pcFIRMS®

Basics Training for pcFIRMS

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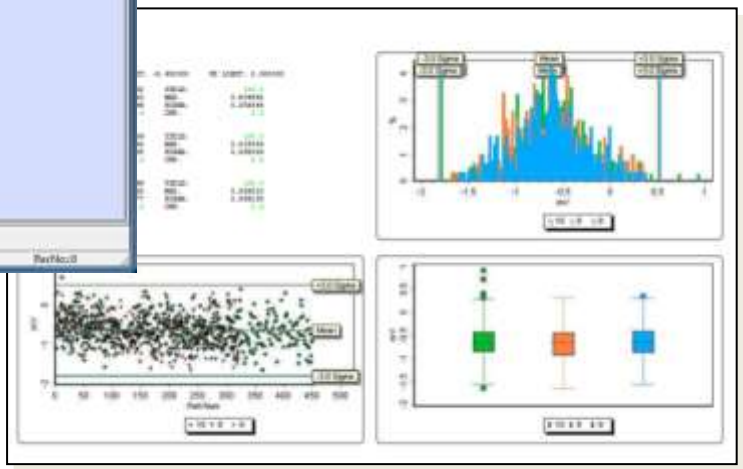
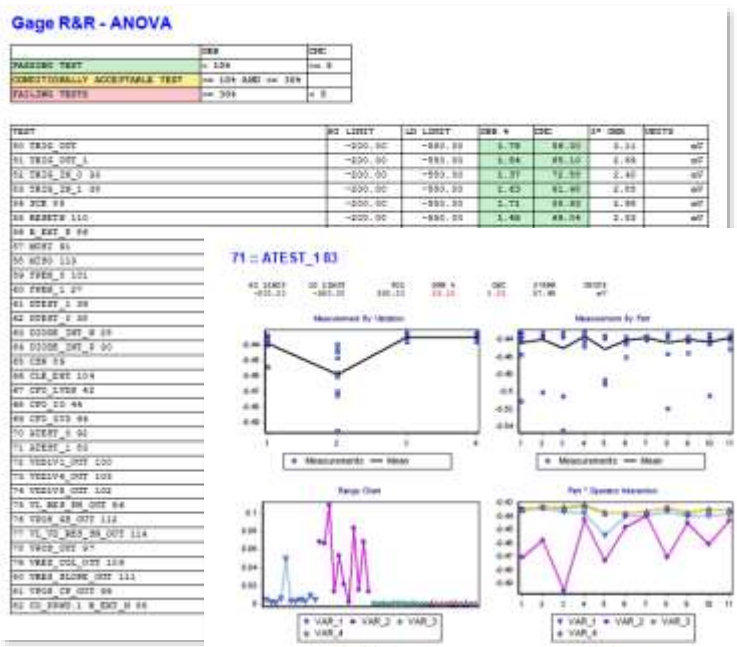
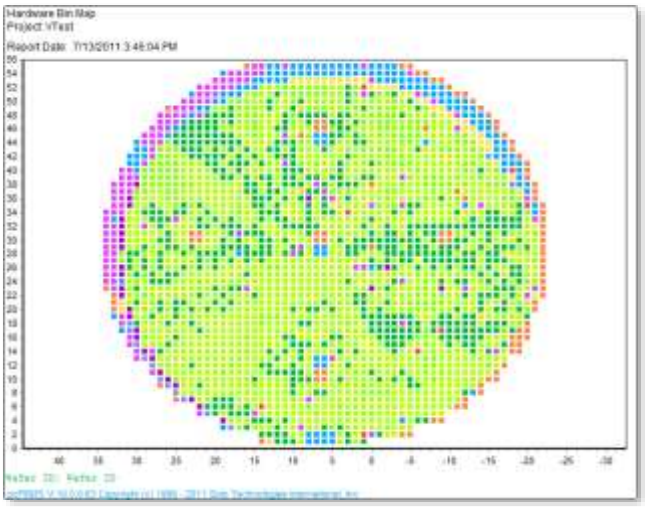
Data to Answers to Profits Fast!







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Introduction

General Information

Welcome to pcFIRMS data analysis and reporting software for test data. pcFIRMS is designed to provide quick and easy analysis and reporting for semiconductor test data. It also provides Perl, JScript, and VBScript engines that are used in conjunction with our FIRMS APIs to create custom charts and reports.

pcFIRMS can be used alone or in conjunction with Soto Technologies International complete suite of automatic Data Collection and Analysis tools. For information on all Soto Technologies International products, contact us at info@sototech.com or www.sototech.com.

This information in this document assumes that pcFIRMS has already been installed. For instructions on the installation of pcFIRMS, please refer to the pcFIRMS Installation Guide.

The audience for this document is assumed to have the following knowledge:

1. Familiarity with the semiconductor test process. Knowledge of the entire semiconductor manufacturing process is helpful, but not necessary to operate pcFIRMS.
2. Basic ability to open programs and manipulate files in a Microsoft Windows environment.
3. Knowledge of basic mathematics principles is helpful.
4. Knowledge of data analysis, statistics, and the STDF Version 4 format are helpful, but not necessary to operate pcFIRMS

Manual Organization

This manual is organized into a series of topics. Each topic will be covered in four steps:

1. Introduction to terms and concepts.
2. A practice session.
3. An exercise that the user is encouraged to do as much on their own as possible.

First part is focusing on using the Graphical User Interface, basic statistics, and built in functionality of pcFIRMS. The second part focuses on design of experiments and practical applications of pcFIRMS. The third part is focused on learning how to automate and customize pcFIRMS using the built in SQL, JScript, VBScript, and PERL engines.

Manual Syllabus

This manual is designed to teach the user how to use pcFIRMS in the Semiconductor Manufacturing process. Since pcFIRMS makes use of statistics, we learn some basics about descriptive statistics and how they apply to manufacturing along the way.

Below is a target schedule as if it were two days of training:

Day 1:

09:00 - 09:20:	Introductions, Starting pcFIRMS, Running JumpStart, Workspaces, & loading data.
09:20 - 09:30:	Exercise 1.
09:30 - 10:00:	Process Capability, Characterization Statistics (Mean, Median, Range, Variance, Standard Deviation (Sigma), Cp, Cpk, IQR, etc.
10:00 - 10:15:	Exercise 2.
10:30 - 10:45:	N-Chart, Advanced PCS
10:45 - 11:00:	Exercise 3.
11:00 - 11:15:	SDS and Comparative Statistics (T-Test, F-Test, 1/cpk delta)
11:15 - 11:30:	Exercise 4.
12:30 - 12:45:	TES and Paired Sample Statistics (Correlation Coefficient, Confidence Intervals)
12:45 - 13:00:	Exercise 5.
13:00 - 13:15:	Bin Trend and Production Monitoring
13:15 - 13:30:	Exercise 6.
13:30 - 14:00:	Gage Capability
14:00 - 14:20:	Exercise 7.
14:35 - 14:55:	Creating and Manipulating Charts
14:55 - 15:15:	Exercise 8.
15:15 - 15:35:	Creating and Manipulating DataViews and ASCII Reports
15:35 - 16:00:	Exercise 9.
16:00 – 17:00:	One on One questions and practice

Day 2:

09:00 - 09:15:	Review
09:15 - 09:30:	Introduction to Design of Experiments (DOE)
09:30 - 09:45:	Encoding Test Conditions
09:45 - 10:05:	Design Characterization (Guardbanded Test Limits)
10:05 - 10:20:	Exercise 10.
10:35 - 10:50:	Virtual Retest
10:50 - 11:05:	Exercise 11.
11:05 - 11:20:	Wafer Mapping
11:20 - 11:35:	pcFIRMS Online Help System
11:35 - 11:45:	Exercise 12.
12:45 – 13:30:	Comprehensive Review Exercise
13:30 – 13:40:	Introduction to the Editors, development process.
13:40 - 13:50:	SELECT Statements
13:50 – 13:55:	Grouping Functions
13:55 - 14:00:	Performing Calculations in the SELECT
14:00 - 14:05:	Column aliasing and report sorting
14:05 - 14:20:	Exercise 13.
14:35 - 14:40:	Introduction to Scripting in pcFIRMS
14:40 - 14:45:	Communicating with the User
14:45 - 14:50:	Creating a Workspace and Loading Data
14:50 - 15:05:	Exercise 14.
15:30 - 15:35:	Embedded SQL
15:35 - 15:50:	Exercise 15.
15:50 - 15:55:	Creating and manipulating a chart
15:55 - 16:05:	Exercise 16.
16:05 - 16:10:	Subroutines in PERL
16:10 - 17:00:	One on One questions and practice

NOTE: If your facility does not deal with any wafer data, the section on wafer mapping & can be omitted.

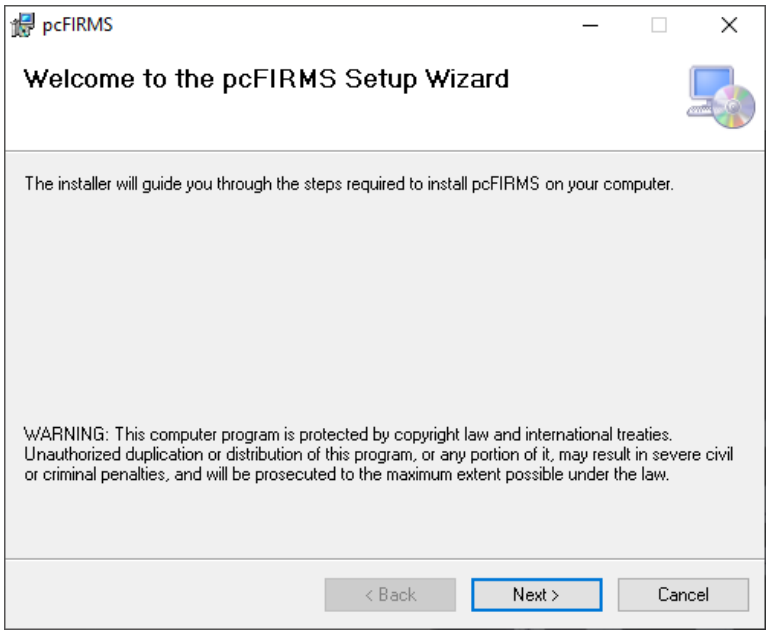
Installing pcFIRMS

Download pcFIRMS

You will be provided with an installer or download credentials to download the installer directly. The installer is in MSI format (Microsoft Software Installer).

Running the Installer

1. Navigate to the location where your pcFIRMS MSI file is located and double click to execute. The pcFIRMS setup Wizard will come up. Click Next.

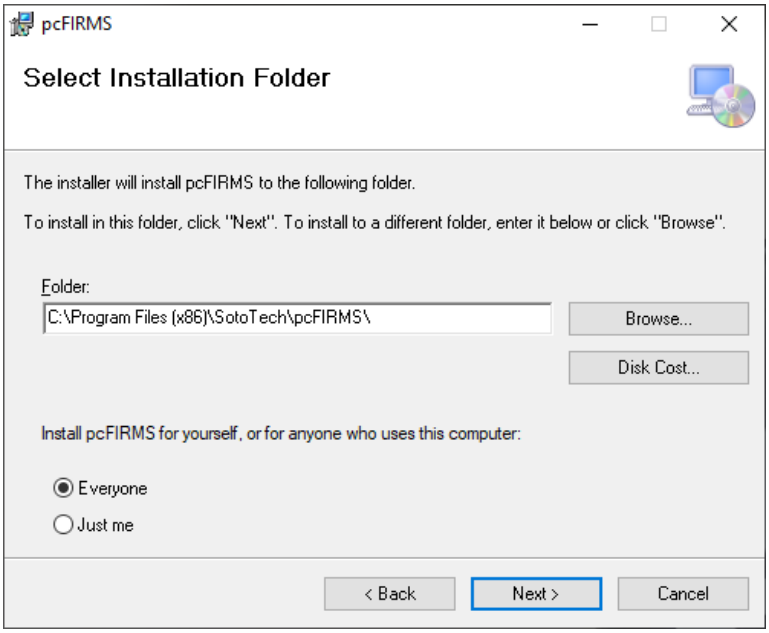


2. Set the location where pcFIRMS will be installed.

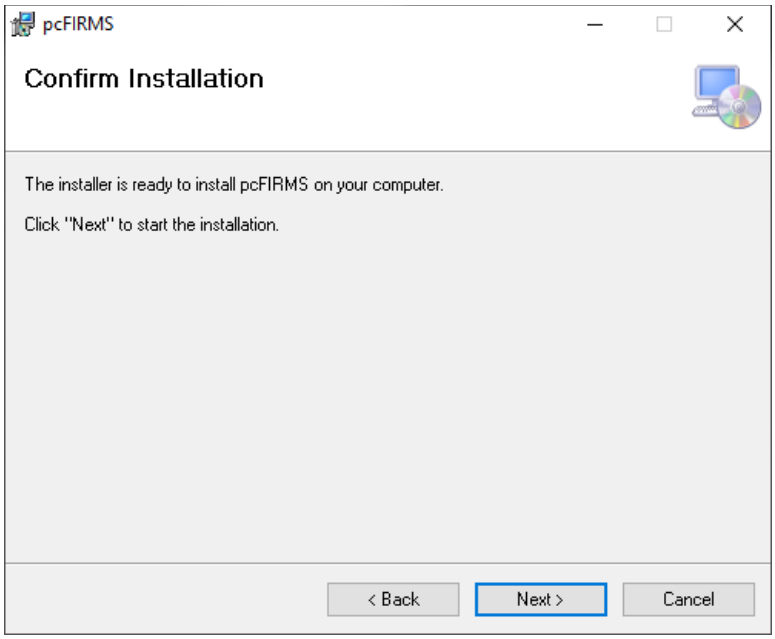
   The default directory is C:\Program Files (x86)\SotoTech\pcFIRMS.

   We recommend installing in the default directory.

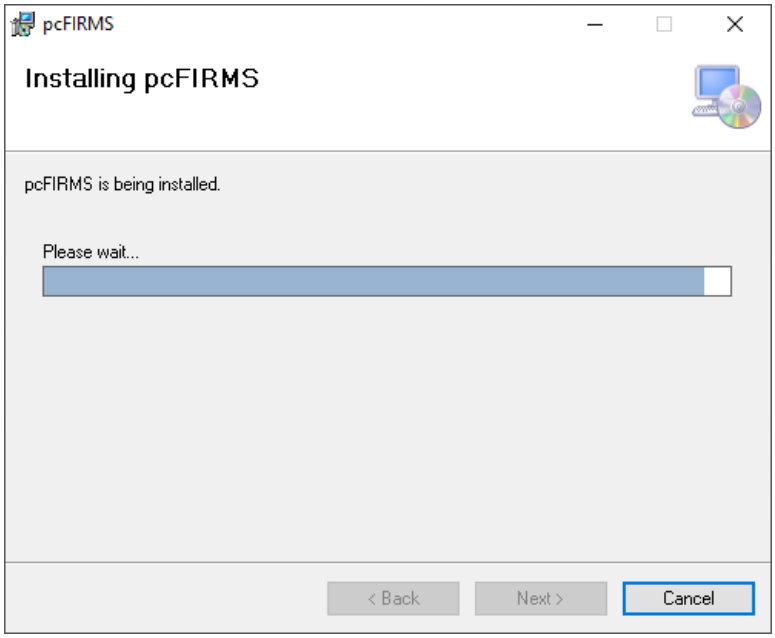
   You can select whether to install for all the accounts in the local system (Everyone) or just the current user (Just me)



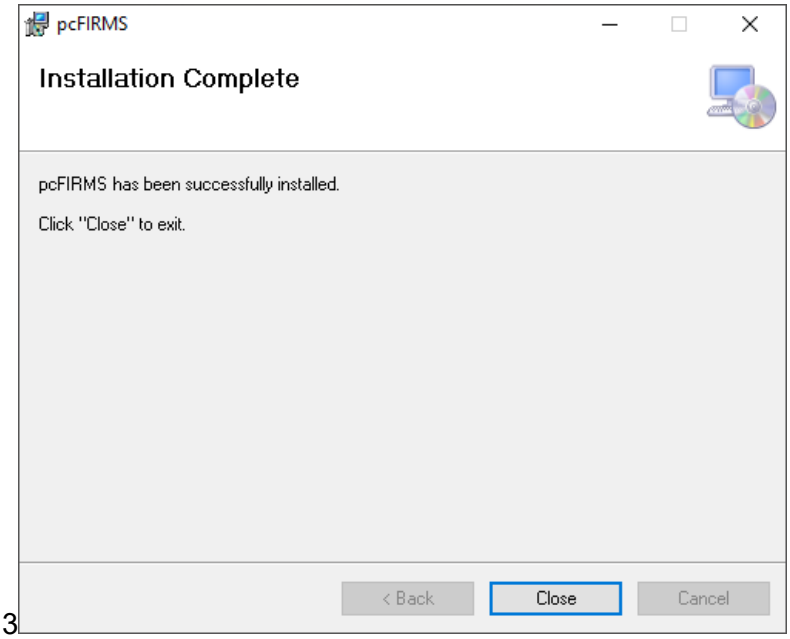
3. Confirm that you want the installation to proceed.



4. The installation wizard will put all necessary files needed by pcFIRMS, including sample STDF files under the specified installation directory.



5. Once the installation process is complete, click the **Close** button to finish.



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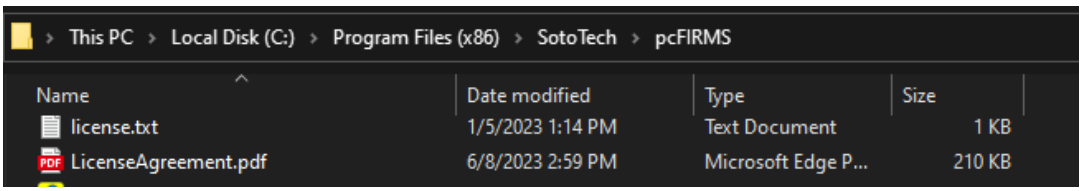
Installing your License

You will be provided with a license file from SotoTech. This license file is named **license.txt** and must be placed in the same directory where the pcFIRMS.exe is located. This is the directory specified during step 2 of the installation wizard.

The default directory is C:\Program Files (x86)\SotoTech\pcFIRMS.



Starting pcFIRMS

pcFIRMS should already be installed on your system. For instructions installing pcFIRMS, please refer to the previous section.

Start pcFIRMS by selecting it in the Windows Start Menu. In a default installation, the location is Start->Programs->pcFIRMS->pcFIRMS.

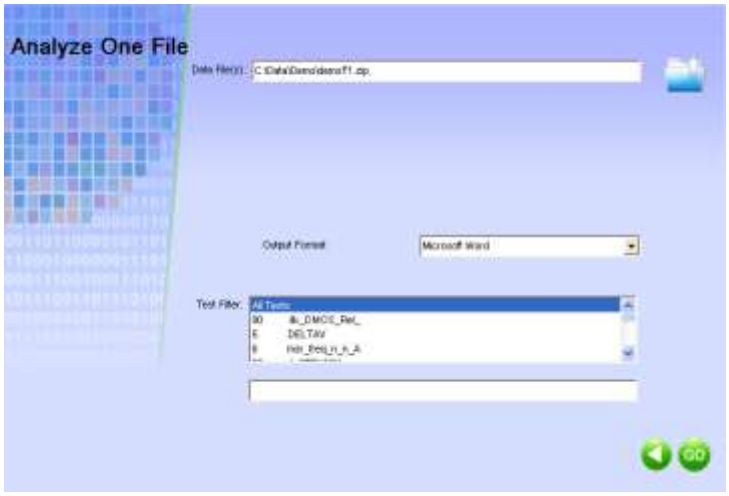
After some initialization is complete, you will be presented with the following window:

The JumpStart Page

To demonstrate how easy it is to get started, just click the “Analyze One File” button on the JumpStart page.

On the next page, click the Browse button  to select the STDF file for which we will run this report.

Then click the Go button in the bottom right corner of the page.



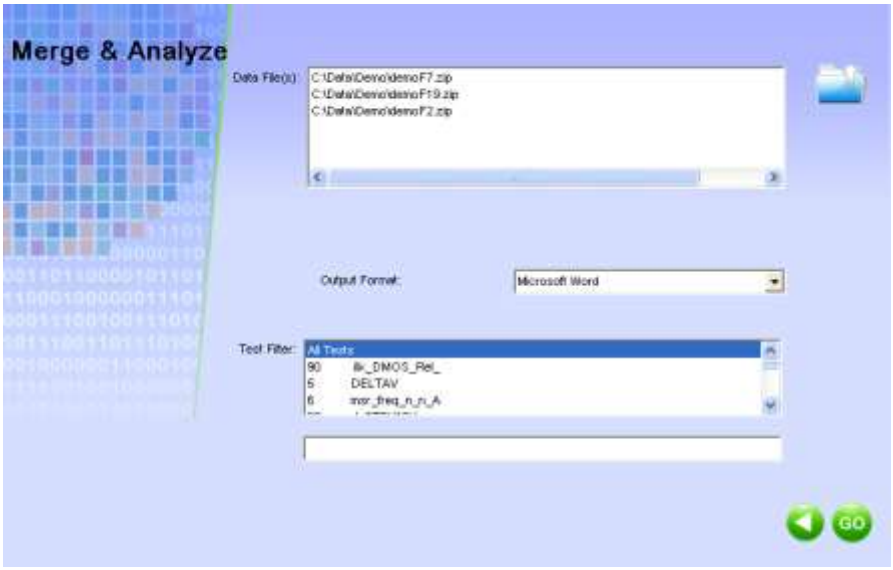
Within a few seconds, your report will open in Microsoft Word.

Note: If you are logged into the machine as Administrator, the default Workspace may not be created.

Note: If you do not have Microsoft Office Installed, change the Output Format to HTML or PDF.

Close the Report.

Now click the “Merge and Analyze” button on the JumpStart Page.



Use the Browse button to select two or three files. You may select a contiguous range of files by holding the “Shift” key down when you click. You may select a non-contiguous set of files by holding down the “Control” key when you click.

Click the Go Button.

When the report opens this time, notice how pcFIRMS automatically merged the data together to create the charts and statistics.

One page in, and pcFIRMS is already a useful tool for you. Now let’s look a little deeper into the usage of pcFIRMS.

Process Capability Study, the Wizard behind the JumpStart

Behind three of the buttons on the JumpStart page is one of the most popular pcFIRMS report wizards: Process Capability Study. This Wizard produces a Word, PDF, or HTML report that contains basic statistics and charts for the tests in the test program.

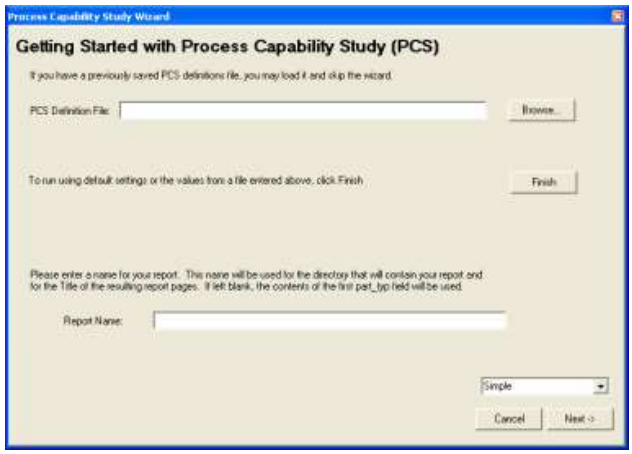
To run this wizard from pcFIRMS (rather than the JumpStart page):

Select **Wizards->Characterization->Process Capability Study** from the menu system.

For this example, just click the “Next ->” button on the bottom right side of the window. (The Wizard will prompt you to load data files if none are present.)

Continue clicking Next-> until you get to a window with a Finish button, then click Finish.

The progress window will keep you informed as each task associated with creating your report completes.



Note: Output to Microsoft Word is turned on by default. If you do not have this product installed, change the output to HTML.

TIP: The settings from the default file of the Process Capability Study are used to create the reports from the JumpStart page. To change the look of the reports for the JumpStart page, just run the PCS Wizard and save the defaults on the “Finish” page!

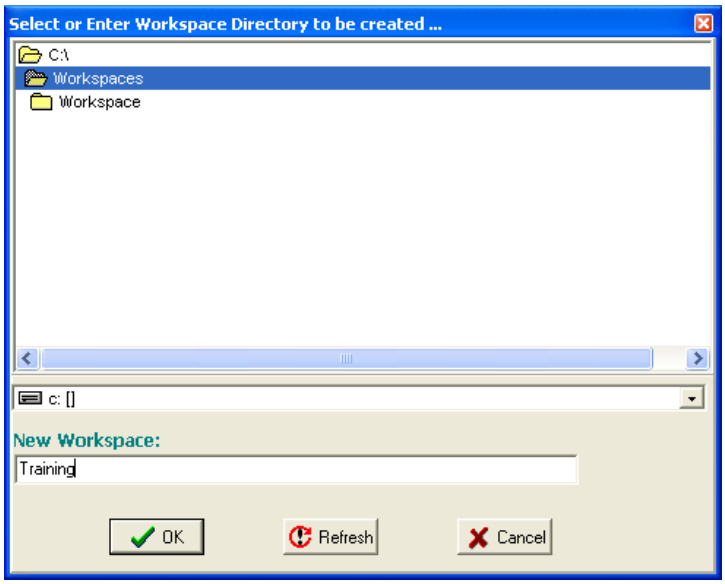
The pcFIRMS Workspace

pcFIRMS is organized into workspaces. A pcFIRMS Workspace is a directory that contains the data, reports (Word, HTML, PDF, etc …), charts, and DataViews from a single data analysis project. The first step in any data analysis project with pcFIRMS is to create a workspace for that project.

To create a pcFIRMS Workspace:

1. In Windows, create a directory called “Workspaces” in C:\, My Documents, on your Desktop, or in some other location that is convenient for you.
2. In pcFIRMS, under the Data tab, click the “New Workspace” button in the side bar or Select File->New Workspace from the menu system.

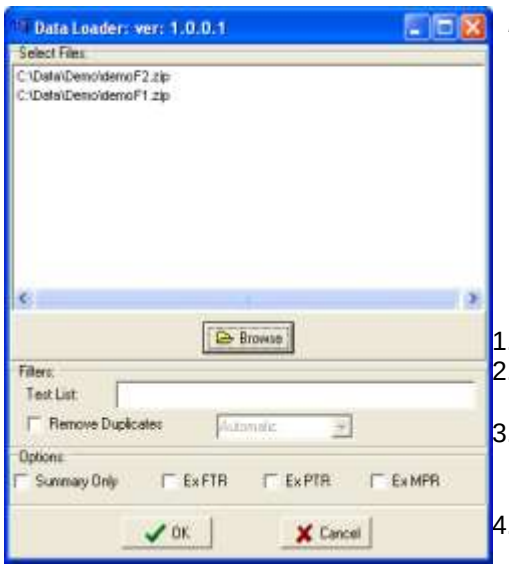
3. Navigate to location where you wish to store the Workspace directory. Type in a name (For Example: Training)
4. Click OK.



NOTE: A directory will be created inside the folder that appears to be open. This is where the new workspace will be stored.

TIP: Create a directory called “Workspaces” in a convenient place (such as C:\, Desktop, or My Documents) and store all of your pcFIRMS workspaces there. This will make them easy to find, backup, and manage.

TIP: If possible, create Workspaces on local drives not on Network mounted drives. pcFIRMS needs fast access to the data loaded in the Workspace. Using Network drives will degrade the performance of the analysis.



Loading Data

pcFIRMS supports data from several file formats. If you have data in a file format that is not currently supported by pcFIRMS, Soto Technologies International will create a converter or loader for your data file format which can be plugged-in to pcFIRMS. Contact Soto Technologies International at info@sototech.com for this support. Be prepared to send us several files in the needed format and a specification for the format if it exists.

