crack

Specimen Thickness (in)             0.502
Net Specimen Thickness (in)         0.502
Specimen Width (in)                 0.3501
Load Cell Calibration (lb/volt)     500
PD Gage Length (in)                 0.031
Initial Crack Length (in)           0.0085
Initial PD (micro-volts)            7.48
Initial Reference PD (microvolts)   459.4
PDGain (Active)                     20000
PDGain (Reference)                  5000

Maximum Load (lbs)                  4400
Stress Ratio (R)                    0.7

Minimum PD Level (%)                -5
Number of PD Cycles                 50
Current Switching Interval          5
Current Delay Factor (seconds)      0.5

Initial a/W                         3.427592E-02
Final a/W                           0.1428163
a/W Increment                       1.428163E-03
Initial Count                       20000
Final Count                         20000000
Count Increment                     20000
Minimum da/dN (in/cycle)            -1
Maximum da/dN (in/cycle)            1

Elapse Time (hrs)                   5.115
Time                                1:44:52PM
Date                                11/04/2007
Kmax (ksi sqrt[in])                 2.436711
Delta K (ksi sqrt[in])              0.7310132
Frequency (Hz)                      20
Waveform Type                       Sine

60.4884,469.4655,59.1915,7729659,0.19719
60.5181,469.4728,59.2197,7729747,0.19728
60.5223,469.4904,59.2215,7729835,0.19729
60.5645,469.4997,59.2617,7729923,0.19743
60.5848,469.4969,59.2819,7730012,0.19749
60.6184,469.5124,59.3128,7730100,0.19760   | DATA STORAGE INTERVAL
60.6287,469.5280,59.3209,7730188,0.19763
60.6713,469.5303,59.3623,7730276,0.19777
60.6998,469.5479,59.3879,7730365,0.19785
```

```
 60.7310,469.5594,59.4170,7730453,0.19795
 60.7505,469.5714,59.4346,7730541,0.19801

Load        R       a/W      a       Pdnum   dK      da/dN       Time         Date
004400.0  0.700  0.5656  0.1980  00013  006.55  9.385E-7  1:45:40 PM  11/4/2007

1,0,0,4399.99,1319.99,60.6162,469.5159,59.3102,7730056
```

(LINE OF DATA FOR .IN3 FILE)

```
 60.7830,469.6082,59.4618,7730629,0.19810
 60.8148,469.6077,59.4928,7730717,0.19821
 60.8498,469.6081,59.5271,7730805,0.19832
 60.8614,469.6085,59.5384,7730893,0.19836
 60.8948,469.6140,59.5704,7730982,0.19847
 60.9360,469.6322,59.6083,7731070,0.19859
 60.9590,469.6354,59.6305,7731158,0.19867
 60.9744,469.6442,59.6444,7731246,0.19872
 61.0019,469.6444,59.6712,7731334,0.19881
 61.0509,469.6786,59.7149,7731423,0.19895
 61.0646,469.6916,59.7266,7731511,0.19899
 61.0899,469.6878,59.7518,7731599,0.19908
```

DATA STORAGE INTERVAL

```
Load        R       a/W      a       Pdnum   dK      da/dN       Time         Date
004400.0  0.700  0.5686  0.1991  00013  006.60  1.002E-6  1:46:33 PM  11/4/2007

1,0,0,4400.00,1319.99,60.9400,469.6384,59.6115,7731070
```

(LINE OF DATA FOR .IN3 FILE)

```
61.1090,469.7225,59.7661,7731687,0.19913
61.1466,469.7124,59.8041,7731775,0.19926
61.1865,469.7188,59.8423,7731863,0.19938
61.2020,469.7520,59.8533,7731951,0.19942
61.2329,469.7534,59.8833,7732040,0.19952
61.2830,469.7624,59.9312,7732128,0.19968
61.2881,469.7719,59.9349,7732216,0.19970
61.3280,469.7694,59.9743,7732304,0.19983
61.3544,469.7902,59.9974,7732393,0.19991
Final crack length exceeded
61.3950,469.8027,60.0356,7732481,0.20004

