User's Guide

Agilent PDQ-AT™ revision 1.01

Agilent Technologies

E3186-90000

January 2000

Legal Notice

The following are copyright notices of the software distributed with PDQ-AT.

GNU Software Use

PDQ-AT relies on Aladdin software for converting Postscript output into PNG and PDF formats. GNU Sort utility was downloaded from a mirror of *http://www.gnu.org* compiled without modifications on HP745/HP-UX 10.20 workstations.

GNU Sort is stored in */opt/AT/bin/sort_st*. Sandia Technologies makes no representation that any modification has been done or is required of this utility. Because many of our clients already use GNU Software, the name change from sort to sort_st is provided only as an aid to the system administrator.

Per GNU copyrights, Sandia Technology makes available the GNU textutils-1_22_tar.gz for a period of three (3) years from the initial release data of PDQ-AT. For distribution and copying costs onto 4 mm tapes, users desiring source code may contact Sandia Technology but are urged instead to visit *http://www.gnu.org* to find the latest versions of this and other UNIX utilities.

PNG and PDF conversion is performed by Ghostscript. This and it's dependent utilities were downloaded from the HP Porting and Archive Centre, which is mirrored internationally. One location is *http://hpux.cs.utah.edu*.

All depots in the Ghostscript set were downloaded in binary form and distributed without modification per terms of the Aladdin Ghostscript Free Public License. For this component, please visit the above site where binary and source versions are located.

All copyrights noticed by Sandia Technologies for the depots required to support Ghostscript can be found in the various */opt* areas for these components.

In order to ensure full disclosure, Sandia Technologies has provided copies of said statements in */opt/AT/copyrights* and in the following paragraphs.

Tcl/Tk was used in the construction of PDQ-AT. Interested parties may contact Sandia Technologies or visit *http://www.gnu.org* for the Tcl/Tk source code (conditions similar to those stated above for the sort utility).

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tkhtml.tcl Version 1.5

This code is based on Angel Li's (angel@flipper.rsmas.miami.edu) HTML rendering code.

Aladdin Ghostscript

Other Notices

Postscript Printing Language was developed by Adobe Systems Incorporated.

The executable graphics file is a Korn-shell script which invokes the University of California at Berkeley X11 utility, xgraph, written by David Harrision.

This software is based in part on the work of the Independent JPEG Group.

Printing History

Edition	Date	
First	April, 1999	for Revision 1.00
Second	January, 2000	for Revision 1.01

Contents

1 Introduction to this Guide

Introduction to this Chapter

This chapter discusses the documentation conventions used within this book and introduces some basic graphic user interface skills and concepts. Specifically, it shows how to recognize a command within a procedure and how to use the mouse.

Those already familiar with window interfaces may not need this chapter.

Documentation Style

In this document, the use of font styles, such as **bold** and *italics*, helps explain concepts related to PDQ-AT.

bold : bold demonstrates window names or file menu commands. For example:

The **PDQ-AT Filter/Sort window** appears.

Select **File > Working List**.

bold italic : bold italic letters demonstrate words or letters you type in or specific computer concepts. For example:

Login to the system as ***root***.

Type ***1.5E+30*** in data variable field.

italic : italic letters demonstrate file names or parts of file names.

...any file that doesn't end with *.dat* (a dataset) or *.plt* (a plot history).

> : When used within a sentence, this is an indicator to "select and drag" with the mouse. For example:

Select **File > Opened Lists**.

Introduction to a Graphics User Interface

If you are new to working on a computer system using a graphic user interface and a mouse, this section will help you develop the beginning skills necessary to use PDQ-AT.

The graphic user interface (GUI, often pronounced "gooey") uses a graphic inside a window and a mouse instead of the keyboard and command lines.

Using the Mouse

Learning how to use the mouse is an exercise in eye-hand coordination, similar to typing. As you grow accustomed to the mouse, you will become faster and begin to recognize repeated hand-finger patterns.

Mice for HP-UX 745/132L Series Workstations have three buttons. Primarily you will use the left button, which your index finger is rests on, for most of the interface. The other two buttons in PDQ-AT also have special assignments. Whenever this document reads *click*, *click-hold*, or *click-drag*, it is referring to the left mouse button. If no other button is indicated, use the left button.

Reference	**Mouse action**
click	Click with the left mouse button.
middle-click	Click with the middle mouse button.
right-click	Click with the right mouse button.
click-drag	Hold down the mouse button while moving the mouse.
double-click	Click twice rapidly with the left mouse button.

Note:
Whenever this document reads *click*, *click-hold,* or *click-drag*, it is referring to the left mouse button.

On every screen except inside the Plot Frames, the right mouse button raises the Online Help screen. For more information on Online Help, see “Getting Help in PDQ-AT” in section 4.3, p. 59.

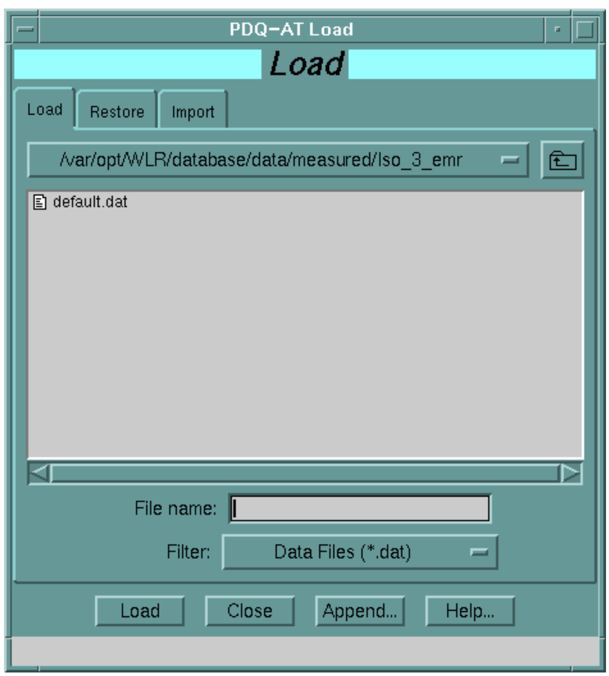
Whenever you move the mouse, the mouse icon moves on the screen. Moving the mouse forward and to the left will move the mouse icon up and to the left.

Mouse Button vs. Screen Button

Places to click on the screen are drawn as and referred to as buttons. In the HP-UX/CDE window manager, the window frame has buttons assigned to iconify and close (see figure 1.0-1 for an example window).

This document refers to mouse buttons as click, middle-click and right-click. The word “button” is reserved for a button in a window.

Figure 1.0-1 **A Sample Window**



Buttons, Tabs, Menus, Pulldowns and Popups

In figure 1.0-1 above, the boxes labeled **Load, Close, Append...**, and **Help...** are buttons. The areas labeled **Load**, **Restore**, and **Import** are tabs that activate the window options.

When the mouse icon moves over a button, the button lights up. In this document, we tell you to *click*, *middle-click*, or *right-click* using the left, middle, or right mouse button respectively on a button.

A pulldown menu is similar to a button except when you click on it, a menu of options become available. Use your mouse to click on the menu button (the **File** menu on the PDQ-AT Main window, for example), then pulldown to the option you desire. Click again on the option.

In this document, we tell you to *select* ***menu name > option name*** to activate a pulldown menu. For example:

To activate help topics, select **Help > Topics**.

A **pop-up menu** is like a button, except when you click on it, a small menu pops up for you to select one out of several options. Unlike the pulldown, though, you will have to click with the left mouse button, keep the button held down, and drag the mouse icon to the desired option.

In this document, we tell you to *click-drag* ***menu name > option name*** to use pop-ups. For example:

To open a specific directory, click-drag **directory > /opt/WLR/database/data/measured**.

Text Field

Text fields are “boxes” in which you can type. Clicking within the field activates it, allowing you to type inside it. In figure 1.0-1 above, next to the words "File name" is a text field.

Editing Text

When editing text, do not use the delete key; PDQ-AT requires you to use the backspace key. Alternatively, you may click-drag the mouse icon over the text you wish to change and begin typing. The selected text is automatically replaced with the newly typed text.

Directory Browser

Many windows include the directory browser, which lists names of files and directories. Files are indicated by an white rectangular icon that appears as if text were written on it. If you are in a load, restore, or import window, double-clicking on the file will perform the load function.

Directories appear as yellow folders. By double-clicking on the folder, the directory opens that folder and lists the contents within.

Note:
If you are unfamiliar with GUI's, don't be afraid move slow. With familiarity comes speed.

Learning the GUI

If you are unfamiliar with GUI's, don't be afraid move slow. You are literally teaching your body how to move, much like riding a bicycle. Work on the basics first, such as clicking — you will pick up speed later.

Keyboard Shortcuts

Another feature to the PDQ-AT interface are the existing keyboard shortcuts. If there is a keyboard shortcut available for a menu command, the letters *Ctrl* appear followed by a plus symbol (+) and another letter, for instance **Ctrl+L**. To use this command without using the mouse, type the ending letter while holding down the control button, just as if you were trying for a capital letter using the shift button. For example:

...to load datasets in PDQ-AT, press **Ctrl+L**.

Tear-away Menus

PDQ-AT uses tear-away menus to help customize the appearance of plots and the PDQ-AT interface. At the top of a tear-away menu, you will see a series of dotted lines. When you select the dotted line, as you would select an option from the menu bar, the menu itself transforms into a window.

Figure 1.0-2 **A sample tear-away, before...**

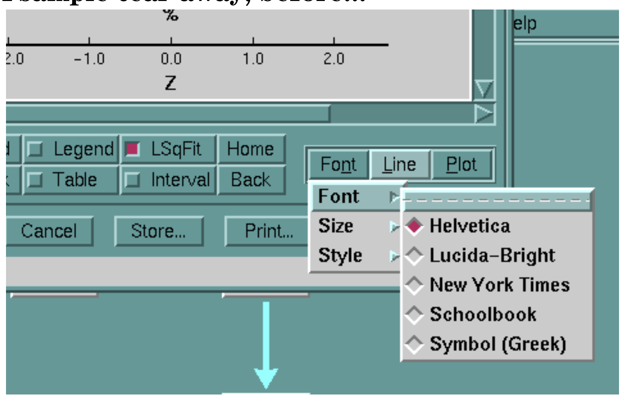


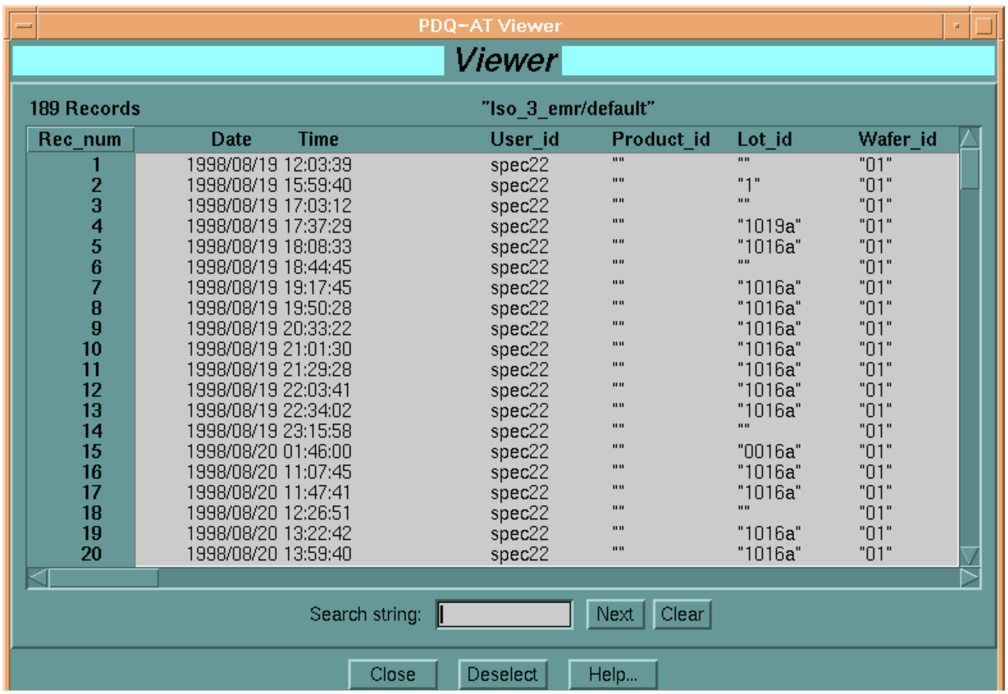
Figure 1.0-3 **...and after**

Once it has become a window, you can use the options right from this new window without having to access the pulldown menu.

Scroll Bar

Scroll bars allow you to scroll information too big to fit inside a window. To scroll the information up, down, left, or right, use the scroll bars to the right and bottom of the window.

Figure 1.0-4 **The PDQ-AT File Viewer window scroll bar**



Clicking on the arrows also moves the information in the direction of the arrow.

Click-dragging on the scroll tab allows you to drag the information to the location you desire.

Iconifying a Window

In the plot frames, PDQ-AT includes a button titled **Iconify**: when clicked, the frame seems to disappear. The frame has become ***iconified*** on the PDQ-AT Main window. For more information about the PDQ-AT Main window and iconifying, see “Overplotting” in section 6.2, p. 184.

Note to Users Familiar with CDE

If you are already familiar with common desktop environments (CDE), you may know other ways to iconify a window. Don’t use these, since there are options when plotting data available within PDQ-AT that makes iconify special.

2 Installation

Introduction to this Chapter

In this chapter, you will learn the minimum requirements of your computer system needed for PDQ-AT, how to install PDQ-AT and configuring your system. Included is a procedure for installation, sample errors, troubleshooting, and the README file containing the latest information.

This chapter includes information on:

- A requirement checklist for installation
- Distribution media
- Installing
- Configuring your system
- Software key
- Installation errors
- README
- Troubleshooting

Requirements Checklist

The following are required before installing or updating this product:

Hardware Requirements

- HP 745/132L Series Workstation
- CD-ROM Drive to load software
- 19 MB free disk space (of which 7.5 MB are transient storage used during the installation process)

System Software Requirements

Note: the following software must be installed and configured before loading.

- HP-UX 10.20
- Agilent PDQ-WLR 2.00 or later

Other Software Requirements

PDQ-AT assumes and depends on the following to acquire and analyze data.

- The data feed comes from PDQ-WLR
- A print spooler is available via the operating system
- 100 dpi X11 fonts are available on the target host

PDQ-AT runs in an HP-UX 10.20 environment with PDQ-WLR data. Nothing prevents users from populating PDQ-WLR data structures with foreign data for use with PDQ-AT. PDQ-AT provides an import function (see “Importing a File” in section 4.4, p. 72).

Distribution Media

Media Types

PDQ-AT is distributed on CD-ROM.

Formats

The distribution media are available in ***HP-UX 10.20/swinstall*** format.

Product Identification

Regardless of the distribution media, the installation product identifier is ***PDQ_AT***. Performing a backup of the target system is strongly recommended before proceeding with any new software installation or upgrade.

Procedure

Installing PDQ-AT

1. Login to the system as *root.*
2. Ensure that neither HP BASIC processes nor Agilent SPECS is running before beginning the installation.
3. Performing a backup of the target system is strongly recommended before proceeding with any new software installation or upgrade.
4. Select an open *dtterm* window.
5. Insert the media into the appropriate drive on your HP workstation.
6. Ensure that the /SD_CDROM mountpoint exists, by typing: *ls -d /SD_CDROM*. If it does not exist, create it by typing: *mkdir /SD_CDROM*
7. Mount the distribution:
   mount -r -F cdfs /dev/dsk/<device_name> /SD_CDROM
8. In the *dtterm* window, enter the command ***swinstall*** to bring up the graphical user interface for the installation process.
9. ***swinstall*** will automatically present a selected window called *Specify Source.*
10. The first selection at the top of the window is labeled **Source Depot Type:** and next to it is a selection button. Use a single left-button mouse click on the selection button to present the depot type menu.
11. Select **Local Tape**.

12. Type */SD_CDROM/PDQ_AT.UPD;1* as the **Source Depot Path...**
13. Click on the **OK** button to complete the source selection.
14. Note that there is one line with the product named ***PDQ_AT*** in the *SD Install - Software Selection* window.
15. Select the line with a single left-button mouse click. The line will be highlighted to indicate that the product is selected.
16. Select the *Action* menu from the menubar, and choose *Install (Analysis)*.
17. The *Install Analysis* window is presented.
18. Click on the **Disk Space...** and **Logfile...** buttons to bring up windows to verify that the target filesystems have sufficient capacity and that the Logfile shows no errors or warnings. Close the *Disk Space* and *Logfile* windows when finished reviewing the data.
19. Click on the **OK** button in the *Install Analysis* window to proceed; or on the **Cancel** button to stop if errors or warnings appeared. Note that the disk usage analysis will be inaccurrate; see “System Changes” on page 18.
20. If installation analysis was successful (you selected **OK**), press the **Yes** button in the *Confirmation* window.
21. While the installation proceeds, select the **Logfile...** button in the *Install Window* to monitor the progress of the installation. Drag the *Logfile* window if needed so that the *Logfile* window and the *Install Window* are visible at the same time.
22. The installation is finished when the **Done** button in the *Install Window* is selectable. Confirm that there are no errors or warnings in the *Logfile* window.
23. Click the **Done** button in the *Install Window.*
24. Select the *File* menu from the menubar of the *SD Install - Software Selection* window, and choose *Exit.*
25. Unmount the distribution media by typing: *umount /SD_CDROM*.
26. The installation is complete.

The installation is complete. Proceed to “License Administration with PDQ-AT” in section 8, p. 197.

System Changes

The following list are the changes made to your system when installing. PDQ-AT requires all of these files to operate properly.

Package Name	Directory	Kilobytes
gs-5.10	/opt/gs-5.10	3816
gs_f_other-5.10	/opt/gs_f_other-5.10	1519
gs_f_std-5.10	/opt/gs_f_std-5.10	2212
	total	7547

These packages are carried as depots internally in the PDQ-AT software depot. The swinstall analysis phase will give incorrect results for this installation. Add the total above to the analysis-phase */opt* usage reported by swinstall.

Systems Configuration

When running PDQ-AT, using the following CDE system configurations is the most compatible. On the CDE Toolbar, open the Style Manager — Window and set the following:

Click in window to make active.

Raise window when made active.

Allow primary windows on top.

Installation Errors

There are some special points to consider when installing this product.

The PDQ-AT distribution includes a number of free utilities.

These utilities are bundled into the PDQ-AT distribution and automatically installed during your swinstall session. Because these are ***swpkg***'ed depots within depots, ***swinstall*** cannot give you an accurate analysis of the disk space that will be needed to complete the installation. As shown in "System Changes" on page 18, more than 7.5 megabytes in */opt* will be consumed than that reported by the swinstall analysis phase. The extra depots are copied into */var/tmp*, installed and then removed during the install execution phase. So, the disk consumption report for */var* is accurate for the installation, but its value is transient because the additional depots are removed following the installation.

If you attempt to install with insufficient free space in /opt, you will have to remove the installed depots using ***swremove***. Refer to "Troubleshooting" in section 2, p. 22.

Always refer to the */opt/AT/notes/README* file for the latest information with any PDQ-AT distribution.

README

PDQ-AT is shipped with special README files in the */opt/AT/notes* directory. Consult these files whenever installing or upgrading PDQ-AT. The *Special_Notes* file found in this area can be viewed at the beginning of the installation, using ***swinstall***, by clicking on the **Description** button. All README files can be accessed by ***swinstall*** by clicking on the **README** button.

Troubleshooting

Trouble may ensue if you don't have the 7.5+ MB in */opt* for the additional utilities (see "System Changes" in section 2, p. 18). If you need to remove the PDQ-AT installation to re-install with more space dedicated to */opt* (using HP-UX LVM utilities) refer to the *swinstall.log* file for the list of depots installed during the PDQ-AT swinstall session.

This version of PDQ-AT includes a special test file that you can use to verify the installation.

In general, the steps you may take to test your installation are:

1. Complete your License Key installation as ***root***. See "License Administration with PDQ-AT" in section 8, p. 197.
2. Login as a normal user, with a ***$HOME*** area defined.
3. Execute ***/opt/AT/bin/pdqat*** at your command prompt.

   You may wish to put */opt/AT/bin* into your default path. Your system administrator can assist you with this.
4. Import */opt/AT/test/at_test.csv*.

   See "Importing a File" in section 4.4, p. 72. A good algorithm name is ***at_test***.
5. Click on the **Analysis** button in the main window.
6. Click on the **Activation Energy** tab in the analyze window.
7. Click on the **Plot** button. Use the built-in defaults for your Activation Energy analysis inputs.

If the plot frame activates, you have installed PDQ-AT correctly.

Optional steps:

8. On the plot frame, click the **Print** button.
9. If you have a PostScript printer, you can send output directly to your printer.
10. Print the output to a PNG or PDF file.

General Error Trap

A general error trap indicates that PDQ-AT is unable to satisfy an analysis request. This can happen for a number of reasons, but generally it occurs when one of the following happens:

1. The selected data had an infinite slope, or you attempted to take the log of a negative value.
2. Imported data was corrupted.
3. The database was corrupted during a system crash.
4. You lack sufficient privileges for directory or file access.

PDQ-AT pre-calculates a number of critical constants when beginning an analysis. If your data creates a line perpendicular to the reference axis (infinite slope), a divide by zero will occur. View the dataset to see if your selected data fits this case; if so, re-select your input.

If you are having trouble with imported data, you may wish to view the original *.csv* file with a text editor. Things to look for are partial records and string data in columns you specified were numerical. If this has occurred, correct the errors and re-import the data.

If you suspect a database file was corrupted, copy the file to a *.csv* file (e.g. *cp default.dat /tmp/default.dat.csv*), and inspect the file using any tool that recognizes *.csv* files, such as a spreadsheet. If partial records or corrupted fields appear (i.e., text in numerical columns), correct the file, re-save it, and then copy to the algorithm data area with a new name (e.g. *cp /tmp/default.dat.csv default_fixed.dat*).

PDQ-WLR and PDQ-AT automatically create files and directories with the correct user permissions, but these can be changed by users from the HP-UX command line. Your system administrator can help you fix permission problems. This sort of problem can occur if you import data to a restricted NFS-mounted disk, for example.

"glob" Message in the General Error Trap

Sometimes PDQ-AT will not allow users to load new files, displaying a "glob" message. PDQ-AT is designed to integrate with PDQ-WLR data. As shipped, PDQ-AT expects to find its data in the */var/opt/WLR/database/data* area. PDQ-AT does this with a combination of two actions: reading the */var/opt/AT/local/.datapaths* file and by reading the *.pdqatdefaults* file. The *.datapaths* file is shipped with a single entry, as follows:

```
/var/opt/WLR/database/data   /var/opt/WLR/database/data
```

This line tells PDQ-AT that the */var/opt/WLR/database/data* area is local. Each line in this file is formatted as:

<algorithm data area store> <algorithm control area store>

For a workstation running PDQ-AT accessing the test workstation's PDQ-WLR data via NFS, there are two solutions available. For illustration purposes, we will refer to the test workstation as 'test745' for the hostname in explaining the two solutions available.

- Suppose that the PDQ-AT workstation has NFS access to the test745 var filesystem with */mnt/test745_var* as the NFS mountpoint.

Solution 1: The best approach for most installations.

1. Shutdown all PDQ-AT processes.
2. Create a */var/opt/WLR* directory, with full world access, on the PDQ-AT workstation.
3. Link to the test745 as follows:

```
ln -sf /mnt/test745_var/opt/WLR/database /var/opt/WLR/database
```

PDQ-AT will recognize */var/opt/WLR/database/data* as if it were a part of the local filesystem.

Solution 2: This alternative is used when the system administrator policies at the using site do not allow for creating additional links to NFS filesystems as shown in Solution 1. (This is rare, but does happen.)

1. Shutdown all PDQ-AT processes.
2. Edit */var/opt/AT/local/.datapaths* to add the following line after the */var/opt/WLR/database/data* entry:

```
/mnt/test745_var/opt/WLR/database/data   /mnt/test745_var/opt/WLR/database/data
```

   This tells PDQ-AT that the */mnt/test745_var* is a valid NFS mountpoint to access the data at */opt/WLR/database/data*. The two parts of the entry simply say that algorithm data and database-controlled data are in the same area.

3. Start PDQ-AT from the PDQ-AT user's account.
4. Begin by selecting **User** preferences from the Prefs pulldown menu.
5. Select the **Misc** tab.
6. Select the new */mnt/test745_var*... area as the new Data Path preference.
7. Save the new preference, which will update the *.pdqatdefaults* file.
8. Close the User Preferences window.

PDQ-AT will now recognize the NFS mounted filesystem as the preferred path for all operations.

** A special note to the system administrator: Due to the use of relative paths, the lowest NFS mountpoint for using PDQ-WLR data is */var/opt/WLR*. We recommend mounting directly to /var so that the PDQ-AT can see the familiar */var/opt/WLR/database* structure when using PDQ-AT, but lower mountpoints are allowed, to the stated limit of */var/opt/WLR*.

NFS - */var/opt/WLR* Mapping Problems

PDQ-WLR users have a great deal of flexibility in specifying the placement of their database, Xgraph, and CSV files. Xgraph, CSV, and Hot Carrier test link data are always written to the */var/opt/WLR/database* area. When PDQ-AT attempts to read data from locations other than */var/opt/WLR/database*, it cannot tell whether users have exercised PDQ-WLR's built-in flexibility, or if the user is really asking for data over an NFS mount, or both. During execution, PDQ-AT asks users to resolve the path to */var/opt/WLR/database* on the actual machine where the data is located. Occasionally, a user will mis-type the correct NFS path to the target */var/opt/WLR/database* area, or specify an NFS path when the target is actually local. PDQ-AT remembers these entries, and has no way to re-prompt for the correct data. If the NFS-mounted data is not being linked correctly, then the system administrator is required to edit the */var/opt/AT/local/.datapaths* file. Its internal structure is identified in the "glob" Message in the General Error Trap above.

File Loading Problems - File Busy

PDQ-WLR and PDQ-AT will manage access to algorithm database area files by directory locking. In the event of a system failure, a stale directory lock may be left behind. This will be evidenced by a dialog window during the Load phase that informs you that a file is in use when no other users (PDQ-WLR or PDQ-AT) are actually using the system. The problem is easily fixed. The lock owner or the system administrator simply needs to remove the *.lock* file in the offending area, usually */var/opt/WLR/database/data/measured/<algorithm_name>*.

The same problem can occur with the .datapaths file in /var/opt/AT/local.

TIF File Options

Not all compression types are supported by applications that claim to read TIF files. If the TIF image is unreadable or creates an application error, try LZW compression. If all else fails, use no compression. Note that a simple plot may only be about 250 kbytes when one of the compression schemes are used; the same file will easily expand to 5 Mbytes uncompressed.

Because of this, GIFs are recommended wherever the target application can support them, as an alternative to TIFs.

To change the TIF configuration for PDQ-AT, as root, edit */etc/opt/AT/tif.config*. Uncomment (delete the # before the entry) the option that fits your needs. Do not forget to comment the previous configuration.

Color Problems

You can get strange colors and shadows if you change your colors from the User Prefs utility while you have active plot frames, either on-screen or iconified. This is normal. This is due to the way the operating system window manager controls the color palette for all process. To correct the problem, change your color preferences at the beginning of the PDQ-AT session.

You may also occasionally get startup warnings indicating that some colors are not available for the application. This is normally the case when you have other color-intensive applications, such as Help or a web browser, which consume a large number of resources. To correct the problem, exit those applications.

Non-Repeatable General Error Traps

If you are very adept at using a mouse and attempt to do several things at once, you may occasionally set a General Error Trap dialog, but be unable to re-create the problem. This is normal. On every windowing system you have used, you have had experiences when you clicked the mouse and nothing seemed to happen. Some users believe that either they didn’t really click, or clicked just outside the button, etc. These explanations are often false. What happens in many cases is that the window manager or operating system was busy and could not keep up with the event queue. PDQ-AT is much more robust than other programs you may have used. When a request cannot be serviced immediately, PDQ-AT routes you the General Error Trap because PDQ-AT manages *everything* it can in your environment. The PDQ-AT developers were able to create this problem by opening 100 files and displaying 150 plot frames while rapidly double-clicking a button that required a single click. You needn’t have a load this heavy for the problem to occur; it’s really up to your particular system and the state that it’s in when you click something very quickly. This problem is *very* rare but it does happen. When this occurs, PDQ-AT is not broken; proceed as if nothing happened.

History Files

PDQ-AT stores history information under */var/opt/AT/history* in files named *.history.<process_id>*. These files are for field maintenance only, and are of use to Sandia Technologies, Inc. only in the event that you have some analysis problem that is hard to duplicate outside of your environment. The system administrator is free to set up a ***cron*** job to remove these files.

License Key Problems

If you are running PDQ-AT on a system that has never run Agilent SPECS you may experience License Key problems. See /opt/AT/notes/README.LicenseKey for details and solutions.

3 Software Design

Introduction to this Chapter

This chapter explains the PDQ-AT process of analyzing WLR data, beginning with why PDQ-AT is a necessary tool, comparing and contrasting PDQ-AT and PDQ-WLR, a generalized explanation for using PDQ-AT, and storing the output from PDQ-AT.

Subjects covered in more detail are the analysis objectives, using the CSV and Xgraph files created by PDQ-WLR, compatibility with other programs, an overview of the PDQ-AT process, plotting, and constraining data. The final section of the chapter explains the many ways to save the data analysis created.

Purpose of PDQ-AT

PDQ-AT is a statistical post-processor and data visualization tool for PDQ-WLR data. PDQ-AT is a single executable program designed to run under the HP-UX 10.20 operating system with a graphic user interface. PDQ-AT allows the user to select data from specific tests, perform statistical analysis, and has sophisticated methods to allow the user to remove anomalous data from final analyses.

PDQ-AT produces presentation-quality graphics on color or black and white Postscript printers, and can be used to export WLR data to other database or analysis tools.

PDQ-AT supports multiple users acessing networked data and can import or export data.

Analysis Operations

PDQ-AT supports the following operations on PDQ-WLR data:

- Sort, filter and extract data
- Allow users to create analyses using a data calculator with scientific functions
- XY plots with least squares fit (LSqFit)
- Log Normal Cumulative Distribution Function (CDF) plots with LSqFit
- Normal CDF with LSqFit
- Weibull distribution with LSqFit
- Extreme Value distribution with LSqFit
- Histogram with normal probability density function (PDF) overlay plots
- Full color wafer map plots
- Electromigration (EM) activation energy analysis with lifetime prediction plot
- Hot carrier (HC) lifetime analysis plot with lifetime prediction plots
- Confidence bounds (upper, lower, both) for all plots with LSqFit
- Statistical Process Control with trend charts

Other related objectives are the ability to easily and quickly perform the above analyses with a minimum of data manipulation. With PDQ-AT, users gather PDQ-WLR data and can transform the data into a plot or an easily exported file.

PDQ-AT vs. PDQ-WLR

The key difference between PDQ-WLR and PDQ-AT is that PDQ-WLR creates the data where PDQ-AT allows users to analyze and visualize the data.

PDQ-AT is designed to be run as a post-test statistical calculator to aid in the analysis of production, development and qualification of test data. PDQ-AT is not designed to be a real-time process monitoring tool. Instead, PDQ-AT can analyze data whenever the user believes there exists a sufficient amount of test data for analysis.

Thus, PDQ-AT can be used at the same time PDQ-WLR is running, but the user is responsible for retrieving new data updates. Running PDQ-AT at the same time as other software does have risks; real-time control software may lose control-timing precision when other CPU intensive tasks are running.

Output Data Hierarchy

PDQ-WLR creates the following areas under the /var file system during its installation; all directories are set to rwxrwxrwx permissions.

```
/var/opt/WLR/inputs:
                Used to store the input file for the ALL_HCI sample
                hot carrier program.

/var/opt/WLR/database:
/var/opt/WLR/database/data:
                All PDQ-WLR output data is managed under this path.

/var/opt/WLR/database/data/hci:
/var/opt/WLR/database/data/hci/all_hci:
/var/opt/WLR/database/data/hci/all_hci/lifetime_ptr:
/var/opt/WLR/database/data/hci/all_hci/stress_ptr:
/var/opt/WLR/database/data/hci/stress_tables:
                Used by the HCI_3_MOS, via HC_LINK_2_MOS, to associate
                stress data, measurement data, and lifetime data from a hot
                carrier test.

/var/opt/WLR/database/data/measured:
                This is the default area for the PDQ-WLR algorithms'
                database tables. Each algorithm will create a new
                subdirectory, using its own name, below this path,
                whenever the algorithm is run for the first time with
                the database recording set on. For example, after the
                first execution of ISO_4_EMR with the default database
                recording conditions set on, the user will find the
                following subdirectory:

        /var/opt/WLR/database/data/measured/Iso_4_emr:

/var/opt/WLR/database/data/csv_files:
                All CSV files are located here, either as actual files,
                or as links to user-specified file names.

/var/opt/WLR/database/data/graphs:
                All executable graphics files are located here, either as
                actual files, or as links to user-specified file names.

/var/opt/WLR/database/data/eps_save:
                When you print to an EPS, PNG or PDF file, the default path
                is this directory.
```

```
/var/opt/WLR/database/wmap:
                All wafer maps created by the Define Wafer action in PDQ-AT
                are saved here.

/var/opt/WLR/database/history:
/var/opt/WLR/database/local:
/var/opt/WLR/database/config:
/var/opt/WLR/database/data/derived:
                The four directories above are reserved for future PDQ
                product use.

/var/opt/WLR/database/database/data/attrib:
                Location of algorithm attributes used by plot legends an
                SPCs.

/var/opt/WLR/database/database/data/plt_save:
                Location of restore (.plt) files.

/var/opt/WLR/database/database/data/export:
/var/opt/WLR/database/database/data/import:
                Both directories above exist for the convenience to users
                to move files to and from a PC network.
```

CSV and Xgraph Files

As specified by the user, PDQ-WLR will create comma separated values (CSV) file and executable graphic (Xgraph) files. If either CSV or Xgraph files are present, users can use PDQ-AT to view their data in an Xgraph plot, and save or print an EPS file.

For more information on CSV and Xgraph files generated by PDQ-WLR, see Chapter 2 in the **PDQ-WLR Software User's Guide**.

Extraction and Compatibility

PDQ-AT output is designed to be compatible with operating systems outside of HP-UX, especially spreadsheet programs. It also supports ASCII standards.

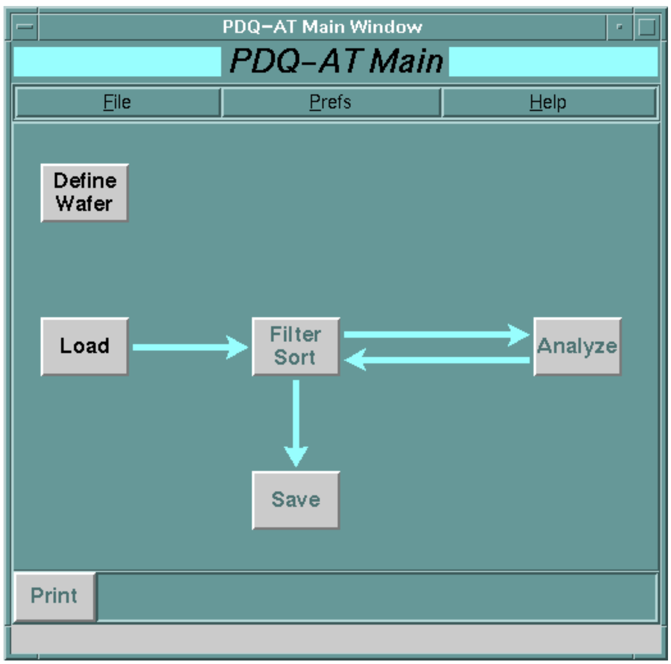
Printing and Print Files

PDQ-AT outputs presentation-quality graphics as EPS, PNG and PDF files.

Using PDQ-AT Overview

PDQ-AT is designed as a flowchart of the analysis process. From left to right, you begin by loading the data, preprocessing the data (sorting and filtering), performing the statistical analysis, then visualizing the data via a plot. Anywhere during this process you may save the current data, the plots created, or the steps taken to create the current data.

Figure 3.0-1 PDQ-AT Main window



Step 1: Loading Data

To work with a dataset, you first need to load it. Those familiar with the common desktop environment will recognize the load window. If you are unfamiliar with using a mouse and graphic user interface, please view the procedure in “Loading Data” in section 4.4, p. 63.

Step 2: Filtering and Sorting Data

Filtering dataset is a process of building a filter expression and applying it to the dataset. Filter expressions are created from relational logic operators and boolean clauses. More information on filtering data is available in “Filtering Data” in section 4.5, p. 75.

Sorting dataset is a process of selecting which data variables you desire to sort by and whether you want the dataset in ascending or descending order. For more information, see “Sorting Data” in section 4.6, p. 85.

Step 3: Analyzing Data

Your PDQ-AT output depends greatly on why you are performing the analysis. PDQ-AT allows you to perform a wide-range of analyses and plot the results, and save the results as new files. PDQ-AT also has intelligent plotting, allowing users to evaluate the integrity of data and constrain the data as necessary.

For those using PDQ-WLR's EM and HC algorithms, PDQ-AT performs lifetime prediction analysis. The procedures for these analyses are presented in "Analyzing Data" in section 5, p. 107.

Step 4: Plotting Data

Once you have chosen your analysis, plotting and overplotting data is performed by one click of a button. Visualization choices include varying the distribution types and customizing the line width, color, point and symbols. For more information, see “Choosing a Plot Analysis” in section 5, p. 109.

Intelligent Plots and Constraining Data

All plots other than lifetime predictions, CSV’s and Xgraph are interactive - you can choose specific data points and examine the data. Thus if a point doesn’t conform to an expected norm, you’re able to view the raw data to understand why and decide if the data is in error.

Lifetime Predictions

For the specialized EM and HC datasets, PDQ-AT can create lifetime predictions. For Activation Energy Lifetime Predictions, see “Activation Energy Lifetime Prediction Procedure” in section 5.5, p. 140. For Hot Carrier Lifetime Predictions, see “Carrier Lifetime Prediction Procedure” in section 5.6, p. 149.

Output: Saving, Exporting, Storing, and Printing to a File

PDQ-AT has multiple ways of generating output from a dataset. Users can save a dataset in a new format, append like datasets, store the history of an analysis, and print an analyzed dataset to an EPS file. Chapter 4, "Using PDQ-AT," handles the procedures for outputting data.

4 Using PDQ-AT

Introduction to this Chapter

Chapter 4 explains how to use PDQ-AT basic functions, such as starting, getting help, loading data, sorting, filtering, importing, and exporting data.

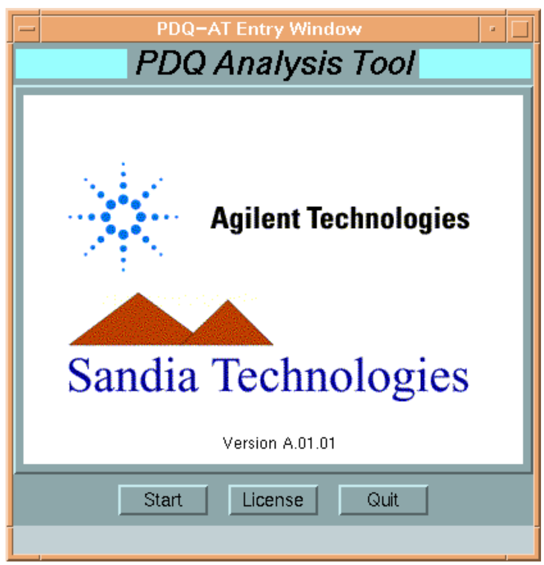
Every tool and step has a procedure with its use. If you can, work hands-on with PDQ-AT on your computer as you read these chapters. You'll learn a lot in a very short time.

