Software Training Guide

ReliaSoft's
ALTA 7

Born of ReliaSoft ingenuity,
Bred to set new standards…

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1 ALTA 7 Training Guide

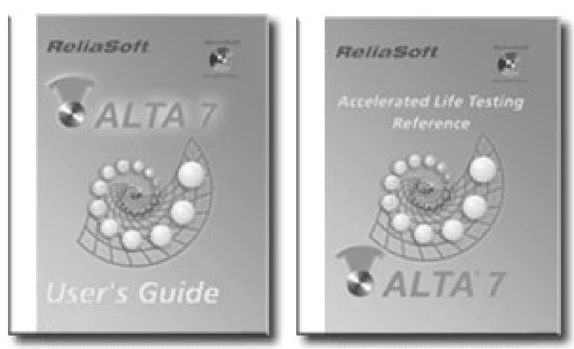
1.1 About this Training Guide

This training guide is intended to provide you with many examples of ALTA 7 Standard (ALTA 7) and ALTA 7 PRO. It begins with step-by-step examples and then proceeds into more advanced examples and questions, including examples specific to ALTA 7 PRO. At any time during the training, please feel free to ask the instructor(s) any questions you might have.

If you have a demonstration version of ALTA 7 or ALTA 7 PRO, you may not be able to save your work for these examples. For this reason, you may wish to work with the sample projects that are shipped with the software instead of creating your own. The name of the file that is shipped with the application and the Folio used is given for each example in this training guide.

1.2 ALTA 7 Documentation

Like all of ReliaSoft's standard software products, ALTA 7 is shipped with detailed printed documentation on the product (*ALTA 7 User's Guide*) and the underlying principles and theory (*ReliaSoft's Accelerated Life Testing Reference*). This training guide is intended to be a supplement to those references.



1.3 Contacting ReliaSoft

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2 Features Summary

2.1 ALTA 7 Standard and ALTA 7 PRO

ReliaSoft offers two versions of ALTA 7, Standard (ALTA 7) and Professional (ALTA 7 PRO). ALTA 7 Standard includes all the analytical capabilities of ALTA 6 along with many upgrades and additions. The standard version is an entry-level tool for the reliability professional interested in basic quantitative accelerated life testing applications. ALTA 7 PRO includes all of the features of the standard version and unleashes years of research and development in implementing advanced techniques, including the ability to analyze time-varying stresses.

The examples included in this training guide have been designed to introduce you to the features available in ALTA 7 and ALTA 7 PRO. This section presents a brief summary of the features in both versions of ALTA 7. If you are already familiar with ALTA's features, you can proceed to Chapter 3, First Steps.

2.2 What’s New in Version 7

ALTA 7 provides more extensive planning, analysis and reporting capabilities than ever before, all in an easy-to-use package. Specific additions and enhancements include:

- **Enhanced Interface**: This intuitive, flexible and completely integrated work center, designed around the Data Folio (similar to an Excel® worksheet), allows you to manage multiple analysis folios and related information all together in a single file. Using the “Project Explorer” approach that is employed in ReliaSoft’s Weibull++ and BlockSim software, ALTA now provides an intuitive, hierarchical (tree) structure to allow you to view and manage one or many standard folios, specialized folios, plot sheets, stress profiles, spreadsheet reports and/or attached documents per project. At the same time, the new work environment “stays true to its roots” so that users who are familiar with previous versions of the software will be able to enter and analyze data in much the same way as always.

- **Additional Life Data Types** are now supported. In addition to complete and right censored data, you can now enter interval censored and/or left censored data as well. Data can be entered either individually or in groups.
- **New Life-Stress Modeling Capabilities:** In addition to the Arrhenius, Eyring, inverse power law, temperature-humidity and temperature-nonthermal life-stress models available in ALTA 7 Standard, ALTA 7 PRO provides the proportional hazards, general log-linear and cumulative damage models. ALTA 7 PRO now also offers the generalized Eyring model. In addition, the cumulative damage model now supports multiple time-varying stresses.
- **Additional Degradation Analysis Models:** In addition to the linear, exponential, power and logarithmic degradation analysis models, ALTA 7 now provides the Gompertz and Lloyd-Lipow models as well.
- **Stress Profiles** are now managed in a Folio-type format, making it easy to manage multiple time-varying stresses within a single project. Instead of managing the Stress Profiles in libraries, you can select one, some or all to quickly and simply import from/export to other projects.
- **Accelerated Life Test Planning Utility** helps you design an efficient testing plan, accounting for the type of stress, method of applying stress, stress levels, number of units to be tested at each stress level and an applicable accelerated life testing model that relates the failure times at accelerated conditions to those at normal conditions.
- **Template-Based Report Generation** allows you to create and format reports with ease, using the same powerful tools and functions available in General Spreadsheets. Save your reports as templates for re-use, or use one of the templates included with the software.
- **Integration with Weibull++ 7:** If you have Weibull++ 7.5 or later installed on your computer, the applications will work in concert. Include all of the analysis types available in both ALTA and Weibull++ in a single project and switch between applications with the click of a button!

2.3 All the Tools You Need for Accelerated Life Testing Analysis

ALTA provides all of the tools that you need for accelerated life testing analysis, including flexible options for data type, life-stress model and lifetime distribution.

2.3.1 Support for All Life Data Types

ALTA 7 now supports all life data types, including interval and left censored data, new in Version 7. You can also alter the data type in the current Standard Folio Data Sheet at any time with the Alter Data Type command.

The data types available in ALTA 7 include:

- **Non-Grouped Data Entry**

    Times-to-failure data (non-censored)

    Times-to-failure with right censored (suspended) data

    Times-to-failure with interval and/or left censored data

- **Grouped Data Entry**

    Times-to-failure data (non-censored)

    Times-to-failure with right censored (suspended) data

Times-to-failure with interval and/or left censored data

2.3.2 Available Life-Stress Models and Life Distributions

ALTA 7 supports the time-independent one or two stress Arrhenius, Eyring, inverse power law, temperature-humidity and temperature-nonthermal life-stress models. You can select to solve these life-stress models with an underlying Weibull, exponential or lognormal life distribution. Maximum likelihood estimation (MLE) is used for all parameter calculations.

In addition, ALTA 7 PRO offers four additional life-stress models: generalized Eyring, proportional hazards, general log-linear and cumulative damage.

The generalized Eyring model allows you to analyze data with two stresses and considers the interaction between the stresses. The flexible general log-linear model allows you to analyze data with up to eight stress types and to specify an exponential, Arrhenius or power transformation for each stress. The proportional hazards model also allows you to analyze data with up to eight stress types using the exponential relation and allows the use of zero as a stress value. The cumulative damage model allows you to analyze data with up to eight stress levels that vary with time and to specify an exponential, Arrhenius or power transformation for each stress.

Once you have selected a life-stress model, you can use ReliaSoft's Distribution Wizard to determine the best life distribution for your current data. The Distribution Wizard estimates the parameters for each of the selected distributions and compares the log-likelihood values, then recommends the one that best fits your data set. You can use Monte Carlo simulation to generate sample data sets based on any of the supported life-stress models and lifetime distributions. This can include complete data, right censored, interval censored and/or left censored data points, according to your specifications.

2.3.2.1 Theory Help

Theory help is available for each life-stress model, underlying life distribution and plot type to better help you understand how ALTA works and how its functions apply to your data. Just click the Theory help button next to your selection and a window will appear with a brief overview of the principles and theory behind your selection.

2.3.3 Managing Stresses

ALTA 7 offers several simple yet powerful ways manage the stress types and stress levels in your data sets.

- You can view or modify the use stress level(s) at any point in the analysis using the Use Stress Level widow.
- You can specify which stress columns are considered when the parameters are calculated in the Select Stress Columns window.
- You can select a stress transformation for each of the selected stresses to be used when the parameters are calculated with the general log-linear life-stress model or the cumulative damage life-stress model in the Stress Transformation window. The general log-linear and cumulative damage models are available only in ALTA 7 PRO.
- In ALTA 7 PRO, you can create profiles for stresses that vary over a period of time, such as step-stresses, ramp stresses and any other quantifiable stress profile. You can assign these stress profiles to data points in the current Standard Folio, which will be analyzed when the parameters are calculated. The stress profiles can also be used in the Monte Carlo data simulation utility and the SimuMatic tool.

2.3.4 Accelerated Life Test Plans

Version 7 introduces the new Accelerated Life Test Plans utility, designed to assist you in planning an accelerated life test that will yield the closest possible estimate of product life at the desired percentile and use stress level. Extensive customization options allow you to specify the type of test plan you want to create, whether to account for one or two stresses, the number of units to be tested at each stress level, the length of the test, etc. The Test Plan will include the stress levels to use in the test, the percentage of total test units that should be tested at each of those stress levels, an estimate of the time when the specified percentage of units will have failed at use stress, and more.

2.3.5 Degradation Analysis

Degradation Analysis Folios allow you to extrapolate the failure times of a product based on its performance (or degradation) over a period of time under accelerated stress conditions. You can transfer the extrapolated failure times into a Standard Folio for further analysis or integrate the two types of folios so that changes in the Degradation Analysis Folio will automatically be reflected in the Standard Folio.

2.4 Results and Plots at the Click of a Button

Always a strength of ALTA, Version 7 continues to make it easy to calculate and present your analysis results in ways that effectively support decision-making.

2.4.1 Quick Calculation Pad

The Quick Calculation Pad (QCP) provides a quick, easy and accurate way for you to obtain results for the most frequently asked reliability questions. This includes Reliability or Probability of Failure, Failure Rate, Warranty Time for a given reliability, B(X) Life, Acceleration Factor and Mean Life calculations. The utility also returns the conditional reliability or probability of failure given the starting age.

2.4.2 Plots and Graphics to Showcase Your Analyses

ALTA continues to offer unparalleled plotting capabilities to demonstrate your analyses visually. You can generate probability, use level, reliability vs. time, unreliability vs. time, *pdf*, failure rate vs. time, life vs. stress, standard deviation vs. stress, acceleration factor vs. stress and residuals plots with the click of a button. The Plot Setup allows you to configure the appearance of plot output and the software also provides a Chart Wizard to create your own custom charts. All plot graphics are metafiles that can be pasted or inserted into other reports and presentations.

The MultiPlot makes it easy to compare analyses by automatically plotting the results for multiple data sets together in the same plot. The Side-by-Side Plots utility allows you to view (and print) multiple plots for a given data set side-by-side. For example, you may want to show the probability, reliability, *pdf* and failure rate plots for a given analysis together in the same window. Alternatively, you may wish to compare the probability or *pdf* plots for a given data set when analyzed with different life-stress models or distributions. Simply select the combination that meets your analysis/reporting needs. You can use RS Draw, ReliaSoft's integrated metafile graphics editor, to edit and annotate the plots generated by ALTA. This utility allows you to insert text, highlight a point or line, mark the coordinates of a point, and much more.

In addition, you can use ReliaSoft's 3D Plot utility to generate a variety of three-dimensional plots. View, print or even modify three-dimensional likelihood function, *pdf*, failure rate, reliability and unreliability plots in moments!

2.5 Additional Tools and Wizards

ALTA also provides many additional tools and wizards designed to streamline, enhance and supplement your analyses.

2.5.1 Spreadsheets for Custom Analyses

General Spreadsheets, which can be incorporated into any ALTA Standard Folio, are used just like an Excel® worksheet to perform your own customized analyses. These spreadsheets provide complete in-cell formula support, cell references, over 200 built-in functions and integration with the Function Wizard and the Chart Wizard. You can use the Function Wizard to insert a wide array of calculated results based on your inputs and, when applicable, a referenced Data Sheet. Available results range from basic math/statistical functions to common reliability analysis results, and much more. In Version 7, this now works more like Excel functions, with the ability to type functions directly into cells and results that are updated automatically when the inputs change. The Chart Wizard leads you through a step-by-step process to create and configure your own custom charts/plots based on a selected data set.

2.5.2 Template-Based Report Generator

The Report Wizard utility allows you to design print-ready reports to showcase your analyses. The template feature makes it easy to apply the same report format to different analyses. This utility has been revised and enhanced in Version 7 and now provides an intuitive spreadsheet-based interface for creating and formatting reports.

2.5.3 References and Wizards

- **Quick Statistical Reference:** Frees you from tedious lookups in tables by returning results for common statistical functions, such as Median Ranks, Chi-Squared values and more at the click of a button.
- **Likelihood Ratio Test:** Allows you to validate the consistency of the shape parameter, beta or standard deviation, across multiple stress levels for the currently calculated data set.
- **Design of Reliability Tests:** Determine the appropriate sample size, test duration or other variable for a reliability demonstration test. Parametric Binomial, Non-Parametric Binomial and Exponential Chi-Squared methods are available and results are displayed in both tables and plots.
- **Tests of Comparison Wizard:** Compare two data sets to determine whether items from the first set will outlast those of the second.
- **Parameter Experimenter:** Solve for a parameter of a distribution given the other parameter(s) and one data point (unreliability at a given time) or solve for all parameters of a distribution given two unreliability data points.
- **Non-Linear Equation Root Finder:** Iteratively solve for a real root of an unconstrained non-linear function using a variable order improved memory method.

2.6 Data Import and Integration with Other ReliaSoft Software

In addition to providing a variety of data sheet formats designed to fit your particular data and analysis requirements, ALTA makes it easy to import data from outside sources, including: ALTA 1.0, 6.0 or 6.5; Weibull++ 4, 5, 6 or MT; Excel® and Tab, Comma, Space or Semi-colon delimited files.

If you have Weibull++ 7.5 or later installed on your computer, ALTA and Weibull++ will work together to expand your analysis capabilities and to save you time and effort. A single project can now include ALTA's Standard Accelerated Life Data Analysis Folios and Weibull++'s Standard Life Data Analysis Folios, in addition to all of the types of Specialized Folios, Additional Plots, Stress Profiles, Other Tools, Reports and Attachments available in both applications. Switch between applications with the click of a button!

2.7 Configure the Workspace to Meet Individual Needs

ALTA makes it easy to configure the interface and analysis settings to meet your specific preferences and needs. For example, the User Setup allows you to specify default options for data sheets, analysis settings, fonts/symbols, etc. The Plot Setup allows you to configure the appearance of the plots that are automatically generated by the software. In addition, you can customize the toolbars and/or adjust the appearance of the workspace by hiding/displaying or changing the position of the Project Explorer and other panels.

2.8 System Requirements

ALTA Version 7 is compiled and designed for Windows NT, 2000 and XP and takes advantage of the features available in these platforms. Minimum system requirements: A 433-MHz Intel Pentium-class processor or equivalent, with 32MB RAM (64MB or more is recommended), SVGA display and at least 80 MB of hard disk space.

3 First Steps

3.1 Starting ALTA 7

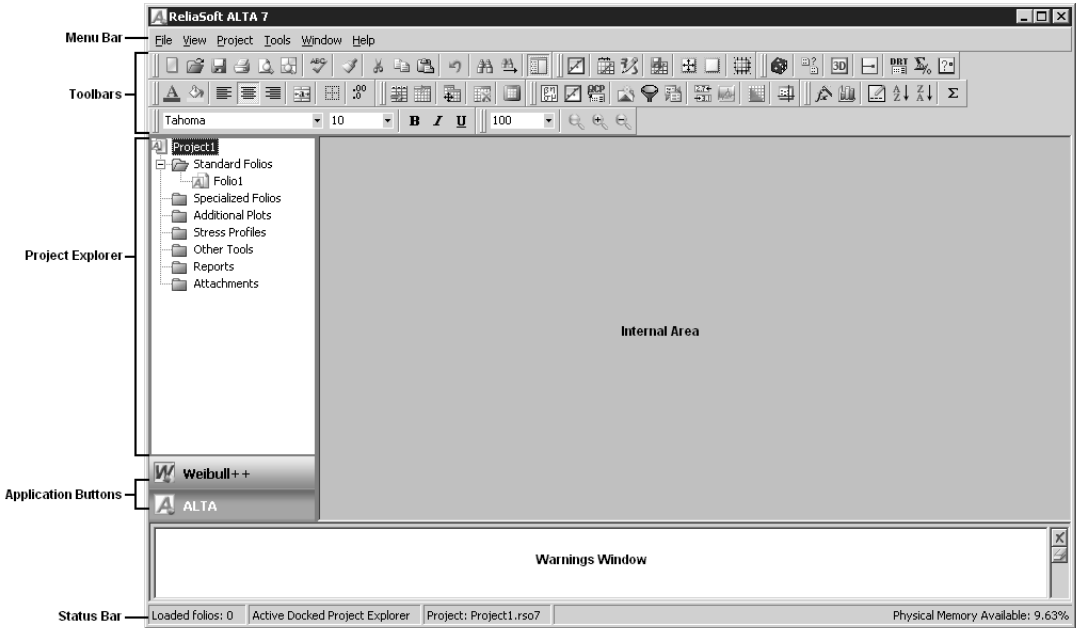
ALTA is a 32-bit application that has been designed to work with Windows NT, 2000 and XP. The internal screens and commands are identical regardless of which operating system you are using, and this training guide is equally applicable. To start ALTA, from **Start** select **Programs**, **ReliaSoft Office** and then **ALTA 7**.

3.2 ALTA Nomenclature

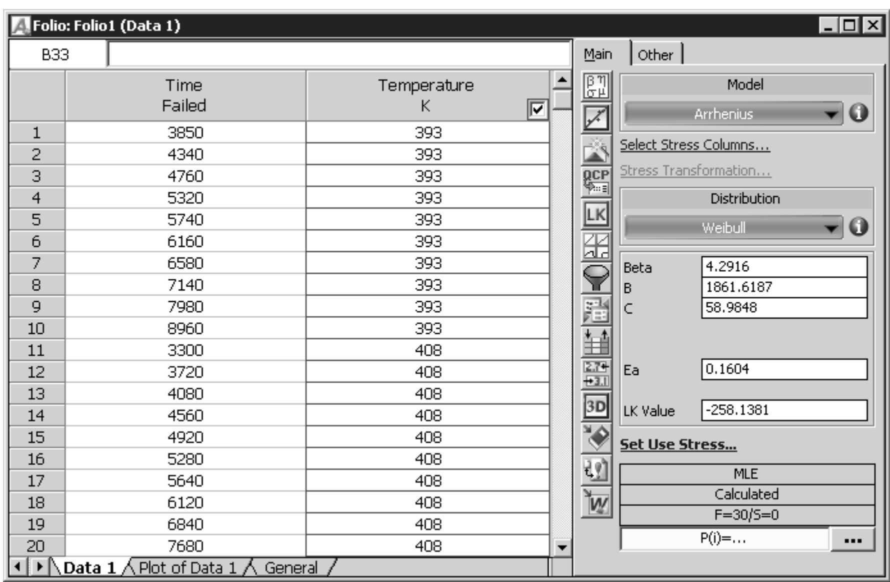
Within ALTA and this training guide, the terms “stress type” and “stress” will be used interchangeably. They refer to the type of stress that is being applied to the product under test. Temperature, humidity and voltage are all stress types or stresses. The term “stress level” refers to the different measurements or levels for a specified stress or combination of stresses that were used to conduct a test. For example, suppose that a test was conducted using temperature as the accelerating stress. The temperatures used were 400K, 500K and 600K and the product is expected to operate normally at a temperature of 300K. Therefore, temperature is the stress type; 400K, 500K and 600K are the stress levels; and 300K is the use stress level for that particular stress type.

3.3 Multiple Document Interface and Standard Folio

The Multiple Document Interface (MDI) is the main window and “manager” for ALTA. The MDI serves as the container for the Project Explorer, all Standard Folios, Specialized Folios, Additional Plots, Stress Profiles, Other Tools, Reports and Attachments and manages the different active windows. The MDI remains open until you close the program. Closing the MDI has the same effect as terminating the program. The next figure shows the MDI of ALTA 7 and its components. The appearance of the MDI will vary depending on the window(s) that are currently open and the configuration settings of the Project Explorer.



The Standard Folio, used for accelerated life data analysis, is the most commonly used Folio in the application. The Standard Folio organizes the entered data in the appropriate Data Sheet and calculates the results. It also contains any Plots and General Spreadsheets associated with the analysis. Each Standard Folio can contain up to 256 data sheets with up to 65,536 data rows per sheet. A Standard Folio is shown in the figure below.



3.4 Getting Help in the ALTA 7 Environment

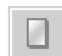
ReliaSoft's ALTA 7 includes complete on-line help documentation. This help can be obtained at any time by pressing **F1** or by selecting **Contents** from the **Help** menu. ALTA 7 also provides theory help, which is available for each life-stress model, underlying life distribution and plot type. Theory help can be accessed by clicking the theory help button (**?**) next to your selection.

3.5 A Quick Overview Example

This section presents you with a very simple example and guides you through the solution. The test case for this example: Five units were reliability tested at a stress level of 406K and the following times-to-failure were observed: 248, 456, 528, 731 and 813 hr. Six units were reliability tested at a stress level of 416K and the following times-to-failure were observed: 164, 176, 289, 319, 340 and 543. Six units were reliability tested at a stress level of 426K and the following times-to-failure were observed: 92, 105, 155, 184, 219 and 235. The use stress level is 356K. The steps to complete the analysis are presented next.

The file for this example is located in the "Training Guide" folder in your application directory (e.g. C:\Program Files\ReliaSoft\ALTA7\Training Guide) and is named "1stSteps.ralp."

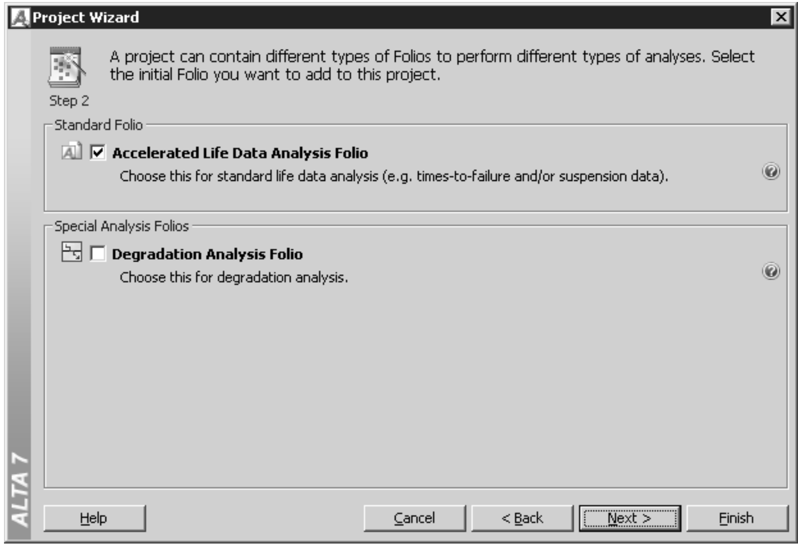
- Create a new project by clicking **Create a New Project** in the initial window that may appear at startup, by selecting **New** from the **File** menu or by clicking the **New** icon.



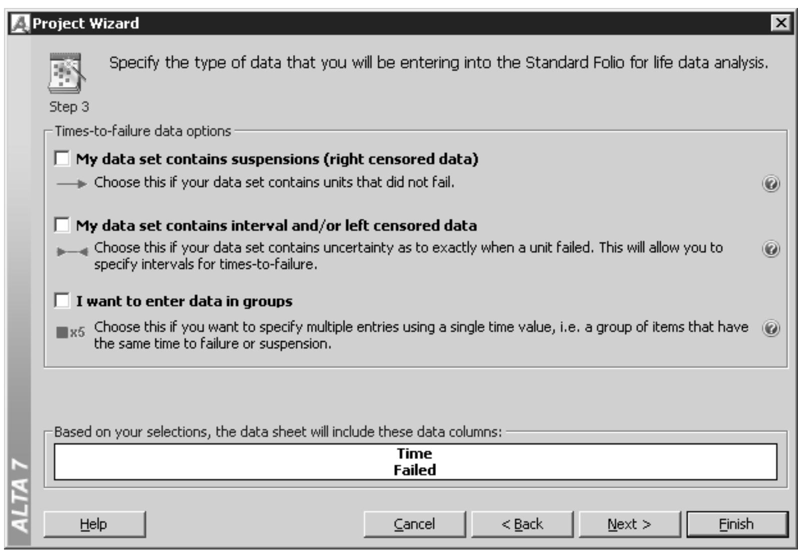
The Project Wizard will be displayed. This wizard guides you through the steps required to create a new project that will meet your analysis needs. The steps displayed will vary depending on your selections for each page. Note that you can click **Finish** from the first page of the wizard to create another project with the same settings as the last project you created. You may also choose to create a new project with items imported from an existing project or based on a saved profile.

- On the first page of the Project Wizard, select to create a new project **By following the wizard** and click **Next>** to proceed to the next step.

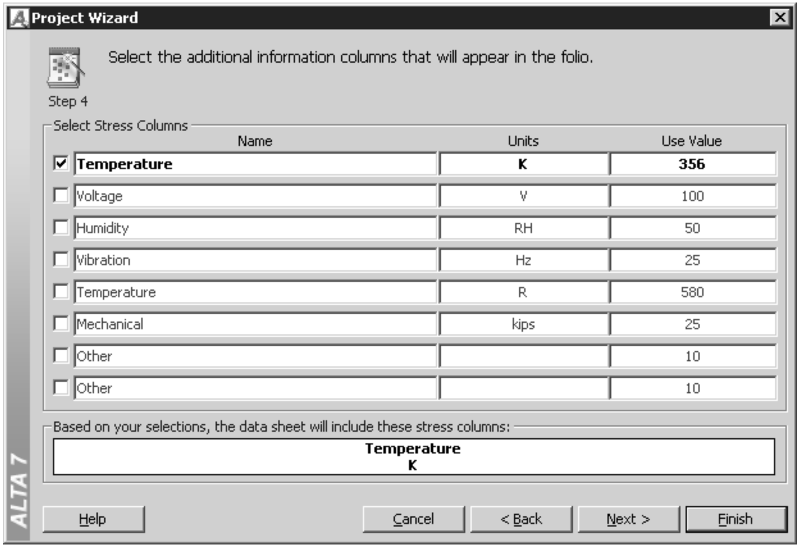
- On the second page of the Project Wizard, make sure that **Accelerated Life Data Analysis Folio** is selected and click **Next>** to proceed to the next step..



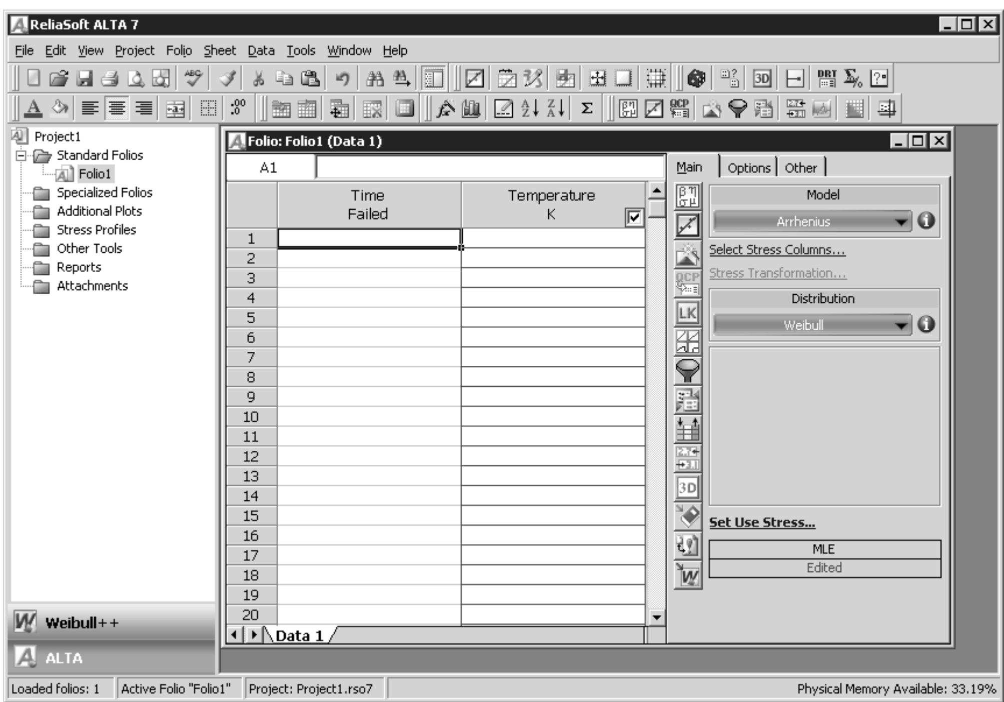
- In this example, you will be working with non-grouped times-to-failure data without suspensions, so on the third page of the Project Wizard, make sure that none of the checkboxes on the page are selected. Click **Next>** to proceed to the next step.



- On the fourth page of the Project Wizard, select the first stress, **Temperature**, and enter **356** in the Use Value field for that stress. Note that the units are already listed as Kelvin (K), so you do not need to change that field. Make sure all other stresses are deselected and click **Next**.

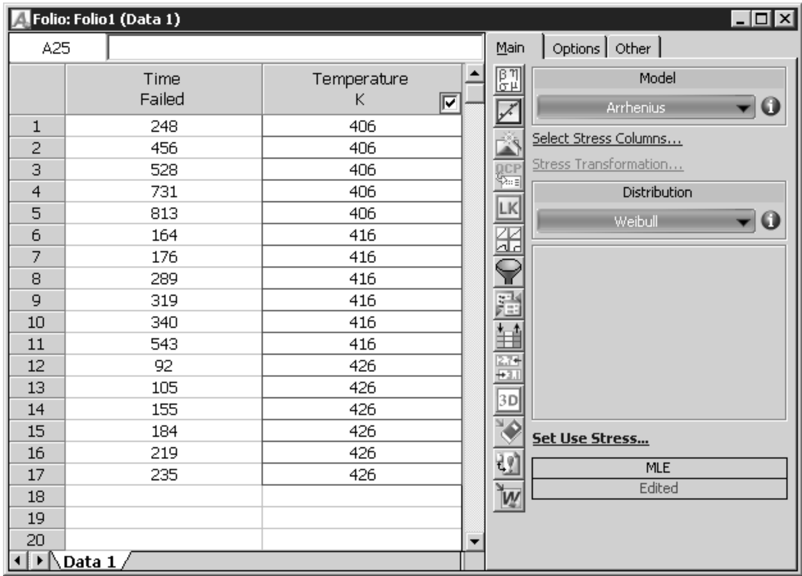


- On the last page, click **Finish** to create the new project according to your specifications. The project will now include one Standard Folio with a Data Sheet that has been configured to accept the type of data that you will be entering for this example, as shown next.



Notice that the heading of the second column displays the stress name and stress units, which were defined in the Project Wizard.

- Type the times-to-failure data in the first column of the Data Sheet under **Time Failed**. Enter the corresponding temperature stress values for each time-to-failure in the second column under **Temperature K**, as shown next.



	Time Failed	Temperature K
1	248	406
2	456	406
3	528	406
4	731	406
5	813	406
6	164	416
7	176	416
8	289	416
9	319	416
10	340	416
11	543	416
12	92	426
13	105	426
14	155	426
15	184	426
16	219	426
17	235	426
18		
19		
20		

Note that the times-to-failure do not need to be sorted; the application will do this for you automatically.

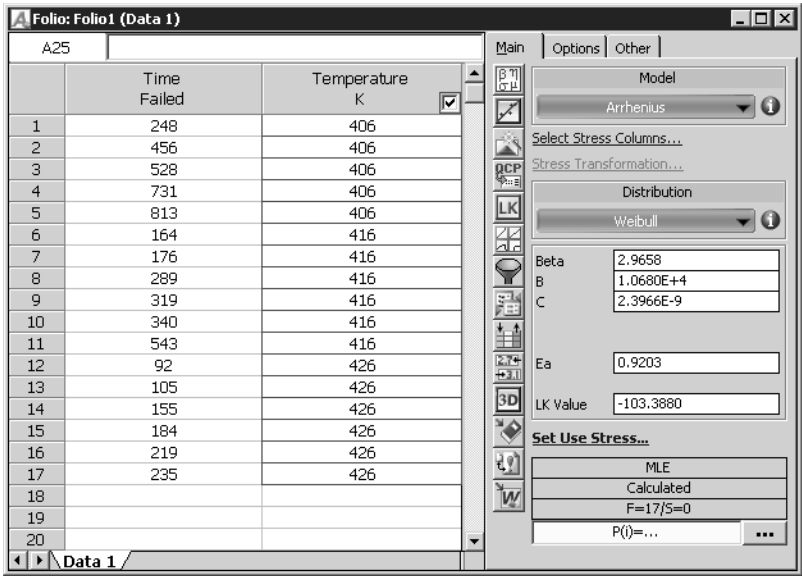
- The next step is to select a life-stress model and an underlying life distribution to calculate the parameters. We assume that you have not changed any of the default settings. The default life-stress relationship is Arrhenius. You can verify this by noticing that Arrhenius is selected from the **Model** drop-down menu on the top of the Standard Folio Control Panel's Main Page, as shown next.

- The **Weibull** distribution is the default underlying life distribution. You can verify this in the Distribution drop-down menu on the Standard Folio Control Panel's Main Page, as shown next.

- All calculations in ALTA 7 use **MLE** (Maximum Likelihood Estimation) as the parameter estimation method. You can check this by looking at the Information area at the bottom of the Standard Folio Control Panel's Main Page, as shown next.

- Once the life-stress model and distribution have been selected, you can calculate the parameters by clicking the **Calculate** icon,

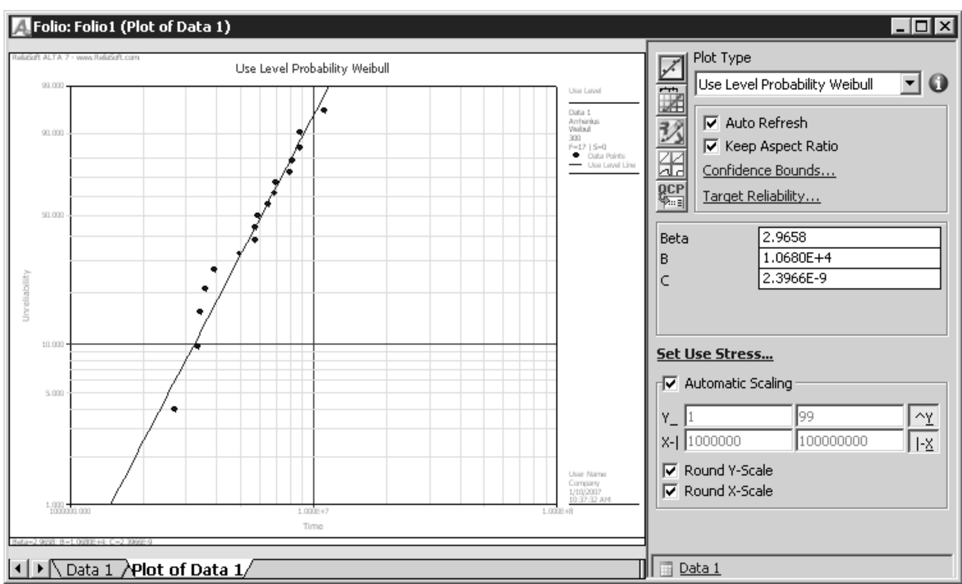
or by selecting **Calculate** from the **Data** menu. The Standard Folio with its parameters calculated is shown next. The estimated parameters will appear in the Results Area, which is located just below the Distribution area.



3.5.1 Plotting the Data

- Plot the data by selecting **Plot** from the **Data** menu or by clicking the **Plot** icon. This icon is displayed in both the Data Analysis Tools toolbar and in the Control Panel.

A new sheet called “Plot of Data 1” will be added to the Folio. The Use Level Probability plot will be displayed by default, as shown next.[1]

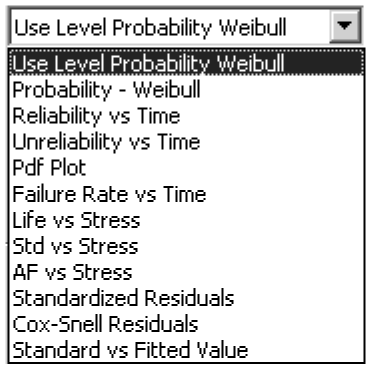


The plot shows the data plotted at the use stress level (356K).

1. If necessary, you may wish to re-size the plot by re-sizing the Folio.

The Plot Sheet provides many options for creating and configuring plots to meet your particular analysis and presentation needs. You may wish to experiment with some of these options at this time. If the **Auto Refresh** command is enabled, the display will be updated automatically to fit your new selections. If not, select **Redraw Plot** from the **Plot** menu or click the **Redraw Plot** icon to implement your selections.

For example, the **Plot Type** menu in the Control Panel allows you to create other types of plots.



You can switch between the Plot Sheet and the Data Sheet using the page index tabs. However, if you edit the data on the Data Sheet, you must recalculate the parameters and refresh the plot on the Plot Sheet for the change to take effect in the plot.

Notice that the analysis settings are displayed in the legend in the top right corner of the plot and the calculated parameters are displayed in the bottom left corner. You can customize these and other display settings from the Plot Setup window. To access the Plot Setup, select **Plot Setup** from the **Plot** menu or click the **Plot Setup** icon.

- When you are finished experimenting with the Plot Setup window, save the project by selecting **Save** from the **File** menu or by clicking the **Save** icon.

- When prompted to specify the name and location for the file, browse to the directory of your choice and type “1stSteps” for the File name.[2] Select the file type *.ralp and click **Save** to close the window and save the file.
- Close the project by selecting **Close** from the **File** menu. You will now be looking at the MDI with no project open.

2. By default, files will be saved in the “My Documents” directory on your computer. You can select a different directory, if desired, and ALTA will “remember” the directory for the next time that you save a file.

4 ALTA 7 Standard Examples

This chapter presents the following examples, which can be performed using both ALTA 7 Standard and ALTA 7 PRO:

Chapter 5 presents examples that are specific to ALTA 7 PRO.

4.1 Example 1: Accelerated Life Testing Data Analysis with Complete Data and a Single Stress

Since the life of a new product under normal operating conditions is expected to be more than 15,000 hr, testing under these conditions is not time-wise feasible. For this reason, it was decided to run an accelerated test for this product. The operating temperature for this product is 323K (50°C) and temperature is the only acceleration variable. A table of the data obtained from the test for three different accelerated stress levels is given next.

Stress Level, K	393K	408K	423K
Times-to-Failure, hr	3850	3300	2750
	4340	3720	3100
	4760	4080	3400
	5320	4560	3800
	5740	4920	4100
	6160	5280	4400
	6580	5640	4700
	7140	6120	5100
	7980	6840	5700
	8960	7680	6400

Do the following:

- Determine the parameters of the Arrhenius-Weibull model.
- Create the Use Level Weibull Probability and Weibull Probability plots.

The file for this example is located in the "Training Guide" folder in your application directory (e.g. C:\Program Files\ReliaSoft\ALTA7\Training Guide) and is named "Training Examples.ralp." Use the "Complete Data" Folio.

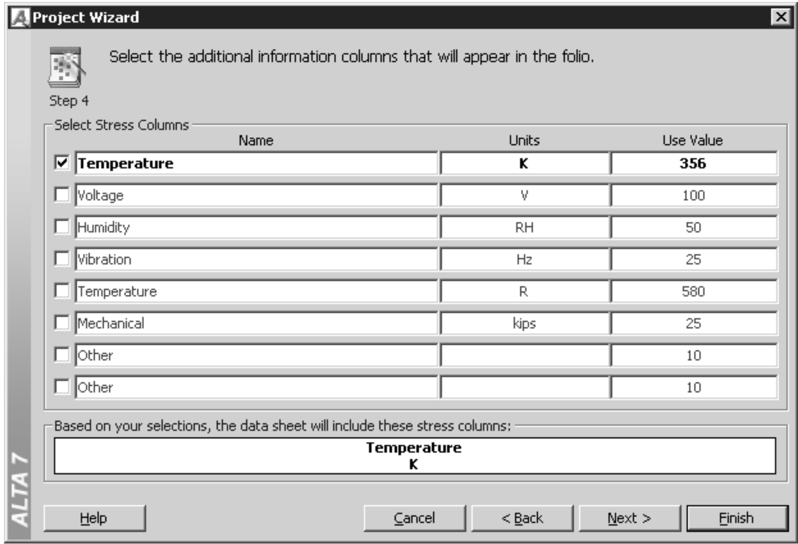
Solution

- Create a new project by clicking **Create a New Project** in the initial window that may appear at startup, by selecting **New...** from the **File** menu or by clicking the **New** icon.

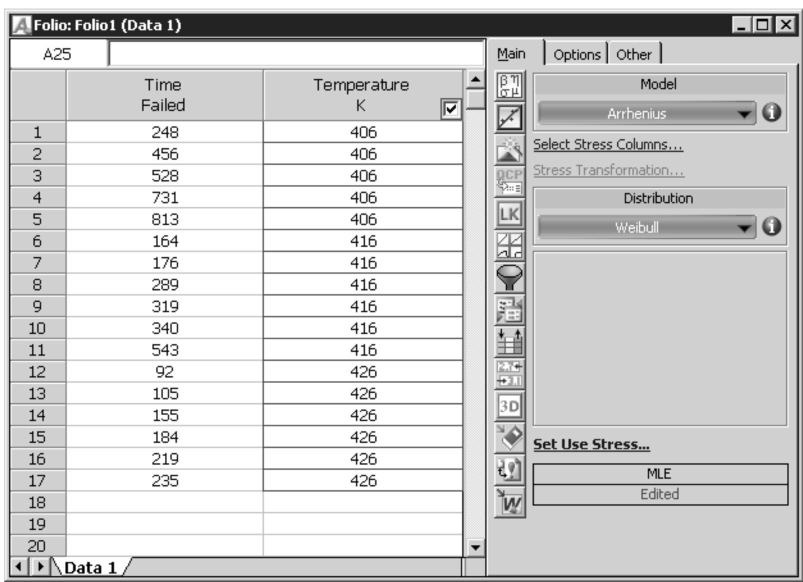
- Select **By following the wizard** on the first page of the Project Wizard and **Accelerated Life Data Analysis Folio** on the second page.

