

Weibull NEWS™

The Latest in Life Data Analysis TechnologySM
From: Dr. Bob Abernethy and Wes Fulton

Edition 18-2004

Editor: Paul Barringer

2004 Weibull Users Conference

Developed and produced by Wes Fulton and Dr. Robert Abernethy

March 22-26, 2004 * Hilton Westchase Hotel, Houston, Texas

- ✓ Learn the latest techniques in failure prediction and reliability engineering
- ✓ Apply them to optimize equipment design, operation and service for maximum profitability.

Sign up now to take advantage of this exceptional learning opportunity:

Weibull Users Conference – March 25-26

The conference provides an opportunity for Weibull Analysis practitioners to interact with leading experts and their colleagues, share new techniques, and learn about latest advances and applications. Get up to speed with the latest in the field of Weibull Engineering. Presenters include:

- ❖ KEYNOTE ADDRESS by **Julius Wang**, Director, RMCtech, North America Sector
- ❖ **Dr. Bob Abernethy**, Consultant
- ❖ **Wes Fulton**, Fulton Findings
- ❖ **Paul Barringer**, Barringer & Associates, Inc.
- ❖ **Kevin Bauman** and **Clark Sterner**: Program Engineers, The Dow Chemical Company
- ❖ **Steve Beamer**: Program Engineer, ExxonMobil Corporation
- ❖ **Richard Unkle**: Program Engineer, General Electric Company
- ❖ **Joe Wauben**: Program Engineer, American Honda Motor Co.

The expert panel for this conference includes the presenters plus **Randy Phillips** of GE Power Systems. The panel will field questions from all participants. Questions can be submitted before the conference or asked during the Question/Answer portion of the program. Send questions ahead of time by e-mail to Clarion Technical Conferences below.

Weibull Failure Detection And Reliability Growth Add Value To Six-Sigma

The organizers will present state-of-the-art in Weibull Engineering technology for continuous improvement in their enterprise. This conference will also explore new directions for Weibull Engineering methods and tool development. Make your voice heard and make an impact on the new wave of quality and reliability practices.

PLUS ... Attendees will get an hour or more of hands-on use with the latest Weibull software in problem solving groups. A challenge problem, which requires ingenuity for solution, will be given out. The expert panel will award the coveted GOSSET MEDAL to the team of participants judged to have the best approach to solution.

Weibull/Lognormal Analysis 3-day Workshop In Houston – March 22-24

Dr. Bob will conduct the standard 3-Day Weibull/Lognormal Analysis Workshop preceding the Users Conference for those new to Weibull analysis. **Ronald Schop**, a reliability expert from the Netherlands, will assist Dr. Bob with contributions of applications from his European experience. All attendees will receive the SuperSMITH software, the New Weibull Handbook, and the PlayTIME computer tutorial. Students are invited to bring in real problems and data from their organization to be analyzed in the workshop with Dr. Bob and Ronald Schop's expertise. After two afternoons of "hands-on" experience with the software, the students will graduate as experts in life data analysis.

Register online for the Users Conference or the Workshop at WWW.CLARION.ORG or call (713) 521-5929 for the 3-day Weibull seminar and Weibull Users Group organized by Clarion Technical Conferences, 3401 Louisiana St., Suite 255, Houston, TX 77002. Tel. (713) 521-5929, Fax (713) 521-9255, e-mail: info@clarion.org

Improvements in WinSMITH Weibull (WSW)/WinSMITH Visual (WSV) Software for SuperSMITH™:

In preparation for the 2004 Weibull Users Conference, important changes made to the SuperSMITH software were compiled. Our goal for the Users Conference is to present the current state of Weibull software capability and to search for ideas on future improvement opportunities.