4.1 Starting PDQ-AT

Open PDQ-AT by typing ***/opt/AT/bin/pdqat*** at the UNIX command prompt. The PDQ-AT Entry window opens with three options: PDQ-AT, License and Quit.

You may wish to put */opt/AT/bin* into your default path. Your system administrator can assist you with this.

Figure 4.1-1 PDQ-AT Entry window



PDQ-AT

Clicking the **Start** button launches the **PDQ-AT Main window**. Click here to perform PDQ-AT tasks and analyses.

License

Clicking the **License** button launches the PDQ-AT License window. Here is where PDQ-AT performs license key administration tasks.

Quit

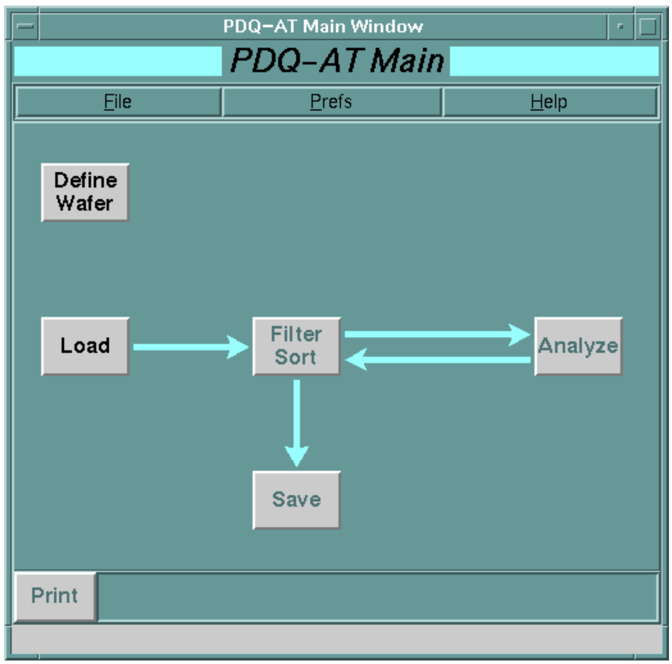
Clicking the **Quit** button quits PDQ-AT.

4.2 PDQ-AT Main

The PDQ-AT Main window is where all analyses begin. The window is designed as a flowchart, showing you the PDQ-AT analysis process and what options are available.

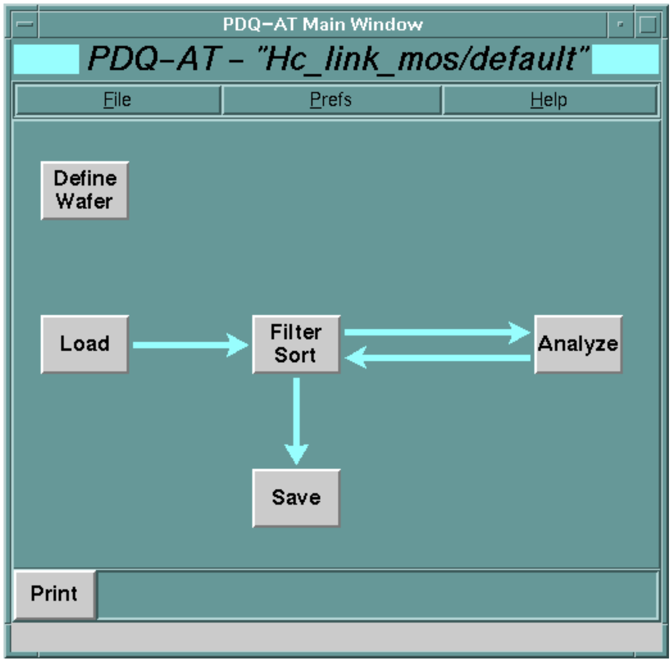
When the PDQ-AT Main window is first opened, the only buttons that are darkened are **Define Wafer** and **Load**.

Figure 4.2-1 PDQ-AT Main window before a dataset is loaded



When first opened, the PDQ-AT Main windows has several grayed-out buttons, indicating no datasets have been loaded. Once a dataset is loaded, the PDQ-AT Main window darkens all the buttons you are able to use.

Figure 4.2-2 **PDQ-AT Main window after a dataset is loaded**



Note:
The PDQ-AT Main window title changes to the name of the active working dataset when you load.

From the main window, PDQ-AT gives access to loading, filtering, sorting, analyzing, and saving data. Once plots have been made, you can also print the plots from the main window. The PDQ-AT Main window title changes to the name of the active working dataset when you load.

PDQ-AT Main Window Menus

At the top of the PDQ-AT Main window are three pulldown menus: ***File***, ***Prefs*** and ***Help***.

File Menu

Option	Description/Action
Load (Ctrl+L)	Opens the Load dialog box.
Working List	List of working datasets for this session.
View...	View the active working dataset. See “Viewing Your Data” in section 4.8, p. 97.
Xgraph...	Opens the Xgraph Browser to view Xgraph data.
New Session	Stops the current session and clears all working sets.
Start Over	Stops the current session, clears all working sets and returns PDQ-AT to entry window.
Quit (Ctrl+Q)	Quits PDQ-AT.

Prefs Menu

The only selection under this menu is ***User Preferences*** which opens the PDQ-AT User Preferences window. In this window, there are four choices: Window, Plot, Color and Miscellaneous.

Preferences allow you to customize the look and feel of PDQ-AT, the outcome of data, and how you view the data.

Note:
All changes are immediately implemented in the current session for all open PDQ-AT windows.

All changes are immediately implemented in the current session for all open PDQ-AT windows. Sometimes, redrawing the windows takes a couple of seconds. The windows may blink but no damage has been done to the system.

Clicking the **Close** button keeps the current preferences for this session only.

Clicking the **Save** button saves the current preferences and keeps these preferences for the next PDQ-AT session.

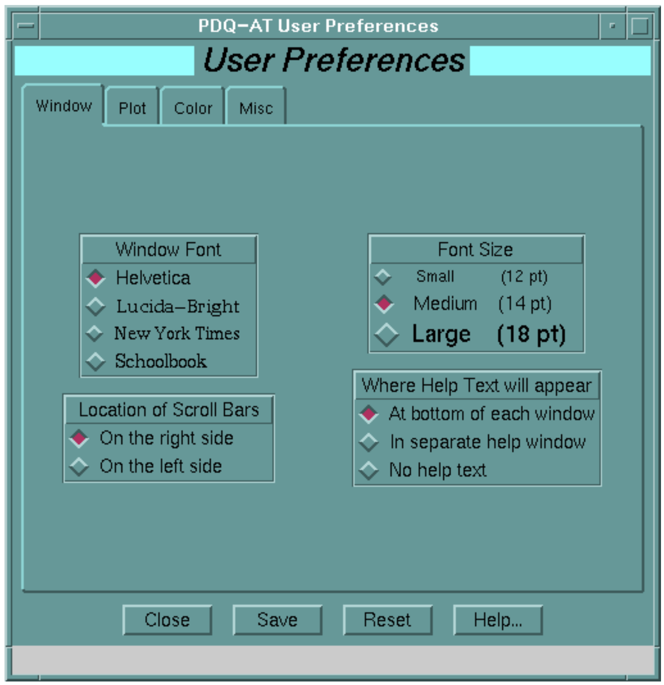
Clicking the **Reset** button clears the current preferences and restores the default preferences.

Clicking the **Help** buttons launches the Online Help feature. For more information on online help, see “Getting Help in PDQ-AT” in section 4.3, p. 59.

Window Preferences

The default window selection is the Windows preferences. From this window you may choose window fonts, font size, location of scroll bars and the location of help text.

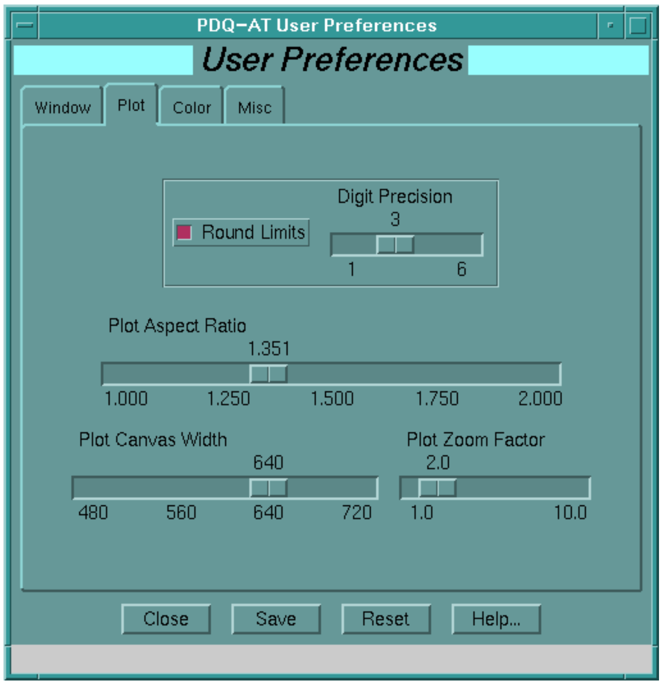
Figure 4.2-3 **PDQ-AT User Preferences for Windows**



Plot Preferences

In the Plot preferences, you can set the digit precision, the plot aspect ratio (golden ratio), canvas width, and setting the zoom factor.

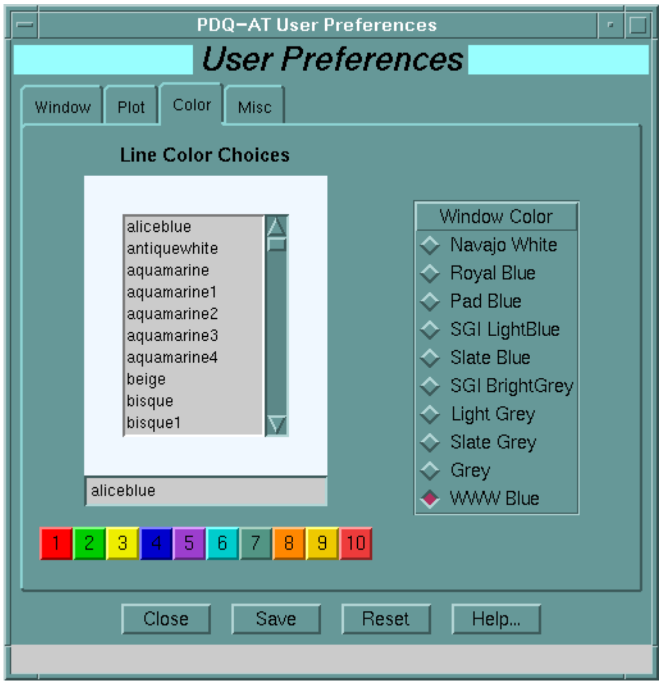
Figure 4.2-4 **PDQ-AT User Preferences for Plots**



Color Preferences

In the Color preferences, you can set the window and line color choices.

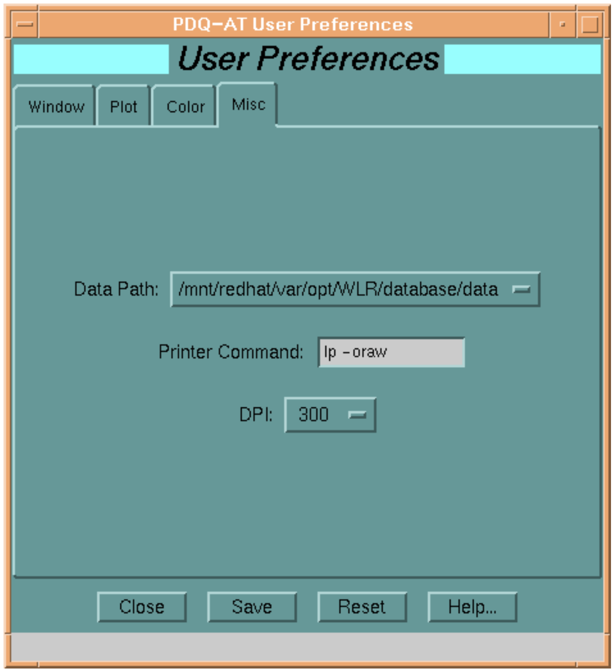
Figure 4.2-5 **PDQ-AT User Preferences for Colors**



Miscellaneous Preferences

In the Miscellaneous preferences, you can set the default data path for the load window and and the default printer command.

Figure 4.2-6 **PDQ-AT User Preferences for Miscellaneous**



The Data Path preference is the default path selected when you are using the Load command. Click-drag the popup to the desired directory to change the data path. For the vast majority of users, the data path will always be */var/opt/WLR/database/data*. No other selections are available until PDQ-AT learns about other PDQ-WLR data present on your system.

The **Printer Command** is your systems default printer command for text and Postscript printing.

Preference Save Files

When launched, PDQ-AT loads the defaults file at */etc/opt/AT/pdqatdefaults*.

Users can save their preferences by pressing the **Save** button on PDQ-AT Preferences window, which creates or changes a ***$HOME/****.pdqatdefaults* file. When you launch PDQ-AT again, it checks for the existence of this file and loads it.

If you desire to change the */etc/opt/AT/pdqatdefaults* file, you must be logged in as *root*, create a ***$HOME/****.pdqatdefaults* file and copy (the *cp* command) the ***$HOME/****.pdqatdefaults* over the */etc/opt/AT/pdqatdefaults* file. Exercise caution here; if you corrupt the */etc/opt/AT/pdqatdefaults* file, you will have to retrieve the distribution backup of this file from */opt/AT/install*.

If your $HOME environment variable is not defined, you cannot save preference changes.

Help Menu

The Help menu and other online help features are covered in “Getting Help in PDQ-AT” in section 4.3, p. 59.

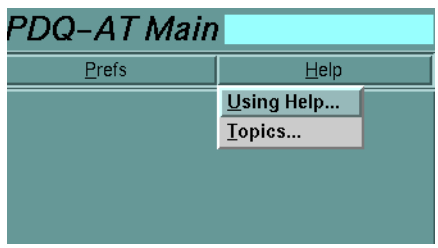
4.3 Getting Help in PDQ-AT

This section demonstrates PDQ-AT's online help features. Here you will learn how to use the online help facility to get help with the topics within the program. Online help is always available — either through the **Help** menu, the Help buttons located within the program or through clicking the right mouse button.

Help Menu

On the PDQ-AT Main Window, the third pull-down menu is Help. Through this menu you can access Using Help and the help Topics.

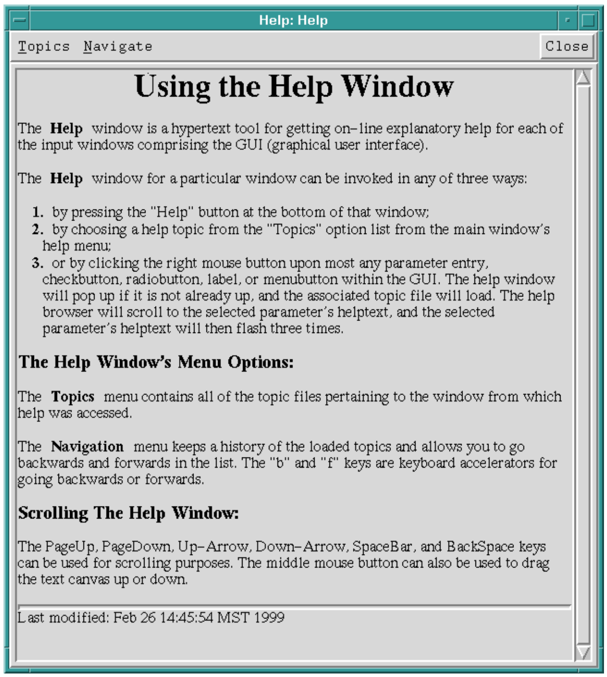
Figure 4.3-1 Help Menu



Using Online Help

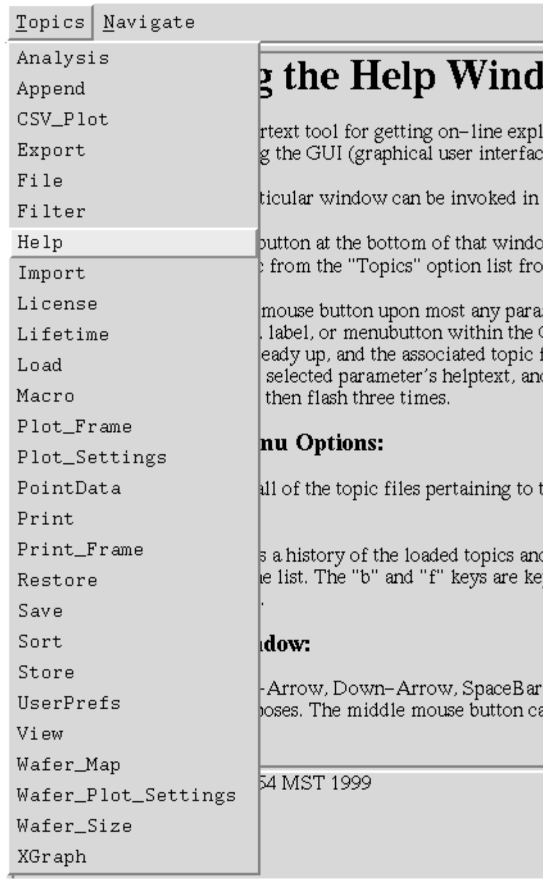
When you select **Help > Using Help**, the PDQ-AT Online Help Window opens, featuring the *How to Use Online Help* topic.

Figure 4.3-2 **PDQ-AT Online Help Window**



At the top of the PDQ-AT Online Help Window are two pulldown menus: **Topics** and **Navigate**. Under the topics menu, there are a list of all the Online Help topics available in this PDQ-AT release. To open online help or a specific topic, select **Topic > *desired topic***.

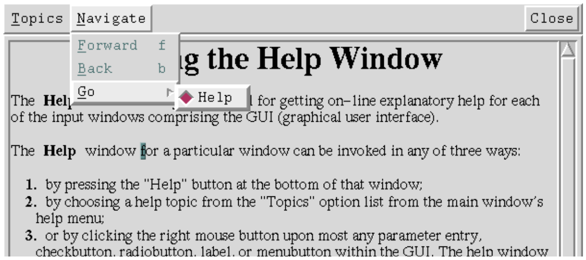
Figure 4.3-3 **Help Topics Menu**



Navigate

The other pulldown menu is **Navigate**. If you have loaded other help files and wish to return to them, you can navigate through these by the use of **Forward**, **Back** and **Go**.

Figure 4.3-4 **Help Navigate Menu**



Forward (or typing ***F***) moves the help window forward to the next open help topic. If you have only one topic open, navigating forward doesn't work. If you are at the end of the open topics, you cannot go any further forward.

Back (or typing ***B***) moves the help window backward to the previous open help topic. If you are at the beginning of the topics, you cannot go any further back.

Selecting **Navigate > Go** opens up a secondary pulldown menu of opened topics. When you select one of these topics and the help window activates displaying the desired help text.

Note:
If you do not know what a specific button does in a window, try a right-click on the button.

The Right Mouse Button

In PDQ-AT, the right mouse button is mapped directly to the online help topics. If you do not know what a specific button does in a window, try a right-click on the button. The PDQ-AT Online Help Window appears displaying the help topic that explains that button.

Help Buttons

On many of the windows and dialog boxes are **Help...** buttons. Clicking on these buttons activates the online help topic for the current window.

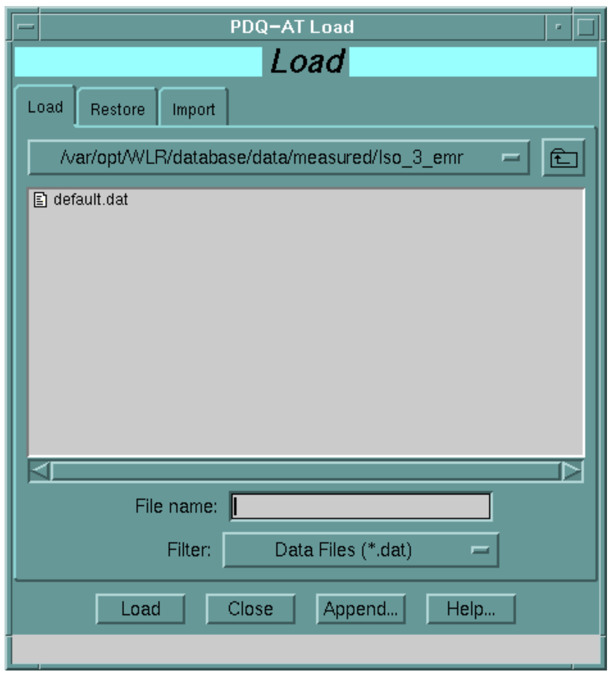
Mouse-Over and Help Text

Whenever you move your mouse over a button, the bottom of the window displays Help Text: a brief description of what a button does when clicked.

4.4 Loading Data

Loading PDQ-WLR data is a simple and common procedure. You will become proficient at loading data by paying attention to the window title at the top of the window and remembering where your data are stored.

Figure 4.4-1 **PDQ-AT Load window: Load option**



At the top of the load window are three tabs: **Load**, **Restore,** and **Import**.

Underneath the tabs is the **Data Path** popup menu, where you can select which directory to load from. To the right of the Data Path is the **Up-Directory** button.

Below the Data Path, the **Directory Browser** displays two types of files and their icons: files and folders. Folders are yellow and indicate sub-directories of the Data Path. Files are white and indicate files that PDQ-AT recognizes according to the **Filter** popup.

Below the Directory Browser is the **File Name** text field and the **Filter** popup menu. If you cannot find a file in a directory, click-drag the Filter popup to read ***All Files (*.*)***. This lists all the files in a directory.

PDQ-AT by default is looking in directories for *.dat* files (the default file designator for WLR files).

Procedure

Loading a Dataset

1. Click on the **Load** button in the PDQ-AT Main window. The PDQ-AT Load window appears as in Figure 4.4-1, “PDQ-AT Load window: Load option” above.

   Alternatively, you may press **Ctrl+L** or select **File > Load**.

2. Select the directory (Algorithm Database Area) of the target using the Data Path popup.

   Which directory the load window opens is configurable in the User Preferences. See “Prefs Menu” in section 4.2, p. 52.

   To change directory up the file path, you may also click on the Up-Directory icon to the right of the data path. To open a directory, double click (using the left mouse button) on any yellow file icon.

3. Click on the file you want to open. The filename appears in the **File Name** text field. PDQ-AT will not load any file that doesn’t end with *.dat* (a dataset).

4. Click the **Load** button.

The PDQ-AT Load window closes and the PDQ-AT Main window activates with the filename of the dataset in the window title.

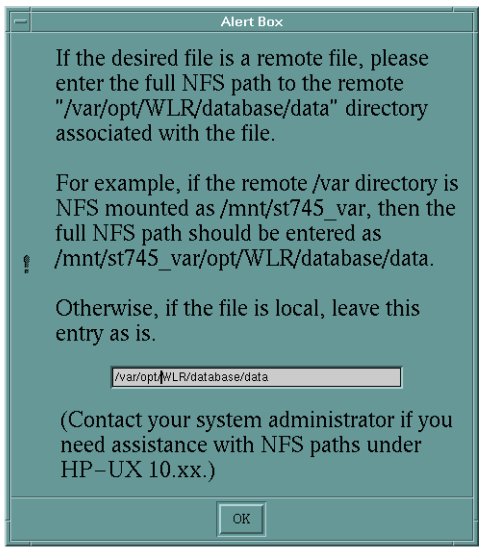
If the filename is not present, the file didn’t load. Confirm you have loaded from the proper directory.

Loading a Dataset Across an NFS Mounted Drive

When loading data from two separate PDQ-WLR programs (e.g., from different machines over a network), PDQ-AT requires the user to locate a set of file links created by the PDQ-WLR process. These lists are for CSV, Xgraph, and HC data. If PDQ-AT cannot find the file links, the dataset will not load.

When PDQ-AT detects that it doesn't have the link list files, the NFS Alert Box appears, requiring you to type the location of the link list files (see figure 4.4-2).

Figure 4.4-2 **NFS Alert Box**



Procedure

Clearing the NFS Alert Box

1. When the NFS Alert Box appears, select the text in the entry field and type the path to the file links. If you do not know the location of the files or about NFS mounted drives, talk to your system administrator.
2. Click **OK**.

PDQ-AT remembers this path for future sessions. The load window closes and the PDQ-AT Main window activates as per a normal load.

Note:
If you are unsure if you have the proper permissions to access files across a network system, contact your system administrator.

If you do not know the location of the file links, seek help from your system administrator before proceeding.

Combining Datasets

Note:
When appending files, ensure that the data variables are in the same order for both files.

PDQ-AT allows users to combine two or more datasets as long as they have matching data types.

You can append two files together by clicking on the **Append...** button located in the load or export windows. When appending these files, both files must have compatible header information — each data field must be in the same order for both files. PDQ-AT enforces this by interrogating the PDQ-WLR algorithm data area that you are trying to append into.

Figure 4.4-3 **PDQ-AT Append window**

Procedure

Appending a File

To append two files together, use the following procedure.

1. In the AT Main click on the Load button. The Load window activates.
2. Using the Data Path and the load field, highlight the first file you need for the append.
3. Click the **Append...** button. The AT Append window appears.

   Note that your selected file is now in the **File 1** text field.
4. Type in the name of the second file to append in the **File 2** text field.
5. Type in the **New File** text field the name of the new file to be created by the append action.

You can only overwrite files when you are Exporting data to CSV files (found under the Save button). You cannot overwrite PDQ-WLR database files using the Append feature. Thus, if you are wanting to append more than two files together, you can add one file at a time.

The two files both must contain identical header information.

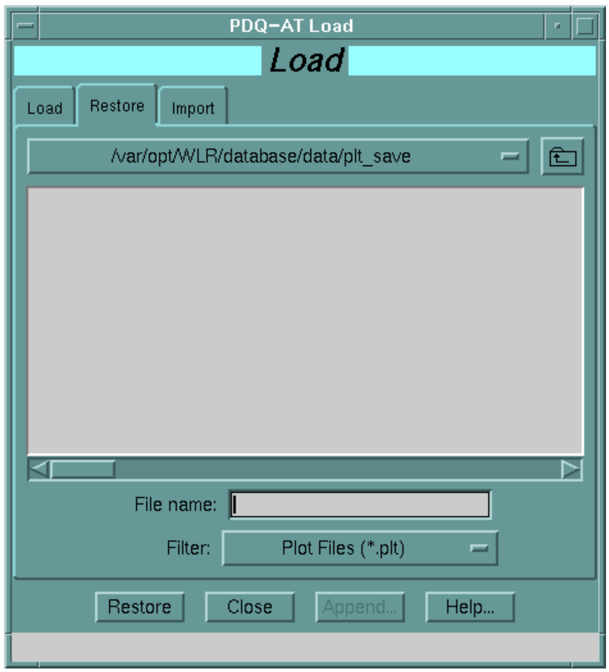
6. Click **Done**.

The PDQ-AT Append window closes and the new file is listed in the Directory Browser.

Recalling a Previous Session Plot

PDQ-AT allows users to store analysis and plot information. To restore a plot, use the procedure below.

Figure 4.4-4 **PDQ-AT Load window: Restore option**



Procedure

Restoring a Plot

Use the procedure below to restore a plot to the active working dataset.

1. From the main window, click the **Load** button. The load window opens.
2. Click on the **Restore** tab. The restore section activates.
3. Locate and highlight the *.plt* file you desire to restore.
4. Click **Restore** button.

The load window closes and the PDQ-AT Plot Frame of your stored data opens. A small window activates indicating that you have successfully restored your data.

Using Non-PDQ-WLR Data

Note:
To import a file, you need to a comma separated value file in ASCII format.

Users can import an ASCII file into the active working dataset, creating a PDQ-WLR algorithm-compliant data area. To import a file, you need to have a comma separated value (CSV) file in ASCII format.

For each file imported, PDQ-AT attempts to create a directory for the new file in the */var/opt/WLR/database/data/measured* directory. The directory name is used to identify an Algorithm Database Area, so when you import files, you will be prompted to give the imported data an algorithm name.

PDQ-WLR Data Format

PDQ-WLR data files' first four rows contain information describing how to handle and display the data. Each column is delimited by commas.

Row 1 ASCII text title for each column.
Variable titles cannot be longer than 15 characters with no blanks — if desirable, use underscores ("_") instead.

Row 2 Text description of the column variable type, completely in lower case letters.
real — real number.
integer — integer number.
string — a string of characters, text.
Strings, even those marked by single or double quotes, cannot contain commas.
date — date in the following format: ***YYYY/mm/dd HH:MM***.

Dates can be partial containing only YYYY/mm/dd or YYYY/mm, such as **1999/02/2** or **1999/10**, but cannot only contain only times, such as 10:30.

Row 3 Text description for each column's engineering units, for example V for volts, and uA for microamps. This description can handle simple one-line expressions.

Note:
PDQ-AT uses the original CSV format definition.

Row 4 ASCII text descriptions for algorithm use, either **input** or **output**.

PDQ-AT uses the original CSV form definition. All strings which includes all of the entries in the first four rows, must be surrounded by double-quotes. Some applications use "lazy formatting" for CSV files, and may not quote these lines correctly. The user is advised to add double-quotes for the four description lines.

If the **first column** is constructed as a PDQ-WLR record identifier, it has the following specific restrictions.

Row 1 Must read ***Rec_num,*** for record number.

Row 2 Must be defined as ***integer***.

Row 3 Must be blank.

Row 4 Must read ***input***.

Row 5 until the end of the file preferably begins with one (1) and increments by one (1) for each successive record.

If you choose to leave off the record identifier column, PDQ-AT will add it automatically for you.

Variable names must be 15 characters or less and can have only letters (upper and lower case), numbers, and underscore characters. Variable names must start with an upper case letter.

Save the file from your spreadsheet tool or other application with a *.csv* extension.

Checklist for Importing a File

Name the file with a *.csv* extension.

Variables names 15 characters or less.

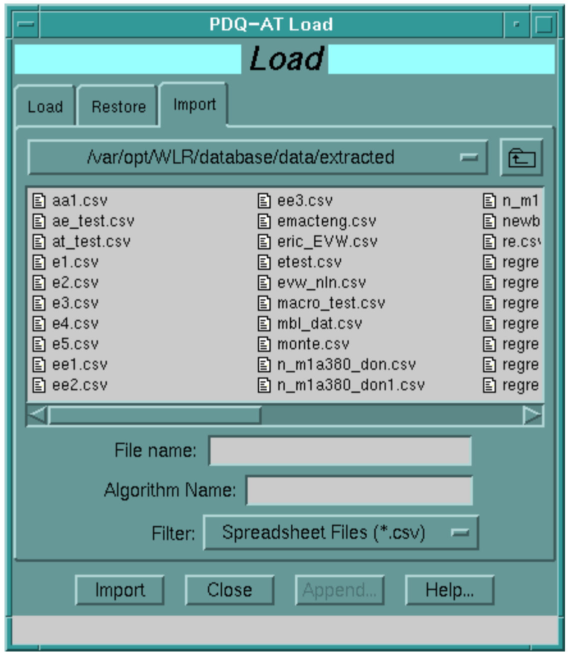
Variables names without spaces (use underscores instead).

Variables begin with a capital letter (upper case).

Ensure all fields have values, even if the value is 0 or "".

Ensure the first column meets the restrictions above.

Figure 4.4-5 **PDQ-AT Load window: Import option**



Procedure

Importing a File

1. From the main window, click the **Load** button. The load window opens.
2. Click on the **Import** tab. The Import section activates.
3. Locate and highlight the file you wish to import. Your file may be located anywhere accessible to your HP-UX user account. By default, PDQ-AT exports files to and imports files from the *var/opt/WLR/database/data/extracted* directory You are free to select a more convenient directory on your network, if applicable.

   If necessary, move the **Filter** popup to read *All Files (*.*)*.
4. Type the algorithm name in the **Algorithm Name** text field.

   PDQ-AT enforces that newly imported files have separate **Algorithm Name** directory in */var/opt/WLR/database/data/measured*.

Note:
The algorithm name establishes an Algorithm Database Area in the same way that PDQ-WLR does.

If the Algorithm name already exists, you can add to the area only if the header definition of your data matches the dictionary (header) definition of the Algorithm Database Area.

5. Click **Import**.

The load window closes, activating AT's main window. Note that the active dataset is now ***algorithm_name/****default.dat*. Your imported file is now located in */var/opt/WLR/database/data/****new_algorithm_name/****default.dat***.**

4.5 Filtering Data

Once you have your dataset loaded, you may need to filter your data either to exclude error codes or to create unique analysis datasets. You may not need to perform this step if your dataset was saved appropriately or contains no errors.

To filter or sort a currently loaded dataset, click on the **Filter/Sort** button in the PDQ-AT Main window. The **PDQ-AT Filter/Sort** window appears. By default, the **Filter** tab is activated. To activate Sort, click on the **Sort** tab.

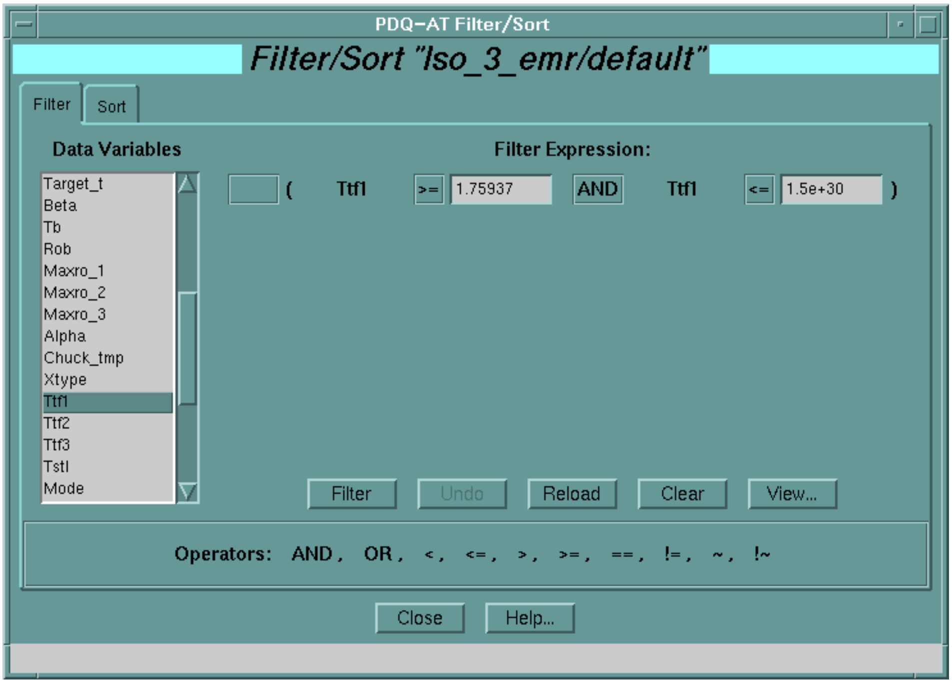
The Filter Operation

Filtering your dataset is an operation of selecting data variables and applying filter expressions. If you are familiar with programming, advanced spread sheet calculations, or structured queries, similarities are easy to spot.

Note:
No filtering is performed until the Filter button is clicked.

Once the filter expression is designed, you filter your dataset by clicking the Filter button. No filtering is performed until the Filter button is clicked. The result of the filter operation becomes the new working data, which may be refiltered by different criteria any number of times. You can view your current dataset by clicking on the **View...** button.

Figure 4.5-1 PDQ-AT Filter/Sort window: Filter option



The filter operator is most frequently used to remove records with errors in the dataset.

If the filtering expression results in an error or too few records in the data, you can restore the dataset by clicking on the **Reload** button. PDQ-AT prompts you to confirm the reloading. If confirmed, the working data becomes a fresh copy of the raw data, allowing the filtering procedure to begin anew.

The **Clear** button clears the filter expression field.

The **View...** button launches the PDQ-AT Viewer with the current dataset. For more information, see "Viewing Your Data" in section 4.8, p. 97. If the Viewer was open when the **Filter** button was clicked, the Viewer will automatically update to show the new working dataset contents.

Filter Expressions

Choose your data variables by clicking in the list in the left scroll box. When you click on one, the filter expression field on the right loads with the appropriate mathematical filter.

The data variables depend on the dataset you have loaded; if the dataset was created by the ISO_3_EMR algorithm, only the variables created by ISO_3_EMR will be present. The following data variables are common to all datasets.

Note:
You may never need most of these common data variables, we document them here for completeness' sake.

Variable	Description
Rec_num	The record number of the test
Date_time	Date and time the test was performed in the following format: ***YYYY/mm/dd HH:MM***.
User_id	User identification of the individual performing the test.
Product_id	Product identification as defined by Agilent SPECS Framework user.
Lot_id	Lot identification as defined by the Agilent SPECS Framework user.
Wafer_id	Wafer identification as defined by Agilent SPECS.
Wafer_name	Name of wafer as defined by Agilent SPECS.
Die_name	Die name as defined in Agilent SPECS WAFER Spec.
Module_name	Module name as defined in Agilent SPECS DIE Spec.
Device_name	Name of the device the test was performed on, as defined in the Agilent SPECS Testplan.
X_position	X position of the device tested, measured in microns.
Y_position	Y position of the device tested, measured in microns.

The X_position and Y_position are prober position values, as determined by the Agilent SPECS Wafer spec of the wafer used for the source of test data.

Relational Operators

Relational operators compare and contrast variables to user defined values. By the use of relational operators such as =, < and >, the user defines values to filter his dataset. The variables may be numbers, in which

Table 4.5-1 **Relative Arithmetic and String Filter Operators**

Operator	Description	Returns True	Returns False
<	arithmetic less than	2 < 5	5 < 5
<=	arithmetic less than or equal to	2 <= 3 2 <= 2	4 <= 3
>	arithmetic greater than	7 > 3	4 > 4
>=	arithmetic greater than or equal to	6 >= 3 4 >= 4	2 >= 5
==	arithmetic equality	2 == 2	2 == 1
!=	arithmetic inequality	4 != 6	4 != 4
~	string equality	Blue ~ Blue	Blue ~ Green
!~	string inequality	Blue !~ Gray	Blue !~ Blue

arithmetic operators are used, or strings, in which string operators are used. A string is a value of one or more ASCII characters.

If accurate, the expression returns TRUE. If the expression is inaccurate, it returns FALSE.

Boolean Operations

PDQ-AT uses boolean operations to filter data. Boolean operations are equations that return TRUE or FALSE. For example, if we filter using the following equation:

X >= 1.0

In the instance of X equal to 2, then the equation returns TRUE, and the record would *not* be filtered out of the dataset. If X were equal to 0, the equation would return FALSE and the record *would* be filtered from the dataset.

When you click on a Data Variable, the boolean operations needed to include all data are entered into the Filter Expression field, expressing the range of the Data Variable if numeric, or a string equality (~) expression if the variable is a string.

If your data contains input or output errors, the right-most boolean clause will display **<= *error code***. For a list of input and output variables and more information on error codes, see the documentation on the specific algorithm generating the data in **PDQ-WLR Software User’s Guide**.

Boolean Clauses and Logical Operators

Most of the filter expressions appear with two boolean clauses separated by ***AND*** logical operator. By clicking on the ***AND*** operator, you raise a popup allowing you to select ***AND***, ***OR***, or ***(delete)***.