Load        R       a/W      a       Pdnum   dK      da/dN       Time         Date
004400.0  0.700  0.5714  0.2000  00013  006.64  1.012E-6  1:47:17 PM  11/4/2007

1,0,0,4400.01,1320.01,61.2526,469.7556,59.9023,7732039
```

C2: Compliance analysis file

Analysis files consist of header information and data, which differs according to the type of test that has been run. A compliance analysis file ([.in3] or [.in4]) appears below:

```
0
0,1,0,2,0,0,0,0,0
 0.886  4.64 -13.32  14.72 -5.6  0
 1.00098 -4.66951  18.4601 -236.825  1214.88 -2143.57
3A,CONTRACT,MATERIAL,0,ENVIRONMENT
GEOM,ORIENT,0, 10.2
0,0,0
,
 0.3863 , 0.3863 , 3.002 ,0,0,0,0,0
 29.73 , 1
 1 , 0 , 32.20281 , 40 ,, 0.1 , 1.1 , 8 ,-5 , 0
Date of test: 8/2/2001
Waveform Type           Sine
EOT
1,0,0,759.33,683.40,32.2028,4251,0.98474,0.400,0.348,0.284,0.174,0.174
2,0,0,743.14,668.82,32.3531,11330,0.98391,0.397,0.352,0.288,0.174,0.174
3,0,0,721.84,649.65,32.5563,22858,0.98250,0.403,0.359,0.293,0.174,0.174
4,0,0,700.40,630.36,32.7689,38919,0.98092,0.427,0.367,0.305,0.174,0.174
5,0,0,679.69,611.72,32.9820,60965,0.97931,0.504,0.383,0.315,0.174,0.174
6,0,0,661.45,595.30,33.1773,86989,0.97783,0.510,0.422,0.324,0.174,0.174
-1,,,,,,,
```

The fields above correspond to the following variables (see Appendix D for a glossary of definitions and codes):

```
DCPD&
KType&,NStress&,NVisuals&,NComments&,VisualType&,ClosureCode&,OP&,ACR&,Blend&
KCoeff(1), KCoeff(2), KCoeff(3), KCoeff(4), KCoeff(5), KCoeff(6)
CCoeff(1), CCoeff(2), CCoeff(3), CCoeff(4), CCoeff(5), CCoeff(6)
TestID$,Contract$,Material$,Temperature,Environment$
Geometry$,Orientation$,Yield,E
PrecrackP,PrecrackR,PrecrackA
dadnFitmax,dadNFitmin,dadNdadN
B,Bnet,W,H,SOW,Notch,GL,Alpha
EvBPi,Cri
KcontrolType(1),KcontrolMode(1),CompDCPDStress(1),Freq(1),PmaxC(1),R(1),AI(1)
,KI(1),C(1),DKI(1)

Crack length visuals and corresponding compliance

Test Date (Comment 1)
Waveform descriptor (Comment 2)
End of Input indicator (Comment 3)
[lines of data, as follows]
Index(1),Exclude(1),Skip(1),Pmax(1),PDelta(1),EvBP(1),CycleCount(1),CR(1),OP1
(1),OP2(1),OP4(1),OP8(1),OP16(1)
```

C3: Potential drop analysis file

A DC potential drop analysis file ([.in3] or [.in4]) appears below:

