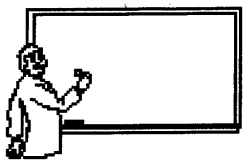

WeibullNEWS

Seventh Edition*

From:Dr. Bob Abernethy &
Wes Fulton

Fall 1993

The New Weibull Handbook™ is Finished! After four years, review by 13 Weibull experts, review by over 400 Workshop students, and four "final" drafts, the New Weibull Handbook is finally complete. Many of you have contributed comments, case studies, new methods. I am indebted to all that helped. Some of the new methods will be mentioned herein. Wes Fulton has done a yeoman's job programming almost all the new methods into "SuperSMITH™" which is short for WeibullSMITH™, VisualSMITH ™, MonteCarloSMITH™, and BiWeibullSMITH™. The New Handbook is the reference for SuperSMITH, the workbook for our Weibull Workshops, Rallys, and User's Conferences, and the text for Weibull analysts. Both beginning and advanced analysis is described with frequent references to the software capabilities. Many case studies from many industries are used to present the methodology. The first edition is special for the WeibullNEWS readers. Later editions will be made available from SAE and ASME with the SuperSMITH software.

Risk Forecast ± Renewal ± Production Units: Failure forecasts by month for five years with and with out replacement of failed units and with addition of new production units is presented in The New Handbook, calculated and tabled by WeibullSMITH™ and plotted with VisualSMITH™. The risk forecast may be failures per month or cumulative failures per month. (Figures 1 & 2.) If a component has several independent failure modes, the risk for each may be plotted and summed by VisualSMITH ™ to show the total predicted failures by month. (Figure 3.)

Optimal Component Replacement: If a part or component has a wear out failure mode and the cost of an unplanned failure is higher than the cost of a planned replacement, there is an optimal time or interval to replace the part. This interval provides the minimum cost per unit time for the component. Of course this requires that the age of the part be tracked. If this record keeping is impossible (non-serialized parts) or too expensive, **Block Component Intervals** may be employed. The cost per unit time for block intervals is higher than optimal age intervals but there is no record keeping. Both types of interval analysis are now available in WeibullSMITH™. VisualSMITH ™ provides plots of the cost per unit time versus the interval age. (Figure 4.) If a system has several components that require replacement, there will usually be an optimal interval for replacing all the components at one time. (Figure 5.)

Duane-AMSAA Modeling: This technology was original developed to track the growth of reliability in development testing. More recently it has been applied to trend analysis for fleets of systems in service. It also provides risk analysis with mixtures of failure modes, missing portions of data, and changing reliability levels. It is widely used. The two most common methods are regression analysis of plotted data and maximum likelihood estimation for interval or grouped data. VisualSMITH ™ provides both capabilities. (Figure 6.)

New Cost Effective Test Methods The original Handbook provided **zero-failure** test plans for substantiating new designs and redesigns with a minimum amount of testing. These were excellent plans for designs that significantly exceed the design requirement. However, for marginally better designs the probability of failing the test was very high. The New Weibull Handbook provides a better method for these marginally better designs:**zero or one-failure** test plans. These designs may require slightly more test time but significantly improve the chances of passing the test. There may even be a reduction in test time with zero-one plans;if the first N-1 units have no failures, the last unit does not have to be tested. Another new concept is **Sudden Death** test plans. This method is widely used in the automotive industry for components such as bearings, wheels, and belts. It is effective as conceived with Weibull, but with Weibayes it offers significant cost reductions and increased accuracy simultaneously. The New Handbook offers guidance for selecting the best of these test plans for your situation.

VisualSMITH ™ has new capabilities: Now provides plots of the CDF, PDF, the suspension ages with the PDF to show the proximity of the fleet to the Weibull, Duane-AMSAA regression and MLE solutions, Failure Forecasts by month with and without renewal, and the optimal age or block replacement intervals. (Figures 7 & 8.)

*Please reproduce the WeibullNews for those in your organization that are not on our mailing list.

Weibull Research Produces Some Surprises MonteCarloSMITH has "taught" us some lessons:

■Weibayes is much more accurate than Weibull for small samples of failures if we know ß. This adds considerable value to Weibull libraries and provides an incentive to use Weibayes with the 0-1 failure tests as well as Sudden Death. Weibayes may be thought of as a one parameter Weibull. The improved accuracy comes from eliminating the uncertainty in η.

■The three parameter Weibull (t_0) has gross precision errors and requires at least 15 to 20 failures. The log normal distribution will be a better choice for most curved data sets.

■Median rank regression is more accurate than maximum likelihood estimates for most of the engineering problems considered. The choice between the two depends on the shape and location of the suspension fleet and the objectives of the analysis. MonteCarloSMITH provides easy comparisons for real applications.