There are five ways to load data into pcFIRMS using the GUI:

1. STDF V4 files from a local disk or mounted network drive.
2. Other formats from a local disk or mounted network drive using a Plug-in STDF Converter or Loader.
3. STDF V4 files from the FIRMS DataPipeline Server (Covered only for customers that have a DataPipeline Server.)
4. Flat files from Excel, ASCII, DB2, or Paradox using the Import Wizard. (We will not cover this in this class.)

NOTE: You must create a new workspace or open a workspace before loading files. See the previous section if you have not created a Workspace.

Load STDF V4 from a Local Disk

1. Click the Load STDF button in the Options area or select Database->Load STDF from the menu. In the resulting dialog box, click the Browse button.
2. In the dialog box, navigate to the location of the file(s) you wish to load. You may select a contiguous range of files by holding the “Shift” key down when you click. You may select a non-contiguous set of files by holding down the “Control” key when you click
3. When the desired STDF files are selected, click “Open”.
4. Click “OK”.

The files will begin loading. A progress bar will keep you informed of the load’s progress.

The Load STDF dialog provides three filters for the data being loaded:

1. In the “Test List” box, you can enter a list of test numbers and test number ranges to be loaded.
2. You can turn on the Remove Duplicates check box which will remove duplicate parts from the data set as it loads.
3. You can turn on the “Summary Only” check box which limits the load to only summary data. Several reports, most notably the Bin Trend Wizard, do not require that the actual measurements be present for the report to be generated. To load only summary information, turn on the “Load Summary Data Only” check box in the Load STDF dialog.
4. You can also exclude certain results records by clicking the appropriate check box.

Loading Other File Formats

Custom Loaders and STDF Converters can be plugged-in to pcFIRMS by placing them in the “CONV” directory where pcFIRMS is installed. (By default this is C:\Program Files\Sototech\pcFIRMS\CONV.) The loader/converter will appear under the Database->Load Other menu the next time pcFIRMS is started. By convention, Soto Technologies prepends the name of the converters with “conv” and the name of loaders with “load”.

To load a file from one of these formats:

1. Select the desired file format from the Database->Load Other menu.
2. In the dialog box, navigate to the location of the file(s) you wish to load. You may select a contiguous range of files by holding the “Shift” key down when you click. You may select a non-contiguous set of files by holding down the “Control” key when you click.
3. When the desired data files are selected, click “Open”.

If the format is converted to STDF V4 before loading, you will be informed that the conversion is occurring. Once all conversions are complete, the files will begin loading. A progress bar will keep you informed of the load’s progress.

Loading STDF Files from the FIRMS DataPipeline Server

The DataPipeline Client is included with pcFIRMS. The DataPipeline Client provides access to data on the FIRMS DataPipeline Server. You can create reports directly in DataPipeline Client, or use DataPipeline Client to download the files to pcFIRMS to do more advanced analysis.

Starting the DataPipeline Client

To start the DataPipeline Client, select Database-> DataPipeline Client from the menu system. The DataPipeline Client will open to the Select Data page.

NOTE: Your DataPipeline Client must be configured to connect to your FIRMS DataPipeline Server. For information on configuring pcFIRMS to connect to the FIRMS DataPipeline Server, refer to the pcFIRMS Administration Manual.

If the DataPipeline Client is configured to Auto Login to the DataPipeline Server, there may be a short delay before the DataPipeline Client window appears. The Connect button will appear depressed when the DataPipeline Client is connected.

If Auto Login is not configured, you will need to connect to the DataPipeline server by clicking the Connect button.

Selecting Data with the DataPipeline Client

Now build a query by right clicking on the pull down menu of each of the fields then selecting one of the values in the resulting list box.

After right clicking, watch the status bar at the bottom of the screen. It will inform you when the list box is loaded by stating how many rows were returned from the database.

Select from the list using the left mouse button and dragging down to the desired value.

Then click any other field on the screen. You will notice a query will begin to build in the top memo area.

Subsequent fields will use the existing query to help you narrow the search.

You may also type directly in to the Query Memo area to add details to your query. If at any time you make a mistake, you can rebuild the query based on the selections made in the fields by clicking the rebuild button.

If you need to start completely over, you can clear all the fields and the Query Memo by clicking the Clear button.

Loading Data into the pcFIRMS Workspace

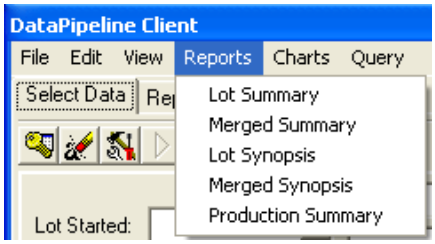
Once you have your query complete, click the execute button to get a list of files matching the query.

Now select the files you want to load in from the list and click the Load Files button. You can watch the progress of the file transfer and load on the status bar.

Close the DataPipeline Client by clicking out on the title bar and you will see your file(s) are now loaded in the pcFIRMS database.

DataPipeline Client Reports

Once you have completed you query, you may also pull any of the DataPipeline Client reports by selecting the desired report from the Reports menu.



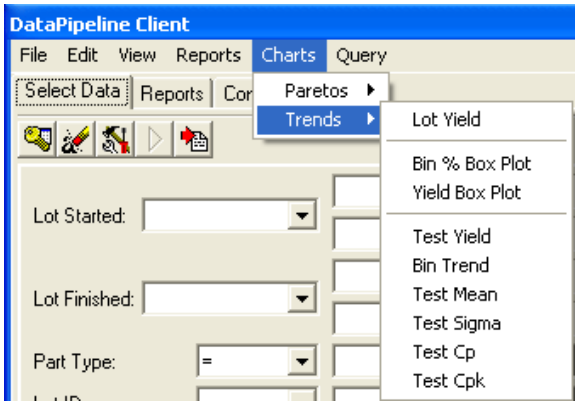
The DataPipeline Client reports are similar to the Production Insight reports in the UNIX version of FIRMS.

These reports appear in the Reports tab of the DataPipeline Client Window.

DataPipeline Client Charts

The DataPipeline Client also provides several charts. These charts allow the user to look at long term trends and paretos without having to download several files into the Workspace. To create DataPipeline Client Charts:

1. Create a query in the same manner as the section on “Selecting Data in the DataPipeline Client” above.
2. Execute the query.
3. Select files in the STDF file list.
4. Select the chart you wish to run.
5. The Chart appears in the Chart tab of pcFIRMS.



Exercise 1:

1. Start pcFIRMS
2. Run “Analyze Many Files” from the JumpStart page.
   (a) Select the v4_demo.stdf and v4_demo2.stdf files.
   (b) What is the difference between this output and the output from the “Merge and Analyze” button?

   _____

   _____

   _____

   (c) Close the report.
3. Create a new Workspace named “Exercise_1a”.
4. Load two of the demo files.
5. Run the Process Capability Wizard.
   (a) Enter “Exercise 1a” as the Report Name.
   (b) Set the Group By field to STDF_NAME.

Working with Your Data:

6. Create a new Workspace named “Exercise_1b”. (Do not delete the old one.)
7. If your company has one of our servers, use the appropriate client to select two files from your favorite part type. If no server is available, go to step “(d)” below.
   (a) (DataPipeline Client only) Run the Merged Summary Report in the FIRMS Client.
   (b) (DataPipeline Client only) Run the Cpk Pareto in the FIRMS Client.
   (c) (DataPipeline Client only) Select all the data for your favorite part type for the previous month. Run the Cpk Trend in the FIRMS Client.
   (d) Load two of your data files into pcFIRMS.
8. Run the Process Capability Wizard as you did in step 5.

Process Capability Statistics

Definition of Terms

Before we continue our training in pcFIRMS, it is prudent to introduce the statistics that are displayed by the Process Capability Study. The uses of statistics are generally divided into two fields:

- **Descriptive Statistics** generally characterizes or describes a set of data elements by graphically displaying the information or describing its central tendencies and how it is distributed.
- **Inferential Statistics** tries to infer information about a population by using information gathered by sampling.

There are some general statistical terms that we will be using throughout this course. Here is a definition of those terms:

- **Element:** A single datum, measurement or characteristic.
- **Population**: The complete set of data elements is termed the population.
- **Sample**: A sample is a portion of a population selected for further analysis.
- **Parameter**: A parameter is a characteristic of the whole population.
- **Statistic**: A statistic is a characteristic of a sample.

Uses and Abuses

Most of the time, samples are used to infer something (draw conclusions) about the population. If an experiment or study was done cautiously and results were interpreted without bias, then the conclusions would be accurate. However, occasionally the conclusions are inaccurate or inaccurately portrayed for the following reasons:

- Bias. Either on purpose or by human nature, the answer is often assumed before analysis begins and the interpretation of the statistics is based on false assumption. A possibility is a company sponsoring a statistics research to prove that their product is better than a competitor.
- Sample is too small.
- Even a large sample may not represent the population.
- Visual aids may be correct, but emphasize different aspects. Specific examples include graphs which don't start at zero thus exaggerating small differences and charts which misuse area to represent proportions. Often a chart will use a symbol which is both twice as long and twice as high to represent something twice as much. The area, in this case however, is four times as much!
- Precise statistics or parameters may incorrectly convey a sense of high accuracy.
- Misleading or unclear percentages are often used.

Statistics are often abused. It is said that there are three kinds of liars: Liars, Damned Liars, and Statisticians. Before acting on or reporting an anomaly detecting by using statistics, always question the data collection methods first. It is sometime helpful to ask the following questions:

- Who did the analysis?
- Who funded the analysis?
- Why was the analysis done?
- Is the sample representative of the population?
- Are their factors outside of the experiment which could impact the result?

Data Types

Data are facts or figures from which conclusions may be drawn. Data can be classified as either numeric or non numeric. Specific terms are used as follows:

- **Qualitative** data are non numeric. Examples of qualitative data in Semiconductor manufacturing are Bin and Pass/Fail. (While bins are usually represented by numbers, they actually describe a family of tests rather than a specific measurement.)
- **Quantitative** data are numeric. The measurements taken for a particular analog test are quantitative.

We can further classify Quantitative as either discrete or continuous.

- **Discrete** data are numeric data that have a finite number of possible values. These do not appear often in Semiconductor Manufacturing data.
- **Continuous** data have infinite possibilities: 1.4, 1.41, 1.414, 1.4142, 1.141421. This data type is the most common in Semiconductor Manufacturing data.

Summary Statistics for Quantitative Data

The Process Capability Study presents summary statistics calculated from quantitative test measurements. In this section, we will learn how these statistics are calculated and how they can be interpreted. Summary, or characterization statistics as they are sometimes called, can be divided into two basic categories: Averages and Dispersion.

Averages

Averages are statistics that describe the center or central tendency of the data. In statistics, there are four types of averages: Mean, Median, Mode, and Mid Range. We will define all four in this course; however, pcFIRMS uses only the mean and median in its analysis.

Mean

The Mean is obtained by summing all elements of the data set and dividing by the number of elements.

Symbolically, the arithmetic mean of sample data is expressed as $\bar{x} = \frac{\sum x_i}{n}$.

Where $\bar{x}$ (pronounced "*x*-bar") is the arithmetic mean for a sample.

Σ is the capital Greek letter sigma and indicates summation.

xi refers to each element of the data set as *i* ranges from 1 to *n*.

n is the number of elements in the data set. Often, the capital letter “N” will be used for populations and the lowercase “n” will be used for sample data.

The equation is essentially the same for finding a population mean; however, the symbol for the population mean is the small Greek letter μ (mu).

Example:

For Data Elements: 48 46 45 91 45 46 47 45 43 47

First we sum the data elements. The sum of these data elements is 503.

Now divide by the number of elements which is 10:

503 / 10 = 50.3

Note: The represented here is the “Arithmetic Mean”. There are several other “means”. For example: Harmonic, Geometric, Quadratic, etc... These other means are beyond the scope of this class.

Median

The Median is the middle element when the data set is arranged in order of magnitude. If there are an odd number of data elements, the median is a member of the data set. If there is an even number of data elements, the median is computed as the arithmetic mean of the middle two.

Example:

For Data Elements: 48 46 45 91 45 46 47 45 43 47

First we order the Data Elements:

43	45	45	45	46	46	47	47	48	91

Since there are 10 data elements, the Median is the Arithmetic Mean of the elements 5 and 6. So Median = 46.

Note how, in this case, the median value seems like a better measure of the center of these elements than the mean. The outlier 91 has a greater impact on the mean.

Mode

The Mode is the data element that occurs most often. In continuous data, this is usually not a useful way to determine the center of the data. The mode can be estimated visually using a histogram.

Example:

For Data Elements: 48 46 45 91 45 46 47 45 43 47

First we order the Data Elements:

43	45	45	45	46	46	47	47	48	91

The value that occurs most often is 45 so the mode of this population is 45.

Mid Range

The Midrange is the mean of the highest and lowest data elements.

Symbolically, midrange is computed as $\frac{X_{max}-X_{min}}{2}$.

Example:

For Data Elements: 48 46 45 91 45 46 47 45 43 47

First we order the Data Elements:

43	45	45	45	46	46	47	47	48	91

The Mid Range is (91 – 43)/2 = 69.5.

The Best Average

Which average to use depends on the data you are analyzing and how you need to analyze it. Here are a few facts that might help:

- Mean, median, and midrange always exist and are unique.
- Mode may not be unique or may not even exist.

- Mean and median are very common and familiar.
- Mode is used less frequently; midrange is rarely used.
- The midrange and the mean can be distorted by extreme data elements (outliers).

As previously mentioned, pcFIRMS uses only mean and median as calculations for average.

Dispersions

Another important characteristic of a data set is how it is distributed, or how far each element is from some measure of central tendency (average). There are several ways to measure the variability of the data. Although the most common and most important is the standard deviation, which provides an average distance for each element from the mean, several others are also important, and are discussed here.

Range

Range is the difference between the highest and lowest data element.

Symbolically, range is computed as $\boldsymbol{X_{max} - X_{min}}$. Although this is very similar to the formula for midrange, please do not make the common mistake of reversing the two. This is not a reliable measure of dispersion, since it only uses two values from the data set. Thus, extreme values can distort the range to be very large while most of the elements may actually be very close together.

Example:

For Data Elements: 48 46 45 91 45 46 47 45 43 47

First we order the Data Elements:

43	45	45	45	46	46	47	47	48	91

The Range is 91 – 43 = 48. If we eliminated the 91 from this population, the Range would be 48 – 43 = 5. The outlier has a very big effect on Range.

Standard Deviation (Sigma)

The Standard Deviation, also called Sigma (because the lowercase Greek letter is used to represent the value symbolically) is another way to calculate dispersion. This is the most common and useful measure because it is the average distance of each element from the mean of the elements.

Essentially, the standard deviation is the average distance of the data elements from the mean.

Sigma is calculated slightly differently for sample data and population data.

The Sigma for sample data is computed as $\boldsymbol{s = \sqrt{\frac{\sum_{i=1}^{N}(x_i - \bar{x})^2}{n-1}}}$.

The Sigma for population data is computed as $\boldsymbol{\sigma = \sqrt{\frac{\sum_{i=1}^{N}(x_i - \mu)^2}{n}}}$.

Notice the difference between the sample and population Sigmas. The sample Sigma uses *n*-1 in the denominator, and is therefore slightly larger than the population sigma which uses *N.* The *n*-1 can be understood in terms of degrees of freedom – a topic which we will below.

Since the standard deviation is a square root, it could be a +/- number. By definition, we take the positive standard deviation.

Example:

For Data Elements: 48 46 45 91 45 46 47 45 43 47

The steps to calculate the population standard deviation are:

1. Get the Mean
2. Get the deviations
3. Square the deviations
4. Add the squares of the deviations
5. Divide by number of elements in the population
6. Take the square root of the result and we have the Standard Deviation

First we calculate the mean of these elements:

The sum of these data elements is 503, the number of elements is 10 so:

503 / 10 = 50.3.

Now we calculate the distance of each element from the mean and square it:

50.3 – 48 = 2.3;	2.3 * 2.3 =	5.29
50.3 – 46 = 4.3;	4.3 * 4.3 =	18.49
50.3 – 45 = 5.3;	5.3 * 5.3 =	28.09
50.3 – 91 = -40.7;	-40.7 * -40.7 =	1656.49
50.3 – 45 = 5.3;	5.3 * 5.3 =	28.09
50.3 – 46 = 4.3;	4.3 * 4.3 =	18.49
50.3 – 47 = 3.3;	3.3 * 3.3 =	10.9
50.3 – 45 = 5.3;	5.3 * 5.3 =	28.09
50.3 – 43 = 7.3;	7.3 * 7.3 =	53.29
50.3 – 44 = 6.3;	6.3 * 6.3 =	39.69

Now we sum all the squares of the distances. The sum is 1858.

To calculate the standard deviation as a population, we divide the sum of the squares by the number of elements. 1858.1/10 = 185.81.

Now take the square root of 185.81 and we have our standard deviation which is: 13.63.

To calculate the standard deviation as a sample, we divide the sum of the squares by the number of elements minus 1. 1858.1/9 = 206.46.

Now take the square root of 206.46 and we have our standard deviation which is: 14.37.

So:

s = 14.37 and σ = 13.63.

Variance

Variance is the third method of measuring dispersion. Compare the two variance formulae with their corresponding standard deviation formulae, and we see that variance is just the square of the standard deviation.

Sample Variance: $\boldsymbol{s^2 = \frac{\sum_{i=1}^{N}(x_i - \bar{x})^2}{n-1}}$

Population Variance: $\boldsymbol{\sigma^2 = \frac{\sum_{i=1}^{N}(x_i - \mu)^2}{n}}$

How pcFIRMS Calculates Sigma

Using these formulas within a computer program is inefficient because it is necessary scan the data twice (First to calculate the mean, second to perform the comparison of each element to the mean.)

For expedience, programs, such as pcFIRMS, use a slightly different, but Algebraically similar formula to calculate Sigma.

The formula used by pcFIRMS is $\boldsymbol{\sigma = \sqrt{\frac{1}{(N-1)}\left[\left(\sum_{i=1}^{N} x_i^2\right) - N\bar{x}^2\right]}}$. Using this formula, a program can make a single pass through the data accumulating the sum of the elements and the sum of the squares of the elements to perform the calculation.

Interquartile Range

The Interquartile Range, or IQR, describes the data in terms of 4 groups each consisting of 25% of the elements. The elements are arranged in numeric order then divided into four divisions or quartiles. The boundaries of these quartiles are called Q1, Q2 (median), and Q3. A way to think of these boundaries is that they are extensions of the median where we divide the population into smaller populations. Using this terminology:

The median divides a population into two halves: a top half and a bottom half. The top half consists of those data elements above the median, whereas the bottom half consists of those data elements below the median. If we subdivide each of these halves yet again, we have quartered the population and each of these division points is termed quartiles. Although one might occasionally speak of the bottom quartile, top quartile, *etc.*, the term quartile technically refers to the three division points and not to the four divisions of the data.

Q1 is the term used for the median of the bottom half.

Q3 is the term used for the median of the top half.

Q2 is another term used for the median.

The precise definition specifies that at least 25% of the data will be less than or equal to Q1 and at least 75% of the data will be less than or equal to Q3.

The IQR is calculated as Q3 – Q1.

Example:

For Data Elements: 48 46 45 91 45 46 47 45 43 47

First we order the Data Elements:

43	45	45	45	46	46	47	47	48	91

Since there are 10 data elements, Q2, or the Median is the Arithmetic Mean of the elements 5 and 6. So Q2 = 46.

Q1 is the center element of the lower 5 elements, so Q1 = 45.

Q3 is the center element of the upper 5 elements, so Q3 = 47.

IQR = Q3 – Q1 or 47 – 45 = 2.

Coefficient of Variation

The coefficient of variation (CV) is defined as the ratio of the Sigma to the Mean. Symbolically, the formula is $\boldsymbol{C_v = \frac{\sigma}{|\mu|}}$.

The coefficient of variation allows comparison of the variation of populations that have significantly different mean values. It is often reported as a percentage (%) by multiplying the above calculation by 100.The coefficient of variation is often used when discussing the normal distribution for positive mean values with the standard deviation significantly less than the mean. This application may be

reasonable for many models, but breaks down theoretically unless the distribution is known to be positive valued, since there is a nonzero probability that the distribution will assume a negative value. When the mean value is near zero, the coefficient of variation is sensitive to change in the standard deviation, limiting its usefulness. pcFIRMS does not calculate the coefficient of variation.

Capability Indices

pcFIRMS uses the basic summary statistics described in the last section with test limits to calculate some slightly more complex statistics that are called Capability Indices. (Indices is the plural of the English word "index"). In this lesson we will discuss 4 of these indices.

C_p

The Capability Index (C_p) is the ratio of the engineering tolerance width to six standard deviations. Six standard deviations, or 6σ, are defined as the natural tolerance of a process. So C_p is the ratio of the engineering tolerance to the natural tolerance of a process.

C_p is represented symbolically as $\boldsymbol{C_p = \frac{UTL - LTL}{6\sigma}}$.

Where:

UTL = Upper Test Limit
LTL = Lower Test Limit
σ = Standard Deviation

Assuming the process distribution is normal and the process average is exactly centered between the engineering requirements, a C_p of 1 would be considered "capable". However, to allow a bit of room for process drift, the generally accepted minimum value for C_p is 1.33. In general, the larger the C_p, the better. For a Six Sigma process (a process that produces 3.4 defects per million opportunities including a 1.5 sigma shift), the value of C_p would be 2.0.

The C_p index has two major shortcomings:

- It cannot be used unless both the upper and lower test limits are defined.
- It does not account for process centering. If the process average is not exactly centered relative to the engineering tolerance, the C_p index will give misleading results. In recent years, the C_p index has largely been replaced by C_{pk} (see below).

C_{pl}

The C_{pl} index is the ratio of the lower part of the distribution when divided on the mean. So it is calculated the difference between the mean value and the lower test limit divided by 3 times the standard deviation.

C_{pl} is represented symbolically as $\boldsymbol{C_{pl} = \frac{\mu - LTL}{3\sigma}}$.

Where:

LTL = Lower Test Limit
σ = Standard Deviation

By itself, the C_{pl} value is not much use. But when compared with the C_{pu} value can determine if the process is balanced about the mean. It is also used to determine C_{pk}.

C_{pu}

The C_{pu} index is the ratio of the upper part of the distribution when divided on the mean. So it is calculated the difference between the upper test limit and the mean value divided by 3 times the standard deviation.

C_{pu} is represented symbolically as $\boldsymbol{C_{pu} = \frac{UTL - \mu}{3\sigma}}$

Where:

UTL = Upper Test Limit
σ = Standard Deviation

Like Cpl, the C_{pu} value is not much use by itself. But when compared with the C_{pl} value can determine if the process is balanced about the mean. It is also used to determine C_{pk}.

C_{pk}

Cpk is the smallest of Cpl and Cpu.

Cpk is represented symbolically as $\boldsymbol{C_{pk} = min(C_{pu}, C_{pl})}$

Since the smallest of these indices represents the nearest limit, the value of Cpk tells you if the process is truly capable of meeting the requirements. A Cpk of at least 1 is required, and 1.33 is preferred. Not that Cpk is closely related to Cp. The difference between Cp and Cpk represents the potential gain to be had from centering the process. For a Six Sigma process, Cpk would be 2.0.

Degrees of Freedom

The Degrees of Freedom is the number of measurements that could be altered independently without changing one or more statistics (such as mean) relating to the set. For a set of n measurements with a known mean, the degrees of freedom = n - 1, since all but one could be changed with compensating change only to one other to produce the same mean.

Here is an example:

Suppose that you have a phone bill that says your household owes $100.

Your mother and father state that $70 of it is theirs and that your younger sibling owes only $5. How much does that leave you?

Here, n=3 (parents, sibling, you), but once you have the total and two more amounts, the last amount is constrained. Since only two amounts can vary, the degrees of freedom are 3 - 1 = 2.

Degrees of freedom are normally designated with the letters “df”.

Another example:

Ten parts are tested. For one particular test, the mean of the results is 55. Thus for the 10 measurements and the given mean, only nine of the values are independent. The last is constrained if the mean is to remain the same. Therefore there are nine degrees of freedom.

df = 10 -1 = 9

The 5 Number Summary

Every population can be described in many different ways statistically. One popular way it uses 5 key numbers that are known as the 5-number summary. These measurements are the minimum value, Q1, the median value, Q2, and the maximum value.

Example:

For Data Elements: 48 46 45 91 45 46 47 45 43 47

First we order the Data Elements:

43	45	45	45	46	46	47	47	48	91

Since there are 10 data elements, Q2, or the Median is the Arithmetic Mean of the elements 5 and 6. So Q2 = 46.

Q1 is the center element of the lower 5 elements, so Q1 = 45.

Q3 is the center element of the upper 5 elements, so Q3 = 47.

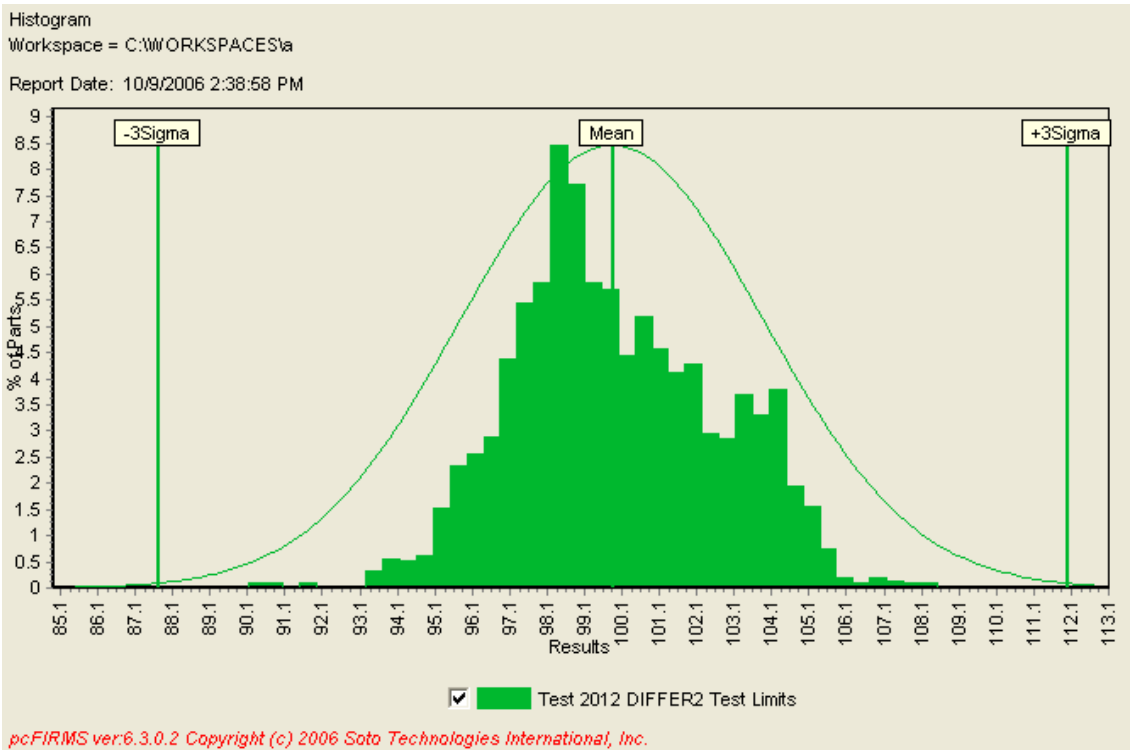
So the 5 number summary for this population is:

Min = 43
Q1 = 45
Media = 46
Q3 = 47
Max = 91

The Bell-shaped, Normal, Gaussian Curve

The bell-shaped curves that are an option on pcFIRMS histograms are called the Normal or Gaussian Curve. These three names for this curve refer to the same thing.

