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Reliability Life Data Analysis

Amnon Ganot - September 2012

ReliaSoft Weibull++ 8

Outline

- Life Data Analysis
- Degradation Analysis
- Design of Reliability Tests
- Warranty Data Analysis
- Target Reliability Estimation
- Stress-Strength Comparison
- Competing Failure Modes Analysis
- Parametric Recurrent Event Data Analysis
- Event Log Data Analysis
- Summary

Overview

Weibull++ 8 Features

- Weibull++ provides the most comprehensive toolset available for reliability life data analysis, calculated results, plots and reporting
- The software supports all data types and all commonly used product lifetime distributions (including the Weibull model and the mixed Weibull model as well as the Exponential, Lognormal, Normal, Generalized Gamma, Gamma, Logistic, Loglogistic, Gumbel, Bayesian-Weibull and Competing Failure Modes).

Weibull++ 8 Features (cont.)

- The software is also packed with tools for related reliability analyses, such as warranty data analysis, degradation data analysis, non-parametric data analysis, recurrent event data analysis and reliability test design.

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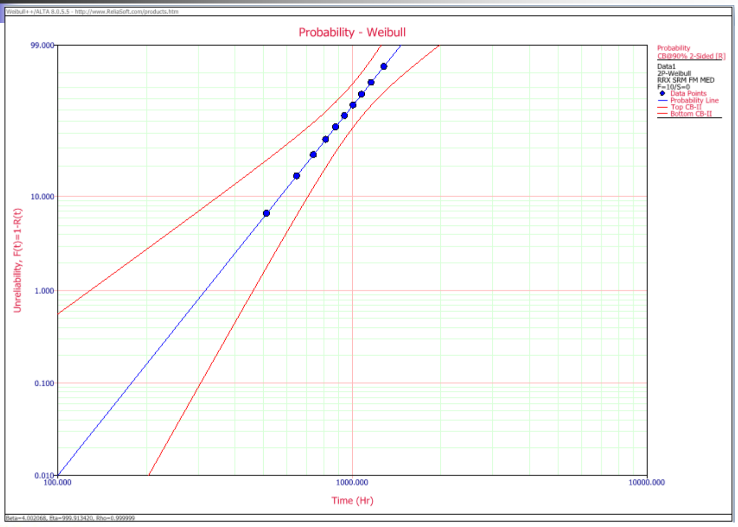
In a Nutshell…

Life Data Analysis

Life Data Analysis

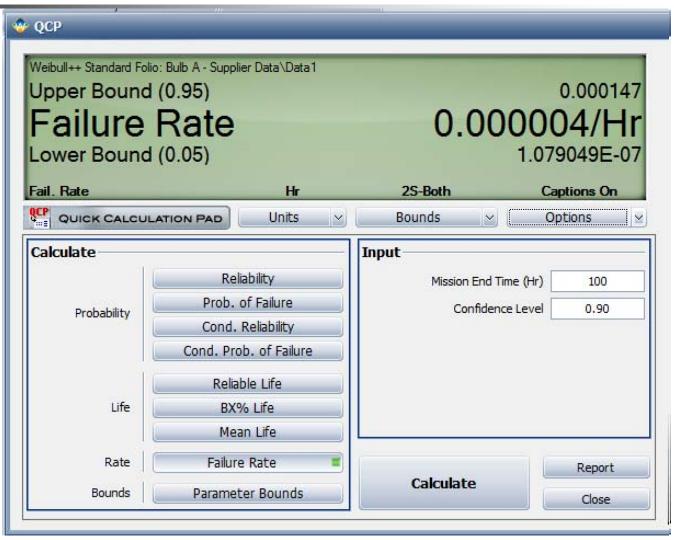
- In life data analysis, the goal is to model and understand the failure rate behavior of a particular item, process or product
- The models are built by taking the observed “life” data, which can be obtained either from the field or from in-house testing
- Because time is a common measure of product life, the life data points are often called *times-to-failure data*
- There are two general types of times-to-failure data: *complete* and *censored*