Significant **WinSMITH Weibull (WSW) revisions** include:

- ❖ **YBath™ advanced mixture analysis** software (created by Carl Tarum) is now included in the standard SuperSMITH Package. Mixture equations are used for precise data values and for precise plot readings when mixture analysis is active.
- ❖ **Outlier test accuracy** was improved with Monte Carlo simulation and a clearer presentation of outlier test results.
- ❖ **Likelihood ratio (lr) confidence and lr contours are available now for probit data.** This allows special techniques such as Barringer Process Reliability to test whether two data sets are significantly different.
- ❖ **Data can now be automatically converted to probit format.** This means that point-by-point data can be locked into graphical position. Barringer Process Reliability techniques can be applied to subsets of the original data.
- ❖ **MTTF with renewal** (and its inverse function) has been added to the calculator option.
- ❖ **P-value estimate (PVE%) model** developed by Wes Fulton is now the preferred measure for probability plotting goodness of fit. This model is based on Monte Carlo simulation of correlation coefficients. It has good accuracy and is fast.
- ❖ **Accelerated test, probabilistic S/N curve, and step-stress analysis** have been improved for clarity, accuracy, and ease-of-use.
- ❖ **The failure forecast (Abernethy Risk)** can model the effectiveness of a corrective action with percent affected for replacements. Plus, suspension quantity for analysis can be adjusted for batch analysis (Wauben modified). Also, delay capability was added when using new parameters for replacement parts to account for deployment lag.
- ❖ **Weibull library icon** was added for starting and maintaining a Weibull library. This feature makes the library input simple and automatic. A Weibull library is a must for continuous improvement.
- ❖ **Variable time range for risk analysis** allows from less than 60 months to several multiples of 60 months.
- ❖ **Delay capability was added for risk analysis** using new parameters for replacement parts to account for deployment lag.
- ❖ **Automatic confidence selection** is possible for analyzing a single set. This selection process is as specified in The New Weibull Handbook section on confidence as best practice.
- ❖ **The fit line analysis can take a partial percent affected value** into account for assistance in batch analysis.

Significant **WinSMITH Visual (WSV) revisions** include:

- ❖ **Important IEC-61710 and IEC-1186 Power Model features** are now included with the Crow/AMSAA capability.
- ❖ **An occurrence/suspension histogram display** was added for the Additional Probability Plot portion of WSV.
- ❖ **The transform section capability of WSV has been expanded** to add a plot of set 1 vs. set 2 (X vs. Y or data vs. fit, etc.) and a plot of the difference between set 1 and set 2 (for viewing residuals).

Common **WSW and WSV revisions** for both software packages:

- ❖ **Line slope value displayed** when adding a line onto the plot using the Zoom icon selection.
- ❖ **Multi-line notes on plots** can be longer. The word wrap is automatic.
- ❖ **Icon map - software tour** - has been added to the HELP file.
- ❖ **File output format is now HTML** as the default. It is easier to send and receive files over the Internet.
- ❖ **Automatic merge capability in the data grid** will consolidate matching values to change the point quantity.

Dr. Bob says:

Crow-AMSAA (C-A) modeling with reliability growth plots, is now a very important part of life data analysis. Some organizations consider Crow-AMSAA to be more important than Weibull analysis!

The New **IEC 61710** standard for applying C-A to repairable systems has fanned the flames with:

- ❖ Confidence bounds for beta and MTBF,
- ❖ Goodness of fit with Cramer-Von Mises,
- ❖ Tests of significance for positive and negative growth, and
- ❖ Unbiased estimators.

C-A is now **best practice** for:

- ❖ Tracking R&D testing where the reliability is changing,
- ❖ Graphically demonstrating events of interest to management,
- ❖ Tracking fleets of repairable systems,
- ❖ Handling really dirty data,
- ❖ Warranty claims forecasting by calendar time, and
- ❖ Failure forecasts when you know you have a batch problem.

Crow-AMSAA plots

C-A methodology does not have the strict data requirements demanded for Weibull plots. For example, Weibull plots require:

1. Weibull age-to-failure data requires knowing the age from time = 0 where time commences, up to the age at failure, for a human example, this means knowing the date of birth and the date of death to get the age-to-failure, and
2. Weibull plots require only a single failure mode for each Weibull plot (excluding mixture analysis techniques).