When we “normalize” something, we make it equal to some standard. In the case of the normal curve, we make the probability that the measurement is somewhere under the curve = 100%. The height of the normal curve represents the probability of the measurement at that given distance away from the mean.



It is also important to note the **symmetry** of the normal curve. Some curves may be slightly distorted or truncated beyond certain limits, but still primarily conform to a bell shape. This is often an important consideration when analyzing data or samples taken from some unknown population.

The Empirical Rule

For a normally distributed data set, the **empirical rule** states that 68% of the data elements are within one standard deviation of the mean, 95% are within two standard deviations, and 99.7% are within three standard deviations. The empirical rule is often stated simply as **68-95-99.7**. Note how this ties in with the range rule of thumb, by stating that 95% of the data usually falls within two standard deviations of the mean.

Z-Scores

A Z-score or "standard score" is the measure of the distance of a data element from the mean of the distribution. Since many data sets have a normal distribution, it is a very helpful way to compare data elements from different populations—populations which may very well have differing means and standard deviations.

For example, if you have a test whose measurements range from 10 – 150 mA and another test whose measurements range from 1,600 – 1,950 Ohms, it can be difficult to compare one to the other.

The formula for Z-score includes the standard deviation and therefore we require two formulas, one for population data and one for sample data:

Z for a population is $\boldsymbol{Z} = \frac{(\boldsymbol{X}-\boldsymbol{\mu})}{\boldsymbol{\sigma}}$.

Z for a sample is $\boldsymbol{Z} = \frac{(\boldsymbol{X}-\overline{\boldsymbol{X}})}{\boldsymbol{s}}$

The following important attributes should be noted about *z*-scores.

- Negative Z-scores indicate a data element's position is below the mean.
- Positive Z-scores indicate a data element's position is above the mean.
- Z-scores should almost always be rounded to two decimal places.

Ordinary or Unusual Scores

Now that we have defined *z*-score, we can define two more terms as follows.

Data elements more than 2 standard deviations away from the mean are termed **unusual**.

Data elements less than 2 standard deviations away from the mean are termed **ordinary**

Exercise 2:

1. Find the mean, median, range, sample standard deviation, and sample variance of the following data: 36,000, 360,000, 3,600,000, 36,000,000, and 360,000,000

   (a) Mean = _____

   (b) Median = _____

   (c) range = _____

   (d) sigma = _____ NOTE: For a population.

   (e) Variance = _____ NOTE: For a population

   (f) Q1 = _____

   (g) Q3 = _____

   (h) IQR = _____

   (i) df = _____

2. Find the mean, median, range, sample standard deviation, and variance of the following data: 1, 2, 3, 4, 5, 6, 7, 8.

   (a) Mean = _____

   (b) Median = _____

   (c) range = _____

   (d) sigma = _____ NOTE: For a population

   (e) variance = _____ NOTE: For a population

   (f) 5 Number summary =

   _____

3. Name the two types of Average calculated by pcFIRMS. _____, _____

4. Write a definition for Standard Deviation:

_____

_____

_____

5. Which value indicates that your process is capable: _____

   (a) C_{pk} = 1.38

   (b) C_{pk} = 2.3

   (c) C_{pk} = 1.0

   (d) Both (a) and (b)

6. Is a negative value for C_{pk} possible? If so, what would a negative C_{pk} indicate?

_____

_____

_____

7. A certain test has a mean of 29. Calculate the *z*-score for this test's mean relative to the historic mean of 21.0 and standard deviation of 4.

_____

_____

_____

8. Given the fact that 50% of a normally distributed data set is within 0.675 standard deviations of the mean, estimate Q_1, Q_3, and the interquartile range for a test with a mean of 29 and standard deviation of 3.0. Would a measurement of 36 be unusual?

_____

_____

_____

Take a break.

pcFIRMS Report Wizards

In the previous section, the first thing we did was run one of the pcFIRMS report Wizards. The goal of the pcFIRMS Report Wizards is to get you from raw data to published report as quickly as possible. Our motto is “Data to Answers to Profits Fast”.

In this section of the training, we will take a look at some of the other pcFIRMS report Wizards.

The Report Wizards are organized according to the primary tasks that face Test and Product Engineers in the Semiconductor Manufacturing Process. These tasks are:

1. Characterize products and processes.
2. Correlate one product or process to another.
3. Optimize a test program.
4. Qualify new test measurement systems.
5. Monitor production.

pcFIRMS provides wizards for each of these tasks.

1. Characterization
   (a) Process Capability Study
   (b) N-Chart
   (c) Design Characterization
   (d) Process Portrait
2. Correlation
   (a) Statistical Differences Study
3. Optimization
   (a) Test Elimination Study
4. Qualification
   (a) Repeatability Study
   (b) Reproducibility Study
   (c) Gage R&R by Average Range
   (d) Gage R&R by ANOVA
5. Production Monitoring
   (a) Bin Trend

In this section of the class, we will take a close look at many of these Wizards. Some of the more advanced features of the Wizards will be covered later.

NOTE: When running most of pcFIRMS Wizards, a pop-up Cancel Button will appear in the upper left corner of your screen. Use this button to cancel the Wizard process.

The N-Chart Wizard

The first of the Characterization Wizards we will look at is the N-Chart Wizard. The N-Chart wizards permits you create a report that contains multiple charts. For each test included in the report, one graph will be created that contains one chart for each group by value. The number of charts per page that you select determines the size of the charts.

1. Start pcFIRMS, Open or Create a Workspace, and load one or more data files. (See these sections in the pcFIRMS Online Help or Basic Training Manual for information.)

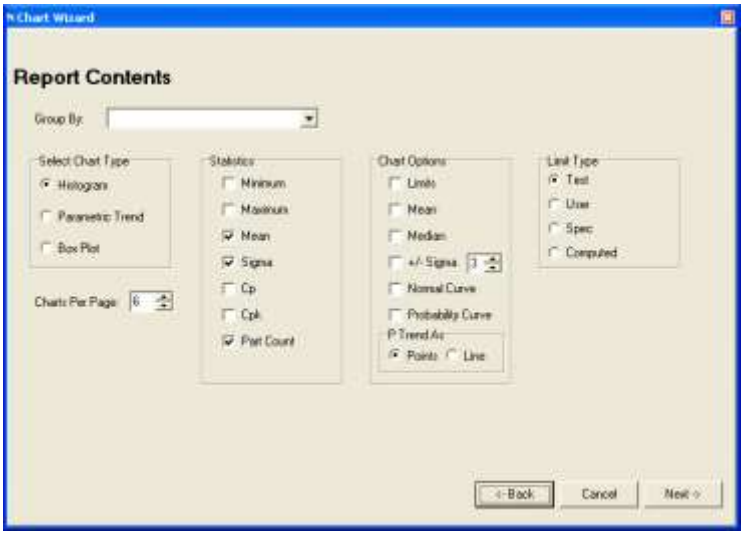
TIP: If you do not create a workspace and load data before running the wizard, the wizard will create a default workspace and prompt you to load data.

2. The N-Chart Wizard is located in the Wizards Menu in the Main Menu of pcFIRMS. To start the wizard select Wizards->Characterization->N Chart Wizard. The following window will appear.

3. If you have previously run the N-Chart wizard and saved the settings in a definitions file, you may select a definitions file to use and then click Finish. If you wish to use the default settings, you may simply click Finish to run the report. Otherwise, go to step 4.

4. The Report Name will be used in the headings of the reports and to name the directory in which the reports will be stored. If left blank, the contents of the part_typ field in the Lot table will be used. Click the Next button.

5. The Report Content page allows you to customize your report options.



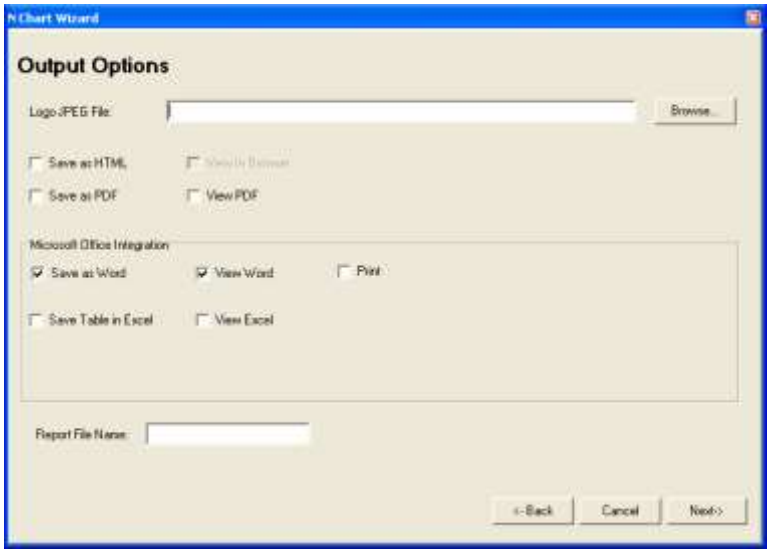
   a. If you select a Group By variable, a graph will be created for each value of the selected variable. For instance, if your dataset contains several files from three different temperatures and you select TST_TEMP as your group by variable, three graphs will created in each chart; one for each temperature.
   b. Select the Chart Type. Your choices are Histogram, Parametric Trend, and Box Plot.
   c. Charts Per Page determines the number of charts on each page of the report. The more charts per page, the smaller the charts.
   d. The Statistics will appear in the heading of the charts. The Statistics are also displayed in a DataView if DataView is a chosen output format.
   e. Chart Options turn on and off certain additional curves for each of the graphs. Not all of the options are available for all the chart types.
   f. Limit Type determines which limit type will be used to calculate statistics and be displayed in the chart.]

Tip: If you choose a large number of charts per page or set a group by variable, you should not choose a lot of statistics because there will not be room to display them in the heading of the chart.

Note: The group by variable only works if the selected group by field is populated by the test program or if you edit the data into the Workspace.

After making your selections, click the Next button.

6. The Output Options page allows you to select the location and format of the output of the report.



   a. Create DataView places the selected statistics in a DataView. If you turn this option on, you will also have the option of saving the resulting table to Excel.
   b. Logo JPEG File allows you to select an Image to use instead of the default_logo.jpg file that is used by default.
   c. Save as HTML will create an HTML version of the report. You may select to view the report and change the location of the report as well.
   d. Save as PDF will create a PDF version of the report. You may select to view the report and change the location of the report as well.
   e. Save as Word will create a Microsoft Word version of the report. You may select to view the report and change the location of the report as well. Selecting the Print check box will send the Word version of the report to a printer automatically.

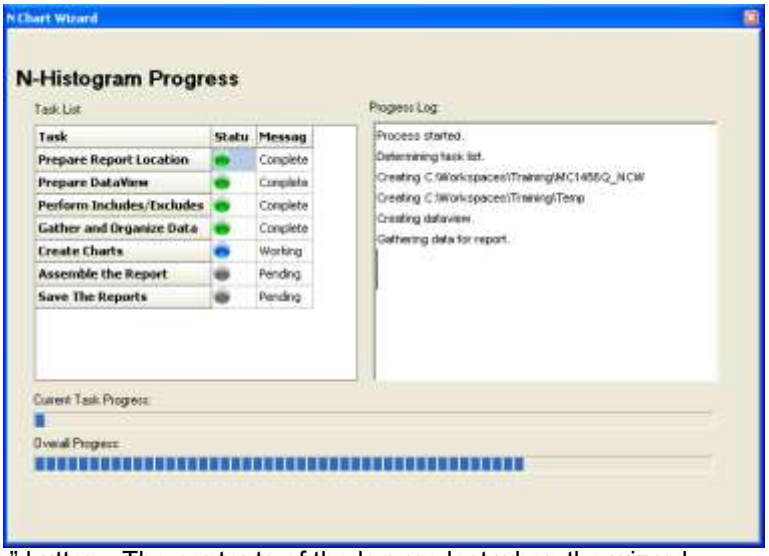
Note: You must have Microsoft Office installed for the Microsoft Integration to function.

7. On the N-Chart Finish page, you can elect to save the current settings in the wizard in a definitions file or as the defaults. These options allow you to start the wizard with the current settings the next time you start the wizard and run the report from the first page.

Tip: Create definition files for different products or customers as the need arises. This will save time during future runs of the Wizard and prevent you having to remember exactly what settings you used for a specific customer or product.

Once you have made your choices, click the Finish button.

8. The N-Chart Progress page will keep you informed of the progress if the report. As each task completes, the status light will turn green, yellow or red.



   a. A green light means the task completed with no problems.
   b. A yellow light means that some warning was generated in the Process Log window.
   c. A red light means the task failed to complete.

   You know the report is complete when the Overall Progress bar is full and the “Close” button appears next to the “Cancel” button. The outputs you selected to “View” should all open automatically.

   If you wish to view the Process Log do so before clicking the “Close” button. The contents of the log are lost when the wizard is closed.

Advanced Process Capability Study

We did a quick introduction to the second Characterization wizard in an earlier section of the class. The Process Capability Study creates a customizable report of statistics and charts. In includes the group by capability so that the user can compare several populations.

If you intend to group by data file, it is far easier and faster to use the JumpStart page.

Clicking the “Analyze Many Files” button produces a PCS report grouped by data file.

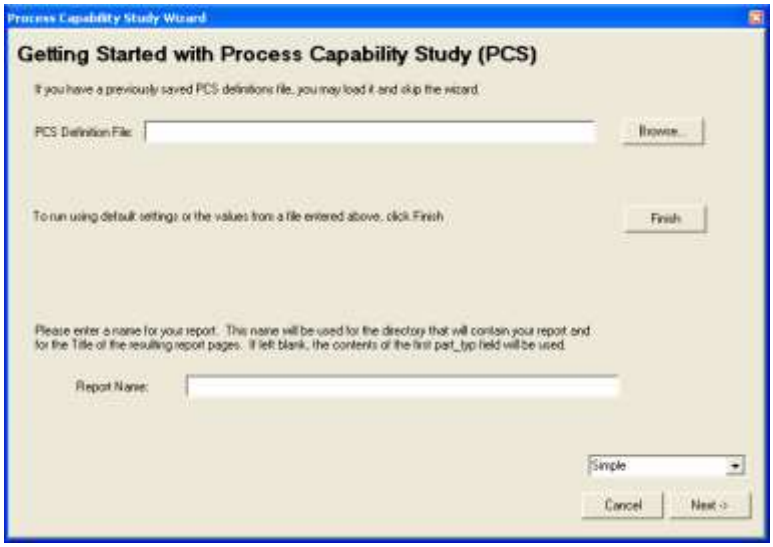
Clicking the “Merge and Analyze” button creates a PCS report with all of the files automatically merged together.

If you wish to group by other variables, you will need to use the Process Capability Wizard.

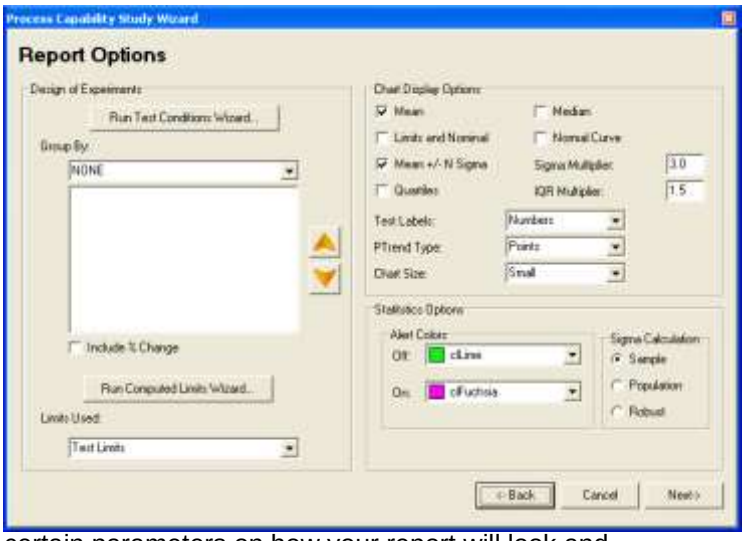
1. Start pcFIRMS, Open or Create a Workspace, and load one or more data files. (See these sections in the pcFIRMS Online Help or Basic Training Manual for information.)

   TIP: If you do not create a workspace and load data before running the wizard, the wizard will create a default workspace and prompt you to load data.

2. The Process Capability Study Wizard is located in the Wizards Menu in the Main Menu of pcFIRMS. To start the wizard select Wizards->Characterization->Process Capability Study.



3. If you have previously run the wizard and saved the settings in a definitions file, you may select a definitions file to use and then click Finish. Otherwise, go to step 4.



   The Report Name will be used in the headings of the reports and to name the directory in which the reports will be stored. If left blank, the contents of the part_typ field in the Lot table will be used. Click the Next button.

   Just above the Cancel and Next buttons is the Mode CheckBox. In Simple Mode, the wizards skip all the Include and Exclude windows. For this exercise, leave the Mode set to “Simple”.

4. The Report Options page lets you set certain parameters on how your report will look and how the data will be grouped.

   a. If you select a Group By variable, a graph will be created for each value of the selected variable. For instance, if your dataset contains several files from three different temperatures and you select TST_TEMP as your group by variable, three graphs will created in each chart; one for each temperature.

   b. Include % Change: Click on to include % change information in the individual test reports.

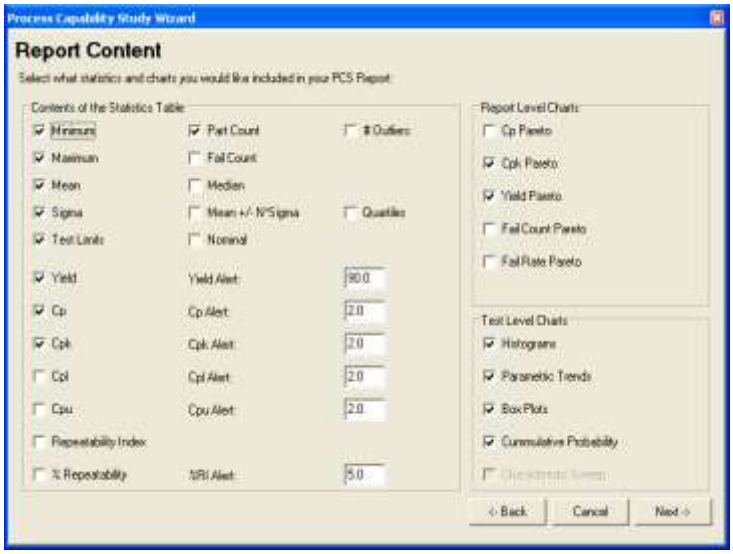
      The first group by value listed will be used as the reference value. You can use the  up and  down arrow buttons to change the order of the group by values.

   c. The Limits Used combo box allows you to select which Limit Type to display and use for calculating statistics. We will discuss the different limit types in the Virtual Retest portion of the class.

   d. The Chart Display Options let’s you choose additional curves, Sigma and IQR multipliers, the size of the charts (large or small), test labels, and Parametric Trend chart type.

   e. Statistics Options let’s you choose Alert Colors and select the type of Sigma Calculation you’d like to use in your report.

      After making your selections, click the Next button.



5. The Report Content page is where you select what statistics and charts you wish to include in the report. The page is separated into three areas:

   a. Contents of the Statistics Table: The selected items will appear in the table of statistics that appears at the front of the report. Several of the statistics have alert levels that you can set.

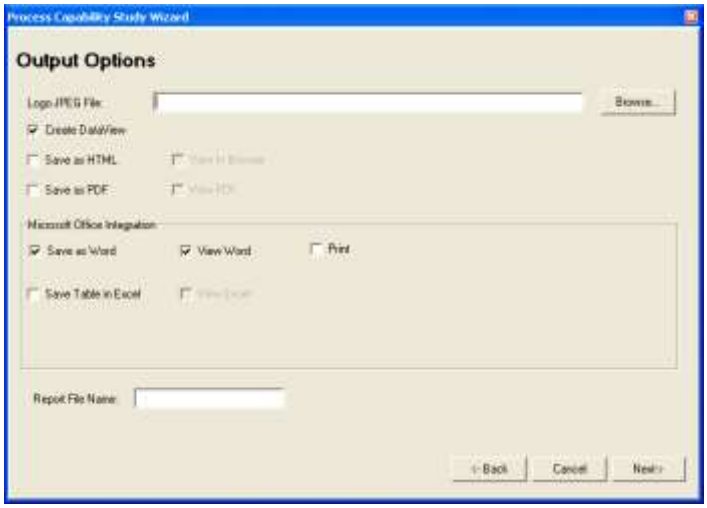
A value falling below these alert levels will cause a color change in that particular cell of the table.

b. Report Level Charts: On the same page as the statistics table, the selected report level charts will appear. These are Pareto type charts that look at all the tests included in the report.

c. Test Level Charts: Each test included in the report will get its own page that will include the selected test level charts.

Note: For report formatting purposes, it is best to limit your selections for the Statistics Table to 10 items (test limits count as two). The program will warn you if you select more than 10, but give you the option to continue.

After making your selections, click the Next button.



6. The Output Options page allows you to select the output format of the report.

a. You can customize your report with a Logo JPEG File to use instead of the default_logo.jpg file that is used by default.

b. You can create a customized DataView.

c. Save as HTML will create an HTML version of the report. You may select to view the report as well.

d. Save as PDF will create a PDF version of the report. You may select to view the report as well.

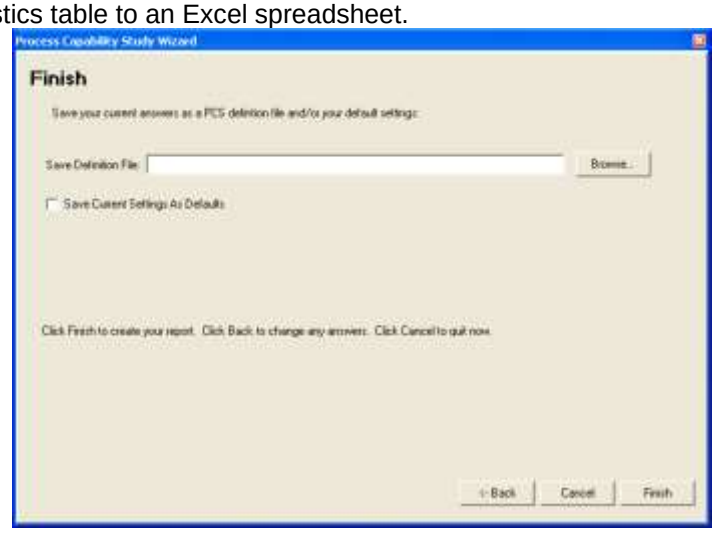
e. Save as Word will create a RTF version of the report, which will open in Microsoft Word or your default document application. You may select to view the report as well. Selecting the Print check box will send the Word version of the report to a printer automatically.

f. Save Table to Excel will save the Statistics table to an Excel spreadsheet.

g. You can customize the Report File Name also.

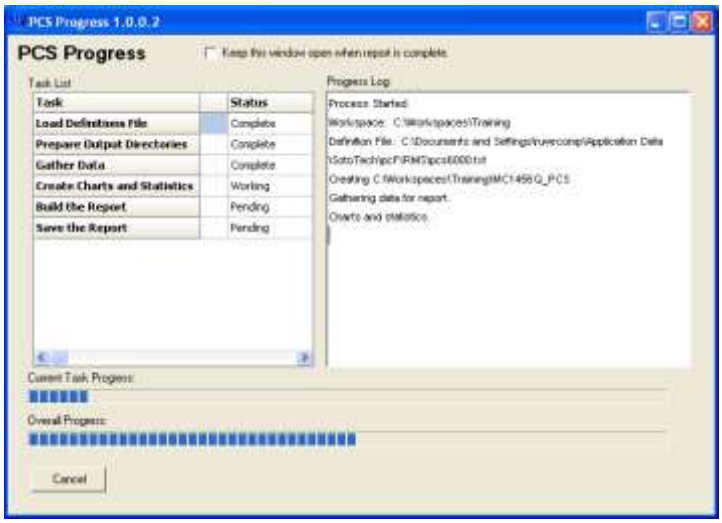
Note: You must have Microsoft Office installed for the Microsoft Integration to function.

7. On the PCS Finish page, you can elect to save the current settings in the wizard in a definitions file or as the defaults. These options allow you to start the wizard with the current settings the next time you start the wizard and run the report from the first page. After making your entries, click the Finish button.



Tip: Create definition files for different products or customers as the need arises. This will save time during future runs of the Wizard and prevent you having to remember exactly what settings you used for a specific customer or product.

8. A progress window will keep you informed of the progress of the report. When complete, the progress window will close. Any output formats you chose to view will open automatically.



Exercise 3

1. Create a new Workspace named “Exercise_2a”.
2. Load v4_demo.stdf
3. Run the N-Chart Wizard with the output set to Word.
4. Load v4_demo2.stdf
5. Run the N-Chart Wizard
   (a) Set the Group By Variable to “STDF_NAME”
   (b) Set the output to Word and PDF
6. Run the Process Capability Study.
   (a) Enter “Ungrouped” for the Report Name.
   (b) When you get to the page that asks for a Group By variable, enter “NONE”.
   (c) Output the Report to HTML and Word.
7. Run the Process Capability Study Again.
   (a) This time, enter “Grouped” for the Report name.
   (b) When you get to the page that asks for a Group By variable, enter “STDF_NAME”.
   (c) Output the Report to HTML and Word.

Working with Your Data:

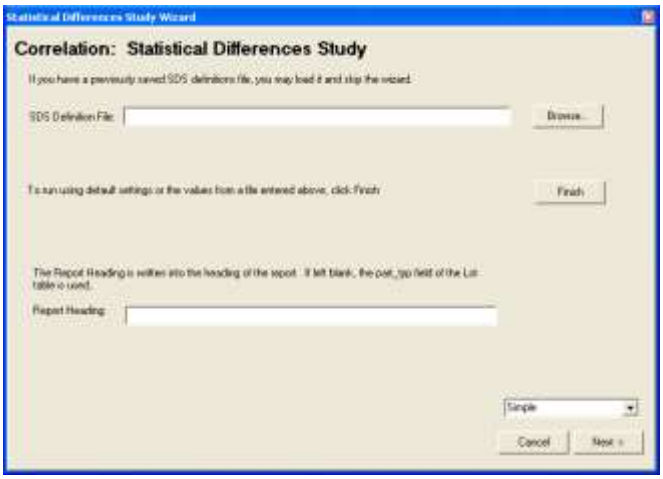
8. Load data files.
   (a) (DataPipeline or Global Gateway Client Only) Use the FIRMS Client or Global Gateway Client to load some files from your favorite part type. (Load at least two files.)
   (b) If you company does NOT use the either Server, load at least two of your files STDF file from disk.
9. Run the N-Chart Wizard.
10. Run the Process Capability Study several times, altering the output each time.
11. If your data is available on the local system (not using a Client tool):
    (a) Click Analyze One File on the JumpStart page and use one of your files.
    (b) Click Analyze Many Files on the JumpStart page and use 3 to 5 of your files.
    (c) Click Merge and Analyze on the JumpStart page and use 3 to 5 of your files.
12. Using the C_{pk} statistic, what is the worst performing test? _____
13. Looking at the page for that test in the report, what causes the C_{pk} to be bad?
    (a) Are there Outliers? _____
    (b) Process is too close to one of the limits? _____
    (c) Process is too wide? _____

Statistical Differences Study

The Statistical Differences Study is the Wizard for correlation. The report statistically compares two populations that you define using the Group By variable.

The easiest way to correlate data in two files it use the JumpStart page. After selecting the two files you wish to correlate, just hit “Go” and your report will done in a few seconds.