■All three confidence methods, beta-binomial, Fisher's matrix, and likelihood ratio are optimistic for sample sizes less than ten. MonteCarloSMITH is recommended for these cases, for data with random suspensions, for parameters such as t_0, r, and Weibayes B lives.

Goodness of Fit 90% and 95% critical correlation coefficients (CCC) are provided in the New Handbook for the Weibull two and three parameter distributions, the normal and the log normal. If the observed correlation coefficient is greater than the 90% CCC, it indicates a "good" fit. If it is less than the 95% CCC value, we arbitrarily label that a "bad" fit. If it is between the 90 and 95% CCC, it is called a "marginal" fit. My experience with the Weibull three parameter, (t_0), is that the correlation coefficient is usually within 1% of the log normal. Given this small difference most analysts have preferred the t_0 Weibull. The CCC curves tell us we should have selected the log normal in these cases. The author and many others have erred in this choice. The 90% CCC values are displayed in the distributional analysis option and the report option with the observed values for comparison. With a few keystrokes the distributional analysis is done, much more accurately than was possible before.

1994 Public Weibull Workshops Dr. Bob: SAE Detroit Feb 28-Mar3, User Conference Mar 21-22, ASME Denver May 2-5, University of Tenn, Palm Beach, Nov; Wes: SAE June and September, Detroit?

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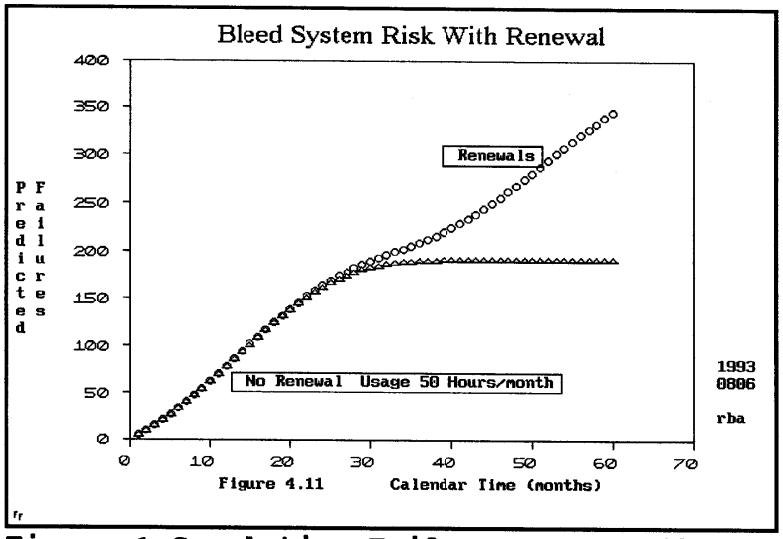