Using the ***AND*** operator allows you to set filter criteria that enforces both sides of the equation to return true. For example:

X >=0 AND X <=2

For any instance of X to be TRUE in the above equation, X must be any value between or equal to 0 and 2. Were X equal to 1, .5, or 2, the equation would return TRUE. If X’s value were -.03 or 2.4, the equation would return FALSE and remove those records from the dataset.

Table 4.5-2 **Logical Operator: *AND***

Given the operation
X >=0.5 *AND* X <=1.5

X equals	Left of *AND*	Right of *AND*	Return
1	TRUE	TRUE	TRUE
.2	FALSE	TRUE	FALSE
1.8	TRUE	FALSE	FALSE

Instead of enforcing that both sides of the equation is true, the ***OR*** operator returns true if the left side ***OR*** the right side is true. The ***AND*** operator always has precedence over the ***OR*** operator.

The ***OR*** expression allows you to exclude a given range. For example:

Table 4.5-3 **Logical Operator: *OR***

Given the operation
X >=1.5 *OR* X <=0.5

X equals	Left of *OR*	Right of *OR*	Return
1	FALSE	FALSE	FALSE
.2	FALSE	TRUE	TRUE
1.8	TRUE	FALSE	TRUE

Creating Complex Filters

Relational operators together with boolean clauses allow you to construct complex and powerful data filters. If a dataset defined the value of X over ten records as follows:

{1 2 3 4 5 6 7 8 9 10}

The range of X is:

(X >= 1) AND (X <= 10)

The filter expression:

(X > 3) AND (X < 7)

would yield the set of records containing X = {4 5 6}, filtering out those records containing X = {1 2 3 7 8 9 10}.

The filter expression:

(X < 3) OR (X > 7)

would yield the set of records for X = {1 2 8 9 10}, filtering out the records containing X = {3 4 5 6 7}.

The filter expression:

(X < 3) AND (X > 7)

would yield the empty set because no value of X can fulfill both left and right clauses at the same time.

The filter expression:

(X > 3) OR (X < 7)

would yield the set of records for X = {1 2 3 4 5 6 7 8 9 10}.

Boolean Clauses with Multiple Variables

Given the following (X,Y) value pairs exist over ten records:

{(1,3) (2,5) (3,4) (4,2) (5,2) (6,3) (7,1) (8,4) (9,5) (10,3)}.

The range of Y is: (Y >= 1) AND (Y <= 5).

The filter expression:

((X > 2) AND (X <= 9)) AND ((Y >= 3) AND (Y <= 4))

would yield the records containing the pairs {(3,4) (6,3) (8,4)}.

The filter expression:

((X > 3) AND (X < 7)) OR (Y == 5)

would yield the records containing the pairs {(2,5) (4,2) (5,2) (6,3) (9,5)}.

Procedure

Creating a Filter Expression

1. In the PDQ-AT Main window, click the **Filter/Sort** button. The PDQ-AT Filter/Sort window appears.
2. Click the **Filter** tab if the Filter option isn't active. The Filter option activates.
3. Select a variable from the list of **Data Variables** on the left side of the Filter window. In the **Filter Expression** field, a default expression is created with the entire range of the variable.

   Note whether or not your data has any error codes by examining the high range (to the right of the ***AND***) of the data. See procedure "Filtering Bad Data Using Error Codes" below for more information.

   If the variable is a number, the Filter Expression field has two boolean expressions separated by ***AND***. The default operators for the two expression are >= (greater than or equal to) on the left and <= (less than or equal to) on the right.

   If the variable is a string, only one expression appears, for which the default is ~ (string equality).

   The relational and logical operators are all popup menus. To change the relational or logical operators, select ***operator > correct operator***. To remove an entire boolean clause, select ***logical operator* > (delete)**.

Note:
You can filter multiple expressions on the same data variables.

4. Define the filter values. In numeric variables, edit by clicking in the field and deleting the text with the backspace key. Type the new value. The default values are the minimum and maximum values of the variable found within the dataset.

   For string values, PDQ-AT creates a pop-up window of all the possible entries.

   Multiple variables may be selected, allowing you to build a complex boolean expression. Variables may be selected more than once.

Note:
You must press the Filter button to filter your data. Clicking the Close button does not filter the data.

5. When finished editing your expressions, click the **Filter** button.

A small window appears indicating a successful filter has been performed. PDQ-AT warns you if there are less than 3 records in your current dataset.

The **filter expression** field can hold only six expressions. If you need more filter expressions, load the first six expressions, filter the dataset as normal, click the **Clear** button, then load the rest of the expressions as necessary.

Procedure

Filtering Bad Data Using Error Codes

PDQ-WLR automatically indicates bad data or testing errors by returning error codes in the test software output variables. Generally speaking, you can filter error codes from your data by excluding any value greater than or equal to *1.5E+30* on output variables. For a list of input and output variables and more information on error codes, see the documentation on the specific algorithm generating the data in **PDQ-WLR Software User's Guide**.

To see if a data variable has an error code, click on the data variable in question. The maximum value occurring for this variable will be displayed in the right-most text field of the new filter expression.

Use the following procedure to filter bad data using error codes.

1. Select the variable that includes errors by clicking on that variable in the Data Variable field. An expression appears in the Filter Expression field.
2. Click in the variable field showing the error code and enter a value less than the one displayed. In general, the value *1.5e+29* will eliminate ALL error codes.
5. Click the **Filter** button.

A small window will appear informing you that you have filtered your data.

4.6 Sorting Data

Sorting is primarily used for exporting and viewing data. PDQ-AT analyses which require rank-ordering or grouping of data will perform these operations automatically, regardless of your sorting criteria specified here.

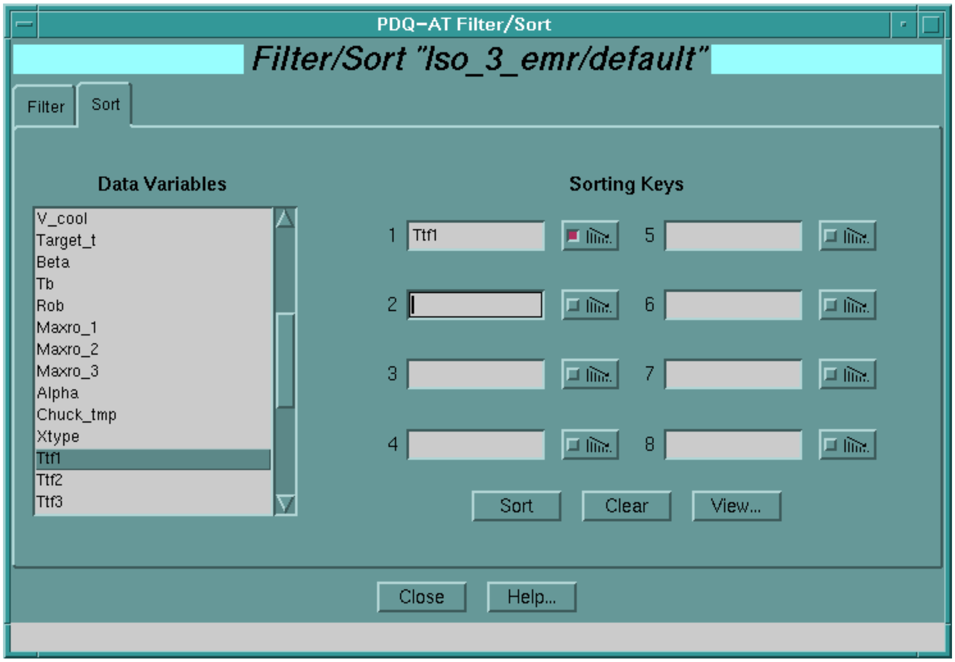
You can sort the records of your dataset on one or more data variables. Additional variables may be used to sort records with identical values in the field of the primary sort key. Up to eight data variables may be selected as sorting keys, and each key may be sorted in ascending or descending order. Data can be sorted by more variables by repeating the process. Remember that eight sort variables translates to 256 levels of data. The default sorting order is ascending order.

Like the filter window, no sorting of data occurs until the S**ort** button is clicked.

The **Clear** button clears the sorting keys. Sorting on the record number yields the original record order.

The working data may be viewed in the Viewer window (see "Viewing Your Data" in section 4.8, p. 97) accessible via the **View...** button.

Figure 4.6-1 **PDQ-AT Filter/Sort window: Sort option**



Sort Example

Sorting is performed alphanumerically in ascending order. For example, given the following (X,Y) value pairs exist over ten records:

{(10,3) (5,2) (7,1) (4,2) (3,4) (1,3) (9,5) (8,4) (2,5) (6,3)}.

Sorting on X yield the following order:

{(1,3) (2,5) (3,4) (4,2) (5,2) (6,3) (7,1) (8,4) (9,5) (10,3)},

while sorting on Y, and secondarily on X would yield:

{(7,1) (4,2) (5,2) (1,3) (6,3) (10,3) (3,4) (8,4) (2,5) (9,5)}.

Sorting a Dataset

Use the following procedure to Sort a dataset.

Note:
You must press the Sort button to sort your data.

1. Click on the **Filter/Sort** button in the PDQ-AT Main window. The PDQ-AT Filter/Sort window appears.
2. Click on the **Sort** tab. The **Sort option** activates.
3. Click on the data variable you want to sort by. To the right, the selected variable appears in the first available sort key.

   If you desire the variable to be sorted in descending order, click the button adjacent to sort key marked with PDQ-AT's descending icon. Variables will be sorted in order of the sort keys used.

   A data variable may not be selected more than once.
4. Enter as many Data Variables as desired. If you desire to sort on more than eight variables, sort the first eight Data Variables, click the **Clear** button, and enter the remaining Data Variables.
5. When all sort keys are entered, click the **Sort** button. Like filtering, no sort operation will occur until the Sort button is clicked.

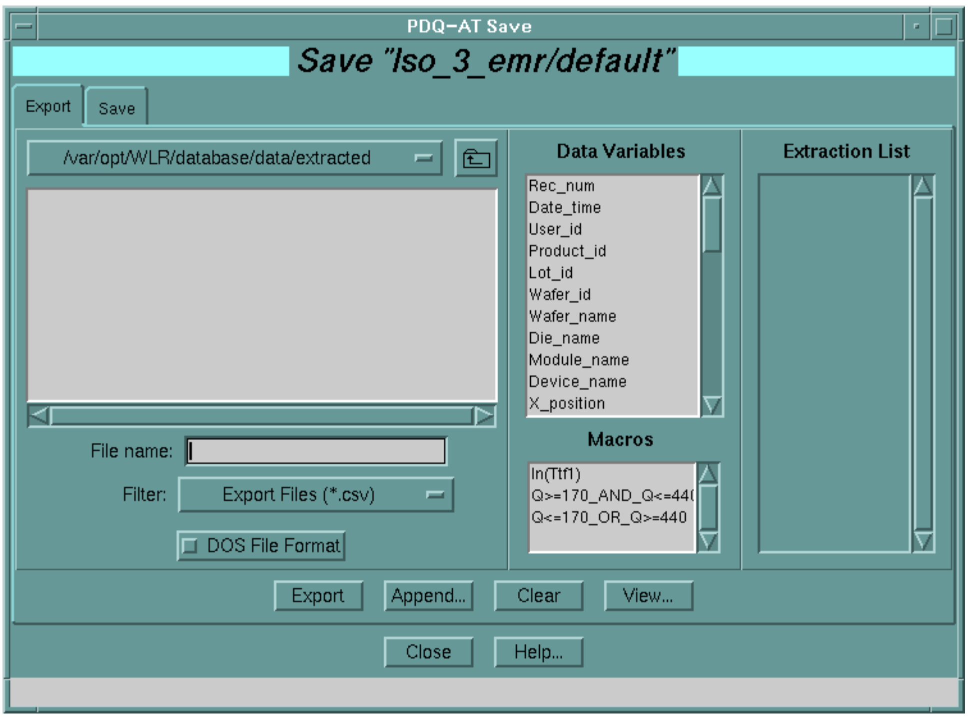
A small confirmation window will appear, indicating a successful sort.

When finished sorting, you may sort again, filter your data, or click close to return to the main window.

4.7 Saving your Data

PDQ-AT provides three ways to store your data: exporting to a CSV file format, saving the current data under a new name, and storing the entire history of a plot. The first two ways to save are available from the PDQ-AT Main window. The third is available only from a plot frame after the dataset has been plotted.

Figure 4.7-1 PDQ-AT Save window: Export option



Clicking on the **Save** button in the PDQ-AT Main window activates the **PDQ-AT Save window**. PDQ-AT allows you to export the active working dataset to an ASCII CSV file. If desired, you may also save this file to be DOS compatible, which adds carriage returns to each line and may be required to allow the file to be loaded directly into a spreadsheet or other program on Microsoft™ operating systems.

By default, the PDQ-AT Save window is set up to export the active working file. Under the **Export** section, the **Data Path** is set on the */var/opt/WLR/database/data/extracted* directory. To the right of the Data Path popup is the **Up-Directory** button. Under the Data Path is a directory browser.

Beneath the directory browser is the **File Name** text field, the **Filter** popup and the **DOS File Format** button. To the right is a list of **Data Variables** found within the active working dataset, below that a list of **Macros** unique to this dataset. To the right of the Data Variables is the **Extraction List**.

At the bottom of the PDQ-AT Save window are the **Export**, **Append...**, **Clear** and **View...** buttons. Below them are the **Close** and **Help...** buttons.

By default, PDQ-AT exports files to */var/opt/WLR/database/data/extracted*.

Using PDQ Data Outside of PDQ-AT

PDQ-WLR and PDQ-AT algorithms can produce comma separated value (*.csv*) files for export to spreadsheets. The **DOS File Format** flag determines if the *.csv* files will be in DOS or UNIX format. For Lotus 1-2-3™, the flag should be on; for Microsoft Excel™, the flag may be left off. Files can always be converted later using the HP-UX *ux2dos* and *dos2ux* utilities.

PDQ-AT allows you to extract data from the active working dataset.

Procedure

Exporting the Active Working Dataset

1. Locate the directory you desire to create your newly exported file by using the **Data Path** popup and the directory browser.
2. Type the filename in the **File Name** text field.
3. Click on the **Data Variables** you wish to export into the new file.

   As you click on a specific data variable, the variable name appears in the extraction list. Use the scroll bar to scroll the list of data variables as necessary.
4. If desired, click on the macros you also are seeking to export.

   If you place your data out of order on the **Extraction List**, move the mouse above the data and click-drag with the middle button to resequence the extraction list.

   If you wish to delete a data variable from the extraction list, move the mouse over the undesired variable and press the **D** key on the keyboard.

If you desire to remove all of the variables from the Extraction List and start over, click the **Clear** button.

5. If desired, click the **DOS File Format** button.
6. Click the **Export** button.

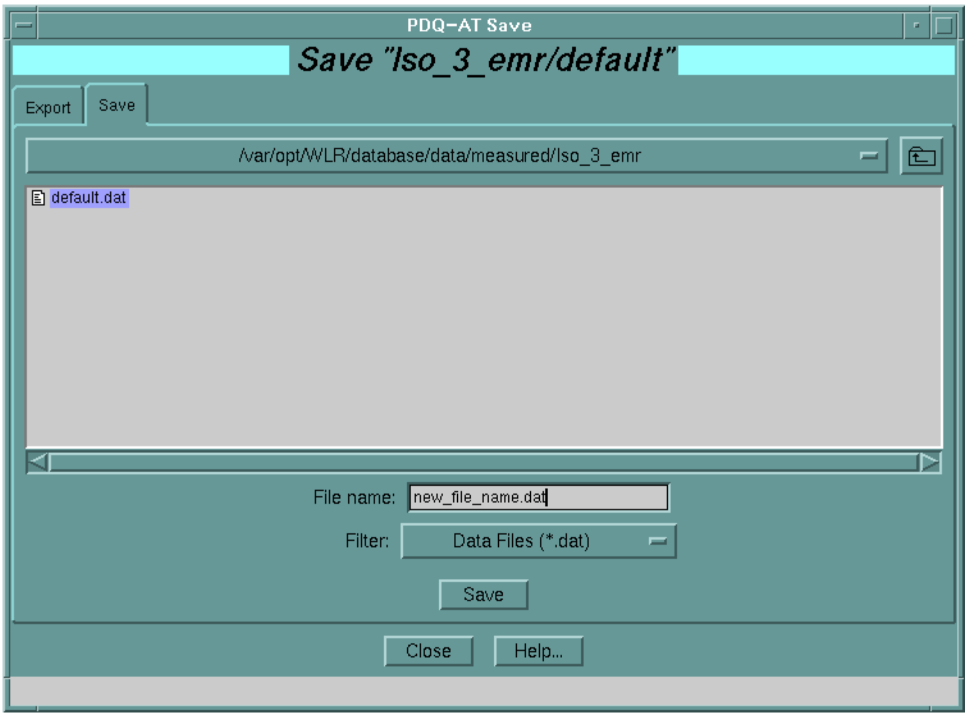
A small window appears confirming the export to your new file name. Exporting data in no way affects the active working data. It only copies the extracted list into a new file.

You can view the active working dataset by clicking the **View...** button. See “Viewing Your Data” in session 4.8, p. 97.

Saving to the PDQ Database

The save section in the **PDQ-AT Save** window is very similar to the load window.

Figure 4.7-2 **PDQ-AT Save window: Save option**



At the top is the **Data Path** and the **Up-Directory** button. Below that the directory browser, the **File** name text field, **Filter** popup menu, and the **Save** button.

Procedure **Saving your Data**

1. Locate the directory you wish to save your file to by using the **Data Path** popup, the **Up-Directory** button and the directory browser.

   Note that files can only be saved in the algorithm directory from which the file came from originally. Iso_4_emr datasets can only be saved in the Iso_4_emr directory.

2. Type the filename in the **File Name** text field
3. Click **Save**.

PDQ-AT does not allow the user to overwrite files created previously.

Recording an Analysis

After you have plotted a dataset, you may store the plot in a PDQ-AT *.plt* format. This format records the dataset(s) loaded, all filter, sort, and reload actions (including multiples of each action), the type of analysis performed, whether the plot has been constrained, overplots, and even the change to plot colors and symbols. You will have a full restore to the plot you have saved, no matter how complicated.

The **PDQ-AT Store** window is very similar to the load and save windows.

At the top is the **Data Path** and the **Up-Directory** button. Below that the directory browser, the **File name** text field, **Filter** popup menu, and the **Store**, **Close,** and **Help** buttons.

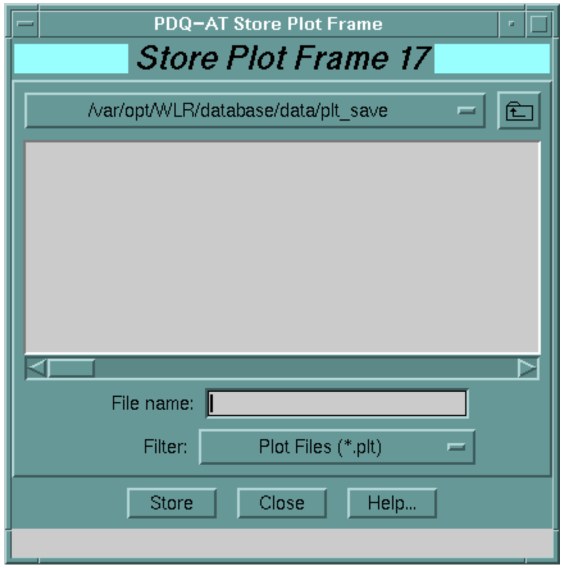
Note:
When storing and restoring plot files, the legend is saved verbatim and may not accurately reflect the working list.

Legends are persistent across stores and restores of plots. The default legend serves as a reminder of which working dataset you are using. When storing and restoring plot files, the legend is saved verbatim and may not accurately reflect the working list.

For example, you create plot from four different *ISO_4_emr/default.dat* working datasets during a session and store the third plot with legend turned on. The legend reads *plotted variable (engineering units) (ISO_4_emr/default.dat-3)*. During another session, you restore these plots. The section of the legend that defines which working list will still read *(ISO_4_emr/default.dat-3)*, no matter where the dataset exists within the working list.

The developers of PDQ-AT strongly recommend you edit the legend or title prior to storing a data plot to accurately reflect the analysis. To change the text within a legend, use the procedure “Editing and Deleting Text” in session 6, p. 168.

Figure 4.7-3 **PDQ-AT Store window**



Procedure

Storing a Plot

1. Type the name you wish to save the plot as in the **File Name** text field.
2. Plots must be stored in */var/opt/WLR/database/data/plt_save*, or an equivalent location referenced via an NFS mounts in use. Locate where you wish to save the file using the **Data Path**, **Up-Directory** button and the directory browser.
3. Click **Store**.

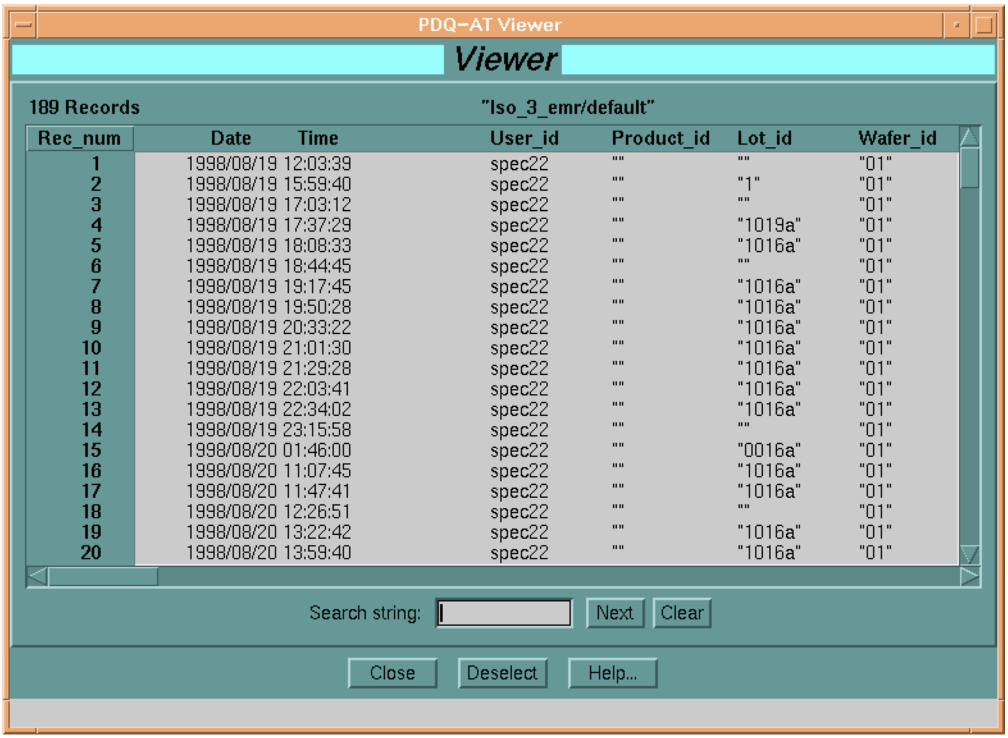
The store window closes and a small window appears to confirm that the store action was successful.

Click **Close** to close this window. Click **Help...** to view the **Online Help** topic on storing plots.

4.8 Viewing Your Data

If you desire to see the actual data from which you are making plots, you can click the **View...** button located on several windows. Alternatively, you may also select **File > View...** in the main window. The Viewer window lists the current dataset in tabular form.

Figure 4.8-1 PDQ-AT Viewer window



Rec_num	Date Time	User_id	Product_id	Lot_id	Wafer_id
1	1998/08/19 12:03:39	spec22	""	""	"01"
2	1998/08/19 15:59:40	spec22	""	"1"	"01"
3	1998/08/19 17:03:12	spec22	""	""	"01"
4	1998/08/19 17:37:29	spec22	""	"1019a"	"01"
5	1998/08/19 18:08:33	spec22	""	"1016a"	"01"
6	1998/08/19 18:44:45	spec22	""	""	"01"
7	1998/08/19 19:17:45	spec22	""	"1016a"	"01"
8	1998/08/19 19:50:28	spec22	""	"1016a"	"01"
9	1998/08/19 20:33:22	spec22	""	"1016a"	"01"
10	1998/08/19 21:01:30	spec22	""	"1016a"	"01"
11	1998/08/19 21:29:28	spec22	""	"1016a"	"01"
12	1998/08/19 22:03:41	spec22	""	"1016a"	"01"
13	1998/08/19 22:34:02	spec22	""	"1016a"	"01"
14	1998/08/19 23:15:58	spec22	""	""	"01"
15	1998/08/20 01:46:00	spec22	""	"0016a"	"01"
16	1998/08/20 11:07:45	spec22	""	"1016a"	"01"
17	1998/08/20 11:47:41	spec22	""	"1016a"	"01"
18	1998/08/20 12:26:51	spec22	""	""	"01"
19	1998/08/20 13:22:42	spec22	""	"1016a"	"01"
20	1998/08/20 13:59:40	spec22	""	"1016a"	"01"

Procedure

Searching the Data with the Viewer

With the PDQ-AT Viewer window (see figure 4.8-1), you may search your for specific information inside the dataset.

1. Type the information you wish to search on in the **Search String** text field.

2. Click the **Next** button. The screen moves forward through the data to find your search string.
3. When ready. click the **Next** button again to find the next search information.

Click the **Clear** button to clear the Search String field.

4.9 Xgraph Browser

Xgraphs are executable graphs created by PDQ-WLR when configured to so. For more information, view the Xgraph section in the PDQ-WLR User's Guide.

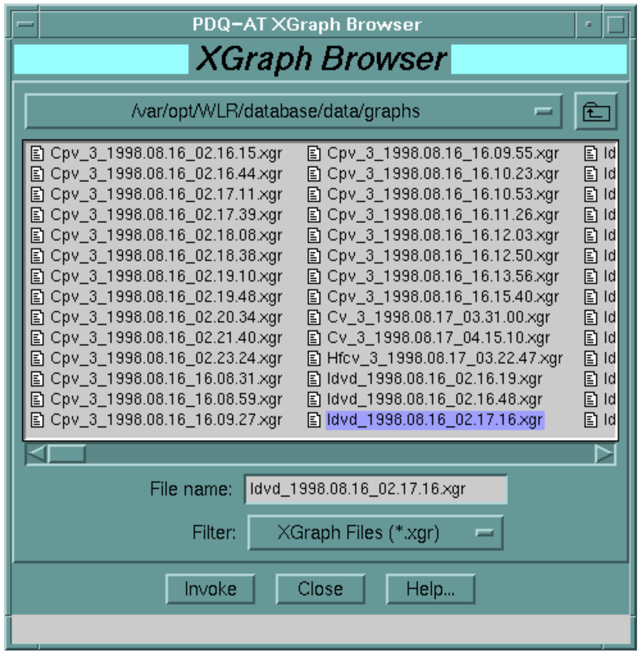
PDQ-AT has two ways to open up Xgraph data: through the PDQ-AT Xgraph Browser and through plot points. To open the PDQ-AT Xgraph Browser, select **File > Xgraph** from the PDQ-AT Main window. The PDQ-AT Xgraph Browser activates.

At the top of the browser is a **Data Path** popup defaulting to the */var/opt/WLR/database/data/graphs* directory. To its right is the **Up-Directory** button. Below that is the directory listing, a **File Name** text field and a filter popup. At the bottom of the window are the **Invoke**, **Close**, and **Help...** buttons.

By either clicking on or typing the name of an Xgraph and clicking the **Invoke** button activates the Xgraph in a new window.

The Xgraph tool is only available for HP 745-series workstations.

Figure 4.9-1 **PDQ-AT Xgraph Browser**



Procedure

Using the Xgraph Browser

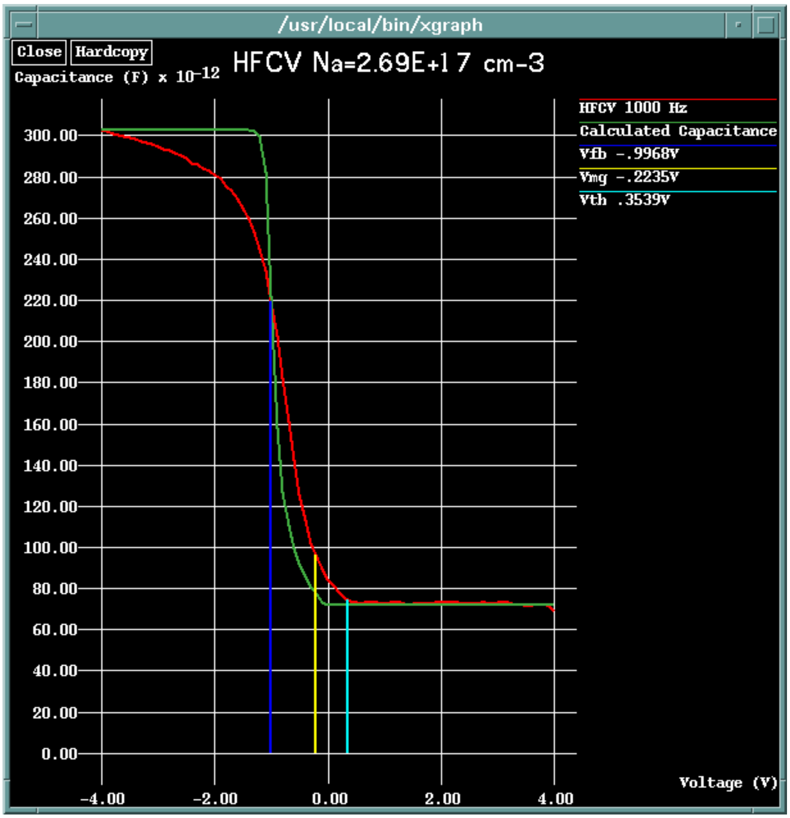
1. To open the PDQ-AT Xgraph Browser, select **File > Xgraph** from the PDQ-AT Main window. The PDQ-AT Xgraph Browser activates.
2. Locate and highlight the xgraph file you wish to display.
3. Either type the file name in the **File Name** text field or click on the file you desire to see graphed.
4. Click the **Invoke** button. The Xgraph Browser closes.

The selected Xgraph launches in a new window. PDQ-AT, like PDQ-WLR, expects to find Xgraph located at */usr/local/bin/xgraph.* If you are accessing PDQ-WLR data over a network, you may need a copy of this file on your machine, which will have to be made by your system administrator. Your software license allows this copying procedure.

Xgraph plots are very specific in nature. You can use Xgraphs to view the data gathered during WLR testing.

Xgraph plots may contain multiple traces. Because of their uniqueness, usually the title indicates what type of data is graphed.

Figure 4.9-2 **PDQ-AT Xgraph Plot**



You may print Xgraphs by clicking the **Hardcopy** button in the top left corner or close the window by clicking on the **Close** button.

4.10 Printing Plot Files

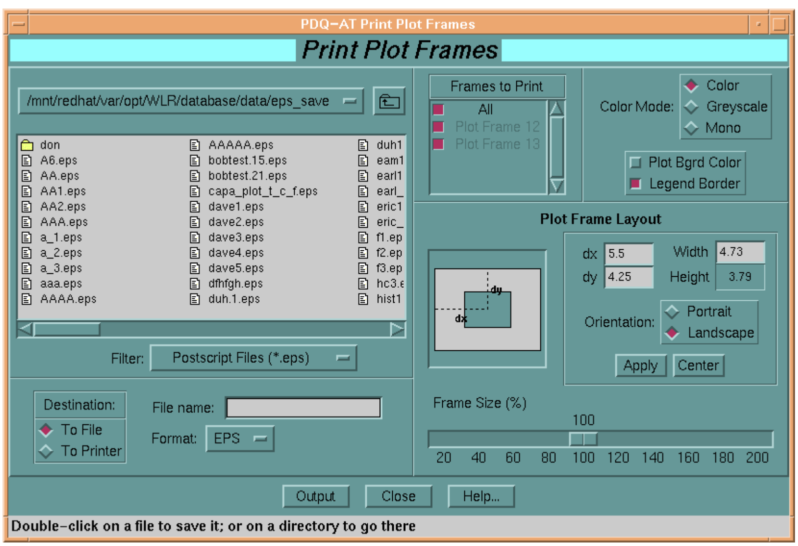
Note:
PDQ-AT prints only what is visible in the plot canvas window.

After you have created plot files, you may print them from two windows inside PDQ-AT. From the PDQ-AT Main window, you can print any or all iconified plot frames, or a single plot from its plot frame. PDQ-AT prints only what is visible in the plot canvas window. Ensure you have sufficiently displayed the plot in the position you want in your final print. For more information on zooming and moving the plot canvas, see “Using Intelligent Plots” in Chapter 6.

If you need to print many plots, it may be easier to create all the plots, iconify them, then use the **Print** button from the main window.

PDQ-AT allows you to print to file as an EPS, PNG, or PDF file. PNG files will constain only the active plot; PDF files will print to a full page.

Figure 4.10-1 PDQ-AT Print window from the PDQ-AT Main window



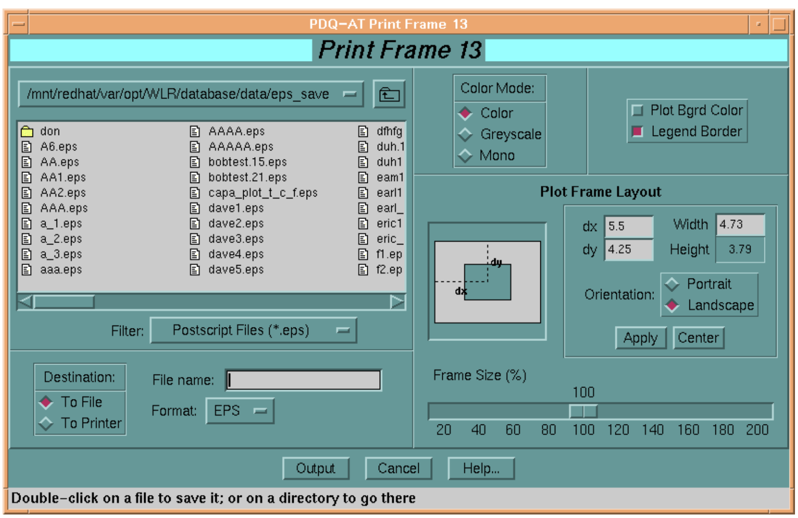
At the top left of the PDQ-AT Print Plot Frames window are the **Data Path** popup, **Up-Directory** button and a directory browser. Below that is a file filter popup. In the bottom left is the print destination buttons: **To File** and **To Printer**, a **File Name** text field and a **Format** popup.

When printing from the PDQ-AT Main window, in the top center of the window is a scroll bar selection of all the plot frames with buttons indicating which are to be printed.

At the center top of the window are two buttons: **Plot Background Color** and **Legend Border.** Plot Background Color prints the plot canvas' background color. Legend Border, when togged, prints a border around a plot legend. At the top right is a selector for **Color**, **Grayscale** or **Mono**.

The bottom right section includes **Orientation** and placement of the plot on a page. Below that is the percentage size of the plot.

Figure 4.10-2 **PDQ-AT Print window from a plot frame**



Procedure

Printing a Plot

Use the following procedure to print one or more plots.

Note:
PDQ-AT will only print the plotted area visible in the plot canvas.

1. Use zoom and the select tool to position the plot canvas where you want to print. Remember, PDQ-AT will only print the plotted area visible in the plot canvas.

   For more information on zoom and select tools, see their respective sections under Chapter 6, Using Intelligent Plots.

2. On the main window or a plot frame, click the **Print** button. The PDQ-AT Print window appears.

3. Click the **To Printer** or **To File** option in the **Destination** field.

   If you desire to print to a file, select the **To File Destination**. By default, the files are saved in */var/opt/WLR/database/data/eps_save*. By using the **Data Path** popup, **Up-Directory** button and the directory viewer, you may save anywhere you have permissions.

   If you desire to print directly, select the **To Printer Destination**. The default Print Cmd will appear, which you modify for this print job.

4. When printing to file, type the name of your file(s) by the **File Name** text field. PDQ-AT will add the file descriptor on the end (*.eps*, *.png*, or *.pdf*).

   If you are printing multiple files, they will be named ***filename.X.****eps* where ***X*** is replaced by the number of the file printed.

5. When printing multiple plots from the main window, you may select all or some with the **Frames to Print**. By default, all plot frames will print.

6. Click the **Plot Background Color** or the **Legend Border** if you desire either.

7. Choose your **Color Mode** by clicking **Color**, **Grayscale** or **Mono**.

8. Select **Portrait** or **Landscape** for the direction of the page to print.

   Landscape is best for Postscript. Portrait is best for PNG and PDF.

9. PDQ-AT centers the print area on the page by default. To move or resize, the values in the **dx**, **dy** and **Width** text fields and then clicking the **Apply** button.

   Alternatively, you may click-drag the print selection in the window.

   To center the print area, click the **Center** button.

10. Click the **Output** button.

A small confirmation window appears. The files are printed to disk or to your default printer. To change printers, change the printer command in the PDQ-AT Preferences window. For more information, see "Prefs Menu" in section 4.2, p. 52.

5 Analyzing Data

Introduction to this Chapter

Once your dataset is filtered and sorted, it is ready to be analyzed and plotted. PDQ-AT has several pre-set plot configurations available and a programmable statistical calculator to create your own plot macros.

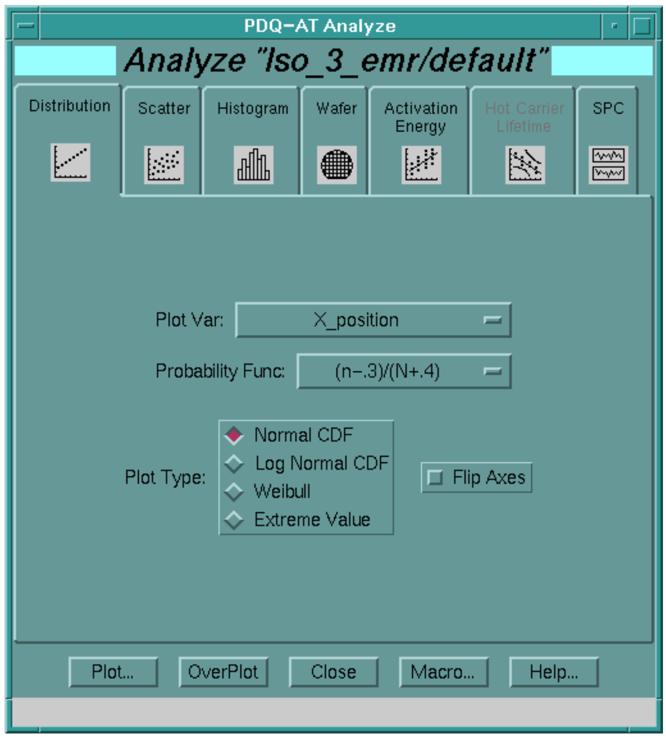
After creating and/or choosing your macros, next step is to represent the data in the form of a plot. All plots in PDQ-AT are intelligent, allowing the user to select a specific plot point, view the data which creates that point and constrain it based on that data.

This chapter covers Distribution, Scatter, Wafer, Histogram, Activation Energy, Hot Carrier Lifetime and SPC plots; creating a programmable macro for plotting; and lifetime predictions for both Activation Energy (Electromigration) and Hot Carrier Lifetime plots.

Choosing a Plot Analysis

In the PDQ-AT Main window, click on the **Analyze** button. The PDQ-AT Analyze Window appears (figure 5.0-1 below).