Weibull analysis provides a simple statistic for components which infers the mode of failure ($\beta < 1$ for infant mortality, $\beta > 1$ for wear out, and $\beta \approx 1$ for random failures). Weibull analysis also gives a single value for describing the characteristic value at failure (η) for the skewed distributions. These statistics provide important clues for corrective actions or coping with expected failures because you will know **how** the failures occur and **when** the failures are expected. Strict data requirements for Weibull plots provide very smart Weibull results but they carry heavy demands for data recording.

Whereas C-A plots provide good information as:

1. C-A plots can tolerate an arbitrary starting point for accumulation of time as you are not forced to zero time,
2. Mixed failure modes are acceptable for analysis which will provide a statistic to tell if failures are increasing ($\beta > 1$), decreasing ($\beta < 1$), or neither increasing/decreasing ($\beta \approx 1$). Mixed failure modes push the C-A analysis, and
3. The visually simple method of extrapolation provides visual evidence of forecasts for future failures.

Two plots are used with C-A analysis. The basic is simply cumulative failures on the vertical Y-axis and cumulative time on the horizontal X-axis. This plot always climbs from the lower left hand corner of the plot towards the upper right hand corner as both time and failures accumulate. Remember our task as reliability engineers is to put a flattening cusp on the trend line so that failures come more slowly. The second plot is derived from the first transforming the Y-axis into cumulative MTBF by dividing the cumulative failures into the cumulative time. The MTBF plot goes up with improvements, or it goes down with increasing failure rates.

Data can be entered directly into WSV or can be easily imported from Excel worksheets with a simple copy/past command. The data details are about time and failure events. Consider the raw failure data shown to the left.

Raw Data			Paste Into WSV	
Event	Failure Date	Failures Recorded	Cum Days	Cum Failures
1	17-Apr-01	Start	-	-
2	17-May-01	1	30	1
3	30-May-01	1	43	2
4	30-Jun-01	1	74	3
5	31-Jul-01	1	105	4
6	1-Sep-01	2	137	6
7	4-Nov-01	1	201	7
8	25-Dec-01	1	252	8
9	1-Mar-02	1	318	9
10	7-May-02	2	385	11
11	1-Sep-02	1	502	12
12	28-Nov-02	1	590	13
13	12-Jul-03	1	816	14

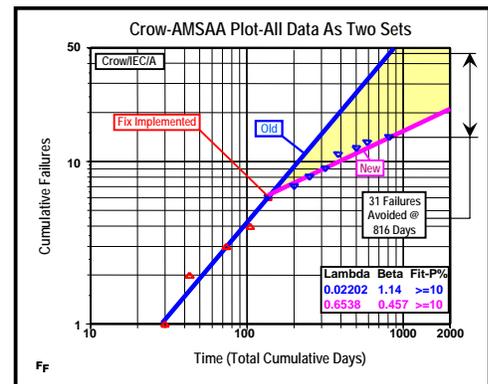
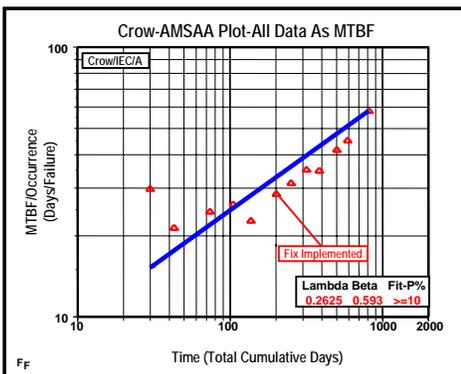
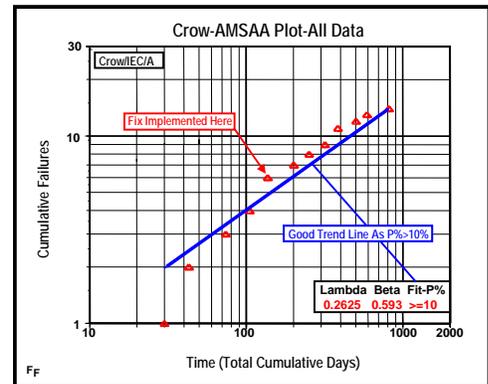
Sept. 1, 2001 is a red letter date representing the initiation of a fix to permanently avoid a failure mode by using improved maintenance methods.