1. Start pcFIRMS, Open or Create a Workspace, and load one or more data files. (See these sections in the pcFIRMS Online Help or Basic Training Manual for information.)



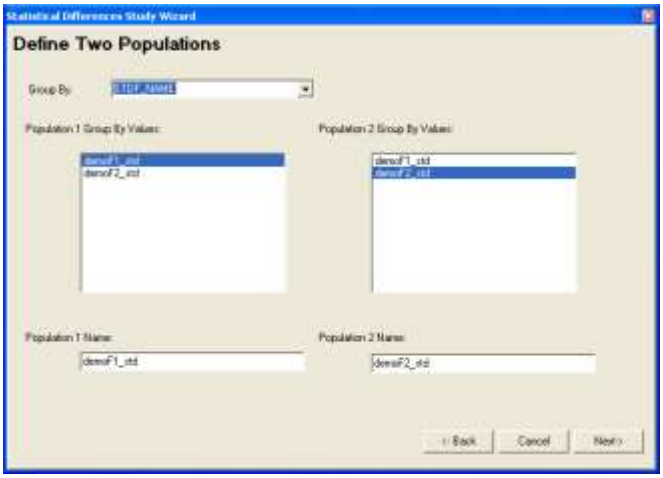
TIP: If you do not create a workspace and load data before running the wizard, the wizard will create a default workspace and prompt you to load data.

NOTE: Unless you are grouping by Test Conditions, at least two data files are required to run the SDS.

2. The Statistical Differences Study Wizard is located in the Wizards Menu in the Main Menu of pcFIRMS. To start the wizard select Wizards->Correlation. The following window will appear.

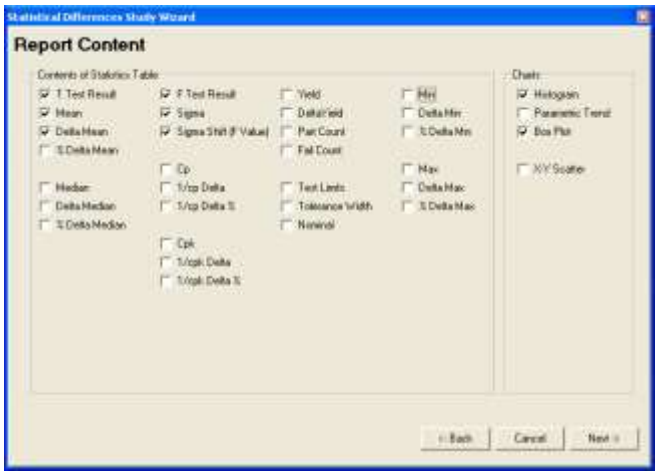
3. If you have previously run the wizard and saved the settings in a definitions file, you may select a definitions file to use and then click Finish. If you wish to use the default settings, you may simply click Finish to run the report. Otherwise, go to step 4.

   The Report Name will be used in the headings of the reports and to name the directory in which the reports will be stored. If left blank, the contents of the part_typ field in the Lot table will be used. Click the Next button.



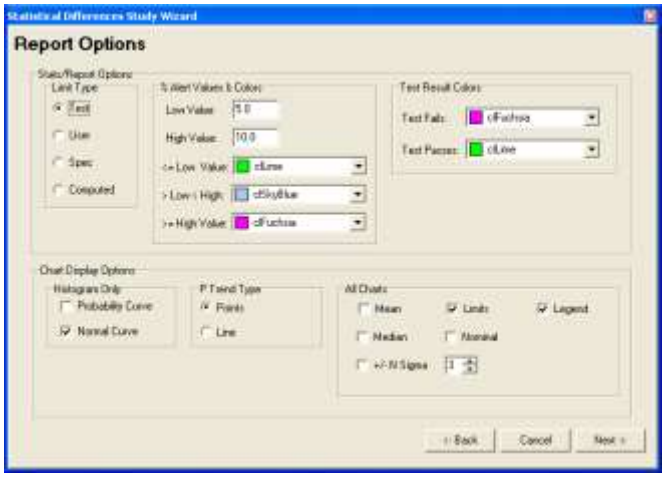
4. Select a Group By variable. All possible values for the selected Group By variable will appear in the two list boxes labeled Population 1 and Population 2. Select the value of the Group By variable that represents each population. By default, the value of the Group By variable will appear as the name of the population. The population names may be changed if desired. Click the Next button.

5. The Report Content window lets you select which type of Charts & Statistic Table Contents you'd like to include in your report. By default, the results of a T-test (comparison of the means) and F-test (comparison of the standard deviations (sigma)). Once you've made your selections, press Next.



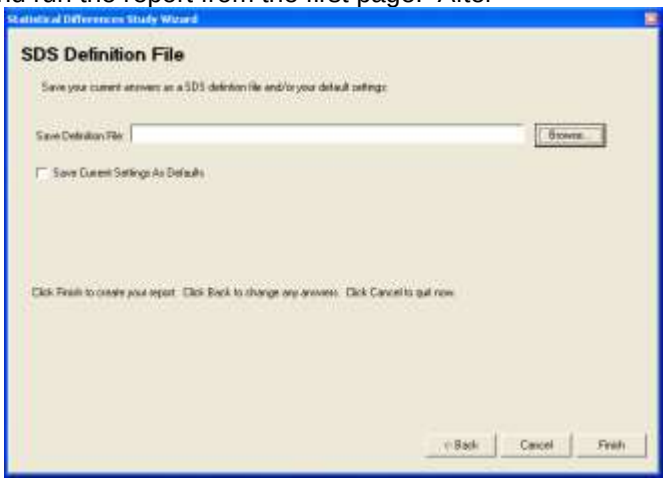
6. The Report Options page defines the appearance of the report. Here you can select alert values and colors, additional curves for the charts, and the Limit Type. After making your selections, click the Next button.

7. The Output Options page allows you to select the location and format of the output of the report.



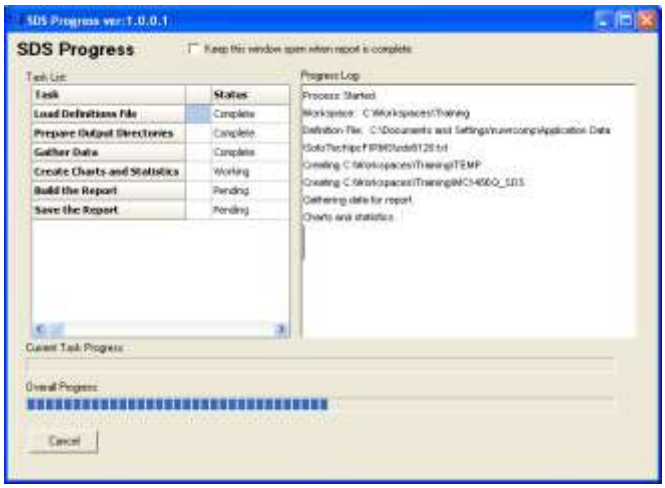
   a. Create DataView places the selected statistics in a DataView. If you turn this option on, you will also have the option of saving the resulting table to Excel.
   b. Logo JPEG File allows you to select an Image to use instead of the default_logo.jpg file that is used by default.
   c. Save as HTML will create an HTML version of the report.
   d. Save as PDF will create a PDF version of the report.
   e. Save as Word will create a Microsoft Word version of the report. Selecting the Print check box will send the Word version of the report to a printer automatically.

8. On the SDS Definition File page, you can elect to save the current settings in the wizard in a definitions file or as the defaults. These options allow you to start the wizard with the current settings the next time you start the wizard and run the report from the first page. After making your entries, click the Finish button.



Tip: Create definition files for different products or customers as the need arises. This will save time during future runs of the Wizard and prevent you having to remember exactly what settings you used for a specific customer or product.

9. The SDS Progress page will keep you informed of the progress if the report. When complete, the progress window will close. Any output formats you chose to view will open automatically.



You know the report is complete when the Overall Progress bar is full and the "Close" button appears next to the "Cancel" button. The outputs you selected to "View" should all open automatically.

If you wish to view the Process Log, click the "Keep this window open when report is complete" check box at the top of the Progress Widow. The contents of the log are lost when the wizard is closed.

10. When you are ready, click the Close button to exit the wizard.

Statistical Differences Study Statistics

The SDS introduces two new statistics. The statistics are T-Test and F-Test. The idea behind the Statistical Differences Study is to determine if two populations are the same or different. The question asked by pcFIRMS is “Are the two populations statistically different?” Therefore, a “Yes” answer means the populations ARE different. A “No” answer means the populations ARE NOT different.

T-Test

The T-Test determines if the population averages are different. The formula used for the t-value is:

$$t = \frac{\mu_1 - \mu_2}{\sqrt{\frac{\sigma^2{}_1}{N_1} + \frac{\sigma^2{}_2}{N_2}}}$$

The numerator is simply the difference of the means of the two populations.

The denominator is the square root of the variance divided by the count of each population, summed together.
The t-value is the ratio of these two values.

Also needed are the degrees of freedom. Since there are two populations, the degrees of freedom are the count -2.

The confidence level, known as the alpha level, is set to .05 in pcFIRMS. This means that 5 times out of a hundred, you would find a statistically significant difference between the means even if there was none.

Given the alpha level, the degrees of freedom, and the t-value, you can look the t-value up in a standard table of significance

The t-value is then compared to a significance table (found in the back of most statistics text books) to determine whether the t-value is large enough to be significant.

F-Test

The F-Test determines if the population dispersions are different. The formula for the F-value is:

$$F = \frac{\sigma^2{}_1}{\sigma^2{}_2}$$

Which is a ration of the variances of the two populations.

If the F-value > 2, the two populations are determined to have statistically different dispersions.

Exercise 4:

1. Click the “Correlate” button on the JumpStart page. Use the v4_demo files.
2. Create a new Workspace named “Exercise_2a”.
3. Load two demo files.
4. Run the Statistical Differences Study several times changing the output columns selected and output format.

Working With Your Data

5. Click Correlate on the JumpStart page and use two of your files.
   a. Are your two files statistically different? _____
6. Create a new Workspace named “Exercise_2b”.
7. Run the Statistical Differences Study several times, altering the output each time.

Break For Lunch

Test Elimination Study

The Test Elimination Study is the Test Program Optimization Wizard. It helps the user to determine if any tests within a test program correlate with one another. If two tests have a very high correlation coefficient, it is possible that one of them can be eliminated or at least reduced to a sampling plan.

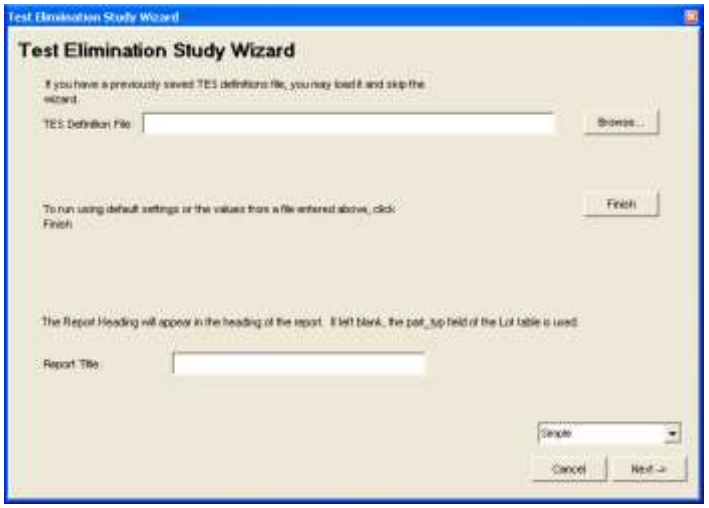
When using a single file for optimization, the fastest and easiest way to run TES is the JumpStart page. Use the Optimize button to get started.

After selecting the STDF file, just hit “Go” and your report will appear in a few seconds.

1. Start pcFIRMS, Open or Create a Workspace, and load one data file. (See these sections in the pcFIRMS Online Help or Basic Training Manual for information.)

TIP: If you do not create a workspace and load data before running the wizard, the wizard will create a default workspace and prompt you to load data

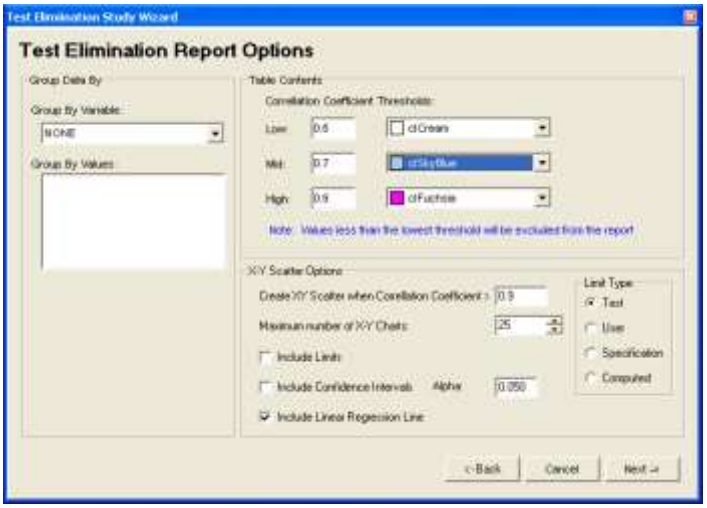
2. The Test Elimination Study Wizard is located in the Wizards Menu in the Main Menu of pcFIRMS. To start the wizard select Wizards->Optimize->Test Elimination Study. The following window will appear.



3. If you have previously run the wizard and saved the settings in a definitions file, you may select a definitions file to use and then click Finish. If you wish to use the default settings, you may simply click Finish to run the report. Otherwise, go to step 4.

   The Report Name will be used in the headings of the reports and to name the directory in which the reports will be stored. If left blank, the contents of the part_typ field in the Lot table will be used. Click the Next button.

   Just above the Cancel and Next buttons is the Mode Check Box. In Simple Mode, the wizards skip all the Include and Exclude windows. For this exercise, leave the Mode set to “Simple”.



4. The Test Elimination Report Options page allows you to control the look and content of the report.

   Here you can select any Group By Variables and Values.

   You can also setup colors for thresholds of the correlation coefficient. Any comparisons which result in a correlation coefficient less than the minimum setting will be left off the report.

   The Test Elimination Study also includes X-Y Linear Correlation charts for each comparison above a certain correlation coefficient.

Once you've made your selects, click the Next button.

5. On the Output Options page you control the output formats created.
   a. Logo JPEG File allows you to select an Image to use instead of the default_logo.jpg file that is used by default.
   b. Save as HTML will create an HTML version of the report. You may select to view the report.
   c. Save as PDF will create a PDF version of the report. You may select to view the report.
   d. Save as Word will create a Microsoft Word version of the report. You may select to view the report. Selecting the Print check box will send the Word version of the report to a printer automatically.
   e. Save Table to Excel will save the sorted list of correlation coefficients to an Excel Spreadsheet. The Full Map is NOT exported.
6. On the Test Elimination Study Definition File page, you can elect to save the current settings in the wizard in a definitions file or as the defaults. These options allow you to start the wizard with the current settings the next time you start the wizard and run the report from the first page. After making your entries, click the Finish button.

Tip: Create definition files for different products or customers as the need arises. This will save time during future runs of the Wizard and prevent you having to remember exactly what settings you used for a specific customer or product.

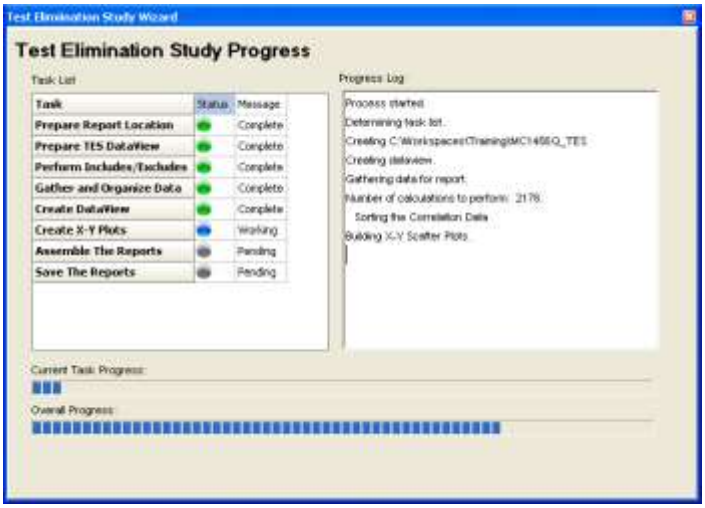
7. The TES Progress page will keep you informed of the progress if the report. As each task completes, the status light will turn green, yellow or red.

   A green light means the task completed with no problems

   A yellow light means that some warning was generated in the Process Log window.

   A red light means the task failed to complete.

   You know the report is complete when the Overall Progress bar is full and the "Close" button appears next to the "Cancel" button. The outputs you selected to "View" should all open automatically.



8. If you wish to view the Process Log do so before clicking the "Close" button. The contents of the log are lost when the wizard is close.

Test Elimination Study Statistics

The TES introduces two new statistics: the Correlation Coefficient and the Confidence Interval. We will discuss the Confidence Interval in more detail later. The Correlation Coefficient is a number between -1.0 and 1.0 that indicates the degree of linear relationship between two data sets.

Symbolically, the Correlation Coefficient is: $\boldsymbol{r_{xy} = \frac{S_{xy}}{S_x S_y}}$

It is the standard deviation of all data elements from both populations divided by the product of the standard deviation of each population.

As the Correlation Coefficient approaches 1.0, the probability that a xy-scatter of the two populations will fall on line increases.

We will discuss this in further depth when we study the X-Y Scatter Plot later.

Exercise 5:

1. Click the Optimize button on the JumpStart page and use the v4demo.std file.
2. Create a new Workspace and name it “Exercise_5a”.
3. Load the demoF1 file.
4. Run the Test Elimination Study Wizard.

Working With Your Data

5. Create a new Workspace named “Exercise_5b”.
6. Load two of your data files.
7. Run the Test Elimination Study.
8. How many tests should be investigated for possible elimination? _____

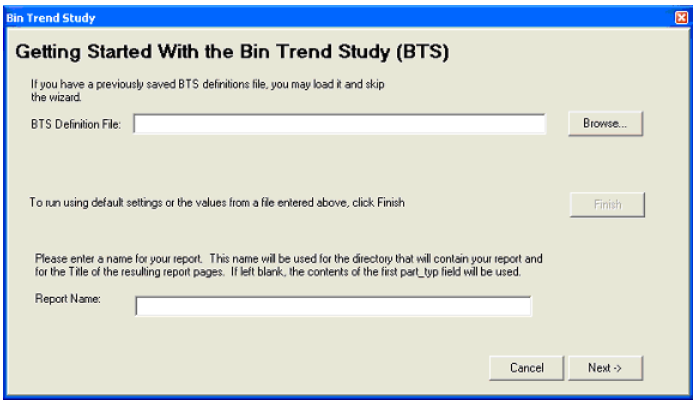
Bin Trend

The Bin Trend Wizard helps you to monitor your production areas. It creates a report that consists of a table of bin yields based on work week. It also creates a Bin Trend Chart for every bin number.

Using Bin Trend

1. Start pcFIRMS, Open or Create a Workspace, and load several STDF files. (See these sections in the pcFIRMS Online Help or Basic Training Manual for information.)

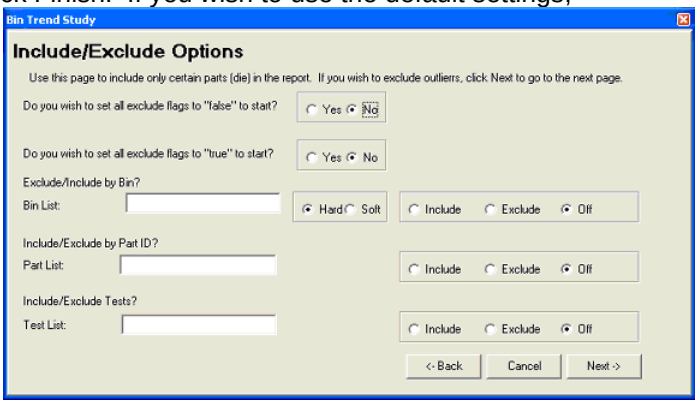
Tip: If you do not create a workspace and load data before running the wizard, the wizard will create a default workspace and prompt you to load data.



Note: You will need a minimum of three data files to get a meaningful report. A minimum of 5 files is suggested.

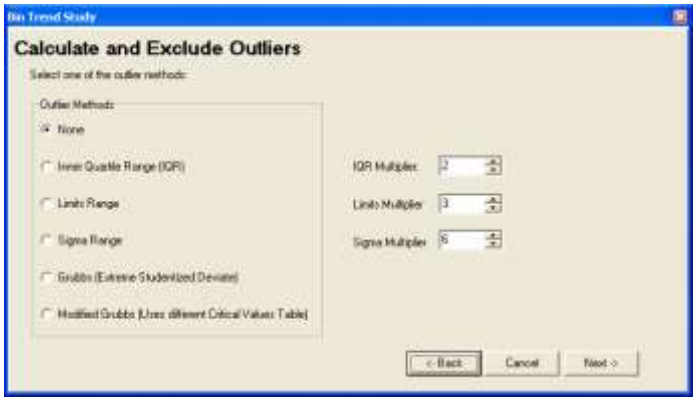
2. The Bin Trend Wizard is located in the Wizards Menu in the Main Menu of pcFIRMS. To start the wizard select Wizards->Bin Trend. The following window will appear.

3. If you have previously run the wizard and saved the settings in a definitions file, you may select a definitions file to use and then click Finish. If you wish to use the default settings, you may simply click Finish to run the report. Otherwise, go to step 4.



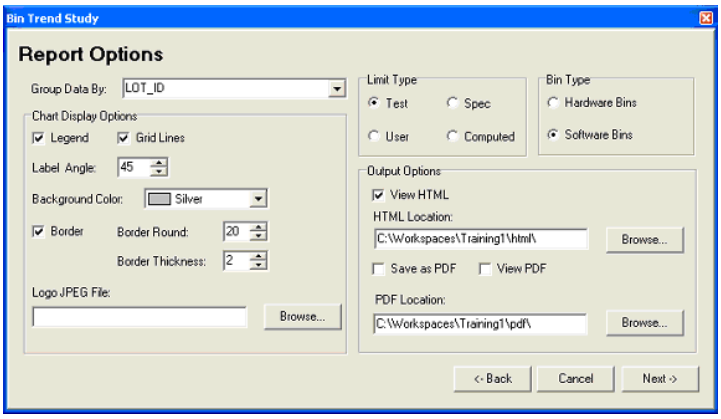
The Report Name will be used in the headings of the reports and to name the directory in which the reports will be stored. If left blank, the contents of the part_typ field in the Lot table will be used. Click the Next button.

4. The Include/Exclude Options page is where the user indicates which parts and tests are to be included in the report. If you wish to make no changes to the Workspace before you run the report, set both flag buttons to “No” and all of the Include/Exclude buttons to “Off”. After making the desired selections, click the Next button.



5. The wizard provides several ways to remove outliers. Select one of the methods, and if applicable, set the appropriate Multiplier. Before running the report, pcFIRMS will set the exclude flags in the Results table for any values that are calculated as outliers. Click the Next button.

6. The Report Options page is where you specify the bin type (hardware or software) and set preferences for the look of the report.



7. On the BTS Definition File page, you can elect to save the current settings in the wizard in a definitions file or as the defaults. These options allow you to start the wizard with the current settings the next time you start the wizard and run the report from the first page. After making your entries, click the Finish button.

8. A progress window will keep you informed of the progress of the report. When complete, the progress window will close. Any output formats you chose to view will open automatically.

Exercise 6:

1. Create a new Workspace named “Exercise 6a”.
2. Load all the demoF* files into the Workspace.
3. Run the Bin Trend Wizard.

Working With Your Data

4. Create a new Workspace named “Exercise 6b”.
5. Load 10 – 30 of your files.
6. Run the Bin Trend Wizard.

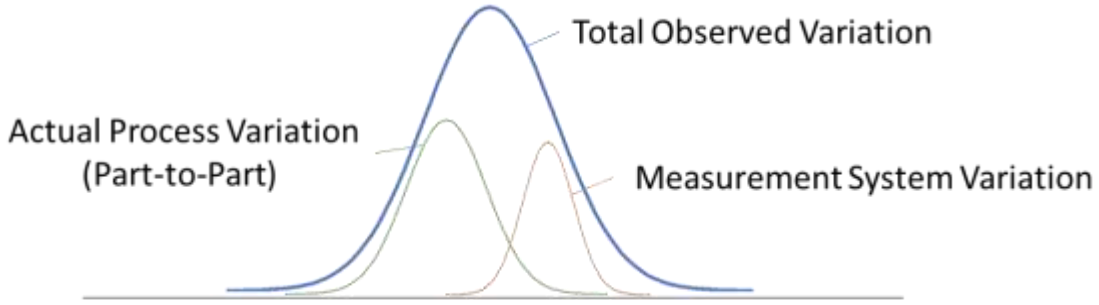
Measurement System Analysis (MSA)

The data analysis capability of pcFIRMS has been expanded to perform Measurement Systems Analysis (MSA) in the form of Gage Repeatability and Reproducibility (Gage R&R) studies as well as control charts. The industry standard implementation of Gage R&R set by the Automotive Industry Action Group (AIAG) Gage R&R specification for ANOVA has been a heavily used feature in pcFIRMS, which is a tool that provides easy-to-use data selection and produces powerful tabular and graphical reports. The widely used Minitab implementation of Gage R&R by ANOVA is also available in pcFIRMS. Convenient features such as Gage R&R by Average and Range (Xbar & R) and Xbar & R control charts provide instant insight into your data.

Gage Repeatability and Reproducibility (R&R)

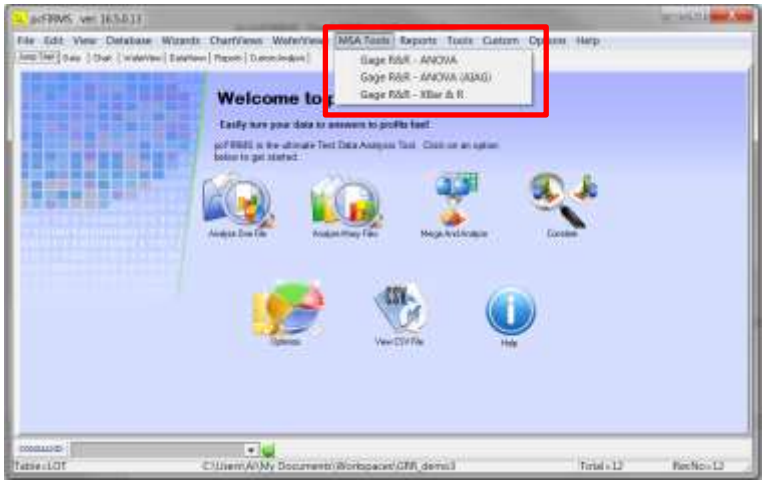
Gage R&R is an estimate of the combined **repeatability** and **reproducibility** for a measurement system.

The image below illustrates the components of total system variation, highlighting the measurement system variation as essentially an error component needed to be minimized.