Figure 5.0-1 **PDQ-AT Analyze Window**



You have a choice of Distribution, Scatter, Histogram, Wafer, Activation Energy, Hot Carrier Lifetime, and SPC plots. Click on the tab section of the analysis you desire. Some choices may be grayed-out, indicating that the dataset you are working with is unable to perform that analysis. For example, if you have a dataset from a Hot Carrier Lifetime test, you will not be able to perform an Activation Energy analysis.

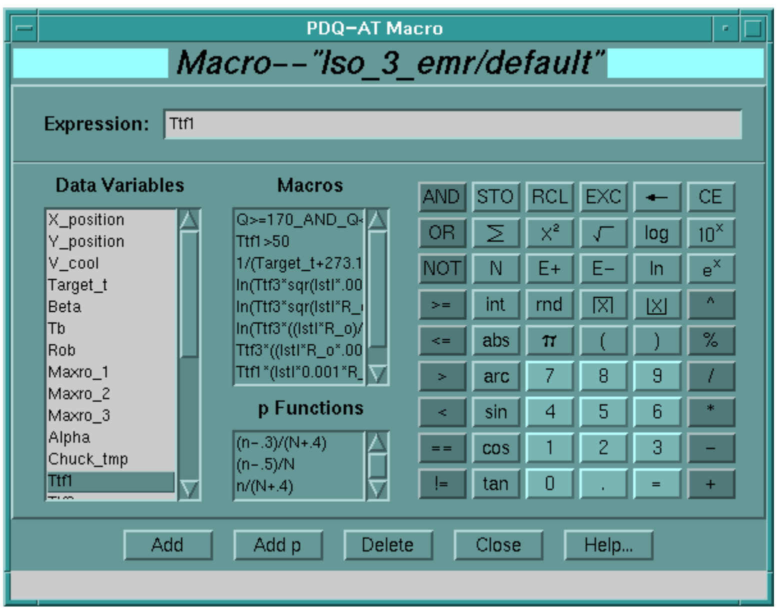
Using Macros

PDQ-AT allows users to define macros for analysis. Once defined, the macro is recorded into the algorithm macro file — thus carrying it over between sessions. Each Algorithm Database Area has its own unique algorithm macro file. Therefore, macros defined for Vramp_3_cap will not appear under Iso_3_emr.

The PDQ-AT Macro feature allows you to define new values based on calculations of existing test data. The most powerful use of the calculator may be the ability to define pass-fail criteria based on any critical parameter.

You can also use the macro calculator to count failures for any given test, implying failures counts at each die location.

Figure 5.0-2 **PDQ-AT Macro window**



Using the N and n Data Variables

N is the total number of records in the current working dataset.

n The array counter for the current working dataset. For example, if you have ten records, with record numbers of 104 to 113, n will be 1 to 10, respectively.

N and *n* are intended for probability estimation functions or p Functions but may be used in macro expressions as well. Other data variables should never be used in p Functions. For more information on p Functions, we recommend **Frugal Sampling Schemes** by James R. King.

The modulus operator (%) requires integers. Calculator functions, such as ceil or floor, generate real numbers. So the expressions used for the modulus function should either use *int* or *rnd* to truncate or round real numbers into integers.

Trigonometric Functions

The macro calculator trigonometric functions operate in radians. For example, sin expects input in radians and asin (arc sine) gives results in radians.

Hot Carrier and Activation Energy Specifics

Macros are not applicable for data used in lifetime calculations made by PDQ-AT other than to satisfy special data export needs.

Procedure

Creating a Macro

Use the following procedure to create a macro for analysis.

1. From any analyze window option, click the **Macro...** button.

   You create your macro by designing a value comprised of a mathematical function using the data variable and the calculator.

2. Click on the variable you wish to manipulate with the macro (e.g. Ttf1).
3. Click on the operator you with which to modify the variable.
4. Click to enter the value with which you desire to modify the variable in step 2. This can be a number or another variable.
5. Repeat steps 2-4 as necessary to create your macro.
6. When ready, click the **Add** button.

Alternatively, if you desire to add a probability function (p Function), you can design a p Function and add by clicking the **Add p** button.

A confirmation window appears informing you that a new macro has been added. You will also see your newly created macro in the macro list.

Any accurate mathematical function can be created and used as a plot variable. If the function is incorrect, for example by entering too many open parentheses or inaccurate use of an operator, PDQ-AT will not allow the macro to be entered.

Macros are saved as part of the algorithm database areas.

Procedure

Creating a Pass-Fail Macro

1. From any analyze window option, click the **Macro...** button.

   You create a pass-fail macro by designing a boolean clause. If the clause is TRUE, the macro returns a value of 1. If the clause is FALSE, the macro returns a value of 0.

   For SPC-b's that require multiple pass-fail clauses, design a single clause as below, add a plus (+) symbol, followed by another boolean clause.

   For more information on boolean clauses and regular expressions, see "Filter Expressions" in section 4.5, p. 77.
2. Click the **Open Parenthesis** "(" button.
3. Click on the **Data Variable** you wish to test with the macro (e.g. Ttf1).
4. Click on the regular expression operator with which to test the variable. This is one of the following operators: ==, !=, >=, >, <=, or <.
5. Click the appropriate buttons to enter the value with which you desire to test the **Data Variable** against. This can be a number or another variable.
6. Click the **Close Parenthesis** ")" button.
7. If you desire complex boolean clauses with **AND**, **OR**, or **NOT**, click the appropriate buttons. This is useful for creating a pass-fail macro. The TRUE condition will return 1, while the FALSE condition will return 0. You are free to choose TRUE implies pass or TRUE implies fail, depending upon your analysis needs.
8. If you desire a multiple pass-fail macro, click the plus symbol (**+**) button. In effect, this will give a count of passes or fails.

   Repeat steps 2-8 as necessary to create your macro.

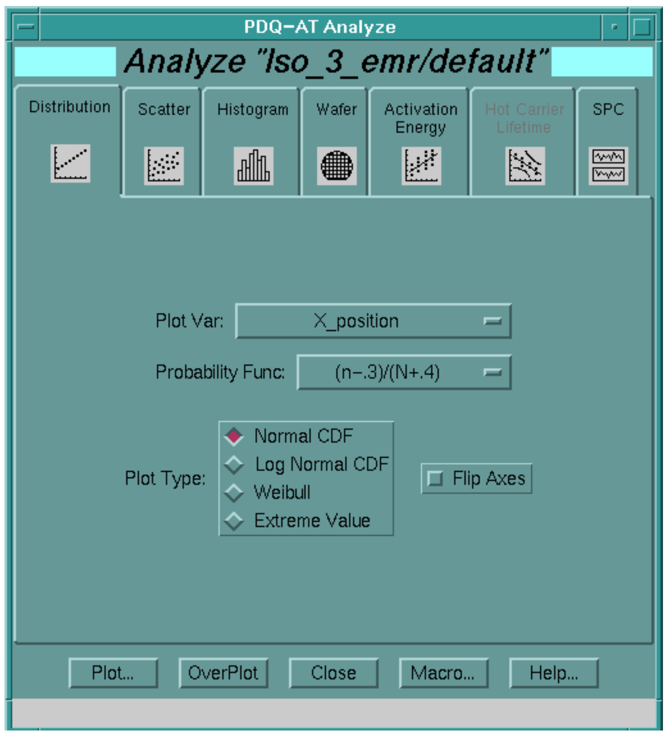
6. When ready, click the **Add** button.

A confirmation window appears informing you that a new macro has been added. You will also see your newly created macro in the macro list.

5.1 Distribution Plot

1. From the PDQ-AT Main window, click on the **Analyze** button. The PDQ-AT Analyze window activates.
2. Click the **Distribution** tab. The Distribution option activates.

Figure 5.1-1 PDQ-AT Analysis Window: Distribution option



3. Select the plot variable, **Plot Var**, expression to be plotted is displayed in this option menu.
4. Select the **Probability Function** for use in calculating the Z values in a distribution plot. You can use the PDQ-AT Macro window to create a new macro for your needs. The default of (n-.3)/(N+.4) is very highly recommended.

5 Select one of the four plot type distributions available:

Normal CDF — create a normal cumulative distribution function (CDF) plot of a variable or macro expression.

Log Normal CDF — create a log normal CDF plot of a variable or macro expression.

Weibull — create a Weibull distribution plot of a variable or macro expression.

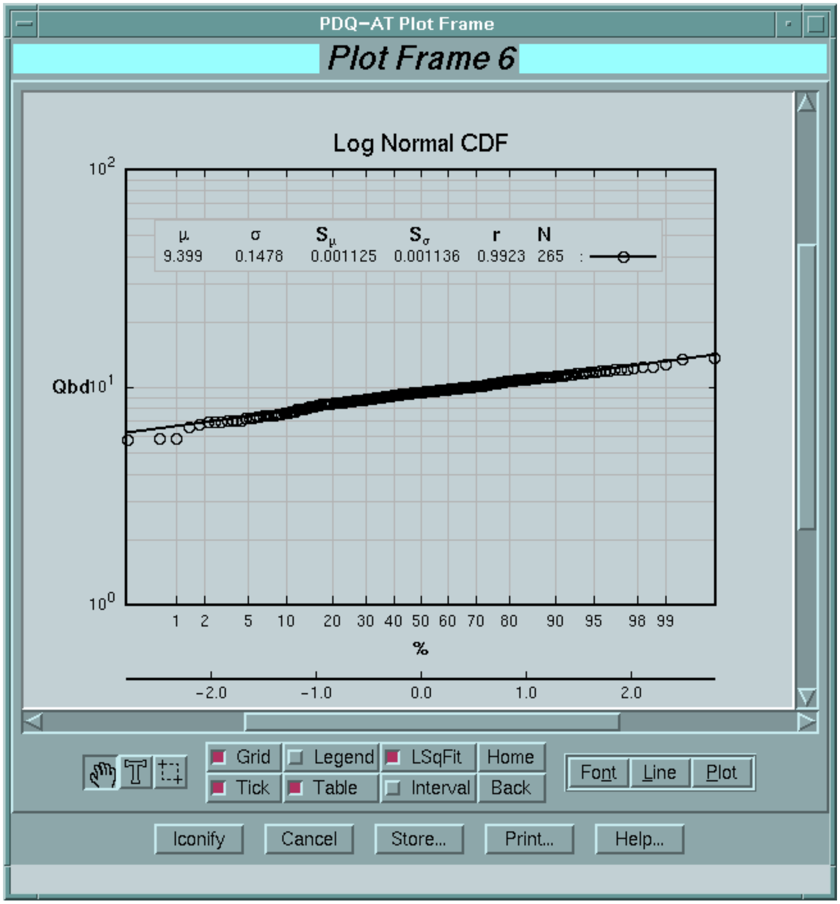
Extreme Value — create an extreme value distribution plot of a variable or macro expression.

6. Click on the **Flip** button to flip the X- and Y-axes, if desired. Normally, the Plot Var should appear on the Y-axis, but this can be reversed using this feature.

7. Click the **Plot** button.

The PDQ-AT Plot Frame window appears, displaying your dataset in your chosen plot type.

Figure 5.1-2 **Sample distribution plot frame**



Customizable Plot Elements

The following buttons can be found on the plot frames pertaining to them.

Grid Toggles the background grid display within the plot canvas. You can customize the grid in the plot settings window under the Grid and Tick options.

Tick Toggles the X- and Y- axes tick mark display within the plot canvas. You can customize the tick in the plot settings window under the Grid and Tick options.

Legend Toggles the display of a legend identifying the plot(s). All plots can have a legend, if desired.

Table Toggles the display of the table of attributes (a.k.a. population parameters), as derived from the Table of Distribution Equations (see "Appendix: Explaining the Analyzed Data" in section 10, p. 205).

LSqFit Toggles the least squares fit plot display within the plot frame.

Interval Toggles confidence interval display within the plot frame. You can customize the confidence intervals' bounds and confidence percentages.

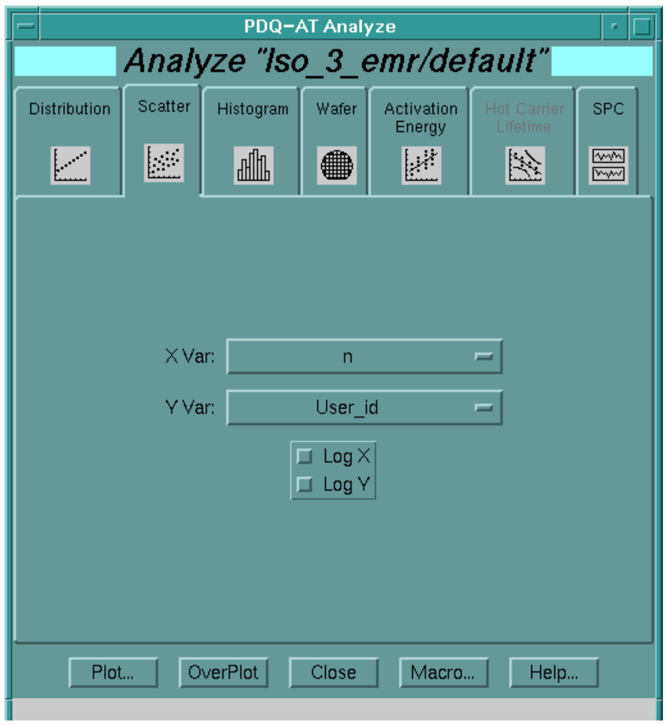
Home Restores the plot canvas view to the original position and zoom.

Back Returns to the plot canvas view prior to the when the **Home** button was invoked.

5.2 Scatter Plot

1. From the PDQ-AT Main window, click on the **Analyze** button. The PDQ-AT Analyze window activates.
2. Click the **Scatter** tab. The scatter analysis option activates.

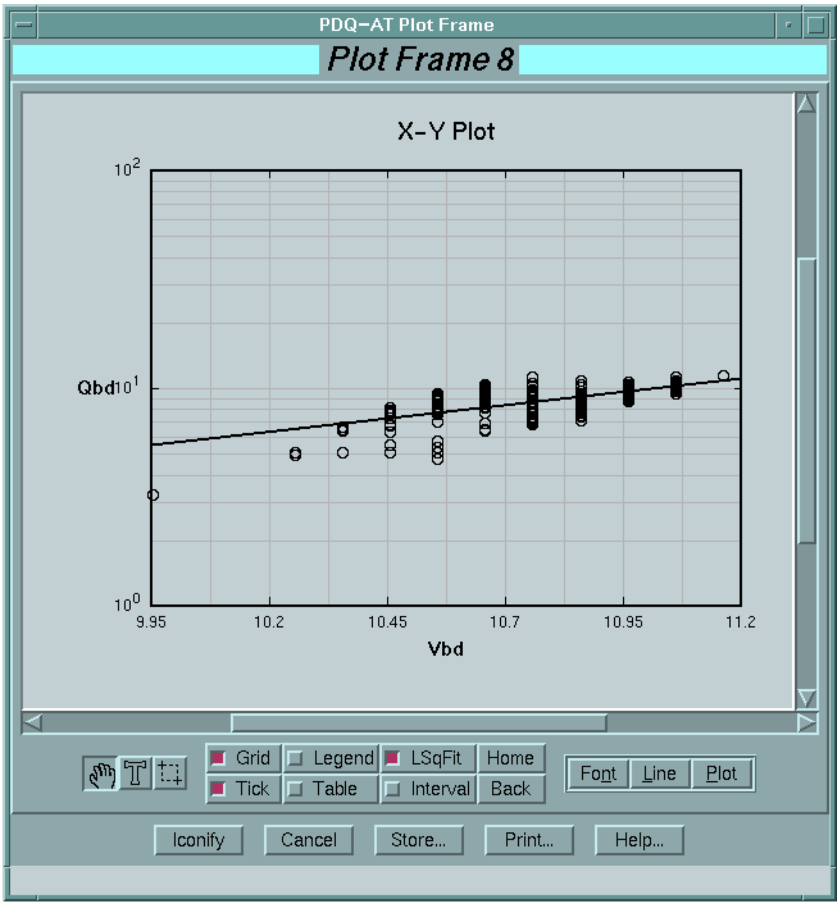
Figure 5.2-1 PDQ-AT Analysis Window: Scatter option



3. Select the X-axis variable, **X Var**, to be plotted.
4. Select the Y-axis variable, **Y Var**, to be plotted.
5. Enable log scaling for X- and/or Y- axes by clicking on the **Log X** or **Log Y** buttons, if desired.
6. Click the **Plot** button.

The PDQ-AT Plot Frame window appears, displaying your dataset in your chosen plot type.

Figure 5.2-2 **Sample scatter plot frame**



Key String Plotting

PDQ-AT allows you to create a scatter plot from key string variables enabling you to cross-reference input and output values with specific variables. Selecting string variables on the X-axis allows you to visualize the relationship between groups of like data. Some possible uses are X Var = Lot_id, Die_name, or Wafer_id. It is meaningless to plot a string variable against a string variable. The attempt should not be made.

Customizable Plot Elements

The following buttons can be found on the plot frames pertaining to them.

Grid Toggles the background grid display within the plot canvas. You can customize the grid in the plot settings window under the Grid and Tick options.

Tick Toggles the X- and Y- axes tick mark display within the plot canvas. You can customize the tick in the plot settings window under the Grid and Tick options.

Legend Toggles the display of a legend identifying the plot(s). All plots can have a legend, if desired.

Table Toggles the display of the table of attributes (a.k.a. population parameters), as derived from the Table of Distribution Equations (see “Appendix: Explaining the Analyzed Data” on page 10-205).

LSqFit Toggles the least squares fit plot display within the plot frame.

Interval Toggles confidence interval display within the plot frame. You can customize the confidence intervals’ bounds and confidence percentages.

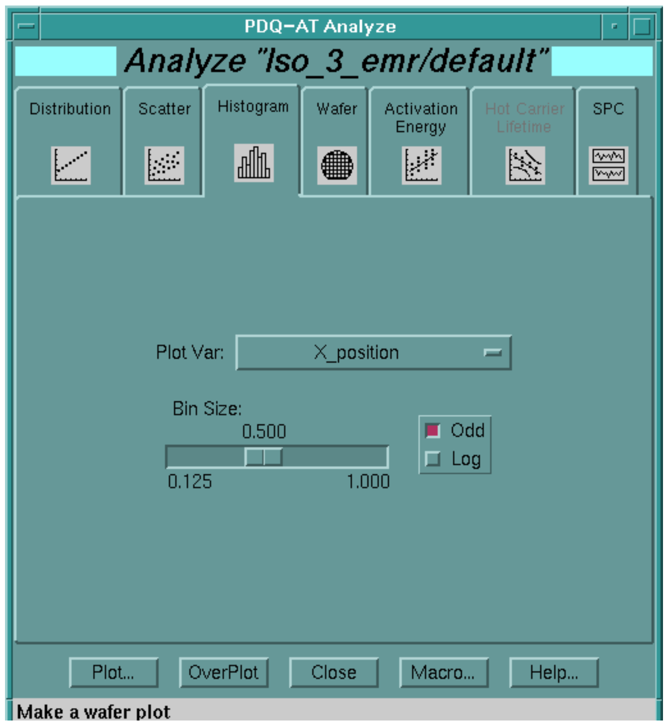
Home Restores the plot canvas view to the original position and zoom.

Back Returns to the plot canvas view prior to the when the **Home** button was invoked.

5.3 Histogram

1. From the PDQ-AT Main window, click on the **Analyze** button. The PDQ-AT Analyze window activates.
2. Click the **Histogram** tab. The Histogram option activates.

Figure 5.3-1 PDQ-AT Analysis Window: Histogram option

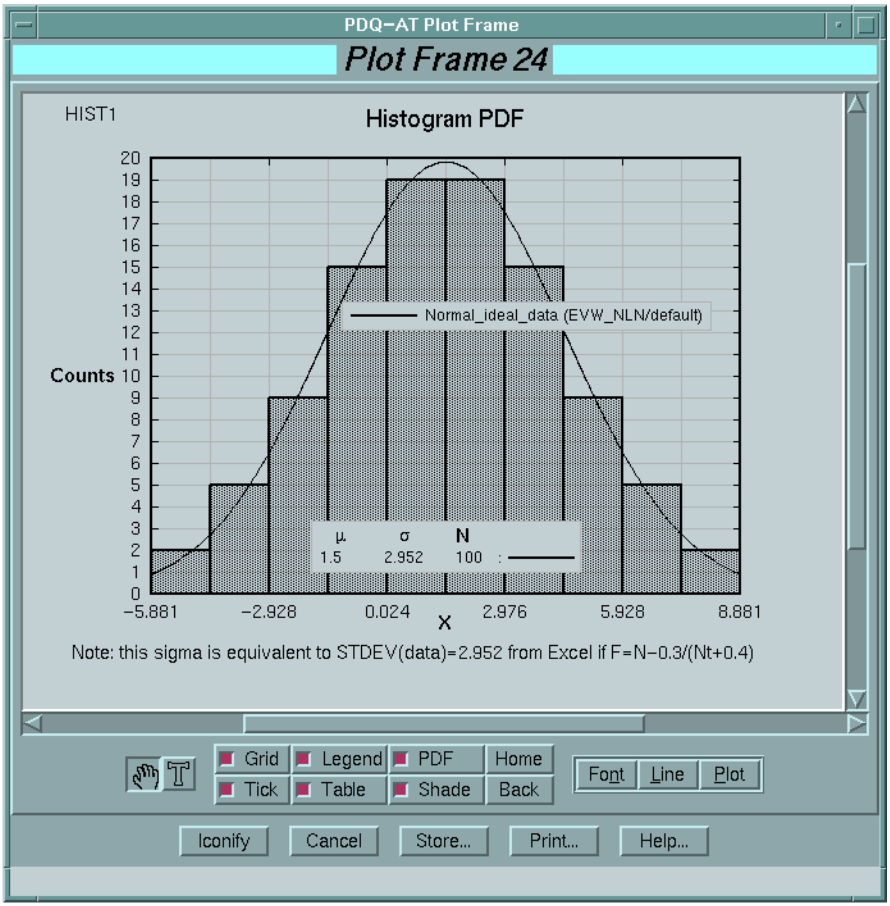


3. Select the plot variable, **Plot Var,** to be plotted in the histogram.
4. Click the **Odd** button if you desire an odd number of histogram bins, with the central one straddling the mean.
5. Click the **Log** button to enable log scaling of the histogram bin sizes rather than uniform bin sizes.
6. Use the **Bin Size** bar to select the size of the histogram bins as a fraction of the sigma standard deviation of the variable data.

7. Click the **Plot** button.

The PDQ-AT Plot Frame window appears, displaying your dataset in a Histogram.

Figure 5.3-2 **Histogram plot frame**



Customizable Plot Elements

The following buttons can be found on the plot frames pertaining to them.

Grid Toggles the background grid display within the plot canvas. You can customize the grid in the plot settings window under the Grid and Tick options.

Tick Toggles the X- and Y- axes tick mark display within the plot canvas. You can customize the tick in the plot settings window under the Grid and Tick options.

Legend Toggles the display of a legend identifying the plot(s). All plots can have a legend, if desired.

Table Toggles the display of the table of attributes (a.k.a. population parameters)**.**

The population parameters are the straightforward calculation of mean and standard deviation for a a normal probability density function for N samples.

PDF Toggles the normal probability density function curves for Histogram plots.

Shading Toggles column shading in Histogram plots.

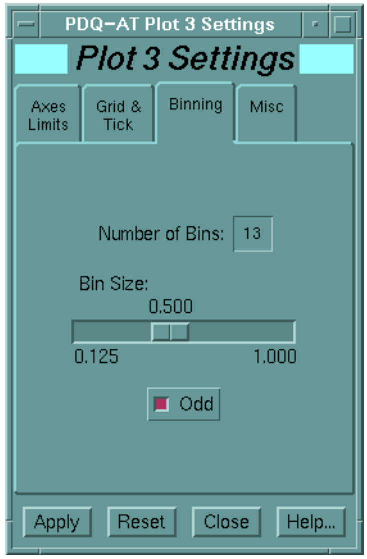
Home Restores the plot canvas view to the original position and zoom.

Back Returns to the plot canvas view prior to the when the **Home** button was invoked.

Histogram Bin Sizes

For Histograms, you can set the binning size with this option. Bin Size is measured as a fraction of the sigma (standard deviation) of the variable data.

Figure 5.3-3 **Plot Settings Window: Binning options**



Procedure

Changing Binning Options

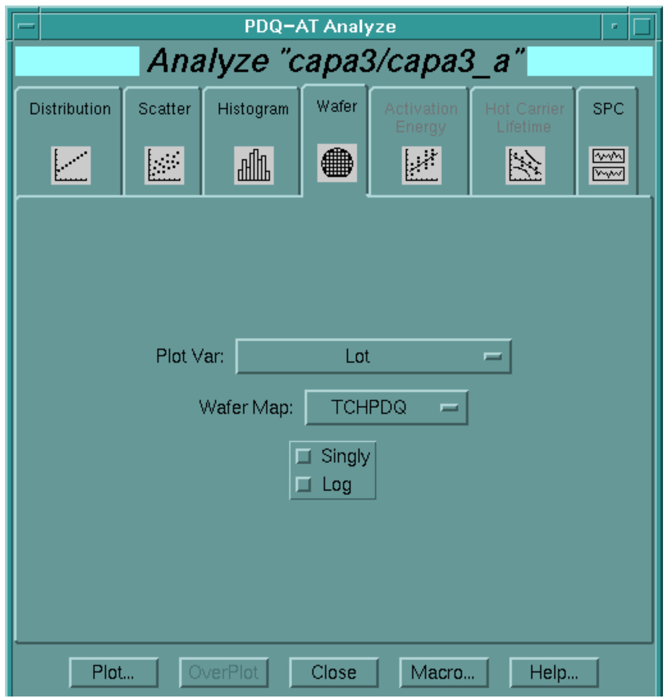
1. Select **Plot > Plot Settings**. The plot setting window appears.
2. If the Binning option is not activated, click on the **Binning** tab.
3. Click-drag the Bin Size to the preferred size. Notice that the **Number of Bins** changes as you do so.
4. Click **Apply**.

The plot canvas changes in accordance to the values entered.

5.4 Wafer Plots

1. From the PDQ-AT Main window, click on the **Analyze** button. The PDQ-AT Analyze window activates.
2. Click the **Wafer** tab. The Wafer option activates.

Figure 5.4-1 **PDQ-AT Analysis window: Wafer option**



3. Select the variable, **Plot Var**, to be plotted.
4. Select the **Wafer Map** definition.

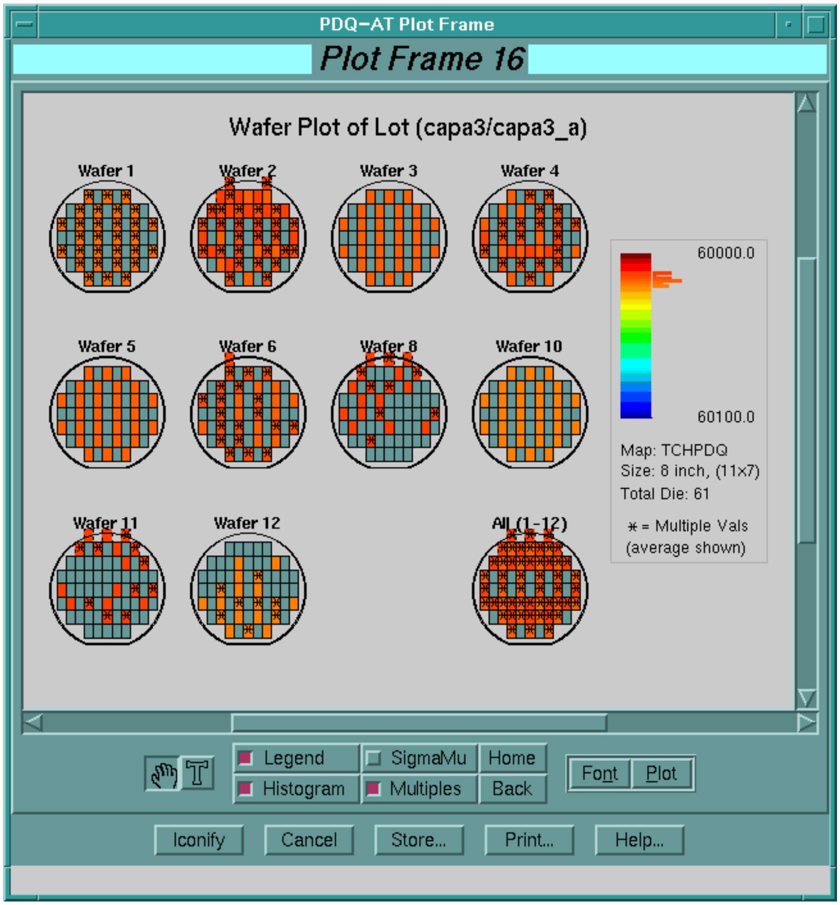
   If the desired map is not in the menu, the user may specify the map in the **Define Wafer** window. The map menu updates automatically once a new map has been defined. See chapter 7, "Wafer Map Definitions" for more information.

Normally, the wafer definition should match the Wafer_name for this data. See “Wafer Map Definitions” in section 7, p. 187.

5. Clicking the **Singly** button displays only one wafer per page, with die index axes on the plot. Without the **Singly** selection, up to 25 wafers are displayed per page, without die index axes.
6. Click **Log** to enable log scaling of the wafer color map.
7. Click the **Plot** button.

The PDQ-AT Plot Frame window appears, displaying your dataset as a Wafer plot.

Figure 5.4-2 **Wafer plot frame**



Customizable Plot Elements

The following buttons can be found on the plot frames pertaining to them.

Legend Toggles the display of a legend identifying the plot(s). All plots can have a legend, if desired.

Histogram Toggles the display of a histogram of occurrences in the color map of wafer plots.

SigmaMu Toggles the display of the sigma and mu (standard deviation and mean) values in the legend of Wafer plots.

Multiples Toggles the display of an asterisk on dice that have multiple values in wafer plots. Clicking upon such a die will bring up a Histogram plot of its multiple values.

Home Restores the plot canvas view to the original position and zoom.

Back Returns to the plot canvas view prior to the when the **Home** button was invoked.

Plot Menu

The plot menu for wafer plots are significantly different than other plots.

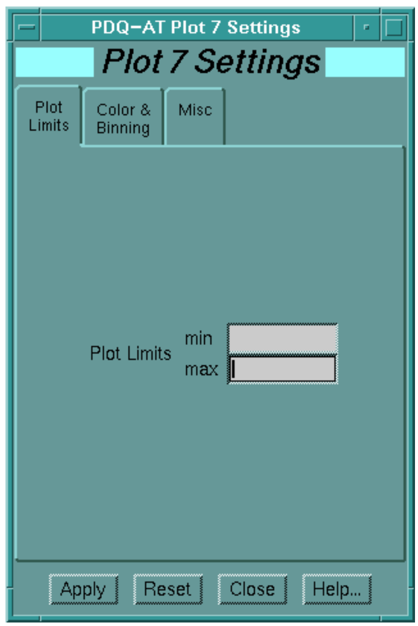
Working with Multiple Wafer Plots

The **Multiples** button activates the multiple indicator (*) on the wafer map. If a wafer area has an asterisk, you can click on it to see a histogram of the multiple values. For more information on histograms, see “Histogram” in section 5.3, p. 123.

Plot Limits Options

Under this option, you can set the Plot Limits.

Figure 5.4-3 **Plot Settings window: Plot Limits options**



Procedure

Changing Plot Limits Options

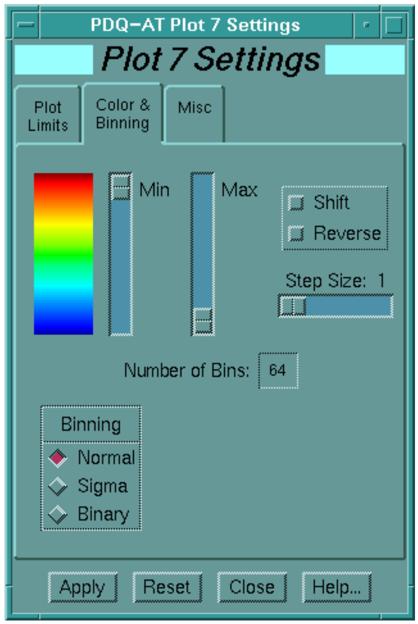
1. Select **Plot > Plot Settings**. The plot setting window appears.
2. If the **Plot Limits** option is not activated, click on the **Plot Limits** tab.
3. Type maximum and minimum plot limits in their respective test fields.
4. Click **Apply**.

The plot canvas changes in accordance to the values typed in.

Color & Binning Options

Under this option, you can set the color and binning for the wafer plot.

Figure 5.4-4 **Plot Settings window: Color & Binning options**



Procedure

Changing Color & Binning Options

1. Select **Plot > Plot Settings**. The plot setting window appears.
2. If the Color & Binning option is not activated, click on the **Color & Binning** tab.
3. Select the color options as desired:
   The **Min** and **Max** set the low and high ends of the range respectively.

   Shift is used to shift the color map as the user prefers when an odd number of bins or colors are selected. Reverse allows you to visualize the low value using either a hot or cold color, as desired.

4. Select the binning options as desired:
   When sigma binning is selected, most color preferences are set automatically.

   Threshold binning allows you to set pass-fail at a glance.

4. Click **Apply**.

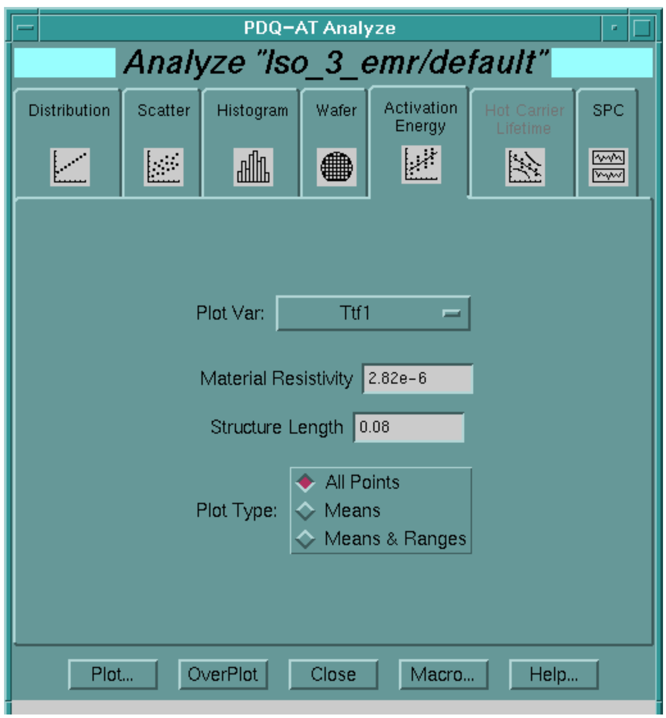
The plot canvas changes in accordance to the values selected.

5.5 Activation Energy

Note: This tab only activates for Iso_3_emr and Iso_4_emr working sets.

1. From the PDQ-AT Main window, click on the **Analyze** button. The PDQ-AT Analyze window activates.
2. Click the **Activation Energy** tab. The Activation Energy option activates.

Figure 5.5-1 PDQ-AT Analysis Window: Activation Energy option

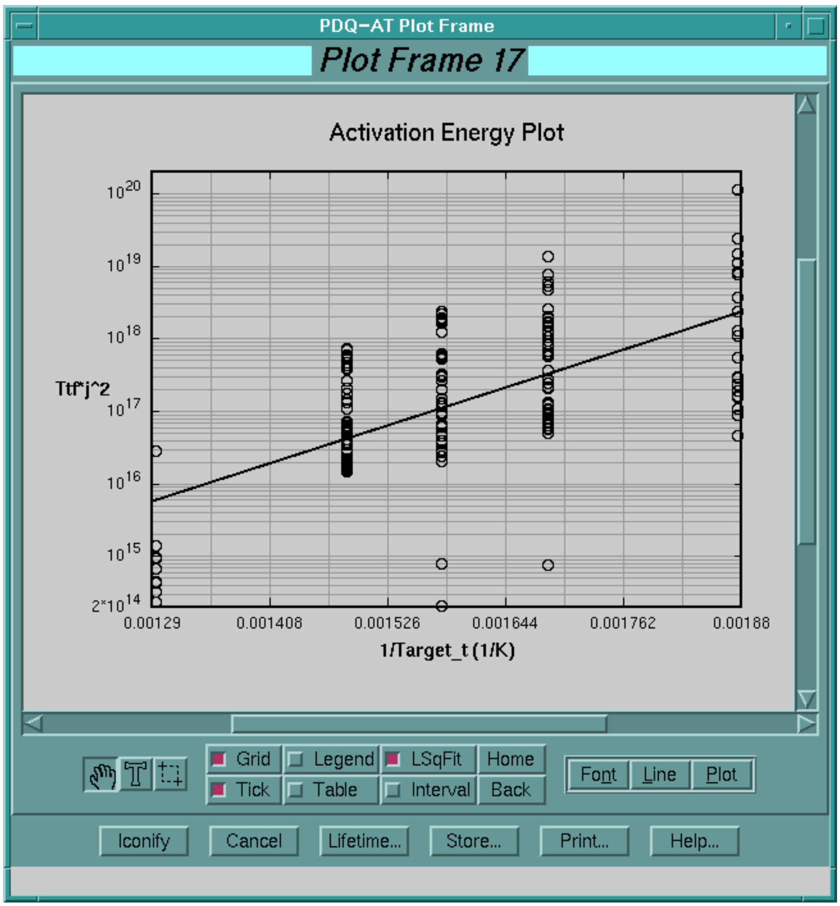


3. Select the desired time to failure: Ttf1, Ttf2 or Ttf3.
4. Set the **Material Resistivity** — the measurement of resistivity of the material tested in ohm-cm units.
5. Set the **Structure Length** — length of the structure tested in cm.

6. Select the Plot Type. All Points plots all the points, Means plots the mean only and Means & Ranges plots the mean and range.
7. Click the **Plot** button.

The PDQ-AT Plot Frame window appears, displaying your dataset in your chosen plot type.

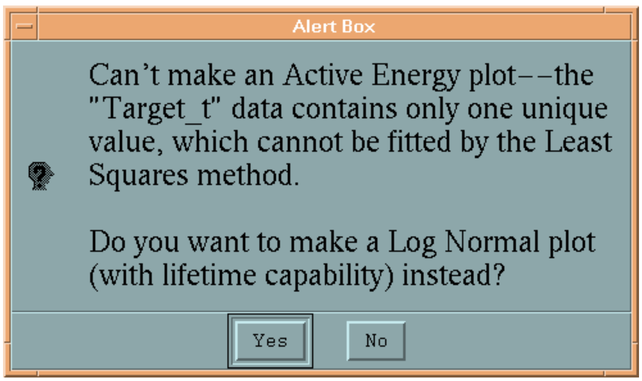
Figure 5.5-2 **Activation Energy plot frame**



You may overplot lifetime plots, but not lifetime predictions. If you have several overplots and wish to create a lifetime prediction for one of them, select the desired plot and click the **Lifetime...** button. For more information, see "Working with Plot Frames" in section 6, p. 167.