```
1
0,1,1,0,2,0,1,0
0.886  4.64 -13.32  14.72 -5.6  0
3A,CONTRACT,MATERIAL,0,ENVIRONMENT
GEOM,ORIENT,0,
0,0,0
,,
 0.5 , 0.5 , 2.0 ,0,0,0
 0.7 , 0.6 , 408.6
 1 , 0 , 507.5967 , 20 ,, 0.7 , 0.6 , 20 ,-6 , 0
Date of test: 10/4/2002
Waveform Type                    Sine
EOT
1,0,0,1889.69,566.92,507.5967,2407
2,0,0,1809.71,542.91,517.6254,6318
3,0,0,1723.49,517.05,529.1204,10864
4,0,0,1640.74,492.22,540.7020,15654
-1,,,,,,
```

The fields above correspond to the following variables (see Appendix D for a glossary of definitions and codes):

```
DCPD&
KType&,NStress&,PDType&,NVisuals&,NComments&,VisualType&,PDColumns&,PDRef&
KCoeff(1), KCoeff(2), KCoeff(3), KCoeff(4), KCoeff(5), KCoeff(6)
TestID$,Contract$,Material$,Temperature,Environment$
Geometry$,Orientation$,Yield,E
PrecrackP,PrecrackR,PrecrackA
dadnFitmax,dadNFitmin,dadNdadN
B,Bnet,W,H,SOW,Notch
PDGL,PDA0,PD0
KcontrolType(1),KcontrolMode(1),CompDCPDStress(1),Freq(1),PmaxC(1),R(1),AI(1)
,KI(1),C(1),DKI(1)
```

Crack length visuals and corresponding DCPD

```
Test Date (Comment 1)
Waveform descriptor (Comment 2)
End of Input indicator (Comment 3)
[lines of data, as follows]
Index(1),Exclude(1),Skip(1),Pmax(1),PDelta(1),PDSum(1),CycleCount(1)
```

Appendix D: Glossary of Analysis File Codes and Terms

Variables:

Alpha	'Ratio of displacement location to W
ACR&	'ACR method of closure active
B	'Specimen thickness
Bnet	'Net specimen thickness
Blend&	'OP and ACR blend method active
Contract$	'Contract
CRi	'Initial CR for ACR
ClosureCode&	'0=off, 1=1% offset... 5=16% offset
Comments$	'Text containing comments
dadNFitmax	'dadN vs. Delta K fit parameters
dadNFitmin	
dadNdadN	
dadNMethod&	'0 = da/dN, 1 = da/dF. 2 = da/dt
DCPD&	'0 = compliance, 1 = DCPD
E	'Modulus of elasticity
Environment$	'Environment
EvBPi	'Initial compliance for ACR
GL	'Gage length for compliance
Geometry$	'Geometry
H	'Specimen height
Ktype&	'Type of K, 0=Polynomial (type 1) , 1=Center crack , 2=Single edge tension (pin loaded) , 3=Single edge bend , 4=Extended compact , 5=Polynomial (type 2) , 6=Surface crack , 7=Single edge tension (rigid) , 8=Corner crack , 9=Look-up table , 10= Polynomial (type 3)
Material$	'Material
Notch	'Notch depth

NVisuals&	'Number of visual observations
NComments&	'Number of comments
NStress&	'Number of stress lines
Orientation$	'Orientation
OP&	'Opening load method of closure active
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
PDColumns&	'Number of PD columns in input file
SOW	'Span to width ratio
SpectrumType&	'0=endpoint, 1=block, 2=flightmixfile
TestID$	'Filename
Temperature	'Temperature
VisualType&	'0 = none, 1 = fixed, 2 = variable adjustment
W	'Specimen width
Yield	'Yield strength

Arrays:

KCoeff(10)	'Stress intensity coefficients
CCoeff(10)	'Compliance coefficients
PDCoeff(10)	'PD Coefficients

KControlType&(10)	'0 = constant load, 1 = K-control
KControlMode&(10)	'0 = fixed R, 1 = constant Kmax
CompDCPDStress(10)	'Value of Comp or DCPD at stress parameter change
Freq(10)	'Cyclic frequency of waveform (Hz)
PmaxC(10)	'Maximum load for constant load control
R(10)	'Stress ratio
AI(10)	'Initial a for K-control