Probability Plots



Beta=4.002068, Eta=999.913420, Rho=0.999999

Quick Calculation Pad



Weibull++ Standard Folio: Bulb A - Supplier Data\Data1

Upper Bound (0.95) 0.000147

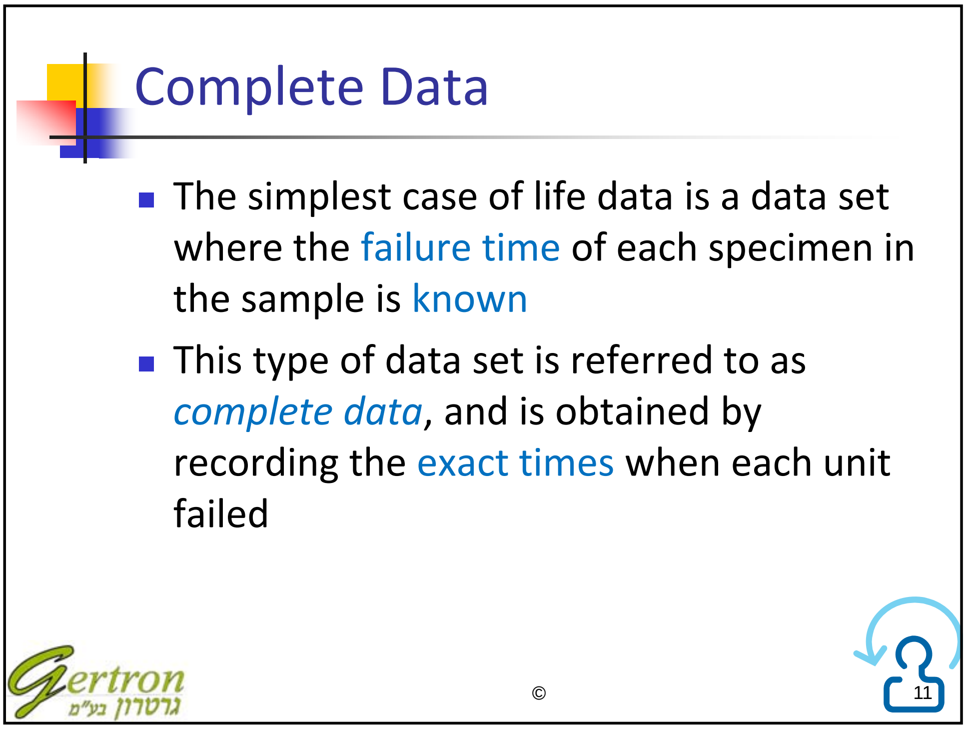
Failure Rate 0.000004/Hr

Lower Bound (0.05) 1.079049E-07

Fail. Rate Hr 2S-Both Captions On

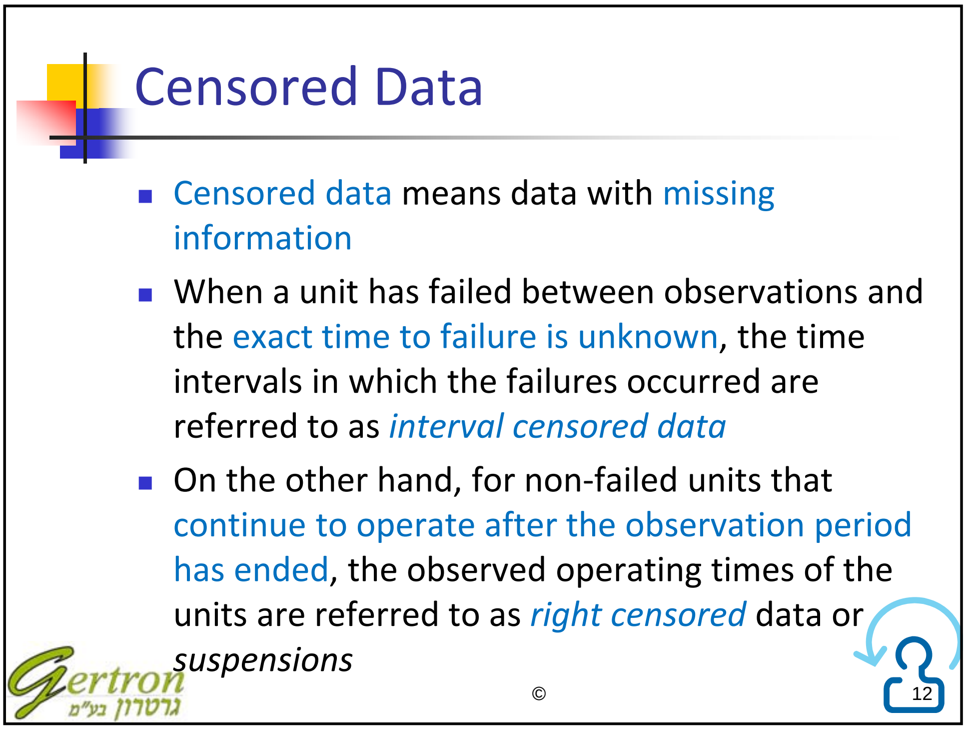
Mission End Time (Hr) 100

Confidence Level 0.90



Complete Data

- The simplest case of life data is a data set where the failure time of each specimen in the sample is known
- This type of data set is referred to as *complete data*, and is obtained by recording the exact times when each unit failed



Censored Data

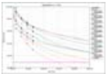
- Censored data means data with missing information
- When a unit has failed between observations and the exact time to failure is unknown, the time intervals in which the failures occurred are referred to as *interval censored data*
- On the other hand, for non-failed units that continue to operate after the observation period has ended, the observed operating times of the units are referred to as *right censored* data or *suspensions*

Degradation Analysis

Degradation Analysis

- Degradation analysis is useful for tests performed on highly reliable products that:
  - cannot feasibly be tested to complete failure under normal operating conditions,
  - are associated with a measurable performance characteristic (e.g., the wear in brake pads) and,
  - are not destroyed upon inspection

Degradation Analysis (cont.)



- This analysis consists of two steps:
  - First, the failure times of the units on test are extrapolated using measurements of their degradation over time. (A unit is considered failed when its degradation reaches a specified critical level.)
  - Second, once these failure times are obtained, life data analysis is used to estimate the reliability of the product