Figure 1 Cumulative Failures Per Month

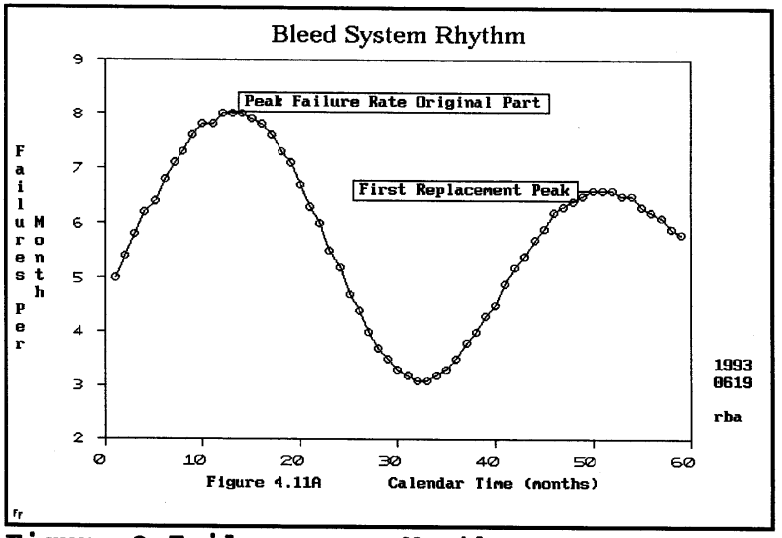


Figure 2 Failures per Month

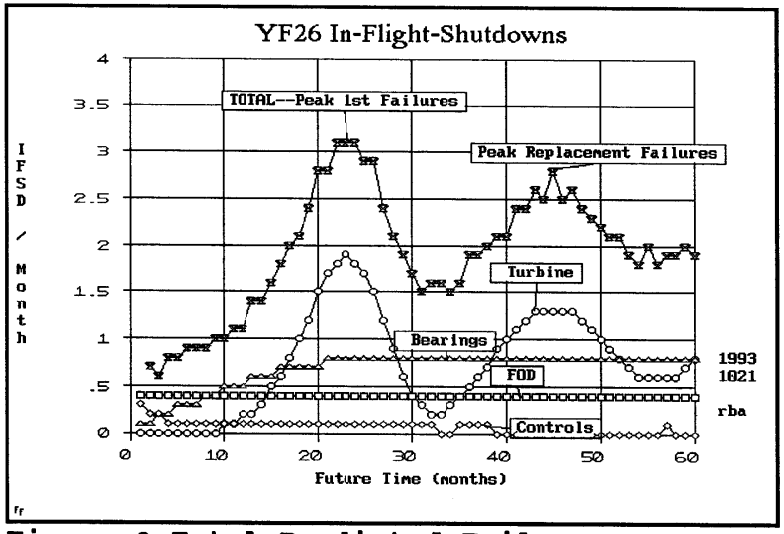


Figure 3 Total Predicted Failures

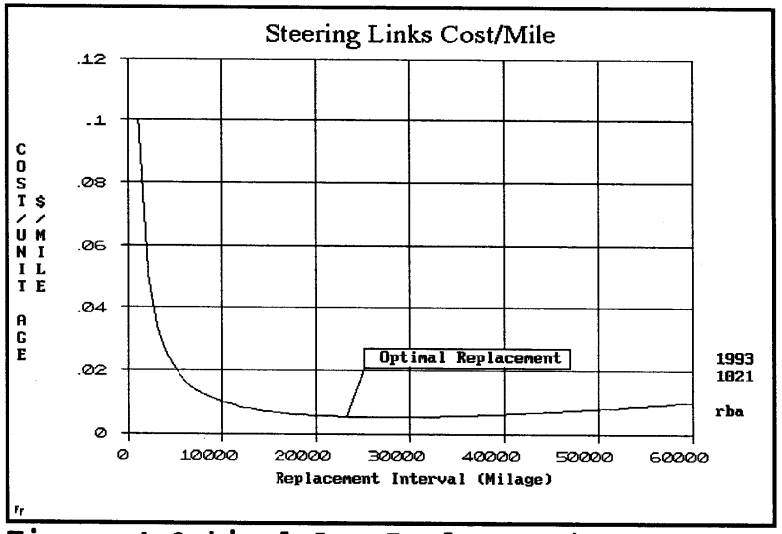


Figure 4 Optimal Age Replacement

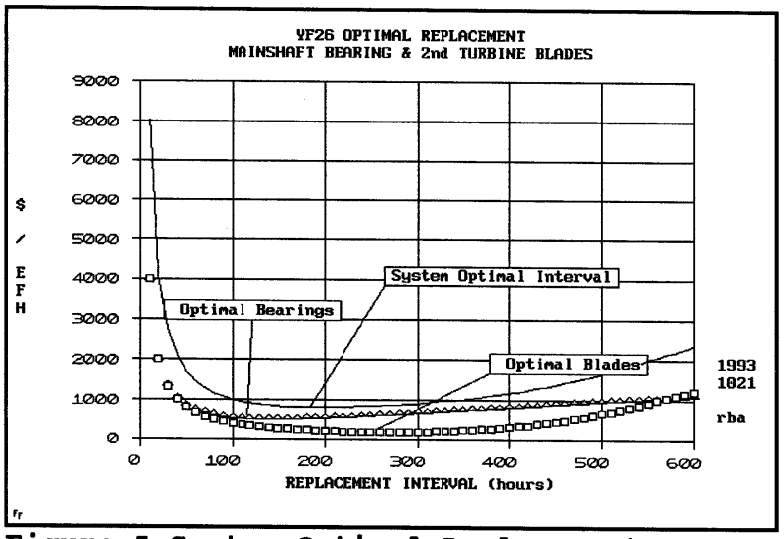


Figure 5 System Optimal Replacement