- On the third page, make sure that none of the checkboxes on the page are selected.

- On the fourth page, select the first stress, **Temperature**, and enter **323** in the Use Value field for that stress, as shown next.

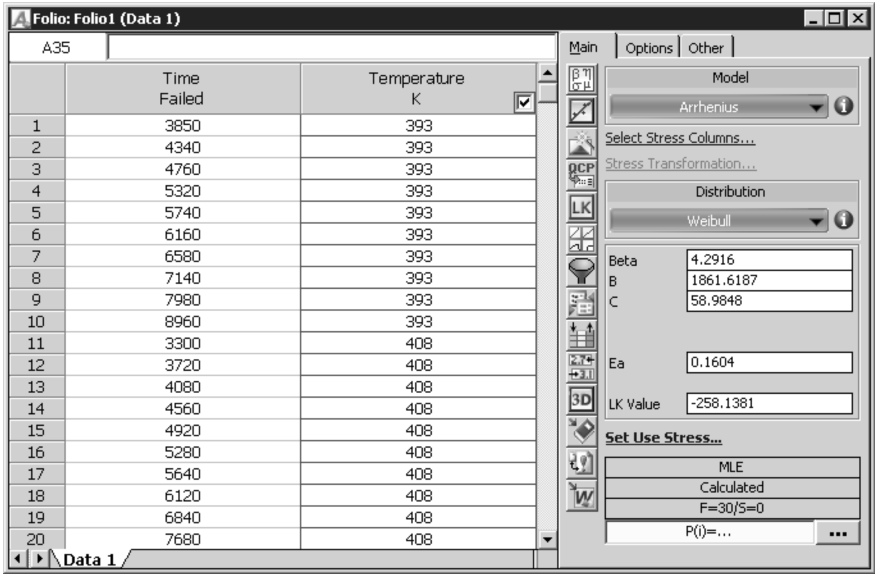


- Click **Finish** to create the new project with the appropriate Standard Folio.
- Type the times-to-failure data in the first column of the Data Sheet under **Time Failed**. Enter the corresponding temperature stress values for each time-to-failure in the second column under **Temperature K**, as shown next. Please note that the figure shown only displays 20 rows of data. Be sure to enter all data for this example as given on page 18. Your Data Sheet should contain 30 rows of data.



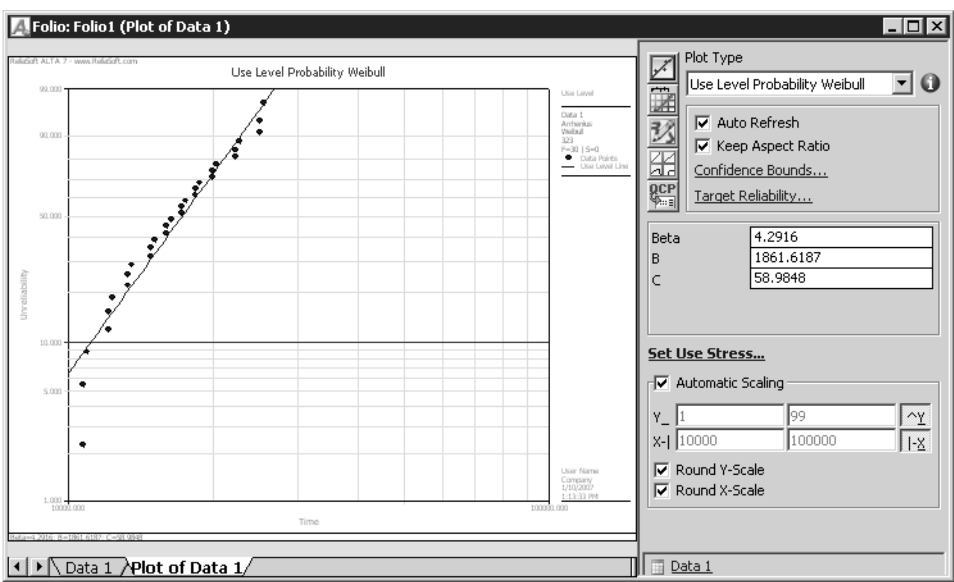
- The next step is to select a life-stress model and a distribution. On the Standard Folio Control Panel's Main Page, select **Arrhenius** under Model and **Weibull** under Distribution, as shown above.
- Calculate the parameters by clicking the **Calculate** icon,

or by selecting **Calculate** from the **Data** menu. The results will appear in the Results area, as shown next.



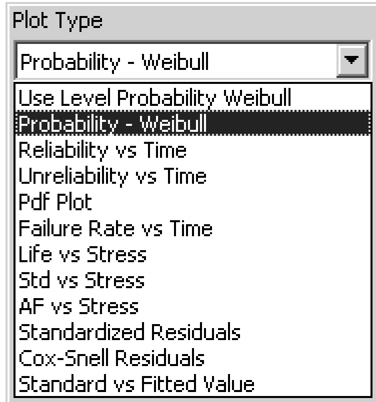
- Plot the data by selecting **Plot** from the **Data** menu or by clicking the **Plot** icon.

The Use Level Weibull Probability plot for this data is shown next.

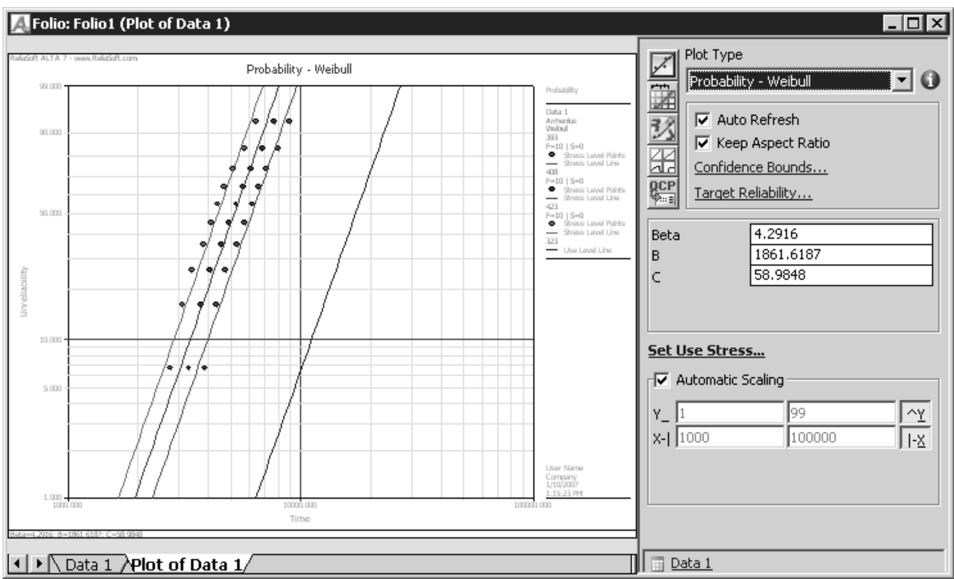


The Use Level Weibull Probability plot is based on the value of the use stress level that you entered when you created the Data Sheet, 323K. Changing the value of the use stress level will change the location of the probability plot.

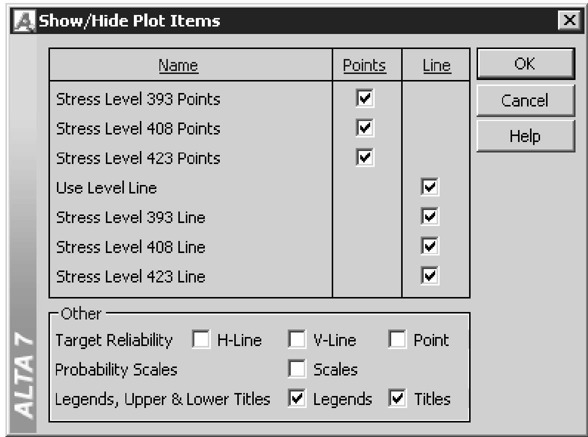
- Plot the Weibull Probability plot by selecting **Probability-Weibull** from the **Plot Type** drop-down menu on the Control Panel.



The Weibull Probability plot is shown next.



- Notice that each accelerated stress level is plotted on the probability plot along with the use stress level. You can select which stress levels appear on the plot using the Show/Hide Plot Items window, which can be opened by selecting **Show/Hide Items** from the **Plot** menu. The Show/Hide Plot Items window is shown next.



This window allows you to select the data you want displayed on the plot and how you want it displayed (*i.e.* points and/or lines).

- For each stress level from the current Data Sheet, decide if you want points and/or lines representing that stress level to appear on the plot and make the appropriate selections. Note that only a line is available for the Use Stress Level, as there were no observations actually made at that stress level
- Click **OK** to accept your selections and return to the Plot Sheet.
- Return to the Data Sheet by clicking the **Data 1** tab at the bottom of the Folio.
- Save the project by selecting **Save** from the **File** menu or by clicking the **Save** icon.
- When prompted to specify the name and location for the file, browse to the directory of your choice and type "Training Examples" for the File name.[1] Select the *.ralp file type and click **Save** to close the window and save the file.
- Leave the project and Folio open and proceed to the next example.

4.2 Example 2: Obtain the Unreliability for a Given Operating Time

What is the unreliability of the units in Example 1 for a mission duration of 9,000 hr, starting the mission at T = 0 with an operating stress level of 323K?

The file for this example is located in the "Training Guide" folder in your application directory (e.g. C:\Program Files\ReliaSoft\ALTA7\Training Guide) and is named "Training Examples.ralp." Use the "Complete Data" Folio.

Solution

There are two methods of solution for this problem. The first and more laborious method is to extract the information directly from the plot. This can be done using ReliaSoft Draw (RS Draw).[2] The second method is to use ALTA's Quick Calculation Pad (QCP) to obtain the exact result. Both methods are presented next.

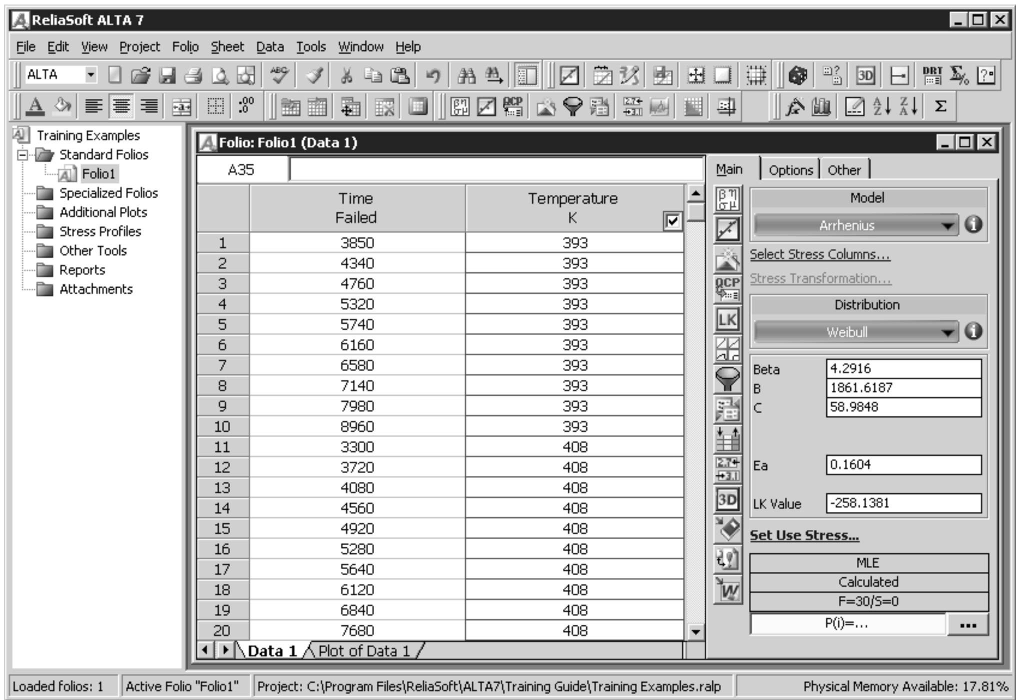
---

1. By default, files will be saved in the "My Documents" directory on your computer. You can select a different directory, if desired, and ALTA will "remember" the directory for the next time that you save a file.

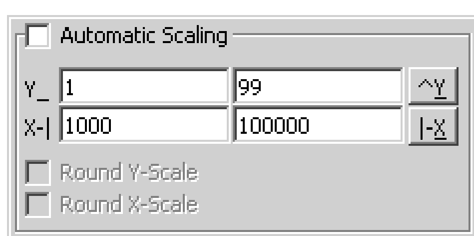
2. RS Draw is presented in detail in Chapter 11 of the *ALTA User's Guide*.

- If Folio1 from the "Training Examples.ralp" project file that you created in the first example is not already active, open the project by selecting **Open** from the **File** menu or by clicking the **Open** icon.

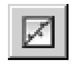
- Browse for the "Training Examples.ralp" file and click **Open**.
- Click the "plus" (+) to the left of the Standard Folios branch in the Project Explorer on the left side of the MDI to display a list of the standard life data analysis folios in the current project. Double-click **Folio1** to open it. The MDI will now look like the figure shown next.



- Click the **Plot of Data 1** tab at the bottom of the Folio to display the Plot Sheet. Make sure that the Use Level Weibull Probability plot is being displayed. For this example, the unreliability for a mission of 9,000 hr is required. However, the minimum value for the X-axis in the use level probability plot is 10,000 hr. You can change the scaling of the plot using the X and Y scaling boxes on the Plot Sheet Control Panel.
- First, de-select the **Automatic Scaling** option above the scaling boxes to disable the automatic scaling. This will activate the X and Y scaling boxes. Next, enter the new value within the appropriate input box. In this case, change the lower limit of the X-axis from 10,000 to 1,000, as shown next.

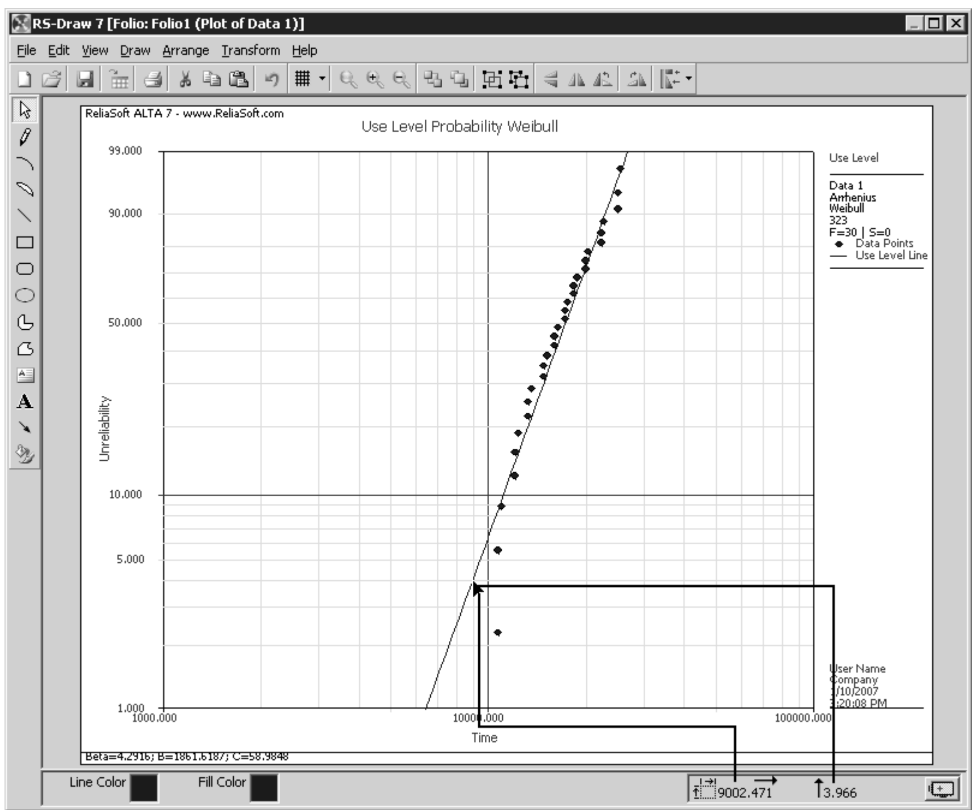


- After typing the new value, press **Enter** if the **Auto Refresh** option is selected. If the **Auto Refresh** option is not selected, click the **Refresh** icon.



- After the plot has been refreshed, click the **RS Draw** icon,

  or select **Edit Plot with RS Draw** from the **Tools** menu. RS Draw can automatically track the position of the mouse cursor and translate the coordinates for you. Obtain the unreliability at T = 9,000 hr by placing the cursor at the intersection of the plotted line and T = 9,000. The position of the cursor is indicated by the Position Indicator located in the lower right corner of the RS Draw window. The x-coordinate (time) is displayed on the left and the y-coordinate (unreliability) is displayed on the right. When the x-coordinate reads approximately 9,000, read off the value of the y-coordinate. You may not be able to obtain the value of the unreliability at exactly 9,000 hours. This is one of the disadvantages of reading the value off the plot. The position of the cursor at the intersection of the plotted line and $T \cong 9000$ is shown next.



  From the Position Indicator, the value of the y-coordinate, the unreliability $Q(T)$, is such that $Q(T) \cong 3.966$ %. Therefore, a good estimate of the probability of failure (unreliability) at 9,000 hours is 3.966%.

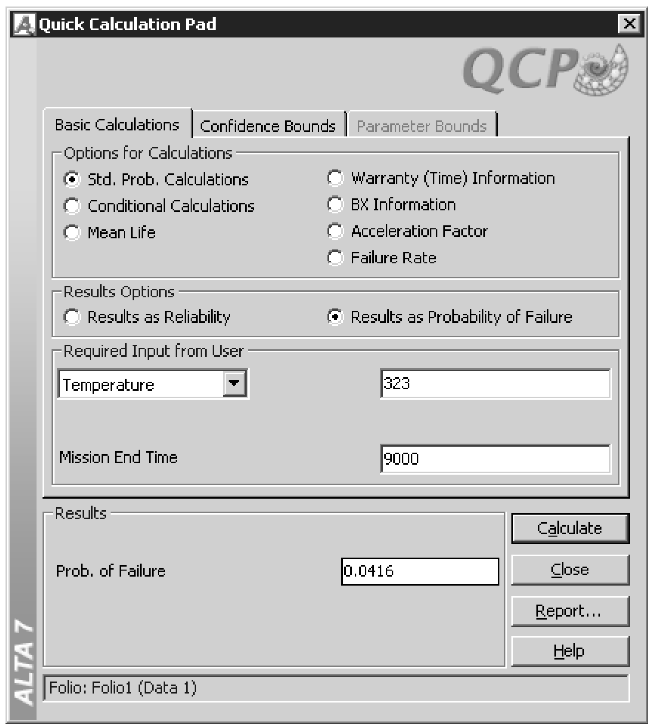
- Close RS Draw. Return to the Data Sheet by clicking the **Data 1** page index tab.

- The second method involves the use of the Quick Calculation Pad (QCP). Open the Quick Calculation Pad by selecting **Quick Calculation Pad** from the **Data** menu or by clicking its icon.

- On the Basic Calculations page, make the following selections/inputs:
    - Options for Calculations: **Std. Prob. Calculations**
    - Results Options: **Results as Probability of Failure**
    - Required Input From User:

      Temperature = **323**

      Mission End Time = **9000**
- Click **Calculate** to obtain the results, as shown next.



The QCP returns a result of $Q(T)$ = 4.16%. This is similar to the result found using the plot. However, the QCP is more accurate and easier to use.

- Close the QCP, save any changes, leave the project and Folio open and proceed to the next example.

4.3 Example 3: Calculate Conditional Reliability and Warranty Time

Using the analysis from Example 1, what is the reliability for a mission duration of T = 3,000 hr, starting the mission at T = 6,000 hr at a use stress level of 323K? Also, what is the warranty time for a reliability of 99% at the same stress level?

The file for this example is located in the "Training Guide" folder in your application directory (e.g. C:\Program Files\ReliaSoft\ALTA7\Training Guide) and is named "Training Examples.ralp." Use the "Complete Data" Folio.

Solution

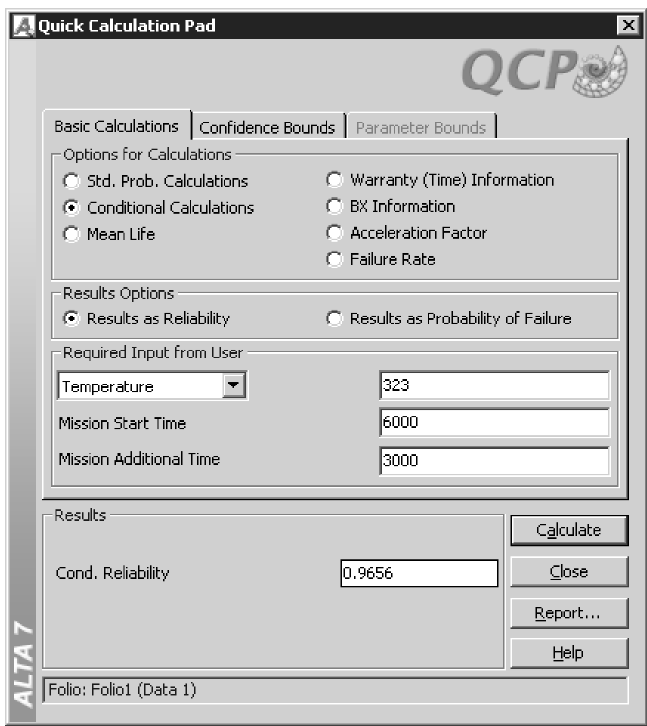
- If Folio1 from the "Training Examples.ralp" project file that you created in the first example is not already active, open the project and Folio now.
- Open the Quick Calculation Pad by selecting **Quick Calculation Pad** from the **Data** menu or by clicking its icon.

- On the Basic Calculations page, make the following selections/inputs:
  - Options for Calculations: **Conditional Calculations**
  - Results Options: **Results as Reliability**
  - Required Input From User:

    Temperature = **323**

    Mission Start Time = **6000**

    Mission Additional Time = **3000**
  - Click **Calculate** to obtain the results, as shown next.



The conditional reliability starting the mission at 6,000 hr and for a 3,000 hr duration is equal to 96.56%. This satisfies the first part of the example.

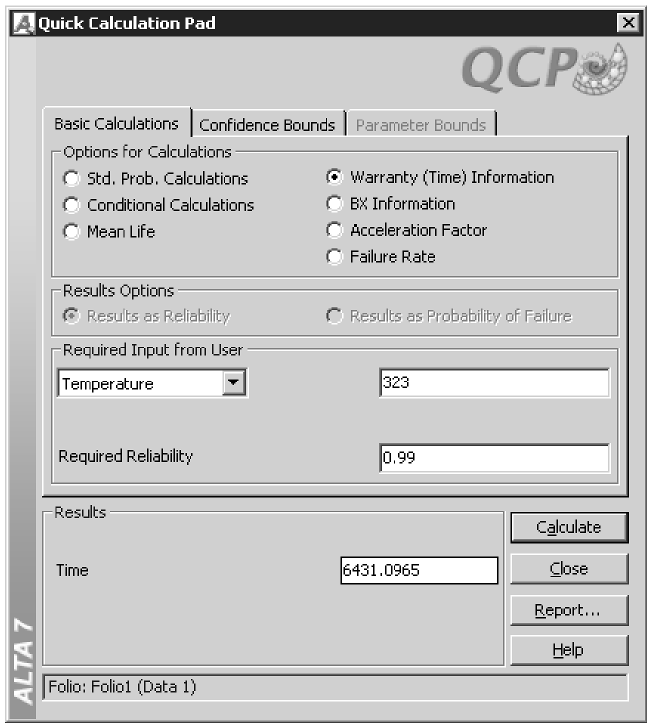
The second part of the example requires the determination of the warranty time for a reliability of 99%. There are multiple ways to obtain this information using ALTA 7. They include:

- Use the Warranty (Time) Information calculation in the Quick Calculation Pad to calculate the value. This calculation is the fastest and most accurate method and is described below (first).

- Use the Life vs. Stress plot and the Specify Life Lines option. This graphical method is described below (second).
- Use the Use Level Weibull Probability plot and RS Draw. This is similar to the procedure described on page 24 and is not described again here.

To use the QCP calculation method to determine the warranty time for 99% reliability, do the following:

- On the Basic Calculations page, make the following selections/inputs:
  - Options for Calculations: **Warranty (Time) Information**
  - Required Input from User: Required Reliability = **0.99**
- Click **Calculate** to obtain the results, as shown next.



The time required for a reliability of 99% is equal to 6431.1 hr.

- Close the QCP by clicking **Close**.

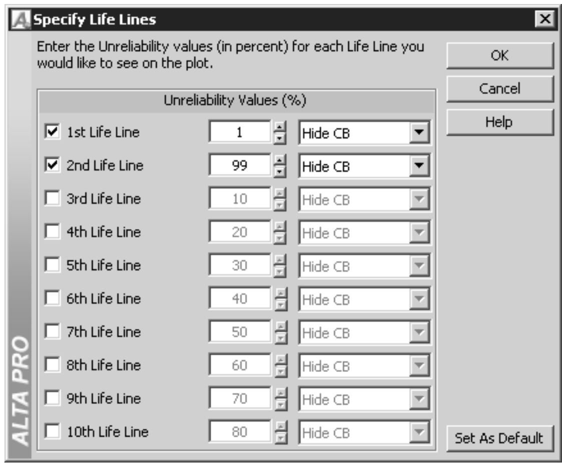
To use the Life vs. Stress plot graphical method to determine the warranty time for 99% reliability, do the following:

- Click the **Plot of Data 1** page index tab to display the plot of the data. The Use Level Weibull Probability plot will probably be displayed. Select **Automatic Scaling** and switch to the Life vs. Stress plot by selecting **Life vs Stress** under **Plot Type**.[3]
- For the Life vs. Stress plot, the scale parameter (eta) and imposed *pdf* will appear on the plot by default. You can also add up to ten additional lines corresponding to ten different percentiles (unreliabilities) by following the steps described next.

---

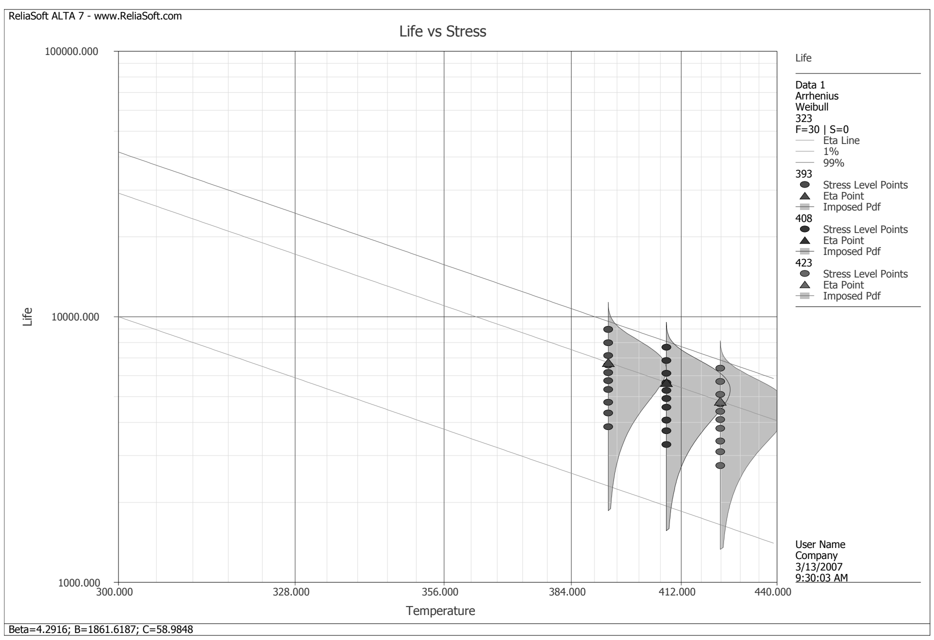
3. If **Auto Refresh** is not selected, you must click the **Refresh** icon for the changes to take effect on the plot.

- Click the Life Lines link on the Plot Sheet Control Panel. The Specify Life Lines window will appear. You can enter up to ten percentile values to be plotted or delete existing values.
- For this example, select the checkboxes beside the first and second values to display them on the plot. Enter **1** for the unreliability value for the first line and **99** for the unreliability for the second line, as shown next.



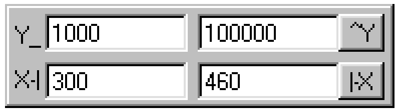
- Click **OK** to close this window.

The refreshed Life vs. Stress plot will look like the one shown next.



The bottom line corresponds to 1% unreliability, the second line is the scale parameter (eta) and the top line corresponds to 99% unreliability.

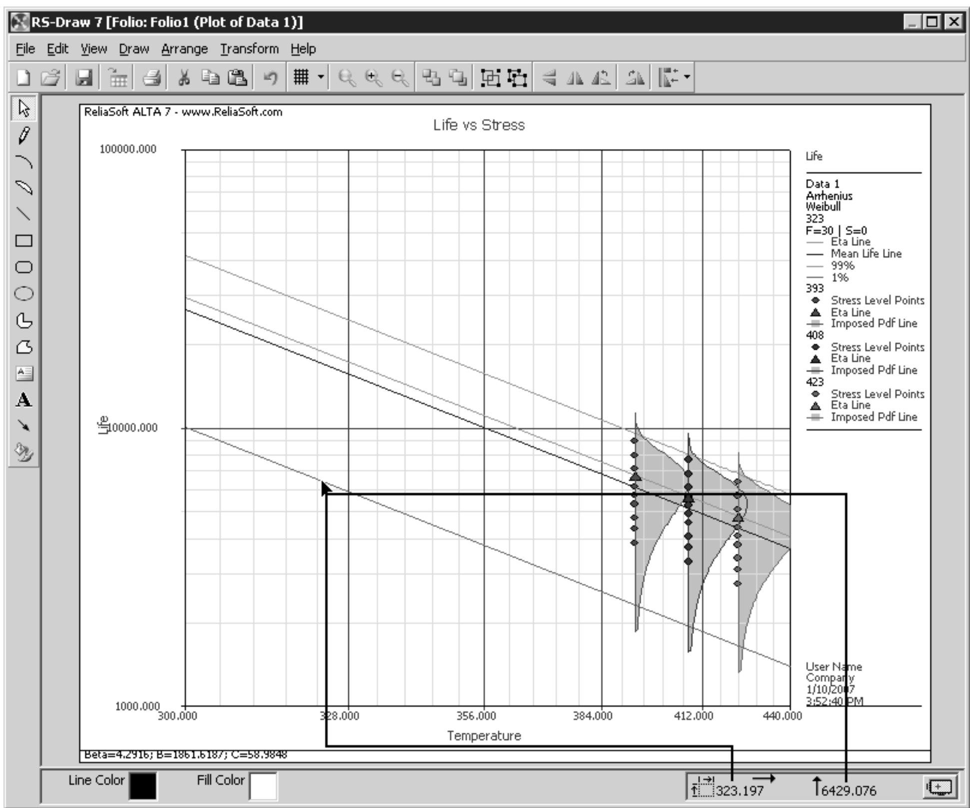
- De-select **Automatic Scaling** and change the scaling to the values shown next. If **Auto Refresh** is selected, press **Enter** to refresh the plot to reflect the changes made to the scaling. If **Auto Refresh** is not selected, then click the **Refresh** icon.



- Select **Edit with RS Draw** from the **Tools** menu or click the **RS Draw** icon.

- Obtain the time for a 99% reliability (or 1% unreliability) by placing the cursor at the intersection of the 1% unreliability line and stress = 323.

The position of the cursor at the intersection of the plotted line and stress = 323 is shown next.



The value of the y-coordinate from the Position Indicator is equal to 6429.1. Therefore, 6429 hr is a good estimate of the warranty time for a 99% reliability. This is similar to the value obtained using the QCP. Again, the QCP is obviously more accurate and easier to use.

- Close RS Draw.
- Close the Folio by clicking the Close button (**X**) in the top right corner.
- Save any changes, leave the project open and proceed to the next example.

4.4 Example 4: Analysis Using Two Stresses

Twelve electronic devices were put in a continuous accelerated test. The accelerated stresses were temperature and voltage, with use level conditions of 328K and 2V. The data obtained are shown in the table below.

Time, hr	Temperature, K	Voltage, V
620	348	3
632	348	3
658	348	3
822	348	3
380	348	5
416	348	5
460	348	5
596	348	5
216	378	3
246	378	3
332	378	3
400	378	3

Do the following:

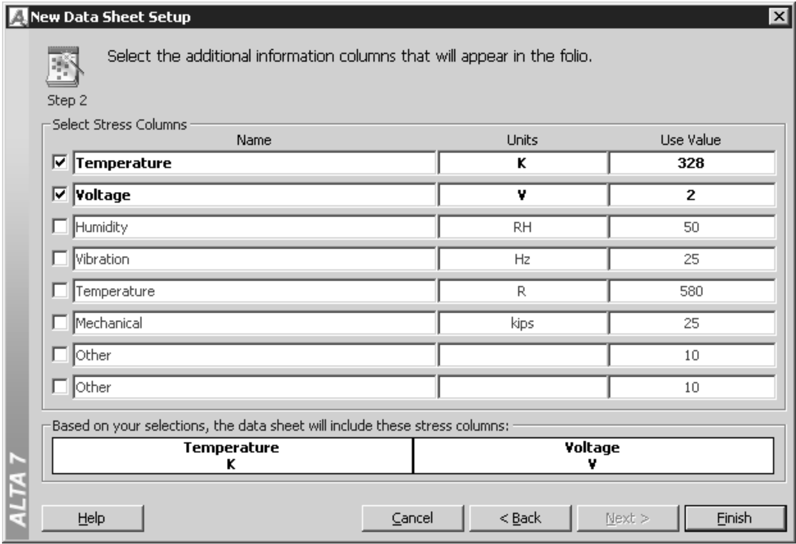
- Calculate the parameters of the Temperature-NonThermal life-stress model and Weibull distribution.
- Obtain the probability plot of the data.
- Estimate the warranty time for a 95% reliability.
- Obtain the Life vs. Stress plot for temperature (Life vs. Temperature).
- Obtain the Life vs. Stress plot for voltage (Life vs. Voltage).

The file for this example is located in the "Training Guide" folder in your application directory (e.g. C:\Program Files\ReliaSoft\ALTA7\Training Guide) and is named "Training Examples.ralp." Use the "Two Stresses" Folio.

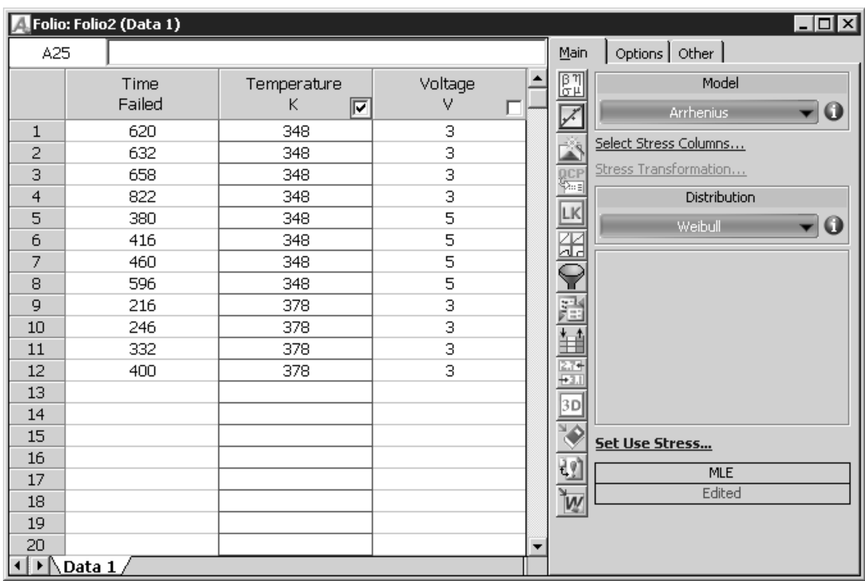
Solution

- With the "Training Examples.ralp" project open, create a new Standard Folio by selecting **Add Standard Folio...** from the **Project** menu or by right-clicking inside the Project Explorer and selecting **Add Standard Folio...** from the shortcut menu.
- The Data Sheet Setup window will appear. You will notice that the two pages of this window are identical to the third and fourth pages of the Project Wizard when the selected Folio is a Standard Folio. On the first page of the Data Sheet Setup window, make sure that none of the checkboxes on the page are selected.

- On the second page, select the first stress, **Temperature**, and enter **328** in the Use Value field for that stress. Also select the second stress, **Voltage**, and enter **2** in the Use Value field for that stress, as shown next.



- Click **Finish** to create the Standard Folio. Note that the Project Explorer now displays two Standard Folios, Folio1 and Folio2.[4]
- Enter the data into the Data Sheet, as shown next.

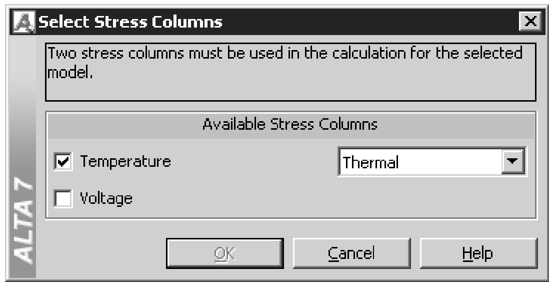


- Select **Temperature-NonThermal** as the life-stress model. Make sure that **Weibull** is selected as the distribution or select it as explained in the previous examples.

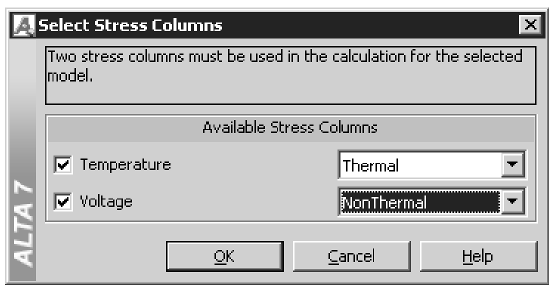
4. Although the default Folio names have been used for these examples, you can rename Folios to be more descriptive, if desired, as has been done in the Training Examples.ralp file that accompanies the software. To rename an item in the Project Explorer, right-click the item and select **Rename Item** from the shortcut menu or select the item and press **F2**.

You will notice that only the Temperature stress column is selected for use in calculation (denoted by red borders in the column and a check in the box in the column header). You can select additional columns in two ways:

- Click the **Select Stress Columns** link on the Main Page of the Standard Folio Control Panel or select **Select Stress Column(s)** from the **Data** menu. The Select Stress Columns window will appear, as shown next.

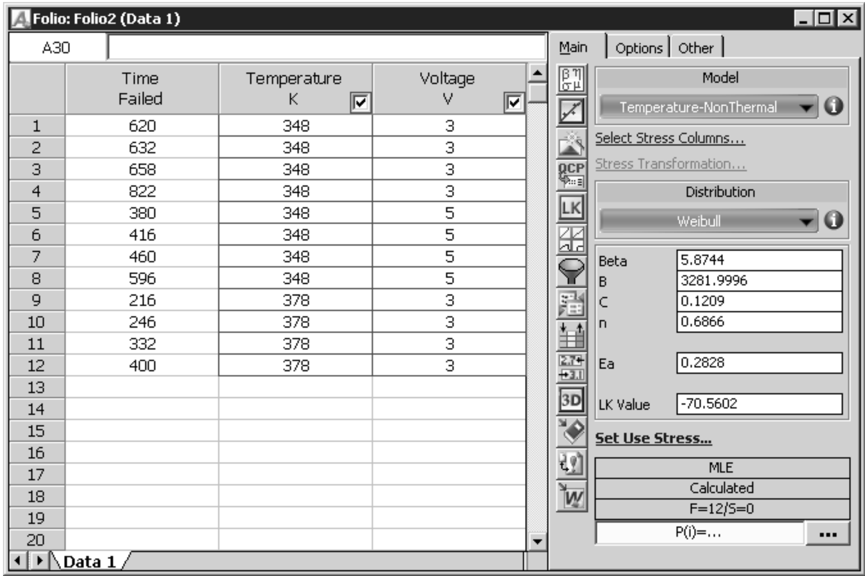


  - Check the box beside Voltage.
  - Because the Temperature-NonThermal life-stress model is selected, you will need to specify which stress is the thermal stress and which is the nonthermal stress. Select **Thermal** for Temperature and **NonThermal** for Voltage, as shown next, then click **OK**.