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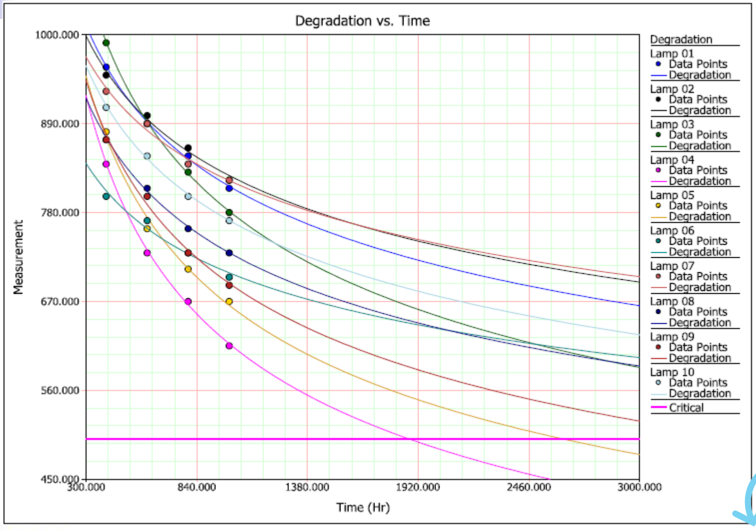
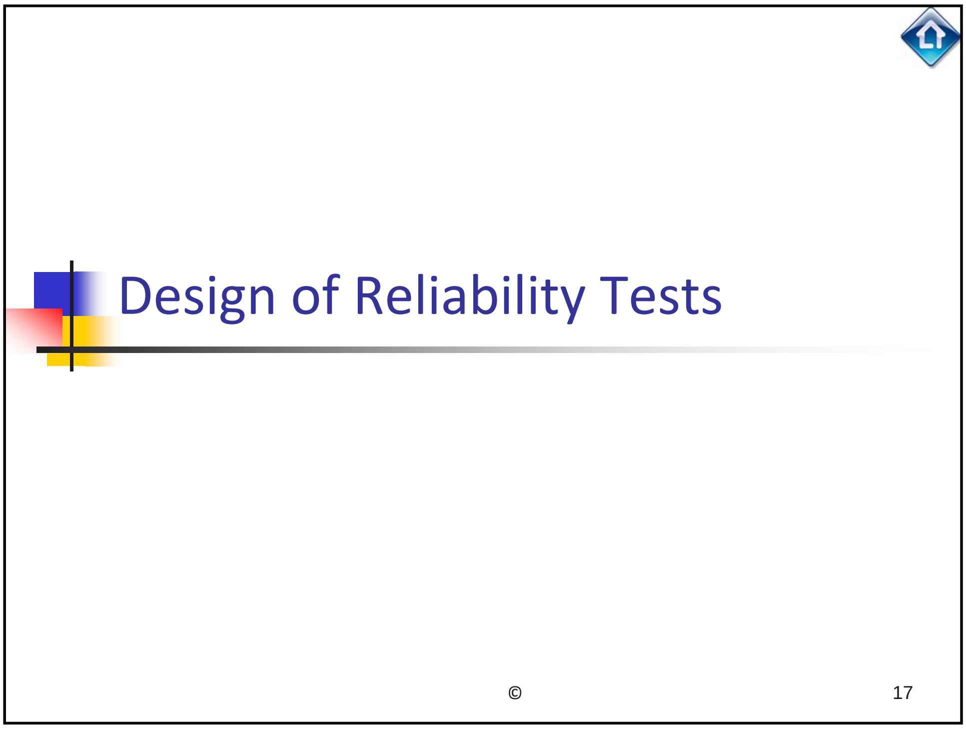
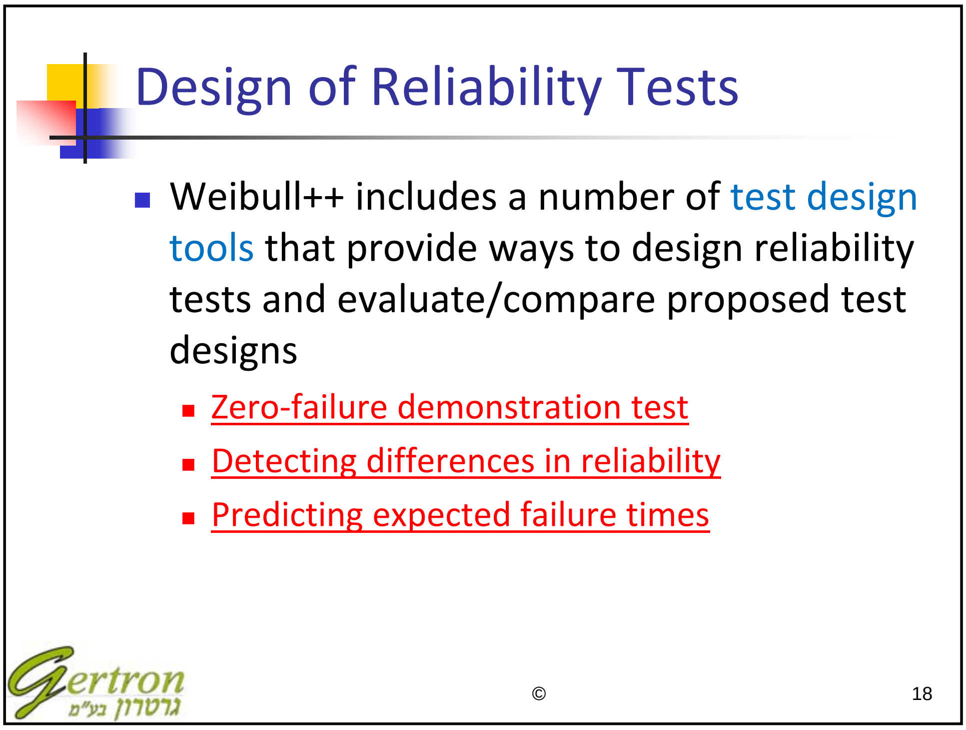
Degradation Vs. Time