Did we get an improvement? How many failures have we avoided?

The C-A plot to the right shows improvements ($\beta < 1$) with a good curve fit. Do we have an improvement cusp at failure 6? The cusp is more visible on the MTBF plot to the left.

Use good engineering judgment. Split the data set into old data and new data as shown in the plot to the right for two sets.

Extrapolate the old and new lines. Find the vertical gap between new and old at 816 days. Show 31 failures avoided with the new procedure. Crow-AMSAA plots



provide strong, graphical, evidence for management that the new maintenance methods are demonstrating improvements.

When will the next failure occur? WSV forecasts the next failure on the new trend line as 133 days into the future at 949 cum days. WSV's report option shows with 90% confidence, the new $\beta = 0.457$ lies between 0.188 and 0.726

Crow-AMSAA methods are simple tools with strong results using failure data from your maintenance records.

Searching For Historical Weibull Documents

Professor Isamu Yoshimoto from Tokyo has produced the oldest (1939) Weibull technical document in English for Dr. Abernethy's library. You can download the 45 page document as a PDF file from <http://www.barringer1.com/wa.htm> concerning "A Statistical Theory Of The Strength Of Materials". We're continuing to search for other documents which are listed at the bottom of the wa.htm page—so if you have copies of the "missing" documents, send Dr. Bob a copy for use in producing a PDF file for posting.

The 1939 document has some interesting points:

1. Dr. Weibull shows how ultimate strength and standard deviation increase as the metal volume of the test sample decreases for a pure tensile stress, i.e., a single value for ultimate strength does not exist.
2. He treats multiple stress directions, bending stresses, torsional stresses, contact stress, etc as probabilistic stresses with constants for characteristics of the material.
3. The Weibull plot of experimental data appears with notations about concavity of plotted data and how to make corrections to achieve a straight line on probability paper (the 3-parameter t_0 correction was known at an early date!, Weibull discusses how to correct for t_0 so the line neither curves up or down as it is very sensitive to the correction, and the number of data points must be "passably large").
4. Plotting positions for experimental data is selected as the arithmetical mean value, $\frac{i}{N+1}$, for calculation convenience instead of the median value and where small or moderately large samples ($N \leq 150$) each data point is used. [Later, Weibull switched to the more accurate median ranks for plotting position.]
5. Weibull's experimental data varied widely and included: bending strength of porcelain rods, tensile strength of Portland cement, cotton fiber strength, cotton fiber length, breaking strength of cotton yarn and fabric strips, strength of Sitka spruce, ultimate strength of stearic acid and plaster-of-Paris. The plaster data had three s-shaped lines for tension, torsion, and bending. The curves lines were transformed into three straight lines by employing a mathematically simple form for a material function $n(\sigma) = \left(\frac{\sigma}{\sigma_o}\right)^m$ where σ_o and m is the least possible number.

Weibull's data also included tensile strength of aluminum die castings, tensile strength of malleable iron castings, tensile strength of drilled test specimens, spark voltage between spherical electrodes in oil, spark voltage between spherical electrodes in air, spark gap voltage in air, and fatigue tests on valve-spring wire with the X-axis transformed into $(\sigma_1 - \frac{1}{T})$ where σ_1 was alternating tension and T was the endurance of the specimen.

Why read old documents? Almost every time you learn something from reading the Master's papers. Everything old is new again!

Gosset is Number 1!

For 40 years Dr. Bob consider Ronald Fisher as the greatest statistician that ever lived. Now, after his research on small sample bias, he considers William Gosset as #1 with Ronald Fisher as #2.