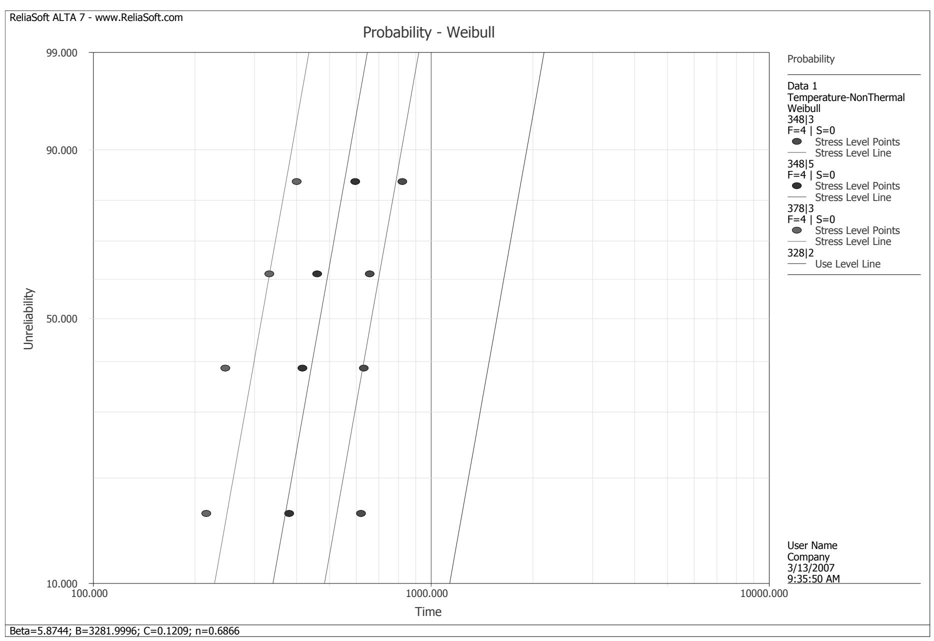
- Instead of using the Select Stress Columns window, you can simply check the checkbox in the header of each stress column that you want to use. Note, however, that there is no way to specify which stress is thermal and which is nonthermal for the Temperature-NonThermal model, so ALTA treats the first selected column as the thermal stress and the second selected column as the nonthermal stress.
- Calculate the parameters by selecting **Calculate** from the **Data** menu or by clicking the **Calculate** icon.

The calculated parameters are shown next.



- Plot the data by selecting **Plot** from the **Data** menu or by clicking the **Plot** icon.

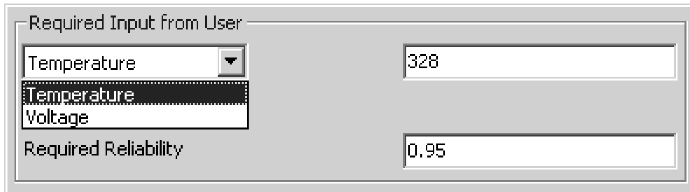
- The Use Level Weibull Probability plot will appear. Select **Probability-Weibull** as the Plot Type and refresh the plot.



Four lines will appear on the probability plot, including three lines for the three combinations of stresses: (348K, 3V), (348K, 5V) and (378K, 3V); and one line for the use stress level (328K, 2V).

- Next, use the Quick Calculation Pad to obtain the warranty time for a reliability of 95%. Open the Quick Calculation Pad by selecting **Quick Calculation Pad** from the **Data** menu or by clicking its icon.

- On the Basic Calculations page, make the following selections/inputs:
  - Options for Calculations: **Warranty (Time) Information**
  - Required Input From User: a drop-down menu will appear that contains both stress types, as shown next. Select a stress type from the menu and enter the corresponding value in the input box.

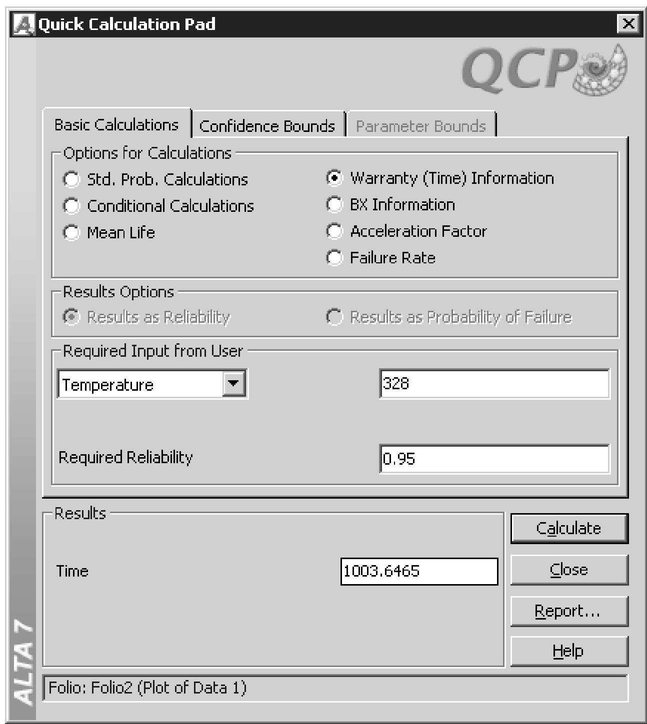


Temperature = **328**

Voltage = **2**

Required Reliability = **0.95**

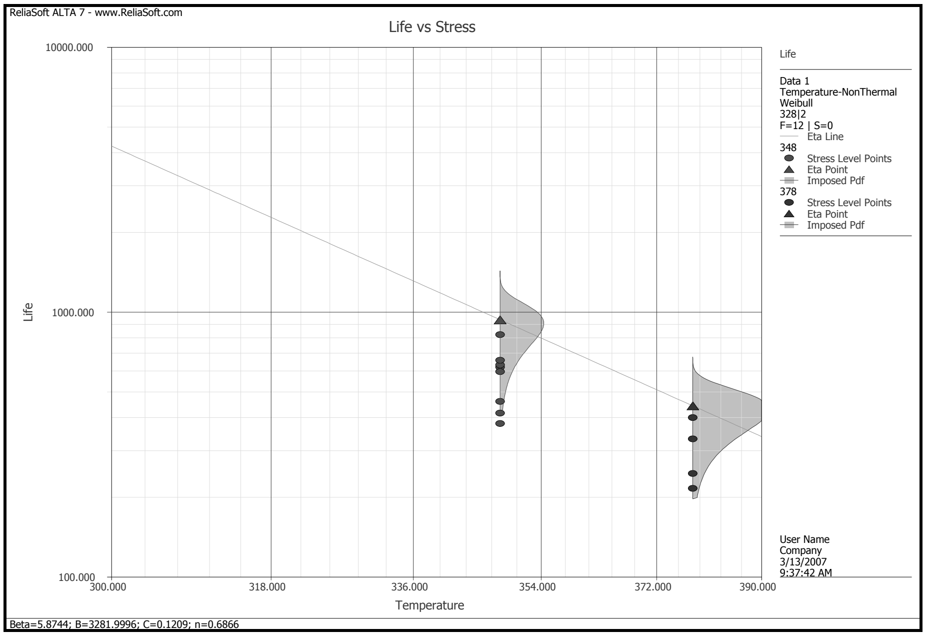
- Click **Calculate** to obtain the results, as shown next.



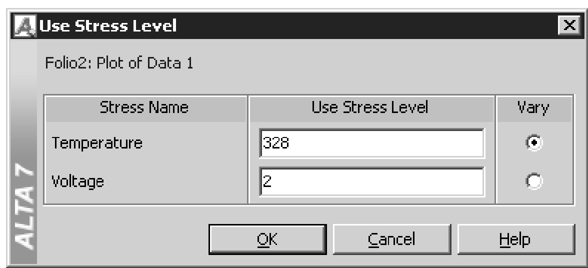
The warranty time for a reliability of 95% is 1,003.6465 hr.

- Close the QCP and return to the Plot Sheet by clicking **Close**.

- Select **Life vs Stress** as the Plot Type in the Plot Sheet Control Panel. The Life vs. Stress plot will appear, as shown next.



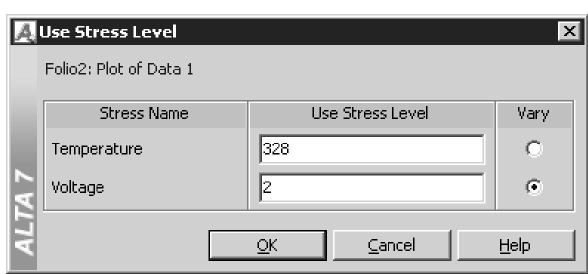
- Open the Use Stress Level window by clicking the **Set Use Stress** link on the Control Panel.



An option labeled **Vary** appears to the right of each stress type, which allows you to specify for one of the stresses to be varied while the other stresses are held constant at the use stress level (*i.e.* if **Vary** is selected for one stress, then the other stresses will be held constant.)

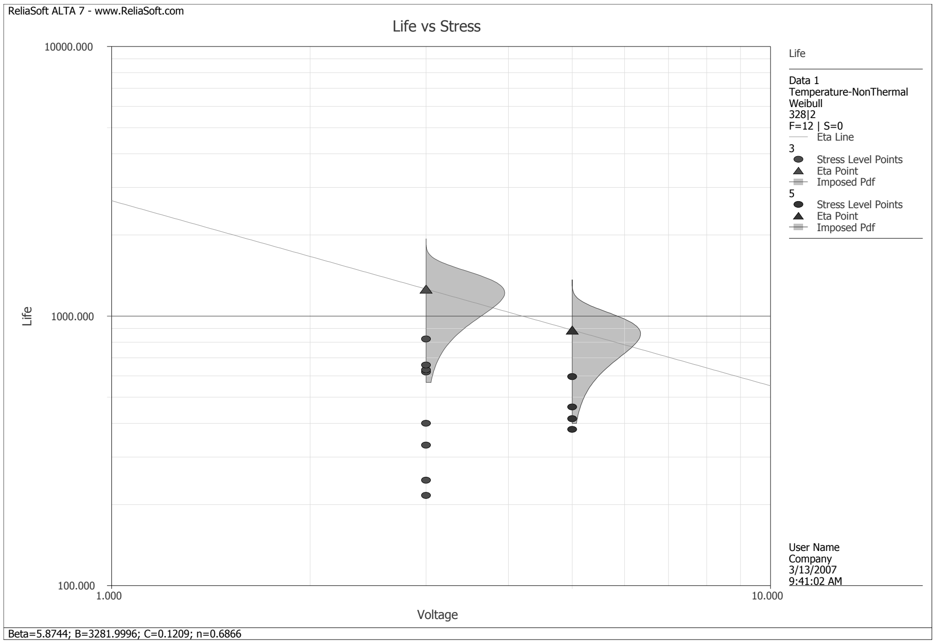
In the previous plot, the Temperature stress was varied, which means that the temperature was plotted and the Voltage stress remained constant at 2V (*i.e*. the plot showed Life vs. Temperature).

- To obtain a Life vs. Voltage plot, select the **Vary** option for the **Voltage** stress, as shown next.



- Click **OK** to close the window and refresh the plot.

The Life vs. Voltage plot for a constant temperature of 328K will appear, as shown next.



- Close the Folio by clicking the Close button (**X**) in the top right corner.
- Save any changes, leave the project open and proceed to the next example.

4.5 Example 5: Grouped Data

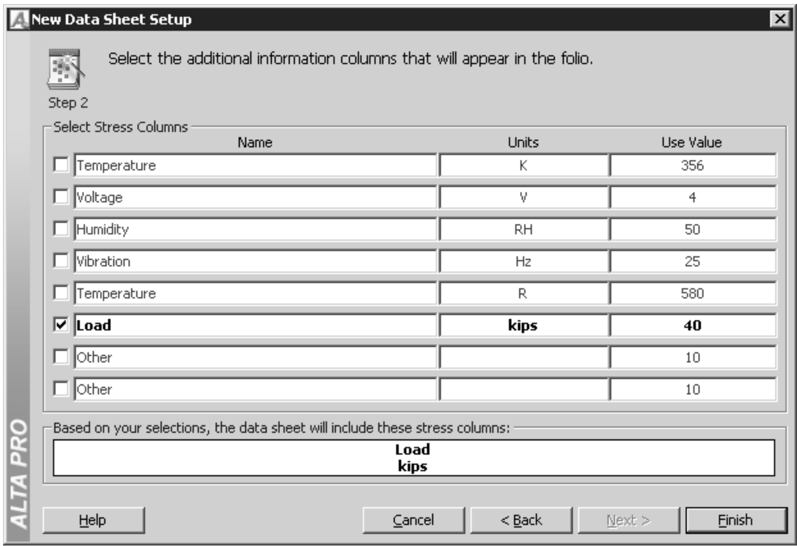
A tensile component of a landing gear was put through an accelerated reliability test to determine whether the return life goal would be achieved under the designed-in load. Fifteen units, N = 15, were tested at three different shock loads. The component was designed for a peak shock load of 40 kips with an estimated return of 10% of the population by 10,000 landings. Using the Inverse Power Law-Lognormal model, determine whether the designed life requirement was met.

Number of Units	Failure, in Landings (simulated)	Load, kips
1	1176	73
3	1512	73
1	3528	73
3	624	98
1	816	98
1	1296	98
1	204	123
1	228	123
1	252	123
1	300	123
1	324	123

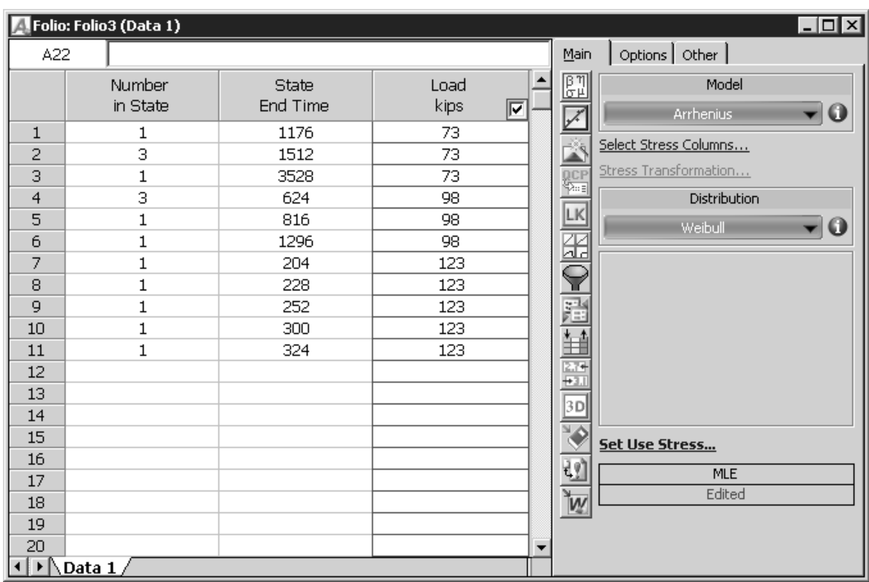
The file for this example is located in the "Training Guide" folder in your application directory (e.g. C:\Program Files\ReliaSoft\ALTA7\Training Guide) and is named "Training Examples.ralp." Use the "Grouped Data" Folio.

Solution

- With the "Training Examples.ralp" project open, create a new Standard Folio by selecting **Add Standard Folio...** from the **Project** menu or by right-clicking inside the Project Explorer and selecting **Add Standard Folio...** from the shortcut menu.
- On the first page of the Data Sheet Setup window, select **I want to enter data in groups** and make sure no other options are selected.
- On the second page, select **Mechanical** as the stress type. Change the Name to **Load** and set the Use Value to **40**, as shown next.



- Click **Finish** to create the Folio.
- Enter the data, as shown next. Note the titles of the column headings.



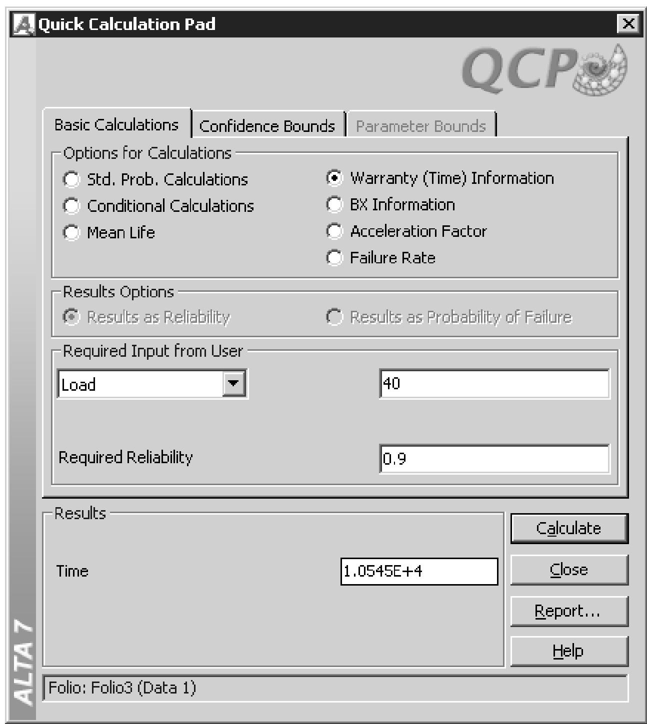
- You can change the heading of the second column, currently **State End Time**, by double-clicking the heading. A window will appear that allows you to change the heading. Type **Simulated Landings** and click **OK**. The row headings can be changed in the same manner, if desired.

- Select **Inverse Power Law** as the life-stress model and **Lognormal** as the underlying life distribution.
- Calculate the parameters and then open the QCP by selecting **Quick Calculation Pad** from the **Data** menu or by clicking its icon.

- On the Basic Calculations page, make the following selections/inputs:
  - Options for Calculations: **Warranty (Time) Information**
  - Required Input from User:

    Load = **40**

    Required Reliability = **0.9**
- Click **Calculate** to obtain the results, as shown next.



The life is estimated to be 10,545 landings, which meets the design specifications. We will continue this example and perform further estimations using the QCP in the next section. Keep the QCP open and proceed to the next example.

4.6 Example 6: Confidence Bounds

In the previous example, it was found that the 10,000 landings life criteria for a 90% reliability was met. However, the estimate of 10,545 landings is very close to the requirement. Additionally, this estimate was obtained at the 50% confidence level. In other words, 50% of the time, life will be greater than 10,545 landings and 50% of the time, life will be less. Repeat the calculation of the previous example and this time include a 90% lower one-sided confidence bound on the estimation of the Warranty (Time) Information.

- We assume that the QCP is still open from the previous example, and Warranty (Time) is still selected with a required reliability of 90% and a stress level of 40.
- Next, go to the Confidence Bounds page by clicking the **Confidence Bounds** tab. Select **Show Confidence Bounds**. More options will appear on the page. Under Show Confidence Bounds, select **Lower One-Sided**. Enter **0.9** in the **Confidence Level** box and click **Calculate** to obtain the results, as shown next.

The 90% lower limit was estimated to be 6729.9599 landings, which is below the design life of 10,000 landings.

- Close the QCP by clicking **Close**.
- Close the Folio by clicking the Close button (**X**) in the top right corner.
- Save any changes, leave the project open and proceed to the next example.

4.7 Example 7: Analysis with Right Censored Data

The following example involves using a data set that contains suspended (right-censored) data.

A certain electronic unit was put through an accelerated test. The test was performed at four different temperature levels; 423K, 443K, 463K and 493K. The use stress level is 393K. The data set obtained from the test is shown next.

Stress Level, K	423K	443K	463K	493K
Times-to-Failure, hr	-	1764	408	408
	-	2772	1120	456
	-	3446	1344	504
	-	3542	1402	504
	-	3780	1440	504
	-	4680	-	-
	-	5196	-	-

Stress Level, K	423K	443K	463K	493K
Suspension Times, hr	6064	5448	1680	528
	6064	5448	1680	528
	6064	5448	1680	528
	6064	-	1680	528
	6064	-	1680	528
	6064	-	-	-
	6064	-	-	-
	6064	-	-	-
	6064	-	-	-
	6064	-	-	-

Do the following:

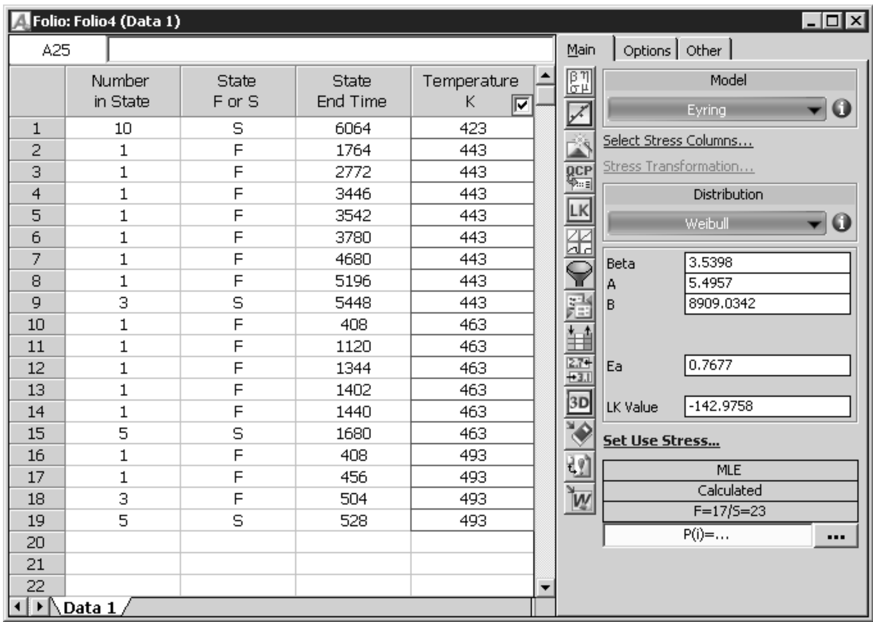
- Enter the data. Use the Eyring-Weibull model to calculate the parameters.
- Obtain the Use Level Probability plot.
- Obtain the Reliability vs. Time plot.
- Obtain the *pdf* plot.
- Obtain the Failure Rate vs. Time plot.
- Obtain the Acceleration Factor vs. Stress plot.
- View all plots at once, including the Life vs. Stress plot, in ALTA's Side-by-Side Plots utility.

The file for this example is located in the "Training Guide" folder in your application directory (e.g. C:\Program Files\ReliaSoft\ALTA7\Training Guide) and is named "Training Examples.ralp." Use the "Right Censored Data" Folio.

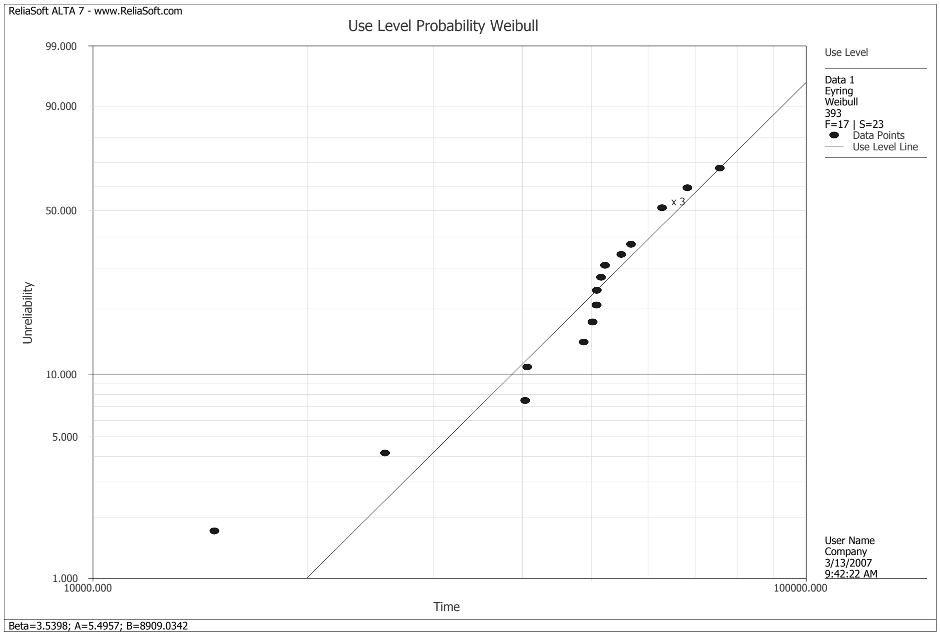
Solution

- With the “Training Examples.ralp” project open, create a new Standard Folio by selecting **Add Standard Folio...** from the **Project** menu or by right-clicking inside the Project Explorer and selecting **Add Standard Folio...** from the shortcut menu.

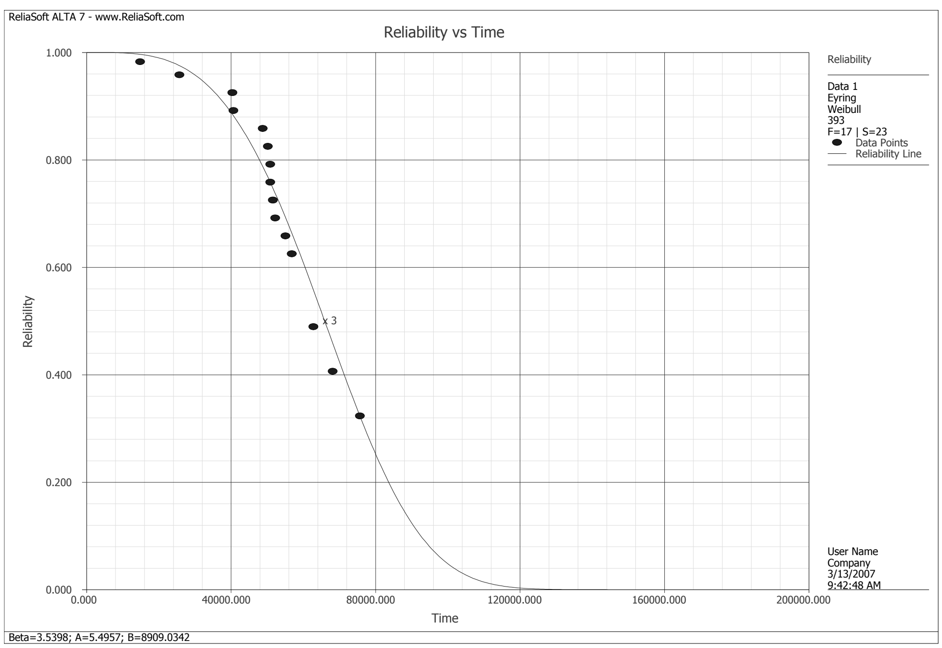
- On the first page of the Data Sheet Setup window, select **My data set contains suspensions (right censored data)** and **I want to enter data in groups**.
- On the second page, select **Temperature** as the stress type and set the Use Value to **393**. Click **Finish** to create the Folio.
- Enter the data and select **Eyring** as the life-stress model and **Weibull** as the underlying life distribution.
- Calculate the parameters by clicking the **Calculate** icon. The calculated parameters are shown next.



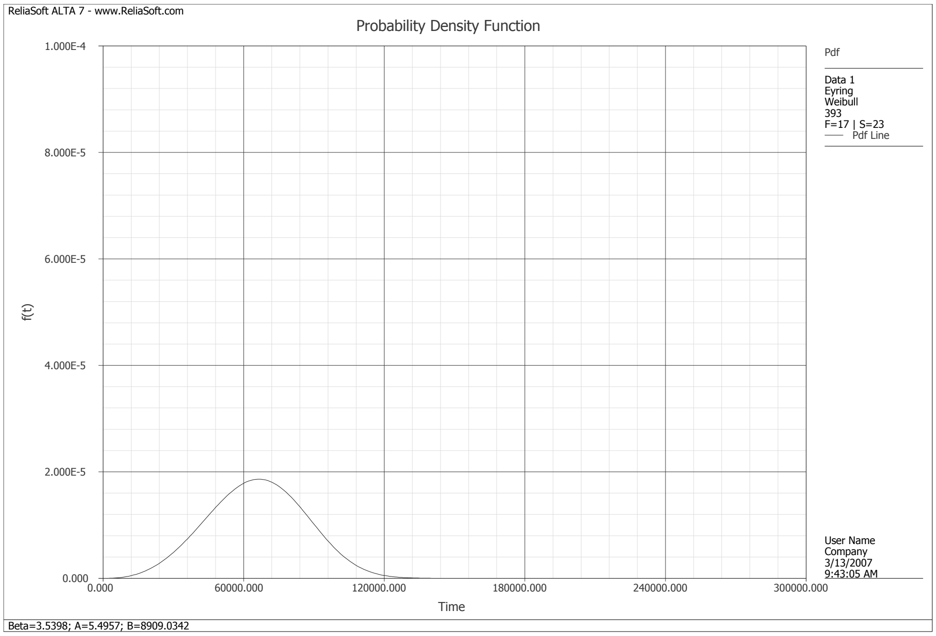
- Plot the data. The Use Level Weibull Probability plot will appear, as shown next.



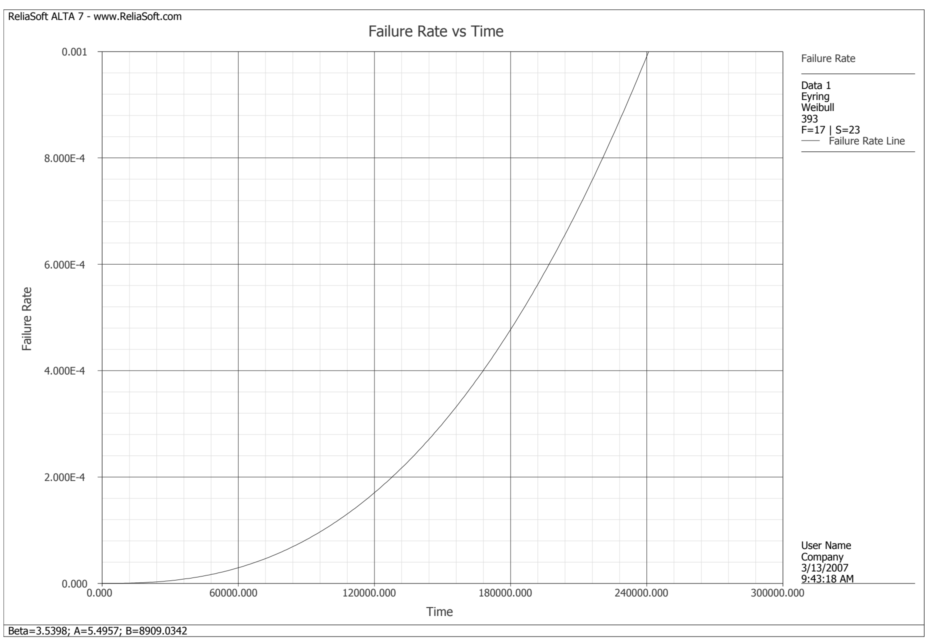
- Obtain the Reliability vs. Time plot by selecting **Reliability vs Time** from the **Plot Type** drop-down menu. The Reliability vs. Time plot is shown next.



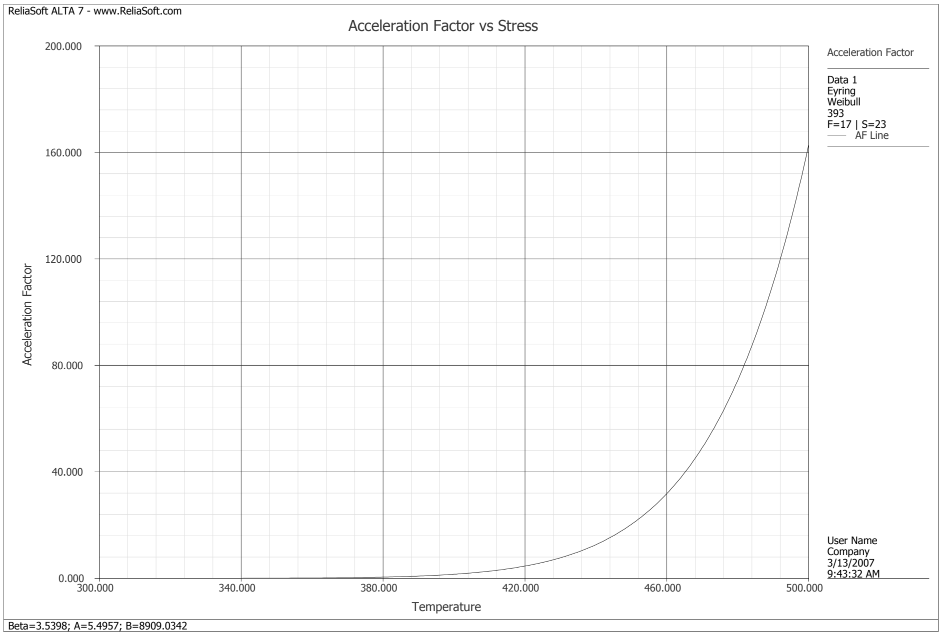
- Next, select **Pdf Plot** from the Plot Type drop-down menu. The Probability Density Function plot is shown next.



- Select **Failure Rate vs Time** from the **Special Plot Type** drop-down menu to obtain the Failure Rate vs. Time plot. The Failure Rate vs. Time plot is shown next.



- Select **AF vs Stress** from the **Plot Type** drop-down menu to obtain the Acceleration Factor vs. Stress plot. The Acceleration Factor vs. Stress plot is shown next.



If you would like to view all of these plots at the same time, along with the Life vs. Stress plot, you can use the Side-by-Side Plots utility. Side-by-Side Plots is available from the Plot Sheet and uses the data, life-stress relationship and distribution from the linked Data Sheet. All plot properties are set to the default settings. With Side-by-Side Plots, you can select from twelve different plot types, three different distributions or five different models to view at once.[5]

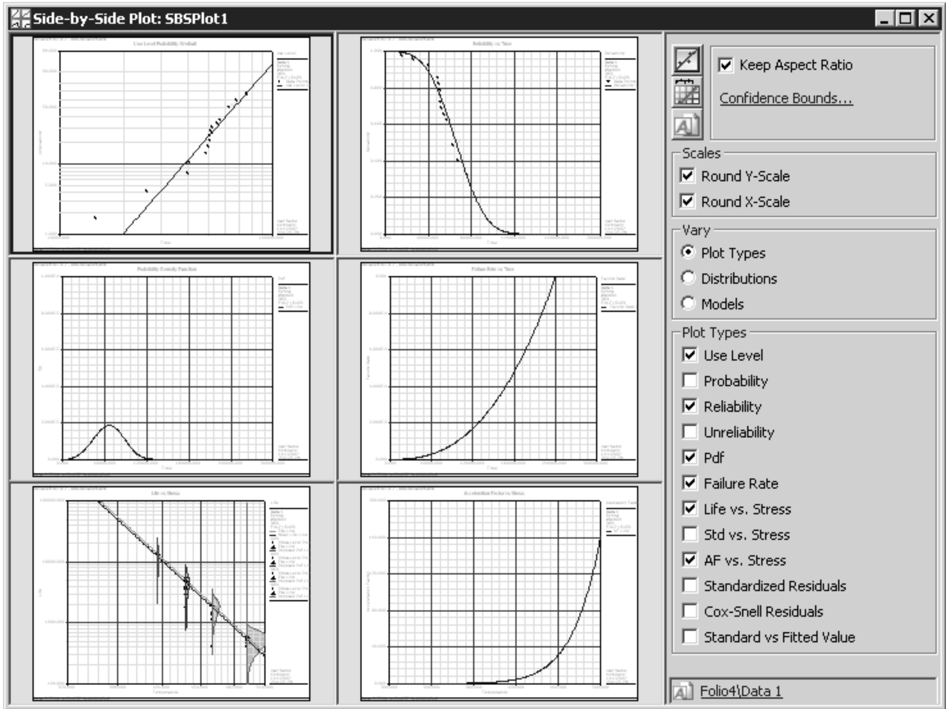
- To open Side-by-Side Plots, click its icon.

The Side-by-Side Plots window will open.

- On the Side-by-Side Plots Control Panel, in the Vary area, select the **Plot Types** option. Twelve plot types will appear. Select to view the **Use Level**, **Reliability**, **Pdf**, **Failure Rate**, **Life vs. Stress** and **AF vs. Stress** plots by clicking the boxes to the left of the corresponding plot types.

5. Note that in ALTA 7 PRO, there are nine different models from which to choose, rather than five.

- Click the **Refresh Plots** button to refresh the plot area to reflect your selections. All six plots will appear in the plot area, as shown next.



- Close the Side-by-Side Plots window and the Folio.
- Save any changes, leave the project open and proceed to the next example.

4.8 Example 8: Plotting Confidence Bounds

In Example 6, you used the QCP to estimate the lower confidence level at a given percentile. This example demonstrates plotting confidence bounds. The use stress level for the following data set is 323K.

Number of Units	State	Time-to-Failure	Temperature
1	Failed	10512	363
3	Failed	11856	363
6	Suspended	12191	363
3	Failed	2436	393
1	Suspended	2436	393
1	Suspended	2772	393
1	Failed	3109	393
4	Suspended	4117	393
1	Suspended	1175	413
1	Failed	1763	413
7	Suspended	1882	413
1	Suspended	1954	413
1	Suspended	1129	433
1	Suspended	1511	433
1	Suspended	1607	433
6	Suspended	1633	433
1	Failed	1895	433

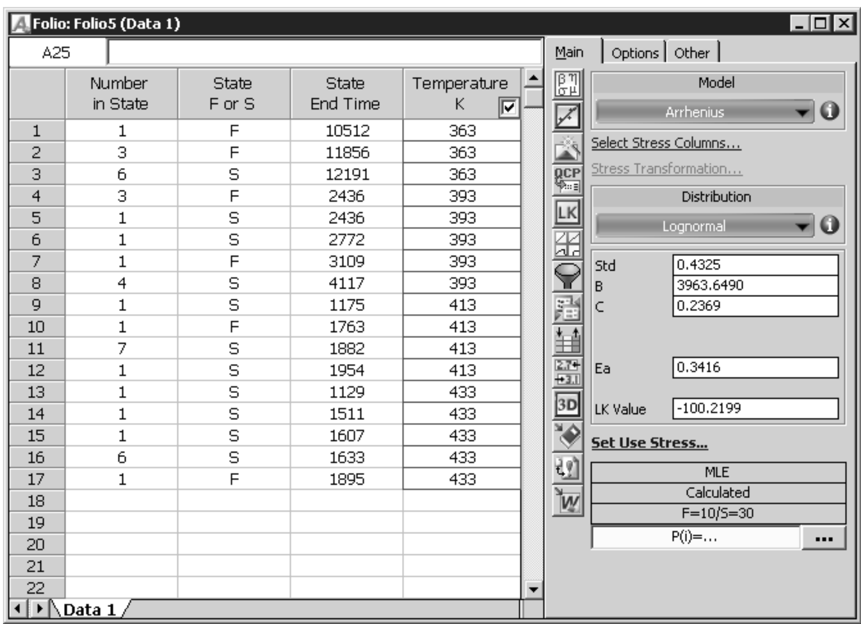
Do the following:

- Determine the parameters for the data using the Arrhenius life-stress relationship and lognormal distribution.
- Obtain the Use Level Lognormal Probability plot for the data with 90%, two-sided Percentile (Type 1) confidence bounds.

The file for this example is located in the "Training Guide" folder in your application directory (e.g. C:\Program Files\ReliaSoft\ALTA7\Training Guide) and is named "Training Examples.ralp." Use the "Plots and Spreadsheets" Folio.

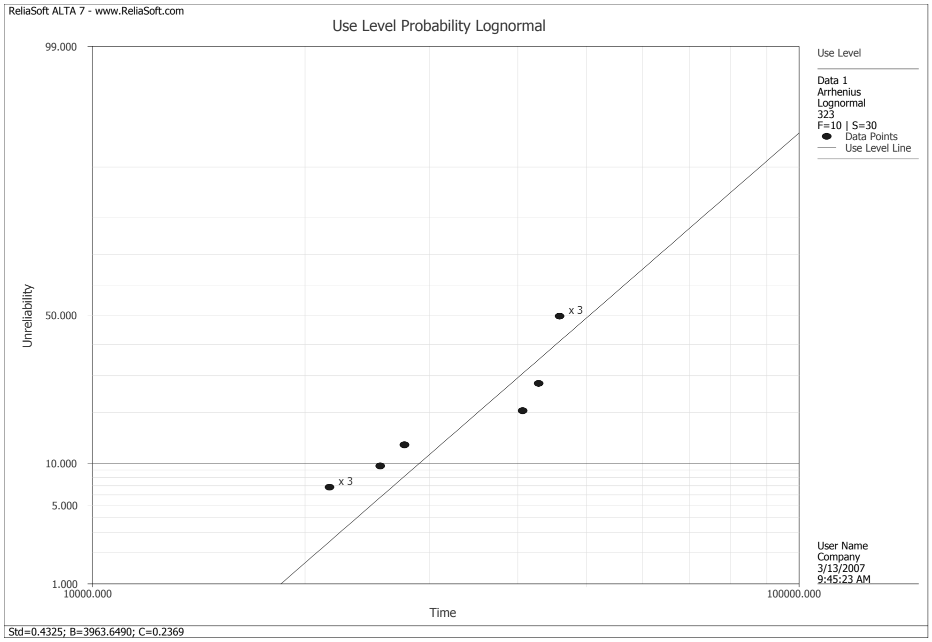
Solution

- With the "Training Examples.ralp" project open, create a new Standard Folio.
- On the first page of the Data Sheet Setup window, select **My data set contains suspensions (right censored data)** and **I want to enter data in groups**.
- On the second page, select **Temperature** as the stress type and set the Use Value to **323**. Click **Finish** to create the Folio.
- Enter the data and select **Arrhenius** as the life-stress model and **Lognormal** as the underlying life distribution. Calculate the parameters. The next figure displays the results.