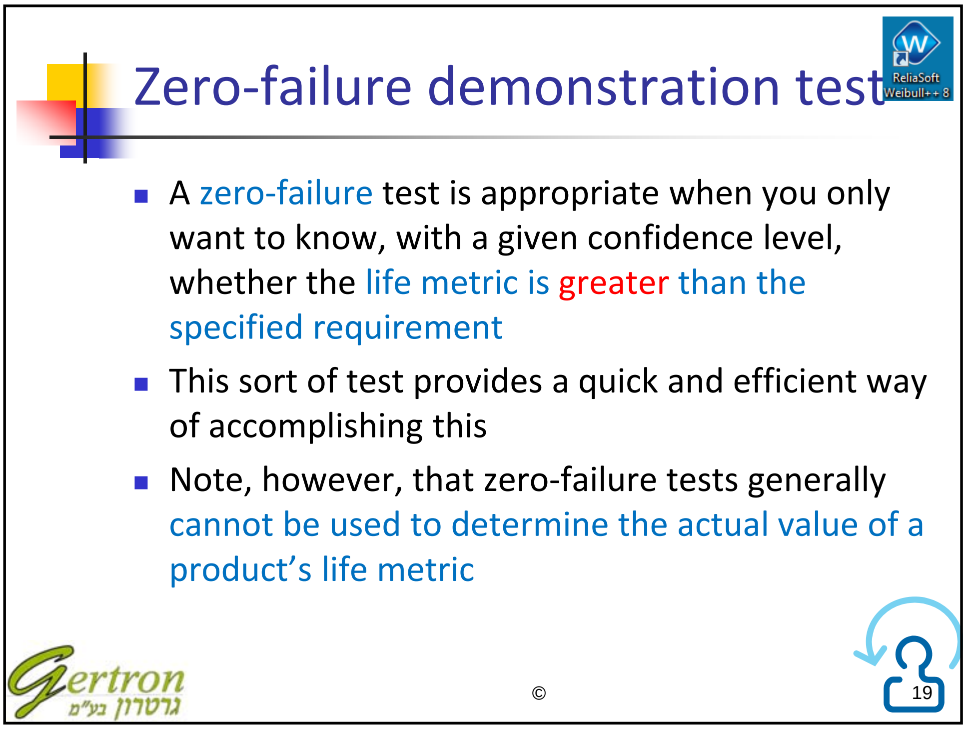


Design of Reliability Tests



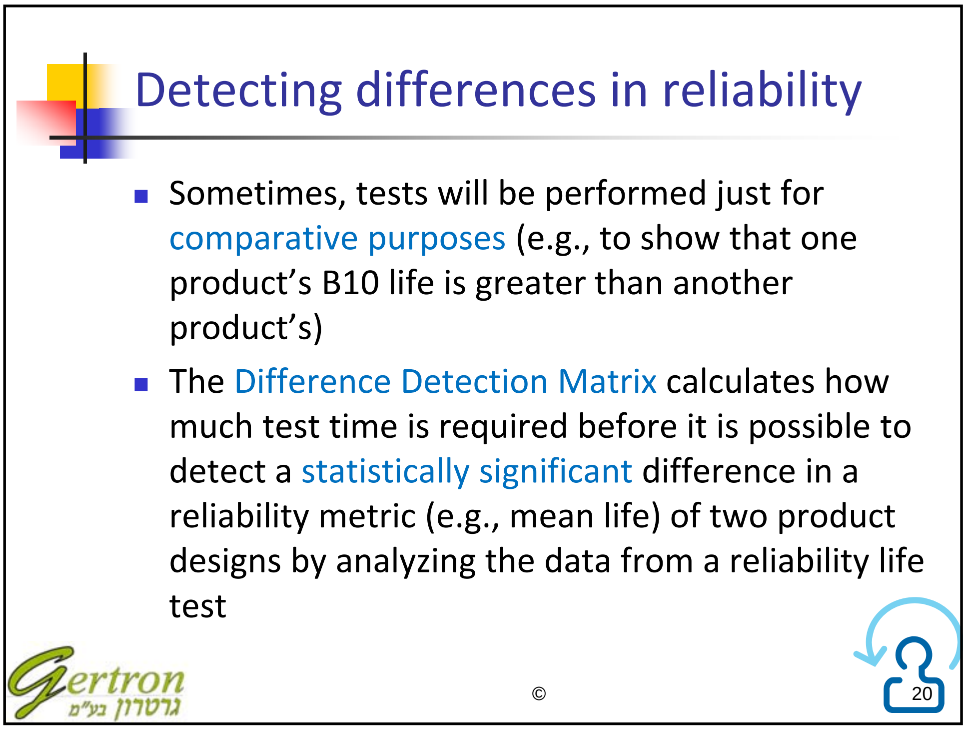
Design of Reliability Tests

- Weibull++ includes a number of test design tools that provide ways to design reliability tests and evaluate/compare proposed test designs
  - Zero-failure demonstration test
  - Detecting differences in reliability
  - Predicting expected failure times



Zero-failure demonstration test

- A zero-failure test is appropriate when you only want to know, with a given confidence level, whether the life metric is greater than the specified requirement
- This sort of test provides a quick and efficient way of accomplishing this
- Note, however, that zero-failure tests generally cannot be used to determine the actual value of a product's life metric



Detecting differences in reliability

- Sometimes, tests will be performed just for comparative purposes (e.g., to show that one product's B10 life is greater than another product's)
- The Difference Detection Matrix calculates how much test time is required before it is possible to detect a statistically significant difference in a reliability metric (e.g., mean life) of two product designs by analyzing the data from a reliability life test

Predicting expected failure times

- In general, this plot tells you that, based on the assumed distribution, you can expect the observed failure times to be within the ranges shown
- If any sequential observed time is outside this range, then the distribution (and thus the reliability) of the observed units should no longer be assumed
- Moreover, if any of the observed failure times is earlier than its predicted interval, then you can infer that the reliability will be less than what was assumed
- Similarly, if any of the actual failure times is greater than its predicted interval, then you can infer that the reliability is greater than what was assumed (at the specified confidence level)

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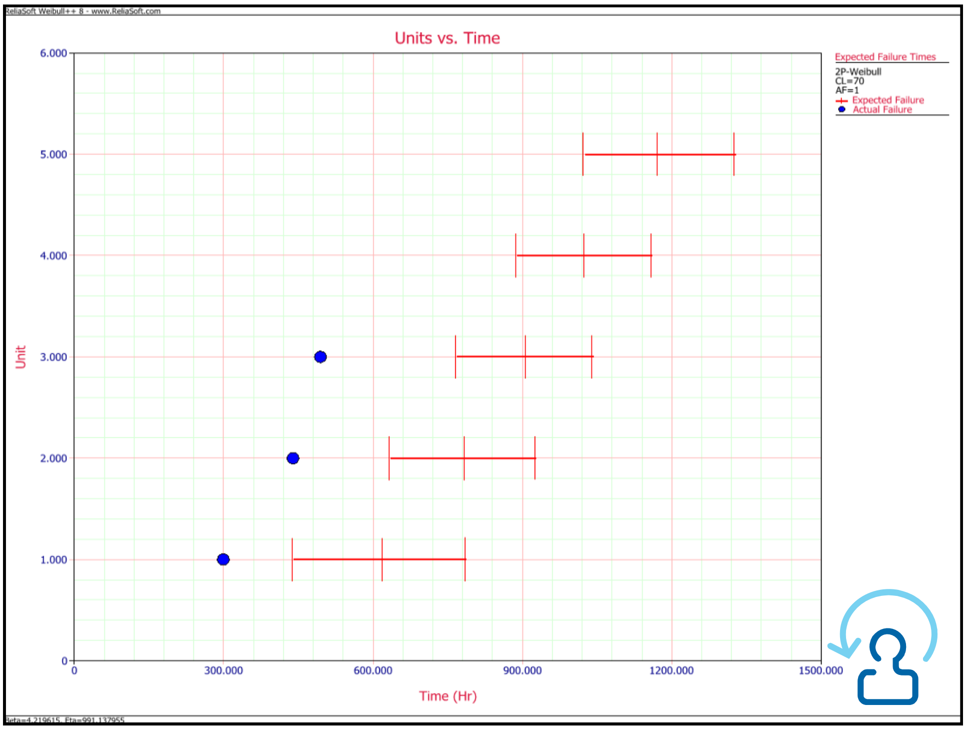

Warranty Analysis

Warranty Analysis

- Development testing allows you to uncover and correct reliability problems before a product is deployed; however, there are instances when a problem is not discovered until the product is in the customer’s hands
- Data obtained from field failures can provide valuable information about how a product actually performs in the real world as well as forecasting product returns

Warranty Analysis (cont.)

- Nevada chart format

Returns Period

Sales Period

Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1		6	13	20	32	38	62	82	97	78	112	113	76	0	0	0	0	0
2			5	9	20	35	52	76	64	76	114	112	89	77	0	0	0	0
3				4	12	19	31	58	56	77	94	87	114	93	76	0	0	0
4					5	13	20	31	39	70	69	104	81	104	108	112	0	0
5						6	10	22	39	48	56	68	89	97	109	92	88	0
6							4	12	22	36	54	61	52	88	101	97	89	94
7								4	10	23	35	53	58	65	68	76	107	78
8									5	10	25	38	33	50	57	79	100	105
9										6	9	22	20	40	41	75	75	80
10											6	12	11	17	29	48	67	67
11												6	4	9	22	40	57	67
12													0	0	1	2	3	8
13														0	0	1	2	5
14															0	0	1	2
15																0	0	1
16																	0	0
17																		0
18																		