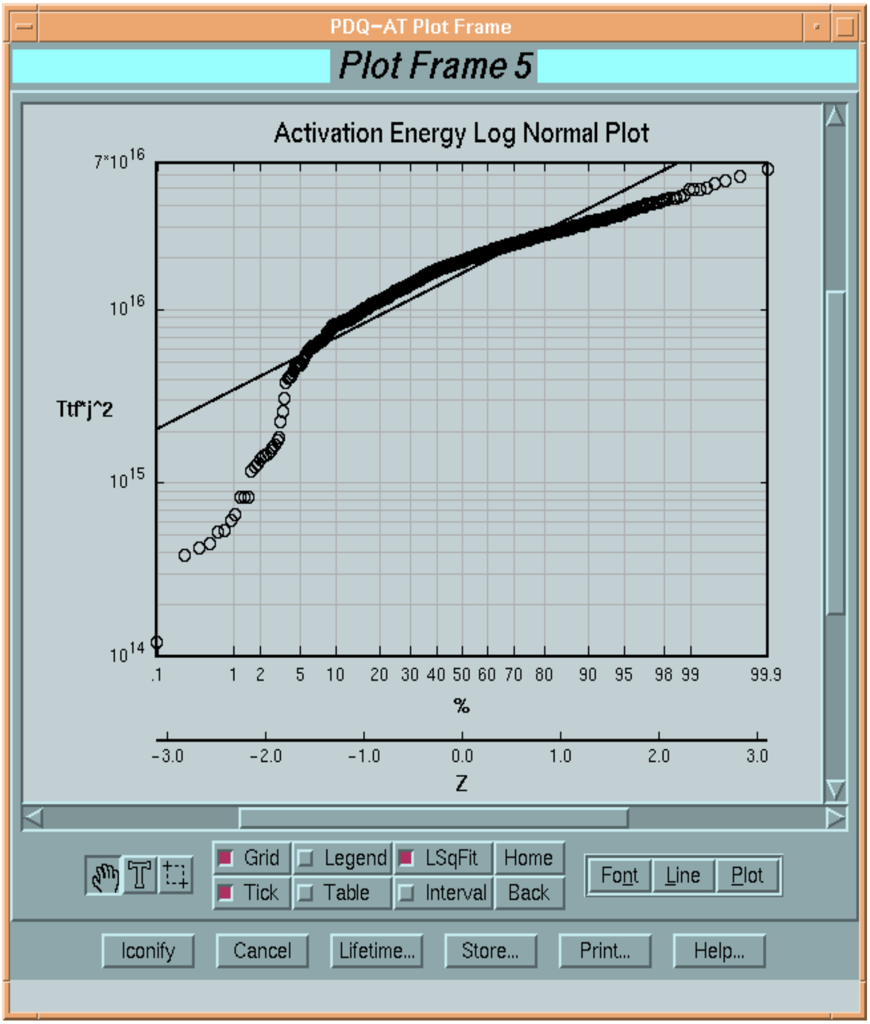
If you have a working set containing a single Target_t value, you will be given the following dialog ...

Figure 5.5-3 **Single Temperature Dialog ...**



Instead of calculating Activation Energy, you'll be allowed to create a log normal plot of the data.

Figure 5.5-4 **Log Normal; Activation Energy Plot**



Customizable Plot Elements

The following buttons can be found on the plot frames pertaining to them.

Grid Toggles the background grid display within the plot canvas. You can customize the grid in the plot settings window under the Grid and Tick options.

Tick Toggles the X- and Y- axes tick mark display within the plot canvas. You can customize the tick in the plot settings window under the Grid and Tick options.

Legend Toggles the display of a legend identifying the plot(s). All plots can have a legend, if desired.

Table Toggles the display of the table of attributes (a.k.a. population parameters), as derived from the Table of Distribution Equations. See “Appendix: Explaining the Analyzed Data” in section 10, p. 205 for more information.

LSqFit Toggles the least squares fit plot display within the plot frame. LSqFit is available only on Distribution and Scatter plots.

Interval Toggles confidence interval display within the plot frame. Confidence intervals are only available in Distribution, Scatter, Activation Energy and Hot Carrier Lifetime plots.

You can cusomize the confidence intervals’ bounds and confidence percentages.

Home Restores the plot canvas view to the original position and zoom.

Back Returns to the plot canvas view prior to the when the **Home** button was invoked.

For more information on working with plot frames, see “Using Intelligent Plots” in section 6, p. 163.

Activation Energy Lifetime Parameters

For an Activation Energy Lifetime Prediction, there are seven values that can be edited.

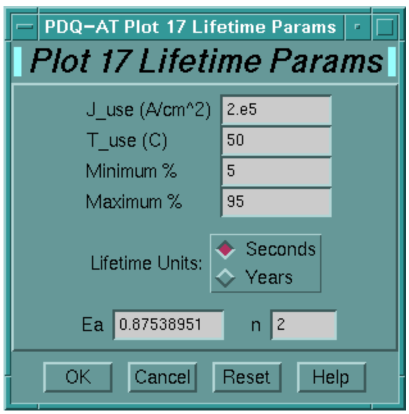
J_use Current density at normal use conditions, measured in amps/cm^2.

T_use Temperature at normal use conditions, measured in Celsius (C).

Min_% Minimum percentage lifetime prediction boundary.

Max_% Maximum percentage lifetime prediction boundary.

Figure 5.5-5 **Activation Energy Lifetime Params**



Lifetime Units Select seconds to plot the time to failure in seconds or years to plot the time to failure in siderial years (31558126 seconds).

Ea EM plot slope, defaults to Ea value of Activation Energy plot. For single temperature Log Normal plot, the default is 0.7 which is an industry standard value.

n Specifies the power of j_use (1 <= n <= 5; defaults to 2).

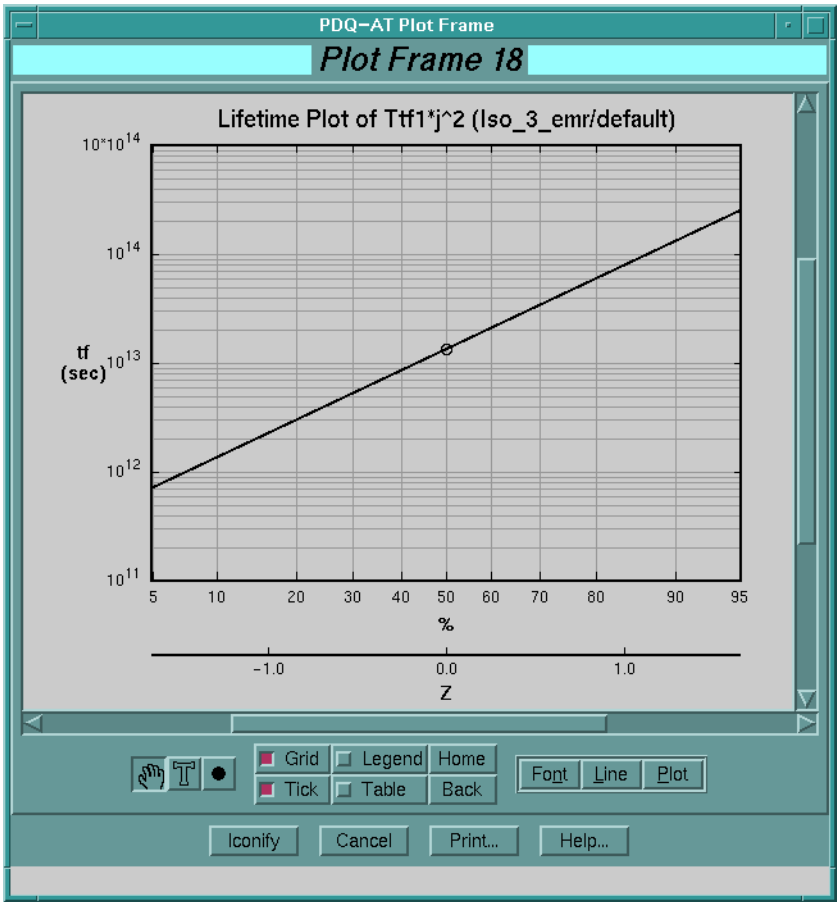
Procedure — Activation Energy Lifetime Prediction Procedure

The following is a procedure for Activation Energy Lifetime Predictions from load to finish.

1. Click on the **Load** button in the PDQ-AT Main Window. The PDQ-AT Load Window appears.

   Alternatively, you may press **Ctrl+L** or select **File > Load**.
2. Select the directory of the target using the **Data Path** popup.
3. Click on the file you want to open. The filename appears in the **File Name** text field. You must select an Iso_3_emr or Iso_4_emr working set.
4. Click the **Load** button. The PDQ-AT Load window closes and the PDQ-AT Main window activates with the filename of the dataset in the main window title.
5. Filter and sort as desired. For more information, see subchapters 4.5 and 4.6 respectively.
6. Click the **Analyze** button. The PDQ-AT Analyze window activates.
7. Click the **Activation Energy** tab. Enter the **Material Resistivity** and the **Structure Length** into their respective text fields.
8. Click the **Plot** button. A new plot frame opens.
9. Constrain the data as necessary. For more information on constraining data, see chapter 6, "Using Intelligent Plots."
10. When ready, click the **Lifetime...** button.
11. Provide the Lifetime parameters, click OK when done.

Figure 5.5-6 **Activation Energy Lifetime Prediction**

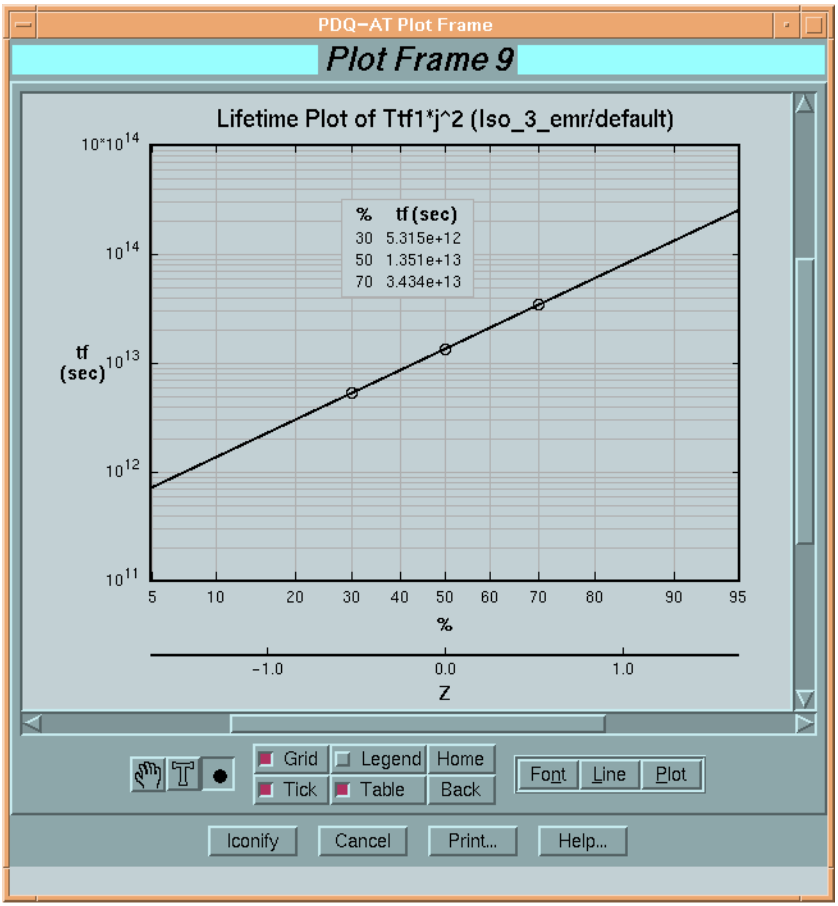


A new plot frame opens with an Activation Energy Lifetime Prediction. Lifetime prediction plots have several features in common with other plots, but the most noticeable feature not in common is, by nature of the plot, that you can not constrain or view plot points.

The "Point Mode" button (black dot) allows the user to add % lifetime points which also show in the table when activated (see figure below).

Moving the mouse icon over the plot points shows the population parameters used to calculate the % lifetime point; the data are displayed in the bottom of the window where the Help Text appears.

Figure 5.5-7 **Activation Energy Lifetime Prediction (after point mode usage)**



Customizable Plot Elements for Lifetime Predictions

The following buttons can be found on the plot frames pertaining to them.

Grid Toggles the background grid display within the plot canvas. You can customize the grid in the plot settings window under the Grid and Tick options.

Tick Toggles the X- and Y- axes tick mark display within the plot canvas. You can customize the tick in the plot settings window under the Grid and Tick options.

Home Restores the plot canvas view to the original position and zoom.

Back Returns to the plot canvas view prior to the when the **Home** button was invoked.

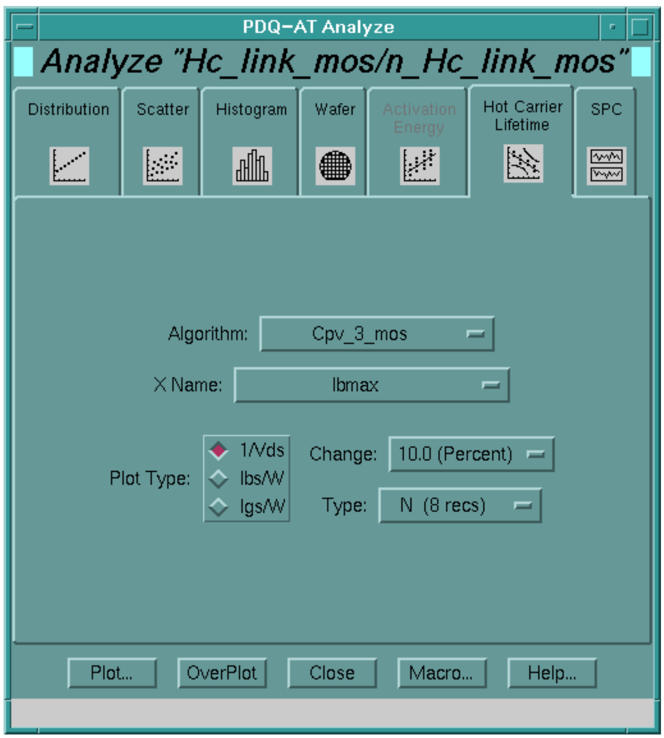
For more information on working with plot frames, see “Using Intelligent Plots” in section 6, p. 163.

5.6 Hot Carrier Lifetime

Note: This tab only activates for Hc_link_mos and Hc_link_2_mos working sets.

1. From the PDQ-AT Main window, click on the **Analyze** button.
2. Click the **Hot Carrier Lifetime** tab. The Hot Carrier Lifetime option activates only when Hc_link_mos data are being used.

Figure 5.6-1 PDQ-AT Analysis Window: Hot Carrier Lifetime option



3. Select which Hot Carrier Lifetime **Algorithm** to plot.

   Only those algorithms for the HC tests selected using Load and Filter will appear. For more information on Hot Carrier Lifetime Algorithms, please see the PDQ-WLR Software User's manual.

4. Select the **X Name** to plot. Only those variables which were chosen for lifetime calculations in the selected HC tests, for the selected Algorithm, will be displayed.
5. Select **Plot Type.** Choose from the following JEDEC suggested Hot Carrier Lifetime Prediction calculations:

   1/Vds

   Ibs/W

   Igs/W

   where:

   Vds = drain voltage, measured in volts (V)

   Ibs = bulk current, measured in microamps (uA)

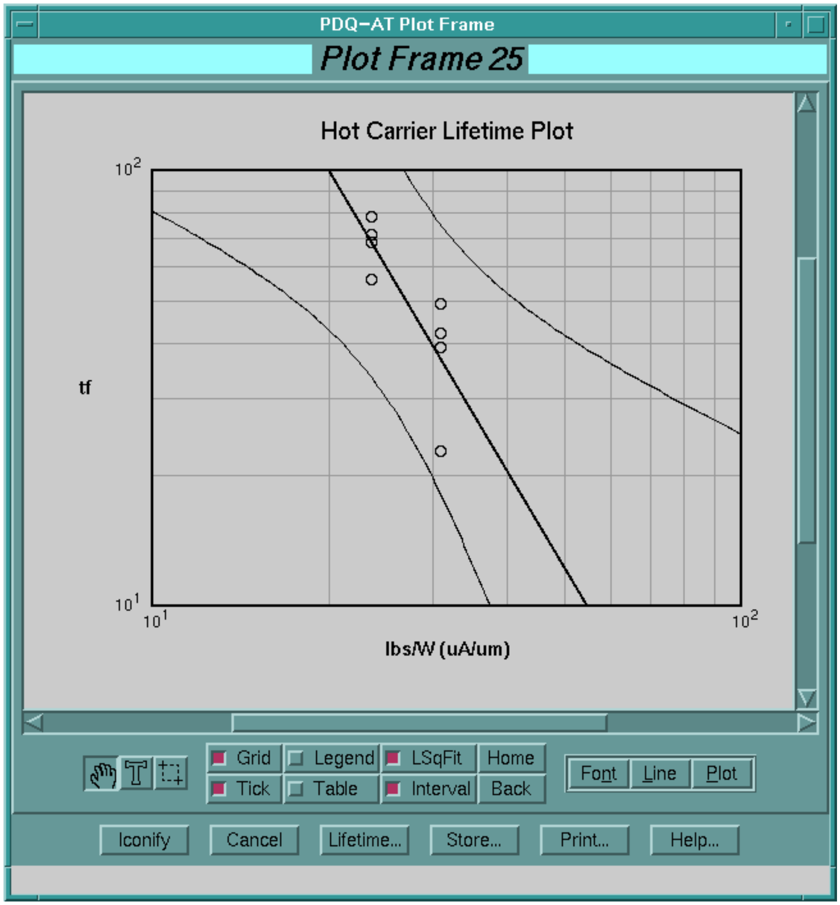
   Igs = gate current, measured in picoamps (pA)

   W = device width in microns (um)
6. Select the **Change %.** Change percent specifies the change percent value to be plotted for the given X Name. The choices of Change % are limited to those selected during the hot carrier tests for this algorithm, on this X Name.
7. Select **N-type** or **P-type** technology stressed during HC testing.
8. Click the **Plot** button.

The PDQ-AT Plot Frame window appears, displaying your dataset in your chosen plot type.

You may overplot lifetime plots, but not lifetime predictions. If you have several overplots and wish to create a lifetime prediction for one of them, select the desired plot and click the **Lifetime...** button. For more information, see “Working with Plot Frames” in section 6, p. 167.

Figure 5.6-2 **Hot Carrier Lifetime plot frame**



Hidden Lifetime_2_mos Data

When working with Hc_link_2_mos algorithm, PDQ-AT loads a hidden copy of Lifetime_2_mos for internal use. If the user loads a new Lifetime_2_mos file, PDQ-AT prompts the user if he or she wants to load another copy, even though a Lifetime_2_mos file isn't listed on the Working List. This is normal behavior when working with linked data and the user should just click the Yes button on the Load Another dialog box.

Customizable Plot Elements

The following buttons can be found on the plot frames pertaining to them.

Grid Toggles the background grid display within the plot canvas. You can customize the grid in the plot settings window under the Grid and Tick options.

Tick Toggles the X- and Y- axes tick mark display within the plot canvas. You can customize the tick in the plot settings window under the Grid and Tick options.

Legend Toggles the display of a legend identifying the plot(s). All plots can have a legend, if desired.

Table Toggles the display of the table of attributes, as defined by JEDEC.

LSqFit Toggles the least squares fit plot display within the plot frame.

Interval Toggles confidence interval display within the plot frame. You can cusomize the confidence intervals' bounds and confidence percentages.

Home Restores the plot canvas view to the original position and zoom.

Back Returns to the plot canvas view prior to the when the **Home** button was invoked.

Hot Carrier Lifetime Parameters

For a Hot Carrier Lifetime Prediction, there are several values that can be edited. These values vary upon the selected Plot Types.

Vds_use Drain voltage at normal use conditions, measured in volts(V).

Ibs_use Bulk current at normal use conditions, measured in microamps (mA).

Igs_use Gate current at normal use conditions, measured in picoamps (pA).

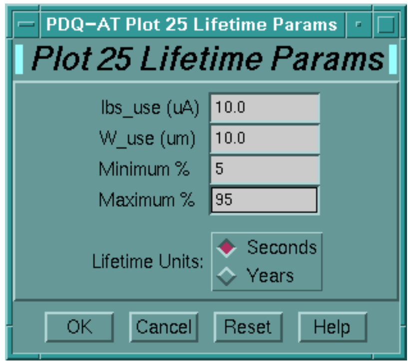
W_use Device width in microns (um) at normal use conditions.

Min_% Minimum percentage lifetime prediction boundary.

Max_% Maximum percentage lifetime prediction boundary.

Lifetime Units Select seconds to plot the time to failure in seconds or years to plot the time to failure in siderial years (31558126 seconds).

Figure 5.6-3 **Hot Carrier Lifetime Parameters Menu**



Procedure

Carrier Lifetime Prediction Procedure

The following is a procedure for Hot Carrier Lifetime Predictions from load to finish.

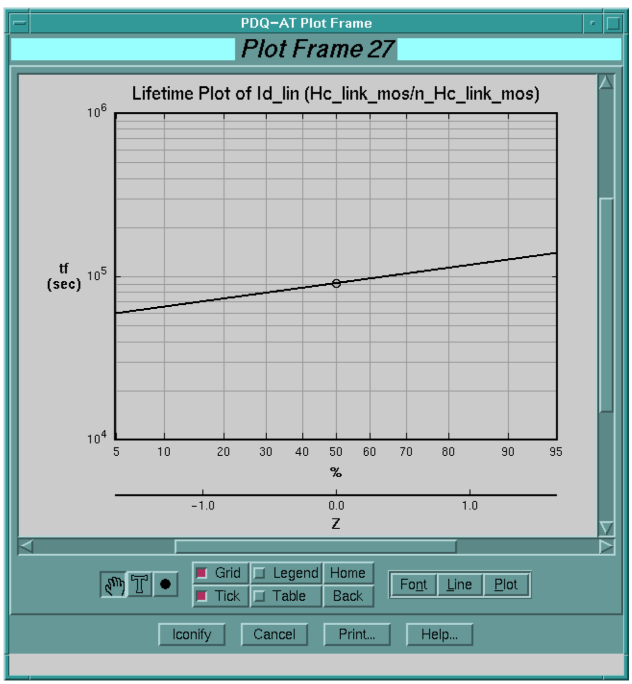
1. Click on the **Load** button in the PDQ-AT Main Window. The PDQ-AT Load Window appears.

   Alternatively, you may press **Ctrl+L** or select **File > Load**.

2. Select the directory of the target using the popup directory widget.
3. Click on the file you want to open. The filename appears in the **File Name** text field. You must select an Hc_link_mos or Hc_link_2_mos working set.
4. Click the **Load** button. The PDQ-AT Load Window closes and the PDQ-AT Main Window activates with the filename of the dataset in the main window title.
5. Filter and sort as desired. For more information, see subchapters 4.5 and 4.6 respectively.
6. Click the **Analyze** button. The PDQ-AT Analyze window activates.
7. Click the **Hot Carrier Lifetime** tab. The Hot Carrier Lifetime option activates.
8. Select which Hot Carrier Lifetime **Algorithm** to plot.

9. Select the **X Name** to plot. This will be the name of a tracked variable you selected during PDQ-WLR testing.
10. Select **Plot Type.**
11. Select the **Change** parameter**.**
12. Select **N-type** or **P-type** technology stressed during HC testing.
13. Click the **Plot** button. A new plot frame opens.
14. Constrain the data as necessary. For more information on constraining data, see chapter 6, "Using Intelligent Plots."
15. When ready, click the **Lifetime...** button.
16. Provide the Lifetime parameters, click OK when done.

Figure 5.6-4 **Hot Carrier Lifetime Prediction**



A new plot frame opens with an Hot Carrier Lifetime Prediction. Lifetime prediction plots have several features in common with other plots, but the most noticeable feature not in common is, by nature of the plot, that you can not constrain or view plot points.

The "Point Mode" button (black dot) allows the user to add % lifetime points which also show in the table when activated.

Moving the mouse icon over the plot points shows the population parameters used to calculate the % lifetime point; the data are displayed in the bottom of the window where the Help Text appears.

Customizable Plot Elements for Lifetime Predictions

The following buttons can be found on the plot frames pertaining to them.

Grid Toggles the background grid display within the plot canvas. You can customize the grid in the plot settings window under the Grid and Tick options.

Tick Toggles the X- and Y- axes tick mark display within the plot canvas. You can customize the tick in the plot settings window under the Grid and Tick options.

Home Restores the plot canvas view to the original position and zoom.

Back Returns to the plot canvas view prior to the when the **Home** button was invoked.

For more information on working with plot frames, see “Using Intelligent Plots” in section 6, p. 163 below.

CSV Files and Test Data Links

PDQ-AT allows users to get a great depth of information on lifetime predictions through the CSV files. If the PDQ-WLR program is configured to create CSV files of the data, you can compare pre- and post-stress variables and the time vs. parameter curve that creates the Hot Carrier Lifetime Prediction.

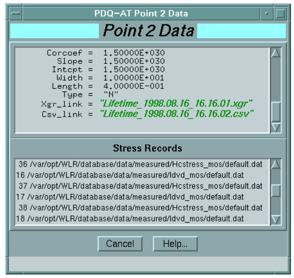
Procedure

Plotting CSV Files

Use the following procedure to plot the pre- and post-stress variables and the Parameter vs. Time curve with CSV files.

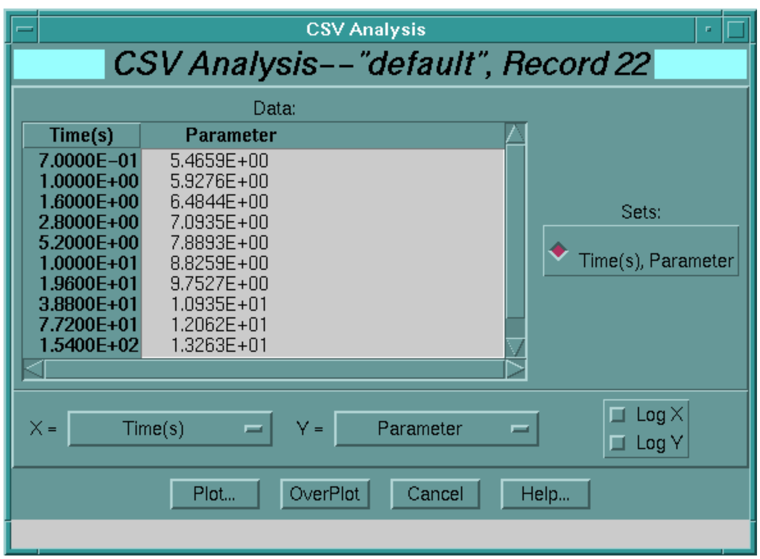
1. Plot a Hot Carrier Lifetime plot as normal. ***Do not iconify this plot frame during this process***.
2. With the **Select** tool, click on a plot point. A point window with stress links appears. This window is the ***original plot point window***.

Figure 5.6-5 **PDQ-AT Plot Point window with Stress links**



3. Scroll down the point data until the **CSV_file** record appears. It is the very last record in the data.
4. Click on the **CSV_file** link. The CSV Analysis window appears.

Figure 5.6-6 **CSV Analysis window**



If this record is not a link (it looks like normal text or is blank) then the CSV file was removed from your system since the test, or your test conditions didn't include creating CSV files. If you desire CSV and/or Xgraph files, see the PDQ-WLR Software User's Guide.

If you select logarithmic graphing and the CSV data are negative, PDQ-AT with then plot the absolute value of the data.

5. Click both **Log X** and **Log Y** buttons.
6. Click the **Plot** button.

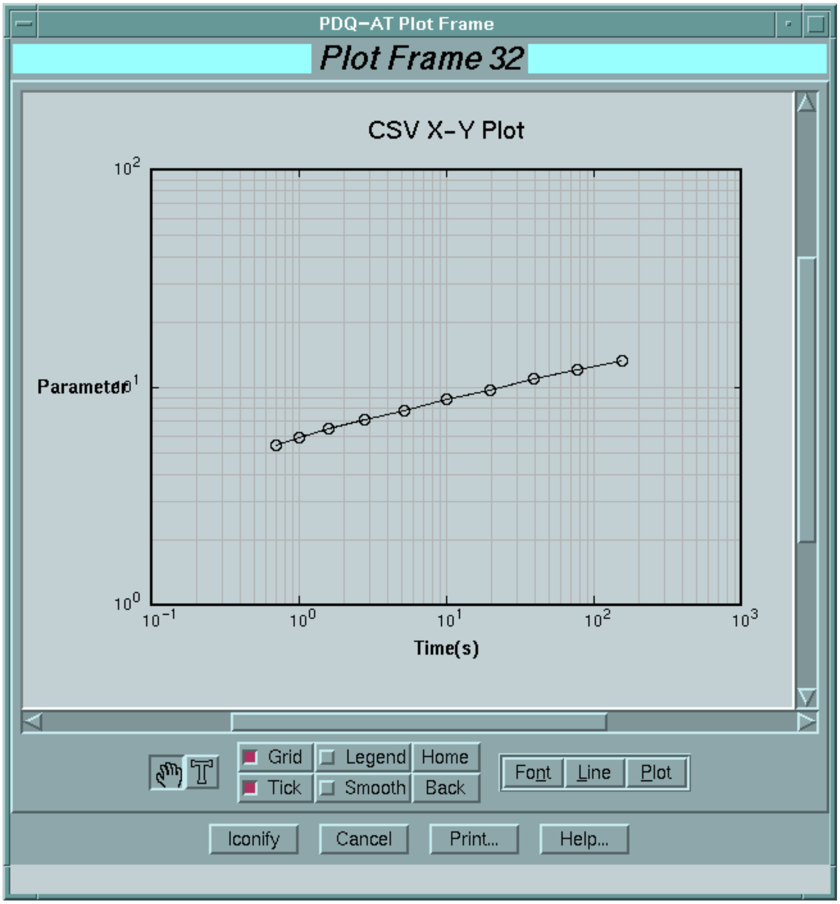
A new plot frame appears displaying the ***Parameter vs. Time curve***. You can iconify this window.

7. Return to the ***original plot point window*** by clicking anywhere inside it. If necessary, move other windows out of the way by click-dragging them.
8. In the **Stress Records** box, click on the first record of a desired algorithm's measurement. A new CSV Analysis Window appears.

   Using Vt_mos, Hot Carrier Lifetime tests may be done in pairs for the linear and saturated regime. Each pair of tests is listed in the Stress Records box.

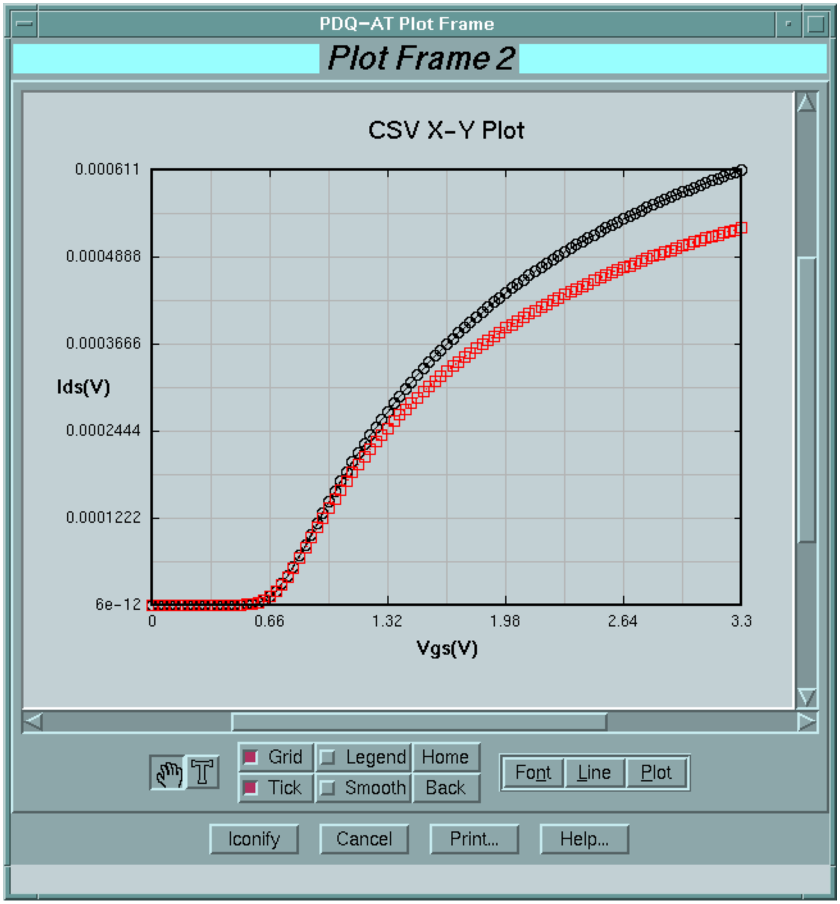
   Because PDQ-WLR has user-defined algorithms, your algorithm selection in PDQ-WLR effects the measured algorithm order. In this case, the first Vt_mos entry may contain linear result data. The next Vt_mos entry in the pair is the first saturated result data.
9. Click the **Plot** button. You have now plotted the time vs. parameter values.

Figure 5.6-7 **Example time vs. parameter plot**



10. Return to the original plot point window.
11. Scroll down in the **Stress Records** box and click the last record corresponding to your selected algorithm type. Another CSV Analysis appears.
12. Click **Overplot**. You may get an error for trying to overplot on the original Hot Carrier plot, which can be safely ignored.

Figure 5.6-8 **Example Stress Record Overplot**



The pre- and post- stress variables are overplotted on each other.

5.7 SPC

Statistical Process Control (SPC) is a technique that identifies processes that are potentially out-of-control with respect to reliability parameters. SPC charts are available for continuous data (SPC-x) and pass/fail data (SPC-b) for critical parameters.

Continuous Data SPC Charts (SPC-x)

SPC calculations result in two graphs displayed on the plot canvas. The top graph shows actual test results either as individual values (**X**) or as the averages of groups of values (**Xbar**). The groups discussed here are the groups defined by the sample variable (**Sample Var**).

The bottom graph shows the variability in the test results in a variety of ways:

S Sigma, the standard deviation of a subgroup

R Range, the range of data for each group in the Xbar graph is shown by corresponding points in the R graph — the absolute difference between the maximum and minimum values.

R = | Plot Var max - Plot Var min |

MR Moving Range, the absolute value of the difference between a point and the previous point

MR = |This Plot Var point - Previous|

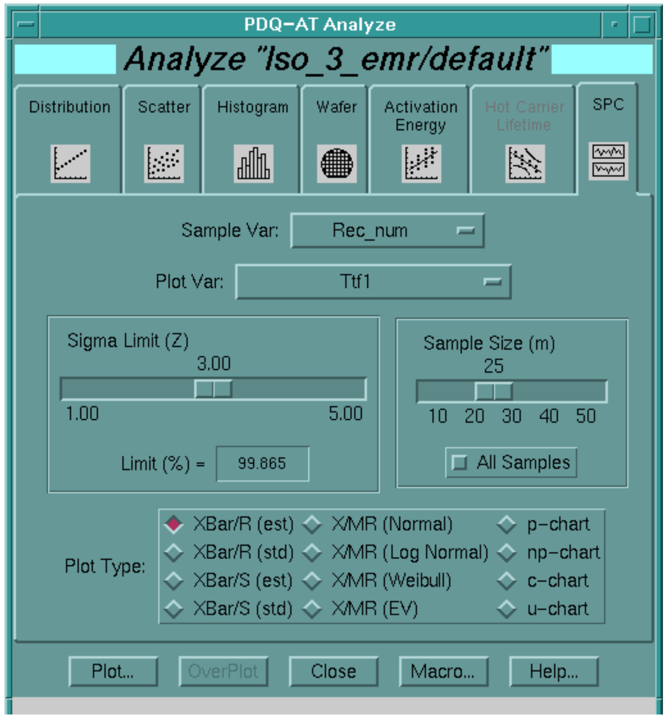
When working with X/MR plot types, you must choose between Normal, Log Normal, Weibull and Extreme Value. This choice affects the calculation to take the distribution type into account when calculating Sigma in engineering units to establish the control limits.

Procedure

Creating an SPC-x Plot

1. From the PDQ-AT Main window, click on the **Analyze** button. The PDQ-AT Analyze window activates.
2. Click on the **SPC** tab. The SPC option activates.

Figure 5.7-1 **PDQ-AT Analysis Window: SPC option**



3. Select the sample variable from the **Sample Var** popup.
4. Select the plot variable from the **Plot Var** popup.
5. Select the Sigma Limit (Z) by sliding the **Sigma Limit** bar. Notice how the **Limit (%)** field changes as you change the Sigma Limit.

Sigma is used to establish the definition of “out-of-control” in the SPC calculations. SPC reference texts suggest a value of 3 for this limit.

6. Select your sample size by click-dragging the **Sample Size** bar. Alternatively, you may click the **All Samples** button, which overrides the **Sample Size** bar.

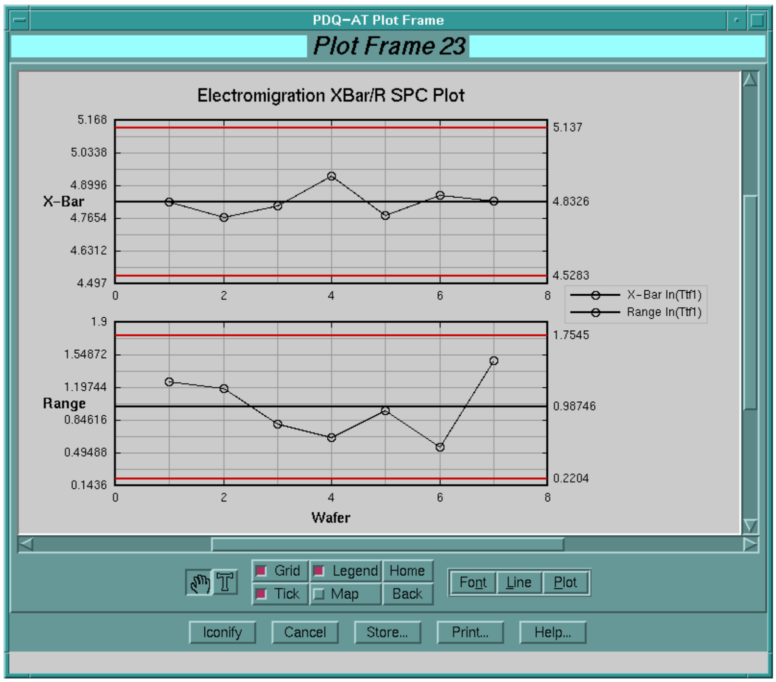
After choosing the Sigma Limit, you must choose the range of data to calculate the reference or “in-control” data Sigma value. This value establishes the control limits in the same engineering unit as your data.

For Xbar types of SPC, the sample size selects the number of groups to use. SPC reference texts suggest that values less than or equal to 30 are desirable.

7. Choose the appropriate plot type. See the explanation above about plot types and SPC's use of them.
8. Click the **Plot** button.

The PDQ-AT Plot Frame window appears, displaying your dataset in your chosen plot type.

Figure 5.7-2 **SPC-x plot frame**



Customizable Plot Elements

The following buttons can be found on the plot frames pertaining to them.

Grid Toggles the background grid display within the plot canvas.

Tick Toggles the X- and Y- axes tick mark display within the plot canvas.

Legend Toggles the display of a legend identifying the plot(s). All plots can have a legend, if desired.

Map Toggles the display of string data type **Sample Var** mapped to ordinal values (1,2,3...).

Home Restores the plot canvas view to the original position and zoom.

Back Returns to the plot canvas view prior to the when the **Home** button was invoked.

For more information on working with plot frames, see “Using Intelligent Plots” in section 6, p. 163 below.