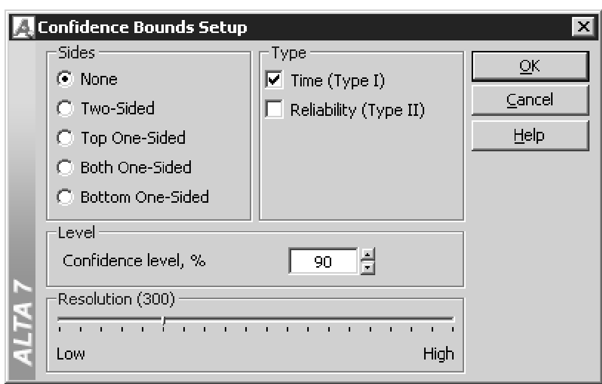


	Number in State	State F or S	State End Time	Temperature K
1	1	F	10512	363
2	3	F	11856	363
3	6	S	12191	363
4	3	F	2436	393
5	1	S	2436	393
6	1	S	2772	393
7	1	F	3109	393
8	4	S	4117	393
9	1	S	1175	413
10	1	F	1763	413
11	7	S	1882	413
12	1	S	1954	413
13	1	S	1129	433
14	1	S	1511	433
15	1	S	1607	433
16	6	S	1633	433
17	1	F	1895	433
18				
19				
20				
21				
22				

- Create a Lognormal Probability plot by clicking the **Plot** icon. The Use Level Lognormal Probability plot will appear on the Plot Sheet, as shown next.

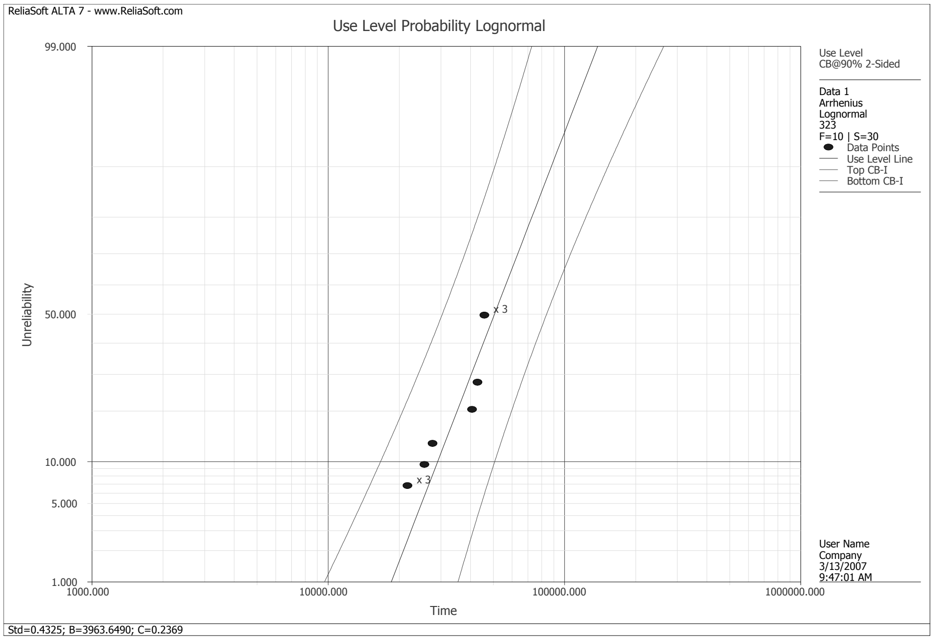


- To plot the confidence bounds, select **Confidence Bounds** from the **Plot** menu or click the **Confidence Bounds** link on the Control Panel. The Confidence Bounds window will appear, as shown next.



- Select **Two Sided** from the **Sides** options and **Time (Type 1)** from the **Type** options. Type **90** for the **Confidence Level (%)** and click **OK**.

The Use Level Probability plot with confidence bounds is shown next.



Notice that the legend now contains information about the plotted confidence bounds.

- Return to the Data Sheet by clicking the **Data 1** page index tab. Save any changes, leave the project and Folio open and proceed to the next example.

4.9 Example 9: Use the General Spreadsheet and Function Wizard

Using the data from Example 8, obtain tabulated values for the failure rate for six different mission end times. The mission end times are 15,000 to 20,000 hr, incremented by 1,000 hr.

The file for this example is located in the "Training Guide" folder in your application directory (e.g. C:\Program Files\ReliaSoft\ALTA7\Training Guide) and is named "Training Examples.ralp." Use the "Plots and Spreadsheets" Folio.

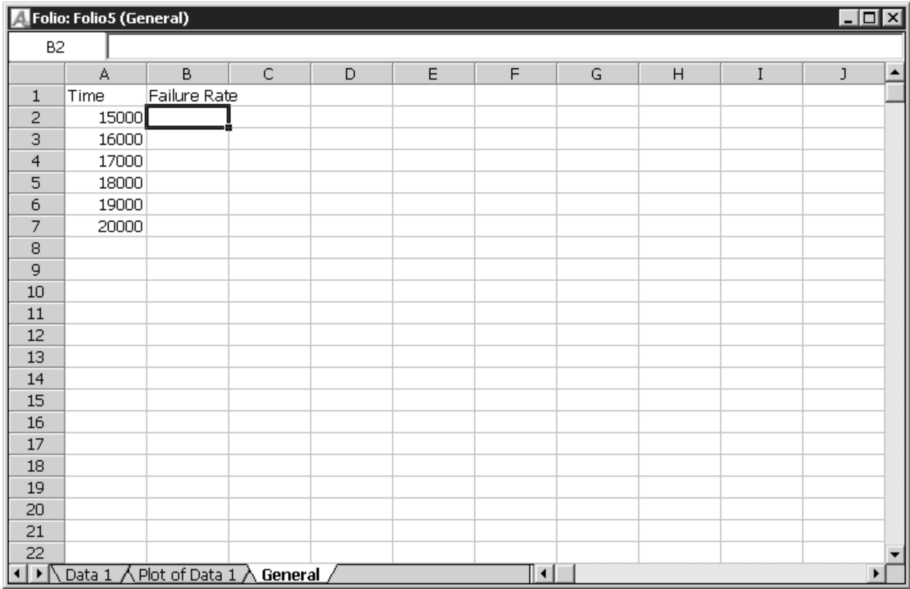
Solution

You can easily accomplish this via the use of the Function Wizard within the General Spreadsheet.[6] The General Spreadsheet is very similar to an Excel® spreadsheet. You can input formulas and edit the cells in a similar manner. The Function Wizard allows you to insert a wide array of calculated results based on your inputs and, when applicable, a referenced Data Sheet.

- If Folio5 from the "Training Examples.ralp" project is not already active, open the project and Folio now.
- Insert a General Spreadsheet by selecting **Insert General Spreadsheet** from the **Folio** menu or by clicking the icon in the Folio Tools toolbar.

6. The General Spreadsheet is presented in detail in Chapter 16 of the *ALTA User's Guide* and the Function Wizard is presented in Chapter 18.

- Type “Time” in cell A1 and “Failure Rate” in cell B1. Then enter 15,000 through 20,000 in cells A2 to A7.[7] Finally, place the cursor into cell B2, as shown next.

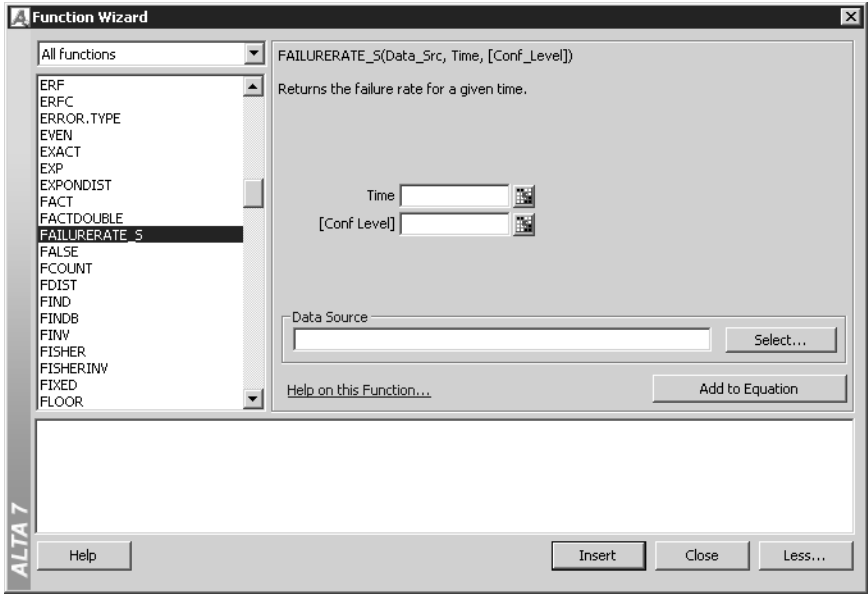


- Open the Function Wizard by selecting **Function Wizard** from the **Data** menu or by clicking the **Function Wizard** icon.

- Select **FAILURERATE_S** from the list of functions. Note that the functions are in alphabetical order and if you click inside the list and start typing the name of the function, the selection will automatically move to the first function in the list that matches the letters you have typed. Also note that the menu

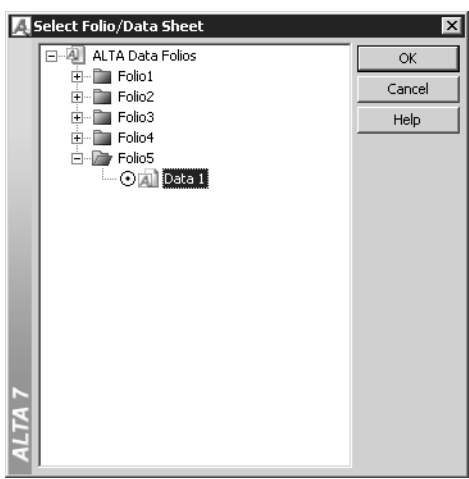
7. To save time, you could also type the equation “=A2+1000” into cell A3 and then copy/paste the equation through cell A11.

above the list allows you to filter the list to display only those functions of a specific type. With the failure rate function selected, the wizard will look like the figure shown next.



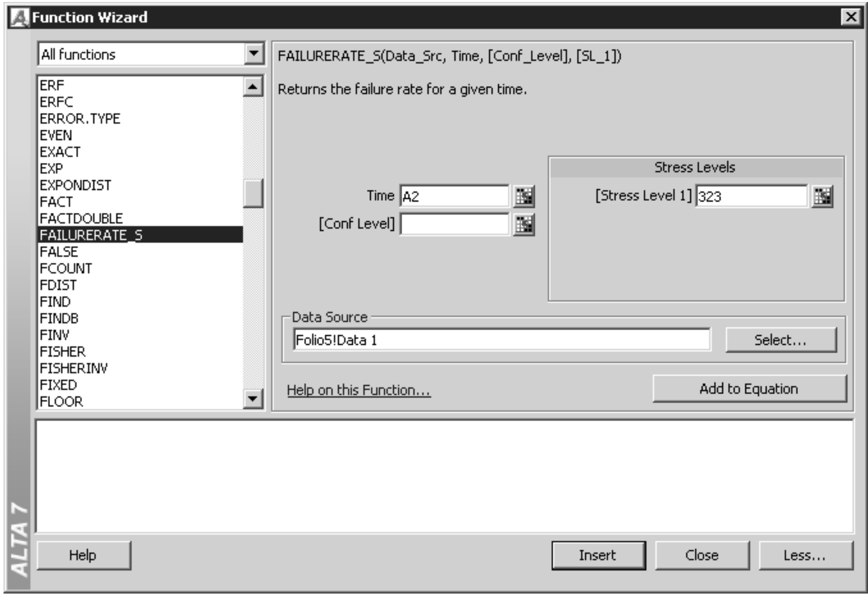
The inputs required for the selected function are displayed on the right side of the window. The text box at the bottom of the window allows you to build the function that will be inserted into the spreadsheet.

- Enter **A2** for Time. This indicates that the time input for the equation will be obtained from the specified cell in the worksheet.
- To specify the existing ALTA analysis that the function result will be based on, click **Select...** to open the Select Folio/Data Sheet window and then navigate to the desired sheet. If you have been performing all of the examples in the Training Examples.ralp project as specified in this training guide, this will be Data 1 in Folio5, as shown next.[8]



[8] If you are using the Training Examples.ralp file included with the software, you will use the Data 1 sheet in the "Plots and Spreadsheets" Standard Folio.

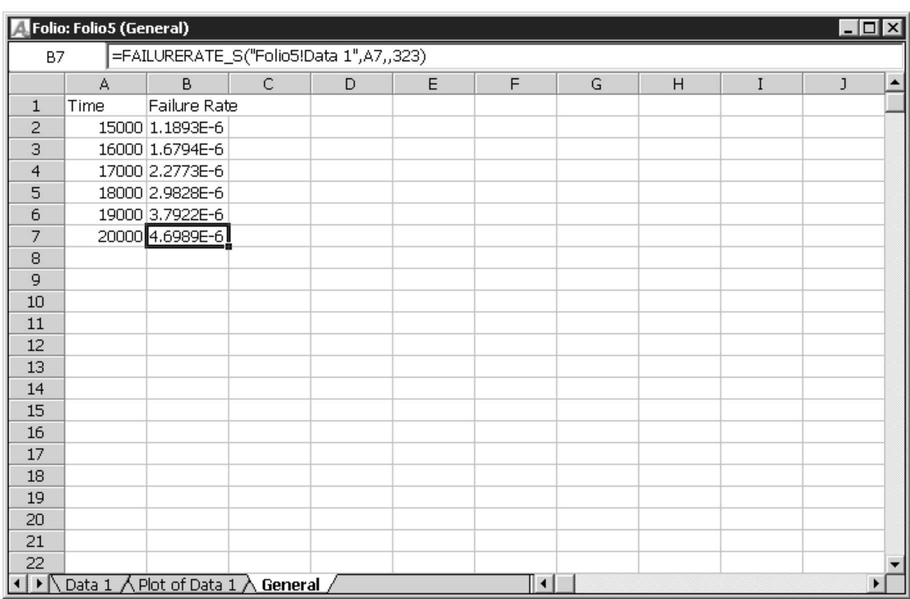
- Click **OK** to close the window and return to the Function Wizard. The wizard will look like the figure shown next.



Notice that an additional input field has appeared, based on the selected Data Sheet. This field allows you to specify the stress level you want to use in the calculation. The default value is the use stress level, taken from the associated Data Sheet.

- Click **Insert** to close the window and insert the function code into the General Spreadsheet. Functions are inserted into the cell that was active when you opened the Function Wizard.
- Copy the function into cells B3 through B7. One way to do this is to position the mouse over the bottom right corner of cell B2 and when the cursor turns into a plus symbol (+), click and drag the mouse to cell B7.

By selecting one of the cells that you copied the function into, you can see that the cell reference was updated to match the current row, as shown next with cell B7 selected.



The table that you have created displays the failure rate for each time in column A, based on the analysis in the associated Data Sheet.

- Save any changes, leave the project and Folio open and proceed to the next example.

4.10 Example 10: 3-D Plots

Using the data from Example 8, obtain the following plots:

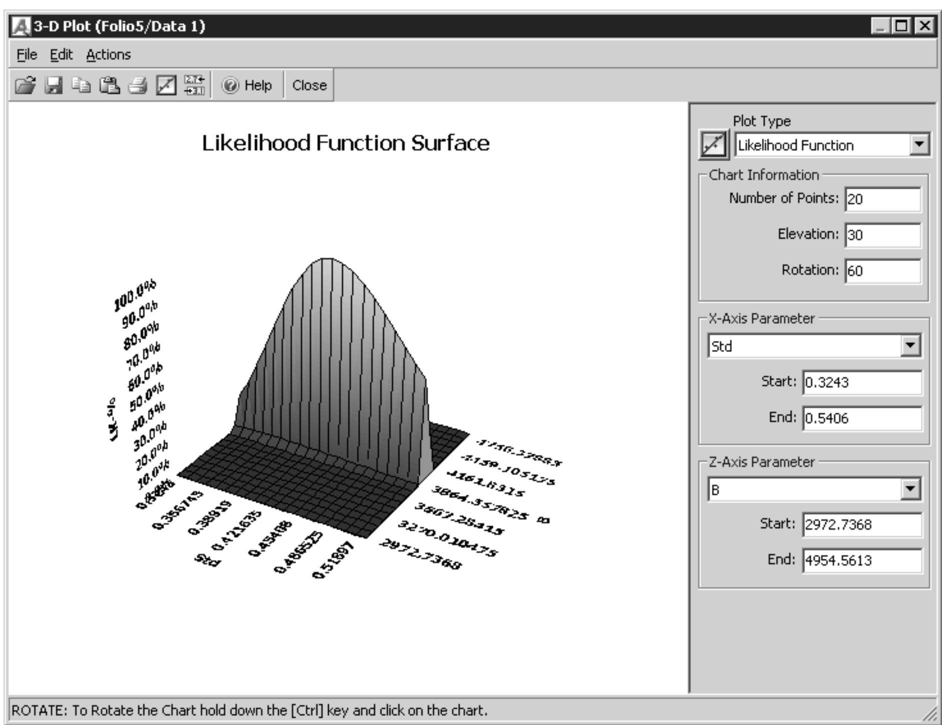
- *pdf* vs. Stress
- Reliability vs. Stress

The file for this example is located in the "Training Guide" folder in your application directory (e.g. C:\Program Files\ReliaSoft\ALTA7\Training Guide) and is named "Training Examples.ralp." Use the "Plots and Spreadsheets" Folio.

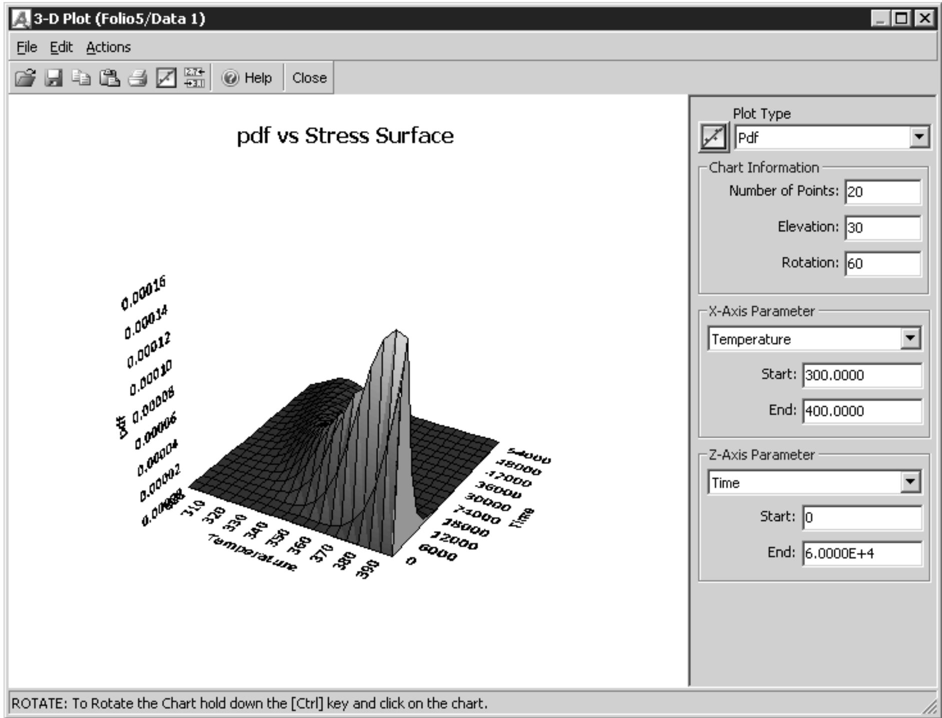
Solution

- Click the Data 1 tab to return to the Data Sheet.
- The *pdf* vs. Stress and Reliability vs. Stress plots can be obtained by selecting **ReliaSoft 3-D Plot** from the **Tools** menu or by clicking the **3-D Plot** icon.

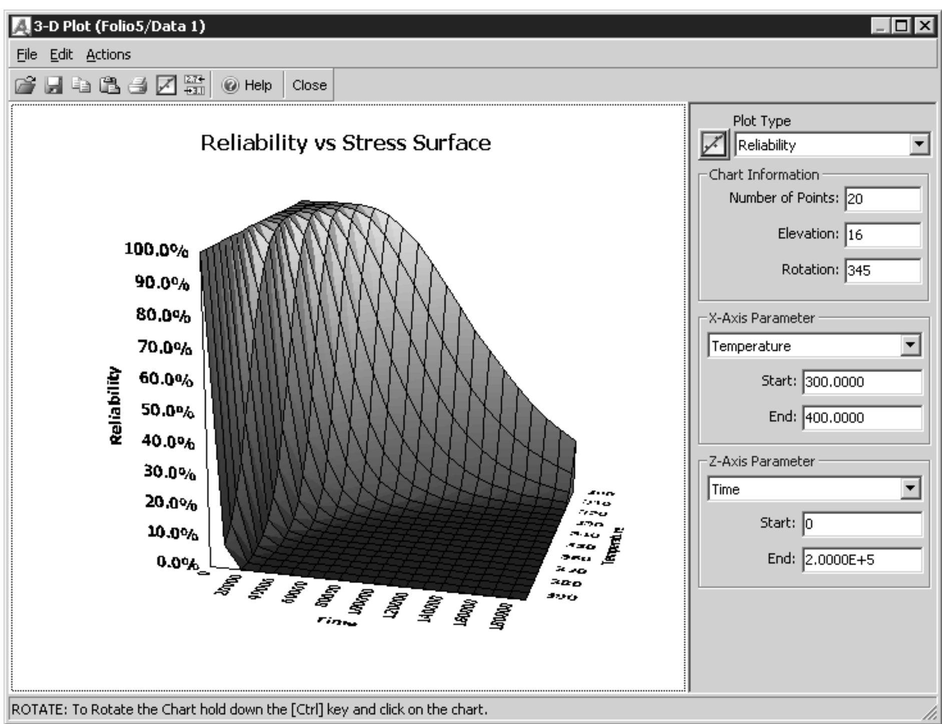
When the 3-D Plot utility is activated, the Likelihood Function plot is displayed by default, as shown next.



- Select the **Pdf** plot from the Plot Type drop-down menu. The generated 3-D *pdf* plot is shown next.



- To rotate the plot, first click the plot. Then, while pressing the **CTRL** key, hold down the left mouse button and move the mouse around to rotate the plot.
- To create the Reliability vs. Stress plot, select **Reliability** from the **Plot Type** menu. The Reliability vs. Stress plot is shown next and has been rotated to display a better view.



- Close the 3-D Plot by clicking the **Close** icon located on the toolbar and close the Folio.
- Save any changes, leave the project open and proceed to the next example.

4.11 Example 11: Determining Activation Energy, B(10) Life and Acceleration Factor, Using Reports for Further Analysis

The accelerating stress for an electronic component is temperature. To meet the specified reliability requirement, the engineer was required to demonstrate with 90% confidence that 90% of the units will continue to operate for 1,000 hr under normal use conditions of 300K. To save time and money, the engineer developed an accelerated life test designed to provide the desired reliability results in a shorter period of time than would be possible with a test performed under normal stress conditions.

Consider the following times-to-failure and times-to-suspension of an electronic component that was placed under an accelerated life test at three different stress levels: 353K, 373K and 393K.

Stress Level	Observed Failures	Observed Suspensions (hr)
353 K	245	250, 250, 250, 250, 250
373 K	110, 180, 200	250, 250, 250
393 K	50, 70, 88, 112, 140, 160	

Do the following:

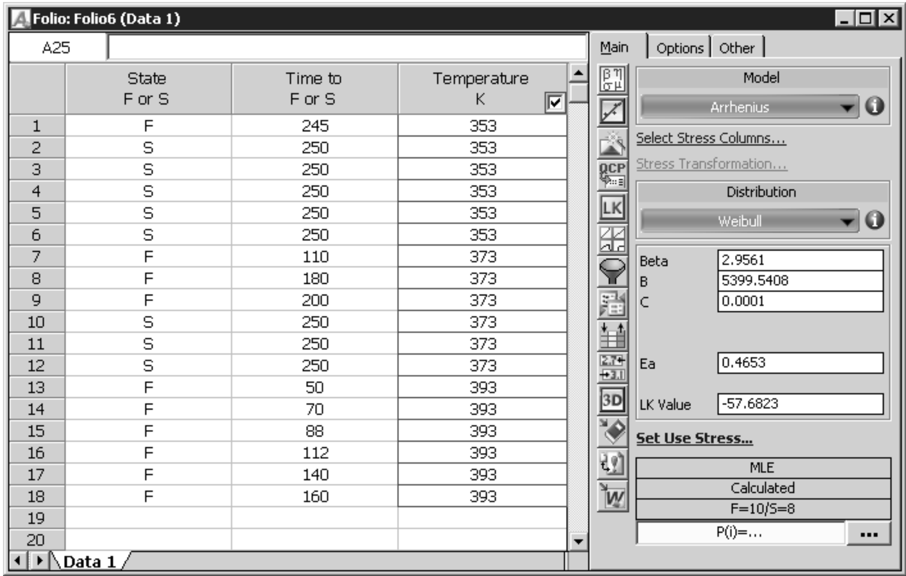
- Determine the activation energy.
- Determine the B(10) life of 1,000 hr at a 90% lower one-sided confidence for the use stress level (300K).
- Plot the Acceleration Factor vs. Stress plot for this example.
- Assuming that 1,000 units will be sold each month, determine the expected number of failures over the next six months so that an appropriate stock of spare parts can be kept on hand

The file for this example is located in the "Training Guide" folder in your application directory (e.g. C:\Program Files\ReliaSoft\ALTA7\Training Guide) and is named "Training Examples.ralp." Use the "Further Analysis" Folio.

Solution

- With the "Training Examples.ralp" project open, create a new Standard Folio.
- On the first page of the Data Sheet Setup window, select **My data set contains suspensions (right censored data)** and make sure no other options are selected.
- On the second page, select **Temperature** as the stress type and set the Use Value to **300**. Click **Finish** to create the Folio.

- Enter the data and select **Arrhenius** as the life-stress model and **Weibull** as the underlying life distribution. Calculate the parameters. The next figure displays the results.



	State F or S	Time to F or S	Temperature K
1	F	245	353
2	S	250	353
3	S	250	353
4	S	250	353
5	S	250	353
6	S	250	353
7	F	110	373
8	F	180	373
9	F	200	373
10	S	250	373
11	S	250	373
12	S	250	373
13	F	50	393
14	F	70	393
15	F	88	393
16	F	112	393
17	F	140	393
18	F	160	393
19			
20			

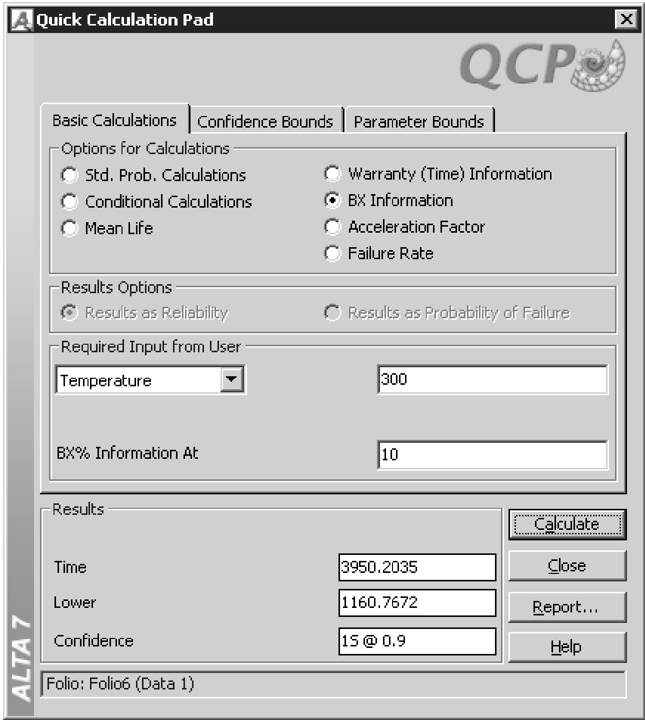
Notice that the Activation Energy (Ea) appears in the Results area. For this example, the Activation Energy = 0.4653.

- Next, open the QCP. On the Confidence Bounds page, select **Show Confidence** and **Show Lower One-Sided**. Make sure that the confidence level is set at 90%.
- On the Basic Calculations page, make the following selections/inputs:
  - Options for Calculations: **BX Information**
  - Required Input From User:

    Temperature = **300**

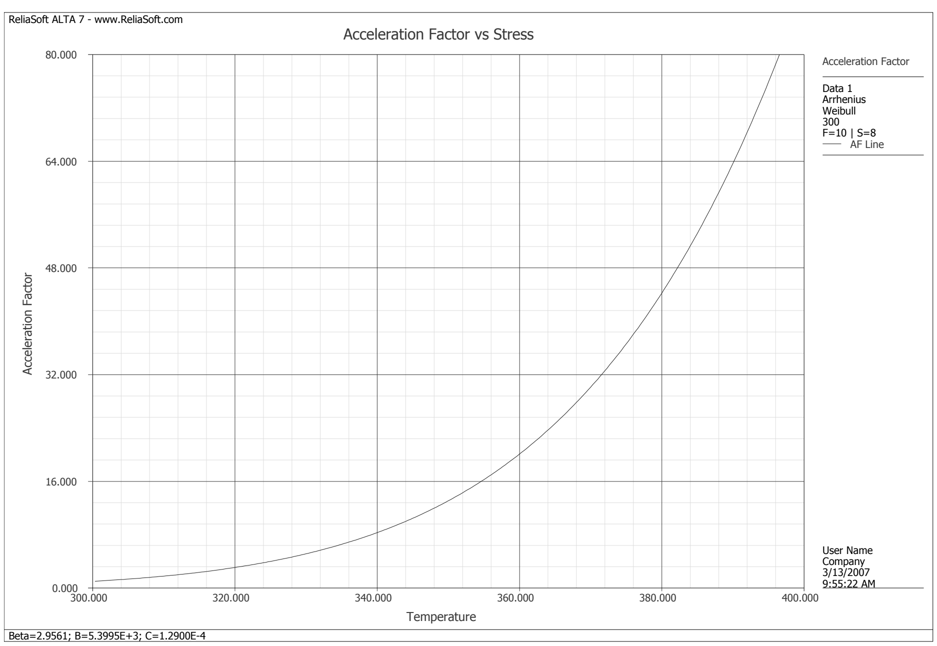
    BX% Information At = **10**

- Click **Calculate** to obtain the results, as shown next..



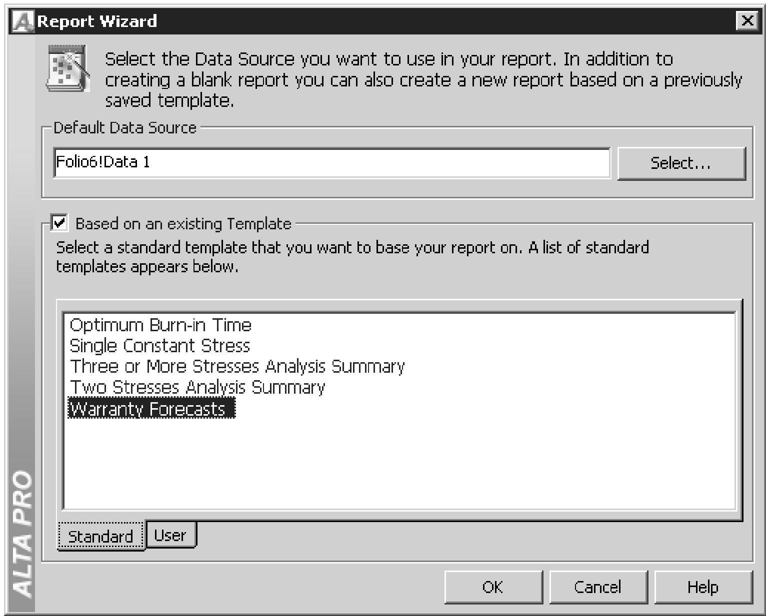
The B(10) life demonstrated at the 90% lower one-sided confidence is 1,161 hr, which is well above the required 1,000 hr.

- Close the QCP and return to the Folio.
- Plot the data. Select **AF vs. Stress** from the Plot Type drop-down menu.
- The Acceleration Factor vs. Stress plot is shown next.

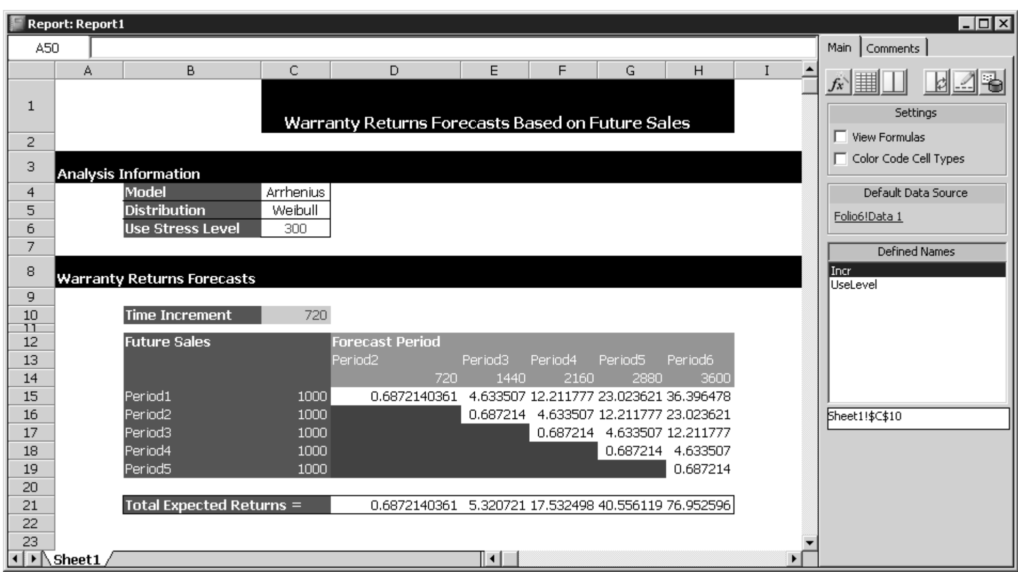


- Return to the Data Sheet and click the **Report Wizard** icon in the Control Panel.

- In the Report Wizard, select to create a report Based on an Existing Template and select the Warranty Forecasts Template, as shown next.[9]



- Click **OK** to create the Report. Enter the use stress level of **300** in the Analysis Information area. In the Warranty Returns Forecasts area, enter **720** in the Time Increment field (24 hours/day * 30 days/month = 720 hours/month) and enter **1000** for the Future Sales values for Periods 1-5. The window will look like the figure shown next.



---

9. Note that if you are using the Training Examples.ralp file included with the software, the Default Data Source will be Further Analysis!Data1.

The projected returns for each upcoming month are displayed in the Total Expected Returns area. From these figures, you can estimate how many spare parts you are likely to need during each time period.

- Close the Report and Folio, save any changes, then proceed to the next example.

4.12 Example 12: Degradation Data Analysis

Consider a chemical solution (*e.g.* ink formulation, medicine, etc.) that degrades with time. A quantitative measure of the quality of the product can be obtained. This measure (QM) is said to be around 100 when the product is first manufactured and decreases with product age. The minimum acceptable value for QM is 50. Products with QM equal to or lower than 50 are considered to be “out of compliance” or failed.

Engineering analysis has indicated that QM has a higher rate of decrease at higher temperatures. Assuming that the product's normal use temperature is 20º C (or 293K), the goal is to determine the shelf life of the product via an accelerated degradation test. For the purpose of this analysis, “shelf life” is defined as the time by which 10% of the products will have a QM that is out of compliance.

For this experiment, fifteen samples of the product were tested, with five samples in each of three environments: 323K, 373K and 383K. Once a month, and for a period of seven months, the QM for each sample was measured and recorded.

	323K					373K					383K				
Month	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	C1	C2	C3	C4	C5
1	97	98	96	99	95	94	94	92	94	90	88	87	82	92	80
2	96	97	94	95	93	93	93	91	90	88	77	86	81	78	78
3	92	94	93	93	88	89	90	90	88	83	83	84	80	76	73
4	91	92	90	91	85	87	88	87	86	80	81	71	77	74	70
5	88	89	85	85	83	85	85	82	80	78	79	77	72	68	68
6	86	86	82	84	82	83	82	79	79	77	77	74	69	67	67
7	85	82	80	79	77	81	78	77	74	72	75	70	67	62	62

Do the following:

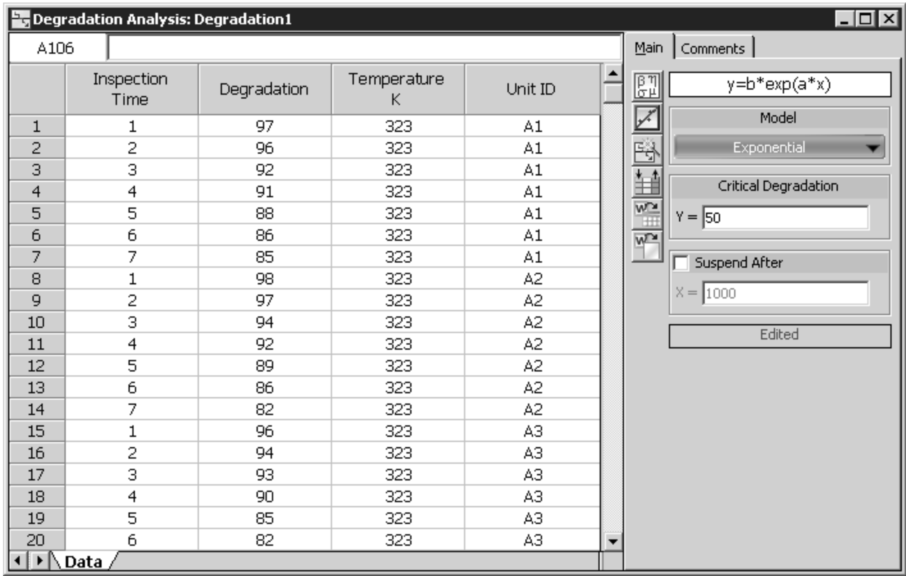
- Determine the shelf life of the product at 293K.

The file for this example is located in the “Training Guide” folder in your application directory (e.g. C:\Program Files\ReliaSoft\ALTA7\Training Guide) and is named “Training Examples.ralp.” Use the “Degradation1” Degradation Analysis Folio.

Solution

- Add a Degradation Analysis Folio to the project.
- In the Degradation Folio Setup window, select the first stress, **Temperature**, and enter **293** in the Use Value field for that stress. Click **Finish** to create the Degradation Analysis Folio.
- Enter the data into the Data Sheet.
- In the Control Panel, select **Exponential** for the Degradation Model and type **50** for the Critical Degradation. There is no Suspension Time for this example.

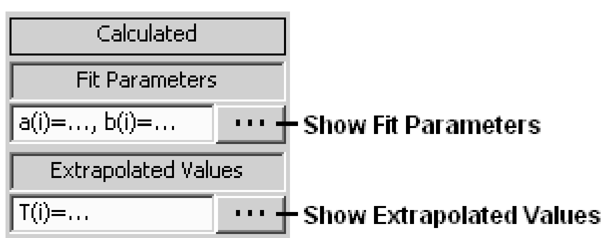
- The Data Sheet will look similar to the one shown next. Be sure the data set is entered as given in the table. All of the data that are applicable for this example do not appear in the next figure, as there are 105 rows of data.



	Inspection Time	Degradation	Temperature K	Unit ID
1	1	97	323	A1
2	2	96	323	A1
3	3	92	323	A1
4	4	91	323	A1
5	5	88	323	A1
6	6	86	323	A1
7	7	85	323	A1
8	1	98	323	A2
9	2	97	323	A2
10	3	94	323	A2
11	4	92	323	A2
12	5	89	323	A2
13	6	86	323	A2
14	7	82	323	A2
15	1	96	323	A3
16	2	94	323	A3
17	3	93	323	A3
18	4	90	323	A3
19	5	85	323	A3
20	6	82	323	A3

- Calculate the parameters by selecting **Calculate** from the **Data** menu or by clicking the **Calculate** icon.

- To view the calculated parameters, click the **Show Fit Parameters** button in the Control Panel. To view the extrapolated failure times, click the **Show Extrapolated Values** button.



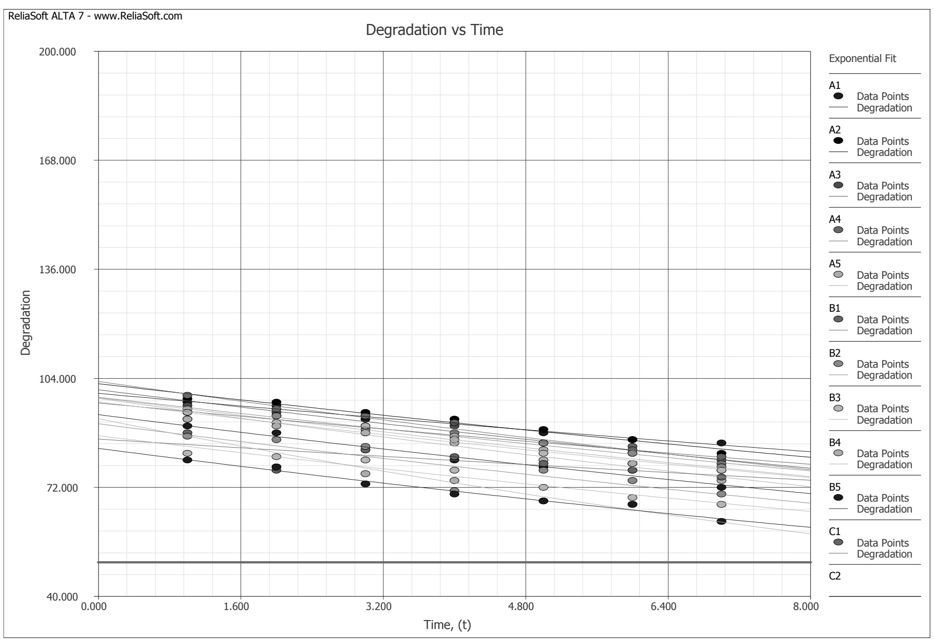
The parameter results are shown next.