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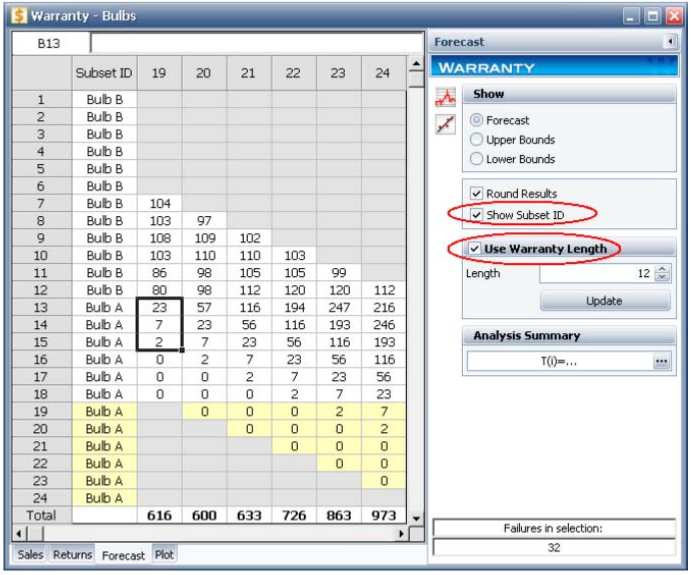
Warranty Forecast Analysis (cont.)



	Subset ID	19	20	21	22	23	24
1	Bulb B						
2	Bulb B						
3	Bulb B						
4	Bulb B						
5	Bulb B						
6	Bulb B						
7	Bulb B	104					
8	Bulb B	103	97				
9	Bulb B	108	109	102			
10	Bulb B	103	110	110	103		
11	Bulb B	86	98	105	105	99	
12	Bulb B	80	98	112	120	120	112
13	Bulb A	23	57	116	194	247	216
14	Bulb A	7	23	56	116	193	246
15	Bulb A	2	7	23	56	116	193
16	Bulb A	0	2	7	23	56	116
17	Bulb A	0	0	2	7	23	56
18	Bulb A	0	0	0	2	7	23
19	Bulb A		0	0	0	2	7
20	Bulb A			0	0	0	2
21	Bulb A				0	0	0
22	Bulb A					0	0
23	Bulb A						0
24	Bulb A						
Total		**616**	**600**	**633**	**726**	**863**	**973**

● Forecast
○ Upper Bounds
○ Lower Bounds

☑ Round Results
☑ Show Subset ID

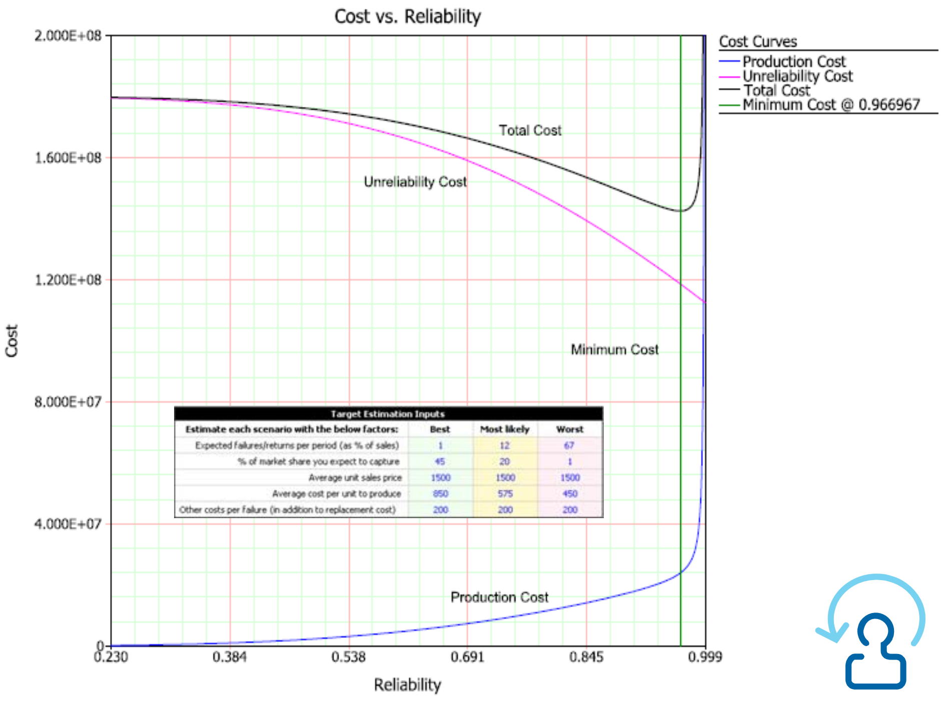
☑ **Use Warranty Length**
Length 12

Failures in selection:
32

Target Reliability Estimation

Target Reliability Estimation

- Deciding on a reliability goal/target involves trade-offs
- This is because higher reliability typically correlates with higher production costs, lower warranty costs and higher market share
- With Weibull++'s Target Reliability tool, you can generate plots that help you visualize and estimate a target reliability that will minimize cost, maximize profit and/or maximize your return on an investment in improving the product’s reliability



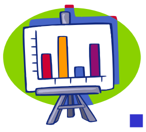
Target Reliability Estimation

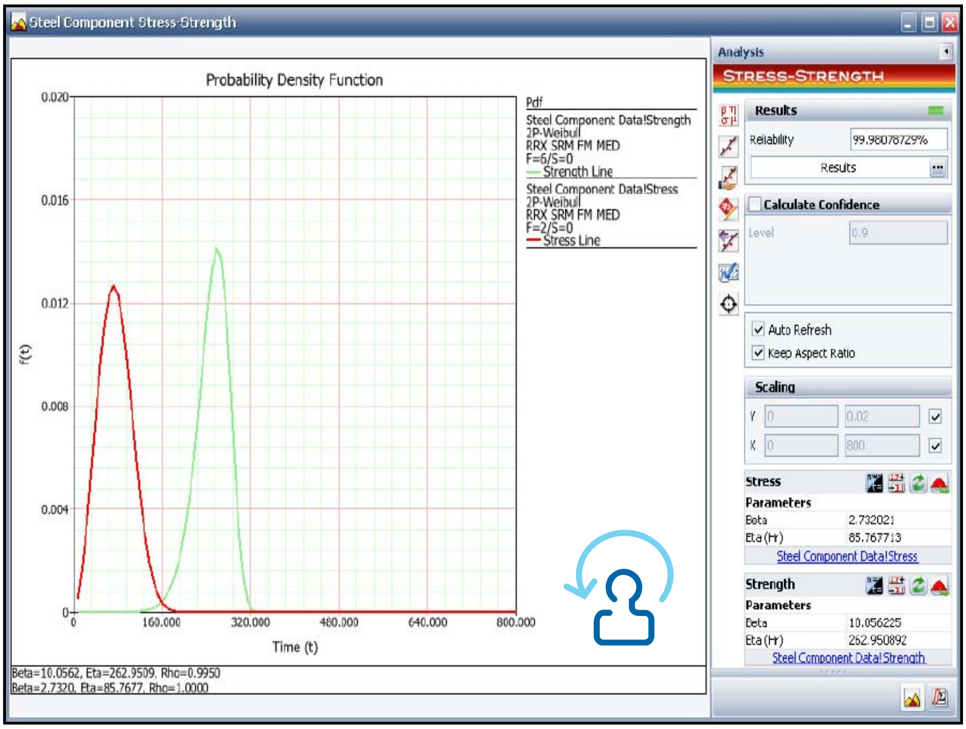
Target Estimation Inputs			
Estimate each scenario with the below factors:	**Best**	**Most likely**	**Worst**
Expected failures/returns per period (as % of sales)	1	12	67
% of market share you expect to capture	45	20	1
Average unit sales price	1500	1500	1500
Average cost per unit to produce	850	575	450
Other costs per failure (in addition to replacement cost)	200	200	200