Pass/Fail SPC Charts (SPC-b)

There are four types of SPC-b calculations, each resulting in one graph on the plot canvas.

p Takes a pass = 1 input for the critical parameter and shows the fractional non-conforming results using binomial statistical calculations. Pass criteria may be created using a boolean expression macro on continuous data for any critical PDQ-WLR parameters.

np Same as **p** above, but multiplied through by sample size to plot the number of non-conforming results.

c Takes a pass=1 input for the critical parameter and shows the non-conforming fraction using a Poisson distribution. Pass criteria may be created using a boolean expression macro on continuous data for any critical PDQ-WLR parameters.

u Takes a failure-count input for the critical parameter. The count may be created by adding boolean failure expressions for any critical PDQ-WLR parameters.

Procedure

Creating an SPC-b Plot

1. From the PDQ-AT Main window, click on the **Analyze** button. The PDQ-AT Analyze window activates.
2. Click on the **SPC** tab. The SPC option activates.
3. Click on the **Macro...** button. The PDQ-AT Macro Calculator activates. Create a pass-fail macro. See “Creating a Pass-Fail Macro” in section 5, p. 112.

   Alternatively, if you have already created the desired Pass-Fail macro, you do not need to perform this step.
4. Select the sample variable from the **Sample Var** popup.

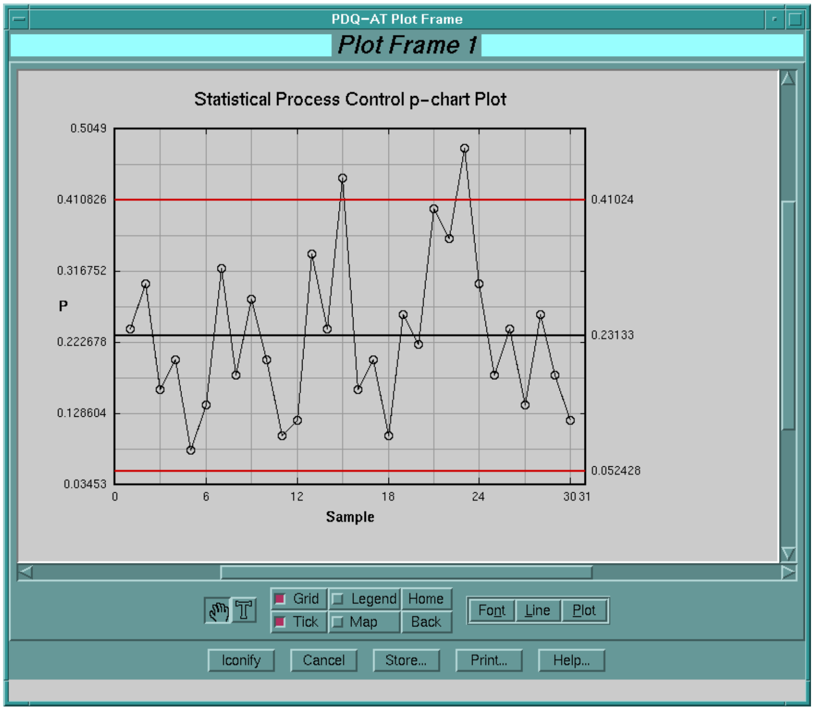
5. Select the plot variable from the **Plot Var** popup.

   The plot variable may be a boolean expression you've created with the PDQ-AT Macro Calculator. p Functions are listed at the bottom of the Sample Plot Sle

6. Select the Sigma Limit (Z) by sliding the **Sigma Limit** bar. Notice how the **Limit (%)** field changes as you change the Sigma Limit. SPC reference texts suggest a value of 3 for this limit.
7. Select your sample size by click-dragging the **Sample Size** bar. Alternatively, you may click the **All Samples** button, which overrides the **Sample Size** bar.
8. Choose the appropriate plot type. See the explanation above about plot types and SPC's use of them, in the right-hand column the SPC-b options.
9. Click the **Plot** button.

The PDQ-AT Plot Frame window appears, displaying your dataset in your chosen plot type.

Figure 5.7-3 **SPC-b plot frame**



Customizable Plot Elements

The following buttons can be found on the plot frames pertaining to them.

Grid Toggles the background grid display within the plot canvas.

Tick Toggles the X- and Y- axes tick mark display within the plot canvas.

Legend Toggles the display of a legend identifying the plot(s). All plots can have a legend, if desired.

Map Toggles the display of string data type **Sample Var** mapped to ordinal values (1,2,3...).

Home Restores the plot canvas view to the original position and zoom.

Back Returns to the plot canvas view prior to the when the **Home** button was invoked.

For more information on working with plot frames, see “Using Intelligent Plots” in section 6, p. 163 below.

6 Using Intelligent Plots

Introduction to this Chapter

Once you plotted the data, PDQ-AT gives you a variety of tools to examine your dataset. This section deals with the general tools common to most plot frames. Each plot frame is specific to the analysis you performed with the data. For more specific information on wafer maps, histograms, lifetime predictions and SPC charts, see their sections above under “Analyzing Data” in section 5, p. 107.

PDQ-AT is highly configurable when displaying and constraining data, allowing you to plot and manipulate plots with the tools listed in this section. One key feature is **overplotting**: the ability to display more than one dataset in a single plot, enabling users to visualize two or more datasets in one graphic.

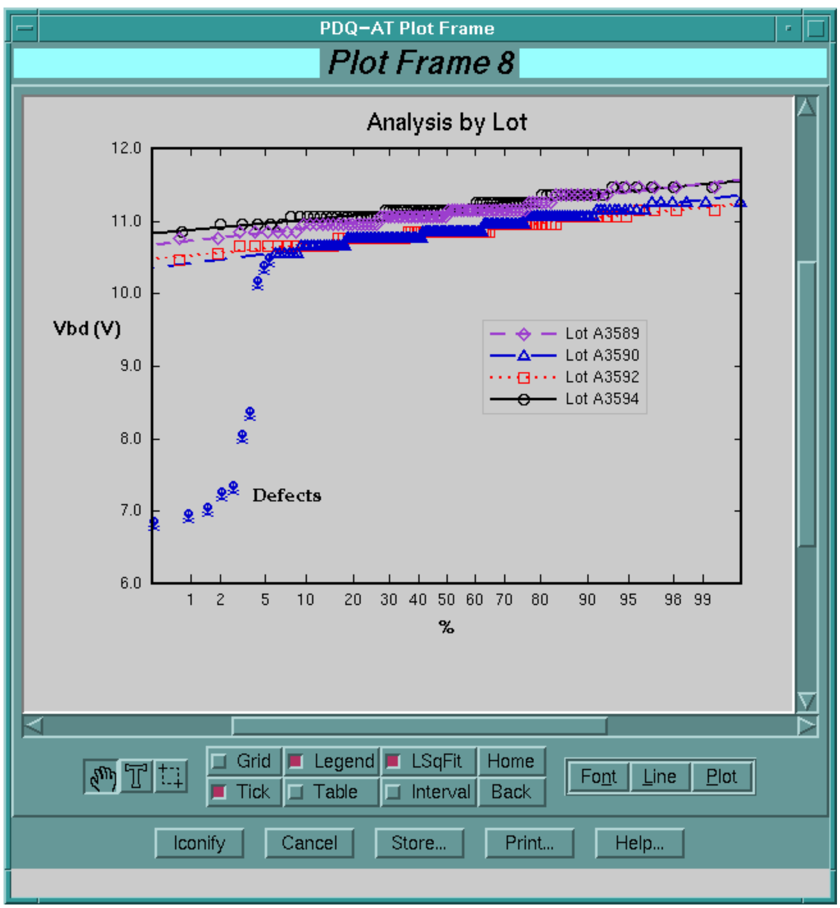
In this chapter, you will learn how to manipulate a plot, view and constrain plot points, and overplot two or more datasets.

The Anatomy of a Plot Frame

This section describes the areas in common to each of the plot frames.

At the top of plot frame is the title and the number of how many plot frames that have been created during this session. Underneath the title is the plot canvas, where the actual data is plotted on an XY axis, on, or in the case of a Wafer plot, on an XY coordinate corresponding to the location on the wafer map. You can manipulate the canvas by scrolling and zooming with the mouse.

Figure 6.0-1 A sample plot frame with overplots



Below most plot canvasses are a series of buttons. The button with the hand icon is the **Select** tool, to its right with the T is the **Text** tool and the third displays two cross-hairs connected by a dotted-line box, which is the **Constrain** tool.

The next series of buttons depends on the type of analysis performed to generate the plot. To their right are the **Home** and **Back** buttons, used for manipulating the plot canvas zoom.

The last three features to their right are three popup menus: **Font**, **Line** and **Plot**.

At the bottom of the plot frame are the **Iconify**, **Cancel**, **Store...**, **Print...** and **Help...** buttons.

Working with Plot Frames

Note:
Middle- and right-clicks control the zoom in the plot canvas.

Zooming

The first tool at your disposal is the ability to zoom into and out from the plot canvas. A middle-click zooms in by a default percentage within the plot window. A right-click zooms out by the same amount. The zoom factor percentage can be set on the **Plot** Setting window, Miscellaneous option.

The **Home** button on the plot frame immediately zooms to the default position of the plot, where the entire plot can be seen.

The **Back** button zooms to the last position on the plot once the Home button has been clicked. This is especially useful for plots with many clustered data points.

Why Zooming is Important

PDQ-AT only prints the information seen within the plot frame, a literal "what-you-see-is-what-you-get" interface. When printing, ensure that the information you desire to print is appropriately displayed on the plot canvas.

Selecting and Moving Plot Elements

The **Select** tool is activated by clicking on the button with a hand in it. When clicked, you can select any of the plot elements. By click-dragging, you can move the plot within the plot frame .

Some elements (such as legends) may be moved on the plot canvas by click-dragging while holding the **Control** key down. To move the plot within the plot frame, click-drag the mouse on the plot canvas itself. The plot moves in the direction you move the mouse.

Working with Text

You can use the **Text** tool to add any amount of test you desire in the plot frame. Use the **Font** popup menus to change the style of the text.

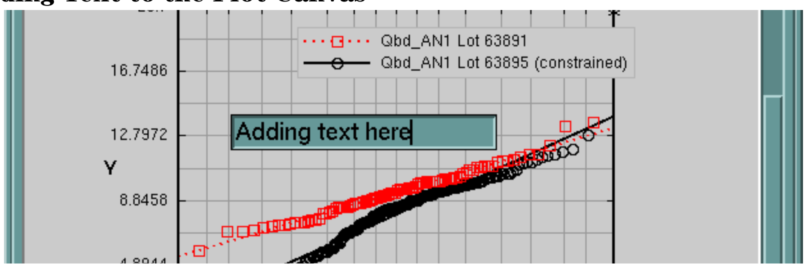
Procedure

Text Tool: Adding Text to Plots

Users may place text in any plots created by PDQ-AT and can change font face, size and text color.

1. Click the **Text** button.
2. Click on the area you desire to add text. A text box appears. See Figure 6.0-2, "Adding Text to the Plot Canvas" below.

Figure 6.0-2 **Adding Text to the Plot Canvas**



Note:
To enter a new line in a text box, type *\n*.

2. Type your desired text with the keyboard.

   To enter a new line, type **\n** in the text box. The new line will not appear until after this procedure is finished.
3. When finished, press **Enter**. The text box disappears.

The new text is now superimposed on the plot, including multiple lines if typed.

Procedure

Editing and Deleting Text

If necessary, you can edit the text already present on a plot, including plot elements like legends.

1. Using the **Select** tool, click on the text you desire to change. The text box activates.
2. Edit as desired. If you wish to delete the text, remove all text from the text box with the **Backspace** keys.
3. Press **Enter** when finished.

The text box disappears and the text is now superimposed on the plot.

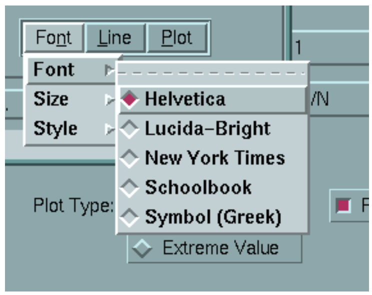
Procedure

Changing Fonts of a Plot Element

PDQ-AT's default font is Helvetica. The font style of any selected text can be changed under the **Fonts** menus. To change the font of any text, including the X- or Y- axes, follow the procedure below.

1. Using the **Select** tool, click on the plot element. The selected element appears highlighted.

Figure 6.0-3 **Font menu options**



Note:
The Font pulldown options are all tear-away menus.

2. Select **Font > *Menu Option***. Menu options for fonts include **Font**, **Size** and **Style**. The **Font** pulldown options are tearaway menus, meaning you can click on the dotted line and move these boxes on the desktop. For more information on tearaway menus, see "Tear-away Menus" in section 1, p. 9.
3. Select on the option you desire.

The plot element changes when you click.

Working with Lines, Symbols, and Colors

Just as you can alter text, PDQ-AT allows you to alter the lines, symbols and colors of your plots. The **Line** popup sub-menus are also tear-aways for easier plot configuration. Changing line options works exactly like changing font options: highlight the line by clicking on it, select **Line > *Menu Option***, then change as desired.

Customizable Plot Elements

The following buttons can be found on the plot frames pertaining to them.

Grid Toggles the background grid display within the plot canvas. Found on Distribution, Scatter, Histogram, Activation Energy, Hot Carrier Lifetime and SPC plots.

You can customize the grid in the plot settings window under the Grid and Tick options.

Tick Toggles the X- and Y- axes tick mark display within the plot canvas. Found on Distribution, Scatter, Histogram, Activation Energy, Hot Carrier Lifetime and SPC plots.

You can customize the tick in the plot settings window under the Grid and Tick options.

Legend Toggles the display of a legend identifying the plot(s). All plots can have a legend, if desired. The legend information contains the plot line and symbol, the plotted variable, engineering units (in parentheses), and the dataset title from the working list (also in parentheses). If the data is constrained, the (constrained) also appears.

Map Toggles the display of string data type **Sample Var** mapped to ordinal values (1,2,3...).

Table Toggles the display of the table of attributes (a.k.a. population parameters), either as defined by JEDEC or derived from the Table of Distribution Equations (see "Appendix: Explaining the Analyzed Data" in section 10, p. 205 for more information). Tables are available on all plots except Wafer plots.

LSqFit Toggles the least squares fit plot display within the plot frame. LSqFit is available only on Distribution, Scatter, Activation Energy, and Hot Carrier Lifetime plots.

Interval Toggles confidence interval display within the plot frame. Confidence intervals are only available in Distribution, Scatter, Activation Energy and Hot Carrier Lifetime plots.

You can customize the confidence intervals' bounds and confidence percentages.

PDF Toggles the normal probability density function curves for Histogram plots.

Shading Toggles column shading in Histogram plots.

Histogram Toggles the display of a histogram of occurrences in the color map of wafer plots.

SigmaMu Toggles the display of the sigma and mu (standard deviation and mean) values in the legend of Wafer plots.

Multiples Toggles the display of an asterisk on dice that have multiple values in wafer plots. Clicking upon such a die will bring up a Histogram plot of its underlying values.

Smooth Toggles smoothing of CSV plot lines**.**

Home Restores the plot canvas view to the original position and zoom.

Back Returns to the plot canvas view prior to the when the **Home** button was invoked.

Legends and Histogram tables are persistent across stores and restores of plots. The default legend serves as a reminder of which working dataset you are using. When storing and restoring plot files, the legend is saved verbatim and may not accurately reflect the working list.

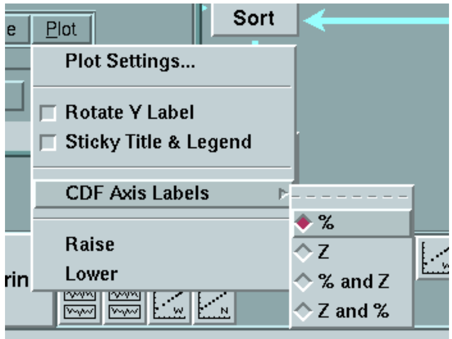
For example, you create plot from four different *ISO_4_emr/default.dat* working datasets during a session and store the third plot with legend turned on. The legend reads ***plotted variable (engineering units)*** *(ISO_4_emr/default.dat-3)*. During another session, you restore these plots. The section of the legend that defines which working list will still read *(ISO_4_emr/default.dat-3)*, no matter where the dataset exists within the working list.

The developers of PDQ-AT strongly recommend you edit the legend or title prior to storing a data plot to accurately reflect the analysis. To change the text within a legend, use the procedure “Editing and Deleting Text” in section 6, p. 168.

Plot Menu

Another way to customize your plot is through the **Plot** menu to the right of the Font and Line menus.

Figure 6.0-4 **Plot menu**



Plot Settings... — activates the plot settings window. See **Plot Settings** below.

Rotate Y Label — toggles this selection if you desire the Y label to be rotated perpendicular to the X label.

Sticky Title & Legend — with sticky title and legend toggled on, when you zoom, the title and legend stay exactly where they are on the plot canvas.

CDF Axis Labels — for CDF plots, these options exist for displaying the CDF axis in percent (%), standard deviaions (Z) or both.

Raise — raises the selected plot to the top. Useful only when overplotting.

Lower — lowers the selected plot to the top. Useful only when overplotting.

Plot Settings

The PDQ-AT Plot Settings window helps you to configure your plots in a variety of ways described below. At the bottom of the plot settings window are four buttons:

Apply Applies all changes made in the plot settings window to the plot frame.

Reset Resets all limits to their originally calculated values.

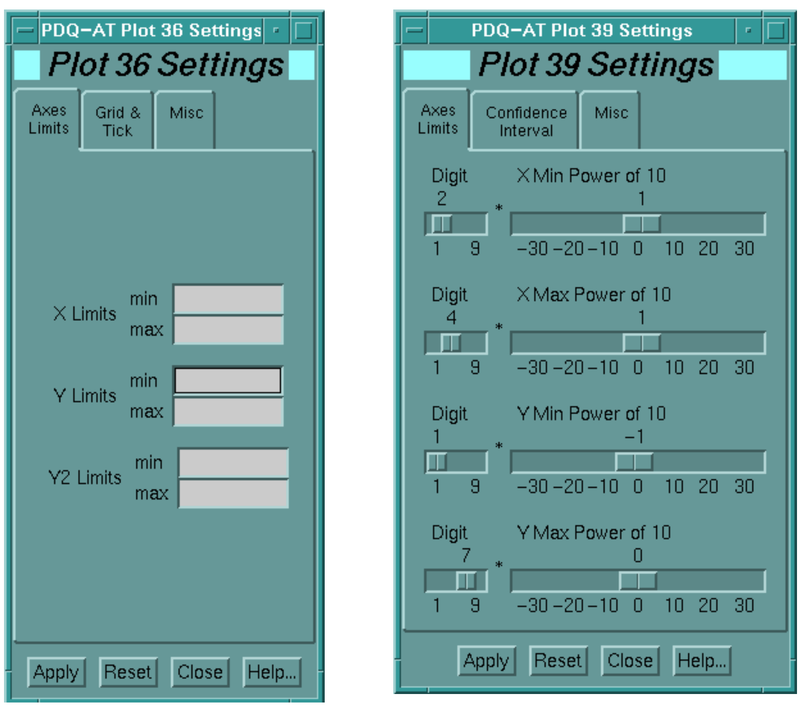
Close Closes the plot settings window.

Help... Launches the Online Help.

Axes Limits

Under Axis Limits, you can set the display of your plot axes both in percentages and limits, depending on the plot. You must provide both minimum and maximum axis limits to adjust the plot.

Figure 6.0-5 Plot Settings window: Axes Limits options



Procedure

Changing Axis Limit

Use the following procedure to set the

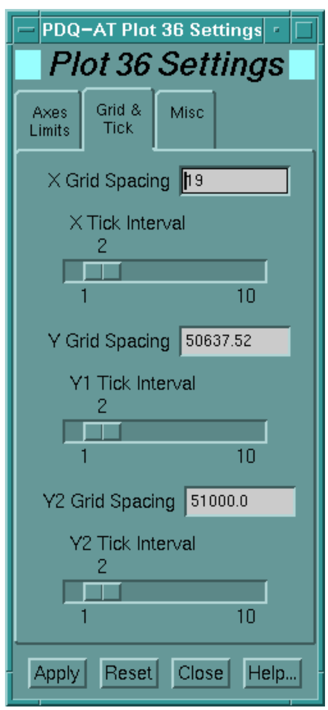
1. Select **Plot > Plot Settings**. The plot setting window appears.
2. If the Axes Limits option is not activated, click on the **Axes Limits** tab.
3. Type the values in the minimum and maximum text fields of the axis you wish to change.
4. Click **Apply**.

The plot canvas changes in accordance to the values typed in.

Grid & Tick

This option widow changes the plot grid spacing and the plot axial tick mark intervals. The **Tick Interval** is the number of grid lines to the next tick mark.

Figure 6.0-6 **Plot Settings window: Grid & Tick options**



Procedure

Changing Grid and Tick Options

1. Select **Plot > Plot Settings**. The plot setting window appears.
2. If the Grid & Tick option is not activated, click on the **Grid & Tick** tab.
3. Type the values in the minimum and maximum text fields of the axis you wish to change.
4. Set the Tick Interval by click-dragging the Tick Interval bar.
5. Click **Apply**.

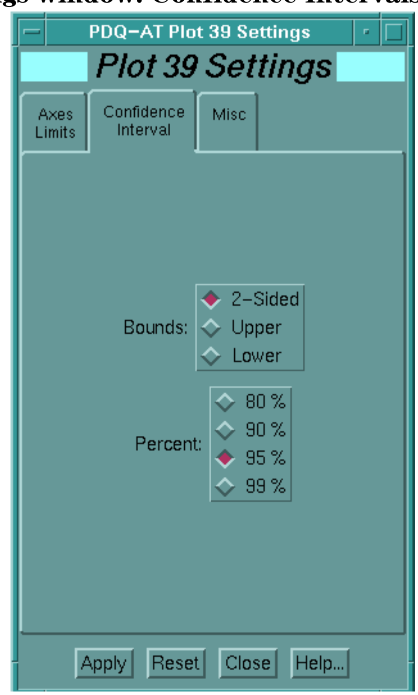
The plot canvas changes in accordance to the values typed in.

Confidence Intervals on XY Plots

On Distribution, Scatter, Activation Energy and Hot Carrier Lifetime plots, you can define the confidence interval to display as the upper, lower, or both bounds.

Also set here is the confidence percentage.

Figure 6.0-7 **Plot Settings window: Confidence Intervals options**



Procedure

Changing Confidence Intervals

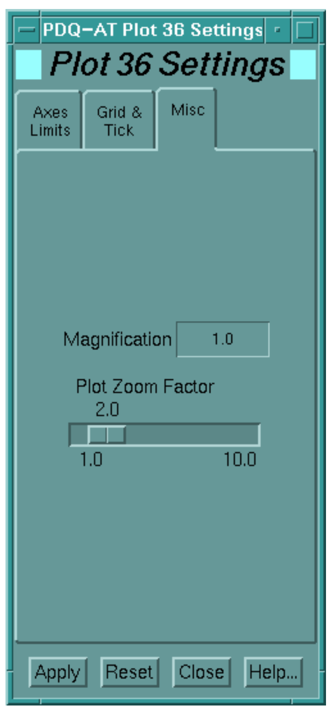
1. Select **Plot > Plot Settings**. The plot setting window appears.
2. If the Confidence Interval option is not activated, click on the **Confidence Interval** tab.
3. Click the Bounds you desire: 2-Sided, Upper, or Lower.
4. Click the confidence **Percent**.
5. Click **Apply**.

The plot canvas changes in accordance to the values selected.

Miscellaneous Options

Under this option, you can set the Plot Zoom Factor — this is the factor that the middle and right mouse buttons zoom in and out by.

Figure 6.0-8 **Plot Settings window: Miscellaneous options**



Procedure

Changing Miscellaneous Options

1. Select **Plot > Plot Settings**. The plot setting window appears.
2. If the Confidence Intervals option is not activated, click on the **Confidence Intervals** tab.
3. Click-drag on the **Plot Zoom Factor** bar. Notice the **Magnification** field change.
4. Click **Apply**.

Zooming with the middle- and right-clicks now operate as selected.

Iconifying the Plot Frame

Note:
It is best to use the Iconify option in PDQ-AT instead of the window manager iconify.

At the bottom left of all plot frames is the **Iconify** button. Clicking this button makes the current plot frame *iconify*, that is, makes an icon out of the entire window.

Iconifying is useful to prevent your desktop environment from having too many windows open at once, making it hard to view your data.

When you iconify a plot frame, an icon is created at the bottom of the PDQ-AT Main window. When you want the plot frame activated, click on the icon. You can identify which plot frame is which by viewing the icon and when you move the mouse over the icon, the help text displays the name of the plot frame.

Iconifying is most important when overplotting. When you click the **Overplot** button, PDQ-AT attempts to overplot on all open (non-iconified) plot frames.

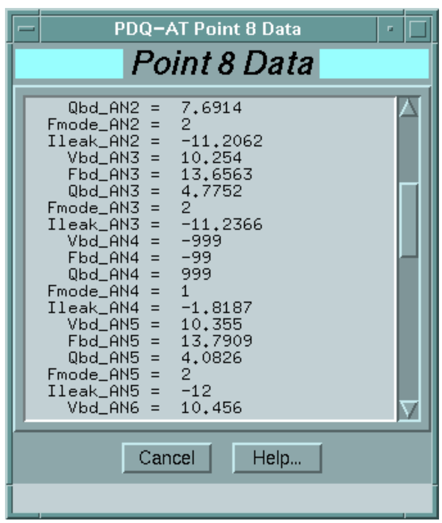
6.1 Constrain Tool: Constraining Data

Plot points in PDQ-AT Plot Frames aren't only markers representing the values of specific data. Plot points represent entire records of data in themselves. You are able to view the specifics of that record, such as the input and output variables, and any CSV or Xgraph data created by the PDQ-WLR test process.

The Constrain tool is used when working with intelligent plots. To use the constrain tool, click on the **Constrain** tool button to the right of the **Text** tool button.

Before you constrain data, you may wish to examine the data specifically.

Figure 6.1-1 **Viewing a Plot Point**



Procedure — Viewing Plot Point Data

Use the following procedure to view plot point data.

1. Activate the Select tool by clicking on the **Select** icon.
2. Center the mouse icon over the data you are specifically interested in. When centered over a plot point, the mouse icon transforms into an upward-pointing arrow.

3. Click on the **Plot** Point.

The PDQ-AT Plot Point window appears. You may have multiple plot point windows open at one time. Inside the plot point window, all of the information related to that plot point is available for review.

If PDQ-WLR is configured to generate CSVs and Xgraphs, then the last two entries may be links to the CSV and Xgraph for this data. Clicking on the link launches an Xgraph Plot window. For more information on Xgraphs, see “Xgraph Browser” in section 4.9, p. 99.

For Hc_link_mos data, the last entry is like the Lifetime_mos and Stress-Data records (see “CSV Files and Test Data Links” in section 5.6, p. 151 for more information).

Procedure

Constraining Plot Points

Use the following procedure to constrain a plot point.

1. Click on the **Constrain** tool button. The mouse icon becomes a cross-hair. When the mouse is centered over a plot point, the mouse icon transforms into a skull and crossbones.
2. Move the mouse above the data point you are interested in and press **D** on the keyboard.

   To constrain multiple plot points, click-drag the mouse across the plot points you desire to constrain.

The constrained plot points transforms into a skull and crossbones, indicating they are now constrained and not included in the fit to the data. The plot canvas redraws itself to update the data displayed.

Below is an example of how a plot canvas can change before and after constraining.

Figure 6.1-2 Example of Constraining Plot Points: Before...

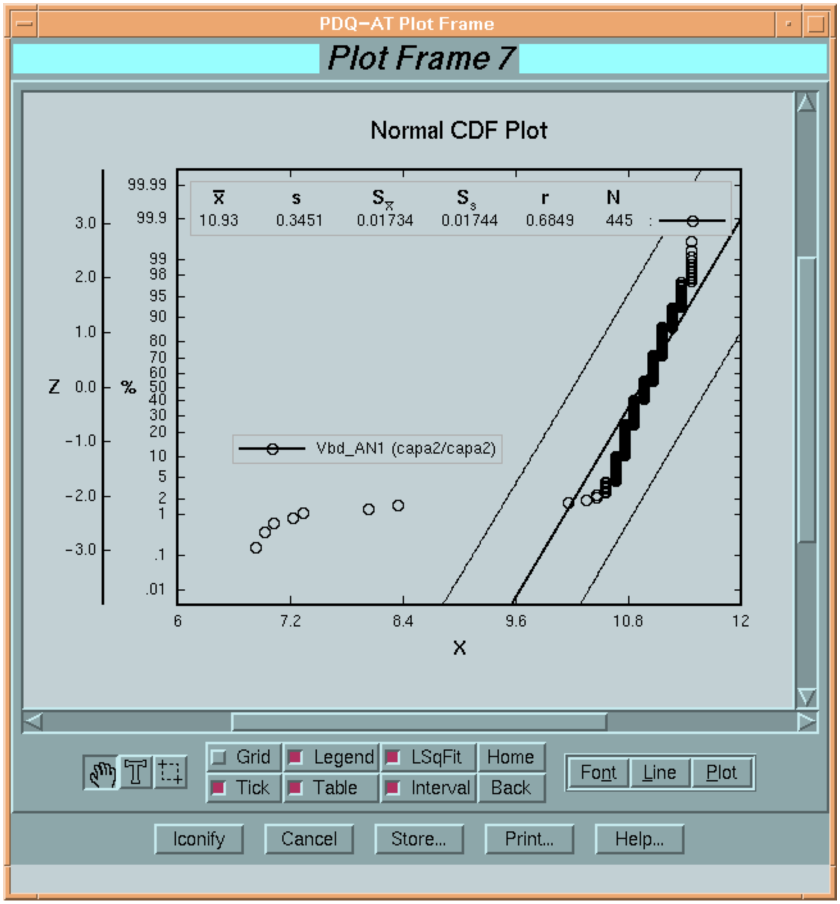
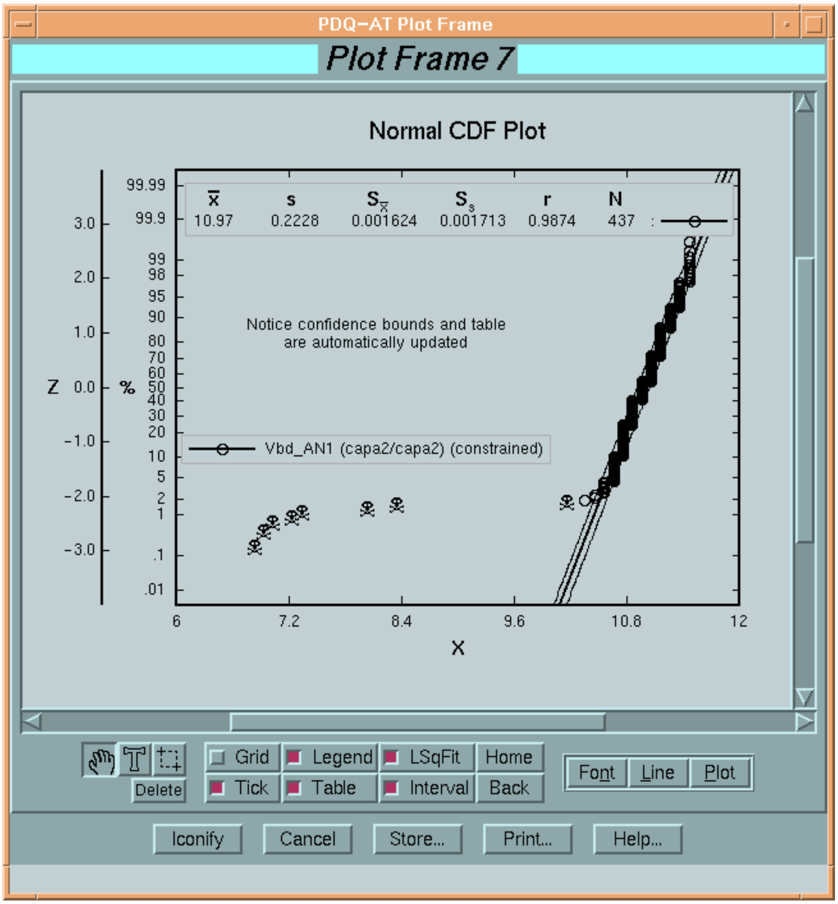
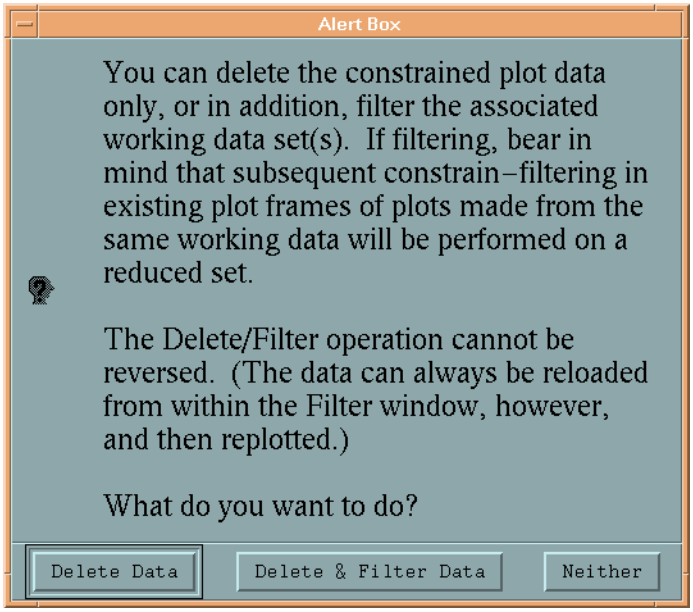


Figure 6.1-3 ...and After



You may wish to constrain data to show values being excluded from a population parameter analysis. Other times, you may find that you would like to simply filter these points out of the plot. For example, your data may have come from different populations that shouldn't be plotted together, such as data from different lots and technologies. You can go back and Filter your working set at this point, or you may use the Delete button below the Constrain tool. When pressed, this button presents the following dialog.

Figure 6.1-4 Delete Dialog



This allows you to extend the Constrain tool to act as a sort of "visual" filter. You have the choice of making the filter apply just to this plot, or to the working dataset and all subsequent plots. For best results and highest ease of use, choose the Delete & Filter Data option for the first plot made in working set. Care should be exercised because it's easy to become confused if you have several plots open for a single working set. In other words, PDQ-AT will do exactly what you ask it to do. As long as you think of this as a shortcut to closing your plot, going back to Filter, and replotting, you should be fine.

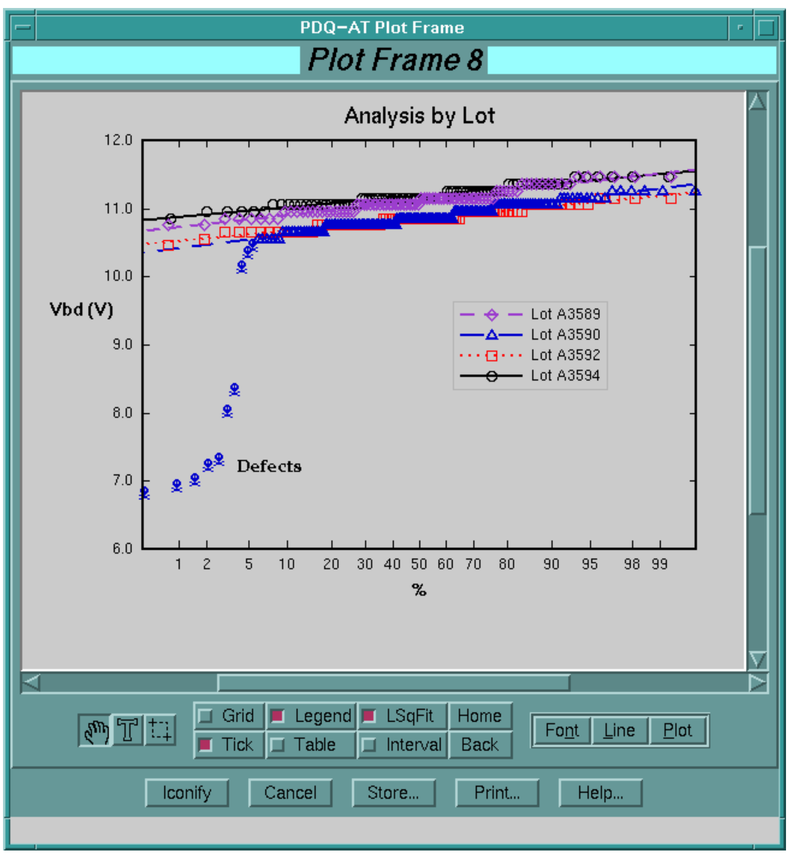
Select either the Constrain or Constrain/Delete as your data needs dictate.

6.2 Overplotting

One of the more sophisticated features of PDQ-AT is it's ability to overplot two or more datasets. You can use PDQ-AT to make each of the plots easily discernible by changing the plot lines, plot colors and plot points, as discussed in the beginning of this chapter.

By default, the plot line is a full line, colored black with circle plot points. When you overplot, PDQ-AT automatically differentiates plots by altering colors, line styles, and symbols.

Figure 6.2-1 Plot Frame with Overplot



By choosing different colors and plot points, you can clearly demonstrate the differences between datasets.

Procedure

Creating an Overplot

Overplots can be made only in XY plots and Histograms. Wafer Maps and Lifetime Predictions cannot be overplotted.

When creating overplots, the new plot attempts to post all un-iconified plot frames.

Note:
When creating overplots, the new plot attempts to post to all un-iconified plot frames.

---

1. Plot a dataset as normal.
2. When finished with the first plot, move the plot frame so you can see the PDQ-AT Analysis window.
3. Click on the PDQ-AT Analyze window to activate it.

   Alternatively, you may return to the PDQ-AT Main window and load a new dataset from scratch, perform any amount of sorting and filtering as necessary, then click the **Analyze** button.
4. Reconfigure PDQ-AT Analyze window for the overplot. This is exactly like making a new plot.
5. Click the **Overplot** button.

The original plot frame activates. Inside the plot frame is the second set of data represented in a new plot. PDQ-AT uses color from the colors preferences. See "PDQ-AT Main" in section 4.2, p. 49, if you desire to change those preferences.

You may now customize this new plot by changing the line, colors or plot points or overplot another analysis.

Procedure

Raising a Plot in an Overplot

Raise and **Lower** are used to raise or lower the currently selected dataset in an overplot.

1. Using the **Select** tool, click on the line symbol of the legend or the LSqFt of the plot you wish to raise. The plot is activated (highlighted).
2. Select **Raise**.

The active Plot raises to the top. Lowering a plot is the exact same procedure only you select Lower from the menu instead of Raise.

Procedure

Deleting a Plot from an Overplot

If you need to delete a dataset, follow this procedure.

1. Using the **Select** tool, click on the line symbol of the legend or the LSqFt of the plot you wish to delete.
2. Press the **D** key.

The selected dataset is removed from the active plot frame.