Results Panel

A30

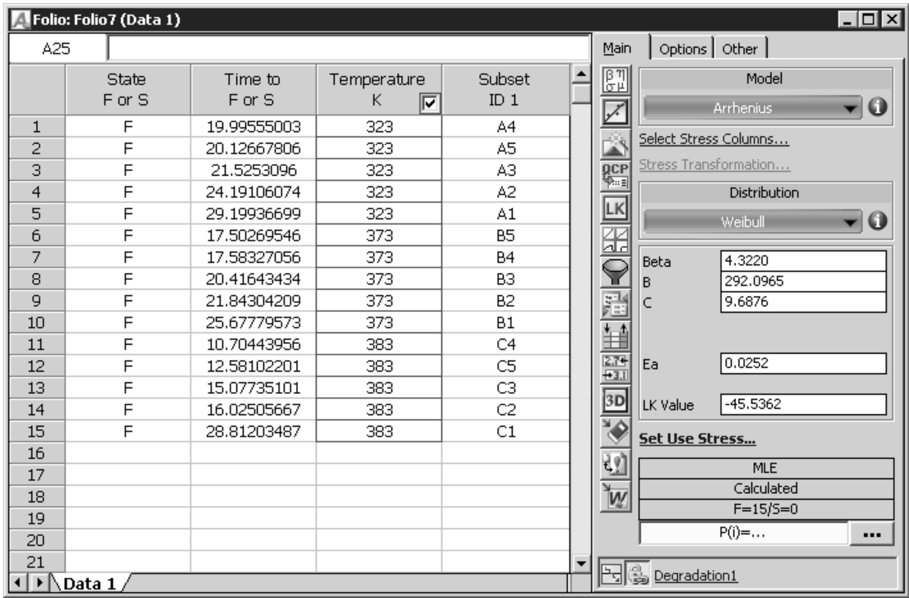
	A	B	C	D	E	F
1	Date: 01-12-2007					
2	User: User Name					
3	Company: Company					
4						
5	Unit ID	Temperature	Parameter a	Parameter b		
6	A1	323	-2.36E-02	99.57923112		
7	A2	323	-2.96E-02	102.4349421		
8	A3	323	-3.25E-02	100.649557		
9	A4	323	-0.03618158626	103.0787979		
10	A5	323	-3.36E-02	98.30186281		
11	B1	373	-2.57E-02	96.77083426		
12	B2	373	-3.10E-02	98.46343551		
13	B3	373	-3.25E-02	97.07242701		
14	B4	373	-3.83E-02	98.12998759		
15	B5	373	-3.57E-02	93.34104183		
16	C1	383	-1.89E-02	86.16824732		
17	C2	383	-0.03713622903	90.6615353		
18	C3	383	-3.69E-02	87.16464239		
19	C4	383	-5.71E-02	92.14904406		
20	C5	383	-4.07E-02	83.4375097		
21						

- Click **Close** to close the Results Panel window.
- Plot the results in a new sheet by selecting **Plot** from the **Data** menu or by clicking the **Plot** icon. With all units selected to be displayed, the plot will look like the one shown next.



- To transfer the extrapolated failure times to a Standard Folio, return to the Data Sheet and select **Transfer Life Data to New Folio** from the **Data** menu or click the icon.

- Double-click the newly created Standard Folio in the Project Explorer to open the new Standard Folio that the failure and suspension times were transferred to.[10] Select **Arrhenius** as the life-stress model and **Weibull** as the distribution. Calculate the parameters. The Folio will look like the one shown next.

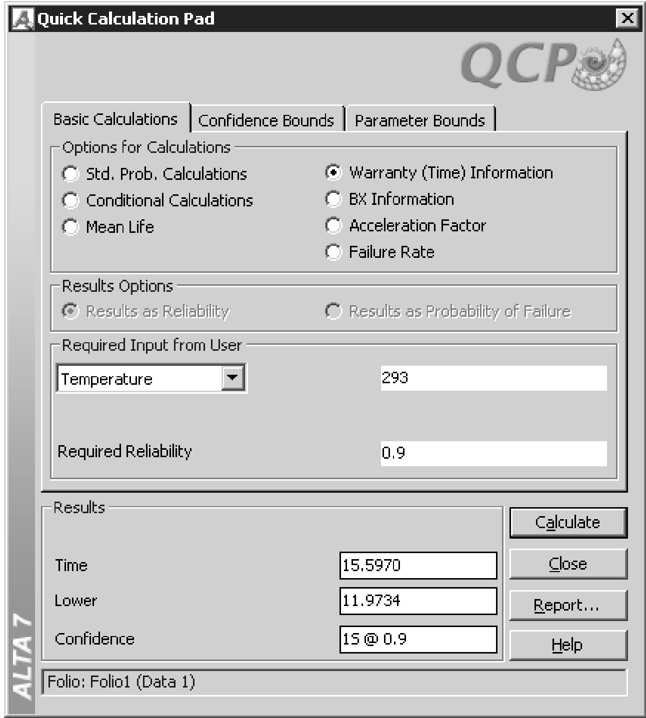


	State F or S	Time to F or S	Temperature K	Subset ID 1
1	F	19.99555003	323	A4
2	F	20.12667806	323	A5
3	F	21.5253096	323	A3
4	F	24.19106074	323	A2
5	F	29.19936699	323	A1
6	F	17.50269546	373	B5
7	F	17.58327056	373	B4
8	F	20.41643434	373	B3
9	F	21.84304209	373	B2
10	F	25.67779573	373	B1
11	F	10.70443956	383	C4
12	F	12.58102201	383	C5
13	F	15.07735101	383	C3
14	F	16.02505667	383	C2
15	F	28.81203487	383	C1
16				
17				
18				
19				
20				
21				

Note that the Specialized Folio that you created for the degradation analysis is now associated with the Standard Folio that you transferred the data to. You can click the link at the bottom of the Control Panel to open the associated Degradation Analysis Folio. In addition, if you change and re-calculate the degradation analysis, the associated Standard Folio will be updated automatically.

10. If you are using the Training Examples.ralp file included with the software, the “Transferred from Degradation” Standard Folio contains this information.

- Open the Quick Calculation Pad. Perform a calculation for Warranty (Time) Information using **293** for the use stress level and **0.9** for the required reliability. The results are shown next.



Using the Degradation Analysis Folio and the QCP, the shelf life is calculated to be about 15.6 months.

- Close the QCP.
- Close the Standard Folio and the Degradation Analysis Folio, save any changes, then proceed to the next example.

4.13 Example 13: Performing a Likelihood Ratio Test

Consider the data summarized in the following table.

	Temperature		
	406 K	**416 K**	**426 K**
Time-to-Failure	248	164	92
	456	176	105
	528	289	155
	731	319	184
	813	340	219
		543	235

This data set illustrates a typical 3-level, constant accelerated stress. The stress in this example is temperature and the Arrhenius life-stress relationship will be used. In this case, the Stress Profile is constant and each stress level can be considered a different profile. The use stress level is 300.

Do the following:

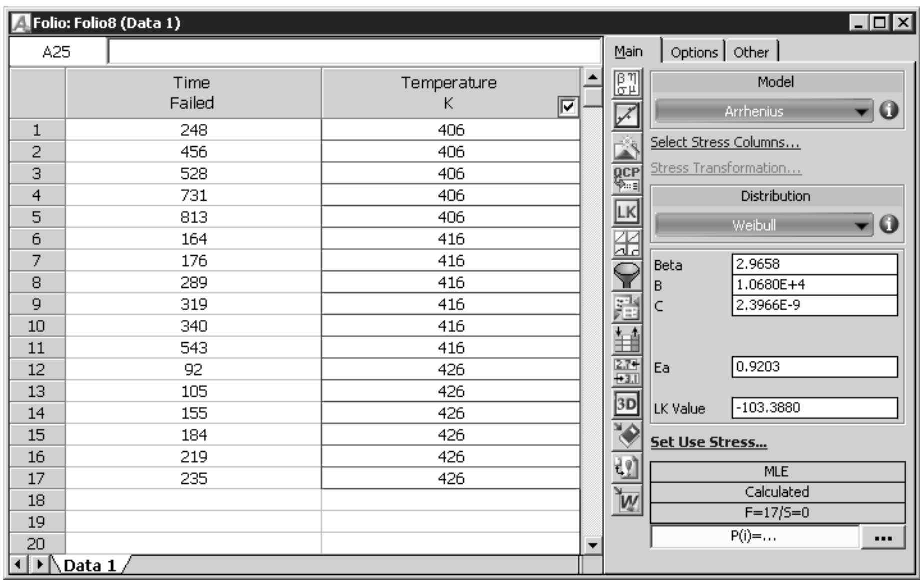
- Obtain the parameters of the model.

- Perform a likelihood ratio test to validate the assumption of a common shape parameter across three stress levels.

The file for this example is located in the "Training Guide" folder in your application directory (e.g. C:\Program Files\ReliaSoft\ALTA7\Training Guide) and is named "Training Examples.ralp." Use the "Likelihood Ratio Test" Folio.

Solution

- Create a new Standard Folio for non-grouped times-to-failure data. On the first page of the Data Sheet Setup window, make sure none of the options are selected.
- On the second page, select **Temperature** as the stress type and set the Use Value to **300**. Click **Finish** to create the Folio.
- Enter the data and calculate the parameters using the Arrhenius life-stress model and the Weibull distribution.

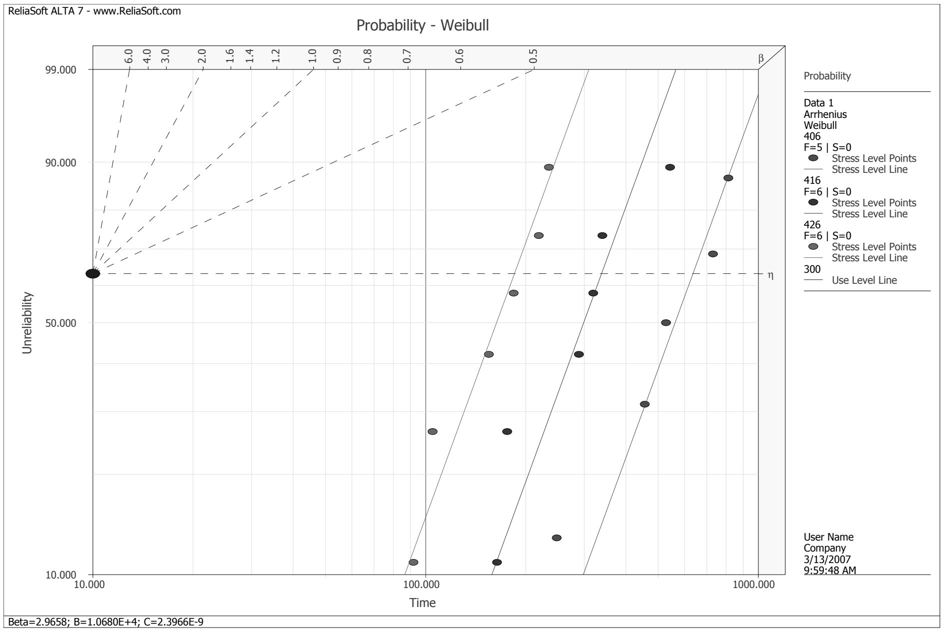


The estimated parameters are found to be:

beta = 2.9658
B = 1.0680E+4
C = 2.3966E-9

- Next, create a Probability plot of the data. Select to show the probability scales on the plot by selecting **Show/Hide Items** from the **Plot** menu. In the Show/Hide Plot Items window, select the Probability

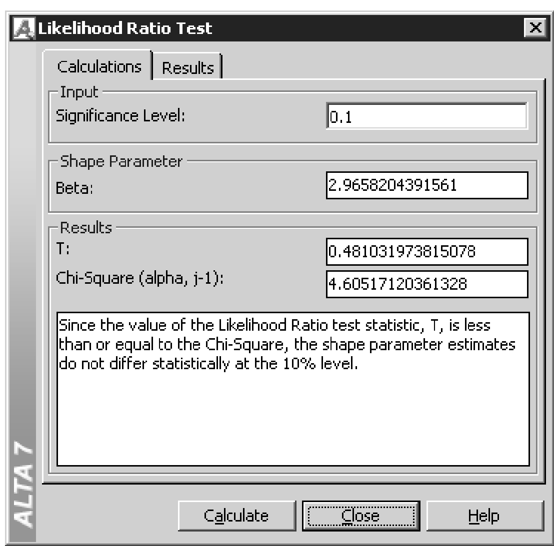
Scales checkbox and click **OK**. You will need to adjust the scaling of the plot, using 1,000 for the upper X-axis.



- You can also perform a likelihood ratio test to validate the assumption of a common shape parameter across the three stress levels. To do this, return to the Data Sheet and click the **Likelihood Ratio Test** icon on the Main Page of the Control Panel,

or select **Likelihood Ratio Test** from the **Data** menu. The Likelihood Ratio Test utility will appear.

- Enter **.1** as the significance level and click **Calculate**. The results will appear, as shown next.



- The value for the likelihood ratio test statistic, T, is less than the value of the chi-square. Therefore, the shape parameter estimates do not differ statistically at the 10% level and it can be stated that the shape parameter remains constant across the three stress levels.

- Exit the Likelihood Ratio Test utility.
- Close the Standard Folio, save any changes, then proceed to the next example.

4.14 Example 14: Creating an Accelerated Life Test Plan

A reliability group in a semiconductor company is planning an accelerated test for an electronic device. 30 test units will be employed for the test and the test is planned to last for 600 hours. Temperature and voltage have been determined to be the main factors affecting the reliability of the device. The normal use conditions of the devices are 300K for temperature and 4V for voltage. The purpose of the experiment is to estimate the B10 life of the device. The reliability engineer wants to use a three-level optimum plan because it will be easier to manage than a five-level test plan.

Based on engineering knowledge, data from a previous design and data from a pilot test, the following information is available:

- An Arrhenius model is assumed for the life-stress relationship associated with temperature and is accurate up to 360K.
- A power model is assumed for the life-stress relationship associated with voltage and is accurate up to 10V.
- The beta parameter for the underlying Weibull distribution is estimated to be 3.
- The probabilities of failure for the product at the end of the test are estimated as follows:
    - Stress 1 = Usage Stress, Stress 2 = Usage Stress: 0.02
    - Stress 1 = Highest Stress, Stress 2 = Usage Stress: 0.9
    - Stress 1 = Usage Stress, Stress 2 = Highest Stress: 0.6

Do the following:

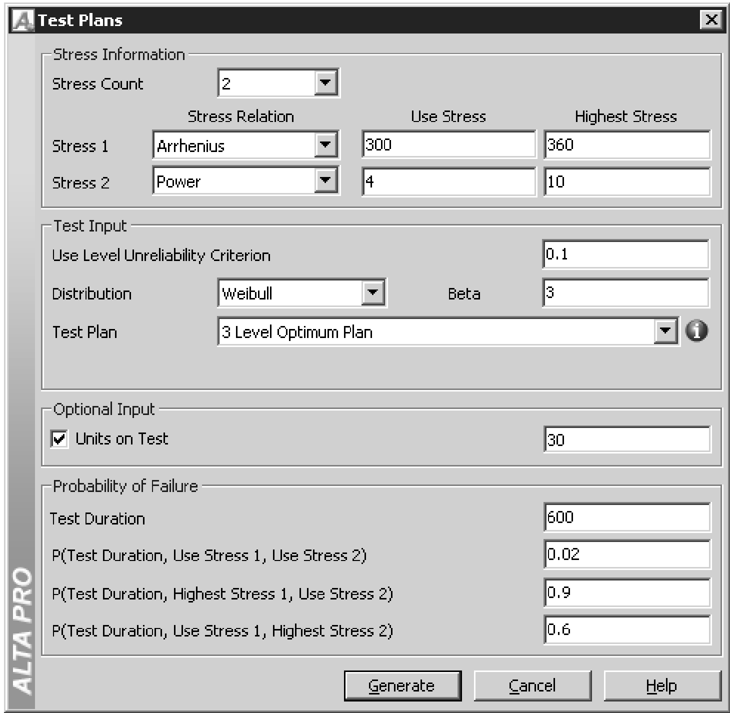
- Create a Test Plan.
- Evaluate the generated Test Plan.

The file for this example is located in the "Training Guide" folder in your application directory (e.g. C:\Program Files\ReliaSoft\ALTA7\Training Guide) and is named "Training Examples.ralp." Use the "Test Plan1" Test Plan.

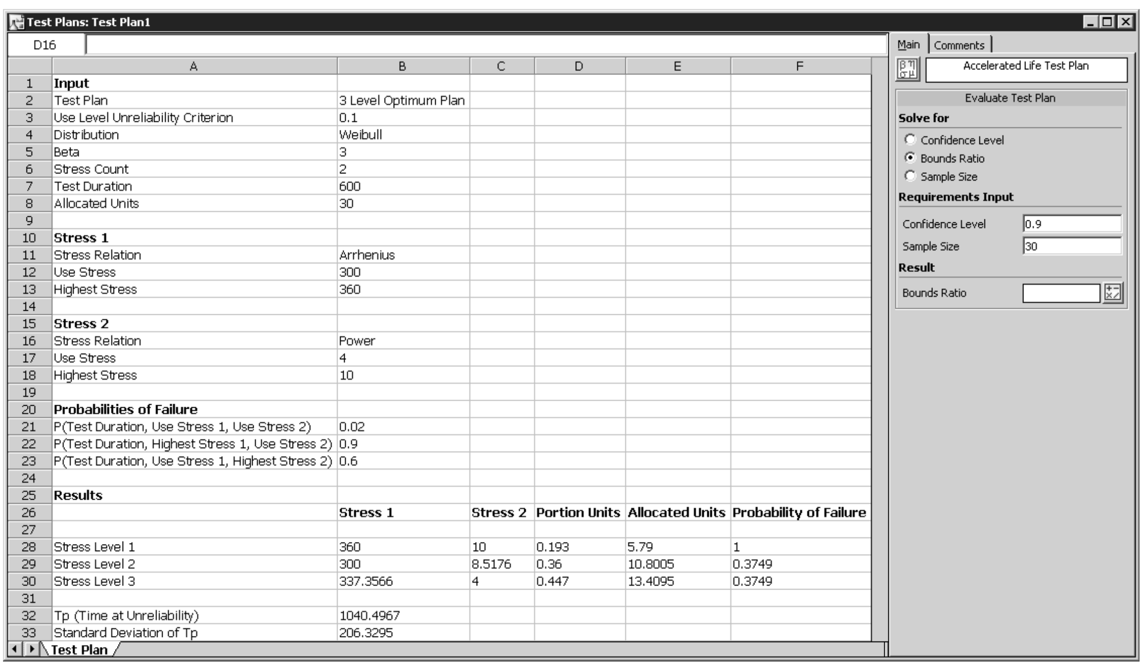
Solution

- With the "Training Examples.ralp" project open, add a new Test Plan to the project.

- In the Setup Window, enter the given information as shown next.



- Click **Generate** to generate the Test Plan, as shown next.



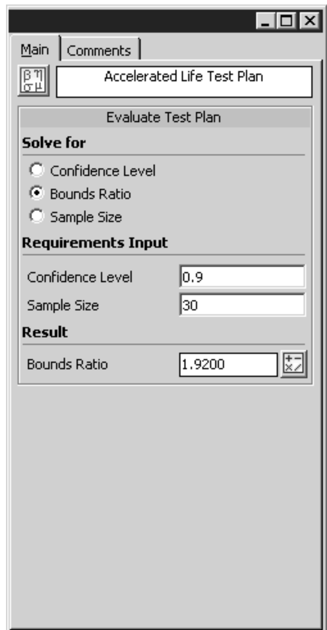
	A	B	C	D	E	F
1	**Input**					
2	Test Plan	3 Level Optimum Plan				
3	Use Level Unreliability Criterion	0.1				
4	Distribution	Weibull				
5	Beta	3				
6	Stress Count	2				
7	Test Duration	600				
8	Allocated Units	30				
9						
10	**Stress 1**					
11	Stress Relation	Arrhenius				
12	Use Stress	300				
13	Highest Stress	360				
14						
15	**Stress 2**					
16	Stress Relation	Power				
17	Use Stress	4				
18	Highest Stress	10				
19						
20	**Probabilities of Failure**					
21	P(Test Duration, Use Stress 1, Use Stress 2)	0.02				
22	P(Test Duration, Highest Stress 1, Use Stress 2)	0.9				
23	P(Test Duration, Use Stress 1, Highest Stress 2)	0.6				
24						
25	**Results**					
26		**Stress 1**	**Stress 2**	**Portion Units**	**Allocated Units**	**Probability of Failure**
27						
28	Stress Level 1	360	10	0.193	5.79	1
29	Stress Level 2	300	8.5176	0.36	10.8005	0.3749
30	Stress Level 3	337.3566	4	0.447	13.4095	0.3749
31						
32	Tp (Time at Unreliability)	1040.4967				
33	Standard Deviation of Tp	206.3295				

The Test Plan specifies that 6 units be tested at 360K and 10V, 11 units be tested at 300K and 8.5 V and the remaining 13 units be tested at 337.4K and 4V. Tp, which is the estimate of the time when 10% of the units will have failed at use stress (*i.e.* B10 life), is 1040.5 hours.

To evaluate the Test Plan, you can solve for any one of three criteria (confidence level, bounds ratio or sample size) given the two other criteria. The bounds ratio is the ratio of the upper confidence bound to the lower confidence bound on Tp.

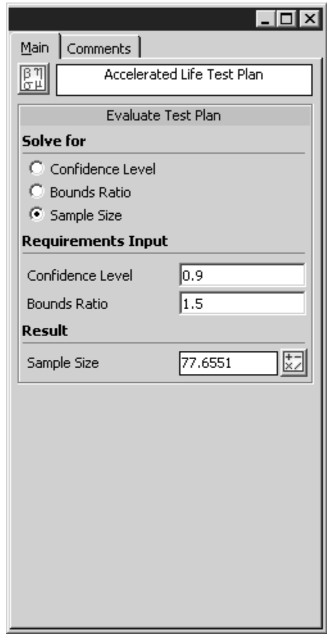
- In the Control Panel, select to solve for **Bounds Ratio**. Enter **0.9** for the confidence level and **30** for the sample size then click **Calculate Results**.

The bounds ratio is calculated as 1.92, as shown next.

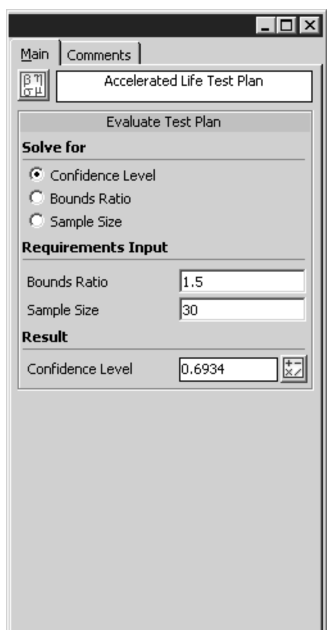


If this calculated bounds ratio is unsatisfactory, you can calculate the required number of units that would meet a certain bounds ratio criterion.

- In the Control Panel, select to solve for **Sample Size**. Enter **1.5** for the bounds ratio (note that the confidence level is retained) then click **Calculate Results**. The required sample size is calculated to be 78 units, as shown next.



If the sample size is kept at 30 units and a bounds ratio of 1.5 is desired, the equivalent confidence level we have in the test is calculated to be 69.34%, as shown next.



- Close the Test Plan, save any changes, then close the project.

5 ALTA 7 PRO Examples

The following examples use time-varying stresses, life-stress relationships and other utilities/ functionalities that are only available in ALTA 7 PRO. Thus, these examples can only be performed using ALTA 7 PRO. Chapter 4 presents examples that can be performed using ALTA 7 Standard.

5.1 Example 15: Simple Step-Stress

An electronic component was subjected to a voltage stress, starting at 2V (use stress level) and increased to 7V in stepwise increments. The following steps were used to apply stress to the products under test: 0 to 250 hr, 2V; 250 to 350 hr, 3V; 350 to 370 hr, 4V; 370 to 380 hr, 5V; 380 to 390 hr, 6V; and 390 to 400 hr, 7V.

Eleven units were available for the test. All eleven units were tested using the same Stress Profile. Units that failed were removed from the test and their total time on test was recorded. The following times-to-failure were observed in the test: 280, 310, 330, 352, 360, 366, 371, 374, 378, 381 and 385 hr.

Do the following:

- Determine the mean life (often called MTTF or MTBF) and B(10) life of these components at the normal use stress level of 2V.

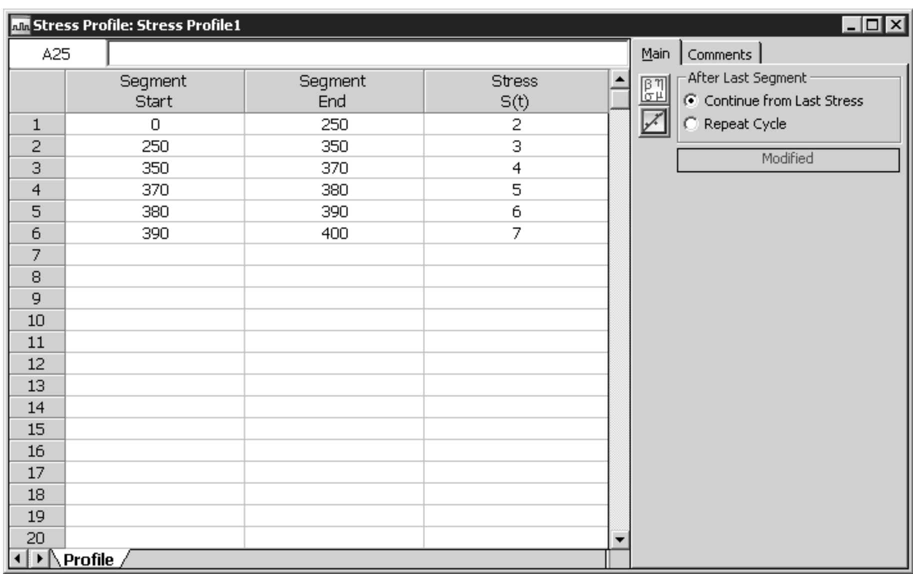
The file for this example is located in the "Training Guide" folder in your application directory (e.g. C:\Program Files\ReliaSoft\ALTA7\Training Guide) and is named "Training Examples PRO.ralp." Use the "Simple Step-Stress" Folio.

Solution

- Create a new project with a Standard Folio for ungrouped times-to-failure data with voltage as the stress type. Set the use stress level as 2V.
- Add a Stress Profile to the project by selecting **Add Stress Profile...** from the **Project** menu or by right-clicking inside the Project Explorer and selecting **Add Stress Profile...** from the shortcut menu.

In a Stress Profile, you can define a time-varying stress in segments. The stress for each of these segments can be a constant value (as in the case of this example) or defined as a function of time.

- Enter the data in the Data Sheet, as shown next.

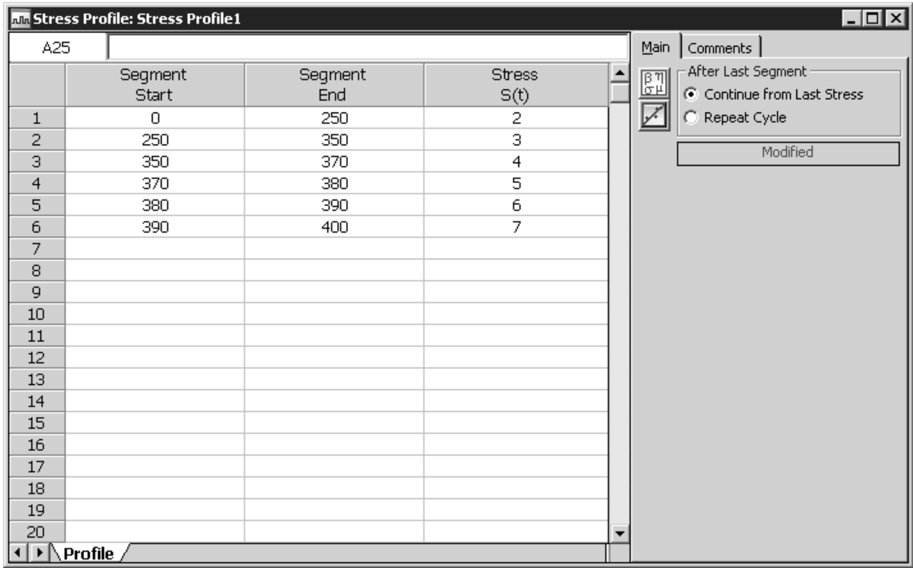


	Segment Start	Segment End	Stress S(t)
1	0	250	2
2	250	350	3
3	350	370	4
4	370	380	5
5	380	390	6
6	390	400	7
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			

- Update the Stress Profile by clicking the **Calculate** icon.

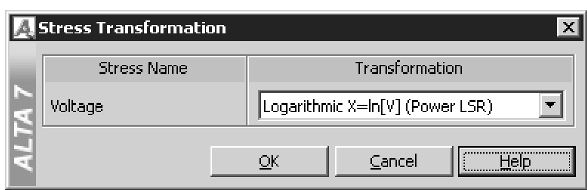
- Next, plot the Stress Profile by clicking the **Plot** icon.

A Plot Sheet will be added to the Stress Profile, as shown next.

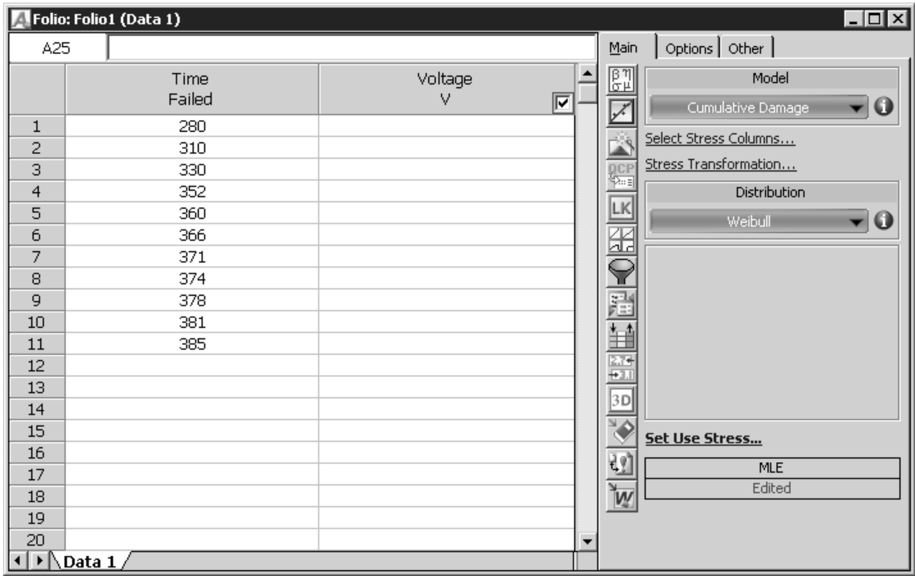


	Segment Start	Segment End	Stress S(t)
1	0	250	2
2	250	350	3
3	350	370	4
4	370	380	5
5	380	390	6
6	390	400	7
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			

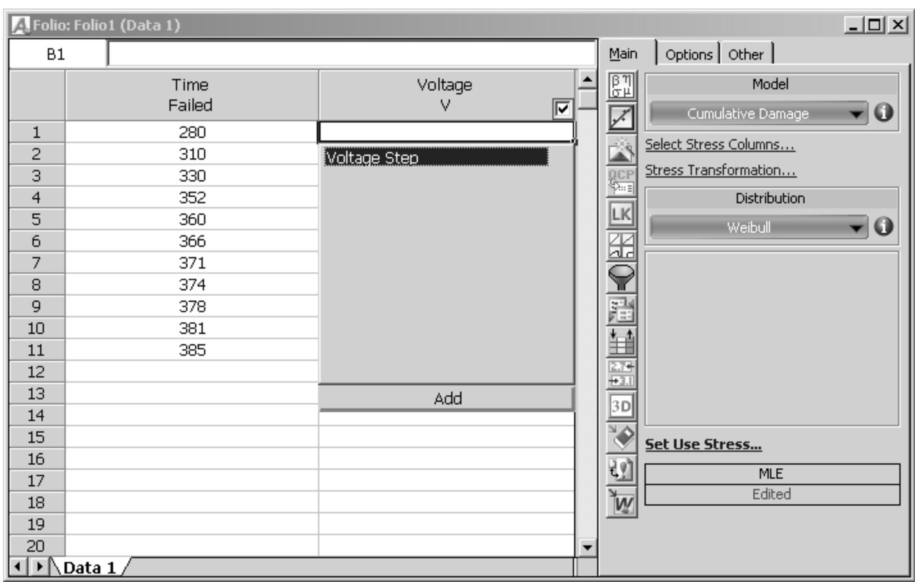
- Name the Stress Profile as **Voltage Step** by right-clicking it in the Project Explorer and selecting **Rename Item**.
- Close the Stress Profile and return to the current Standard Folio.
- On the Control Panel, select **Cumulative Damage** as the life-stress model and **Weibull** as the underlying distribution.
- Click the Stress Transformation link. The Stress Transformation window will appear. Select **Logarithmic (Power LSR)** as the transformation to be applied to the Voltage stress, as shown next, and click **OK**.



- Enter the times-to-failure data in the Time Failed column, as shown next.

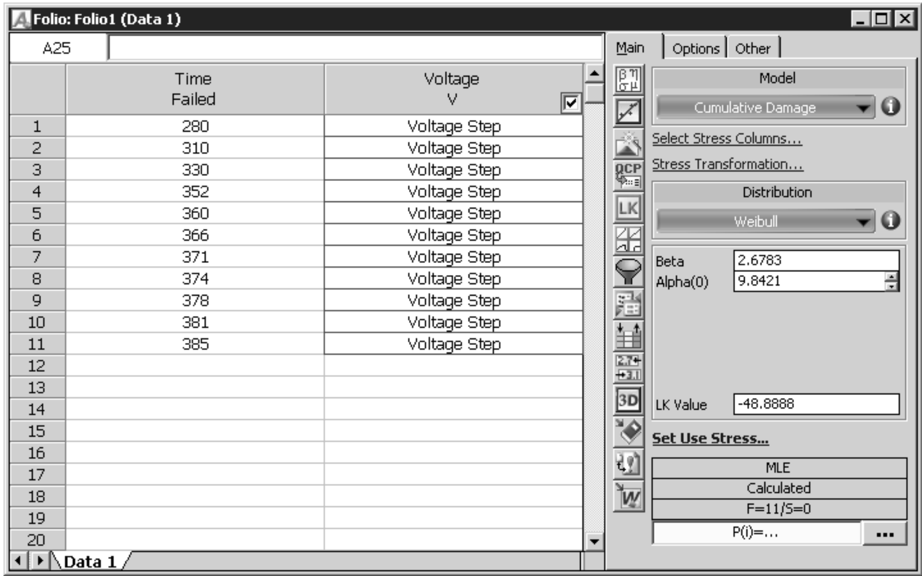


- Next, assign the Voltage Step Stress Profile to each data point by right-clicking a cell in the Voltage column. A window will appear to display a list of all the Stress Profiles in the project, as shown next.

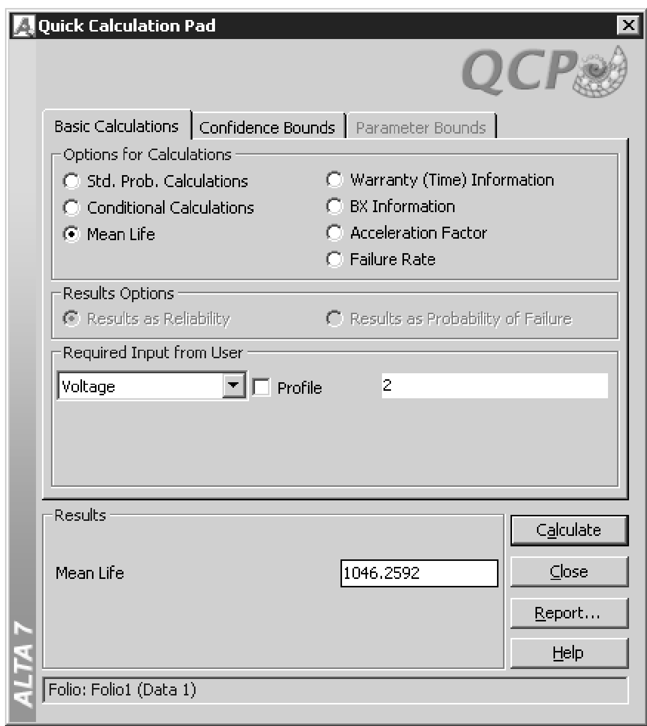


- Click to select the **Voltage Step** Stress Profile and click **Add** to assign the profile to the data point. The Stress Profile name will appear in the Voltage cell. Repeat this step to assign the Stress Profile to the rest of the data points.

- Calculate the parameters. The results are shown next.

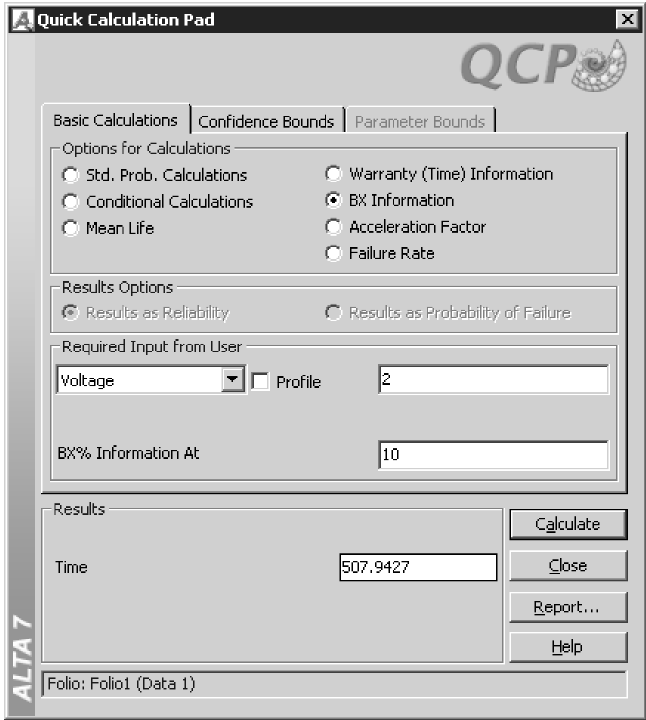


- Open the QCP. Calculate the mean life for the voltage stress at the use stress level of 2V. (Note that confidence bounds may be displayed if you have already been working with other examples in this guide.)



The mean life of the components is calculated to be 1,046 hr.

- Now calculate the B(10) life at the use stress level of 2V.



The B(10) life of the components is calculated to be approximately 508 hr.

- Close the QCP and the Folio.
- Save the project as Training Examples PRO.ralp.
- Leave the project open and proceed to the next example.

5.2 Example 16: Multiple Time-Varying Stresses

The cumulative damage model allows you to analyze accelerated life testing data with up to eight time-varying stresses. In this example, we consider such a case and look at how to create stress profiles in which stress is a function of time.

A sample of 18 units of an electronic component was subjected to temperature and voltage stresses. The temperature was initially set at 100K (use stress level) and was then increased linearly to 200K over a period of 20 hr. At 120 hr, the temperature was again increased to 300K over a 20-hr period. The voltage was initially set at 4V (use stress level) and was then increased linearly to 8V over a period of 10 hr. At 110 hr, the voltage was again increased to 12V over a 10-hr period. The following times-to-failure were observed in the test: 171, 174, 192, 195, 200, 210, 220, 231, 233, 240, 242, 244, 245, 245, 250, 270, 271 and 274 hr.