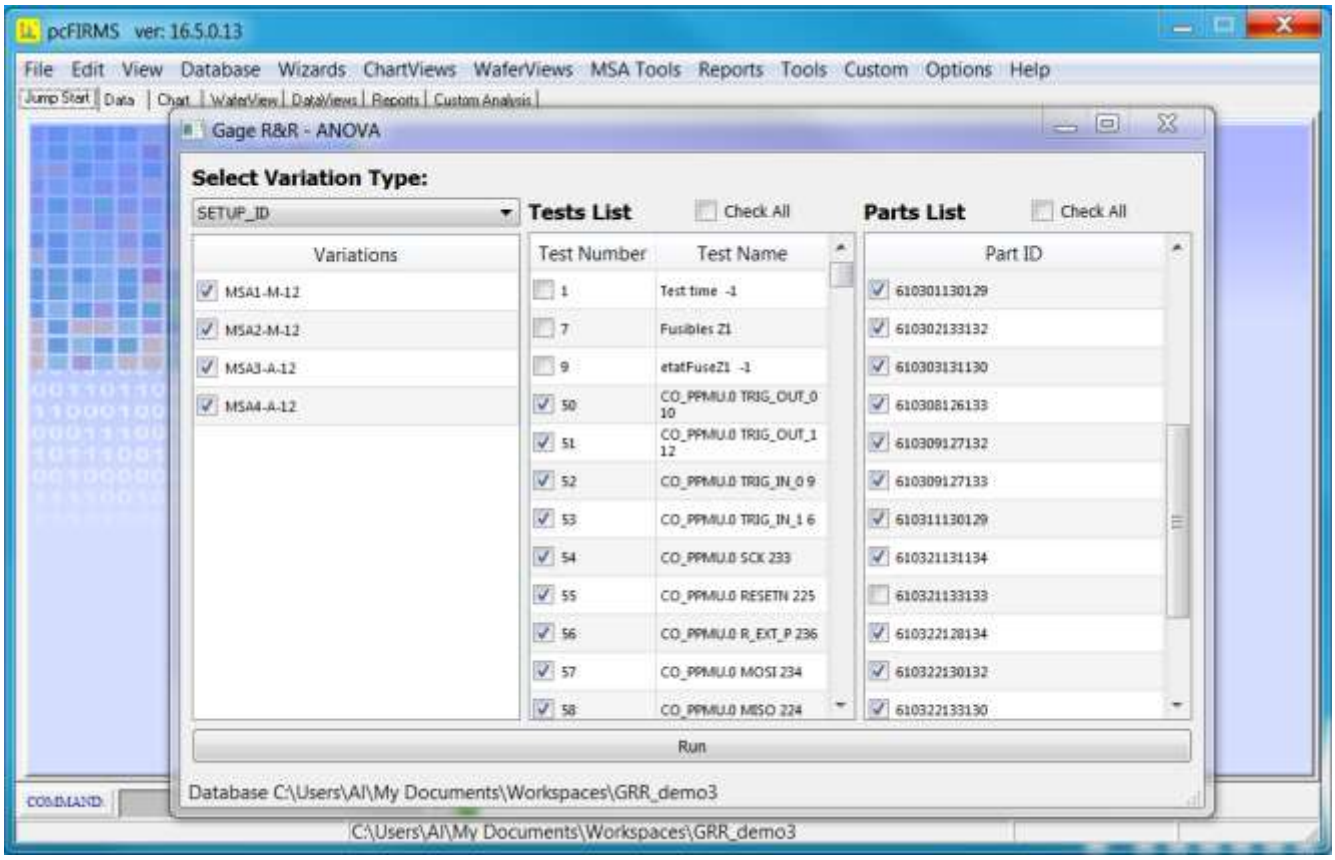
$$\sigma^2_{Observed} = \sigma^2_{Actual} + \sigma^2_{Measurement}$$

In pcFIRMS, Gage R&R is selected in the **MSA Tools** drop-down button.



Select desired method: XBar & R, ANOVA, and ANOVA (AIAG). The difference in ANOVA methods is that the AIAG version uses the *Fixed Effects* model (as specified in the AIAG MSA version 4 manual) and the other uses the *Random Effects* model which is also used in Minitab (for Crossed Gage R&R Study).

pcFIRMS Gage R&R provides was to specify what data you want for the study. The **Variations** are equivalent to the **Operator** or **Appraiser** nomenclature. Select desired tests and parts (ID). The tool automatically handles the amount of repeat testing counts in the loaded data.



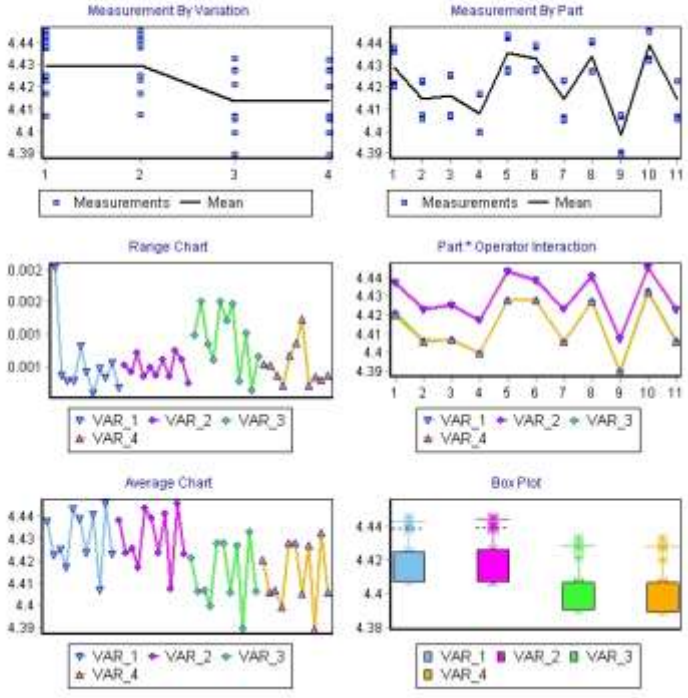
Here is a sample report output, which contains tabular and the graphical control charts:

	GRR	CMC
PASSING TEST	< 10%	>= 5
CONDITIONALLY ACCEPTABLE TEST	>= 10% AND <= 30%	
FAILING TESTS	>= 30%	< 5

TEST	HI LIMIT	LO LIMIT	GRR %	CMC	3* GRR	UNITS
500 Regul.0 VPOS_CP_OUT 99	4.50	4.35	36.88	2.71	0.03	V
501 Regul.1 VRES_COL_OUT 109	2.70	2.25	38.20	2.62	0.09	V
502 Regul.2 VNEG_GS_OUT 104	-1.15	-1.55	4.82	20.76	0.01	V
503 Regul.3 VDD1V1_OUT 100	1.35	1.20	7.87	12.71	0.01	V
504 Regul.4 VRES_SLOPE_OUT 111	2.70	2.50	24.62	4.06	0.02	V
505 Regul.5 VPOS_GS_OUT 112	3.75	3.45	0.50	201.29	0.00	V
506 Regul.6 VL_VD_RES_SH_OUT 114	850.00	750.00	49.10	2.04	17.15	mV
507 Regul.7 VL_RES_PH_OUT 96	315.00	275.00	87.32	1.15	16.15	mV
508 Regul.8 VDD1V8_OUT 102	1.90	1.70	3.73	26.80	0.00	V
509 Regul.9 VDD1V4_OUT 103	1.65	1.50	15.13	6.61	0.01	V
510 Regul.10 VCE_RES_OUT 105	-1.30	-1.50	14.08	7.10	0.01	V
511 Regul.11 VPOS_OUT 97	4.36	4.15	1.01	99.42	0.00	V
512 Regul.12 VNEG_TX_OUT 108	-1.15	-1.55	4.50	22.24	0.01	V
513 Regul.13 R_EXT_N 86	40.00	0.00	3.93	25.47	0.79	mV
514 Regul.14 R_EXT_P 86	1.30	1.15	0.43	234.73	0.00	V
520 Iregula.0 VL_VD_RES_SH_IN_1 12	2000.00	-2000.00	13.65	7.33	272.92	nA
521 Iregula.0 VL_RES_PH_IN_1 29	2000.00	-2000.00	13.55	7.38	270.97	nA
522 Iregula.1 VRES_COL_IN_1 13	3500.00	-3500.00	8.74	11.44	306.00	nA
523 IVGSTXlastepa VNEG_GS_IN_1 15	2.00	-2.00	5.47	10.56	0.19	uA
524 IVGSTXlastepa VNEG_TX_IN_1 14	2.00	-2.00	10.48	9.54	0.21	uA
525 IVposRes VPOS_RES_1 30	2.00	-2.00	9.06	11.03	0.18	uA
540 Diode temperature DIODE_INT_P 90	40.00	25.00	45.50	2.20	3.41	°C

500 :: Regul.0 VPOS_CP_OUT 99

HI LIMIT	LO LIMIT	TOL	GRR %	CMC	3*GRR	UNITS
4.50	4.35	0.15	36.88	2.71	0.03	V



Basic Charting

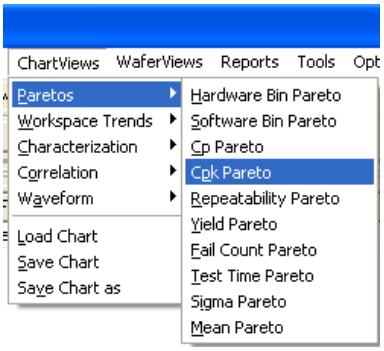
Creating the Basic pcFIRMS charts is very simple. You just select the chart you wish from the Charts menu, enter any necessary options and the chart is created. You may browse back and see charts that you have created in the past or forward to see more recent charts. You can create your own report by exporting the Charts to Microsoft Word.

Note: Before creating a chart you must have at least one STDF file loaded in the database.

Tip: Once you begin browsing the charts, you can no longer use the options panel to change them, only the Chart Editor.

Your First Chart

To create a chart, we must first create a Workspace and load some data. For this example, we will use the files provided by pcFIRMS. In the exercises, you will get a chance to use them on files from your favorite part type.

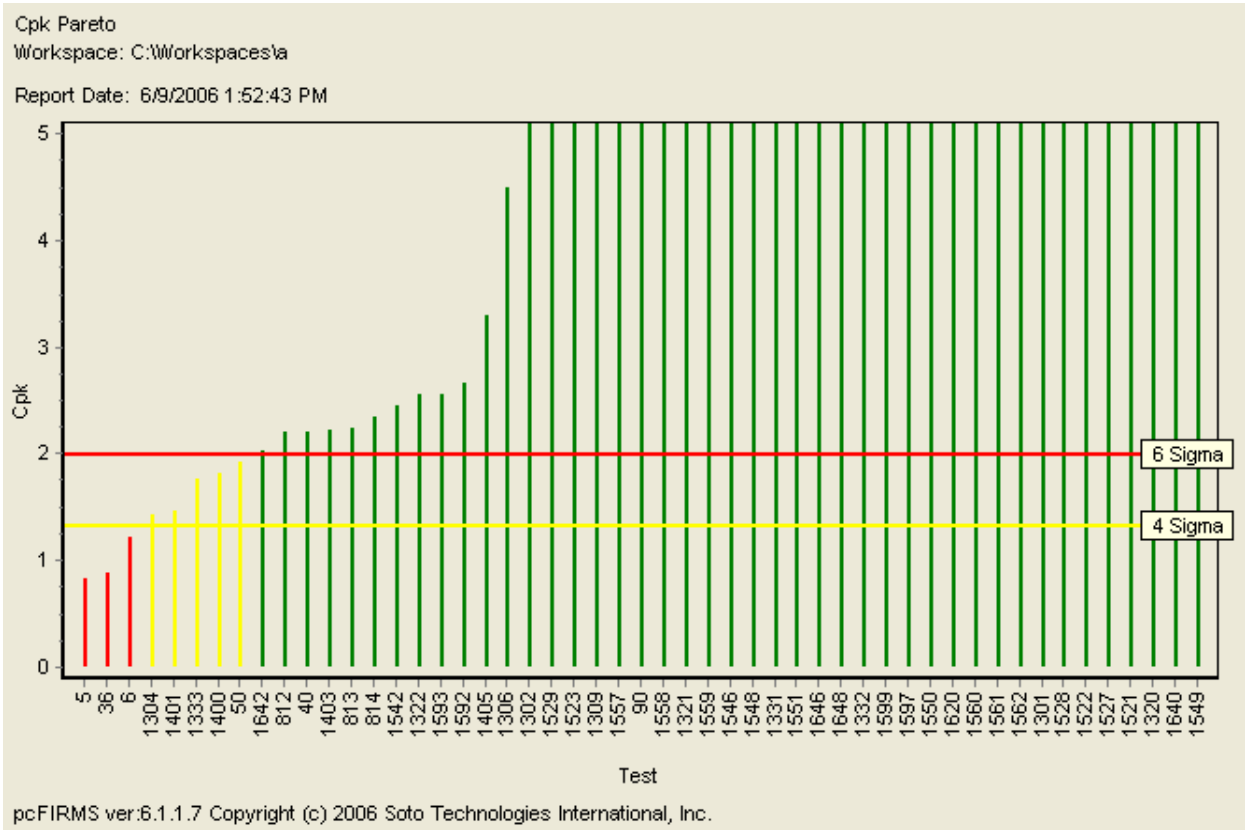


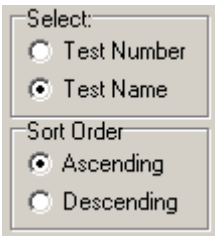
Create a Workspace and load the demoF1 STDF file.

Select ChartViews->Paretos->Cpk Pareto from the menu system.

After a second or two, you will see your chart.

In the options area you will see the capability to change the sort order, the labels and the Group By variable for this chart.



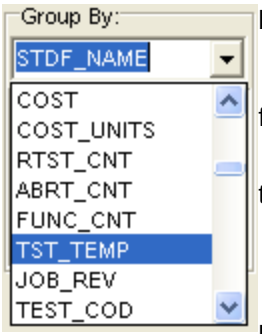


Alter the chart so that the X-axis labels are the test numbers instead of the test names.

Change the sort order from ascending to descending. Then change it back to ascending.

Now load the demoF2 STDF file. Run the Cpk Pareto. The results you see are based on the combined data from both files. pcFIRMS automatically merges any data necessary to do this type of charting.

Set the Group By variable to TST_TEMP. Make sure that both files are selected in the List Box. Click the Graph button. 



The Chart will redraw and you will see two bars for each test, one from each of the files.

This chart quickly tells you that test number 5 (named DELTAV) is the poorest performing test with regards to process capability.

Chart DataViews

Most charts create an associated DataView that contains the data behind the Chart. To see the DataView, click on the DataView tab and look for a DataView with a name associated with the chart you just created.

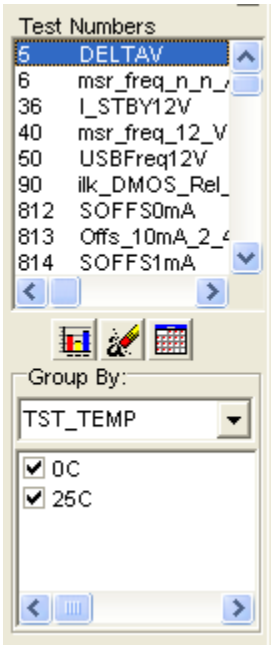
To view the DataView for the Cpk Chart, Click on the DataView Page the find the DataView named Cpk Pareto.

Chart Manipulation

The pcFIRMS charting engine allows you to edit the chart in pretty much any way you wish to. Let's create a histogram and use the Chart Editor to alter it.

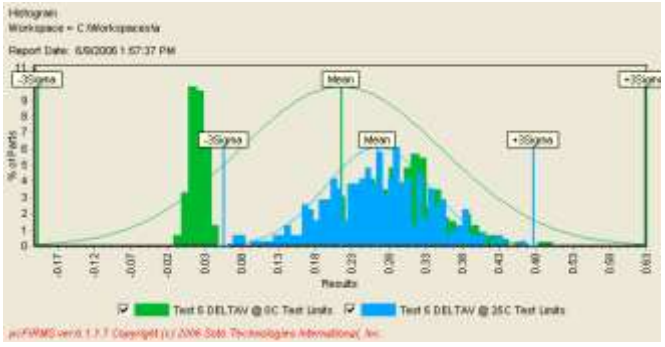
1. Using the same Workspace from the previous section, select ChartViews->Characterization->Histogram from the menu system.
2. Set the group by variable to "TST_TEMP".
3. Locate test 5 DELTAV in the test list and double click on it.

Tip: You can also select the test with a single click and then click the Graph button.

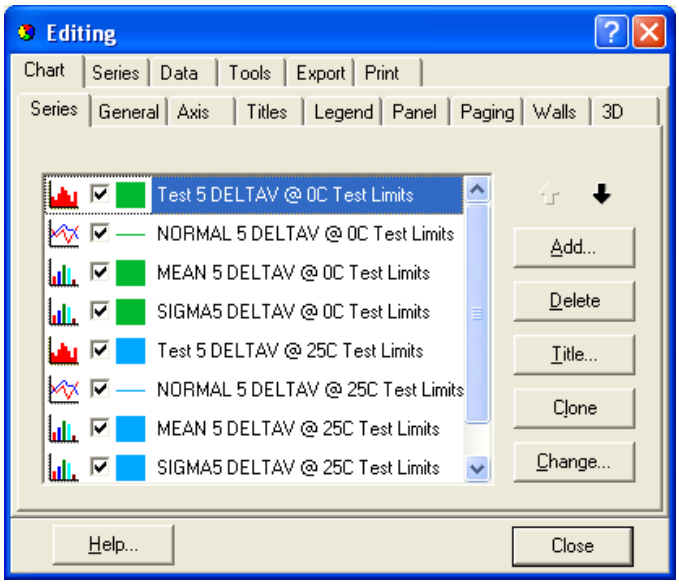


In the lower part of the options area, there are options to change the limit type (more on this later) and to turn other bars on and off, such as the mean, median, and +/- 3 Sigma.

In the tool bar above the chart, you can turn on the legend, a grid containing data, and a text area that contains statistics.



On some charts, you will see an option to display the charts as "Stacked". If you turn this option on, each data series will be presented in its own chart rather than overlaid. In some cases, this makes the graphs easier to compare to one another. From the chart tool bar, you can also turn on the Chart Tool Bar that contains the tools necessary to manipulate the contents of the chart.



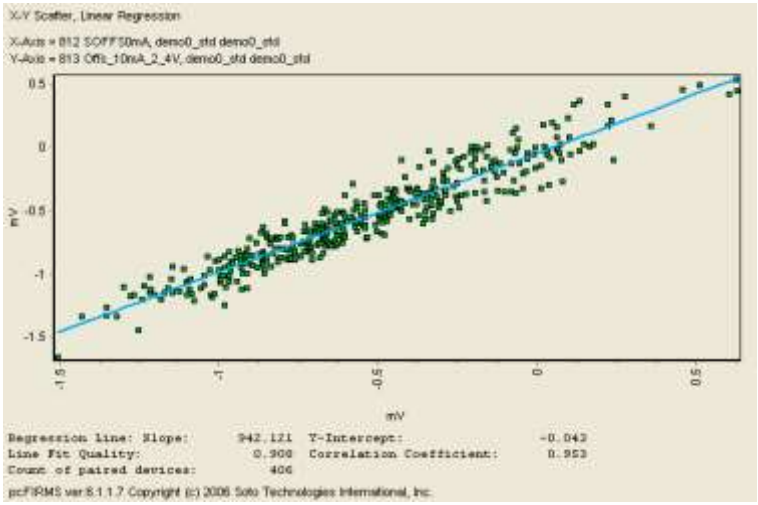
Click the Chart Editor button  on the new tool bar to open the Chart Editor.

On the front page of the Chart Editor is a listing of all the available Data Series in the chart.

You can turn them on and off using the check box next to the name of each series. You can change their order in the graph by clicking the up and down arrows.

This is also the tool you use to change Axis labels, Axis scales, the title of the chart, the footer of the chart and many other parts of the chart.

Close the Chart Editor by clicking the Close button or by clicking out of the window.



Correlation Charts

For correlating data in file to another or from one test to another, use the pcFIRMS XY Scatter plot.

Creating an X-Y Scatter

1. Create a Workspace and load the Temp_0 STDF File
2. Select ChartViews->Correlation->XY Scatter from the menu.
3. Choose test 812 for population 1.
4. Choose test 813 for population 2.
5. Click the graph button. 

Creating Output from a Chart

The pcFIRMS Charting engine provides the capability to export any chat to Word, HTML, or PDF. You can also Copy and Paste the chart to another application. The chart may be saved to a native format.

Word

To export a graph and associated data to a Word file:

1. Click on the Export to Word button.  A standard open dialog box will appear.
2. In the dialog box, navigate to the desired location for your report.
3. Select an existing Word file or type in the name of a new one. If an existing Word file is selected, the chart will be added as a new page at the end of the document.
4. Once you have a Word file open, you can append additional charts to the Word file by clicking the Word+  button. This will quickly append the chart to the open file without having to wait for Word to open.

TIP: Customize your word report by putting your company's logo in jpeg format in the default_logo.jpg file. This file must be located in the pcFIRMS installation directory, which is by default: C:\Program Files\Sototech\pcFIRMS.

HTML

To export a graph and associated data to an HTML document:

1. Click on the Export to HTML button. A dialog box will appear prompting for a directory into which to save the HTML report.
2. In the dialog box, navigate to the desired location for your report. The report will be created in the directory that appears to be an open folder. pcFIRMS will create an images directory inside the selected folder and an index.htm file that contains the report.

TIP: Customize your HTML report by putting your company's logo in jpeg format in the default_logo.jpg file. This file must be located in the pcFIRMS installation directory, which is by default: C:\Program Files\Sototech\pcFIRMS.

PDF

To export a graph and associated data to a PDF file:

1. Click on the Export to Word button. A standard open dialog box will appear.
2. In the dialog box, navigate to the desired location for your report.
3. Select an existing PDF file or type in the name of a new one. If an existing PDF file is selected, the file will be deleted and the new chart written to a new file of the same name.

NOTE: PDF does not support the capability of opening an existing file and appending it. If you need this support, use the export to Word function and Adobe Acrobat to create a PDF file from the Word file.

TIP: Customize your PDF report by putting your company's logo in jpeg format in the default_logo.jpg file. This file must be located in the pcFIRMS installation directory, which is by default: C:\Program Files\Sototech\pcFIRMS.

Copy and Paste

You can Copy and Paste the chart into any application that supports the Windows Clipboard. To Copy the chart, click the Copy Chart button on the tool bar.

NOTE: You must have the tool bar turned on.

Chart File

To save a chart in a binary, native format:

1. Select ChartViews->Save Chart As from the menu system. A standard Save dialog box will appear.
2. In the dialog box, navigate to the location where you want to save the file.
3. Enter a name for the chart and click "Save".

To reload the chart into pcFIRMS:

1. Select ChartViews->Load Chart from the menu system. A standard Open dialog bow will appear.
2. In the dialog box, navigate to the location of the chart you wish to load.
3. Select the chart you wish to load and click “Open”.

NOTE: Only the chart object is saved. The Data Grid and Text Areas are not saved.

TIP: The chart and all the information associated with the chart are saved in the chart buffer. You can go back to previous charts using the Chart Browser on the tool bar.

Exercise 8:

1. Create a new Workspace named “Exercise_8a”.
2. Load the v4_demo.stdf and v4_demo2.stdf files.
3. Create Box Plots for test 2008 grouped by “STDF_NAME”.
   (a) The Box Plot is located under Charts->Characterization
4. Turn on the tool bar and open the Chart Editor.
5. Change the Title of the Chart to “Box Plots for 2008”;
6. Copy the chart to the clipboard.
7. Open PowerPoint or Word and paste the chart.

Working With Your Data

8. Create a new Workspace named “Exercise_8b
9. Load 4 of your files.
10. Create a Cpk Pareto.
    (a) Make note of the worst performing test.
11. Create a Parametric Trend grouped by “STDF_NAME” for the worst performing test.
12. Open the Graph Editor
13. Add a new line that represents the average.
14. Add a new line that represents the maximum.
15. This is done the same way as average; just choose the “High” function.
16. Add a new line that represents the minimum.
17. This is done the same way as maximum, just choose the “Low” function.
18. Give each of the new series a name that makes sense.
19. Turn off the original lines.
20. Export the chart to Word.
21. Create a Sweep chart.
    (a) The Sweep chart is located under Charts->Characterization

22. Export the chart to Word.

Reports

pcFIRMS features two kinds of reports: ASCII and DataViews. The ASCII Reports are created in Rich Text Format (rtf) and can be saved as ASCII Text files or exported to Microsoft Word.

The DataViews are created in a data table and can be exported to Word and Excel.

ASCII Reports

Creating ASCII Reports

Let's start by creating a Lot Summary report.

1. Create a Workspace and load v4_demo.stdf.
2. Select Reports->ASCII->Lot Summary from the menu system.

NOTE: If the report doesn't run, click the Create Report button. 

When more than one file is loaded "Lot" versions of each report give you one report for each file. "Merged" versions of each report give one report with all the data merged together. Group By support for the reports is in the road map.

Saving and Opening ASCII Reports

To save the Lot Summary report created in the previous section, click the Save Report button  on the toolbar. If this is the first time you clicked the button since creating a new report, you will be prompted for a file name. Otherwise, the contents will just be saved to the last file name given.

To open a saved report, first clear the current report by clicking the Clear Report button.  Then click the Open Report button  , navigate to the location of the report you want to Open and click "Open".

When a report is loaded, any additional reports will be appended to the current one. To create a new report, you must clear the current report.

Exporting to Word

To export a report to a new Microsoft Word file, click the Export to Word button.  Word will open and your report will appear in a new document. To append to a Microsoft Word file that you previously used and is still open, click the Word-plus button. 

Dataviews

Creating Dataviews

Let's create the HBIN Pareto Dataview:

Using the same workspace from the previous section, select Reports->Dataviews->Paretos->Hardware Bin Pareto. The DataViews page will become the active page and you will see the report in the table.

TIP: To reorder the report, just click on any column heading in the DataView to sort by that column. Click the same heading again to change the sort order (ascending/descending).

Creating Output From a Dataview

Excel

To export a DataView to an Excel Workbook:

1. Click on the Export to Excel button.  A standard Save dialog box will appear.
2. In the dialog box, navigate to the desired location for your report.
3. Select an existing Excel file or type in the name of a new one. If an existing Excel file is selected, the chart will be added as a new Sheet in the Workbook.

Word

To export a DataView to a Word file:

1. Click on the Export to Word button.  A standard Save dialog box will appear.
2. In the dialog box, navigate to the desired location for your report.
3. Select an existing Word file or type in the name of a new one. If an existing Word file is selected, the chart will be added as a new page at the end of the document.

NOTE: If a new document is created, pcFIRMS will create a document based on the template PCFIRMSReport.dot located in the installation directory of pcFIRMS (By default: C:\Program Files\Sototech\pcFIRMS). The graphic contained in the file default_logo.jpg will be used as a logo in the report.

TIP: Customize your word report by putting your company's logo in jpeg format in the default_logo.jpg file. This file must be located in the pcFIRMS installation directory, which is by default: C:\Program Files\Sototech\pcFIRMS.