```
KI(10)                    'Initial Kmax for K-control
C(10)                     'K-gradient for K-control
DKI(10)                   'Initial delta K for constant Kmax

Index&(5000)              'Index
IM&(5000)                 'Modified Index
Exclude&(5000)            'If 1 then exclude line of data
Skip&(5000)               'If 1 then skip next da/dN data point
Pmax(5000)                'Pmax
PDelta(5000)              'Delta P
EvBP(5000)                'EvB/P
PDSum(5000)               'Active PD
PDRefSum(5000)            'Reference PD
PDNormSum(5000)           'Normalized PD
PD4Sum(5000)              'Gage 4 PD
CycleCount&(5000)         'Cycle count
CR(5000)                  'Compliance ratio
OP1(5000)                 '1% offset closure level
OP2(5000)                 '2% offset closure level
OP4(5000)                 '4% offset closure level
OP8(5000)                 '8% offset closure level
OP16(5000)                '16% offset closure level
ElapseTime&(5000)         'Elapse time
DispAtZeroLoad (5000)     'Displacement at zero load


PDL(5000)                 'PD values for look-up table
AWL(5000)                 'a/W values for look-up table
```

Appendix E: What to Do About Lost Analysis Files

At the end of a test, analysis (.in3) files are sometimes lost through power failure or human error. Redundant systems, however, allow these files to be reconstructed in two different ways.

E1: Automatic Backup Files