William S Gosset, 1876-1937, was a chemist trained at Oxford who joined the Guinness brewery in 1899. He was the pioneer of small sample analysis inventing "Student's t," C4, and the "F" test. He was a brewmaster who never gave up making beer in spite of becoming a world class statistician. He pioneered small sample statistics and inspired both Karl Pearson and Ronald Fisher to develop small sample methods. Moreover, among these three peers Gosset was the nice friendly person, the other two being outspoken and arrogant. He was the communication link between these two arch enemies

Gosset developed methods to reduce the small sample MLE bias for the normal distribution, first by substituting (n-1) for (n) in the denominator of the estimate of the standard deviation and later by developing the C4 correction. This work is now applied to the log normal as the MLE-Reduced Bias Adjustment (RBA) and is most useful for life data analysis. Dr. Bob applied Gosset's medicine to the Weibull, producing the new MLE-RBA for Weibull. These methods are now available in the WinSMITH Weibull producing extraordinary accuracy compared to MLE for small samples. MLE is obsolete unless you have extremely large samples, 500 or more failures. The MLE-Reduced Bias Adjustment is available in WinSMITH Weibull software.

Ronald Fisher considered Gosset to be his best friend. Fisher wrote in Gosset's obituary:

"Student's" work has shown that a better course is open to us... He...rendered obsolete the restriction that the sample must be "sufficiently large"... One immense advantage which "Student" possessed was his concern with, and responsibility for, the practical interpretation of experimental data. If more mathematicians shared this advantage there can be no doubt that mathematical research would be more fruitfully directed than it often is."

2004 ORDER FORM

Weibull / Lognormal Workshop - Please contact either Dr. Bob Abernethy or Wes Fulton as listed below for participation.

NWH: The New Weibull Handbook[®], 4th Edition - The worldwide standard Weibull reference and the reference text for Weibull software. It describes the latest methodology for life data analysis, and includes many case studies. Figures and equations are large print for easy reading. This is the standard reference adopted by the U.S. military, the FAA, NASA, and hundreds of business organizations.

WSW: WinSMITH[™] Weibull Software, Version 4.0 - The leading Weibull (lognormal, Gumbel, ...) plotting and analysis software for Windows with advancements in warranty data conversion, design comparison, failure forecasting, Monte Carlo confidence bounds, Barringer process reliability, accelerated testing and step-stress analysis, probabilistic S/N curve, and other methods. Many are not available elsewhere.

WSV: WinSMITH[™] Visual Software, Version 4.0 - General scientific plotting for Windows with curve fitting, functions, transforms, and Crow/AMSAA (Duane) reliability growth modeling per IEC. It generates auxiliary plots from WSW data such as risk plots, optimal replacement plots, likelihood contours, ACH, hazard, PDF, and CDF plots. WSV is the logical partner to WSW. Can be operated from WSW.

YB: YBATH[™] Mixture Analysis Software, Version 1.25 – Multi-failure mode Weibull probability analysis software for mixtures of data.

PT: PlayTIME[™] with SuperSMITH Tutorial Booklet - Computer exercises and coaching notes with case study data examples.

SS: SuperSMITH[™] Package - All above plus special YBath (YB) mixture analysis software (SS includes NWH, WSW, WSV, YB, and PT) bundled and discounted. This complete package of Weibull self-study materials is included at no extra charge with all standard workshops.

Weibull Training Videotape – Three real actual case studies show how Weibull provides practical solutions. Available on VHS or CD.

New Methods for Life Data Analysis-A Management Overview Seven case studies show the latest methods and applications in a PowerPoint presentation emphasizing the benefits of this analysis, designed for group presentations to managers and engineers, plus how-to-do-the-case-studies, step-by-step, in a “Word” document. This material compliments the video above so the New Methods and Weibull Training film are packaged together on one CD. Updated January 2004.

Ordering Handbooks and Software: Orders may be E-mailed, faxed, or mailed to either Dr. Bob Abernethy, Wes Fulton or Paul Barringer. Payment for handbooks must be by check or money order—although Fulton and Barringer can handle credit cards. Purchase orders from overseas companies must be prepaid before shipment. Shipments are usually sent priority (or global priority) mail. Call us, E-mail, or FAX us for questions, quantity discounts and upgrade costs. DEMO software can be quickly downloaded from our website and unlocked to FULL capability by password. Prices are subject to change without notice.