7 Wafer Map Definitions

Introduction to this Chapter

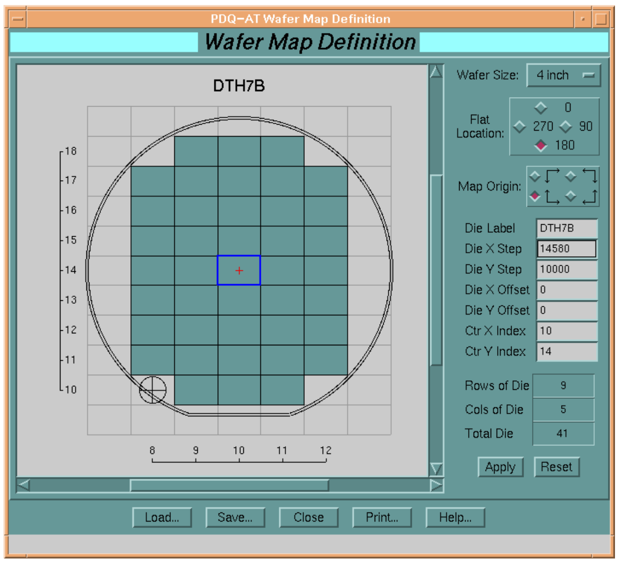
This chapter explains how to use PDQ-AT to define and import Agilent SPECS-defined wafer maps, saving, and loading the designs to a computer file.

In this chapter you will learn how to create new wafer definitions; import existing Agilent SPECS wafer definitions; save and load wafer definition files.

Wafer Map Definitions

The Wafer Map Definition window is where you can define the die grid layout (map) on a semiconductor wafer for use in making wafer plots in the Analysis window.

Figure 7.0-1 **Wafer Map Definition window**



The **Apply** button changes the wafer map image and die grid layout based on the parameters changed. See "Defining a Wafer" below.

The **Load...** button opens the Load Wafer window. See "Loading a Wafer Definition" below.

The **Save...** button opens the Save Wafer window. See "Saving a Wafer Definition" below.

The **Close** button closes the PDQ-AT Wafer Map Definition window, activating the main window.

The **Reset** button will return any altered parameters back to their original state.

The **Print...** button prints the current wafer map parameters.

The **Help...** button launches the Online Help page for this window.

New Wafer Definitions

It is important for the name of your new wafer definition files to match the names of the wafers currently stored or planned for in your PDQ database. PDQ-AT attempts to match these items to select the correct wafer map by defaults for creating wafer plots.

Agilent SPECS Definition

If you are using Agilent SPECS to control PDQ-WLR, there is no need to re-define the wafer you've tested for PDQ-AT. Simply load your applicable Agilent SPECS *.waf* files and then save them in PDQ-AT's *.wmap* format. The Save tool's browser is independent from the Load tool's file browser. Set the Load browser to display **.waf* files. You can navigate through any of your Agilent SPECS areas to locate *.waf* files, and PDQ-AT will remember where to deposit the *.wmap* version of the files.

Note: Some autoprobers, such as the Electroglas EG4080, use an auto-alignment feature which does not require separate offset values in the Agilent SPECS wafer spec. In these cases, your imported wafer spec may display incorrectly. Correct the problem by entering the true offset value for the die on your wafer, using the following procedure.

Procedure

Defining a Wafer

1. Select the **Wafer Diameter**. From this menu button you can select the diameter of the wafer. The default is six inches.
2. Select the **Flat Location**. Here you can specify the location of the wafer flat. The default is 180.

   0 the flat will be at the top of the wafer.

   180 the flat will be at the bottom of the wafer.

   270 the flat will be at the left of the wafer.

   90 the flat will be at the right of the wafer.
3. Select the **Map Origin**, the origin of the die map's coordinate system. The default is LL.

   LL place the origin at the lower left.

UL	place the origin at the upper left.
UR	place the origin at the upper right.
LR	place the origin at the lower right.

4. Type the Die Label in the **Die Label** text field.

   The Die Label is used as the title for the wafer map.

5. Type the Die X Step in the **Die X Step** text field.

   The Die X Step specifies the horizontal dimension in microns of each die.

6. Type the Die Y Step in the **Die Y Step** text field.

   The Die Y Step specifies the vertical dimension in microns of each die.

7. Type the Die X Offset in **Die X Offset** text field.

   The Die X Offset specifies the horizontal distance in microns of the middle die's left edge with respect to the center of the wafer. An offset of zero means that the central point of the wafer will lie between the two middle columns of dice.

8. Type the Die Y Offset in the **Die Y Offset** text field.

   The Die Y Offset specifies the vertical distance in microns of the middle die's bottom edge with respect to the center of the wafer. An offset of zero means that the central point of the wafer will lie between the two middle rows of dice.

9. Type the center X coordinate in the **Ctr X Index** text field.

10. Type the center Y coordinate in the **Ctr Y Index** text field.

    The crosshair is placed in the exact (physical) location of the wafer. The center die is highlighted in blue. If there are an even number of rows or columns, the center die coordinate is always rounded up. If you are using Agilent SPECS, the center die should match your wafer spec. See figure 7.0-1 for an example of an accurately defined wafer map.

11. Press the **Apply** button to invoke any entered quantities into the wafer map.

The Wafer Map updates. Notice how the **Rows of Die**, **Cols of Die** and **Total Die** changes also.

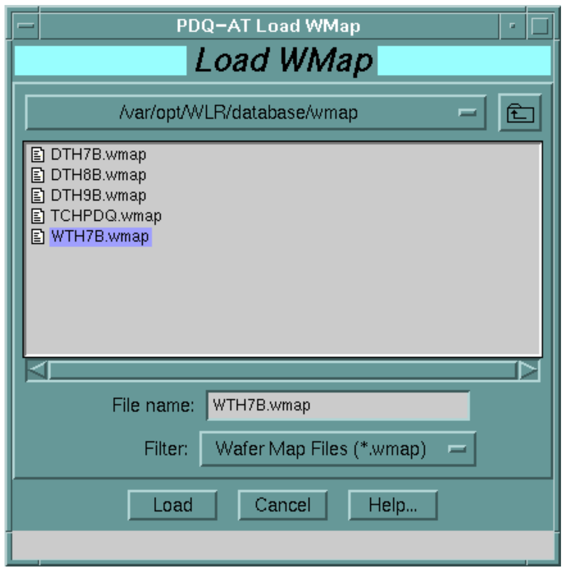
Rows of Die	States the number of die rows in the current mapping.
Cols of Die	States the number of die columns in the current mapping.
Total Die	States the total number of dice in the current mapping.

Procedure

Loading a Wafer Definition

A previously defined wafer map may be loaded into the tool via the Load button to view its parameters and use them as the basis for a new map definition.

Figure 7.0-2 **PDQ-AT Load WMap window**



You may edit previously existing Wafer Map Definitions, save them as new definitions, or overwrite old definitions.

1. From the PDQ-AT Wafer Map Definition window, click the **Load...** button. The PDQ-AT Load WMap window activates.
2. Locate and highlight the file you wish to load. Your file may be located anywhere accessible to your HP-UX user account. By default, PDQ-AT tries to load from and save to wafer maps files from the */var/opt/WLR/database/data/wmap* directory.

   If necessary, move the **Filter** popup to read *All Files (*.*)* or *Wafer Spec Files (*.waf)*.
3. Click the **Load** button.

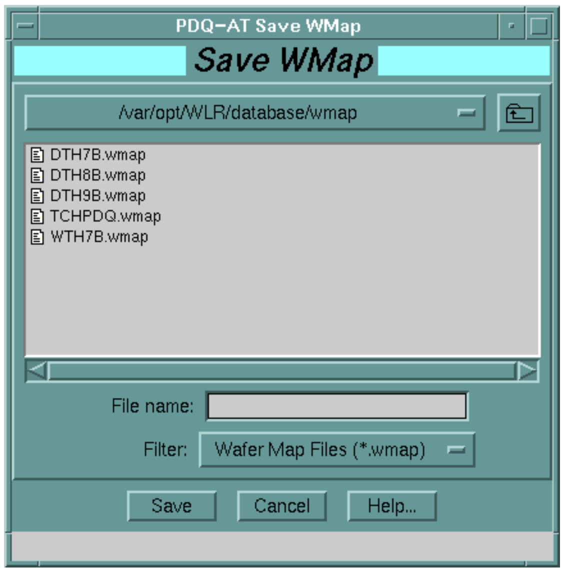
The Wafer Map file loads and opens in the PDQ-AT Wafer Map Definition window.

Procedure

Saving a Wafer Definition

Pressing the Save button will bring up a window in which you can specify a file in which to save the wafer definition.

Figure 7.0-3 **PDQ-AT Save WMap window**



Note:
It is important for the name of your new wafer definition files to match the names of the wafers currently stored or planned for in your PDQ database. Agilent SPECS users should use the same name as the Wafer Spec.

The file name will be added to the **Map** menu in the **Wafer Plot Type** section in the PDQ-AT Analyze window for selection in plotting a wafer map variable expression.

1. From the PDQ-AT Wafer Map Definition window, click the **Save** button. The PDQ-AT Load WMap window activates.
2. Type the name of the wafer map in the File Name text field. PDQ-AT will automatically add the extension *.wmap*.
3. Wafer maps must be stored in */var/opt/WLR/database/wmap*, or an equivalent location referenced via an NFS mounts in use.
4. Click the **Save** button.

The PDQ-AT Save WMap window closes. Your file is now saved.

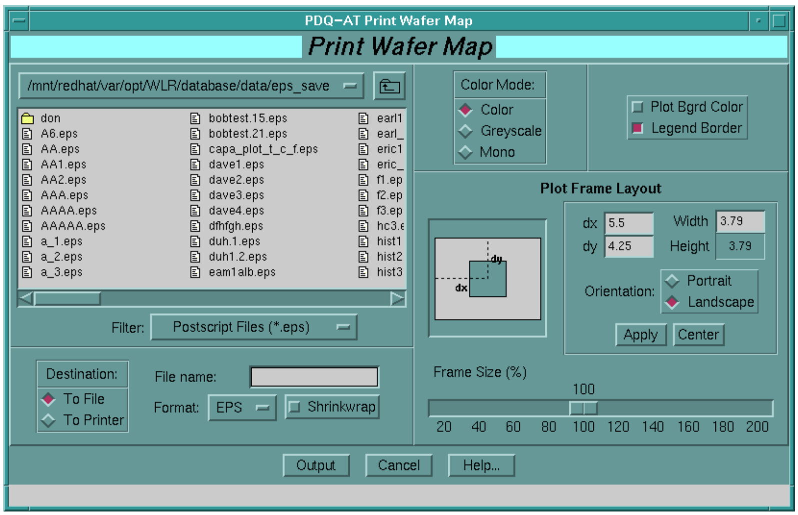
Procedure

Printing a Wafer Definition

Use the following procedure to print a wafer definition.

1. On the PDQ-AT Wafer Map Definition window, click the **Print** button. The PDQ-AT Print Wafer Map window appears.

Figure 7.0-4 **PDQ-AT Print Wafer Map window**



3. Click the **To Printer** option in the **Destination** field.

   If you desire to print to a file, select the **To File Destination**. By default, the files are saved in */var/opt/WLR/database/data/eps_save.* By using the **Data Path** popup, **Up-Directory** button and the directory viewer, you may save anywhere you have permissions.

4. Type the name of your file(s) by the **File Name** text field. PDQ-AT will add the file descriptor on the end (*.eps*, *.gif*, or *.tif*).

6. Click the **Plot Background Color** or the **Legend Border** if you desire either.

7. Choose your **Color Mode** by clicking **Color**, **Grayscale** or **Mono**.

8. Select **Portrait** or **Landscape** for the direction of the page to print.

   Landscape is best for Postscript. Portrait is best for PNG and PDF.

9. PDQ-AT centers the print area on the page by default. To move or resize, change the values in the **dx**, **dy** and **Width** text fields and then click the **Apply** button.

   To center the print area, click the **Center** button.

10. Click the **Output** button.

A small confirmation window appears. The files are printed to disk or to your default printer. To change printers, change either the **Print Cmd** field or modify the default printer command in the PDQ-AT Preferences window. For more information, see “Prefs Menu” in section 4.2, p. 52.

8 License Administration with PDQ-AT

Introduction to this Chapter

This chapter introducers the use of License Administration of PDQ-AT. In this chapter you will learn to enter a license key, select key ports, and clear any authorization locks if errors occur.

Use must have ***root*** access to use this feature.

License Administration

The PDQ-AT License Administration window allows you enter a license key, change the key ports, and clear any authorization locks.

General Warning

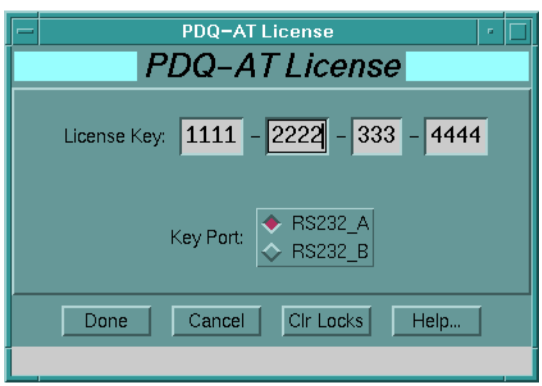
When working with the License Administration features, ***ensure that no other PDQ-AT processes are running***.

Users with root access may edit the */etc/opt/AT/at_license* file by hand, but this is not recommended; using the License Administration window ensures that the *at_license* file will be correctly formatted. If you are planning to do this, ensure that no other PDQ-AT processes are running.

Failure to heed these warnings may cause file and data corruption.

If the */etc/opt/AT/at_license* file becomes corrupted, the system administrator can copy in the original distribution file default from */opt/AT/install*. The owner of the */etc/opt/AT/at_license* file must be *root*, the group must be *sys*, and the permissions must be *rw-r--r--*.

Figure 8.0-1 PDQ-AT License Administration window



Note:
You must have root access to use this feature.

License Key Value supplied by HP for use with the RS-232 HASP key suppled with your PDQ-AT distribution.

Key Port Select RS-232 A or RS-232 B, depending upon where you installed the HASP key.

Done The */etc/opt/AT/at_license* file is updated when this is clicked.

Cancel Discards changes.

Clr Locks In the event of a file system or critical process failure, stale locks may be left erroneously on your system, preventing PDQ-AT use. Pressing this button will clear all locks. Use with caution, if pressed while a PDQ-AT analysis session is active, that session will be terminated.

9 Appendix: Data Algorithms

PDQ-WLR Algorithms

This appendix covers the data you may want to track for each of the PDQ-WLR algorithms

Table 9.0-1 PDQ-WLR Algorithms and Sample Parameters, part 1

Typical Routines	Example Output Parameters	Typical Analysis
VRAMP_3_CAP	Vbd	Normal or Extreme Value CDF, Wafer plot, CSV I-V plot, Xbar/S or X/MR SPC
VRAMP_3_CAP	Qbd	Log Normal CDF, Log Wafer plot
VTDDB_3_CAP	Tbd	Weibull or Log Normal CDF, Log Wafer plot
VTDDB_3_CAP	Qbd	Weibull or Log Normal CDF
JRAMP_3_CAP	Qbd	Log Normal or Weibull CDF, Log Wafer plot
JRAMP_3_CAP	Ibd	Normal or Log Normal CDF
JTDDB_3_CAP	Tbd	Weibull or Log Normal CDF, Log Wafer plot
JTDDB_3_CAP	Qbd	Weibull or Log Normal CDF
HFCV_3_CAP	Tox, Vfb or Nb	Normal CDF, Wafer plot, CSV C-V plot
MBLION_3_CAP	Nm	Normal CDF
MBLION_SHS	D1f, D2f or D3f	Normal CDF, Wafer plot
KELRES_3_EMR	Resist	Normal CDF, Wafer plot
TVP_3_EMR	Q	Normal CDF, Wafer plot, Histogram

Table 9.0-2 PDQ-WLR Algorithms and Sample Parameters, part 2

Typical Routines	Example Output Parameters	Typical Analysis
ISO_4_EMR	Ttf	Log Normal CDF, Activation Energy, X/MR (Log) SPC
ISO_4_EMR	Q	Normal CDF
BEM_3_EMR	E1	Log Normal CDF
CPV_3_MOS	Ibmax	Xbar/S or X/MR SPC, normal or Log Normal CDF, Wafer plot
CPV_3_MOS	V1o or V2o	Wafer plot, Normal CDF, Xbar/S SPC
CPF_3_MOS	Dit or Icp	Log Normal CDF, Wafer plot
S_MOS	S	Normal CDF
DOP_MOS	Nm	Normal CDF
VT_MOS	Gm, Vtci, Vtext or Idlin	Normal CDF, Xbar/S SPC
IDIBIG_MOS, STRSMEAS_2_MOS	Id, Ib or Ig	Log Normal CDF, Ib/Id
HC_LINK_2_MOS	Lifetimes at stress condition	Hot Carrier Lifetime, CSV plot % vs. time, CSV plot I-V curves

10 Appendix: Explaining the Analyzed Data

Introduction to this Appendix

This appendix describes some example data analysis you might create with WLR data taken by the PDQ-WLR test software. All examples here have been created with PDQ-WLR and PDQ-AT.

Table of Distribution Equations

Each PDQ Plot can display a table of population parameters, whose definitions vary based upon the type of plot or analysis. The derivation of these values is quite simple. In the (x,y) column of Table 10.0-1, below, are the standard equations for X-Y pairs, an intercept, a slope, the standard errors about the intercept and slope, the correlation coefficient, and the sample size. For each plotted dataset, the X and Y values are transformed as specified in the table. For example, with a Log Normal CDF, the natural logarithms of the data are taken first. Then, the line-fit equations specified in the (x,y) column are calculated. Finally, the table of population parameters is generated by applying the appropriate transforms from the appropriate column. Using the Log Normal CDF again as an example, the reported standard deviation is the slope of the fitted line in semi-log space.

The logarithmic data have an intercept standard estimate error definition that includes the scalar definitions in the table and an error term defined as "Bounds" in the table Notes. (Note that this is different than the plotted Confidence Interval bounds, whose equation is taken from standard texts and is not repeated here.)

Table10.0-1 Table of Distribution Equations, part 1

	x, y	Normal CDF	Log Normal CDF
y	$y = a + bx$	y	$\ln(y)$
x	x	$Z = P^{-1}(p_n)$	$Z = P^{-1}(p_n)$
a	$a = \frac{(\sum y - b\sum x)}{N}$	$\bar{x} = a$	$\mu = e^a$
b	$b = \Delta S_{xy}$	$s = b$	$\sigma = b$
S_a	$S_a = \frac{S_e\sqrt{\left\lvert N + \Delta(\sum x)^2 \right\rvert}}{N}$	$S_{\bar{x}} = S_a$	$S_\mu = S_a$ *note 1.1*
S_b	$S_b = S_e\sqrt{\lvert\Delta\rvert}$	$S_s = S_b$	$S_\sigma = S_b$
r	$r = S_{xy}\sqrt{\left\lvert\frac{\Delta}{S_{yy}}\right\rvert}$	r	r
N	N	N	N

Table10.0-2 Table of Distribution Equations, part 2

	Weibull	Extreme Value	Activation Energy
y	$\ln(y)$	y	$\ln(T_f \times j^2) = \ln\left(T_{tf} \times \left(\frac{I_{STL}R}{\rho_0 L}\right)^2\right)$
x	$\ln(-\ln(1-p_n))$	$\ln(-\ln(1-p_n))$	$\frac{1}{T} = \frac{1}{\mathrm{Target\_t+273.16}}$
a	$\alpha = e^a$	$\xi = a$	$A = e^a$
b	$\beta = \frac{1}{b}$	$\delta = b$	$E_a = b \times 8.617 \times 10^{-5}$
S_a	$S_\alpha = S_a$ *note 1.2*	$S_\xi = S_a$	$S_A = S_a$ *note 1.3*
S_b	$S_\beta = S_b$ *note 2*	$S_\delta = S_b$	$S_{E_a} = S_b \times 8.617 \times 10^{-5}$
r	r	r	r
N	N	N	N

Table10.0-3 Table of Distribution Equations, part 3

	Hot Carrier 1/Vds	Hot Carrier Ibs/W	Hot Carrier Igs/W
y	$\ln(Tf)$	$\ln(Tf)$	$\ln(Tf)$
x	$\frac{1}{Vds}$	$\ln\left(\frac{Ibs}{W}\right)$	$\ln\left(\frac{Igs}{W}\right)$
a	$t_0 = e^a$	$C = e^a$	$C = e^a$
b	$B = b$	$b = -b$	$b = -b$
S_a	$S_{t_0} = S_a$ *note 1.4*	$S_C = S_a$ *note 1.5*	$S_C = S_a$ *note 1.5*
S_b	$S_B = S_b$	$S_b = S_b$	$S_b = S_b$
r	r	r	r
N	N	N	N

For the above equations, the following equations apply.

$$S_{xx} = \sum x^2 - \frac{\left(\sum x\right)^2}{N}$$

$$S_{xy} = \sum xy - \frac{\sum x \sum y}{N}$$

$$S_{yy} = \sum y^2 - \frac{\left(\sum y\right)^2}{N}$$

$$\Delta = \frac{1}{S_{xx}}$$

$$S_e = \sqrt{\left|\frac{(S_{yy} - bS_{xy})}{N-2}\right|}$$

$$P(z) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{Z} e^{-\frac{t^2}{2}} dt$$

The following equation is used to generate the cumulative percentage of rank-ordered data point n from sample size N.

$$p_n = \frac{n - 0.3}{N + 0.4}$$

This can be replaced with a user defined equation using the pFunction feature of the Macro tool.

Notes: Error bounds in engineering units appearing in tables 10.0-1 and 10.0-2.

1.1

$$\text{Bounds} = \mu e^{\pm S_\mu} - \mu$$

1.2

$$\text{Bounds} = \alpha e^{\pm S_\alpha} - \alpha$$

1.3

$$\text{Bounds} = A e^{\pm S_A} - A$$

1.4

$$\text{Bounds} = t_0 e^{\pm S_{t_0}} - t_0$$

1.5

$$\text{Bounds} = C e^{\pm S_C} - C$$

2.

$$\text{Bounds} = \beta - \frac{1}{\frac{1}{\beta} \pm S_b}$$

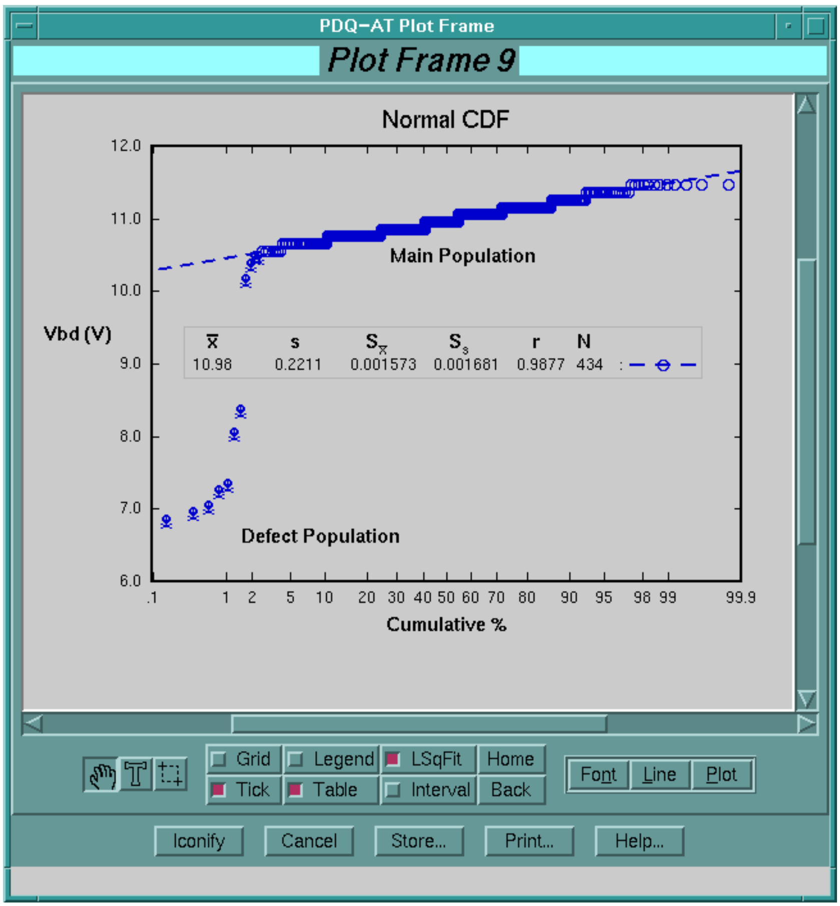
Normal CDF

A normal CDF distribution plot can be used to examine most traditional parametrics like Vt, Ids, Gm, sheet resistance, as well as normally distributed reliability data.

A straight line on this plot indicates a single normal distribution such as a bell shaped histogram. An "S" shape on this curve indicates multiple distributions. The lower Vbd values are part of a separate defect population. The quick identification of reliability defects such as these are important because they may indicate problems with IC products.

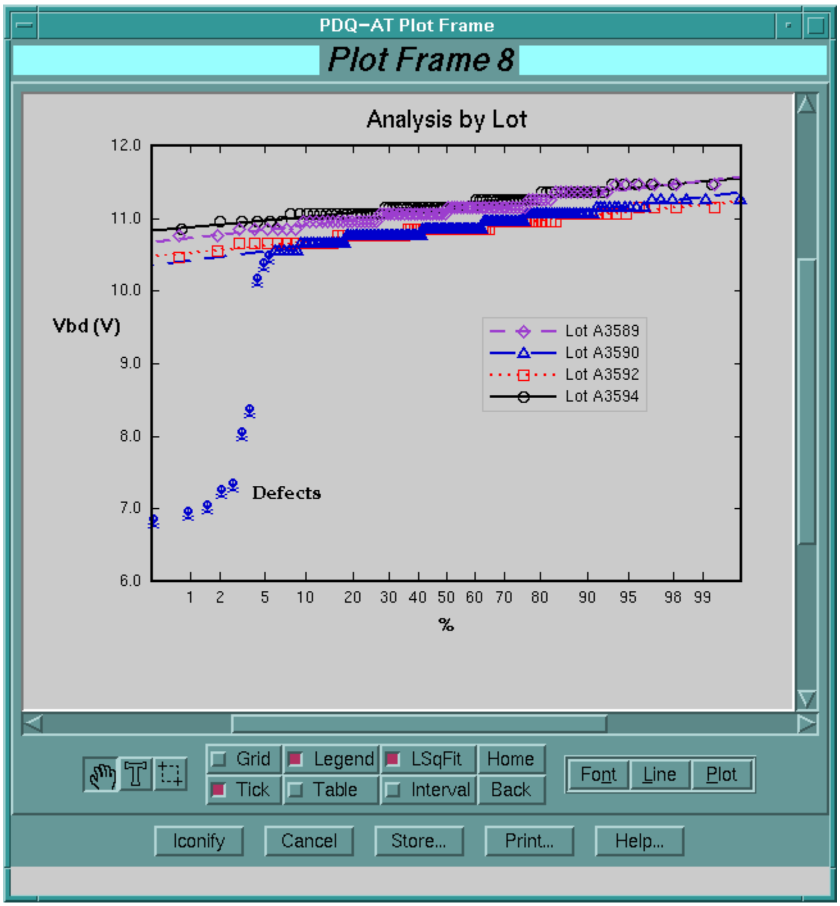
The normal CDF plot below (figure 10.0-1) shows variation in oxide breakdown voltage, Vbd, resulting from a ramped test. The main population is clearly seen to follow a normal distribution.

Figure 10.0-1 Normal CDF Distribution Plot



Sometimes analyzing the data by lot will reveal the source of the defect data. The plot below (figure 10.0-2) shows four lots of ramped oxide breakdown data plotted on a normal cumulative distribution plot. Here we see that the defects are present in one lot.

Figure 10.0-2 **Normal CDF Analysis by Lot**



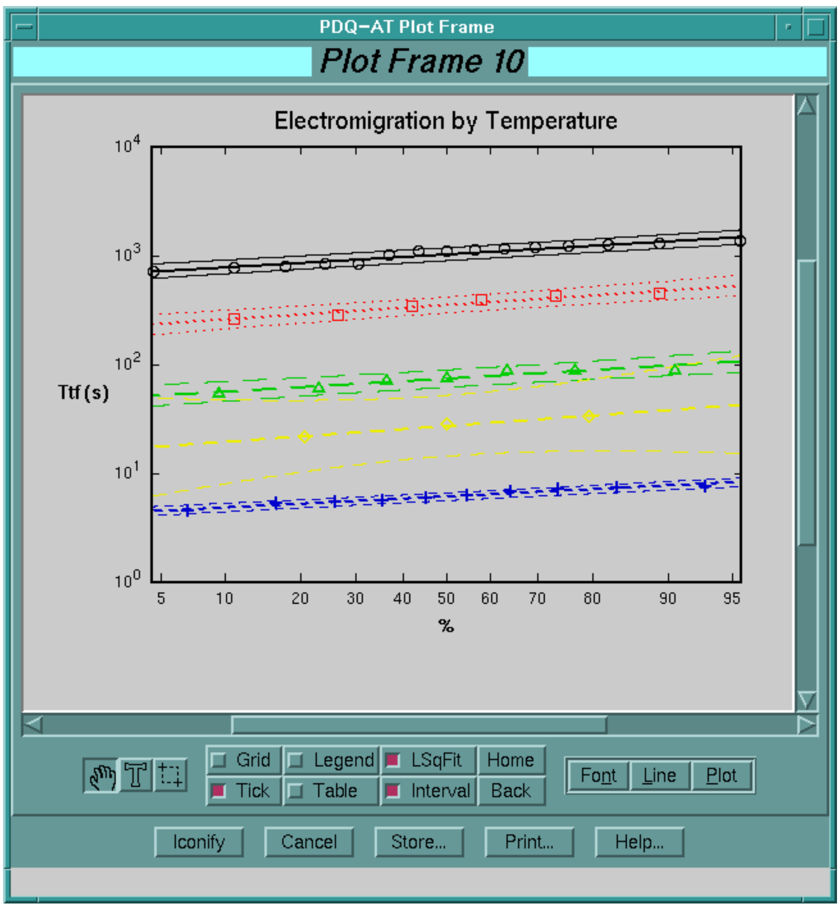
Log Normal CDF

The log normal CDF distribution is described by two parameters, mu and sigma. Mu is the median (50%) of the distribution and has the same units at the data. Sigma represents the slope of the distribution in log space. Typical values range from 0.3 to 1.

The log normal CDF distribution analysis fits many reliability engineering applications such as the lifetime model which describes failures occurring when damage has reached a specific level (e.g. modeling mechanical stress failure mechanisms). In such models, it is assumed that the rupture was caused when a crack in the structure reached a given size and the growth of the crack at any instant of time is a random proportion of its size at that time.

The log normal CDF distribution is frequently used to describe electromigration (EM) times-to-failure. The figure below (figure 10.0-3) shows the log normal distribution of EM time-to-failures at various test temperatures. The Y-axis is on a logarithmic scale. In this example, each curve represents EM tests performed at the same stress temperature. Here we see that the each temperature test has about the same slope (log normal CDF sigma).

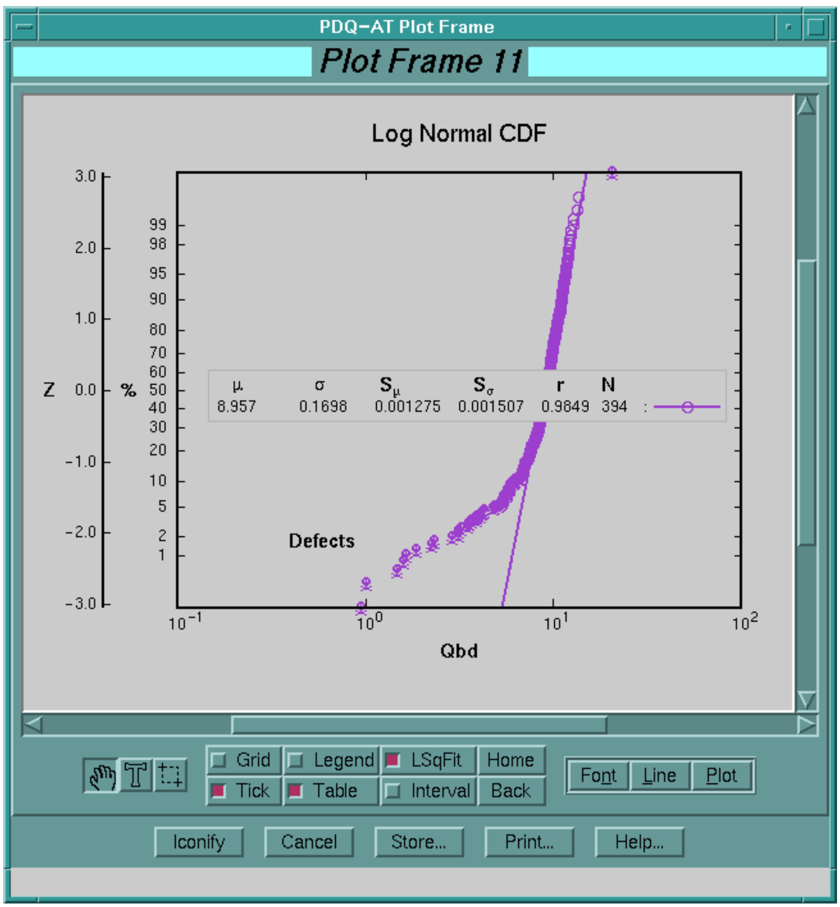
Figure 10.0-3 Log Normal CDF Example



The hot carrier lifetimes (times-to-failure) are adequately described by a log normal CDF distribution. For example, the lifetime of nMOSFET or pMOSFET stressed under the same constant voltage stress should follow a log normal CDF model.

The log normal CDF model may also describe the intrinsic oxide breakdown time-to-failure data. Or, as shown below in figure 10.0-4, it can model the variation in oxide charge-to-breakdown (Qbd). A Weibull distribution can also be applied to oxide time-to-failure data.

Figure 10.0-4 Oxide Charge to Breakdown Plot



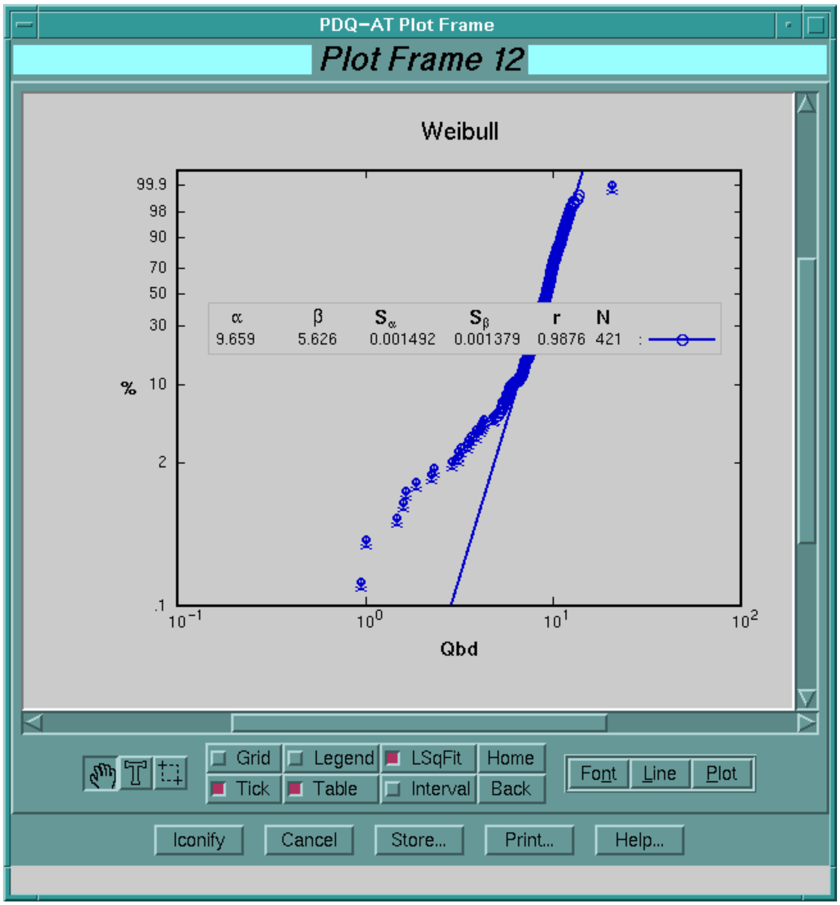
Weibull

The Weibull distribution is described by two parameters, alpha and beta. Alpha is the intercept where the cumulative percent is 63.2%. Alpha has the same units as the data. Beta represents the slope of the distribution. Typical ranges for Beta are from 0.5 to 5. The Weibull distribution can represent increasing, decreasing or constant failure rates. Because of this flexibility, it is sometimes used when adequate knowledge of the underlying distribution is not available.

The Weibull distribution can describe a wide range of time-to-failure reliability phenomena such as a lifetime models for relays, ball bearings, and, fo course, semiconductors.

The Weibull distribution has been used to describe the oxide time-to-breakdown distribution. A Weibull distribution of the oxide charge to breakdown is shown below (figure 10.0-5). Time-to-failure constant voltage or constant current oxide breakdown tests can also be analyzed using a Weibull distribution.

Figure 10.0-5 Weibull Plot for Oxide Charge to Breakdown



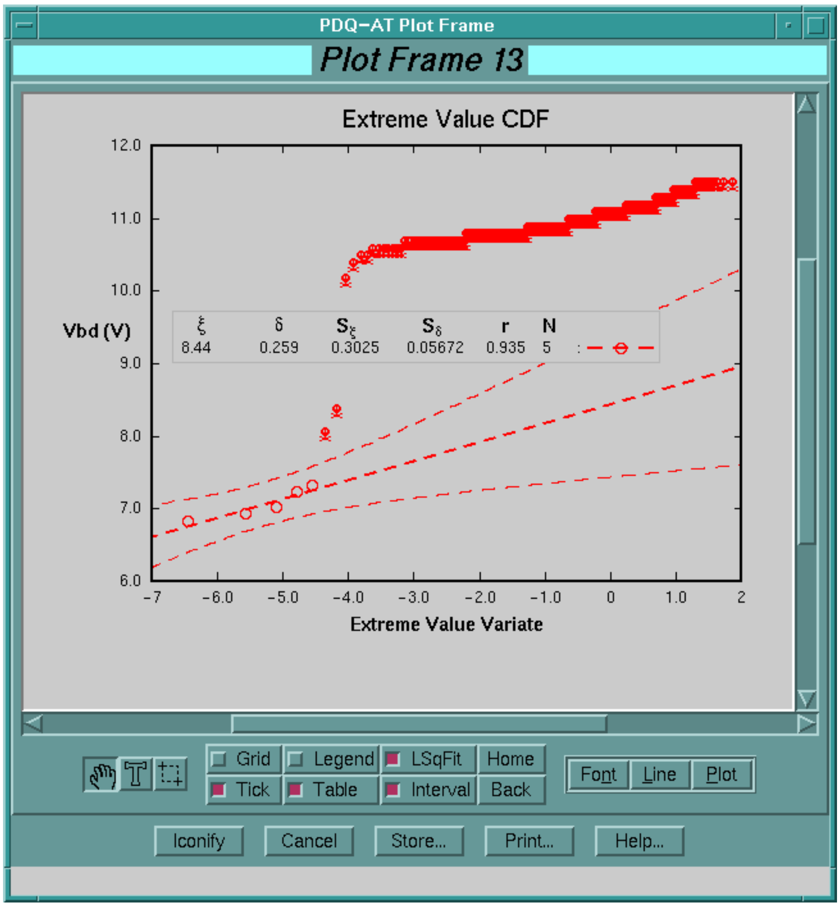
Extreme Value

The Extreme Value distribution usually describes failures that are represented by the extreme occurrence such as systems which have components connected in series. When the first component fails, the system will fail.

The extreme value minimum type 1 distribution is implemented in PDQ-AT. This distribution is highly skewed toward shorter failure time. The extreme value distribution has been used to described oxide breakdown data.