Exercise 9:

1. Create a new Workspace named “Exercise_9a”.
2. Load v4_demo.stdf.
3. Run the Characterization DataView
4. Load v4_demo2.stdf.
5. Run the Characterization DataView
6. Open the Options->Reports Window and select STDF_NAME as the Group By variable.
7. Run the Characterization DataView
8. Export the Characterization DataView to Excel
9. Load the DemoF1.std file.
10. Run the Results DataView

Working With Your Data

1. Create a new Workspace named “Exercise_9b”.
   (a) If your company uses the DataPipeline or Global Gateway Server, use the FIRMS Client to load some files from your favorite part type. (Load at least two files.)
   (b) If you company does NOT use the DataPipeline or Global Gateway Server, load at least two of your files STDF file from disk.
2. Open the Options->Reports Window and select NONE as the Group By variable.
3. Create a Cpk Pareto DataView.
   (a) Make note of the worst performing testt
4. Run the Characterization DataView
   (a) Look for the worst performing test.
      i. Does it yield poorly? _____
      ii. Is the Cp also bad? _____
5. Open the Options->Reports Window and select STDF_NAME as the Group By variable.
6. Run the Characterization DataView
   (a) Look for the worst performing test.
      i. Are one of the populations responsible for the poor Cpk? _____

End of First Day

Review Exercise:

1. Start pcFIRMS.
2. Run Analyze One from JumpStart
3. Run Merge and Analyze from JumpStart
4. Run Analyze Many from JumpStart
5. Create a Workspace named Review1.
6. Load two STDF files.
7. Run the Process Capability Study so that the report is similar to clicking the “Merge and Analyze” button on the JumpStart page.
8. Run the Process Capability Study so that the report is similar to clicking the “Analyze Many Files” button on the JumpStart page.
9. Run the Statistical Difference Study
10. Create a Workspace named Review2.
11. Load one STDF File.
12. Run the Test Elimination Study.
    (a) Are there any tests that you should investigate to further? _____
13. Create a Cpk Pareto
    (a) Save it to Word.
14. Create a Yield Pareto
    (a) Add it to the Word file.
15. Create a Characterization DataView.
    (a) Add it to the Word file.
16. Create a Histogram for the worst performing test as determined by Cpk.
    (a) Add it to the Word file.
    (b) Is the cause of the low Cpk value the Average or the Dispersion? _____
17. Create a Histogram for the worst performing test as determined by Yield.
    (a) Add it to the Word file.
    (b) Is this the same test as number 16? _____
    (c) Save the Word file and close it.
18. Write a definition for standard deviation:

_____

_____

19. What is the difference between Cp and Cpk?

_____

_____

Introduction to Design of Experiments

As applied to Semiconductor Manufacturing, Design of Experiments (DOE) is a process where the engineer can vary several test conditions to help:

- Determine the characteristics of a device
- Determine optimal manufacturing processes
- Configure optimal test conditions
- Verify Test Limits
- Set guardbanded test limits.

To gather data for DOE analysis, an engineer might use different corners of the wafer for different manufacturing processes, test at several different test temperatures, apply different levels of input voltage, or alter the frequency of the clock among many other possibilities.

Definitions of Terms

There are several terms which need to be defined before proceeding with this part of the training.

- Variable: The name of a Test Condition. Examples: VDD, Temp, or Freq.
- Units: The units of measure for the variable. Examples: V (Volts), C (Degrees Celsius), MHz (Megahertz).
- Setting: A value of a Test Condition. Example: VDD = 4.3V
- Level: One distinct set of variable settings. Example: VDD = 5.3 V, Temp = 0 C, Freq = 5 MHz

Example Experiment

In this example, the engineer has a device that he needs to characterize at three test temperatures and 2 frequencies. This results in six possible levels. A table of possible levels for this experiment would look like this:

Level	*Temp in C*	*Freq in MHz*
1	0	5
2	0	10
3	25	5
4	25	10
5	80	5
6	80	10

Collecting the Data

Then engineer must collect the data under controlled conditions so that the values for the test conditions are encoded into the data set properly. A wizard in pcFIRMS, called the Test Conditions Wizard aids the engineer in encoding the test conditions. But the engineer must know ahead of time how the data is organized.

Often you will be collecting the data in some combination of the following processes.

File Organization

In file organization, each STDF file represents a level. This is the simplest way to collect and encode the test conditions. It is most useful when all of the test conditions are changed at the test process and external to the test program. The process for collecting the data in this manner is as follows:

1. Set the test conditions to the settings for level 1.
2. Execute the test program on all devices.
3. Close the STDF file.
4. Set the test conditions to the settings for level 2.
5. Execute the test program on all devices.
6. Close STDF file
7. Repeat for all levels

Using the example above, this process would result in 6 STDF files; one for each level.

Part Organization

Part organization is useful when using wafer corners as part of the analysis. If wafer corner is the only Test Condition, the engineer can test the parts from each corner and save the data in separate STDF files. If each corner of the wafer is to have further test conditions applied at test (such as Test Temperature, VDD, or frequency) then each group of parts can be run sequentially.

Here is an example process:

1. Set the test conditions to the settings for level 1.
2. Execute the test program on the parts from the first corner.
3. Execute the test program on the parts from the second corner.
4. Repeat until all devices have been tested.
5. Close the STDF file.
6. Set the test conditions to the settings for level 2.
7. Execute the test program on the parts from the first corner.
8. Execute the test program on the parts from the second corner.
9. Repeat until all devices have been tested.
10. Close the STDF file.
11. Repeat for all levels

The wafer corner information will be encoded by part. The remaining test conditions can be encoded by file.

Test Organization

When the engineer needs to vary a test condition within the test program, it is necessary to encode the test condition by test number.

Here is the process:

1. Set the test conditions to the settings for level 1.
2. Put the first part in the test socket.
3. Run the test program for level 1.

4. Set the test conditions to the settings for level 2. (Often this change is made by the test program itself.
5. Run the test program for level 2.
6. Continue until all levels have been tested.
7. Put the next part in the socket.
8. Repeat until all parts are tested.

The test conditions altered by test will all be in the same STDF file.

Encoding the Test Conditions

pcFIRMS provides a Wizard to help you encode your test conditions into the Workspace. If you wish to write the test condition into the STDF file during test, you can do this also.

From Within Your Test Program

The variables and units are written to the USER_TXT field in the MIR record of the STDF file. The string should be pipe "|" delimited. Each field contains the variable and the units for that variable. Here is an example:

VDD@V|TEMP@C|FREQ@MHz

The settings are written into the TEST_TXT field of the PTR, MPR, and FTR records. This string is also pipe "|" delimited. Each field contains a value for the corresponding variable in the USER_TXT field. Here is an example:

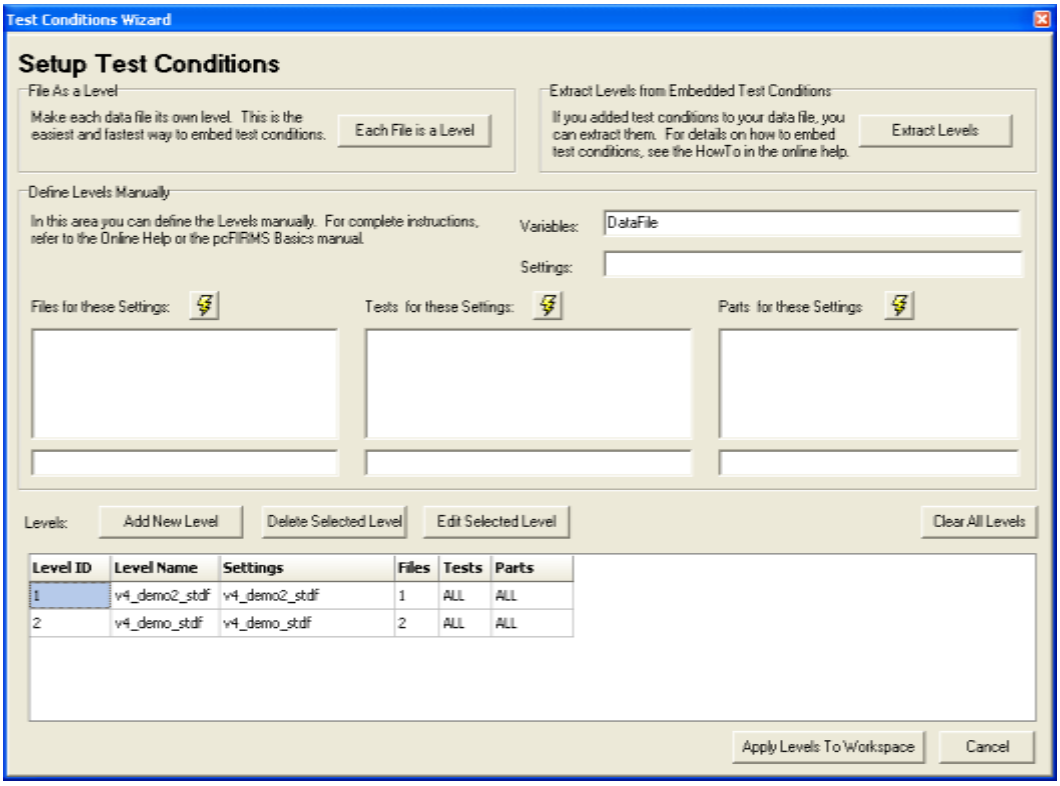
4.3|25|5.0

The Test Conditions Wizard

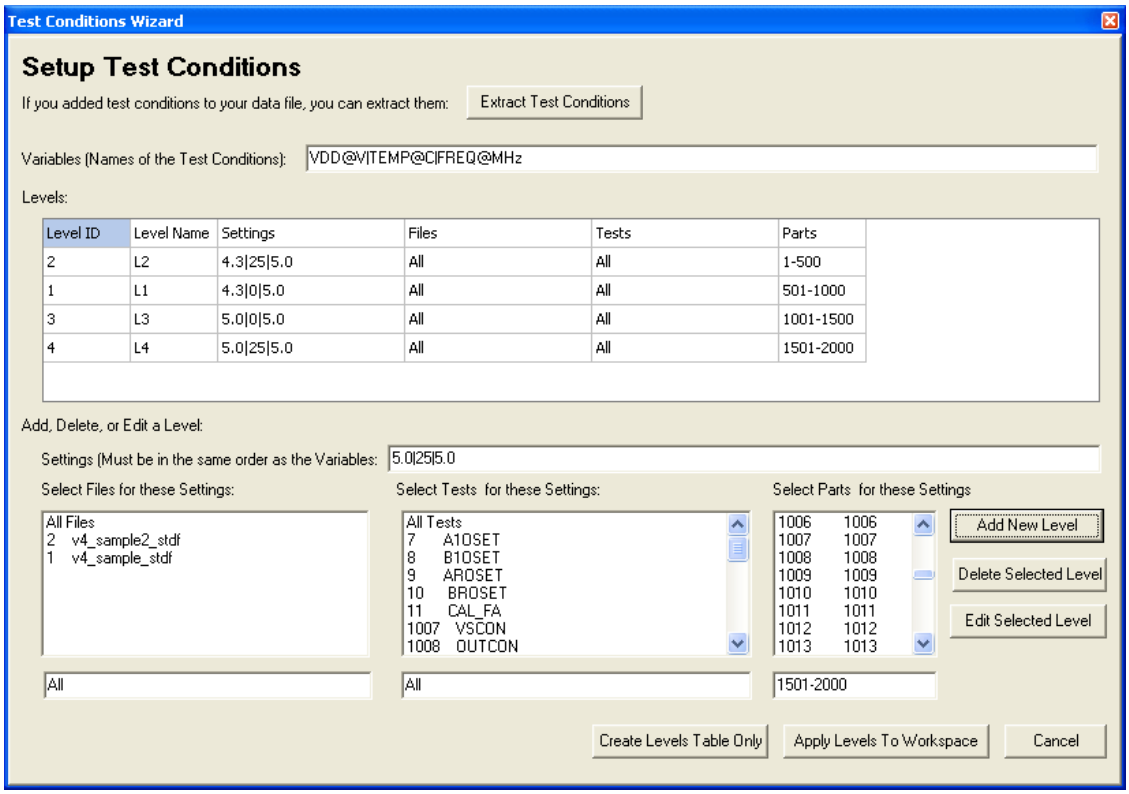
In the event your tester platform does not support writing strings to STDF fields, you tester does not produce STDF data, or you are unable to alter your test program to include the test conditions, pcFIRMS provides the Test Conditions Wizard allows you to encode your test conditions into the Workspace after the files are loaded into pcFIRMS.

Using the Test Conditions Wizard

1. Start pcFIRMS, Open or Create a Workspace, and load one or more data files. (See these sections in the pcFIRMS Online Help or Basic Training Manual for information.)
2. The Test Conditions Wizard is located in the Wizards Menu in the Main Menu of pcFIRMS. To start the wizard select Wizards->Test Conditions Wizard. The following window will appear.



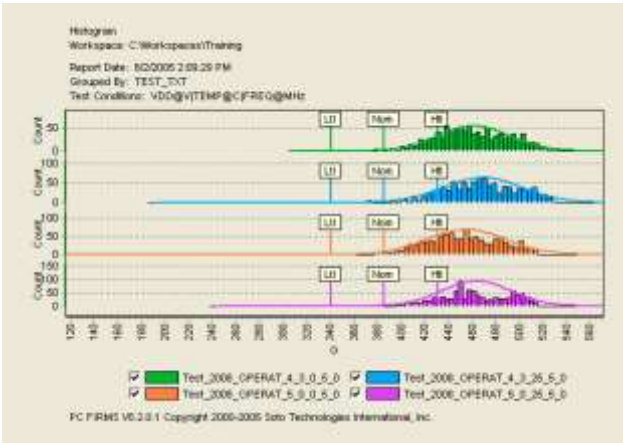
3. Enter the Variables as a pipe delimited list in the "Variables" box.
   a. Example: VDD@V|TEMP@C|FREQ@MHz
4. Enter the first level (group of settings) in the "Settings" box.
   b. Example: 4.3|25|5.0
5. Select the files, tests, and parts to which this Level applies.
6. Click the "Add New Level" button.
7. Repeat steps 2 - 4 until all Levels have been added. When you are finished, the wizard should appear as follows:



8. Click the "Add Levels to Workspace" button. After applying the levels, the Wizard will close.

Showing the Results with Histogram

Let's create a Histogram to show the results of the Test Conditions Wizard:



1. In the same Workspace, Select ChartViews->Characterization->Histogram
2. Set the Group By Variable to TEST_TXT. All your test conditions you defined should show in the Group By list.
3. Double-click on a test in the Test list to create the histograms. pcFIRMS will generate one histogram for each set of test conditions.

What is Changed By the Test Conditions Wizard

The Test Conditions Wizard saves the Test Condition information in two places in the Workspace:

1. The variable names from the "Test Conditions Variables" field are stored in the USER_TXT field of the Lot table.
2. A table called Levels is populated with the Level Names and their associated settings.
3. The test conditions are stored in the TEST_TXT field of the appropriate measurements in the Results or Multi Results table.

Note: Any information previously stored in these fields will be overwritten. The fields used have a limitation of 255 characters.

The information is also stored in a CSV formatted file in the Workspace directory.

The Design Characterization Wizard

The Design Characterization Wizard (DCW) combines components of some of the other pcFIRMS wizards plus adds some features of its own. The purpose of the wizard is:

- Provide a means to determine redundant or correlating tests under certain test conditions
- Calculate the best case test limits for each test
- Verify the test limits
- Show the effect of test conditions on each test.

Note: You must define Test Conditions to perform this type of analysis. For more information on defining Test Conditions, see the earlier section on Test Conditions in this document or in the Online Help System.

The DCW report contains two main parts:

1. Test Correlation: Locates redundant tests in the test program and creates X-Y scatter plots for redundant candidates
2. Guardbanded Test Limits: Computes limits based on a formula for each level and determines if the computed limits are outside the test limits. The widest computed limits are used to determine worst case statistics for all the tests. Histograms are created for each test grouped by level.

Test Correlation

The Test Correlation part of the DCW report contains two subsections:

1. Table of Correlation Coefficients
2. X-Y Linear Correlation Charts

Table of Correlation Coefficients

The DCW compares each test to all the other tests in the Workspace. Optionally, the populations can further be defined by a test condition. The columns of the table are the population name (test number, test name, and test conditions setting of each population) and the correlation coefficient.

X-Y Linear Correlation Charts

For each population with a correlation coefficient over a specified value (by default .9), an X-Y Linear Correlation Chart is created. These are displayed 2 to a page.

Guardbanded Test Limits

The Guardbanded Test Limits part of the DCW report contains three subsections:

1. Test Conditions Table
2. Guardbanded Limits Table
3. Individual Test Reports

Test Conditions Table

The Test Conditions Table is a copy of the Limits table from the Workspace. The level names, level ids, and test conditions values are included in this table.

Guardbanded Limits Table

The Guardbanded Limits Table contains the test lo limit and hi limit, computed lo limit and hi limit, nominal, and a comparison column for each test at each level. If an asterisk ("*") appears in the comparison column, this indicates that the computed limit for that test and level is outside the test limit.

Individual Test Reports

Each test in the Workspace has a page in the DCW report that includes a Guardbanded Histogram grouped by Level. The notes on the page include the minimum lo limit, maximum hi limit, lowest minimum result, highest maximum result, maximum sigma, minimum Cp, and minimum Cpk.

Cp and Cpk are calculated using the minimum lo limit and the maximum hi limit.

Using the Design Characterization Wizard

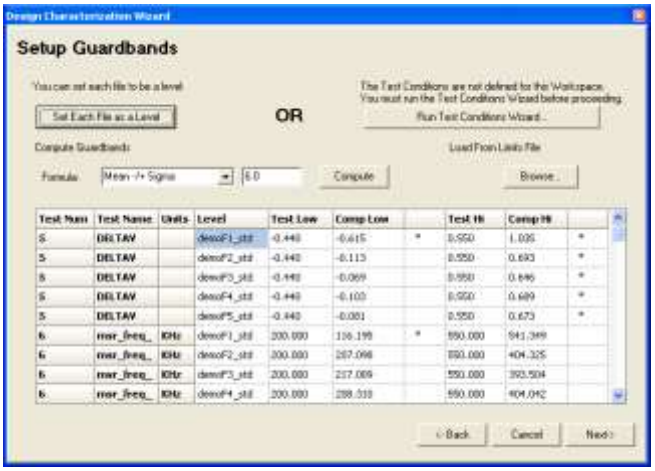
To start the Design Characterization Wizard (DCW) select Wizards->Characterization->Design Characterization from the menu system.

Getting Started page:

You can enter a definition file (if one was previously saved), then click the finish button.

You can enter a Report Name. The Report Name is used to name the output files for the report and as the heading. If no Report Name is entered, the contents of the Part Type field in the Lot table are used.

You can set the Wizard to "Simple" or "Advanced" to reduce the number of pages required to complete the Wizard. The Pages skipped by the "Simple" setting are the Include/Exclude pages. If using the "Simple" method, proceed to the "Setup Guardbands" section.



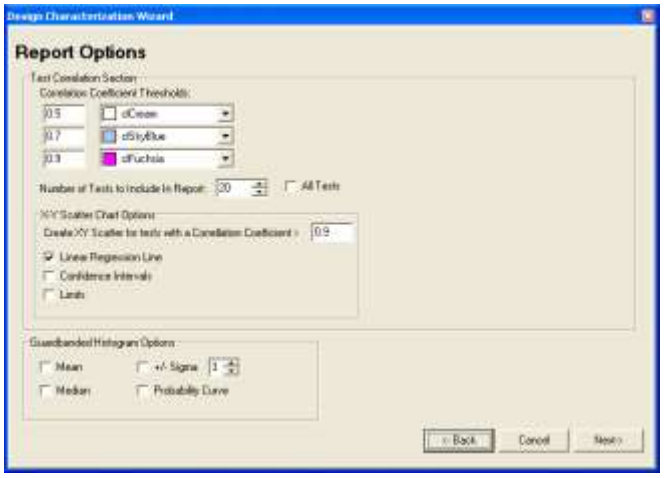
Setup Guardbands:

You must define Test Conditions for the DCW to work. If you have not previously defined Test Conditions for this Workspace, the easiest was to define Test Conditions is to click the "Set Each

File as Level" button. This creates and applies the levels and calculates the Guardbands based on the current formula selected. If you have many test conditions, click the "Run Test Conditions Wizard" button and define the Test Conditions.

If you use the Test Condition Wizard to define your test conditions, you must also define a formula for calculating the Guardbanded Limits or Load Limits from a File. To use a formula, select the desired formula in the Formula combo box, set the multiplier (if necessary), then click “Compute”.

Report Options:



On this page, you can set options for the different charts and tables in the report.

In the Test Correlation Section, you can set the three Correlation Coefficient Thresholds. The thresholds should proceed from lowest to highest down the page.

Values lower than the lowest threshold setting will not appear in the report.

Values greater than or equal to the lowest but less than the middle threshold will be the low color.

Values greater than or equal to the middle threshold but lower than the high threshold will be the middle color.

Values greater than or equal to the high threshold will be the high color.

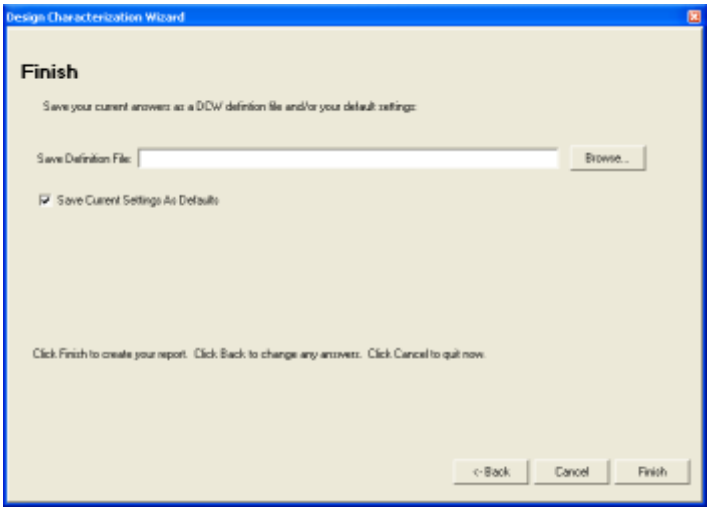
You can limit the total number of lines in the table by setting the "Number of Tests" and clicking off the "All Tests" check box.

X-Y Linear Correlation charts will be created for each correlation where the correlation coefficient is greater than the value indicated in the "Create X-Y Scatter" box.

To include the test limits on the X-Y charts, click the "Test Limits" check box ON.

By default, the Guardbanded Histograms will include maximum and minimum limits for all levels. You can display any of the optional curves in the Guardbanded Histograms by clicking the check box for that curve "ON".

Output Options:



You may select a custom logo JPEG file. If no logo file is specified the ${ProgramDir}\default_logo.jpg file is used.

You may elect to create the complete report in HTML, PDF, and/or Word. The tabular data may be created in Excel.

Finish:

You can save your current settings as the default settings by clicking the "Save Current Settings" check box "ON".

You can save your current settings in a definitions file to load the next time you run the Wizard by specifying a complete file path for the definitions file in the "Definitions File" box.

Click "Finish" to begin creating the DCW report.

Exercise 10

1. Create a new Workspace named Exercise_10a.
2. Load 3 STDF files.
3. Run the Design Characterization Report using each file as a level.
   (a) Turn off the Correlation portion of the Report.
4. Create a new Workspace named Exercise_8b.
5. Load 6 STDF files.
6. Run the Test Conditions Wizard
   (a) Encode the data from the Levels table on page 64.
7. Create a Cpk Pareto
8. Create a Histogram for the worst performing test grouped by TEST_TXT.
   (a) Which population affects the Cpk the most?
9. Run the Design Characterization Wizard.
   (a) On the Setup Guardbands page, just click the “Compute” button.

Take a Break

Virtual Retest

pcFIRMS provides the means to do “what if” analysis for different sets of limits. This is a very powerful tool for convincing designers, customers, and management that a slight move in the limits can have great financial rewards.

Limit Types

pcFIRMS supports four different limit types:

1. Test Limits: The limits are usually the limits used during the actual test process. pcFIRMS extracts these from the lo_limit and hi_limit fields of the PTR record in STDF files.
2. User Limits: User defined limits can be edited in the data tables themselves or loaded from a file.
3. Spec Limits: Typically, the limits that appear in the data sheet for the part type. pcFIRMS extracts these from the lo_spec and hi_spec fields of the PTR record in STDF files. They can also be loaded from a file.
4. Computed Limits: Calculated based on a formula. Currently, pcFIRMS will compute limits based on Normal Tolerance and mean +/- some number of sigma.

All limit types can be saved and loaded from ASCII files. Currently, you can copy the test limits into the user limits. All limits are stored in the Limits (LIM, firms_lim) table.

Copying Limits

To copy the test limits to the user limits:

1. Go to the Data page and the Limit table. (This is so you can watch the copy occur, you do not have to have the Limit table active for this to work.)
2. Select Database->Test Limits->Copy to User Limits from the menu system, and you’re done.

Saving Limits

You can save any of the limit types to a file. In this case, we will save the test limits:

1. Select Database->Test Limits->Save Test Limits from the menu system.
2. Navigate to your desktop and click “Save”.

The Limits File Format

The ASCII text file created when you use the Save Limits menu items in pcFIRMS is as follows:

1. The first several lines are a legend explaining the format of the file.
2. The test program name from the data file, whose limits were exported, appears in the line marked “job_nam”.
3. The remaining lines are formatted into 6 pipe (|) delimited fields:
   a. Test Number (TEST_NUM)
   b. Test Name (TEST_NAM)
   c. Units of measure (UNITS)
   d. Low Limit (LO_LIMIT)
   e. High Limit (HI_LIMIT)
   f. Relational Operator. (REL_OP)

   The relational operator is an integer used to change how the limits are interpreted by pcFIRMS:

   0 = LO_LIMIT < RESULT < HI_LIMIT
   1 = LO_LIMIT <= RESULT <= HI_LIMIT

2 = LO_LIMIT < RESULT
3 = LO_LIMIT <= RESULT
4 = RESULT < HI_LIMIT
5 = RESULT <= HI_LIMIT
-1 = DON'T CARE

Loading Limits

You can load any of the limit types from a file. In this case, we will load user limits. First, we need to edit the file we just export.

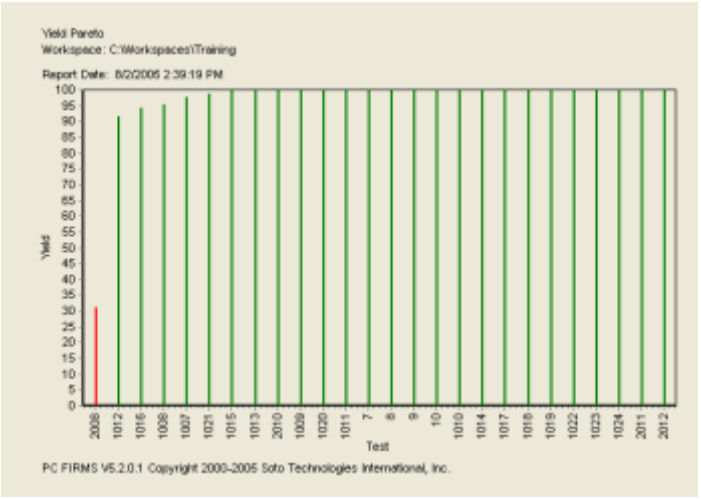
1. Open the limits file saved in the previous section in Notepad.
2. Make the following edits to the file:
   a. Change the lower limit of test 2008 to 100 and the upper limit to 1000.
   b. Add the relational operator of tests 7 – 10 as –1.
   c. Add the relational operator of test 1008 to be 0.
   d. Add the relational operator of tests 1007, 1009-1010 to be 4.
3. Save the file and exit Notepad.
4. In pcFIRMS, select Database->User Limits->Load User Limits.
5. Navigate to the file you edited in step 2 and click “Open”. The limits from the file will load into the User Limits fields of the Limits table.

TIP: Keep a library of test limit files in a known directory so you do not have to constantly rebuild them.

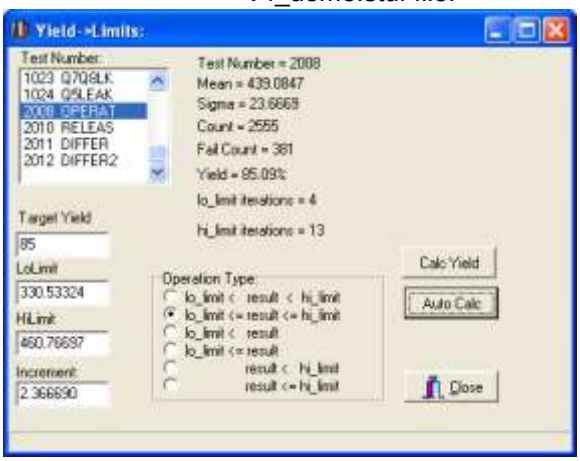
Running Virtual Retest

Once you have defined one or more limits, you are ready to run Virtual Retest. Virtual Retest checks each test on each part against the new limits and sets a part flag as to whether the each part passed or failed. The new limits are used to calculate all new statistics. Several of the charts and reports include the ability to set “limit type”. This determines which limit type is used for statistics and display in the chart and report.