Analysis backup files are automatically stored during the test, provided **Enable Automatic Analysis File Storage** has been selected on the **Storage** tab in the testing program. By default, these files are saved every two hours (or as determined on the **Storage** tab) and their filenames have no extension. If an [.in3] file is missing at analysis time, rename the backup file with the [.in3] extension. This file will subsequently be recognized by the analysis program. Since the backup file is updated only periodically, it may be missing a few lines of data towards the end of the test. These can be copied and pasted from the automatically-saved log file, using a text editor.

E2: Reconstructing [.in3] Files from Log Files

In the rare case that a backup file cannot be found, reconstruction of the analysis file is possible using the **FCGR Testing Program**; a text editor such as Notepad; Excel(in the case of large data files); and the test's log file.

Analysis files consist of two parts: *header information* and *data* (see the previous appendices for a full discussion of analysis files). The header and data are reconstructed in a two-step process.

First, recreate the header using the **FCGR Testing Program** as follows:

- Start the **FCGR Testing Program**
- Assign a **Test ID**
- Load **Test Parameters**
- Enter correct **Dimensions** and **Stress Parameters**
- Save the new analysis file (Ver.3) and close the test program
- Using a text editor such as **Notepad**, open the new analysis file, which now has a [.in3] extension

The new analysis file should look like the header example given in the earlier appendices.

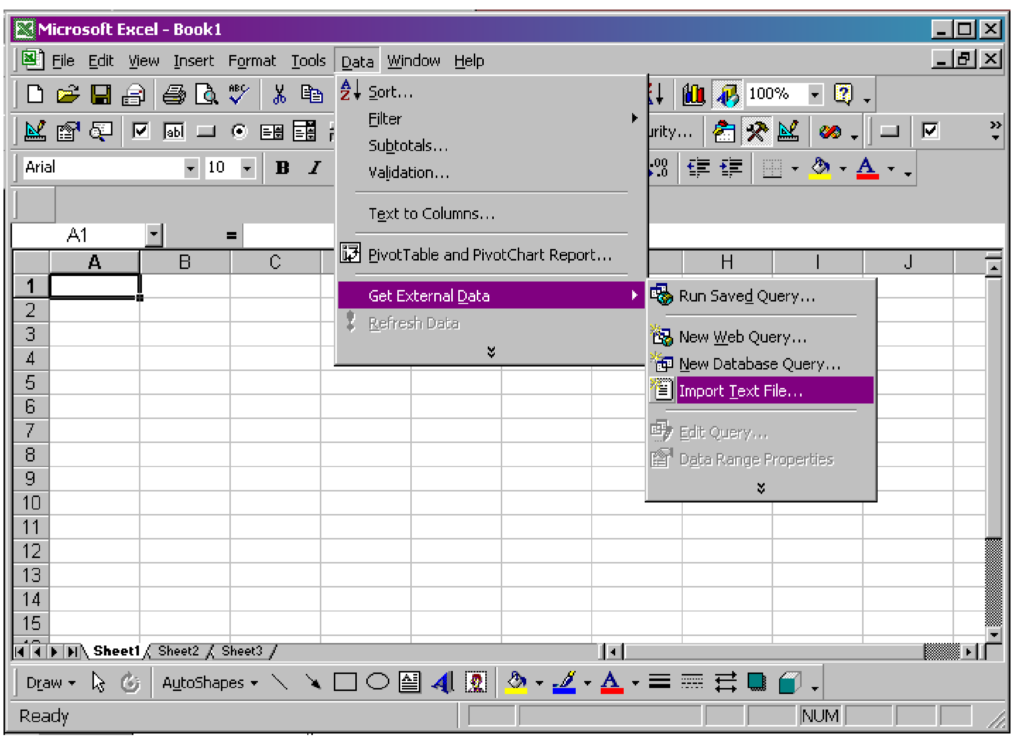
Second, retrieve the data from the original test's log file (see Appendix C1 for more information about log files) and insert them between 'EOT' and the final line of commas, as follows. It is not necessary to change the index from 1.