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1-281-852-6810 (TEL), hpaul@barringer1.com

	List Price (\$US) Each	Quantity	Total
NWH - The New Weibull Handbook	98.00	X _____	= \$ _____
PT - PlayTIME Tutorial Booklet	48.00	X _____	= \$ _____
WSW - WinSMITH Weibull Software	580.00	X _____	= \$ _____
WSV - WinSMITH Visual Software	480.00	X _____	= \$ _____
YBath – Mixture Analysis Software	380.00	X _____	= \$ _____
SS - SuperSMITH Package (ALL OF THE ABOVE)	960.00	X _____	= \$ _____
Weibull Training Film, Pick one: _____ Videotape or _____ CD	50.00	X _____	= \$ _____
New Methods Overview With Weibull Training CD	98.00	X _____	= \$ _____
NOTE: Enter shipping and handling cost below and then add last column for grand total cost.			
Shipping and Handling (for most orders*)	20.00 (40.00 overseas)	X _____	= \$ _____
GRAND TOTAL COST			= \$ _____

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2004 On-Site Weibull/Log Normal Workshops

Three-Day Complete Workshop – Our standard seminar includes treatment of the Fourth edition of The New Weibull Handbook[®], and the latest upgrade of the SuperSMITH[™] software including two afternoons of hands-on computer tutorial (PlayTIME[™]) covering every type of problem and every option. The Workshop is designed to bring the novice to full expert capability. Topics include failure analysis, optimal parts replacement, cost analysis, failure prediction, warranty analysis, reliability system models, and substantiation test design. Crow-AMSAA modeling is stressed.



Four-Day Workshop - Follow Up Consulting or Model Simulation - The complete Workshop plus a fourth day for student presentations of their own real problem analysis completed in the workshop. This allows Dr. Bob and the class to serve as a consulting forum reviewing each problem. The students should be strongly urged to bring one or more of their own problems to the workshop. Students get consulting on their real problems and show how they are applying the new techniques learned. Managers are invited. Alternatively, the fourth day may be devoted to system simulation tools for building models of any level of complexity regarding reliability, maintainability, safety, spare parts, logistics analysis and warranty-guarantee costs including a half day hands-on with computer simulation models.

Half-Day Management Overview - Following a 3 or 4-day Weibull Workshop, a morning presentation to senior managers may be scheduled to provide an overview of this new technology including application to their problems.

Fees: For Weibull Workshops in the USA, Canada and Mexico:

Workshop Days→	3-Day Workshop	½-Day Overview	4-Day Workshop	1-Day Refresher
8 or Less students	\$7896	\$1330	\$9784	\$2800
Extra Students > 8	\$840	No charge	\$976	\$350

Examples:

Students	3-Day	3-Day/Student	4-Day	4-Day/Student
8	\$7896	\$987	\$9784	\$1223
10	\$9576	\$958	\$11736	\$1174
15	\$13776	\$918	\$16616	\$1108
20	\$17976	\$899	\$21496	\$1075
25	\$22176	\$887	\$26376	\$1055

The fees include the SuperSMITH Package: The New Weibull Handbook 4th Edition, PlayTIME with SuperSMITH computer tutorial, the WinSMITH Weibull and Visual software valued at \$960 for each student, plus a graduation certificate for each student as well as our travel expenses.

On-Site Workshop Advantages: Workshop features include introduction, video, lectures using case studies, Weibull experiments in low cycle fatigue, classwork, hands-on computer tutorial, student analysis of their own data & problems, many question & answer periods, oral quiz, graduation. We tailor the workshops to your specific needs. We can use your data and problems in the special computer tutorial. We can add, or delete, or emphasize specific topics. The students are invited to bring their own problems to the workshop. The cost per student is about half of the fee for our public workshops and there are no travel costs for the students. The New Weibull Handbook is provided well in advance to allow study before the workshop. The latest life data technology will be presented including failure and warranty forecasting, new methods for minimizing testing costs and time, comparing the new design with the old design, confidence intervals and trending fleets of in-service units for reliability, safety and maintainability. E-mail or call Dr. Bob for more detailed information. See www.barringer1.com, for information on workshops in life cycle cost and production process control.

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