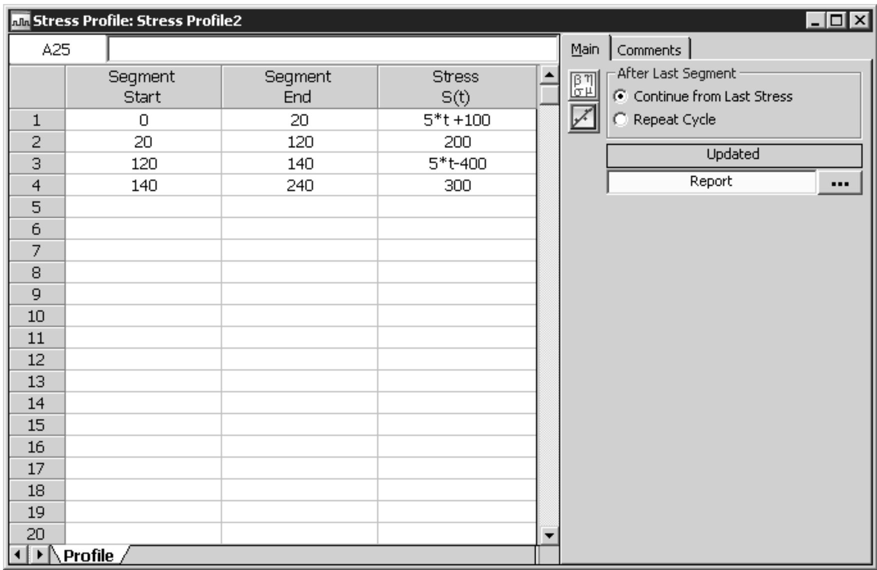
Do the following:

- Determine the B(10) life of these components at the normal use stress levels of 100K and 4V.
- Determine how the B(10) life would change if the voltage use stress level were 2V instead of 4V.

The file for this example is located in the "Training Guide" folder in your application directory (e.g. C:\Program Files\ReliaSoft\ALTA7\Training Guide) and is named "Training Examples PRO.ralp." Use the "Multiple Time-Varying Stresses" Folio.

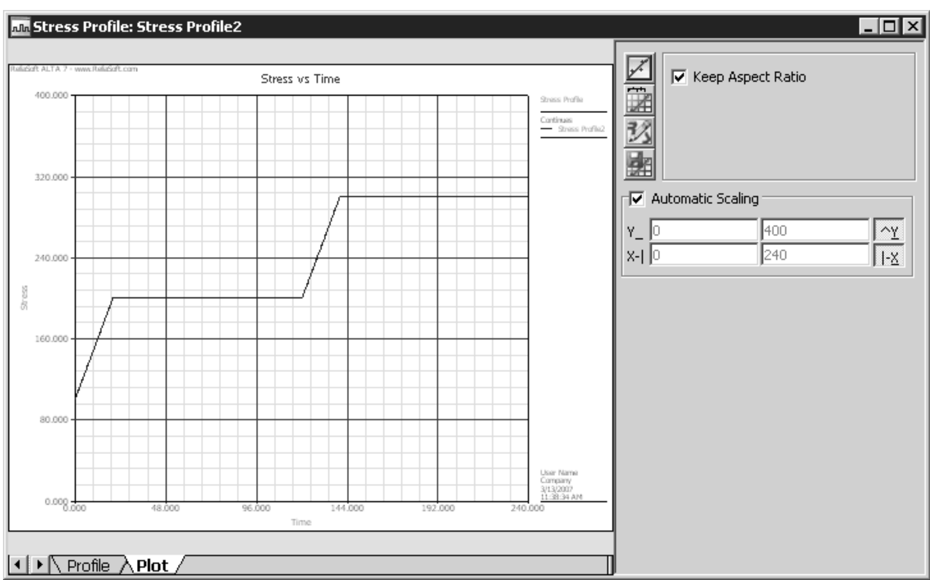
Solution

- Create a new Standard Folio for ungrouped times-to-failure data with temperature and voltage as the stress types. Set the temperature use stress level to 100K and the voltage use stress level to 4V.
- Add a Stress Profile to the project.
- Enter the data in the Data Sheet, as shown next.



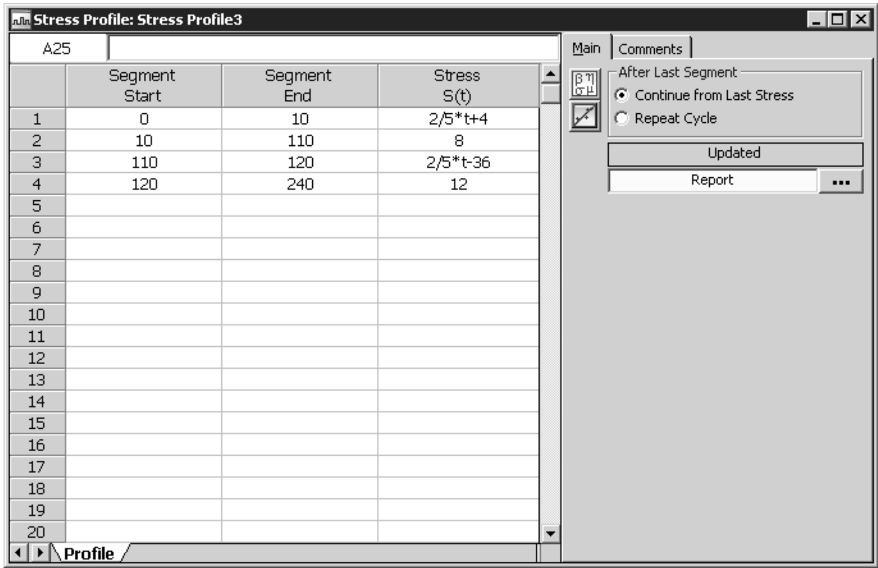
Note that the periods during which the stress is being increased are represented as functions of time. The mathematical formulas for these lines are easily obtained, as you have the starting and ending points for each line.

- Update the Stress Profile by clicking the **Calculate** icon then plot the Stress Profile by clicking the **Plot** icon. The plot of the Stress Profile will look like the one shown next.

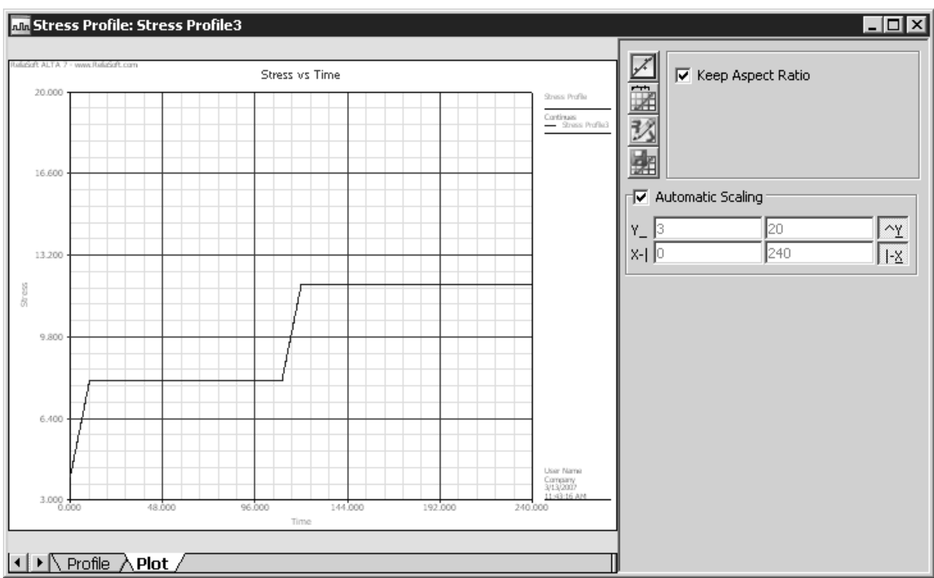


- Name the Stress Profile as **Temp Profile** by right-clicking the item in the Project Explorer and selecting **Rename Item**.

- Add another Stress Profile to the project.
- Enter the data in the Data Sheet, as shown next.

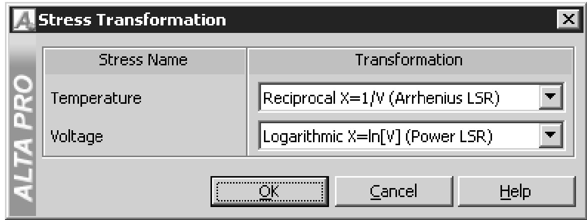


- Update the Stress Profile by clicking the **Calculate** icon then plot the Stress Profile by clicking the **Plot** icon. The plot of the Stress Profile will look like the one shown next.

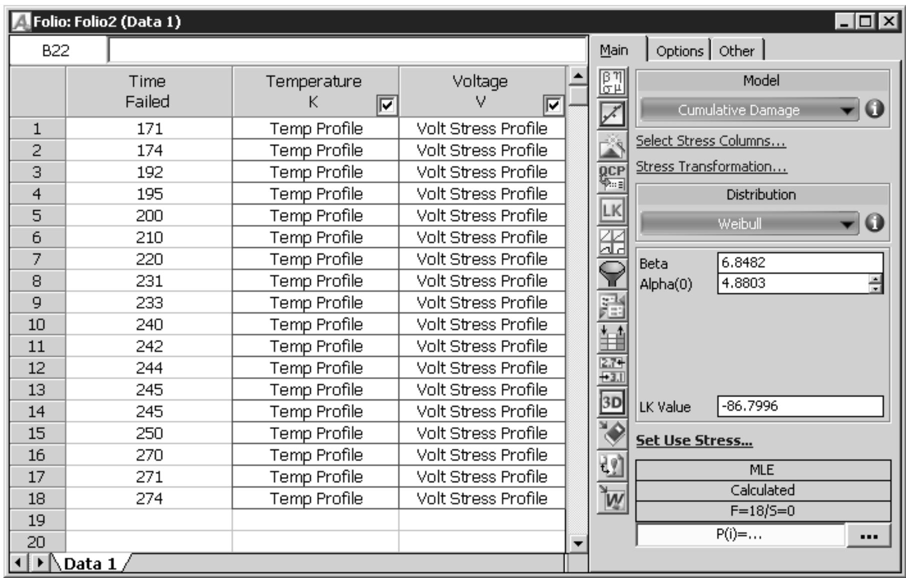


- Name the Stress Profile as **Volt Stress Profile** by right-clicking the item in the Project Explorer and selecting **Rename Item**.
- Close the Stress Profiles and return to the current Standard Folio.
- On the Control Panel, select **Cumulative Damage** as the life-stress model and **Weibull** as the underlying distribution.
- Click the **Stress Transformation** link. The Stress Transformation window will appear. Select the **Reciprocal (Arrhenius LSR)** transformation to be applied to the temperature stress and the

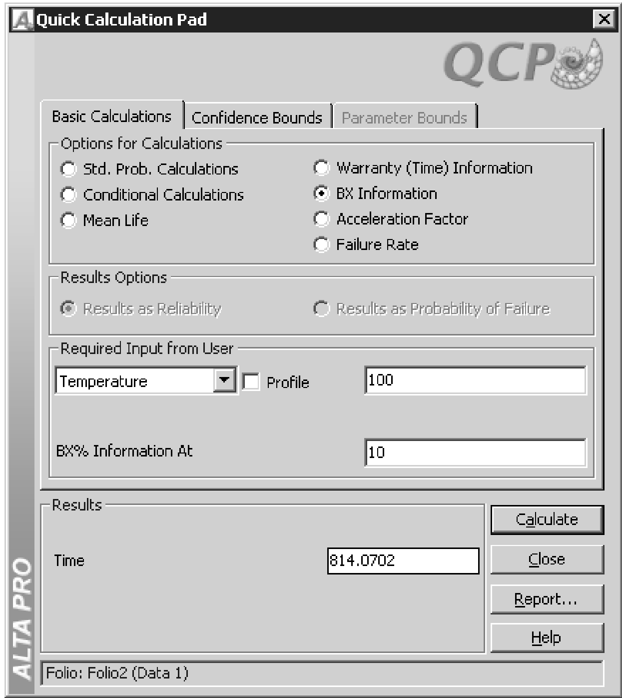
Logarithmic (Power LSR) transformation to be applied to the voltage stress, as shown next, and click **OK**.



- Enter the times-to-failure data in the Time Failed column. Assign the Temp Profile to each data point in the Temperature column and the Volt Stress Profile to each data point in the Voltage column then calculate the parameters. The results are shown next.

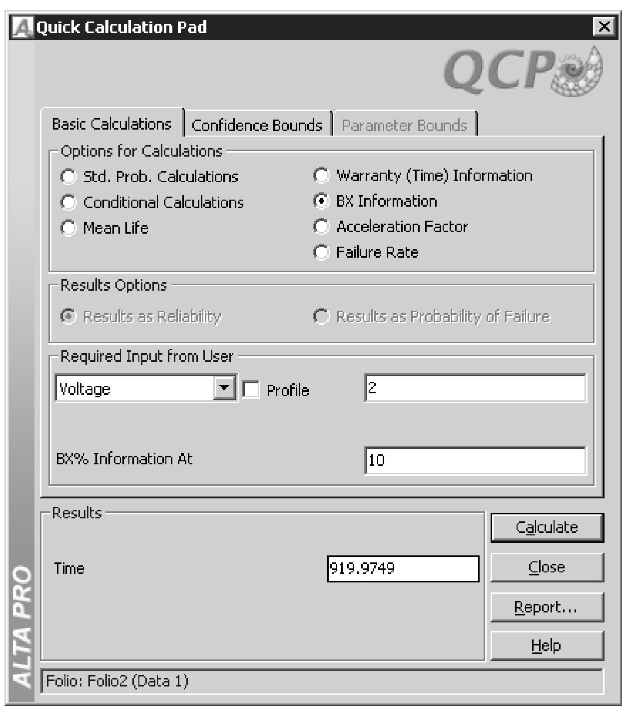


- Open the QCP and calculate the B(10) life of the component. Do not change the temperature or voltage values in the Required Input from User section, as these are set to the specified use stress levels by default. The results are shown next.



The B(10) life at the use stress levels of 100K and 4V is found to be 814.07 hr.

- Change the voltage stress level by selecting **Voltage** from the drop-down in the Required Input from User section. Change the value to 2V and calculate the B(10) life, as shown next.



If the component is used at 100K and 2V instead of 4V, the B(10) life is found to be 919.97 hr.

- Close the QCP and the Folio and save any changes. Leave the project open and proceed to the next example.

5.3 Example 17: Percentage Stress

The cumulative damage life-stress model allows you to analyze accelerated life testing data with multiple constant or time-varying stresses. This example provides another way to look at multiple stresses.

Consider a test in which multiple stresses were applied simultaneously to a particular automotive part in order to precipitate failures more quickly than they would occur under normal use conditions. The engineers responsible for the test were able to quantify the combination of applied stresses in terms of a “percentage stress” as compared to typical stress levels (or assumed field conditions). In this scenario, the typical stress (field or use stress) was defined as 100% and any combination of the test stresses was quantified as a percentage over the typical stress. For example, if the combination of stresses on a test were determined to be two times higher than typical conditions, then the stress on test would be said to be at 200%.

The test was set up and run as a step-stress test (*i.e.* the stresses were increased in a stepwise fashion) and the time on test was measured in hours. The Stress Profile was as follows: until 200 hr, the equivalent applied stress was 125%; from 200 to 300 hr, it was 175%; from 300 to 350 hr, it was 200%; and from 350 to 375 hr, it was 250%. The test was terminated after 375 hr and any units that were still running after that point were right-censored (suspended). Additionally, based on prior analysis/knowledge, the engineers stated that each hour on test under normal use conditions (*i.e.* at 100% stress measure) was equivalent to approximately 100 miles of normal driving.

The test was conducted and the following times-to-failure and times-to-suspension under the stated Stress Profile were observed:

Times-to-Failure	Times-to-Suspension
252	375
280	375
320	375
328	
335	
354	
361	
362	
368	

After performing failure analysis on the failed parts, it was determined that the failure that occurred at 328 hr was due to mechanisms other than the ones considered. That data point was therefore identified as a suspension in the current analysis. The modified data set for this analysis was:

Times-to-Failure	Times-to-Suspension
252	328
280	375
320	375
335	375
354	
361	
362	
368	

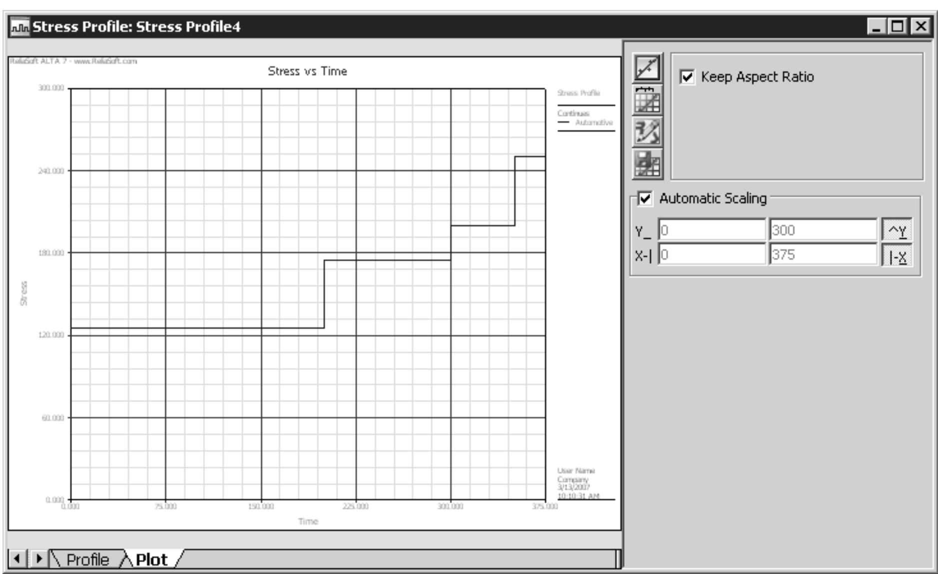
Do the following:

- Determine the B1 life for the part (*i.e*. time at which reliability is equal to 99%) at the typical operating conditions (*i.e.* stress = 100%), in miles.

The file for this example is located in the "Training Guide" folder in your application directory (e.g. C:\Program Files\ReliaSoft\ALTA7\Training Guide) and is named "Training Examples PRO.ralp." Use the "Percentage Stress" Folio.

Solution

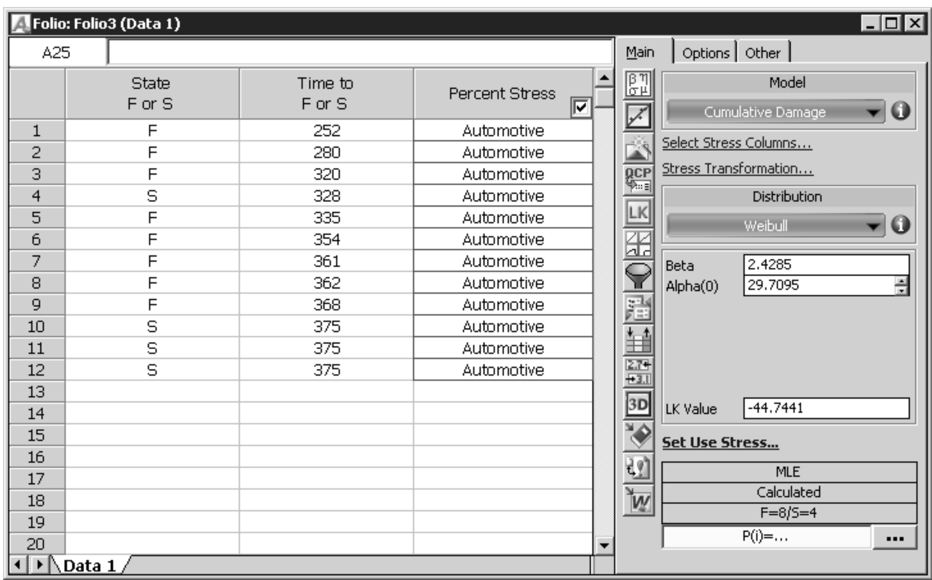
- Create a new Standard Folio for times-to-failure data with suspensions. Select **Other** as the stress type, change the stress name to "**Percent Stress**" and set the use stress to **100**.
- Once the Folio has been created, add a Stress Profile to the project.
- Enter the data in the Data Sheet, then plot the Stress Profile by clicking the **Plot** icon. The Stress Profile will look like the one shown next.



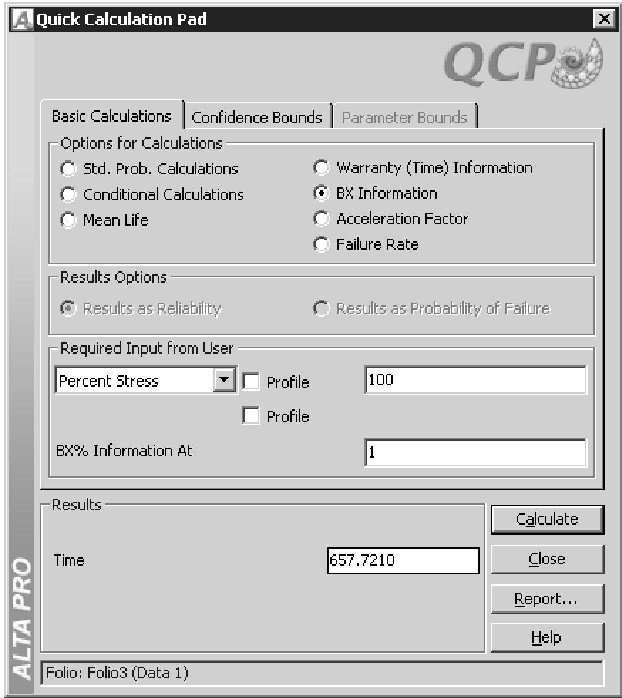
- Name the Stress Profile as **Automotive** by right-clicking it in the Project Explorer and selecting **Rename Item**.
- Close the Stress Profile and return to the current Standard Folio.

- On the Control Panel, select **Cumulative Damage** as the life-stress model and **Weibull** as the underlying distribution.
- Click the Stress Transformation link. The Stress Transformation window will appear. Select **Logarithmic (Power LSR)** as the transformation to be applied to the Percent Stress, as shown next, and click **OK**.

- Enter the observed times and state (failed or suspended) into the Data Sheet. Next, assign the Automotive Stress Profile to each data point by right-clicking each cell in the Percent Stress column and selecting **Automotive** from the window that appears.
- Calculate the parameters. The results are shown next.



- Open the QCP and calculate the B(1) life of the component at the use stress level of 100%. The results are shown next.



The B(1) life is found to be 657 hours. Based on the given multiplier, the B(1) life in miles would then be 657 test-hr*100 (miles/test-hr)= 65,700 miles.

- Close the QCP and the Folio, save any changes, then leave the project open and proceed to the next example.

5.4 Example 18: Analyzing Multiple Stresses With the General Log-Linear Model

In many cases, the life of a product is a function of stress and some other engineering variable, such as material, vendor or operation type. For this type of product, ALTA 7 PRO provides the general log-linear life-stress relationship, which allows you to analyze up to eight stress types and specify an underlying relationship for each stress. This example demonstrates the use of this model.

A sample of electronic components was subjected to a quantitative accelerated life test in which three stress types were applied to the units. The stress types included temperature, voltage and a third indicator variable to describe whether the units were operated continuously or turned on and off. The Stress Profile for this test is presented in the first table and the time-to-failure and time-to-suspension data are presented in the second table. The normal use stress levels are 328K for temperature and 10V for voltage.

Profile	Temp (K)	Voltage (V)	Operation Type
A	358	12	On/Off
B	358	12	Continuous
C	378	12	On/Off
D	378	12	Continuous
E	378	16	On/Off
F	378	16	Continuous
G	398	12	On/Off
H	398	12	Continuous

Time (Profile)	Time (Profile)	Time (Profile)	Time (Profile)
498 (A)	211 (D)	249 (E)	134 (G)
750 (A)	266 (D)	145 (F)	163 (G)
445 (B)	298 (D)	192 (F)	116 (H)
586 (B)	343 (D)	208 (F)	149 (H)
691 (B)	364 (D)	231 (F)	155 (H)
176 (C)	387 (D)	254 (F)	173 (H)
252 (C)	118 (E)	293 (F)	193 (H)
309 (C)	163 (E)	87 (G)	214 (H)
398 (C)	210 (E)	112 (G)	
20 units suspended at 750 (B) 14 units suspended at 445 (D)		10 units suspended at 300 (F) 7 units suspended at 228 (H)	

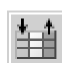
Do the following:

- Specify a transformation relationship for each stress type and estimate the parameters using the general log-linear life-stress relationship.
- Determine which of the stress types has a greater effect on the life of the product in terms of accelerating failure.

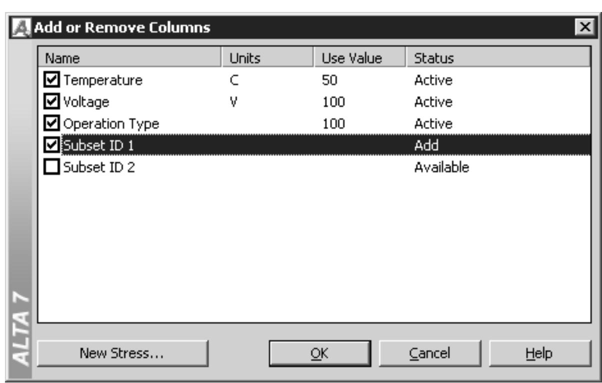
The file for this example is located in the "Training Guide" folder in your application directory (e.g. C:\Program Files\ReliaSoft\ALTA7\Training Guide) and is named "Training Examples PRO.ralp." Use the "GLL Multiple Stresses" Folio.

Solution

- Create a Standard Folio for grouped times-to-failure with suspensions data with three stress columns for temperature, voltage and operation type.
- Once the Folio has been created, insert a Subset ID column into the Data Sheet by clicking the **Add or Remove Columns** icon on the Control Panel.

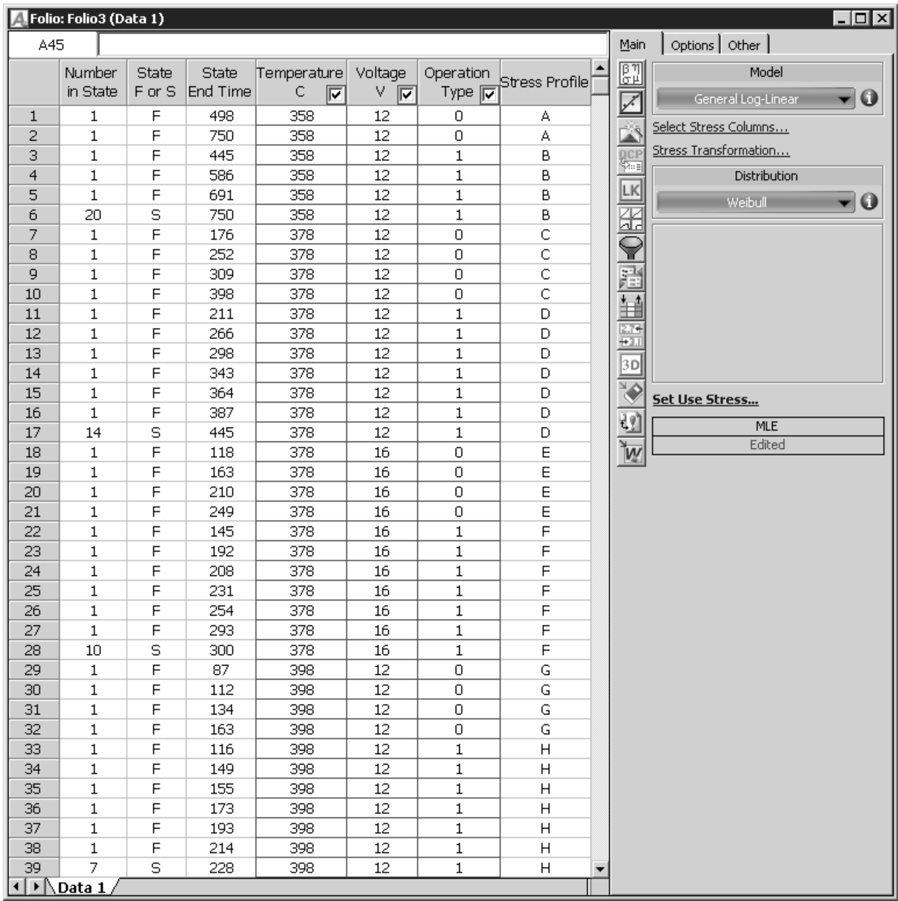


- In the Add or Remove Columns window that appears, select **Insert Subset ID Column**, as shown next, and then click **OK**.



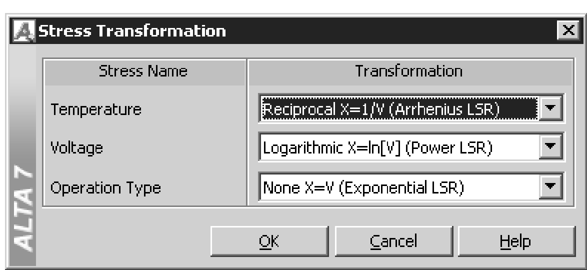
- Once the Subset ID column has been inserted into the Data Folio, double-click the column heading to open the Change Headings window. Rename the column heading to **Stress Profile** to identify the column as the one in which the Stress Profile identifier will be entered.

- Select the checkbox in each of the three stress columns to indicate that all three columns will be used in calculating the Folio.
- Enter the data into the Data Sheet, as shown next. In the Operation Type column, enter 0 or 1 to indicate on/off or continuous operation, respectively.



	Number in State	State F or S	State End Time	Temperature C	Voltage V	Operation Type	Stress Profile
1	1	F	498	358	12	0	A
2	1	F	750	358	12	0	A
3	1	F	445	358	12	1	B
4	1	F	586	358	12	1	B
5	1	F	691	358	12	1	B
6	20	S	750	358	12	1	B
7	1	F	176	378	12	0	C
8	1	F	252	378	12	0	C
9	1	F	309	378	12	0	C
10	1	F	398	378	12	0	C
11	1	F	211	378	12	1	D
12	1	F	266	378	12	1	D
13	1	F	298	378	12	1	D
14	1	F	343	378	12	1	D
15	1	F	364	378	12	1	D
16	1	F	387	378	12	1	D
17	14	S	445	378	12	1	D
18	1	F	118	378	16	0	E
19	1	F	163	378	16	0	E
20	1	F	210	378	16	0	E
21	1	F	249	378	16	0	E
22	1	F	145	378	16	1	F
23	1	F	192	378	16	1	F
24	1	F	208	378	16	1	F
25	1	F	231	378	16	1	F
26	1	F	254	378	16	1	F
27	1	F	293	378	16	1	F
28	10	S	300	378	16	1	F
29	1	F	87	398	12	0	G
30	1	F	112	398	12	0	G
31	1	F	134	398	12	0	G
32	1	F	163	398	12	0	G
33	1	F	116	398	12	1	H
34	1	F	149	398	12	1	H
35	1	F	155	398	12	1	H
36	1	F	173	398	12	1	H
37	1	F	193	398	12	1	H
38	1	F	214	398	12	1	H
39	7	S	228	398	12	1	H

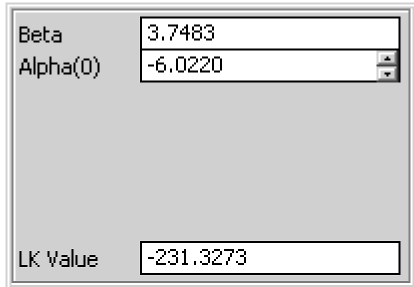
- Next, select **General Log-Linear** as the life-stress model and **Weibull** as the underlying life distribution.
- Click the **Stress Transformation** link to open the Stress Transformation window. In this window, you can specify the transformation relationship for each stress type. For this example, the temperature stress follows an Arrhenius model, the voltage stress follows a power model and no transformation will be performed on the operation type. The Stress Transformation window will look similar to the one shown next.



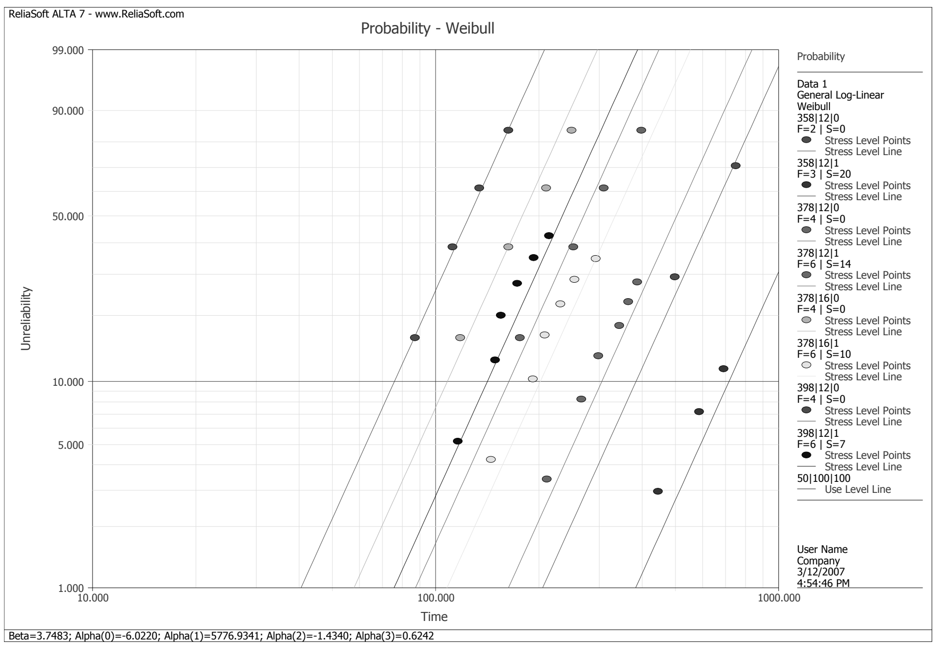
Stress Name	Transformation
Temperature	Reciprocal X=1/V (Arrhenius LSR)
Voltage	Logarithmic X=ln[V] (Power LSR)
Operation Type	None X=V (Exponential LSR)

- Click **OK** to accept your selections and close the window.

- Calculate the parameters. The calculated parameters are shown next.

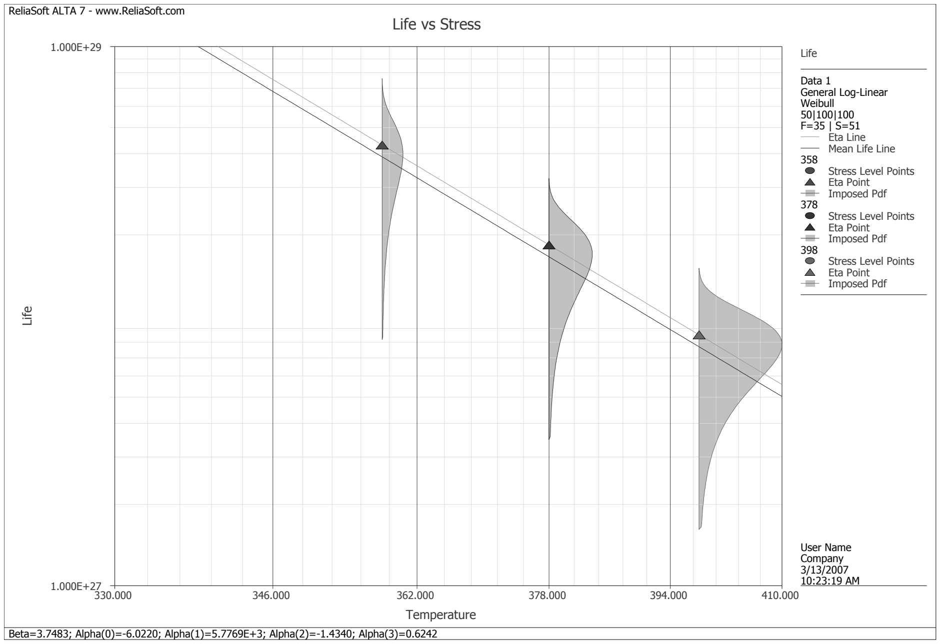


- Next, plot the parameters on a Weibull Probability plot. (You may need to change the scaling of the plot to 1000 for the upper X-axis.) The plot will look similar to the one shown next.



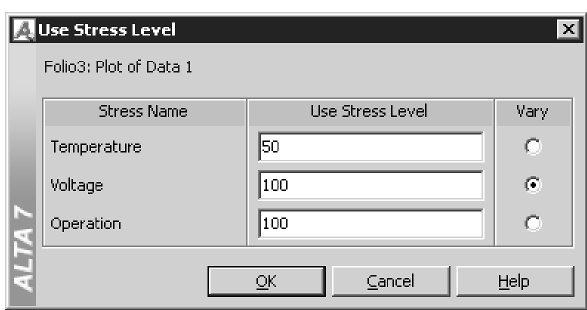
The Weibull Probability plot can be used to examine the choice of an underlying life distribution and the assumption of a common slope (shape parameter) at all stress levels. The linearity of the data and the fact that the data for each stress level appears parallel reinforce the assumptions made.

- Next obtain the Life vs. Stress plot for temperature, as shown next. (You may need to return the settings to Automatic Scaling.)

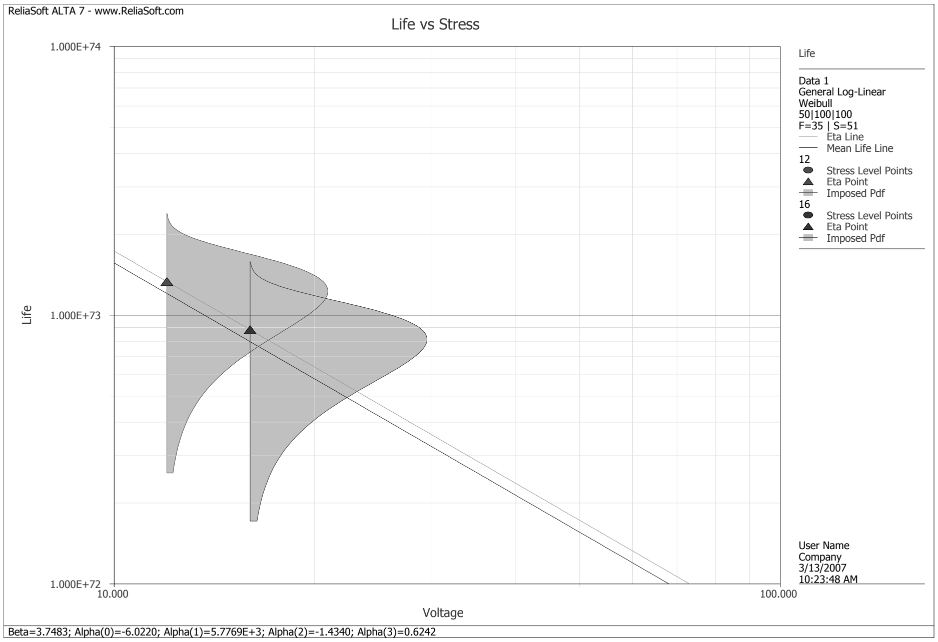


Life vs. Stress plots can be very useful in assessing the effect of each stress on a product's failure. In this case, since the life is a function of three stresses, three different Life vs. Stress plots are available. The above plot was created by holding the voltage and operation type stresses constant at the desired use level and varying the temperature stress. The method to create a Life vs. Stress plot where the voltage varies is presented next.

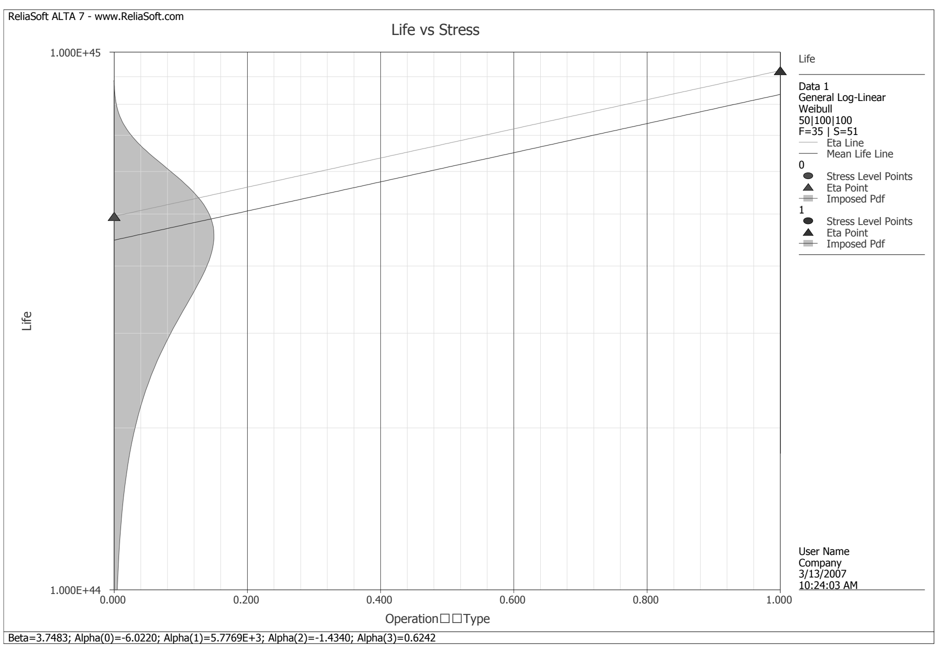
- Use the Use Stress Level window to create a Life vs. Stress plot for voltage by clicking the **Set Use Stress** link on the Plot Sheet Control Panel.
- In the Use Stress Level window, click the **Vary** option next to Voltage and click **OK**.



- The Life vs. Stress plot for voltage will appear, as shown next.



- Finally, select to vary the operation type in the Use Stress Level window and click **OK**.
- The Life vs. Stress plot for operation type will appear, as shown next.



In this plot, the effects of two different operation types on life can be observed. You can see that the on/off cycling has a greater effect on the life of the product in terms of accelerating failure than the continuous operation. In other words, a higher reliability can be achieved by running the product continuously.

- Close the Folio, save any changes, then leave the project open and proceed to the next example.