EOT
1,0,0,2541.88,763.06,399.2490,8699265
1,0,0,2426.89,728.04,400.5242,8703177
-1,,,,,,

If the test was short and the .log file contains only a few lines of data, it is possible to cut and paste them into the new analysis file using a text editor. It is not necessary to change the index from 1.

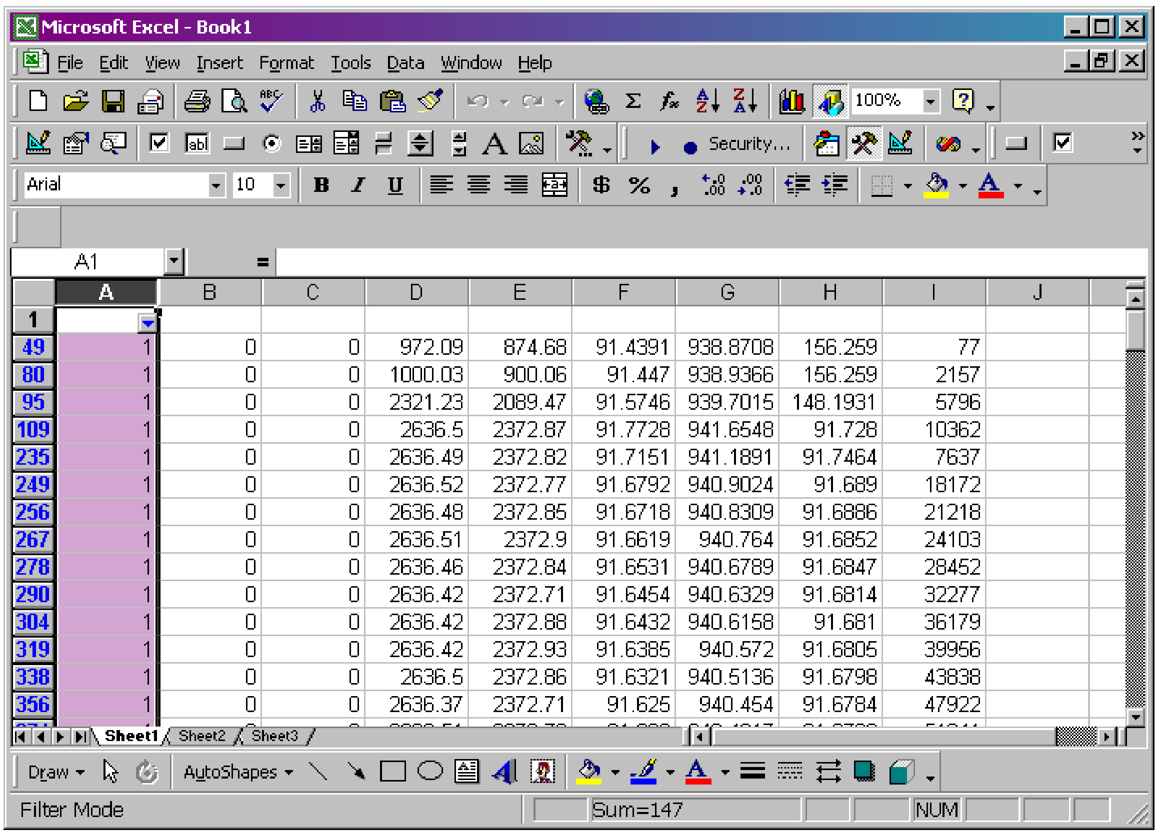
For larger files, which may contain hundreds of lines of data, it is necessary to filter the data lines out of the log file before pasting them into the analysis file. A convenient method takes advantage of Microsoft Excel's data-filtering capabilities. This approach is detailed below.

1. Open Excel and make sure the upper left cell of Sheet1 is active (indicated by a darkened rectangle).
2. Go the **Data** menu and **Get External Data/Import Text File.** Locate the log file using the Windows dialog box. Be sure to change the file type to **All Files** to show text documents. Once selected, click **Import**.



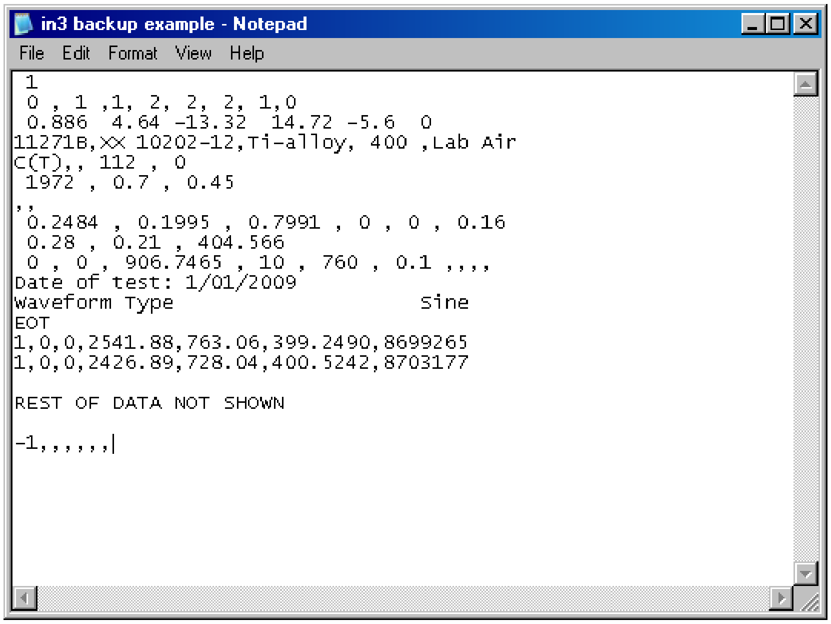
4. A pop-up menu appears. Select **Delimited** as the file type that best describes the data and click **Next**.

5. In the new window, set **Delimiters** to **Comma**, and click **Finish**.
6. The **Import Data** pop-up window appears. Click **Properties** and de-select **Adjust Column Width**. Click **OK** and import the data to the existing worksheet. *The data should now reside on Sheet1, starting in column A.*
7. Click on the letter **A** (Column Heading, upper left). *This should highlight the entire column.*