Stress-Strength Comparison

Stress-Strength Comparison

- Generally, the reliability of a product is calculated based on its ability to perform without failure for a specified period of time
- In some cases, however, you may need to obtain the reliability of a product based on its ability to withstand an applied stress without failure, rather than the length of time it continues to operate
- An example is a wooden beam that may buckle under a load that is over a certain weight limit





Steel Component Data!Strength
2P-Weibull
RRX SRM FM MED
F=6/S=0

Steel Component Data!Stress
2P-Weibull
RRX SRM FM MED
F=2/S=0

Beta=10.0562, Eta=262.9509, Rho=0.9950
Beta=2.7320, Eta=85.7677, Rho=1.0000

Reliability: 99.98078729%

☐ Calculate Confidence
Level: 0.9

☑ Auto Refresh
☑ Keep Aspect Ratio

Y: 0 – 0.02 ☑
X: 0 – 800 ☑

Stress

Parameters	
Beta	2.732021
Eta (Hr)	85.767713

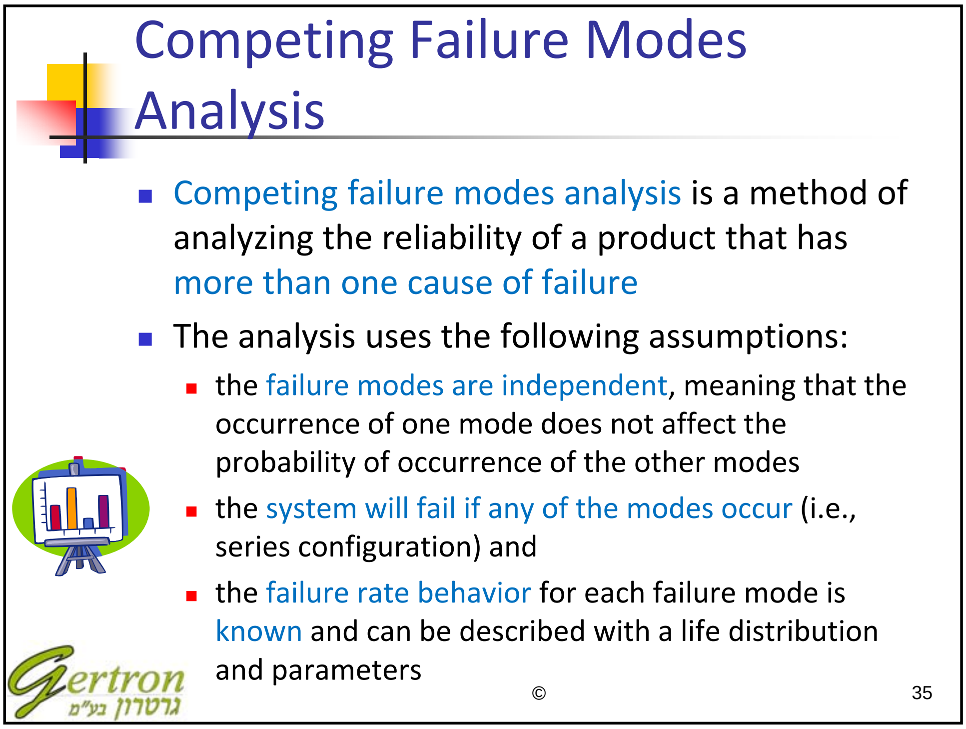
Steel Component Data!Stress

Strength

Parameters	
Beta	10.056225
Eta (Hr)	262.950892

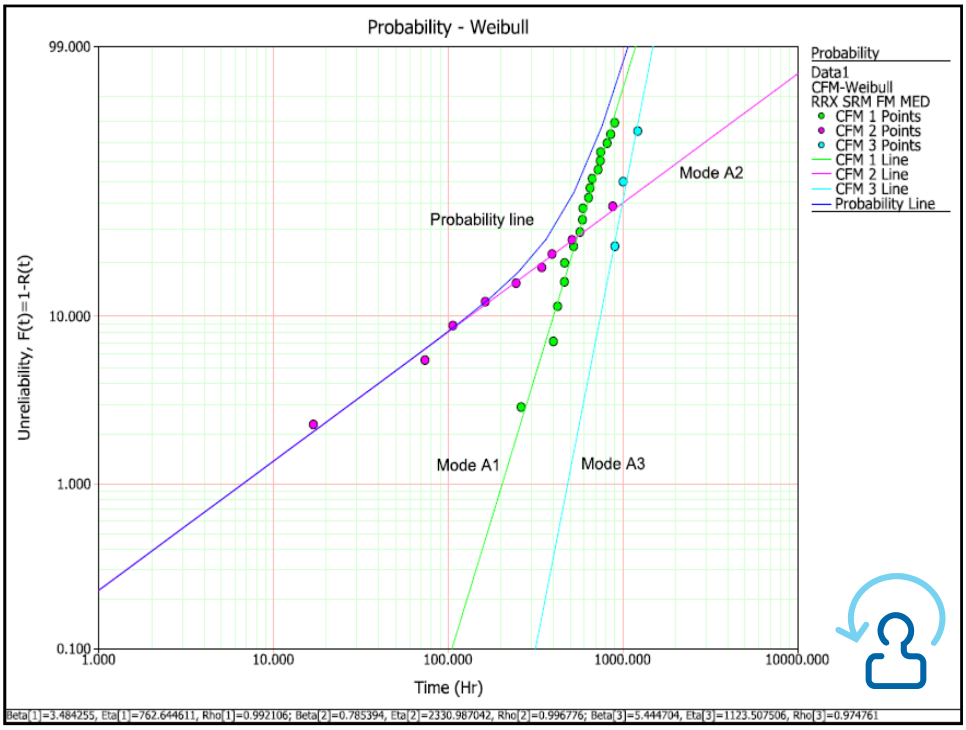
Steel Component Data!Strength

Competing Failure Modes Analysis



Competing Failure Modes Analysis

- Competing failure modes analysis is a method of analyzing the reliability of a product that has more than one cause of failure
- The analysis uses the following assumptions:
  - the failure modes are independent, meaning that the occurrence of one mode does not affect the probability of occurrence of the other modes
  - the system will fail if any of the modes occur (i.e., series configuration) and
  - the failure rate behavior for each failure mode is known and can be described with a life distribution and parameters