5.5 Example 19: Using Time as a Stress

A specific consumer product (*e.g.* a mouthwash, shampoo, etc.) is made up of three main ingredients (ingredients A, B and C) that have a characteristic (*e.g.* concentration) that may or may not change with time. A quantitative measure of the characteristic can be obtained and this measure must be within a specified range for compliance. If any measure is outside its specified range, then the product is out of compliance and considered to be failed. There are no known dependencies among these ingredients. Thus, they are assumed to be statistically independent.

For this study, 40 random specimens were stored at normal use conditions. At 3, 6, 9 and 12 months, 10 specimens were removed and measured. The measurement process is a destructive test (*i.e.* when the specimen is opened for testing, the required readings are taken and that specimen is then disposed of). Measurements for each ingredient at each time period are given in the following tables.

Age 3 Months		
A	B	C
148.533	175.408	119.853
146.979	177.573	118.101
151.168	174.804	120.201
148.524	181.830	118.927
150.983	173.719	118.871
147.298	180.436	120.573
151.991	177.803	120.509
147.943	183.400	119.548
147.935	175.052	119.377
147.850	175.042	120.113

Age 6 Months		
A	B	C
149.962	177.463	122.563
149.163	178.558	121.591
150.751	179.695	120.248
151.167	173.966	122.344
150.271	174.587	116.607
146.807	168.769	121.484
151.221	178.237	119.790
144.748	174.663	120.913
150.213	175.739	122.134
148.985	178.125	121.384

Age 9 Months		
A	B	C
141.827	173.111	124.105
148.871	176.514	124.191
145.960	173.073	124.411
149.549	168.307	125.076
149.296	177.982	125.016
148.001	177.039	122.150
148.885	174.057	124.283
149.960	174.417	124.218
150.764	174.989	124.059
148.395	171.699	124.679

Age 12 Months		
A	B	C
152.260	171.996	125.700
148.770	170.633	125.303
150.876	166.890	124.577
147.071	170.672	124.745
149.444	172.412	122.214
148.816	168.712	126.855
150.350	171.519	127.101
149.196	170.150	122.457
148.685	172.875	126.165
147.969	168.171	124.895

The acceptable range for each ingredient is shown next.

Acceptable Range			
	A	**B**	**C**
Low	142	155	110
High	156	185	135

If viewed from a "traditional reliability" perspective, the test in this example is not an accelerated test. However, its analysis will require that we employ the fundamental principles of QALT analysis. The measured value of each characteristic (as measured after each holding period) can be viewed as the random variable (the time value in standard QALT analysis) affected by the aging process (the stress value). In other words, the stress on each sample is the time in the holding cell and the random variable (what we traditionally think of as time-to-failure) is the value of the measured characteristic.

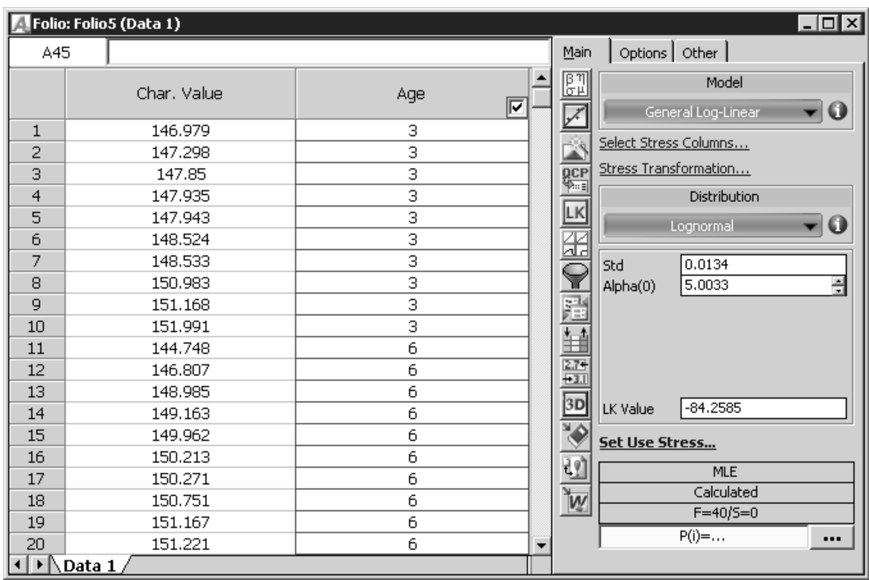
Do the following:

- The product has a shelf life of 24 months. Using the lognormal distribution along with a General Log-Linear model, determine the probability that a given specimen will be out of compliance at/after this time period.

The file for this example is located in the "Training Guide" folder in your application directory (e.g. C:\Program Files\ReliaSoft\ALTA7\Training Guide) and is named "Training Examples PRO.ralp." Use the "Time As a Stress" Folio.

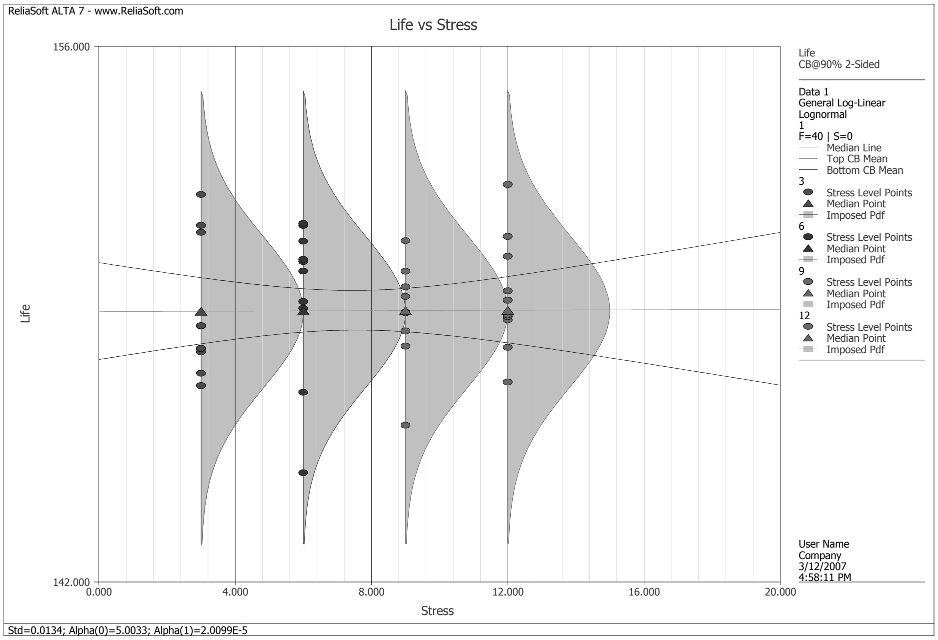
Solution

- Create a new Standard Folio for times-to-failure data. Select **Other** as the stress type, change the stress name to "**Age**" and set the use stress to 1.
- In the new Folio, rename the Time Failed column to "**Char. Value**." Enter the data for ingredient A.
- Select **General Log-Linear** as the life-stress relationship and open the Stress Transformation window to specify an untransformed relationship by selecting **None**.
- Select the **Lognormal** distribution and calculate the parameters, as shown next. (Please note that the figure shown next displays only 20 rows of data. Be sure to enter all of the data for this example as given in the table on page 88. Your Data Sheet will contain 40 rows of data.)

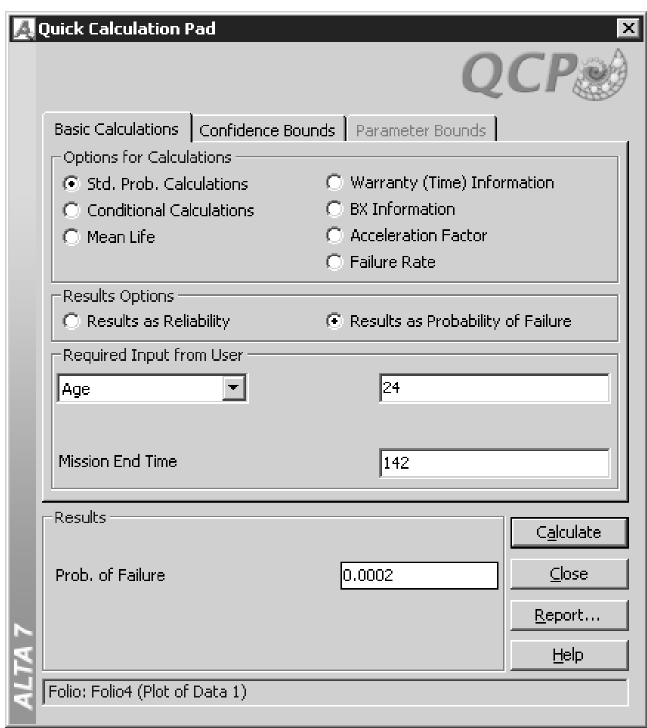


- Next, plot the Life vs. Stress plot with 90% two-sided confidence intervals. Change the scaling of the plot to reflect the acceptable range for product A.

- As can be seen from the plot shown next, no increase or decrease in the characteristic is noted. In other words, age (at least up to the 12 months of observation) does not appear to affect the characteristic for this ingredient.

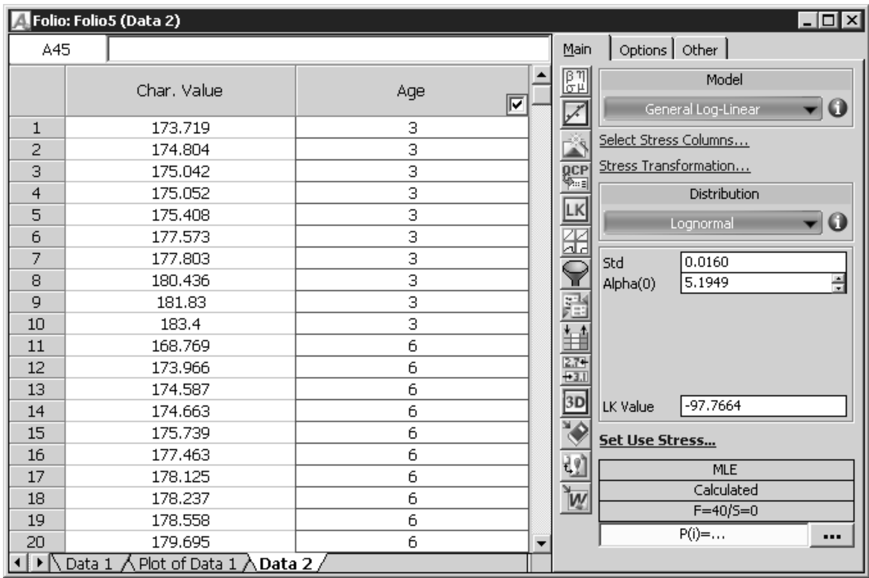


- Next, use the QCP to determine the probability that ingredient A will be below the limit after 24 months, as shown next. Also determine the probability that ingredient A will be above the limit after 24 months.



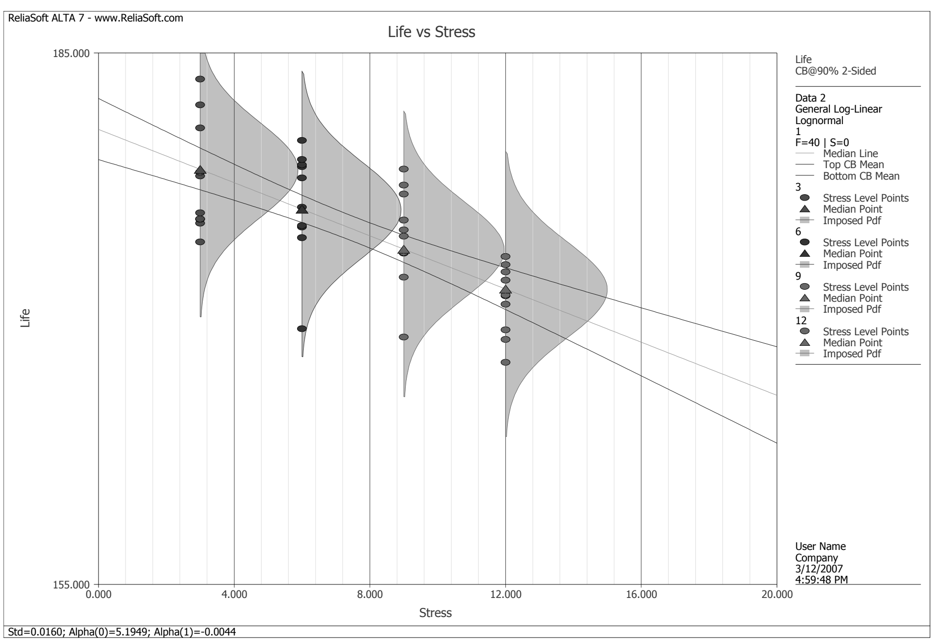
The probability of ingredient A being below limit after 24 months is 0.02% and the probability of ingredient A being above limit after 24 months is 0.03%

- Close the QCP.
- Insert a new Data Sheet with the same settings as the first one into the Folio by selecting **Insert Data Sheet** from the **Folio** menu.
- In the new Data Sheet, enter the data for ingredient B. Calculate the parameters using the same settings from the ingredient A analysis, as shown next. (Again, only 20 of the 40 rows of data are displayed in this figure.)

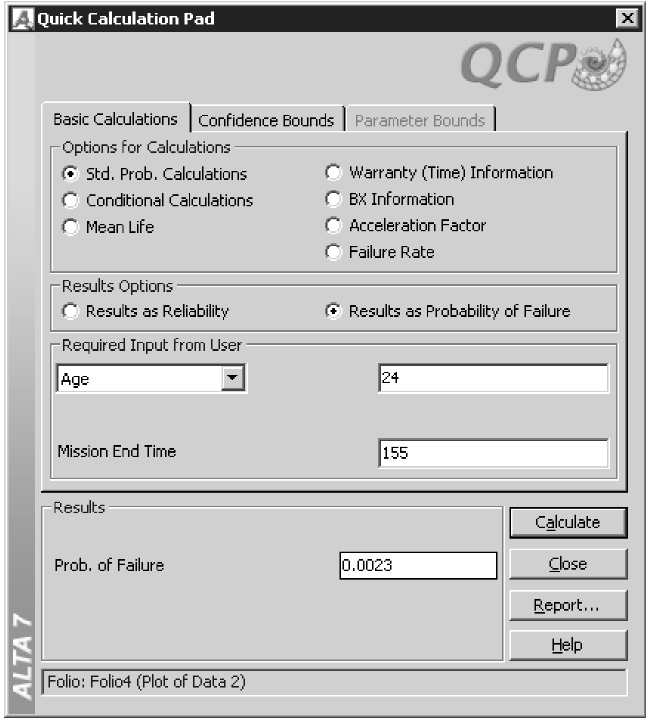


	Char. Value	Age
1	173.719	3
2	174.804	3
3	175.042	3
4	175.052	3
5	175.408	3
6	177.573	3
7	177.803	3
8	180.436	3
9	181.83	3
10	183.4	3
11	168.769	6
12	173.966	6
13	174.587	6
14	174.663	6
15	175.739	6
16	177.463	6
17	178.125	6
18	178.237	6
19	178.558	6
20	179.695	6

- Plot the Life vs. Stress plot with 90% two-sided confidence intervals. Change the scaling of the plot to reflect the acceptable range for product B. As can be seen from this plot, there is a noticeable decrease in the characteristic.

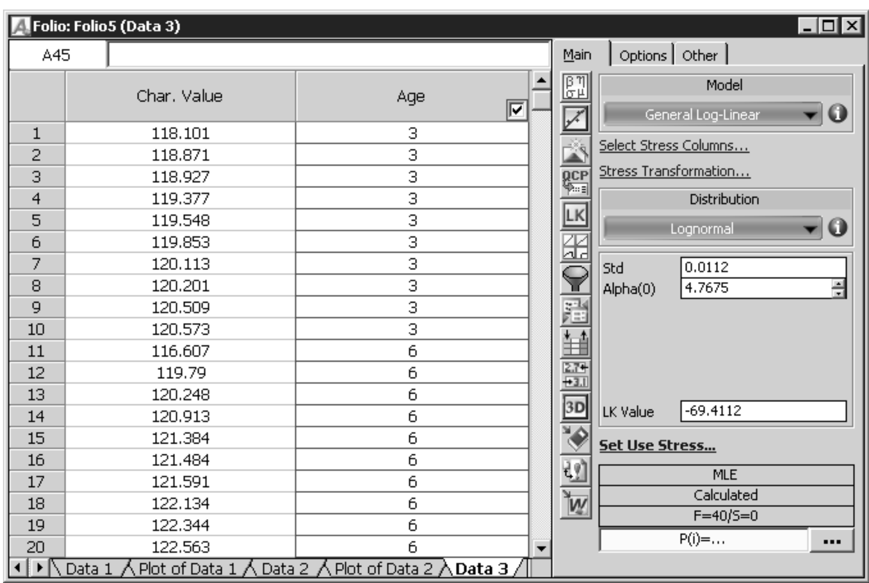


- Use the QCP to determine the probability that ingredient B will be below the limit after 24 months, as shown next. Also determine the probability of ingredient B being above the limit after 24 months.

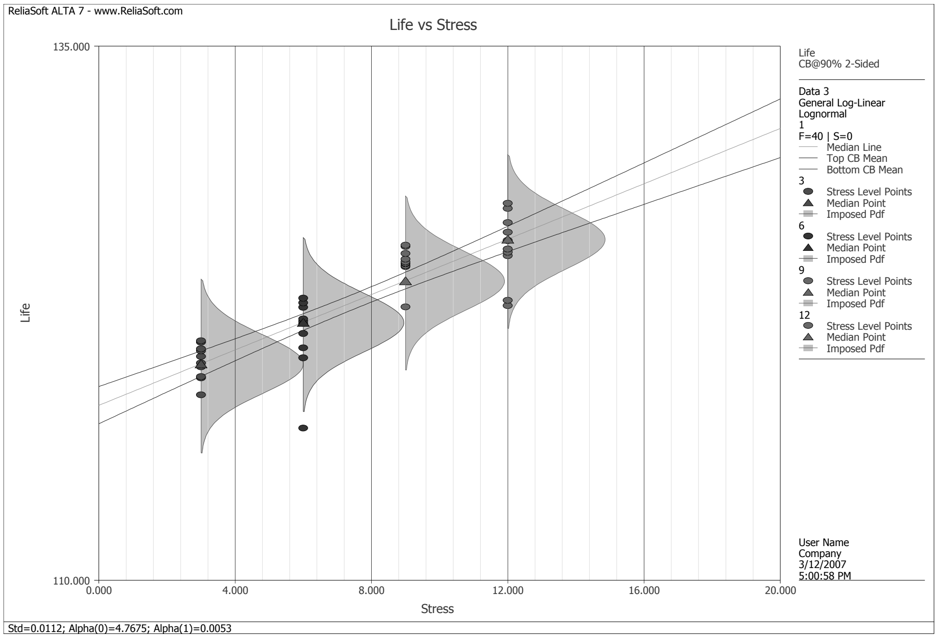


The probability of ingredient B being below the limit after 24 months is 0.23% and the probability of ingredient B being above the limit after 24 months is 0.00%

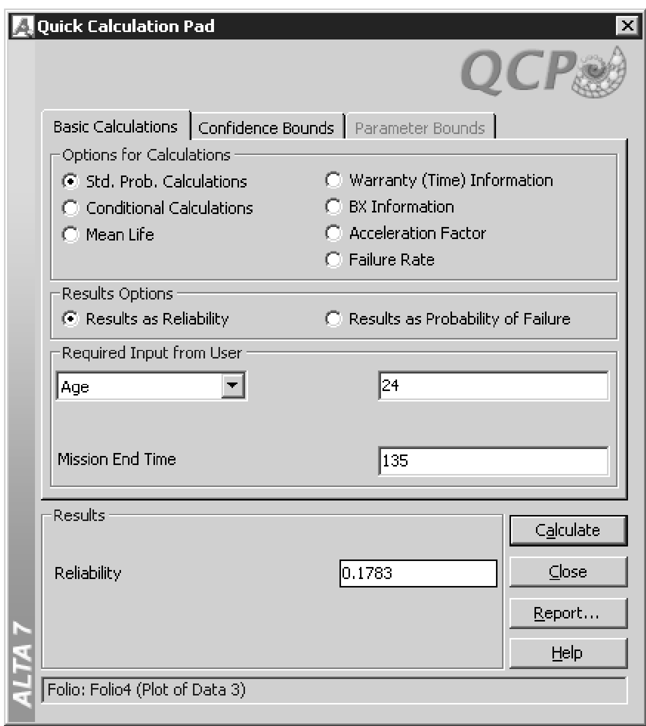
- Close the QCP and insert a third Data Sheet into the Folio, using the settings given previously.
- Enter the data for ingredient C and calculate the parameters using the same settings from the ingredient A and B analyses, as shown next (with 20 of the 40 rows of data displayed).



- Plot the Life vs. Stress plot with 90% two-sided confidence intervals. Change the scaling of the plot to reflect the acceptable range for product C. As can be seen from this plot, there is a noticeable increase in the characteristic.



- Use the QCP to determine the probability that ingredient C will be below the limit after 24 months, as shown next. Also use the QCP to determine the probability that ingredient C will be above the limit.



The probability of ingredient C being below the limit after 24 months is 0.00% and the probability of ingredient C being above the limit after 24 months is 17.83%.

- The results from the QCP calculations for each ingredient are shown next.

	Ingredient A	Ingredient B	Ingredient C
Below Limit	0.02%	0.23%	0.00%
Above Limit	0.03%	0.00%	17.83%

In this case, the main contributing factor will be the the probability that ingredient C exceeds the limit, which is significantly high. Having identified ingredient C as the main cause of failure, appropriate corrective actions may be required.

- Close the QCP and the Folio, save any changes, then leave the project open and proceed to the next example.

5.6 Example 20 Time-Varying Use Stress Levels

A new design is being considered for tanks that are intended to be used with heat exchangers for automotive applications. It is desired to estimate whether the new design will meet its intended target before releasing it to production. The target is a reliability of 90% at 2,000 hr of use, with a 90% confidence.

The stimulus that has the greatest effect on the life of the tanks is pressure, measured in pounds per square inch (psi). In order to perform an accelerated life test on these tanks, groups of tanks were put on a pressure cycling test. This test involves putting the tanks on a test fixture, pressurizing them to 5.5 psi and then rapidly increasing the pressure to either 15 psi or 21 psi. The tanks are held at the elevated pressure for an amount of time and then rapidly decreased to the original pressure. For each pressure cycle, the tank spends 80% of the time at the elevated pressure and 20% of the time at the “default” pressure of 5.5 psi. Since the cycle repeats every 10 hr, each cycle can be thought of as a square wave. Thus, for each cycle, the tank is held at 5.5 psi for 1 hr (one-tenth of the cycle), the pressure is rapidly increased to either 15 psi or 21 psi and held for 8 hr (eight-tenths of the cycle), then the pressure is rapidly reduced to 5.5 psi and held for an additional 1 hr. The test fixture is capable of increasing and decreasing the pressure of the test units in a rapid fashion, so much so that the transitions between the pressure levels can be considered simultaneous for the purposes of this test.

The test was conducted with two groups of test units: 22 units were tested with the 15 psi profile and 10 units were tested with the 21 psi profile. All of the units were tested to failure. That is, the Stress Profile was repeated until all of the units on test had failed. The failure data set is contained in the following table:

Time-to-Failure (hr) for 15 psi Profile	Time-to-Failure (hr) for 21 psi Profile
2241	1175
2493	1369
3308	4238
4018	4392
4596	4774
4845	5109
5300	5156
5691	5422
5908	7189
6466	7551
6471	-
6720	-

Time-to-Failure (hr) for 15 psi Profile	Time-to-Failure (hr) for 21 psi Profile
6742	-
7718	-
8658	-
8927	-
9809	-
10155	-
10536	-
11194	-
11590	-
12774	-

As can be seen from the data, the range of failure times for the 15 psi pressure cycling test (2241 – 12774 hr) is larger than the range for the 21 psi test (1175 – 7551 hr), indicating an inverse relationship between life and stress. However, the data set will need to be formally analyzed to see if this conjecture is correct.

The anticipated Stress Profile for the tank under normal use conditions for a mission of 2,000 hr is 6 psi for 66.7% of its life, 11 psi for 25% of its life and 14 psi for 8.3% of its life.

Do the following:

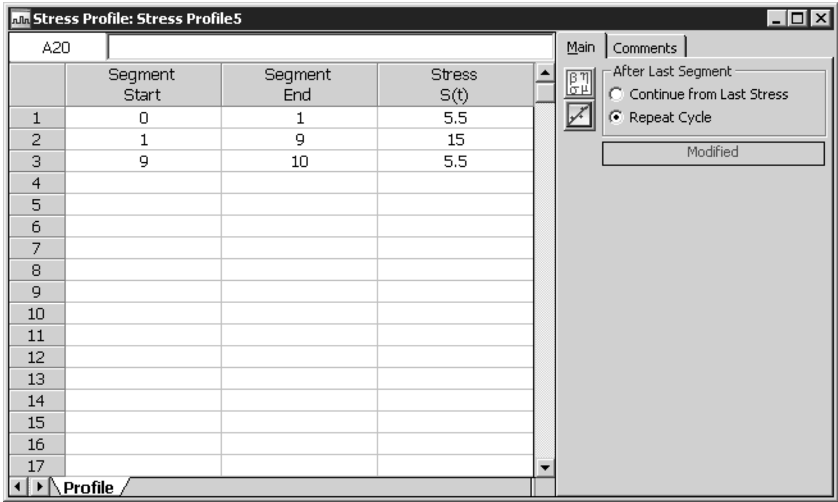
- Create two accelerated Stress Profiles for the 15 psi pressure cycling test and for the 21 psi pressure cycling test.
- Analyze the data with the Cumulative Damage-Weibull model and a Power relation to confirm whether or not life is inversely proportional to stress.
- Create a use Stress Profile to describe the anticipated use stress level for the tanks.
- Estimate whether the new design will meet its intended target before releasing it to production.

The file for this example is located in the "Training Guide" folder in your application directory (e.g. C:\Program Files\ReliaSoft\ALTA7\Training Guide) and is named "Training Examples PRO.ralp." Use the "Time-Varying Use Stress" Folio.

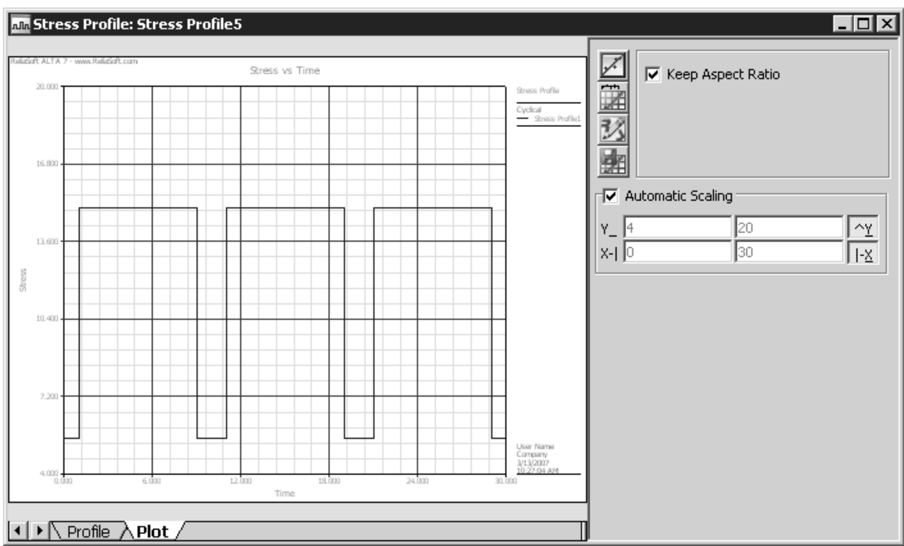
Solution

- Create a new Standard Folio for times-to-failure data. Select **Other** as the stress type, change the stress name to "**Pressure**," enter "**psi**" for the units and set the use stress level to 1 psi.
- Add a new Stress Profile to the project by selecting **Add Stress Profile...** from the **Project** menu or by right-clicking inside the Project Explorer and selecting **Add Stress Profile...** from the shortcut menu.

- In the Stress Profile Explorer, create a profile for the 15 psi pressure cycling test, as shown next. Make sure to select **Repeat Cycle** to specify that the test repeats itself until the units fail.

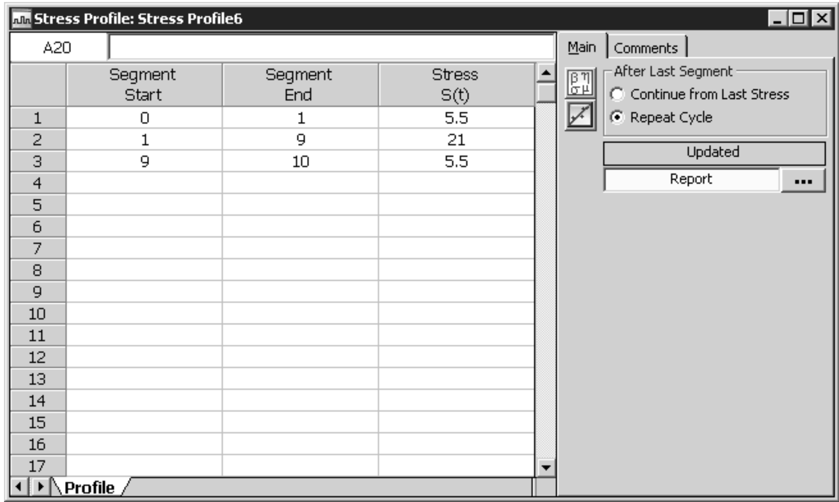


- Plot the Stress Profile, as shown next.

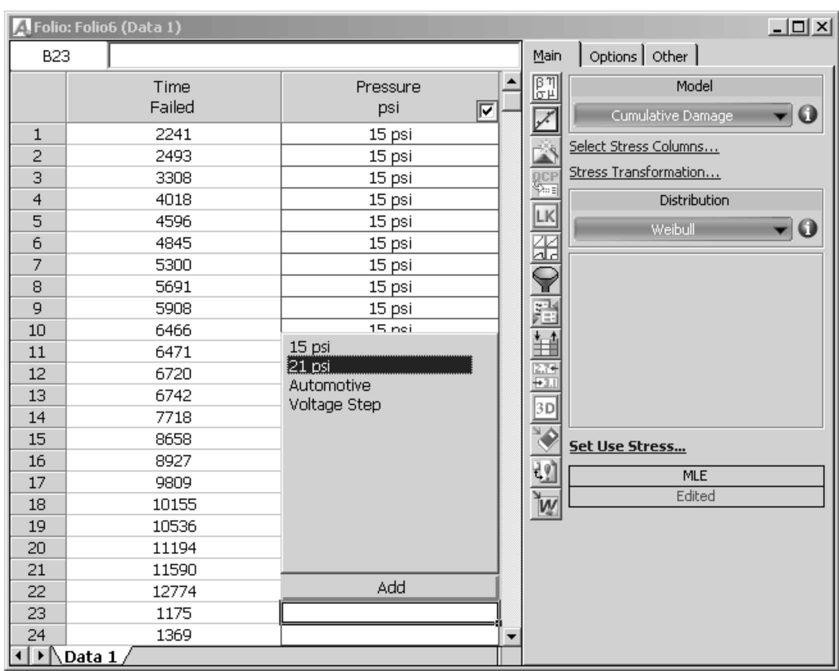


- Name the Stress Profile as **15 psi** by right-clicking it in the Project Explorer and selecting **Rename Item**. Close the Stress Profile.

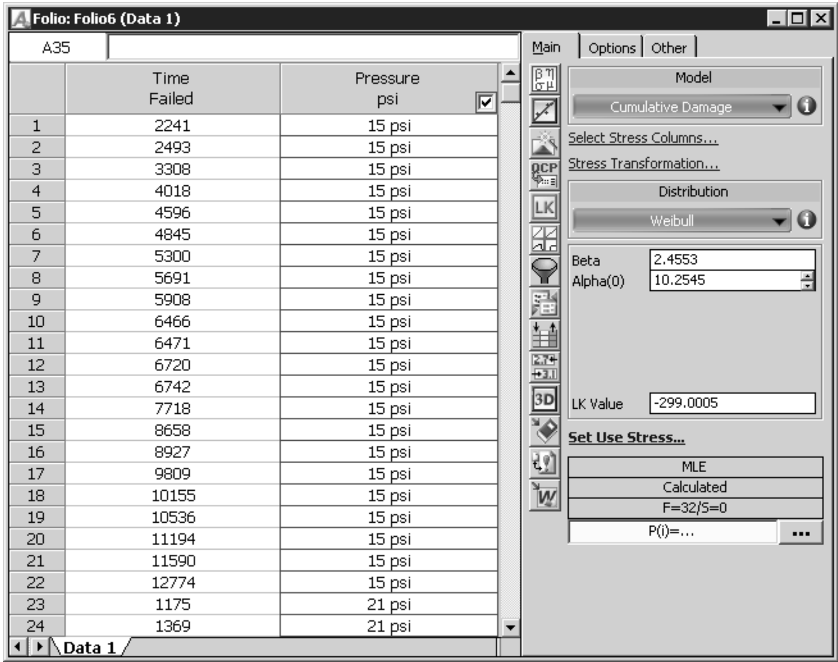
- Add another new Stress Profile. Enter the segments/stresses for the 21 psi pressure cycling test, as shown next. Remember to specify that the test repeats itself.



- Update the profile by clicking the **Calculate** button, then close it.
- Name the Stress Profile **21 psi**.
- In the Standard Folio, select **Cumulative Damage** as the life-stress model and **Weibull** as the underlying distribution.
- Click the Stress Transformation link and select the **Logarithmic** transformation (*i.e.* the power life-stress relation), then click **OK**.
- Enter the times-to-failure data from the failure data set and assign the corresponding Stress Profile (15 psi or 21 psi) to each data point, as shown next. (Please note that the figure shown next displays only 24 rows of data. Be sure to enter all of the data for this example as given in the table on page 94. Your Data Sheet will contain 32 rows of data.)



- Calculate the parameters. The results are shown next.



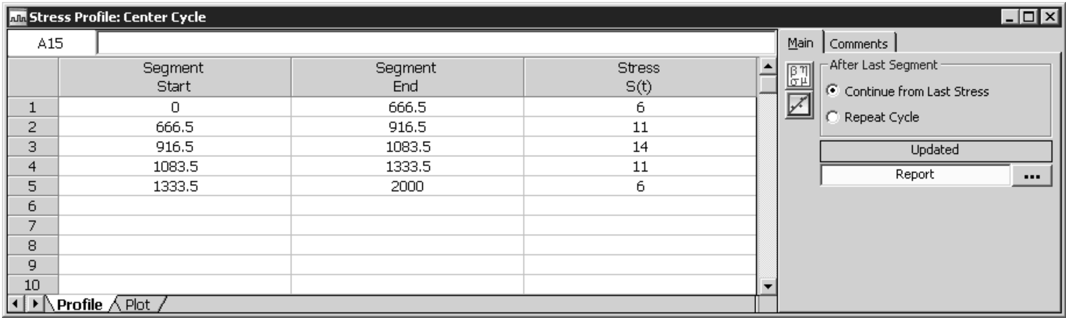
The parameter estimates resulting from this analysis are:

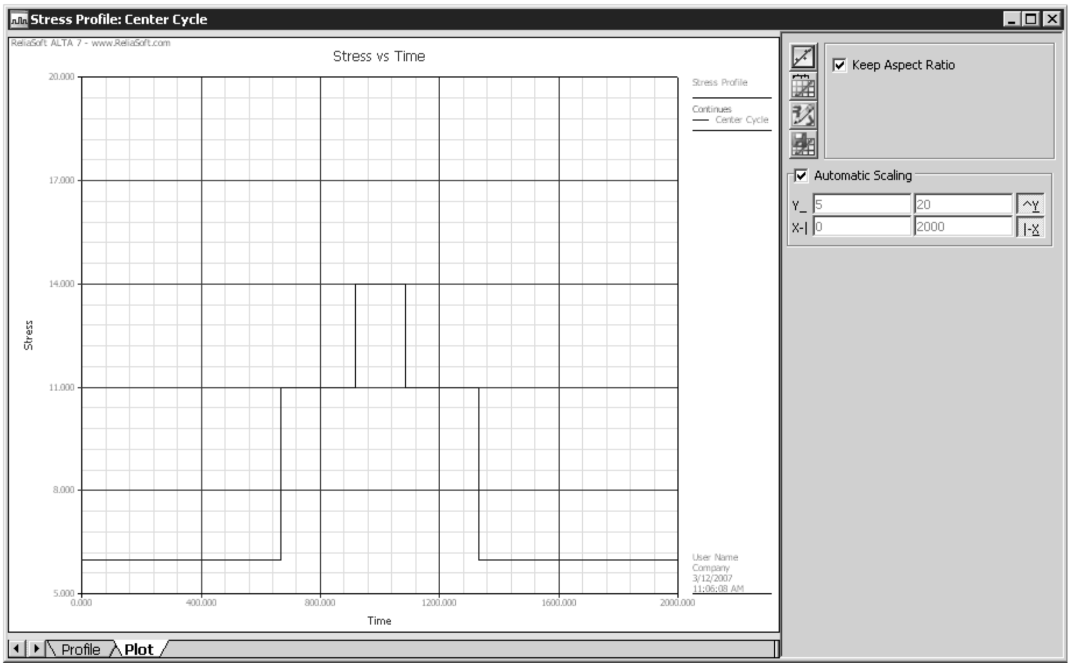
Beta = 2.4553
Alpha(0) = 10.2545
Alpha(1) = -0.5278

Note that the Alpha parameters are displayed in a single parameter field. Click the up/down arrows that appear in the field to scroll through the Alpha parameters. The fact that the life-stress relationship parameter α_1 is negative confirms the hypothesis that life is inversely proportional to stress.

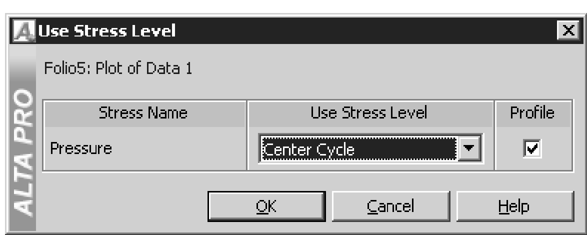
- Now create the time-varying use Stress Profile for a mission of 2,000 hr. To do this, add a new Stress Profile named **Center Cycle** and enter the segments/stresses for the use Stress Profile, as shown next.

You can see that this profile has the highest stress in the middle of the profile, similar to the pressure cycles that were used for the test Stress Profiles.



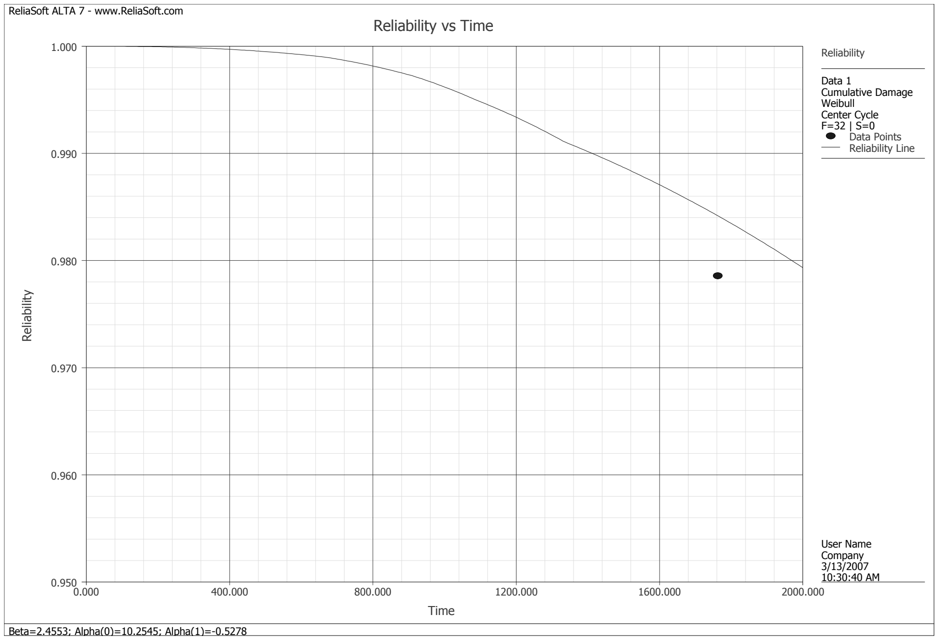


- Close the Stress Profile.
- Replace the static use stress value with the time-dependent Stress Profile that you have just created. To do this, click the **Set Use Stress** link in the Control Panel to open the Use Stress Level window, select **Profile** and select **Center Cycle** from the Use Stress Level drop-down, as shown next.