8. Go to **Data/Filter/Auto Filter**. *A drop down arrow will appear in column A, row 1.*
9. Click the arrow and select the integer 1 as the only filter identifier (the rest of the default filters may need to be deselected). At this point, only the data lines will be shown. The integer 1 takes the place of the index of the data point. This will not affect the analysis. See below for an example:



	A	B	C	D	E	F	G	H	I	J
1										
49	1	0	0	972.09	874.68	91.4391	938.8708	156.259	77	
80	1	0	0	1000.03	900.06	91.447	938.9366	156.259	2157	
95	1	0	0	2321.23	2089.47	91.5746	939.7015	148.1931	5796	
109	1	0	0	2636.5	2372.87	91.7728	941.6548	91.728	10362	
235	1	0	0	2636.49	2372.82	91.7151	941.1891	91.7464	7637	
249	1	0	0	2636.52	2372.77	91.6792	940.9024	91.689	18172	
256	1	0	0	2636.48	2372.85	91.6718	940.8309	91.6886	21218	
267	1	0	0	2636.51	2372.9	91.6619	940.764	91.6852	24103	
278	1	0	0	2636.46	2372.84	91.6531	940.6789	91.6847	28452	
290	1	0	0	2636.42	2372.71	91.6454	940.6329	91.6814	32277	
304	1	0	0	2636.42	2372.88	91.6432	940.6158	91.681	36179	
319	1	0	0	2636.42	2372.93	91.6385	940.572	91.6805	39956	
338	1	0	0	2636.5	2372.86	91.6321	940.5136	91.6798	43838	
356	1	0	0	2636.37	2372.71	91.625	940.454	91.6784	47922	

10. Select all the data and paste them into a blank worksheet (Sheet2 or Sheet3).
12. Go back to Sheet1 and **Edit/Delete**.
13. Save the active sheet where the data now resides under a new name using **Save As.** Choose **File Type.CSV**.
14. Close **Excel**.
15. Reopen the file that you just created using **Notepad** or another text editor. This is done by right clicking on the file and using the **Open With …** command.