Let’s do a run through of Virtual Retest in attempt to get a better yield from our v4_demo file.



1. Create a Workspace and load the v4_demo.stdf file.



2. Run the Yield Pareto.

a. We can clearly see that if we could get the yield for test 2008 up to around 85%, the yield for the entire process would increase. So what limits for test 2008 would increase the yield for this test to 85%? We can find out by running the Computed Limits Wizard

3. To run the Computed Limits Wizard select Wizards->Computed Limits Wizard from the pcFIRMS menu.

4. Select “Yield” and click the “Next” button.

5. Select test 2008 in the list and click the “Calc Yield” button. The test limits are displayed and the yield is shown to be 31% which matches the Yield Pareto we created.

6. Enter “85” as the target yield and click the “Auto Calc” button. After a few iterations, the program informs us that limits of about 330 and 460 will result in a yield of about 85%.

7. Close the wizard by clicking the “Close” button.

8. Now export the test limits to a file by selecting Database->Test Limits->Save Test Limits. Save the limits to the desktop of some other convenient location.

9. Open the file in Notepad or WordPad. You will need to add some relational operators and set the limits of test 2008 to our target limits. Here is what the lines should look like when you are done:

```
7 | A1OSET | V | -0.00999999977648258 | 0.00999999977648258 | -1
8 | B1OSET | V | -0.00999999977648258 | 0.00999999977648258 | -1
9 | AROSET | V | -0.00999999977648258 | 0.00999999977648258 | -1
10 | BROSET | V | -0.00999999977648258 | 0.00999999977648258 | -1
1007 | VSCON | V | -2 | -0.5 | 4
1008 | OUTCON | V | -2 | -0.5 | 0
1009 | TP1CON | V | -2 | -0.5 | 4
1010 | TP2CON | V | -2 | -0.5 | 4
1011 | TP3CON | V | 0.5 | 2 | 1
1012 | OUTHI | V | 2 | 16 | 1
1013 | IS6V | A | 0.00100000004749745 | 0.00600000005215406 | 1
1014 | IS16V | A | 0.00249999994412065 | 0.00989999994635582 | 1
1015 | VREG6V | V | 4.19999980926514 | 5.40000009536743 | 1
1016 | VREG8V | V | 5 | 5.59999990463257 | 1
1017 | DVREG | V | 0 | 0.5 | 1
1018 | ZDIODE | V | 0 | 0.200000002980232 | 1
1019 | IS34V | A | 0.00100000004749745 | 0.0149999996647239 | 1
1020 | R6 | OHM | 3300 | 10000 | 1
1021 | VOUT20 | V | 0 | 0.25 | 1
1022 | VOUT40 | V | 0 | 0.754999995231628 | 1
1023 | Q7Q8LK | A | 0 | 3.00000010611257E-7 | 1
1024 | Q5LEAK | A | 0 | 1.99999999495049E-6 | 1
2008 | OPERAT | G | 330 | 460 | 1
2010 | RELEAS | G | 270 | 360 | 1
2011 | DIFFER | G | 70 | 230 | 1
2012 | DIFFER2 | G | 70 | 230 | 1
```

10. Now load the limits into the User Limits by selecting Database->User Limits->Load User Limits from the menu system.

11. To run the Virtual Retest, select Wizard->Virtual Retest.

12. When asked if you wish to set only the Part Id flags, answer “Yes”.

13. When the process completes, the DataViews page will become active and a Virtual Retest DataView will be displayed. There will be data for all limit types that are present. To see the results of the limit change we made, scroll down to test 2008. You will see a change in the Cp, Cpk, and the yield. Our yield for test 2008 is now 84.3%!

The Virtual Retest ASCII Report

Once you have completed the Virtual Retest, you can use the Virtual Retest ASCII reports to get complete information about the change in limits. pcFIRMS includes fields in the Lot table for cost per die and cost units.

Click on the Data page and the Lot Table. Locate the fields named COST and COST_UNITS. Enter “.38” for the COST and “Dollars” for the COST_UNITS.

NOTE: You will need to click in another database field, or click the Post button to save the last value entered in the Workspace.

You are now ready run the Lot Virtual Retest report.

1. Select Reports->ASCII->Lot Virtual Retest from the menu system.
2. Clear any reports left over from previous sections.
3. Click the Create Report button.

Virtual Retest Cumulative Summary

Limit Type	Part Count	Good Count	Lot Yield	Dollars Made	Fail Count	Dollars Lost
Test	2555	571	22.30	216.98	1984	753.92
User	2555	1827	71.50	694.26	728	276.64

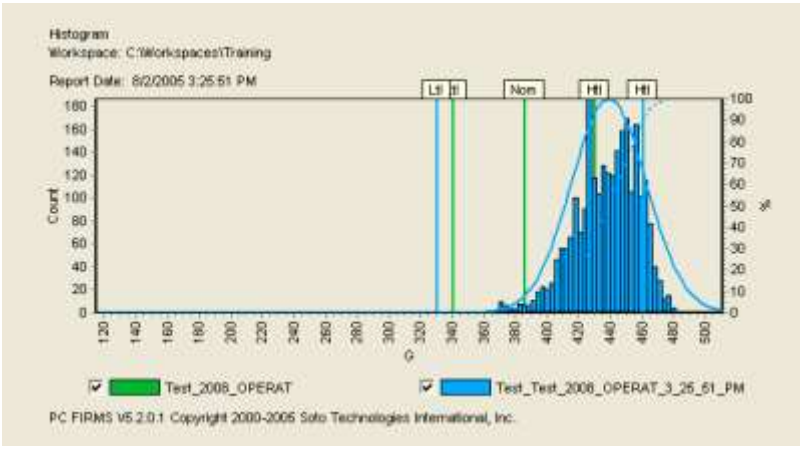
Failed Test Count Summary

Test Number	Test Name	Test Yield	User Yield
2008	OPERAT	31.10	84.30

Virtual Synopsis Summary

Test #	Test Name/ Limit Type	Units/ Lo Limit	Parts/ Hi Limit	Min/ Yield	Max/ Fails	Mean/ Cp	Std Dev/ Cpk
2008	OPERAT	G	2555	115.00	483.00	439.00	23.70
	Test	340.00	430.00	31.10	1761	0.63	-0.13
	User	330.00	460.00	84.30	400	0.92	0.29

With the original test limits we were throwing away $753.92 worth of product. With our change to test 2008, we are now only throwing away $276.64; a savings of almost $500 per wafer!



Virtual Retest in Charts

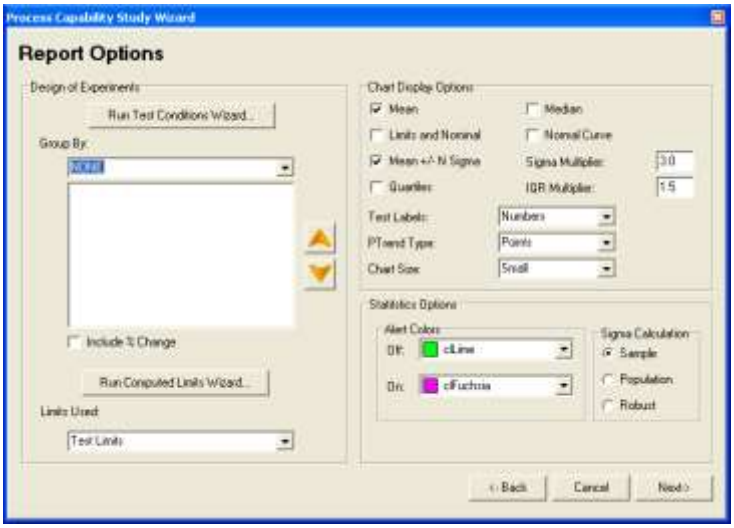
The limit types can be set in various charts, wafer maps, and wizards to make use the Virtual Retest results.

1. In the same Workspace where you ran the Virtual Retest example, create a histogram for test 2008.
2. Now, change the limit indicator from TEST LIMITS to USER LIMITS and double click test 2008 again.
3. You get a second histogram with statistics and limits representing the user limits.

Virtual Retest and the Wizards

Many of the Wizards support the use of the Virtual Retest results for statistics and charting. As an example of this let's run the Process Capability Study.

1. In the same Workspace where you ran the Virtual Retest example, select Wizards->Characterization->Process Capability Study from the menu.
2. Click "Next" until you get to the Report Options page.
3. Select "User Limits" as the Limits Used.
4. Complete the Wizard.



Exercise 11:

1. Create a new Workspace named “Exercise_11a”
2. Load v4_demo.stdf
3. Set up the limits to run Virtual Retest.
   (a) Copy the Test Limits to the User Limits
   (b) Edit the Limits for test 2008. Set them to 100 and 1000.
   (c) Set the Relational Operators as demonstrated in the class session above.
   (d) Save the User Limits to a file
   (e) Edit the file and expand the limits for test 1007
   (f) Load the edited file into the Spec limits
   (g) Compute limits using the +/- Sigma method. Set the Sigma multiplier to 6.
   (h) Edit the Lot Table and add a cost per die and cost units
4. Run Virtual Retest
5. Run the Lot Virtual Retest Report
6. Create a Cpk Pareto
7. Alter the Cpk Pareto to use the Computed Limits. Explain what you see.

_____

_____

_____

8. Create a Histogram using the Test Limits.
9. Add a histogram for the same test using the Computed Limits.

Working With Your Data

10. Create a new Workspace named “Exercise_11b”
11. Load 2 to 10 of files from your favorite part type.
12. Run the Merged Summary report.
    (a) Save the report.
13. Run the Merged Synopsis report
14. Load the Merged Summary report from step 10
    (a) Run the Merged Synopsis report again
    (b) Export the report to Word
    (c) Change the font to Courier New size 8.
    (d) Save the Word document.
15. Create a DataView of Hardware Bins.
    (a) Export the DataView to Excel

16. Create one of the other DataViews.
    (a) Export the DataView to the same Excel file.
17. Create a new Workspace and name it “Exercise_9C”.
18. Load one STDF file from a part type that yields less than 100%.
19. Run the Yield Pareto
20. Use the Computed Limits Wizard to compute limits that will raise the worst performing test to 100%.
21. Create User Limits using your calculations.
22. Run the Virtual Retest Wizard
23. Create a Histogram for the test using Test Limits.
24. Add a Histogram for the test using User Limits.
25. Export the Histogram to a Word File.
26. Add Cost and Cost Units to the Lot Table
27. Run the Lot Virtual Retest ASCII Report.
28. Save the results to a Word file.

Wafer Mapping

pcFIRMS supports summary and parametric wafer mapping for one or many wafers.

Single Wafer Maps

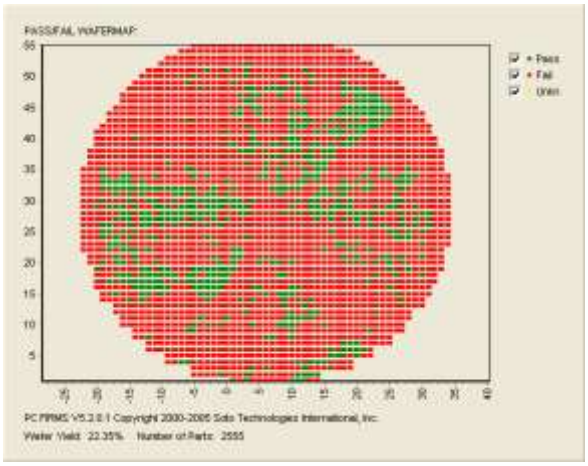
Summary Maps

Let's start with the simplest map; a Pass/Fail map for a single wafer.

Create a Workspace and load v4_demo.stdf.

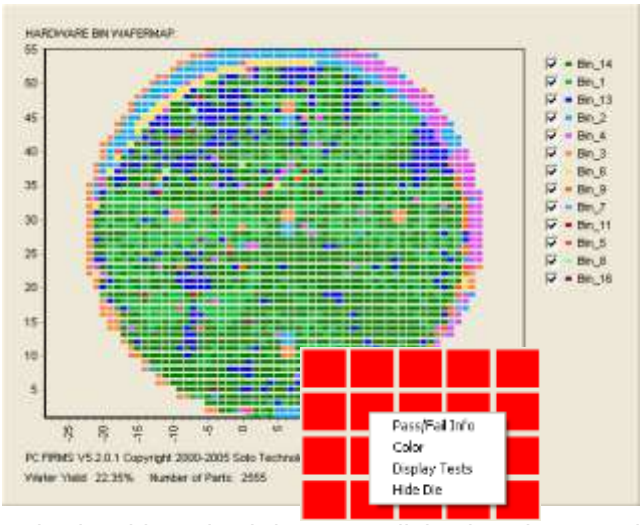
Select WaferView->Pass/Fail from the menu system.

By default green means pass, red means fail.



Let's step it up one notch and create a bin map. Select WaferView->Hardware Bins map from the menu system.

The Bin maps take each bin and assign it a color.

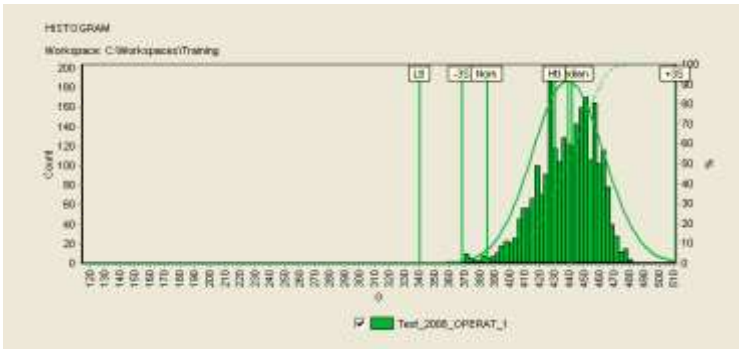


With both of these maps, you can right-click on each die and get some information.

The Info box contains the X-Y coordinates, Bin information, PASS/FAIL, and part number.

You can change the color associated with the category for the die.

You can display the tests executed on this die. Selecting this option brings up a dialog box that contains two tables: one with all the tests executed and one with the test that failed. These tables can be exported to Excel. You can also select a test in either of these tables and create Characterization charts, such as Histograms for the selected test.



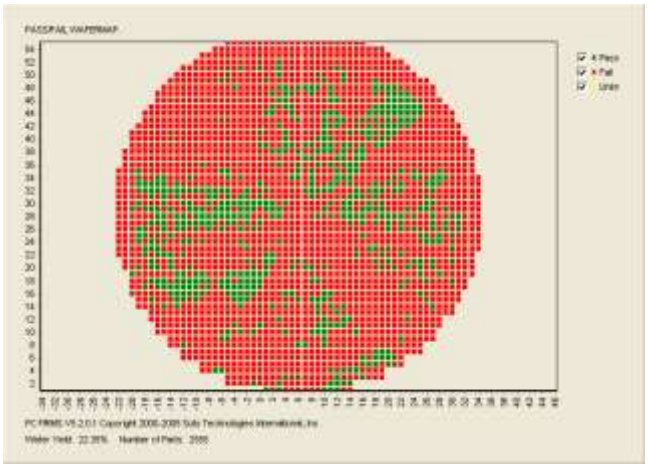
Virtual Retest and Summary Wafers

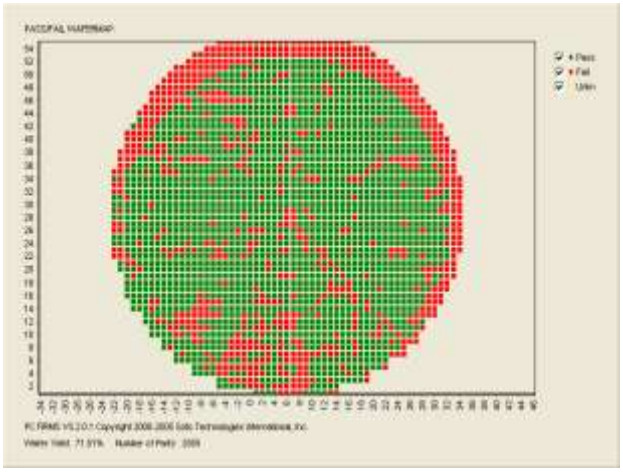
The Pass/Fail map supports the Virtual Retest results. You can see what a Pass/Fail map looks like after applying new limits. To try this, execute virtual retest or open a Workspace where you have executed Virtual Retest before.

Create a Pass/Fail Wafer Map.

Set the Flag to User.

You see a greater number of green die with the User flag than the Test flag.



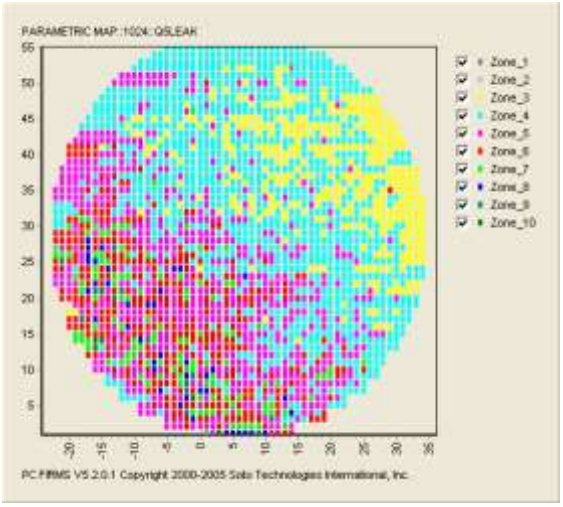


Parametric Maps

For single wafers, pcFIRMS offers two kinds of Parametric Maps: Analog and Parametric.

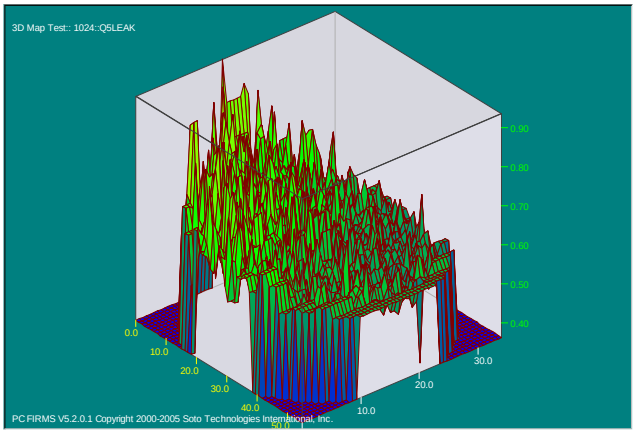
To create a Parametric Map:

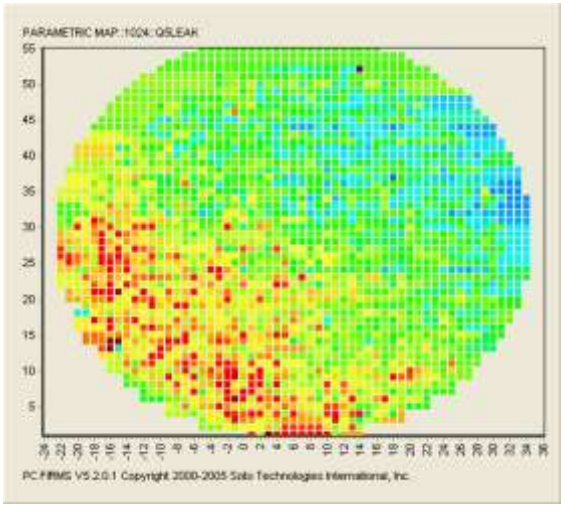
1. Select WaferViews->Parametric from the menu system.
2. Double-click the desired test in the Test List. For the example below, select test 1024.



Parametric Wafer Maps have three display modes. By default, the range of results is divided into 10 equal buckets, each of which is assigned a color.

Another display mode is Gradient where colors are assigned as a ratiometric comparison the wavelength



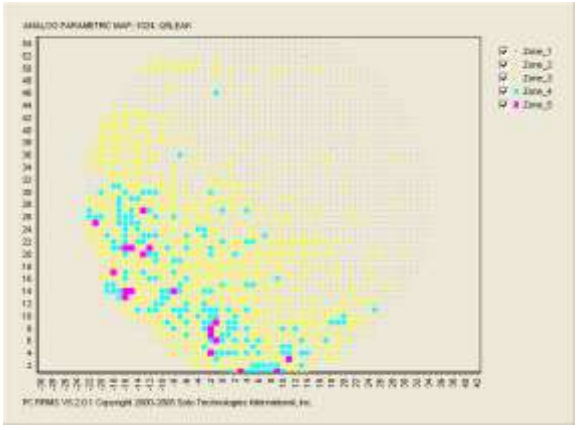


value to the measurement. The greater the measurement, the closer to the red end of spectrum it is. To activate the Gradient mode, click on the Gradient checkbox.

The last of the display modes for Parametric type wafer maps is 3D. Here a spatial analysis is made of the measurement and the greater the value of the

measurement, the greater the Z value in three dimensional space. To activate 3D display mode, click on the 3D checkbox.

The 3D wafermap can be rotated by dragging the wafer with the mouse. 2D wafers must be rotated using the radio buttons in the Options area of the wafer mapping tool. You can also flip 2D wafer across the axes so that if your prober has a different idea of what direction is positive and negative than pcFIRMS, you can make the wafer map look like the actual wafer.



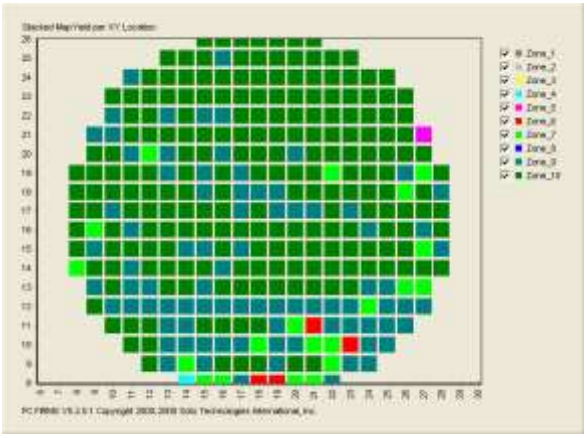
The Analog Parametric Map adjusts the size of the die ratiometrically to the value of the measurement; the larger the magnitude of the measurement, the larger the die.

Cumulative Maps

pcFIRMS provides the capability to look at stacks of maps. This is done by taking a statistic of all die from a certain X-Y location down through the stack. The Cumulative Maps are located in the WaferViews->Cumulative directory.

Let's create a Yield Cumulative Map.

1. Create a new Workspace.
2. Load 5 to 10 Demo files. (Do not use v4_demo files, the wafers do not line up properly.)
3. Select WaferViews->Cumulative->Yield.



Since cumulative wafers use a calculated floating point number for values, all of the cumulative maps have similar display modes and features to the Parametric Map.

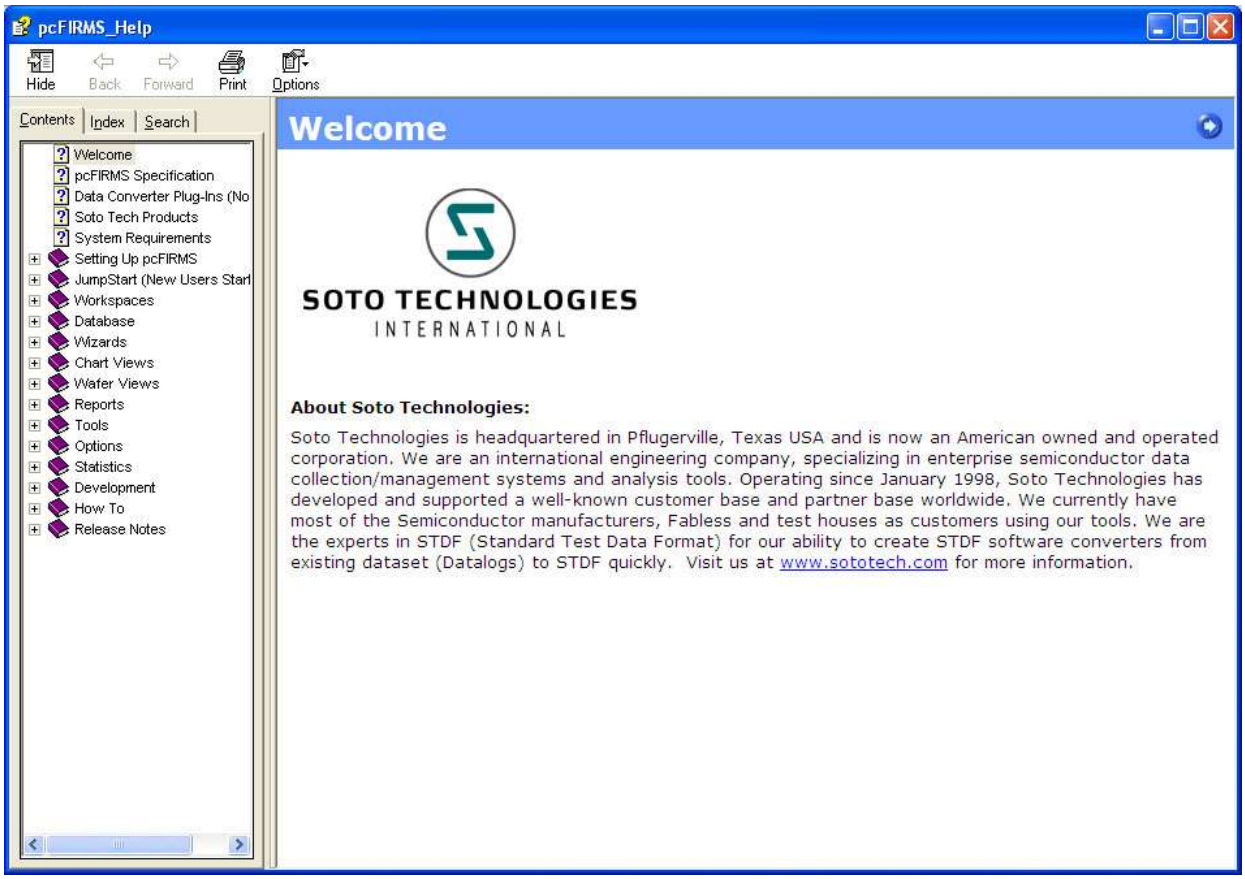
Using Online Help

pcFIRMS features a Compiled HTML based online help system.

To access Online Help, click the Help button on the JumpStart page or select Help->Help from the menu system.

You can then navigate in the Contents page, enter keywords in the Index page or words to search for in the Search page.

The Online Help is updated and expanded with every release of pcFIRMS. Please submit any additions or corrections to support@sototech.com.



Exercise 12:

1. In pcFIRMS, create a Workspace named “Exercise_11a”.
2. Load v4_demo.stdf.
3. Create the Hardware Bin Wafer Map.
    a. Export the Wafer Map to the Word Document.
4. Create a Histogram.
    a. Change the Title of the Histogram to include the test number.
    b. Turn the legend on.
    c. Export the Histogram to the same Word Document you created in step 5.
5. Find the formula for Cpk in the Online Help.
    a. Copy and paste the formula into the Word Document.
6. Create a Cpk Pareto.
    a. Export the Cpk Pareto to the same Word Document you created in step 5.
7. Create Parametric Wafer Map for each of the 6 worst performing tests.
    a. Alter the maps to use the Gradient display mode.
    b. Save each one into the Word Document.
8. Create a new Workspace named “Exercise_11b”.
9. Load 10 of the Demo Files.
10. Create a Cpk Pareto.
11. Create a Cpk Cumulative Wafer Map for the 5 worst performing tests.
    a. Export to a new Word file.
12. Run the Process Capability Study and Group By Node Name.