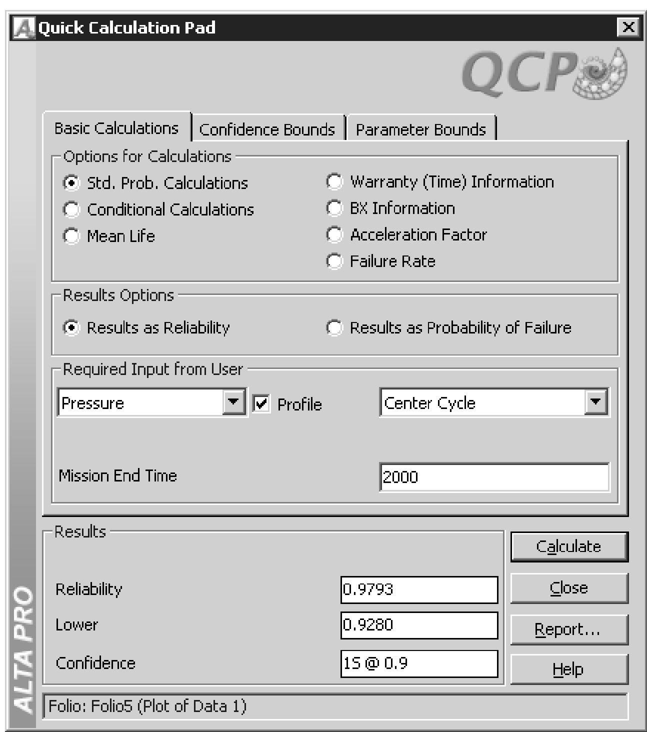


- Click **OK** to return to the Plot sheet. Select the Reliability vs. Time plot type.

- The Reliability vs. Time plot for the analysis with the time-varying use Stress Profile is shown next. Change the scaling of the plot to reflect the 2,000 hr mission time (X-axis). You may also need to change the scaling to 0.95 for the lower Y-axis and 1.0 for the upper Y-axis to see the plot in detail.



- Use the QCP to calculate the reliability for the lower limit with 90% confidence bounds for a mission of 2,000 hr at the time-varying use Stress Profile, as shown next. You will need to select **Show Confidence Bounds** and **Lower One-Sided** then specify a confidence level of 0.9 on the Confidence Bounds tab.



The 90% lower, one-sided reliability is calculated to be 92.80%. This exceeds the requirement of 90% and the design can be released to production.

- Close the QCP and the Folio, save any changes, then leave the project open and proceed to the next example.

5.7 Example 21: Quantifying Acceleration Factors with the Proportional Hazards Model

This example requires you to have Weibull++ 7.5 installed on your computer.

In this example, we look at a way of using the proportional hazards model to help quantify an acceleration factor that can link reliability results from in-house testing labs and the reliability experienced by items in the field.

In order to determine the acceleration factor between the test and the field, test data and field data from the same model of the product must be compared. The test and field data are presented in the following table. Note that the time units differ between the in-house test and the field data; the test data set is in hours and the field data set is in months. Rather than converting one set of data to the other's time units, this discrepancy will be dealt with after the data have been analyzed.

Test Data Times-to-Failure (in hr)	Field Data Times-to-Failure (in months)
50	18
92	8
97	10
98	11
102	13
110	14
122	16
70	17
144	18
47	-
-	11 units suspended at 19 months

Do the following:

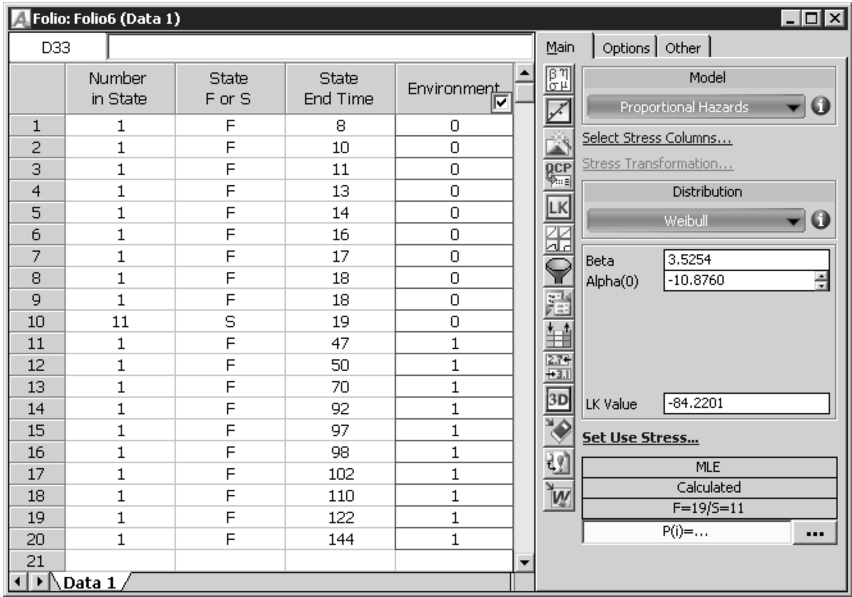
- Analyze the data with the Proportional Hazards-Weibull model to examine the relationship between lab and field data.
- Use the Probability and Contour plots to validate the assumptions regarding the nature of the relationship between test lab and field use.
- Determine the acceleration factor between the lab tests and the field.

The file for this example is located in the "Training Guide" folder in your application directory (e.g. C:\Program Files\ReliaSoft\ALTA7\Training Guide) and is named "Training Examples PRO.ralp." Use the "Proportional Hazards" Folio.

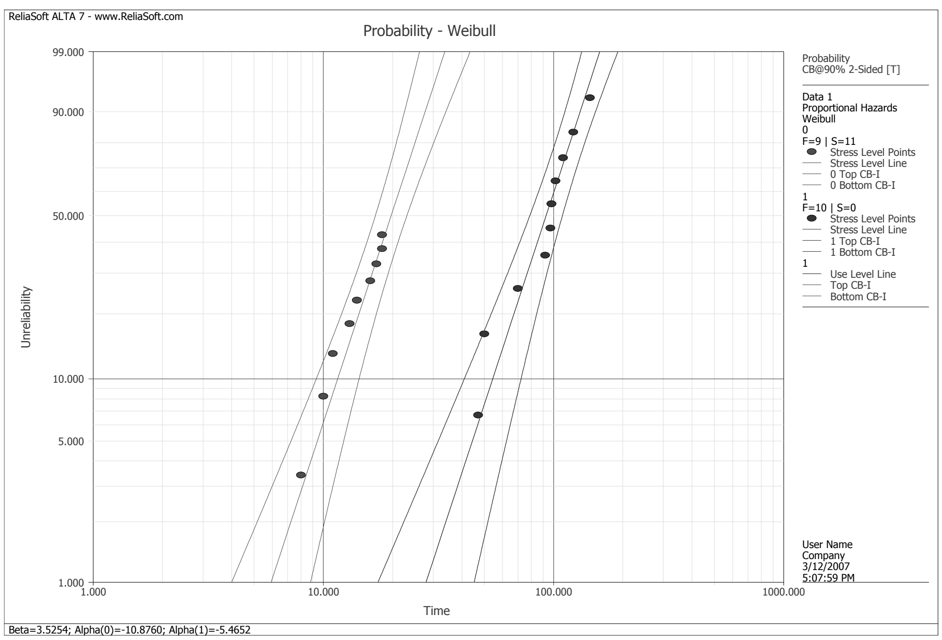
Solution

- Create a new Standard Folio for grouped times-to-failure data with suspensions and set Environment as the stress factor.
- Enter the test and field data in the Data Sheet, using 0 to denote field use and 1 to denote lab testing.

- Calculate the parameters using the proportional hazards model, as shown next.



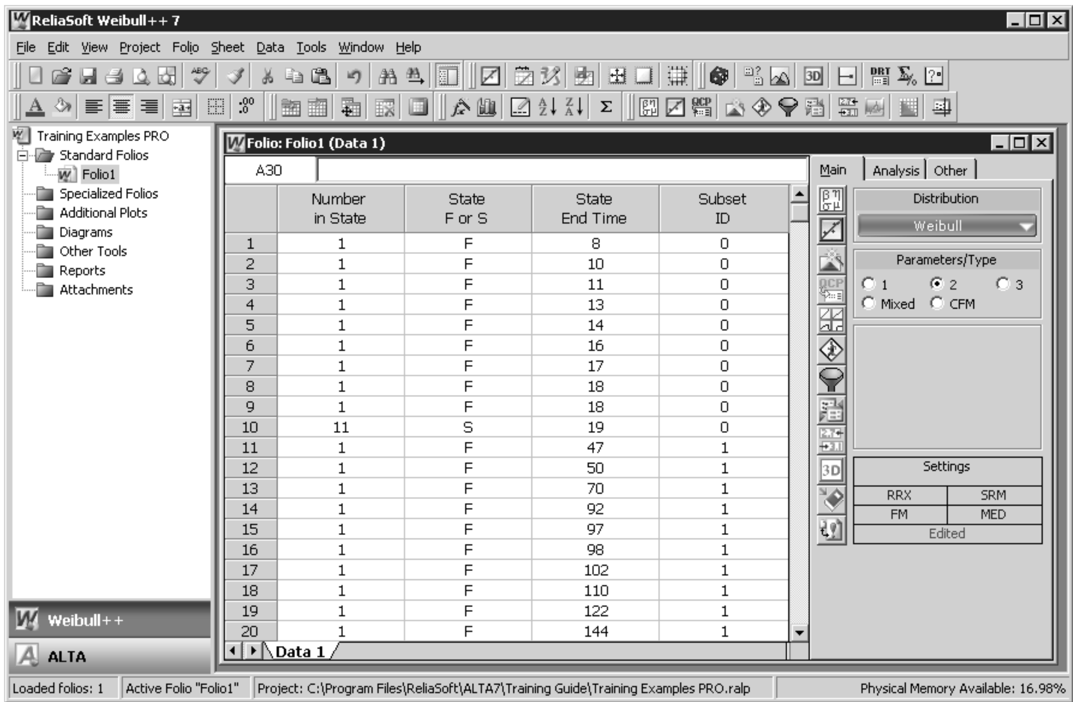
- Next, create a Weibull probability plot with 90% two-sided confidence intervals to make sure that assumptions regarding the nature of the relationship between test lab and field use are valid. Basically, if the same failure modes are being attained at different stress levels, the slope of the Weibull probability plot should be the same at the different stresses. This is shown in the following plot.



- As the plot indicates, the data points for both environments conform closely to the calculated beta value of 3.53.

- You can also use a Contour plot to examine the assumptions about the relationship. To do this, return to the Data Sheet and send the data to Weibull++ by clicking the **Transfer Data to Weibull++** icon on the Control Panel,

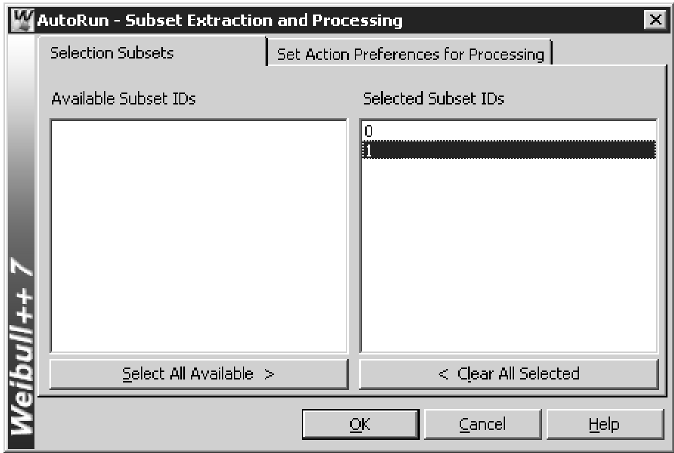
or by selecting **Transfer to Weibull++** from the **Data** menu.[1] The software will automatically switch to the Weibull++ application and the transferred data will appear in a Standard Folio, as shown next.



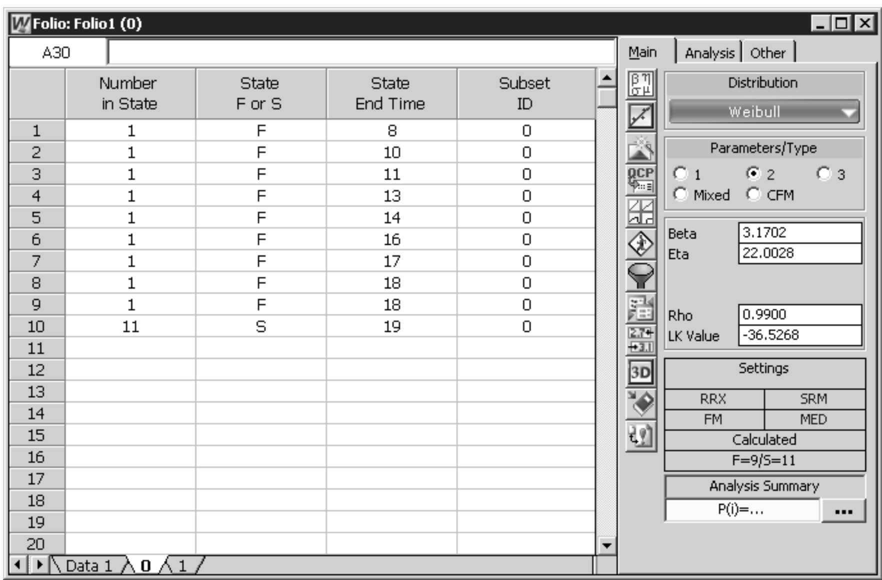
- Once the data has been transferred to Weibull++, use the Batch Auto Run utility to put the field use data and the test data in two separate Data Sheets. Open the Batch Auto Run by clicking its icon on the Control Panel.

[1] Weibull++ can only be activated if version 7.5 or later is installed on your computer. Note that if you are using the Training Examples PRO.ralp file included with the software, the Weibull++ Folio for this example is saved within the project-- simply switch to Weibull++ to view it.

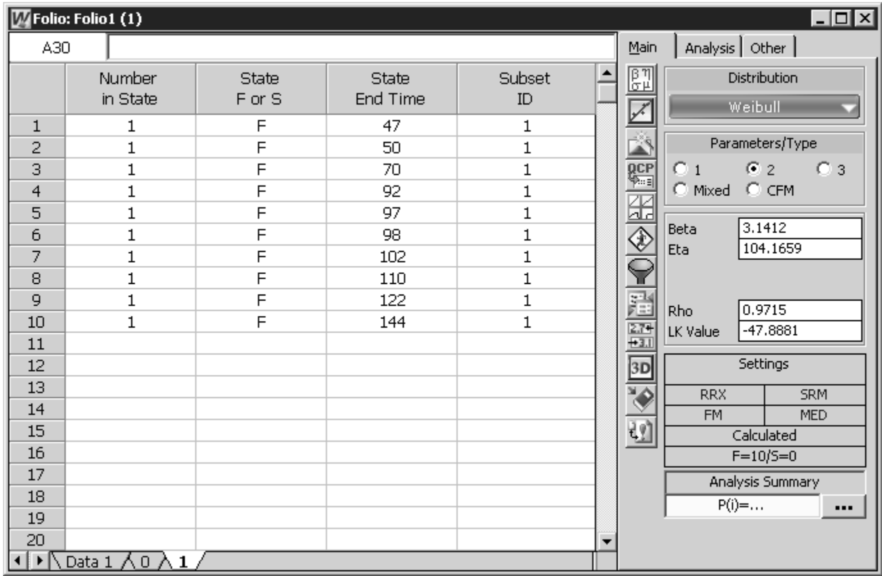
- In the window that appears, click **Select All Available**. Both Subsets ID's (0 representing the field use data and 1 representing the test data) will appear under the Selected Subset ID's area, as shown next. Click **OK**.



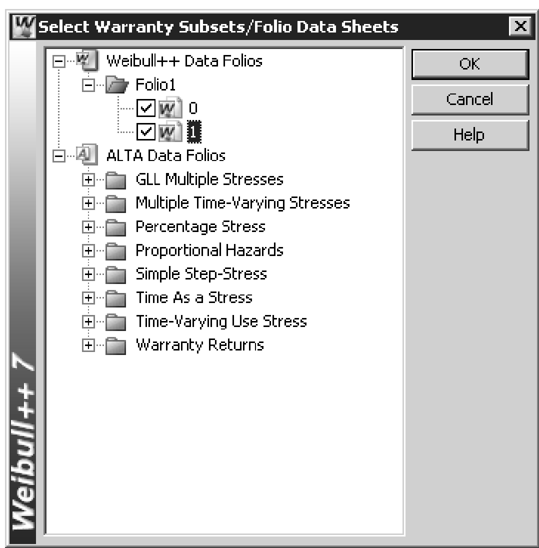
- The field use data will appear in the Data Sheet labeled "0" with the parameters calculated, as shown next.



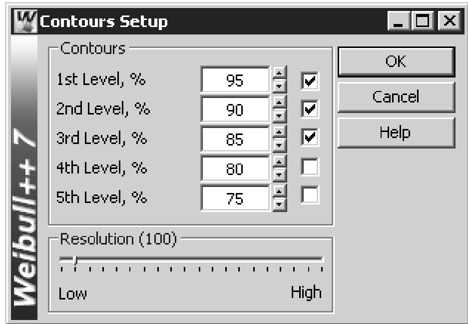
- The test data will appear in the Data Sheet labeled "1" with the parameters calculated, as shown next.



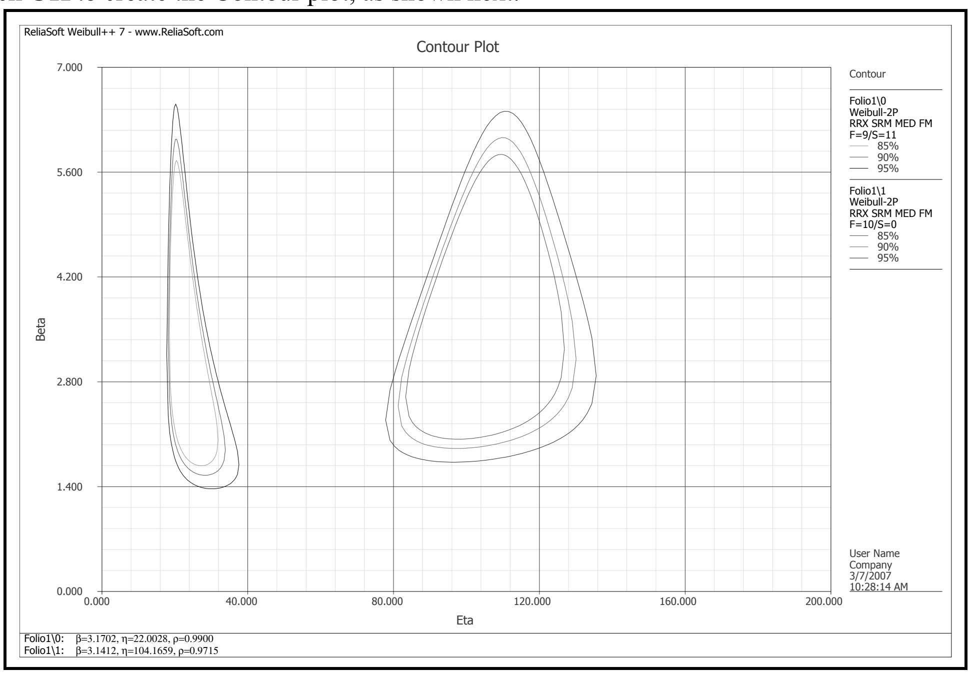
- Next, add a MultiPlot to the Weibull++ project by selecting **Add Additional Plot** then **Add MultiPlot** from the **Project** menu.
- In the Select Warranty Subsets/Folio Data Sheets window that appears, select Folio1 Data Sheets 0 and 1, as shown next, and click **OK**.



- Select **Contour Plot** as the plot type. In the Contours Setup window that appears, select to plot the 1st, 2nd and 3rd levels at 95, 90 and 85 percent, as shown next.



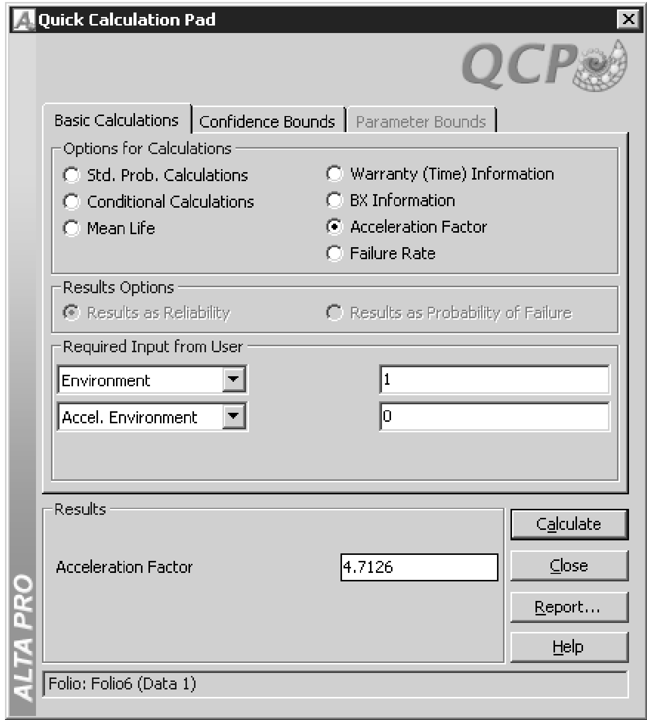
- Click **OK** to create the Contour plot, as shown next.



The Contour plot indicates that the values of eta vary between the two environments, but the beta values fall within the same range. This further supports the assumption that the units are undergoing the same failure modes in both the lab and the field.

- Return to ALTA by clicking the **ALTA** application button at the bottom of the Project Explorer.

- In ALTA, open the QCP and calculate the acceleration factor between the lab and field data. The results are shown next (note that confidence bounds have been turned off on the Confidence Bounds tab).



This calculation indicates that the acceleration factor from the field data (represented by stress level 1) to the lab data (represented by stress level 0) is 4.7. In other words, the units in the field fail 4.7 times faster than the units in the test lab.

Since the time units for the two data sets are different (the lab test times were in hours, while the field data points were in months), we can say that 4.7 hours of time for this particular test is equivalent to one month in the field. We have now quantified the acceleration factor between the lab testing and the field.

- Close the QCP and the Folio, save any changes, then leave the project open and proceed to the next example.

5.8 Example 22: Estimating Warranty Returns

This example requires you to have Weibull++ 7.5 installed on your computer.

Consider an electric motor that has been designed for a washing machine. The actual load sizes for the motors in the field will vary depending on the way that the individual user employs each machine. The manufacturer provides a warranty of 1,000 cycles for this motor. In order to make adequate preparations to support the warranty, the manufacturer wants to estimate the percentage of returns that can be expected during the warranty period. The life of the motor is clearly dependent on the applied load and the applied load varies based on customer usage patterns. In other words, there is a distribution that governs customer usage.

The manufacturer tested the life of the motor at different loads with the following results:

Cycles-to-Failure	Load (lb)
2386	6
3593	6
4045	6
6372	6
6448	6
1414	8
2147	8
3209	8
4026	8
4113	8
5117	8
6127	8
6352	8
819	12
1281	12
1441	12
1796	12
1856	12
2427	12
2645	12
2715	12
3671	12
4881	12
5 motors were suspended at 6500 cycles at the 6 lb load 1 motor was suspended at 6500 cycles at the 8 lb load	

Customer usage information was also available from similar applications, obtained by conducting a survey on a representative sample of customers and recording the sizes of the loads that they placed into their washing machines. A Weibull distribution was fitted to the data and the following parameters were obtained:

beta = 2
eta = 6.2

Do the following:

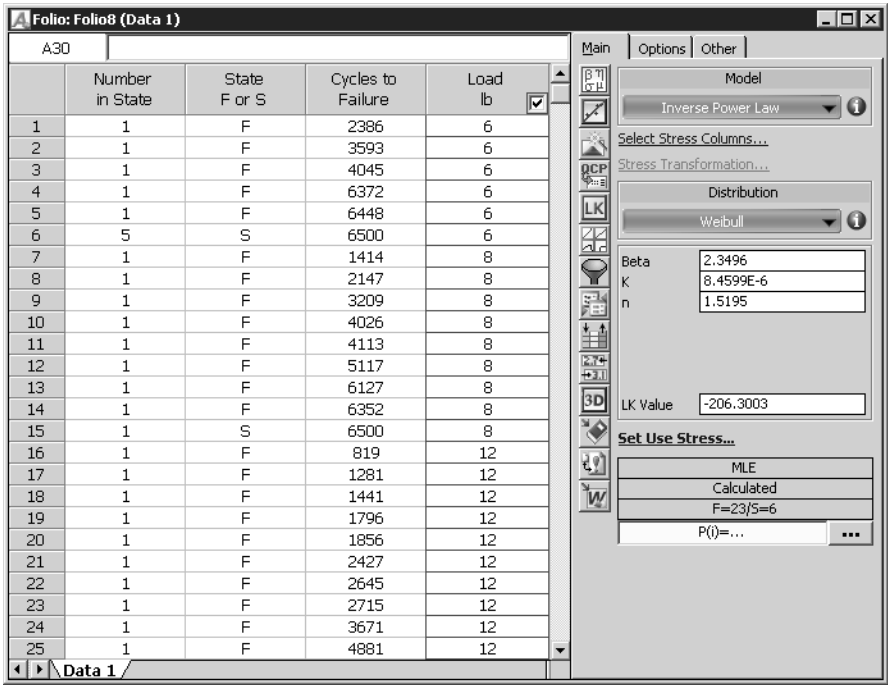
- Determine the unreliability at 1,000 cycles using different loads.
- Estimate the number of returns that can be expected during the warranty period.

The file for this example is located in the "Training Guide" folder in your application directory (e.g. C:\Program Files\ReliaSoft\ALTA7\Training Guide) and is named "Training Examples PRO.ralp." Use the "Warranty Returns" Folio.

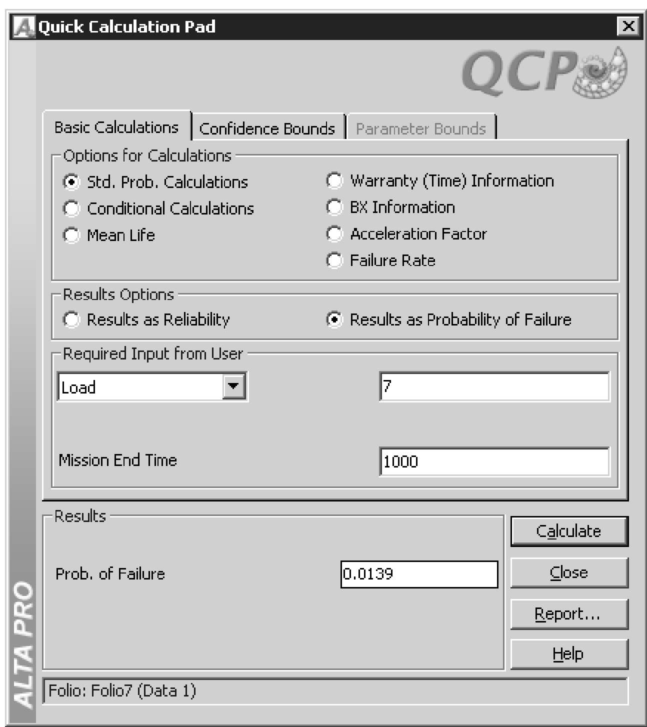
Solution

- Create a new Standard Folio for grouped times-to-failure data with suspensions. Select **Other** as the stress type, change the stress name to "**Load**" and the units to "**lb**".

- In the Data Sheet, rename the State End Time column to "**Cycles to failure**."
- Enter the data into the Data Sheet and calculate the parameters using the Weibull distribution and inverse power law relationship, as shown next.



- The next step is to determine the unreliability at 1,000 cycles using different loadings. Use the QCP to calculate the unreliability for a load of 7 lbs, as shown next.

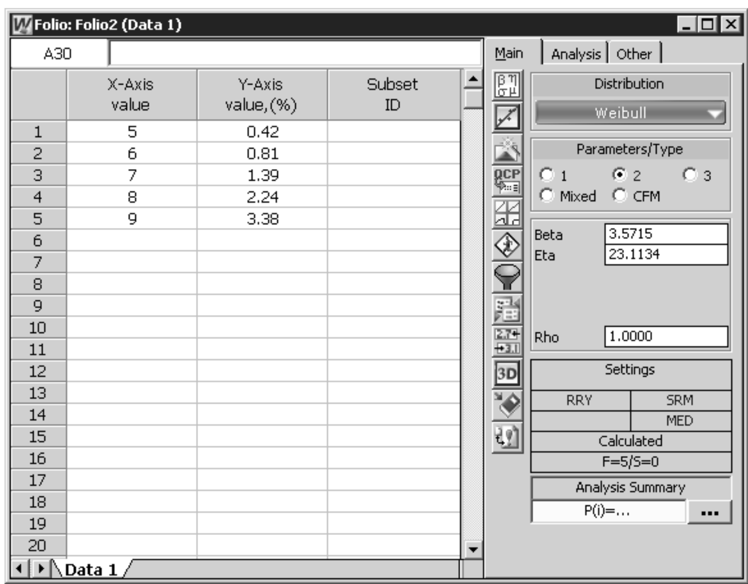


- Continue to use the QCP to obtain values for loads of 5, 6, 8 and 9 lbs. These values are given (in percent) in the next table:

Load (lb)	% Failing at 1,000 Cycles
5	0.42
6	0.81
7	1.39
8	2.24
9	3.38

Using this data set, we can obtain the distribution of the percentage of units failing during the warranty period of 1,000 cycles at each load size. This can be performed using the free-form data type in Weibull++ 7.

- Activate Weibull++ 7 by clicking the **Weibull++** application button at the bottom of the Project Explorer. You will notice that the Standard Folio from the previous example is already present.
- Create a Standard Folio for free-form data.[2]
- In the new Weibull++ Data Sheet, enter the values that were obtained for each load and calculate the parameters using the 2-parameter Weibull distribution with RRY for the parameter estimation, as shown next.



- Insert another Data Sheet into the same Weibull++ Folio (*i.e.* select **Insert Data Sheet** from the **Folio** menu) for ungrouped complete times-to-failure data.
- In the new Data Sheet, set the 2-parameter Weibull distribution and click **Calculate**. In the window that appears, set beta = 2 and eta = 6.2 then click **OK**.

Now we have two distributions, one giving the percentage of units operating at each load size and the other giving the percentage of units that fail at each load size during the warranty period of 1,000 cycles. The stress-strength interference analysis in Weibull++ can now be used to obtain the percentage failing during warranty from the whole range of load sizes applied in the field.

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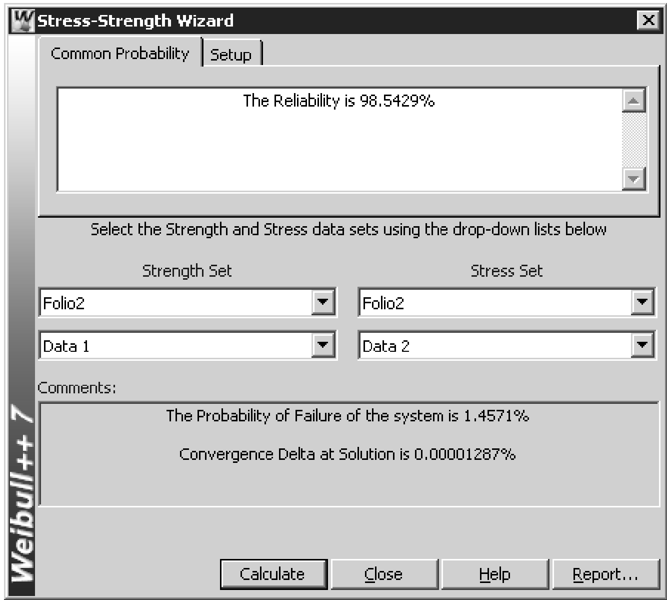
2. Note that if you are using the Training Examples PRO.ralp file included with the software, the Weibull++ Folio for this example is saved within the project-- simply switch to Weibull++ to view it.

- To do this, activate the Stress-Strength Wizard by selecting **Stress-Strength Calculations** from the **Tools** menu.
- Set **Folio 2 Data 1** as the Strength Set and **Folio 2 Data 2** as the Stress Set. Click **Calculate**.



Based on this analysis, it is estimated that approximately 1.46% of the units will fail under warranty.

- Close the Stress-Strength Wizard.
- Return to ALTA by clicking the **ALTA** application button at the bottom of the Project Explorer.
- Close the QCP and the Folio, save any changes, then close the project.

6 Practice Questions

The following practice examples can be performed using ALTA 7 Standard and ALTA 7 PRO. The answers to these practice questions can be found in Chapter 7.

Create a new project in which to perform these practice questions.

6.1 Practice Question 1

The following data set was obtained from an accelerated test. Fifteen units were tested at 2200 rpm, 2500 rpm and 2800 rpm. The use stress level is 1500 rpm.

Stress Level, rpm	2200 rpm	2500 rpm	2800 rpm
Times-to-failure, hr	-	290	140
	-	310	167
	-	316	211
	-	339	264
	-	-	309
Suspension time, hr	500	451	-
	500	-	-
	500	-	-
	500	-	-
	500	-	-

1. Determine how you would classify this data set, *i.e.* non-grouped or grouped, with or without suspensions.
2. Create a new Data Folio and enter the data.

3. Determine the parameters for this data set using the Inverse Power Law-Lognormal model.
4. Obtain the Lognormal Probability plot.
5. Obtain the Use Level Lognormal Probability plot.
6. Save your project as PracticeQuestions.rso7.
7. Close the Folio.

6.2 Practice Question 2

ACME Inc. Manufacturing has implemented an accelerated testing program for their new product design. A total of 40 units were tested at four different pressure levels. The operating stress level is 170 psi.

Stress Level, psi	220 psi	230 psi	240 psi	250 psi
Times-to-failure, hr	165	93	72	26
	177	106	73	44
	238	156	99	63
	290	170	124	68
	320	185	134	69
	340	214	150	72
	341	220	182	77
	380	236	186	96
	449	252	190	131
	544	288	228	140

1. Determine the parameters of the inverse power law life-stress relationship and Weibull distribution.
2. Obtain the Use Level Weibull Probability plot for this data set.
3. Plot the 90%, two-sided confidence bounds (Type II). Open RS Draw and save your plot as MyPlot1.wmf.
4. Experiment with annotating the plot while in RS Draw.
5. From the plot determine:
   i. The reliability of these units for a mission of 1,000 hr, R(1,000 hr).
   ii. The 90%, two-sided confidence limits on the reliability for a mission of 1,000 hr (Type II).
   iii. The mission duration for these units if ACME Inc. requires a 90% reliability at the 50% confidence level.
   iv. The mission range if ACME Inc. requires a 90% reliability at the 90% confidence level (Type I).
6. Using the Quick Calculation Pad, determine:
   i. The reliability of these units for a mission of 1,000 hr, R(1,000 hr).
   ii. The 90%, two-sided confidence limits on the reliability for a mission of 1,000 hr.
   iii. The mission duration for these units if ACME Inc. requires a 90% reliability at the 50% confidence level.
   iv. The mission range if ACME Inc. requires a 90% reliability at the 90% confidence level.
   v. The 90% two-sided confidence limits on the parameters.
7. Obtain the Reliability vs. Time plot for these units.
8. Obtain the Time vs. Stress plot for a 5% unreliability.
9. Obtain the Failure Rate vs. Time plot for these units. From the plot, what is the failure rate of these units at 6,000 hr?

10. Obtain the Acceleration Factor vs. Stress plot. From the plot, what is the acceleration factor at 260 psi?
11. Save your file and close the Folio.

6.3 Practice Question 3

The following data set was obtained from an accelerated test in which temperature and humidity were the accelerated stresses. The use stress levels are 348K for temperature and 0.20 for relative humidity.

Time-to-Failure, hr	Temperature, K	Humidity
310	378	0.40
316	378	0.40
329	378	0.40
411	378	0.40
280	378	0.80
298	378	0.80
320	378	0.80
388	378	0.80
108	398	0.40
123	398	0.40
166	398	0.40
200	398	0.40

1. Using the temperature-humidity life-stress relationship and Weibull distribution, determine the life for a 90% reliability at the use stress levels.
2. Obtain the Life vs. Temperature plot.
3. Obtain the Life vs. Humidity plot.
4. Change the entered humidity values from decimals to percentages (*i.e.* from 0.4 to 40). Repeat Step 1 (note that the use level humidity is now 20). Do you see any difference in your estimation?

6.4 Practice Question 4

Open the Folio from Practice Question 2 (Folio2).

1. Insert a new Data Sheet for ungrouped complete data with no censoring into this Folio, using the same pressure stress. *(You will now have an empty Data Sheet, as well as the one you saved from Question 2)*.
2. Copy the data from Question 2 and paste it into the empty Data Sheet. Delete the last ten entries for the 250 psi stress level. Use the inverse power law life-stress relationship and Weibull distribution to calculate the parameters of the new data set.
3. Insert another Data Sheet for ungrouped complete data with no censoring into this Folio, using the same pressure stress, and again copy the data from Question 2 and paste it into the newly created Data Sheet. This time, delete the last twenty entries for the 240 psi and 250 psi stress levels. Calculate the parameters for the inverse power law life-stress relationship and Weibull distribution.
4. Plot the Use Level Weibull Probability plot at 200 psi for each data set individually.
5. Plot the 90% two-sided confidence bounds and customize each plot to your liking.
6. Add a MultiPlot to the Folio and select the Use Level Weibull Probability plot for all three data sets to be displayed. You may need to customize the colors using the Plot Setup in order to determine which confidence bounds apply to each data set. What do you observe about the confidence bounds for each data set, especially Data 3 with the 20 failures?

7. Find the range of each confidence interval for each case using the QCP and for a 90% reliability at 200 psi. What happens to the confidence bounds when the number of test stresses increases? Why?
8. Close the Folio when you are finished and save the project.

6.5 Practice Question 5

In accelerated life data analysis, the *pdf*, the reliability and the failure rate are functions of both stress and time. Thus, three-dimensional plots give you a good understanding of the behavior of such functions.

1. Open the Folio from Practice Question 1 (Folio1).
2. Calculate the parameters using the inverse power law life-stress relationship and lognormal distribution.
3. Plot the Failure Rate Function using ALTA's 3-D Plot utility.
4. Press **Ctrl** and click the plot. Simultaneously move the mouse in the direction you would like to rotate the plot.
5. What is the behavior of the failure rate as time increases on a constant stress line?
6. When finished, leave the Folio open.

6.6 Practice Question 6

Once you have generated the data, created your plots and calculated what you wanted to calculate, the next step is to generate a report. ALTA 7 allows you to do this very easily.

1. Folio1 should already be open.
2. Calculate the parameters if they are not calculated.
3. Create a Use Level Lognormal Probability Plot with 90% two-sided confidence bounds, then return to the Data Sheet.
4. Click the **Report Wizard** icon in the Standard Folio Control Panel. The Report Wizard will appear, with the "Data 1" Data Sheet in Folio1 already selected as the default data source.
5. Create a report based on the Single Constant Stress Template.
6. In cell C10, enter the use stress level (**1500**). In cell C11, enter the highest stress level used in the test (**2800**). Leave the confidence bounds at their defaults of 5% and 95%.
7. Return to the Plot Sheet in Folio1, right-click the plot and select **Copy**.
8. Return to the Report and, in the Estimates and Two-Sided Confidence Bounds for Distribution Percentiles section at the bottom of the Report, right-click in cell B49 and select **Paste**.
9. Resize the plot to your liking.
10. Close the Report and save the project.

6.7 Practice Question 7

The Monte Carlo Data generator is a useful tool that allows you to generate values for any combination of the available life-stress relationships and distributions. This example will take you through such a scenario.

1. Open the Monte Carlo utility by clicking its icon.

2. Generate a data set using the Eyring life-stress relationship and lognormal distribution with std = 0.3, A = 2, B = 5,000. Create 25 data points for each of the two stress levels: 323 and 343.
3. Calculate the parameters.
4. Are the parameters equal to the ones used in the Monte Carlo generator? Comments?
5. Generate another Monte Carlo data set using the same distribution and parameters.

7 Answers to Practice Questions

The purpose of this section is to provide answers to the Practice Questions in Chapter 6. Due to the structure and process required for Questions 6 and 7, answers are not provided.

7.1 Practice Question 1

1. Grouped times-to-failure with suspensions
3. $\sigma = 0.2485$, K = 1.6896E-21, n = 5.3571

7.2 Practice Question 2

1. $\beta = 3.0092$, K = 3.2679E-27, n = 10.2181
5. From the plot:

   i. R(1,000 hr) ≅ 99.25%

   ii. Upper CL ≅ 99.9%, Lower CL ≅ 94%

   iii. Mission Duration ≅ 2,300 hr

   iv. Requires a mission range of approximately 1,260 - 4,370 hr
6. From the QCP:

   i. R(1,000 hr) = 99.19%

   ii. Upper CL = 99.90%, Lower CL = 93.82%

   iii. Mission Duration = 2,344.1964 hr

   iv. Requires a mission range of 1,259.5799 - 4,362.7698 hr

   v. β : 2.4541, 3.6899, K: 1.3662E-31, 7.8166E-23, n: 8.3708, 12.0654

9. Failure Rate ≅ 8.88E-04
10. Acceleration Factor ≅ 73.46

7.3 Practice Question 3

1. T = 1,008.6986 hr.
4. No, there is no difference.

7.4 Practice Question 4

6. The bounds for Data 3 are very wide.
7. Data 1: 313.6396 - 632.6267 hr
   Data 2: 286.8053 - 643.2723 hr
   Data 3: 328.8520 - 1167.7188 hr
   There is less uncertainty in the extrapolation when the number of test stresses increases.

7.5 Practice Question 5

5. The failure rate increases.