```
 1
 0 , 1 ,1, 2, 2, 2, 1,0
 0.886  4.64 -13.32  14.72 -5.6  0
11271B,XX 10202-12,Ti-alloy, 400 ,Lab Air
C(T),, 112 , 0
 1972 , 0.7 , 0.45
,,
 0.2484 , 0.1995 , 0.7991 , 0 , 0 , 0.16
 0.28 , 0.21 , 404.566
 0 , 0 , 906.7465 , 10 , 760 , 0.1 ,,,,
Date of test: 1/01/2009
Waveform Type                    Sine
EOT
1,0,0,2541.88,763.06,399.2490,8699265
1,0,0,2426.89,728.04,400.5242,8703177

REST OF DATA NOT SHOWN

-1,,,,,,
```

16. Cut and paste the data lines into the [.in3] file, between EOT and the last line.
17. Save this file using **Save** as opposed to **Save As…**, which may change the file extension.
18. The recreated [.in3] file is now complete.

Appendix F: Saving Program Menus and Displays to a File

Any active menu or display may be saved to a file. This is especially useful for obtaining an image of the load-displacement or da/dN-delta K display.

1. Choose the active window to be saved.
2. Press **Alt - Prt Scrn**.
3. Open WordPad or Microsoft Word and select **Paste Special** under the **Edit** menu.
4. Respond **OK** to Device Independent Bitmap.
5. Use the file menu to print or save the image in another program such as Word.

Appendix G: Stress Intensity Solutions

The following stress intensity solutions are used by the FTA testing software. Terminology is defined first:

- Kmax maximum stress intensity (ksi sqrt(in)
- Pmax maximum load (lbs)
- B thickness (in)
- W width (in)
- AWK crack length/width
- AT crack length (in) (AT = AWK * W)
- Kcoeff(n) K coefficients for polynomial type of expression (compact tension for example)
- PI as in 3.1415929
- FAW f(a/w)

All K expressions use same form for FAW and same formula for K as follows:

Kmax = FAW * Pmax / (1000 * B * Sqr(W))

Polynomial (Type 1) Solution:

FAW = KCoeff(1) + KCoeff(2) * AWK + KCoeff(3) * AWK ^ 2 + KCoeff(4) * AWK ^ 3
FAW = FAW + KCoeff(5) * AWK ^ 4 + KCoeff(6) * AWK ^ 5
FAW = FAW * (2 + AWK) / ((1 - AWK) ^ 1.5)

Polynomial (Type 2) Solution:

FAW = KCoeff(1) + KCoeff(2) * AWK + KCoeff(3) * AWK ^ 2 + KCoeff(4) * AWK ^ 3
FAW = FAW + KCoeff(5) * AWK ^ 4 + KCoeff(6) * AWK ^ 5
FAW = FAW * Sqr(PI * AT) / Sqr(W)

Polynomial (Type 3) Solution:

FAW = KCoeff(1) + KCoeff(2) * AWK + KCoeff(3) * AWK ^ 2 + KCoeff(4) * AWK ^ 3
FAW = FAW + KCoeff(5) * AWK ^ 4 + KCoeff(6) * AWK ^ 5
FAW = FAW

Center Crack Solution:

FAW = Sqr(0.5 * (PI * AWK / 2) * (1 / Cos(PI * AWK / 2)))

Single Edge Crack Solution:

```
Term1 = PI * AT / (2 * W)
If Term1 > 0 Then
   Term2 = Sqr((1 / Term1) * Tan(Term1))
   Term2 = Term2 * (0.752 + 2.02 * AWK + 0.37 * (1 - Sin(Term1)) ^ 3) / Cos(Term1)
   FAW = Term2 * Sqr(PI * AT) / Sqr(W)
Else
   FAW = 0
```

Bend Solution:

```
FAW = 3 * Sqr(AWK) * (1.99 - AWK * (1 - AWK) * (2.15 - 3.93 * AWK + 2.7 * AWK * AWK))
FAW = FAW / (2 * (1 + 2 * AWK) * (1 - AWK) ^ 1.5)
FAW = FAW * SOW
```

Extended Compact Solution:

```
FAW = 3.97 - 10.88 * AWK + 26.25 * AWK ^ 2 - 38.9 * AWK ^ 3 + 30.15 * AWK ^ 4 - 9.27 *
      AWK ^ 5
FAW = FAW * (AWK ^ 0.5) * (1.4 + AWK) / ((1 - AWK) ^ 1.5)
```

Surface Crack Solution:

```
Term1 = Sqr(1 / Cos((PI * (AT / B) * (Sqr(AWK)))))
Term2 = (1.04 + 0.2071 * AWK ^ 2 - 0.1061 * AWK ^ 4) * Term1
FAW = Term2 * Sqr(PI * (AT / 2.464)) / Sqr(W)
```

SEN (Rigid) Solution:

```
Term1 = 1.1216 + 0.1103 * AWK + 1.9889 * AWK ^ 2 + 2.2911 * AWK ^ 3 -10.0095 * AWK
^ 4 +8.441 * AWK ^ 5
FAW = Term1 * Sqr(PI * AT) / Sqr(W)
```

Corner Crack Solution:

```
If AWK < 0.2 Then
      FAW = 1.16 * (2 / PI) * Sqr(PI * AT) / Sqr(W)
Else
      Term1 = 1.12 - 0.13 * AWK + 1.84 * AWK ^ 2 + 0.11 * AWK ^ 3 + 0.8 * AWK ^ 4
      FAW = Term1 * (2 / PI) * Sqr(PI * AT) / Sqr(W)
```

Acknowledgement
Thanks to Pete Blair for the ADwin art