Parametric Recurrent Event Data Analysis

Parametric Recurrent Event Data Analysis

- In life data analysis, it is assumed that the components being analyzed are non-repairable; that is, they are either discarded or replaced upon failure
- However, for complex systems such as automobiles, computers, aircraft, etc., it is likely that the system will be repaired (not discarded) upon failure
- Failures are recurring events in the life of a repairable system, and data from such a system are known as *recurrent event data*

Parametric Recurrent Event Data Analysis (cont.)

- In the reliability field, recurrent event data analysis has many applications such as:
  - Evaluating whether the population repair (or cost) rate increases or decreases with age (this is useful for product retirement and burn-in decisions).
  - Estimating the average number or cost of repairs per unit on warranty or over the design life of the product
  - Comparing two or more sets of data obtained from different designs, production periods, maintenance policies, environments, operating conditions, etc.
  - Predicting future numbers and costs of repairs

Event Log Data Analysis

Event Log Data Analysis

- Event logs, or maintenance logs, capture information about a piece of equipment's failures and repairs, such as the date/time the equipment failed and the date/time the equipment was restored
- This information is useful for helping companies achieve productivity goals by giving insight about the failure modes, frequency of outages, repair duration, uptime/downtime and availability of the equipment
- Objective - Obtain the times-to-failure and times-to-repair distributions of each subsystem

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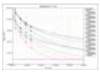
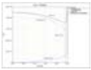
Summary

- Life Data Analysis - In life data analysis, the goal is to model and understand the failure rate behavior of a particular item, process or product
  - Complete Data
  - Censored Data

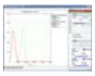


- Degradation Analysis - useful for tests performed on (highly reliable) products that are associated with a measurable performance characteristic
- Warranty Analysis - Data obtained from field failures can provide valuable information about how a product actually performs in the real world as well as forecasting product returns

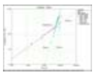
Summary (cont.)



- Target Reliability Estimation - higher reliability typically correlates with higher production costs, lower warranty costs and higher market share



- Stress-Strength Comparison - reliability of a product based on its ability to withstand an applied stress without failure, rather than the length of time it continues to operate



- Competing Failure Modes Analysis - a method of analyzing the reliability of a product that has more than one cause of failure

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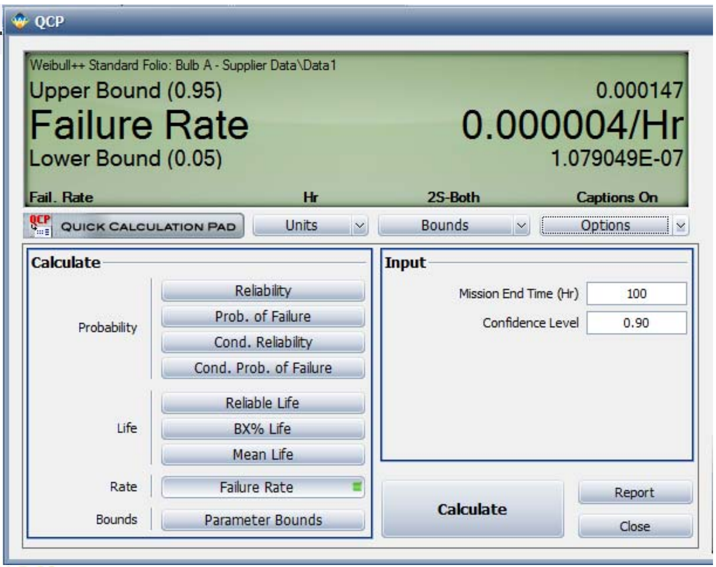
Summary (cont.)

- Parametric Recurrent Event Data Analysis - Failures are recurring events in the life of a repairable system, and data from such a system are known as *recurrent event data*
- Event Log Data Analysis - Obtain the times-to-failure and times-to-repair distributions of each subsystem



QCP

Weibull++ Standard Folio: Bulb A - Supplier Data\Data1

Upper Bound (0.95) 0.000147

Failure Rate 0.000004/Hr

Lower Bound (0.05) 1.079049E-07

Fail. Rate Hr 2S-Both Captions On

Mission End Time (Hr): 100

Confidence Level: 0.90

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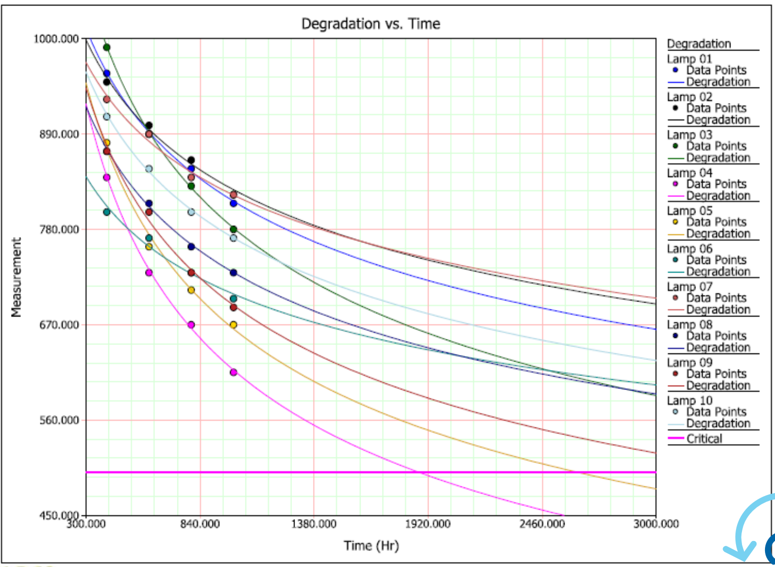