The example below (figure 10.0-6) shows ramped oxide breakdown data. Note that the main population does not appear to be well described by a Extreme Value distribution (it is not a straight line on the Extreme Value scale). But the defect population is better described as an extreme value distribution.

Figure 10.0-6 **Extreme Value Plot of Ramped Oxide Breakdown**

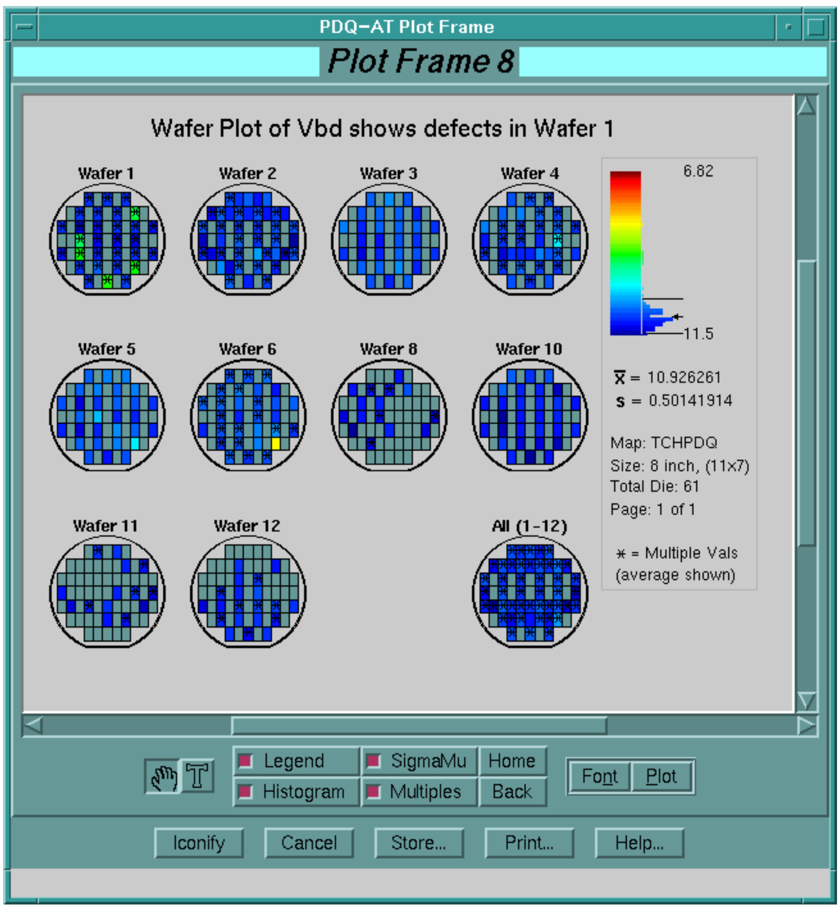


Wafer Plots

Wafer plots (a colored display of test values at die locations on a wafer map) of parametric data have been used for years to aid in identification of yield problems. Many reliability problems also have a distinctive wafer pattern. For example, plasma damage may have a circular wafer pattern or implant shadowing may have a top to bottom wafer plot variation.

In figure 10.0-7 below, the parameter displayed is the ramped oxide breakdown voltage, Vbd. This sample contains four lots of data with multiple wafers, resulting in multiple values at many die sites (multiple values are indicated by the *). In figure 10.0-7, the display is the average value at each site. Note that there are defects (lower Vbd) which seem to be clustered in wafer 1.

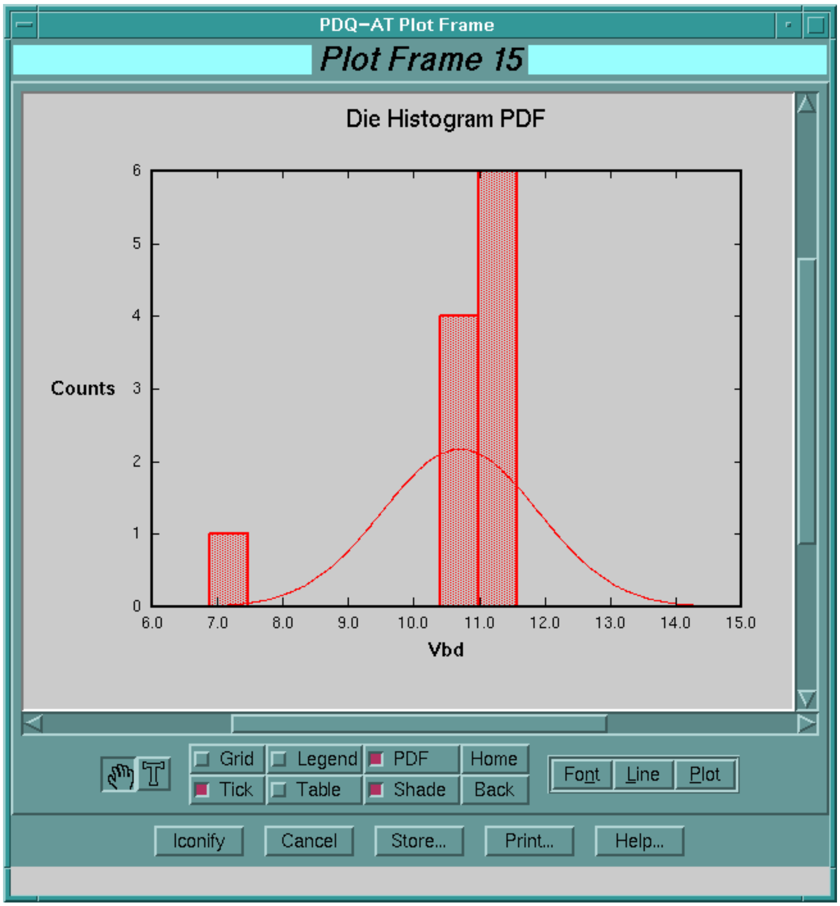
Figure 10.0-7 Ramped Oxide Breakdown



The combination bar graph/histogram also contains the data used to generate wafer maps. In the figure above, you can see several defective values below the main population.

We can create a histogram of all the Vbd in one site. This is shown below for one of the sites on the outside of all the wafers.

Figure 10.0-8 **Wafer Plot Histogram**



By examining the wafer plots for a single lot, we determined that most of the defects were in wafer 1 in one lot.

For reliability data that is logarithmically distributed such as electromigration, oxide, or hot carrier time-to-failure data, the wafer plots can also be displayed in a logarithmic color scale.

Activation Energy

The electromigration lifetime is governed by Black's equation,

$$T_f = \left(\frac{A}{J^2}\right)\exp\left(\frac{E_a}{kT}\right)$$

where

T_f = Time to failure (s)

A = Empirical constant (A^2-s/cm^4)

j = Applied current density (A/cm^2)

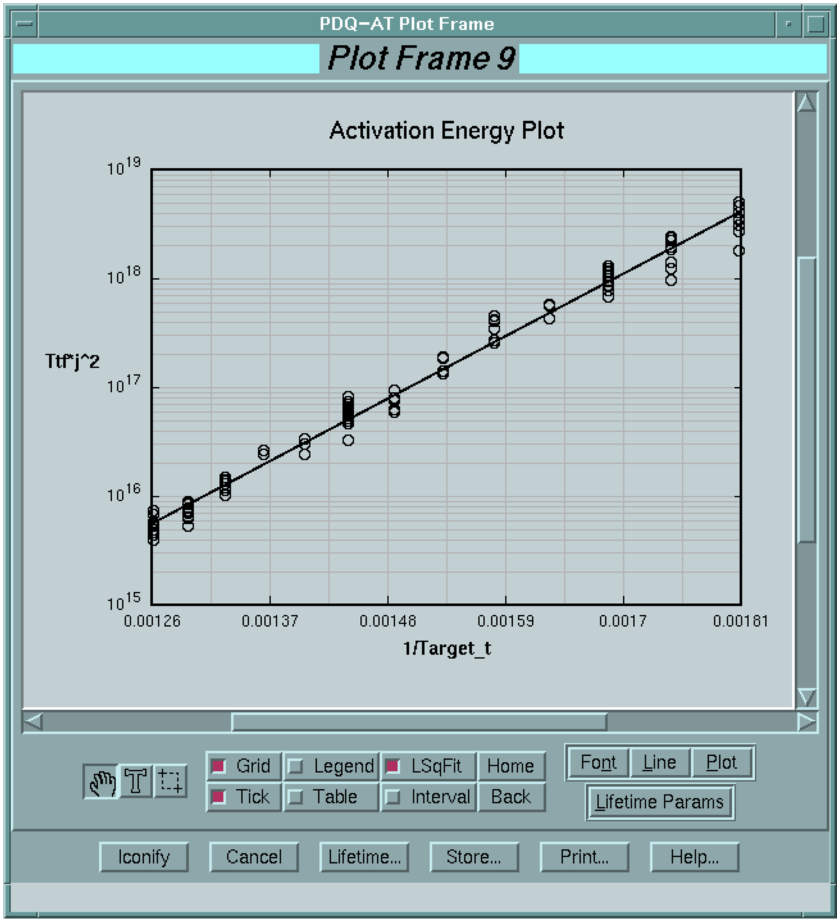
E_a = Activation energy for diffusion (eV)

k = Boltzmann's constant (8.617 x 10^{-5} eV/K)

T = Temperature (K)

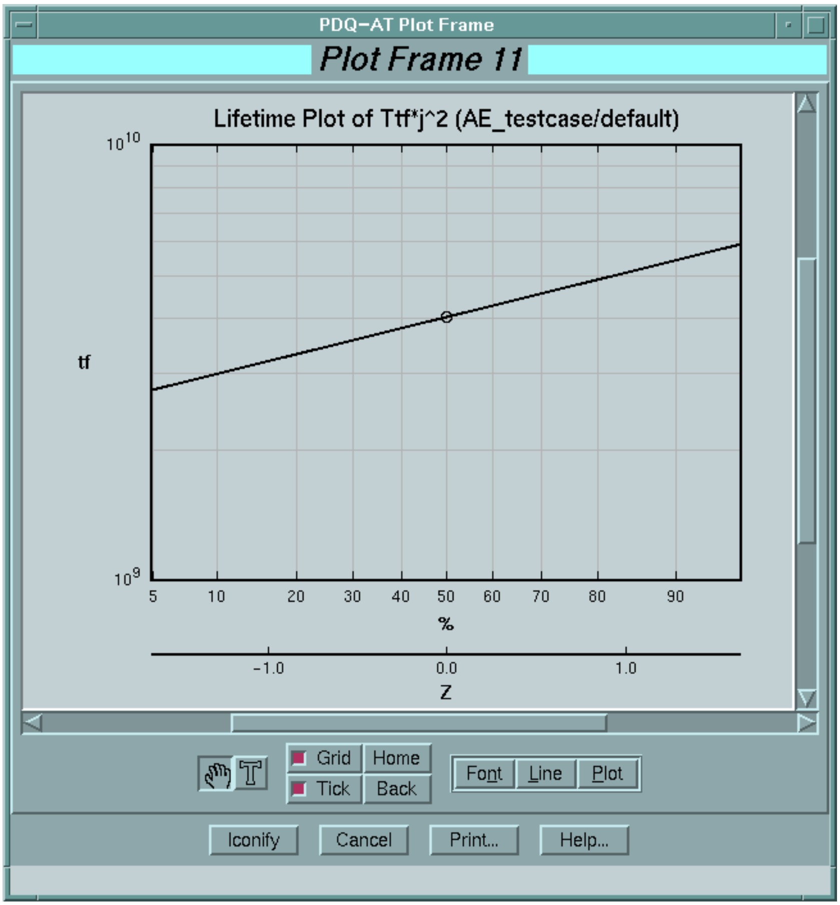
Black's equation governs the lifetime as a function of the stress conditions (current density and temperature) and is essential for extrapolating wafer level data to the integrated circuits normal operating conditions to estimate the lifetime of a metal stripe under normal operating conditions.

Figure 10.0-9 Activation Energy plot



The two key parameters measured from electromigration tests over several test temperatures are A and E_a. They are extracted from the data by plotting measured time to failure times current density squared versus inverse temperature in semi-log format. The activation energy is extracted from the slope of the resulting straight line (E_a = slope times k) and A is the intercept. These two parameters along with the statistics of A are used in determining the reliability of the metal line under any stress condition through Black's equation. In general, the higher E_a and A, and the lower the log-normal sigma of A, the more reliable the metal process.

Figure 10.0-10 Activation Energy Lifetime Prediction



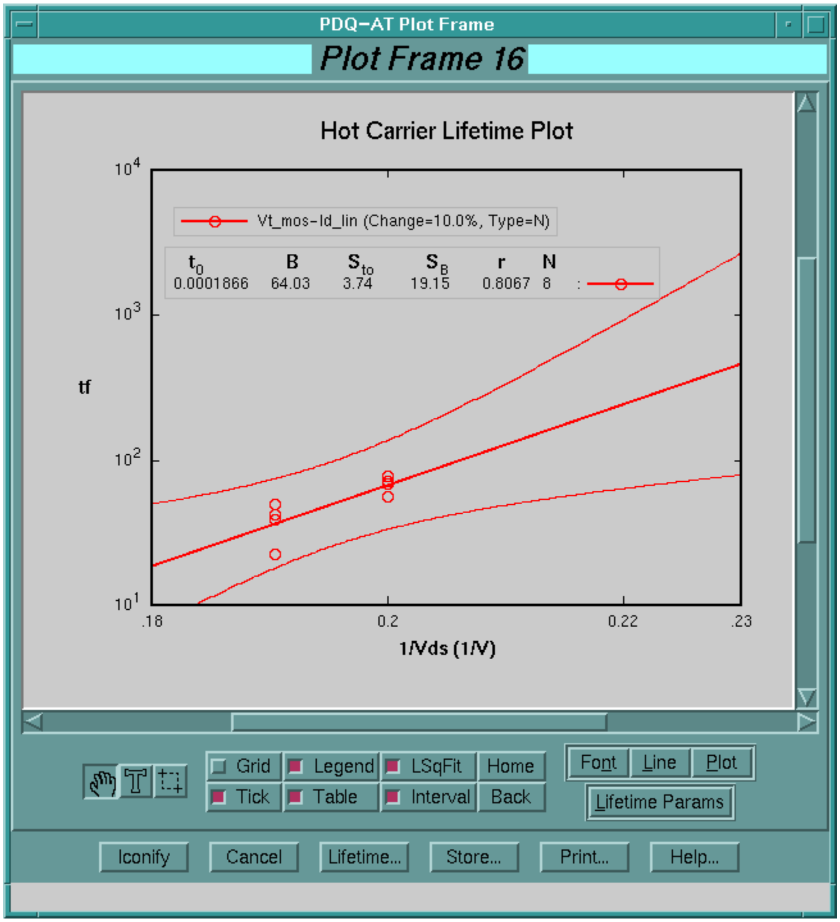
Hot Carrier Lifetime Predictions

Hot carriers are energetic carriers with enough energy to cause device damage. In MOSFETs, hot carriers change transistor parametrics such as threshold voltage, drive current and transconductance. The hot carrier-induced degradation causes a monotonic change with the logarithm of stress time. This damage mechanism is worse for smaller geometry devices and higher operating voltages.

PDQ-AT directly supports three different degradation models: 1/Vds, Ibs/W and Igs/W. Additional models can be added via the PDQ-AT Macro Window (see SubChapter 5.1) and scatter plots.

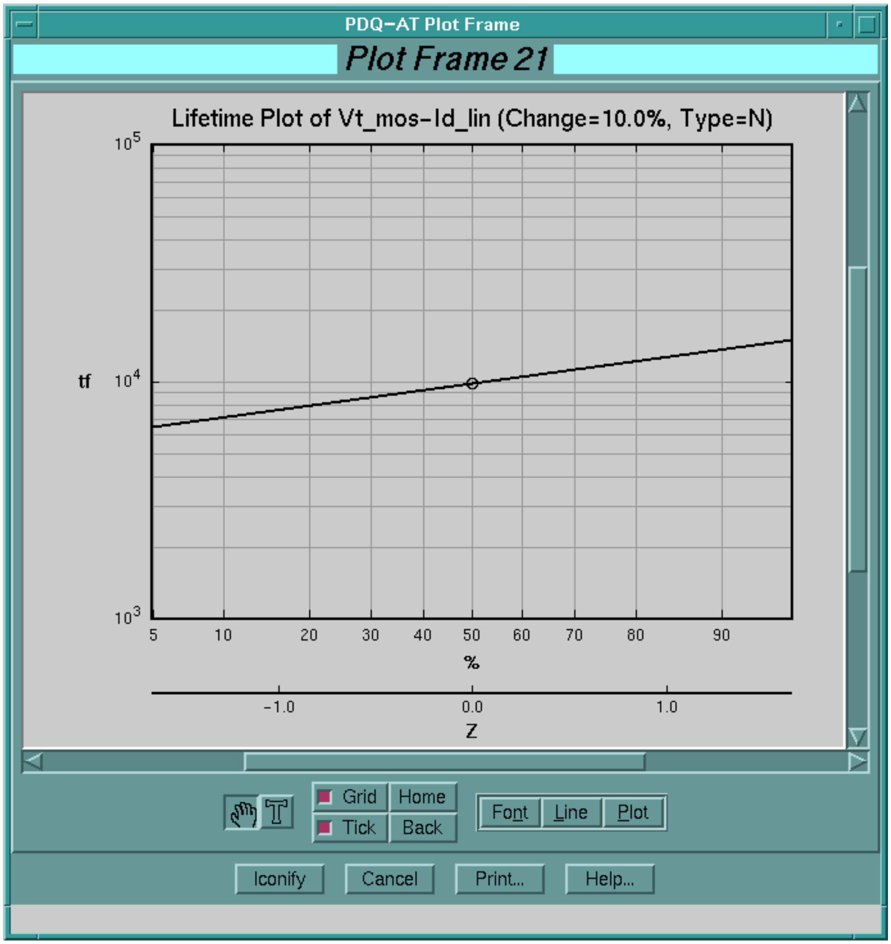
An example hot carrier lifetime plot using a 1/Vds acceleration model is shown below in figure 10.0-11. Here, the lifetime is assumed to be modeled as t_f=t_o * exp(B/Vds) where t_f is the failure time (lifetime), B is the slope of the this curve and to is the intercept. In this example, there exists a large variation in confidence bounds due to very small sample size (8). This clearly shows the trade-off between sample size and confidence in extrapolation. When using the 1/Vds acceleration method, all the devices should be stressed so as to result in the same physical degradation mechanism.

Figure 10.0-11 Hot Carrier Device Lifetime



To calculate the lifetime at user specified conditions, usually worst-case operating voltage, PDQ-AT uses a physical acceleration physical model (1/Vd in this case) and the log normal CDF statistical model. The lifetime plot shown below (figure 10.0-12) is an estimate of the median lifetime at use condition and the distribution (slope) is estimated from variation in the data. The lifetime is quite low in this case, around 10,000 seconds, due to monitoring the linear drain current (which is highly susceptible to hot carrier damage); testing a small device geometry device; and testing a non-optimized developmental process. Because the error in extrapolation, one must also be in careful in interpreting and using the extrapolated lifetime information.

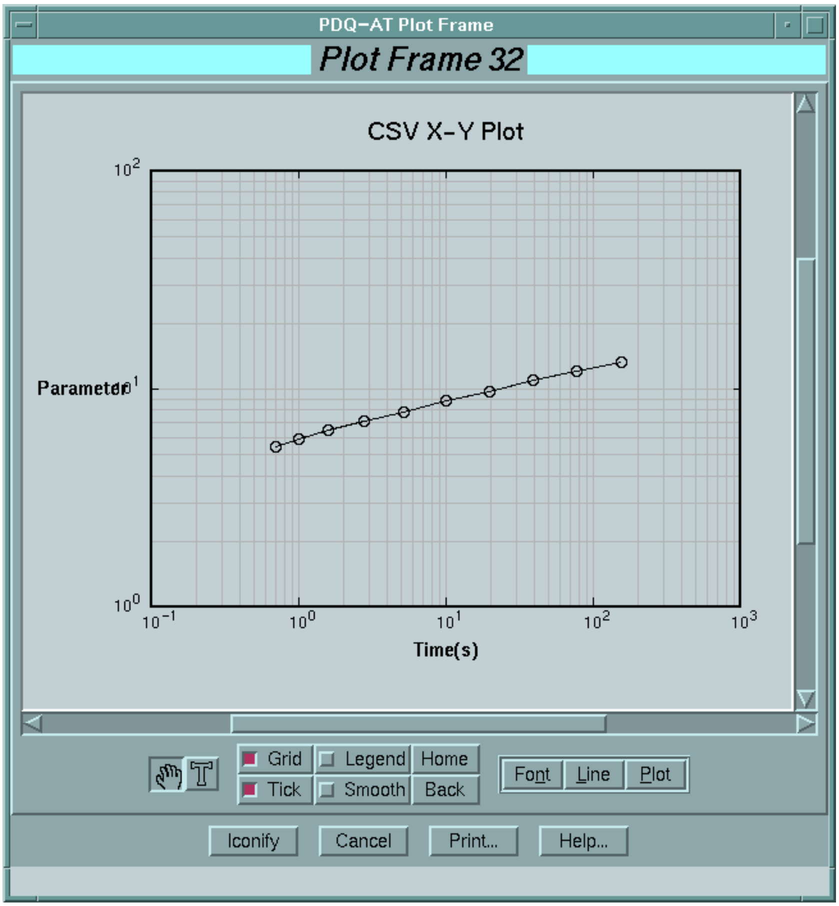
Figure 10.0-12 Hot Carrier Lifetime Prediction



Hot carrier lifetime plots are derived from large amounts of underlying data. If using PDQ-WLR testing software for hot carrier tests, the underlying data is interrelated and linked together so that it can be easily retrieved using PDQ-AT. Examination of this data is often useful in isolating the case of defective data. For the exact procedure, see “Plotting CSV Files” in section 5.6, p. 151.

The lifetime as a function of stress condition data is derived from a parameter degradation versus time curve. Clicking on one of the data points will reveal the time curve associated with that point. An example is shown in figure 10.0-13 below.

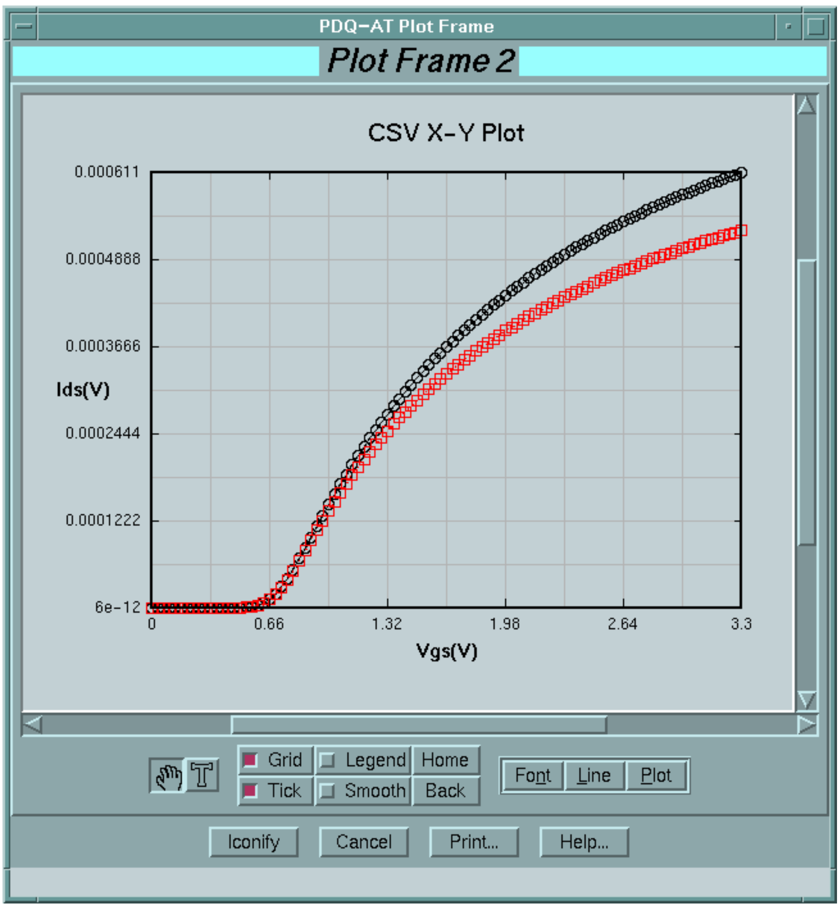
Figure 10.0-13 Parameter Degradation vs. Time Curve



Here we see the time change in linear drain current plotted in a log-log format. To first order, the linear drain current follows a power law relationship. This is consistent with interface state damage in n-channel MOSFETs. There is a small amount of saturation in the curve, which can occur in LDD devices. The time where there is 10% change is defined as the lifetime for these devices.

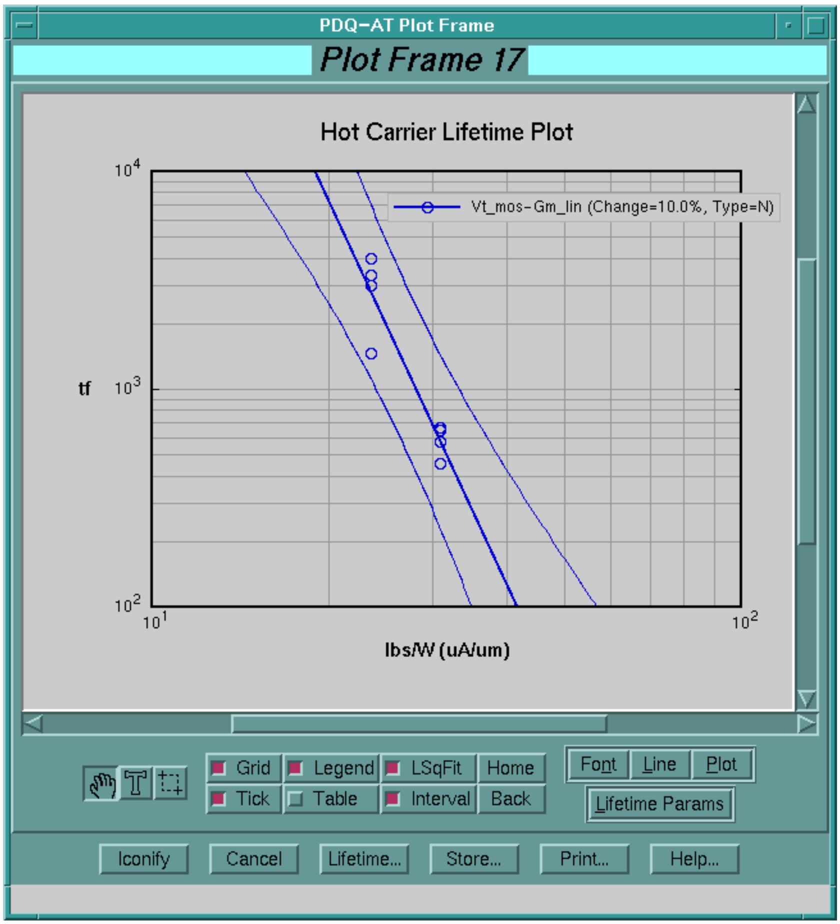
Each of these percentage change points is derived from an underlying curve (I-V curve in this case). If this data is stored, it can also be examined using PDQ-AT. The example below (figure 10.0-14) shows the drain current versus gate current plots for the first stress point and the last stress point in the previous curve. From these curves we can quickly see that there is a large shift in linear drain current and a very small change in the threshold voltage. This result is typical for LDD n-channel MOSFETs.

Figure 10.0-14 Underlying Curve



Another useful acceleration parameter is the Ibs/W. Ibs is the initial substrate current at the stress condition. The example below (figure 10.0-15) shows the lifetime of the linear maximum transconductance for an n-MOSFET device in a deep-submicron technology. Ideally, the slope is around -3 (on this log-X, log-Y scale). The slope can vary depending on the acceleration level and degradation mechanism.

Figure 10.0-15 Lifetime of Linear Maximum Transconductance



If electron trapping is important (e.g. p-channel MOSFETs with gate lengths greater than 0.25um and some n-channel MOSFETs), the Igs/W model may also be used. Igs is the initial gate current at the stress condition.

Statistical Process Control

Statistical process control is used to gauge the stability of a process and is usable with parametric and reliability data.

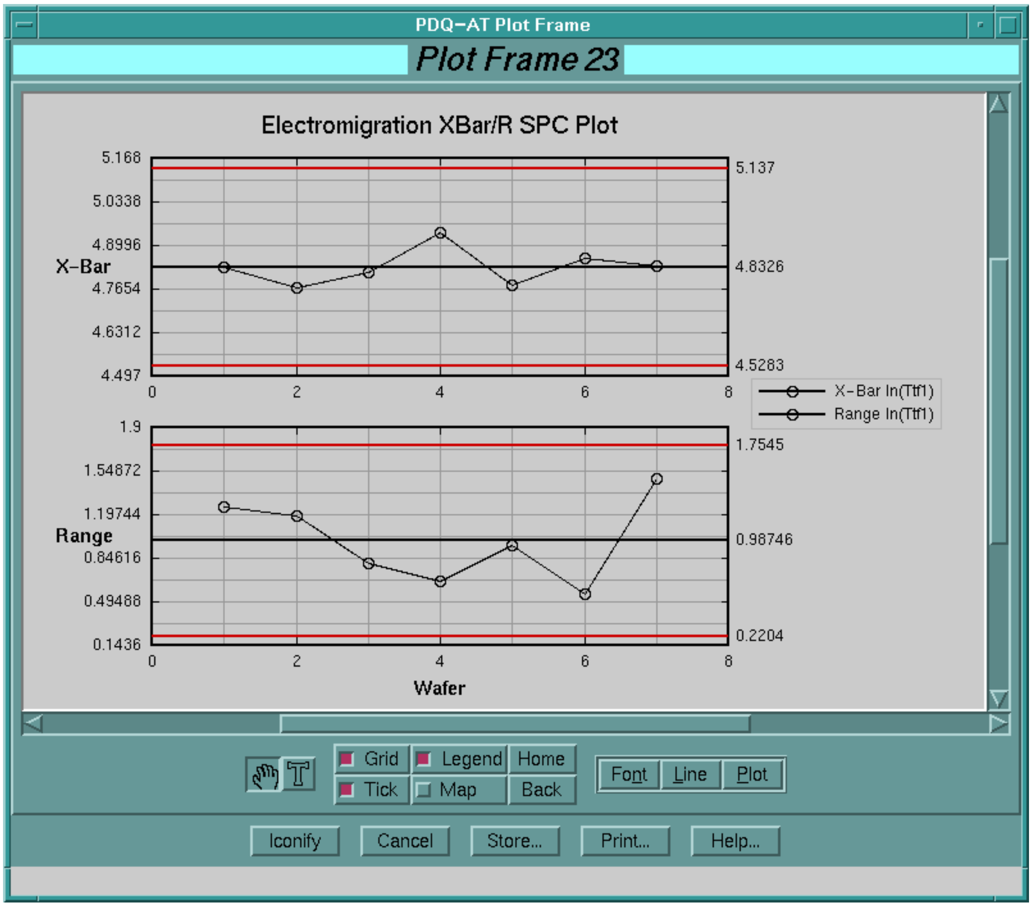
Fundamental to SPC analysis and interpretation is the choice of rational subgroups. Ideally, the data analyzed is a random sample. If the same samples are always selected for testing and, for whatever reason, a correlation between the samples exists, then the randomness assumption is violated and the interpretation of the SPC charts becomes more difficult.

Additionally, testing and monitoring the proper physically relevant parameters is critical to an effective SPC program. If the measurements are not predictive, which is to say the measurements are directly physically related to longer term reliability tests and process reliability, then SPC monitoring will, at best, be a waste of time. At worst, these SPC charts will indicate an incorrectly out-of-control process and cause needless and expensive corrective actions.

A number of SPC charts are available with PDQ-AT. Xbar-R and Xbar-S chart are used when the rational subgroup is greater than 1. This subgroup might be tests done on a date, or by wafer or by lot. In this case Xbar refers to the average value of the observations that is calculated from the samples in each subgroup. R refers to the range of the samples and S is the standard deviation of the samples in each subgroup. The confidence bounds are calculated based on a user specified sigma (3 sigma is recommended) level with the assumption of normally distributed data.

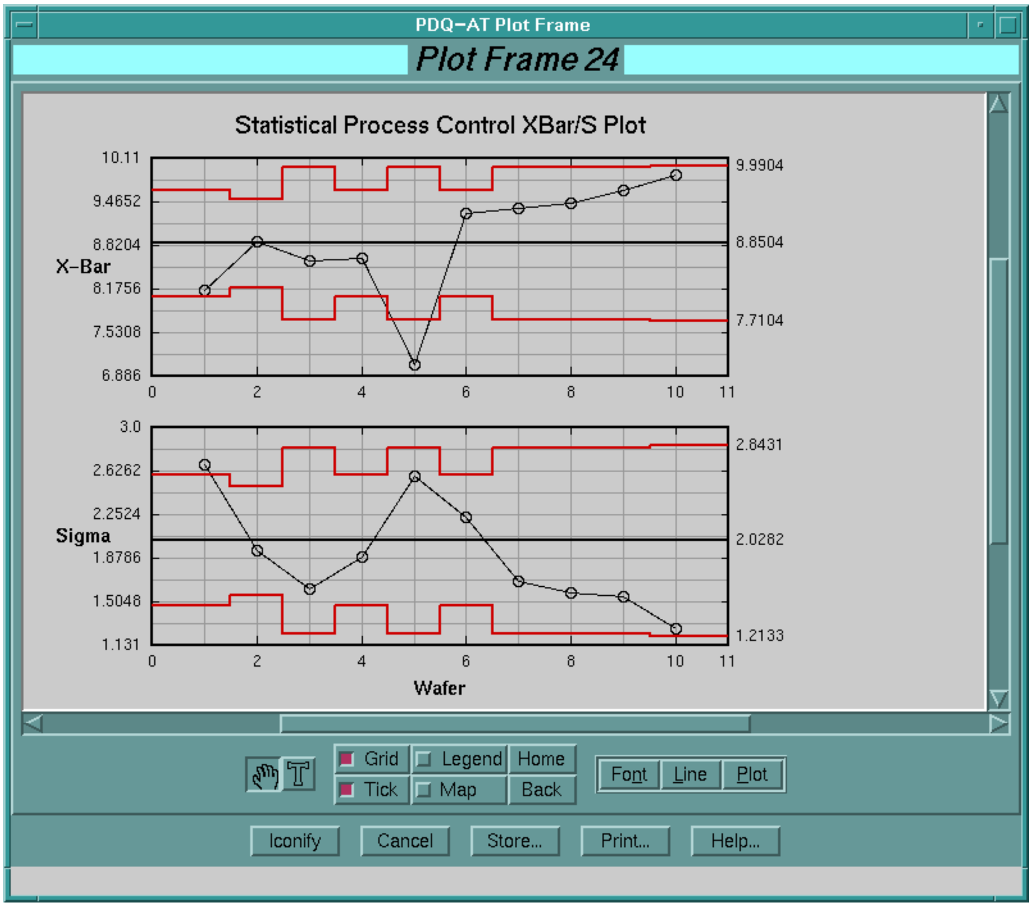
The example below in figure 10.0-16 shows an Xbar/R chart of electromigration data by wafer. To first order, since the values do not exceed the confidence limits, the process is said to be under control.

Figure 10.0-16 Xbar/R of Electromigration Data by Wafer



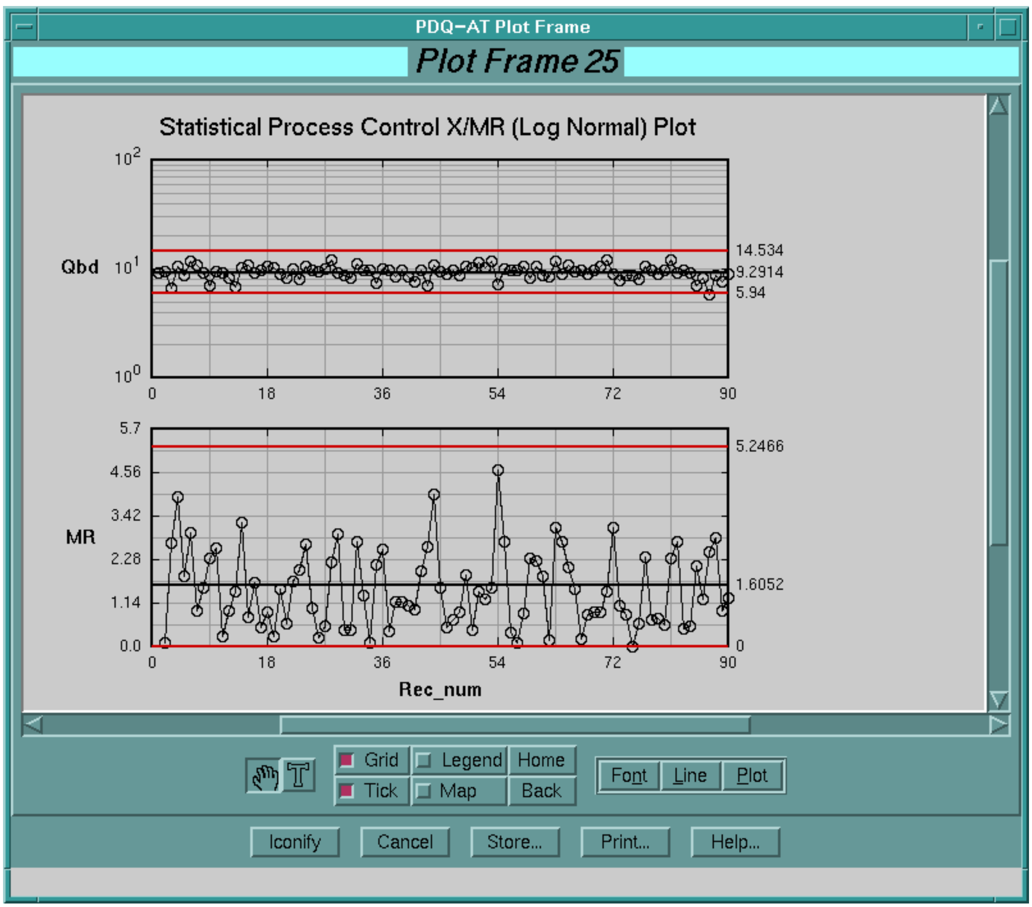
When analyzing data with varying sample sizes, use an Xbar/S SPC chart. An SPC chart for oxide breakdown is shown below (figure 10.0-17). Note that the control limits vary due to the varying sample size.

Figure 10.0-17 Oxide Breakdown with Wafer Groups



You can also analyze individual raw data using the X/MR charts. X is the individual value and MR is the moving range of the data. Unlike the average values calculated in the Xbar/S or Xbar/R charts, the raw data points (samples within a group) may not be normally distributed. For example, the individual Qbd values may be log normally distributed. As a result, PDQ-AT provides several different types of X/MR charts based on the underlying distribution of the raw data. For normally distributed data use the X/MR chart. This might include Vbd data from oxide breakdown experiments. For log normally distributed data such as electromigration or hot-carrier time-to-failures, you can use the X/MR (log normal CDF) chart to perform SPC. The confidence bounds are based on a fit to the log normal CDF distribution of the underlying data. The example below shows the X/MR (log normal CDF) SPC chart for oxide breakdown data.

Figure 10.0-18 **X/MR Log Normal CDF**



In a similar manner, Weibull or extreme value individual data can be used with the X/MR (Weibull) and X/MR (EV) charts.