Break for Lunch

Comprehensive Review Exercise:

NOTE: Use YOUR data where ever possible.
Remember to close the reports after you view them.

1. Run “Analyze One File” from the JumpStart page.
2. Run “Analyze Many Files” from the JumpStart page
3. Run “Merge and Analyze” from JumpStart page on the same files as #2.
4. Create a new Workspace named “Review1”.
5. Load the data file you used in #1 above.
6. Run the Process Capability Study in such a way that it looks just like the report in #1.
7. Load two additional data files.
8. Run the Process Capability Study in such a way that it looks just like the report created in #2.
9. Run the Process Capability Study in such a way that it looks just like the report created in #3.
10. Run the Process Capability Study again.
    (a) Load demoF1, demoF2 and demoF3
    (b) Enter “Review” as the Report Name.
    (c) Set the Group By field to TST_TEMP
    (d) Set the reference group to 25C.
    (e) Turn on the % change option.
11. Create a new Workspace named “Review 2”.
12. Run the SDS against two data files.
13. Create a new Workspace named “Review 3”
14. Run TES against one data file.
15. Create a new Workspace named “Review 4”
16. Load 9 data files.
17. Run the Design Characterization Wizard for the following test conditions

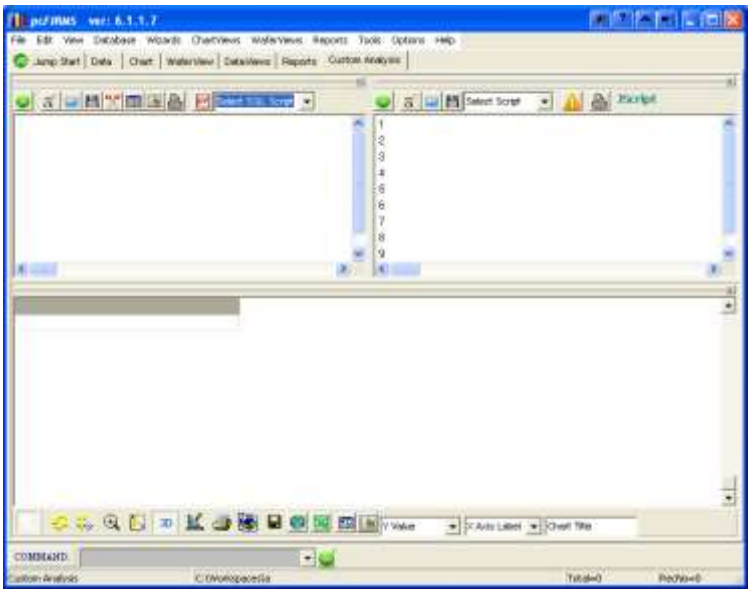
TEMP	VDD
0	4.3
0	5.0
0	5.5
25	4.3
25	5.0
25	5.5
80	4.3
80	5.0
80	5.5

18. Create a new Workspace named “Review 5”.
19. Load 10 demoF* STDF files.
20. Create the Cpk Cumulative wafer map

21. Export the normal, gradient, and 3D maps to Word.
22. Create a Cpl Pareto
23. Export it to Word
24. Create a Cpk Pareto
25. Export it to Word
26. By looking at the two charts, what is the first test whose mean is closest to the lower test limit?
27. Create a new Workspace named “Review 6”
28. Setup and run Virtual Retest on a data file so that the limits produce Cpks of 2.0 for all tests.

SQL Basics

This section of the document describes the Structured Query Language (SQL) that is used to create the custom charts in pcFIRMS.



Introduction

The Structured Query Language (SQL) is an ANSI standard language used to communicate with relational databases. The SQL engine included with pcFIRMS meets most of the requirements in the ANSI standard. We invite the user to attempt to use all ANSI standard commands associated with SQL in pcFIRMS and report any problems to support@sototech.com.

Extensive SQL Help is available in pcFIRMS at Help->Help SQL in the menu system.

The Select Statement

The basic command for querying a database in SQL is the SELECT statement. It consists of several clauses. The basic three clauses are:

1. The “SELECT” clause is used to indicate which columns you want displayed in your report.
2. The “FROM” clause determines which table(s) the data is in.
3. The keyword “WHERE” is used to limit the scope of the data returned.

We will add additional clauses to the SELECT statement in a later section.

SQL Conventions

There are some conventions used when programming in SQL. It is important to note that these are conventions only, SQL is not case sensitive, nor does it matter whether you put all the clauses on one line or break them up over multiple lines.

1. All keywords in upper case
2. All column and field names in lower case
3. The values of the columns much match both content and case.
4. Each clause on its own line
5. If the list of columns or tables is greater than 2, list them vertically.
6. Indent compound statements

Your First Query

To begin with, we need to create a Workspace and load the v4_demo.stdf file.

In these examples, we will build a report that contains the information necessary to build a Hardware Bin Pareto. Here are the SQL statements that we will begin with:

```
SELECT hbin_num,
       hbin_nam,
       hbin_cnt
  FROM firms_hbin
 WHERE hbin_cnt >0
   AND hbin_num < 65535
```

Enter this SQL program, called a query, in the SQL Editor of the Custom Analysis panel of pcFIRMS. Click the execute button. A report containing the requested columns will appear in the data grid.

In this query, we check for hbin_cnt > 0 because we do not wish to include any bins in our report that did not have any parts associated with them. We check for hbin_num < 65535 because this number is the invalid flag in the STDF Version 4 specification.

Grouping Functions

Now, load the v4_demo2.stdf so that both files are loaded.

If we have multiple STDF files in the pcFIRMS database, it is possible that some of the Bins may be repeated. In that event, we need to sum the bin counts. For this purpose we will use the SUM grouping function. Anytime you use a grouping function, we must also add a new clause called GROUP BY. In our case, we want the total number of bins for each occurrence of hbin_num and hbin_nam. So we list these columns in the GROUP BY clause.

```
SELECT hbin_num,
       hbin_nam,
       sum(hbin_cnt)
FROM firms_hbin
WHERE hbin_cnt >0
  AND hbin_num < 65535
GROUP BY hbin_num,
         hbin_nam
```

Calculating Percent

If we want to include a bin percentage in our report, it is necessary to perform a calculation. You can create a column in your report that is the result of a calculation in the SELECT clause:

```
SELECT hbin_num,
       hbin_nam,
       sum(hbin_cnt),
       sum(hbin_cnt)/sum(part_cnt) * 100
FROM firms_hbin,
     firms_lot
WHERE hbin_cnt >0
  AND hbin_cnt < 65535
  AND part_cnt > 0
  AND firms_hbin.ID = firms_lot.ID
GROUP BY hbin_num,
         hbin_nam
```

The calculation in the SELECT statement is carried out before creating the column in the report. Since we wanted to include part_cnt in our calculation, we had to add the firms_lot table to our FROM clause. In the WHERE clause, we added two lines:

1. Since we divide by part_cnt, we must be sure that part_cnt is greater than zero or we will get an error.
2. The ID is the field that relates the pcFIRMS database. The firms_hbin.ID = firms_lot.ID line in the WHERE clause performs a table join based on the key field. This line in a query is called a Table Join.

Column Aliases

You can rename the columns by adding a new name just after the column name in the SELECT statement. This makes your column headings easier to read.

```
SELECT hbin_num,
       hbin_nam,
       sum(hbin_cnt),
       sum(hbin_cnt)/sum(part_cnt) * 100 AS BinPercent
FROM firms_hbin,
     firms_lot
WHERE hbin_cnt >0
  AND hbin_num < 65535
  AND part_cnt > 0
  AND firms_hbin.ID = firms_lot.ID
GROUP BY hbin_num,
         hbin_nam
```

Sorting the Report

To make this report a pareto, we need to sort by either the bin_cnt or BinPercent depending on which value we are interested in. This is accomplished by adding the ORDER BY clause to the SELECT statement. Here is the resulting query:

```
SELECT hbin_num,
       hbin_nam,
       sum(hbin_cnt) BinCount,
       sum(hbin_cnt)/sum(part_cnt) * 100 BinPercent
FROM firms_hbin,
     firms_lot
WHERE hbin_cnt >0
  AND hbin_num < 65535
  AND part_cnt > 0
  AND firms_hbin.ID = firms_lot.ID
GROUP BY hbin_num,
         hbin_nam
ORDER BY BinCount DESC
```

Note that the keyword DESC is used to perform a descending sort. By default, sorts are ascending. You can explicitly declare a sort to be ascending by using the keyword ASC.

The pcFIRMS Database Schema

The pcFIRMS Database Schema is in the pcFIRMS Online Help. You will need this handy to know the names of the tables and fields.

Method 1:

1. Bring up the Online Help.
2. Click Workspaces.
3. Click Data Table Types.
4. This will show you all the tables in the pcFIRMS Database.
5. Click the Synopsis Table

Method 2:

1. Bring up the Online Help.
2. Click on the Search Tab.
3. Enter the field name you are looking for. For example l_cpk.
4. Click List Topics. You'll see several items listed. Find the Synopsis Table.

Here you find a listing and description of all the fields in the Synopsis table.

Exercise 13:

1. Create a new Workspace named “Exercise_13”.
2. Load 2 of your STDF files into the Workspace.
3. Do a manual calculate statistics. (Database->Calc Stats)
4. Create a query that lists the test number, test name, max, min, mean, sigma, Cp, and Cpk for all tests.
5. Alter the query so that it is sorted by Cpk.
6. Save the query so that you can reload it from the pull down menu.

Take a Break

Scripting Basics

In this section we will learn to use the pcFIRMS API set to select data and create graphs. pcFIRMS give you the option to use Perl, VBScript, or JScript. In the class, we will be using VBScript.

We will introduce many of the pcFIRMS APIs in this course. For a complete listing please consult the pcFIRMS Online Help.

The process for creating and using scripts is a simple one. On the Custom Analysis tab of pcFIRMS is a script editor. The currently selected scripting language is written in the tool bar of the editor. To select a different scripting language go to Options->Development->Script Language in the menu system and select the desired language. You then type your program into the scripting editor and click the execute button when done. 

You may save your script by selecting the save button.  The script will then be available in the script pull down menu.

JScript Basics

Before we get started, there are a few things you need to know about JScript.

1. Each statement should end with a semicolon (;). While this is not a requirement of JScript, it will keep your code so that it will work with PERL as well.
2. Variables are not declared.
3. Scalar variables are variables that hold a single value. Again, to keep your code compatible with PERL you should create and use by prefixing the variable name with a dollar sign ($).
4. Variables are assigned values using the equals sign (=).
5. When comparisons are performed in “if” statements and “while” loops, the double equals (==).
6. When concatenating strings together, use the plus “+” sign. This will NOT be compatible with PERL. The PERL concatenation character is the period “.”.

These items will become clearer to you as we progress.

Communicating With the User

One of the fundamental requirements of programming is communicating with the user. pcFIRMS provides two API’s that you may use to communicate with the user through dialog boxes:

1. ShowMessage(AnsiString):

   Display a message box with an OK button.

2. AnsiString InputBox(AnsiString ACaption, AnsiString APrompt, AnsiString Adefault)

   Display an input dialog box that enables the user to enter a string and returns the string.

So let’s get started. We want to start fresh, so create a new Workspace and then delete it.

1. Start pcFIRMS.
2. Select the Custom Analysis Tab.
3. Select Options->Development->Script Language->Perl.
4. Type the following into the Script Editor:

```
$myString = InputBox(“Name Entry”,”Please enter your name:”,”No Name”);
ShowMessage($myString);
```

5. Click the execute button in the script editor to execute the program.

This program creates a dialog box that permits the user to enter some text. The text is returned and stored in the scalar variable myString. Then, another dialog box is displayed that contains the string entered by the user.

Congratulations, you are now a pcFIRMS Perl programmer.

Creating a Workspace

In general, the process of using pcFIRMS is to create a Workspace, select certain STDF files, load them into pcFIRMS, select subset of the data, and create a report or chart. We will take each of these steps one at a time to create a complete program.

We will start by creating a Workspace. There are two APIs used to create a Workspace:

1. bool create_database()

   Produce a dialog box that allows the user to select an existing workspace or type in the name of a new workspace. If an existing workspace is selected, the workspace is loaded. If a new name is typed, a new workspace is created.

   This API will return 1 if it is successful or 0 if it fails to create the workspace for some reason.

2. bool create_database_q(AnsiString Db_name)

   Create a new pcFIRMS workspace if the named workspace does not exist. Open the workspace if the named workspace already exists.

This API will return 1 if it is successful or 0 if it fails to create the workspace for some reason.

If you have not already done so, create a directory called “Workspaces” in your C:\ drive, My Documents, your desktop, or some other convenient location. In the examples, the location is C:\.

1. Start pcFIRMS.
2. Select the Custom Analysis Tab
3. Select Options->Development->Script Language->JScript in the menu system
4. Enter the following code in the editor:

```
$status = create_database_q("C:\\Workspaces\\training");
if ($status == 0)
{
   ShowMessage("Workspace failed.");
   exit;
}
else
{
   ShowMessage("Workspace created.");
}
```

5. Execute the code.
6. Once the code has no problems, save it so that we can load it again later.

There are several concepts introduced here. In the first line of the script, we run the API to create the Workspace and capture the returned Boolean value in the scalar variable $status. We then use and if/else construct to check the status variable and display an appropriate message.

Loading STDF Files

Now let's load some STDF files. There are several APIs that are used for loading STDF files. In this section, we will load the files directly from a disk. Here are the two APIs that perform this function:

1. bool load_stdf()

   Produce a dialog box that allows the user to select STDF files. Loads the selected STDF files into the current database and calculates local statistics.

   This API will return 1 if it is successful or 0 if it fails to create the workspace for some reason.

2. bool load_stdf_q(AnsiString STDF_Name)

   Load an STDF file from a specific path. No graphical interface is displayed.

   This API will return 1 if it is successful or 0 if it fails to create the workspace for some reason.

In our first example we will load the STDF files using a GUI.

1. Start pcFIRMS and load the script you created in the first section.
2. Delete the workspace created in the last section
3. Alter the script so that it looks like the following:

```
$status = create_database_q("C:\\Workspaces\\training");
if ($status == 0)
{
   ShowMessage("Workspace failed.");
   exit;
}
$status = load_stdf();

if ($status == 0)
{
   ShowMessage("STDF Load failed.");
   exit;
}
ShowMessage("STDF Load successful.");
```

4. Execute the script
5. Save the script as "training".

Exercise 14:

1. Create and execute a script that does the following:
    i. Uses a dialog box to allow the user to create a workspace.
    ii. Automatically loads the v4_demo.stdf file.
    iii. Reports whether the database creation and load were successful.
2. Save this script as “Exercise_14”.
3. Break for lunch.

Selecting a Subset of the Data

There are several APIs that allow you to select data from the pcFIRMS Workspace. In this class, we will use the SQL APIs that allow you to setup and execute a query.

Before we create the workspace, we will add a step that deletes the workspace if it already exists. This API is:

delete_database_q(AnsiString DB_Name, int rmdir)

> Deletes the database located at the path indicated by DB_Name with no GUI. If rmdir is set to 0, the database directory is deleted. If rmdir is not 0 (zero), the database directory is not deleted.

Before we attempt to query the data, we must be sure that all statistics have been calculated. The API that accomplishes this is:

recalc_stats()

> Calculates local statistics based on the current exclude settings and limits for all STDF files in the database.

The APIs used for SQL are the following:

SQL_Clear()

> Clear the SQL buffer for a new SQL query.

SQL_Add(AnsiString sql_str)

> Add a string value which contains an SQL query.

SQL_Execute()

> Execute the added SQL query.

bool SQL_ReadBool(int column)

> Return the content of the indicated column number in the current SQL Query.

double SQL_ReadFloat(int column)

> Return the content of the indicated column number in the current SQL Query.

int SQL_ReadInt(int column)

> Return the content of the indicated column number in the current SQL Query.

AnsiString SQL_ReadString(int column)

> Return the content of the indicated column number in the current SQL Query

SQL_First()

> Set the Query Pointer to the first row returned by the current SQL Query.

SQL_Last()

> Set the Query Pointer to the last row returned by the current SQL Query.

SQL_Next()

> Set the Query Pointer to the next row returned by the current SQL Query.

SQL_Prior()

Set the Query Pointer to the previous row returned by the current SQL Query.

int SQL_RecordCount()

Return the number of records returned by the current SQL Query.

SQL_RecNo(int RecNo)

Set the Query Pointer to the indicated record number in the current SQL Query.

int SQL_cRecNo()

Return the current record number in the current SQL Query.

SQL_Exec(AnsiString TxtSQL)

Performs the function of clear, add and execute in one statement.

To add this next bit of code:

1. You need to open the training query we created in the last section.
2. Edit the code to look like the following:

```
delete_database_q("C:\\Workspaces\\training",0);
$status = create_database_q("C:\\Workspaces\\training");
if ($status == 0)
{
   ShowMessage("Workspace failed.");
   exit;
}

$status = load_stdf();

if ($status == 0)
{
   ShowMessage("STDF Load failed.");
   exit;
}
recalc_stats();
```

3. Execute the code.
4. Once the code executes with no errors, save the script.
5. Edit the code to look like the following:

```
delete_database_q("C:\\Workspaces\\training",0);
$status = create_database_q("C:\\Workspaces\\training");
if ($status == 0)
{
   ShowMessage("Workspace failed.");
   exit;
}

$status = load_stdf();

if ($status == 0)
{
   ShowMessage("STDF Load failed.");
   exit;
}
recalc_stats();

SQL_Clear();
SQL_Add("SELECT test_num, test_nam, l_cpk”);
```

```
SQL_Add("FROM firms_syn");
SQL_Add("WHERE l_cpk IS NOT NULL");
SQL_Add("ORDER BY l_cpk");
SQL_Execute();
```

6. Execute the code.
7. When the code complete successfully, save it.

Loading Data from the DataPipeline Server

The APIs that get data from the FIRMS DataPipeline Server work in several steps:

1. Connect to the server.
2. Get a list of STDF files based on a query.
3. Load the files from the server.

Here are the APIs associated with this process:

Connect_to_FIRMS(AnsiString username, AnsiString password, AnsiString database)

> Connects to the database indicated by "database" using the username indicated by "username" and password indicated by "password". The database is the service name of the ODBC connection configured for you system. See the pcFIRMS Administration manual for more details on FIRMS Client configuration.

int firms_stdf_list(AnsiString whereClause)

> Returns a list of STDF files matching the whereClause from the FIRMS DataPipeline Server and loads them into the FIRMS Client data grid. A connection to the Oracle database must be made prior to running this function.
>
> Returns 0 if the query processes with no errors.
>
> Returns Non-0 if an Oracle error occurred.

int Load_From_Server()

> Load the current list of STDF files from the FIRMS Server. This API initiates an FTP and a load_stdf_q. The current FTP configuration in the FIRMS Client is used.

int load_stdf_from_server(AnsiString stdf_name, AnsiString test_list)

> Load the STDF files indicated by stdf_name from the FIRMS DataPipeline Server, loading only those tests that are in test_list. Stdf_name may contain wildcard characters '%'. The API then loads all files that match the stdf_name.
>
> Returns 0 if load was successful. Returns 1 if the load was unsuccessful.

Practice

Let's work from our old script and create a new one that uses FIRMS Client APIs to load the data. Here is the code. You will need to replace <username> with your oracle username, <password> with your oracle password, <database> with your ODBC service name for the FIRMS DataPipeline Server, and <whereClause> with a where clause that makes since for your parts.

```
delete_database_q("C:\\Workspaces\\training",0);
$status = create_database_q("C:\\Workspaces\\training");
if ($status == 0)
{
   ShowMessage("Workspace failed.");
   exit;
}
```

```
Connect_to_FIRMS("<username>","<password>","<database>");

$status = firms_stdf_list("<whereClause>");
if($status == 0)
{
   ShowMessage("Oracle error occurred during file retrieval.");
   exit;
}

$status = Load_From_Server();
if($status !== 0)
{
   ShowMessage("Load from server failed.");
   exit;
}

recalc_stats();
SQL_Clear();
SQL_Add("SELECT test_num, test_nam, l_cpk”);
SQL_Add(“FROM firms_syn“);
SQL_Add(“WHERE l_cpk IS NOT NULL”);
SQL_Add(“ORDER BY l_cpk");
SQL_Execute();
```

Exercise 15

1. Create and execute a PERL script that does the following:
    i. Creates a workspace.
    ii. Prompts the user for a part type.
    iii. Loads 2 to 5 files that part type from the DataPipeline Server.
    iv. Reports whether the database creation and load were successful.
    v. Calculates the Statistics
    vi. Queries the database for test_num, test_nam, and Cpk.
2. Save this script as “Exercise_15”.
3. Take a 15 minute break.

Creating a Chart

NOTE: The examples from this point on use the local STDF load version of the script. If you wish to continue using the FIRMS Client version, you may, but your results will differ from the examples.

pcFIRMS provides several APIs to create, save, and edit a chart. In this section, we will add code to create a chart from the data we collected in the previous section. We also introduce the Perl FOR loop.

The syntax for a Perl for loop:

```
for (initial value; comparison, value increment)
{
   statements;
}
```

The initial value section is where we set our loop index to its beginning value.
The comparison section contains the comparison that determines the exit criteria of the loop.
The value increment is where the loop index variable is incremented.

Here are the API's used to create and edit the chart:

chrt(AnsiString chrt_name)

Create an empty chart with the given name.

series(AnsiString chrt_name, AnsiString series_name, int stype)

Creates a series of the given series name of type indicated to the chart with the given chart name.

Possible stypes:
0 = bar
1 = line
2 = point

add(AnsiString chrt_name, AnsiString series_name, double value, AnsiString user_label)

Add the given value as a data point to the series of series name of chart of chart name. User label is the X Axis label for the data point. Use for bar and line graphs.

chrt_title_clr(AnsiString chrt_name)

Clear the title of the given chart.

chrt_title_add(AnsiString chrt_name, AnsiString text)

Append the text to the title of the chart of chart name.

Practice

1. Create a workspace, load the v4_demo.stdf and v4_demo2.stdf files, and load the training.pl Perl script.
2. Edit the code to look like the following:

```
delete_database_q("C:\\Workspaces\\training",0);
$status = create_database_q("C:\\Workspaces\\training");
if ($status == 0)
{
   ShowMessage("Workspace failed.");
   exit;
}
```

```
$status = load_stdf();
if ($status == 0)
{
   ShowMessage("STDF Load failed.");
   exit;
}
ShowMessage("STDF Load successful.");
recalc_stats();
SQL_Clear();
SQL_Add("SELECT test_num, test_nam, l_cpk ");
SQL_Add("FROM firms_syn ");
SQL_Add("WHERE l_cpk != 0");
SQL_Add("ORDER BY l_cpk");
SQL_Execute();
SQL_First();
chrt("MyChart");
series("MyChart","MySeries",0);
for ($i = 1; $i <= SQL_RecordCount(); $i++)
{
   add("MyChart","MySeries",SQL_ReadFloat(2), SQL_ReadString(1));
   SQL_Next();
}
SQL_Clear();
SQL_Add("SELECT part_typ, lot_id ");
SQL_Add("FROM firms_lot");
SQL_Execute();
chrt_title_clr("MyChart");
chrt_title_add("MyChart","CPK PARETO FOR");
chrt_title_add("MyChart","Part Type:  "+SQL_ReadString(0));
chrt_title_add("MyChart","Lot ID   :  "+SQL_ReadString(1));
```

Once the code completes successfully, save it.

Exercise 16:

1. Create and execute a PERL script that does the following:
   i. Creates a workspace.
   ii. Prompts the user for a part type.
   iii. Loads 1 file from that part type from the DataPipeline Server.
   iv. Creates a Cpk Pareto Chart
2. Save this script as “Exercise_16”.

Subroutines in PERL

One of the advantages to using PERL over VBScript or JScript is the availability of subroutines. This means you can write several smaller programs that can then be reused.

PERL offers many ways to declare and define subroutines. For further information on this subject, we suggest reading *Programming PERL* from O'Reilly (www.oreilly.com).

Declaring a Subroutine

The keyword **sub** is used to declare and/or define a subroutine in PERL. PERL does not support named formal parameters but the arguments passed to a subroutine are stored in the array @_. We can use **my** to extract the values.

Here is an example:

```
sub display
{
   my ($message) = @_;
   ShowMessage($message);
}

$test = "Hello";
$test2 = "Goodbye";
display($test);
display($test2);
```

In this example, a subroutine named display is created that displays the scaler string that is passed to it. We then call the subroutine with two different strings.

An Example with Charts

Here is a second, more useful example. Here we create a histogram for every test number between 2008 and 2012.

```
delete_database_q("C:\\workspace\\training",0);
$status = create_database_q("C:\\workspace\\training");
if ($status = 0)
{
   ShowMessage("Workspace failed.");
   exit;
}

$status = load_stdf();

for ($i = 2008; $i <= 2012; $i++)
{
   $Name = "Hist".$i;
   newChart($Name,$i);
}
ShowMessage("Done with Loop");

sub newChart
{
  my ($Chartname, $test) = @_;
  stats_by_group("NONE", "NONE",$test);
  chrt($Chartname);
  chrt_title_clr($Chartname);
  chrt_title_add($Chartname,$test);
  $rval = add_hist($Chartname,"NONE","NONE",$test,
```

```
                                    1,1,1,3,1,1,1,1);
                }
```

Appendix: Answers to Statistical Exercises

From Exercise 2:

1. Answers:
   a) Mean = 79,999,200,
   b) Median = 3,600,000
   c) range = 359,964,000
   d) standard deviation = 150,815,887.9
   e) sample variance = 2.27E+16
   f) Q1 = 198,000
   g) Q3 = 198,000,000
   h) IQR = 197,802,000
   i) df = 4
2. Find the mean, median, range, sample standard deviation, and variance of the following data: 1, 2, 3, 4, 5, 6, 7, 8.
   a) mean = 4.5
   b) median = 4.5
   c) range = 7.0
   d) standard deviation = 2.29
   e) sample variance = 5.25
   f) 5 Number summary = Min = 1, Q1 = 2.5, Median = 4.5, Q3 = 6.5, Max = 8
3. A certain test has a mean of 29. Calculate the *z*-score for this test's mean relative to the historic mean of 21.0 and standard deviation of 4.

   In this case, the mean values are the measurements. We use the Z-score formula. The current mean is 29, historical mean is 21.0. So the equation looks like this:

   (29-21)/4.7 = 1.70
4. Given the fact that 50% of a normally distributed data set is within 0.675 standard deviations of the mean, estimate Q_1, Q_3, and the interquartile range for a test with a mean of 29 and standard deviation of 3.0. Would a measurement of 36 be unusual?

   The Z-Score is the distance from the mean in standard deviations. We are given the Z-score as 0.675. Since the Z-Score can be both above and below the mean, we must calculate the statistics for both +/- the standard deviation. Since we are given the mean and standard deviation, we can estimate Q1 and Q3 with the following equation:

   $z = \pm 0.675 = (x - 29)/3.0m$

   $x = 26.975$ or 31.025

   $Q_1 = 27.0$

   $Q_3 = 31.0$

IQR = Q_3 - Q_1 = 31.0 - 27.0 = 4.0

A measurement is unusual if it is more than 2 standard deviations from the mean. The mean is 29, and the standard deviation is 3.0, so we can calculate the “usual” barrier with the following equation:

29 + 2s = 29 + 6.0 = 35.0

35.0 < 36, so yes, this is an unusual measurement.