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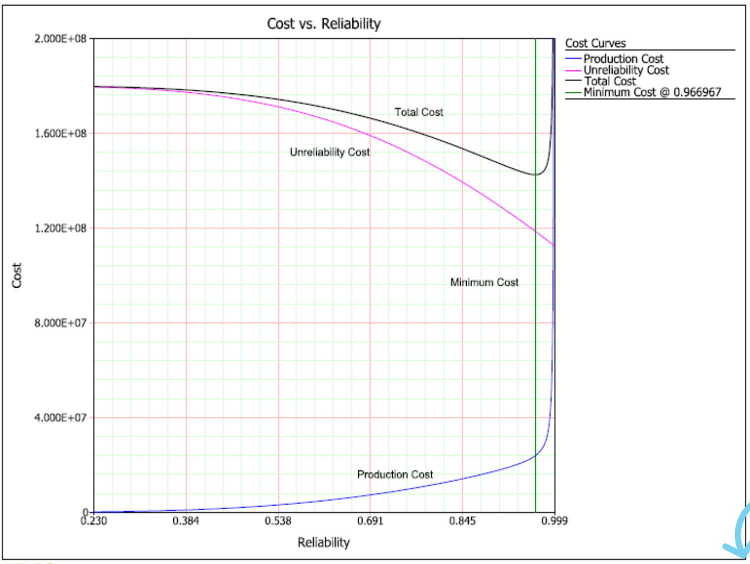

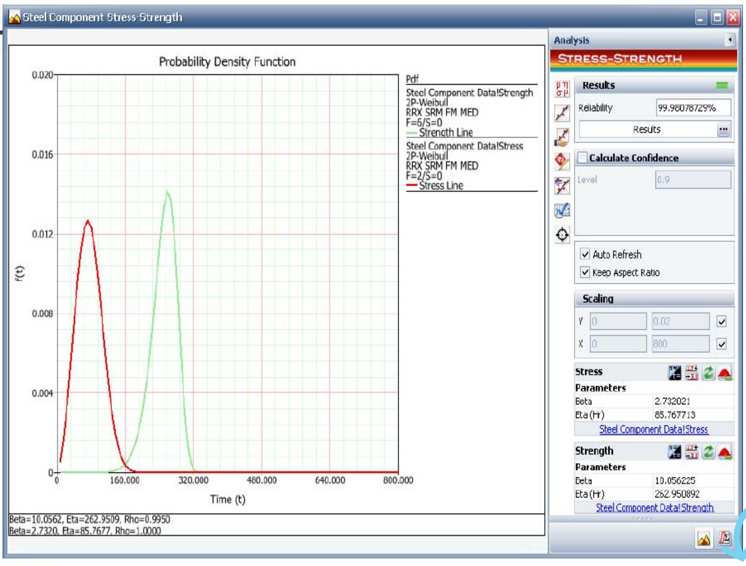

Pdf
Steel Component Data!Strength
2P-Weibull
RRX SRM FM MED
F=6/S=0
🟩 Strength Line
Steel Component Data!Stress
2P-Weibull
RRX SRM FM MED
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🟥 Stress Line

Beta=10.0562, Eta=262.9509, Rho=0.9950
Beta=2.7320, Eta=85.7677, Rho=1.0000

Results

Reliability: 99.98078729%

Results

☐ **Calculate Confidence**

Level: 0.9

☑ Auto Refresh
☑ Keep Aspect Ratio

Scaling

Y: 0 0.02 ☑
X: 0 800 ☑

Stress

Parameters

Beta	2.732021
Eta (Hr)	85.767713

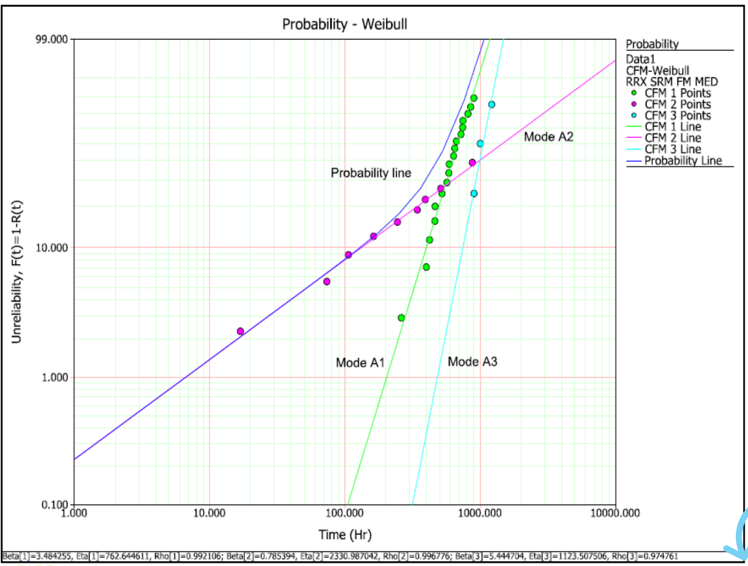
Steel Component Data!Stress

Strength

Parameters

Beta	10.056225
Eta (Hr)	262.950892

Steel Component Data!Strength



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Amnon Ganot, CRE

- RAMS Expert at ORBOTECH Ltd. & CTO at GERTRON Ltd. RAMS Consulting Services
- Amnon Ganot is the RAMS expert at Orbotech ltd. Amnon is working at Orbotech for the last 22 years. Prior to being the RAMS expert, Amnon was the RAMS & Standard Compliance manager of Orbotech.
- During his cadence as the RAMS & Standard Compliance manager, he concentrated on developing methodologies for RAMS such as ALT, FMEA (Quick & Extended), DFM, DFR, Design for Standard Compliance, HALT, etc. Prior to the former job, he was, for more than 25 years, a project manager and system engineer in multidisciplinary projects in the medical, communication and industrial field.
- In the last four years, Amnon is occupied as CTO of Gertron Ltd., performing RAMS consulting services.
- Amnon holds a B.Sc in Electrical Engineering from the Technion Israel Institute of Technology, Israel. Amnon received his MBA from the Tel-Aviv University, Israel. Amnon is an ASQ Certified Reliability Engineer (CRE) as well as ISQ Certified Reliability Engineer (CREI)
- Contact Inf.: Gertron Ltd., P.O.Box 164, Yavne, Israel 81101
  Phone: +972 54 4942373 Fax: +972 3 9410685
  E-Mail: amnon-g@inter.net.il

Questions?

Thanks for your attention