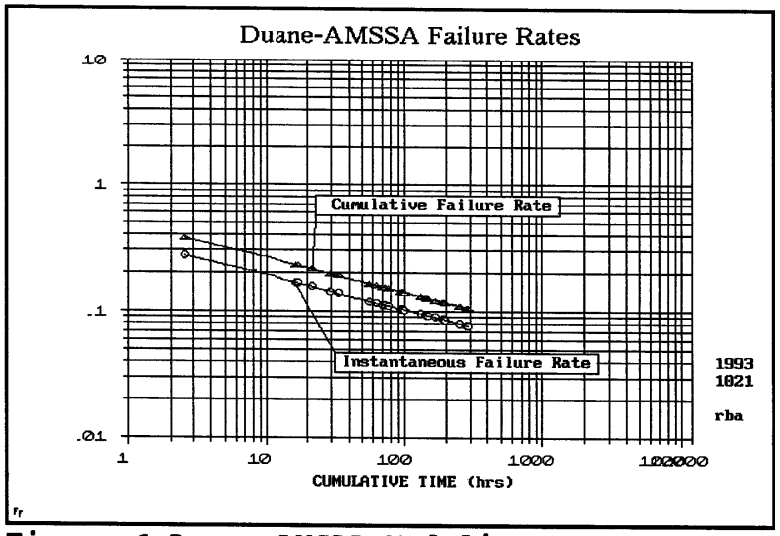


Figure 6 Duane-AMSAA Modeling

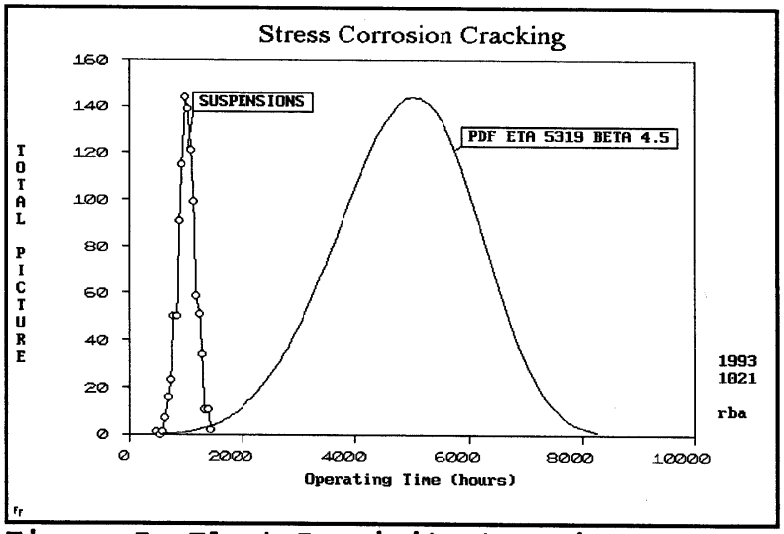


Figure 7 Fleet Proximity to Weibull

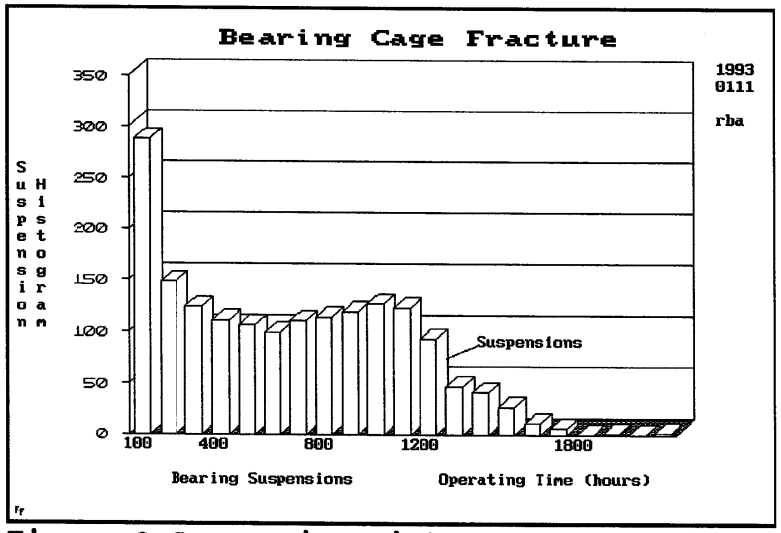
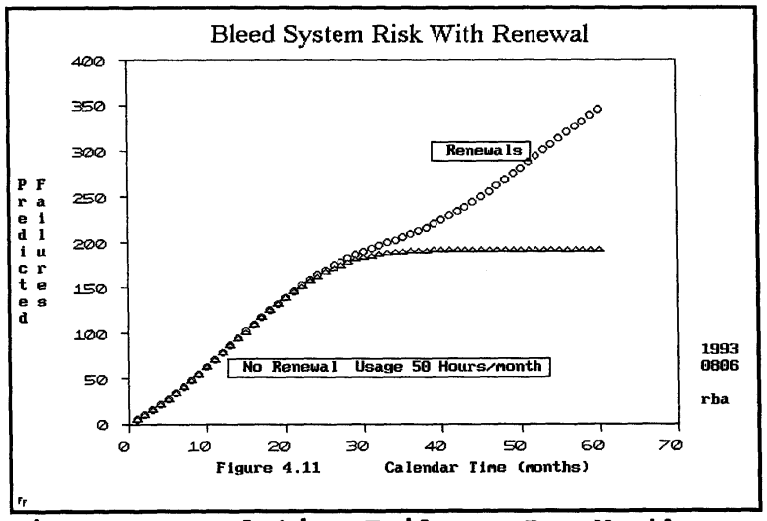


Figure 8 Suspension Histogram



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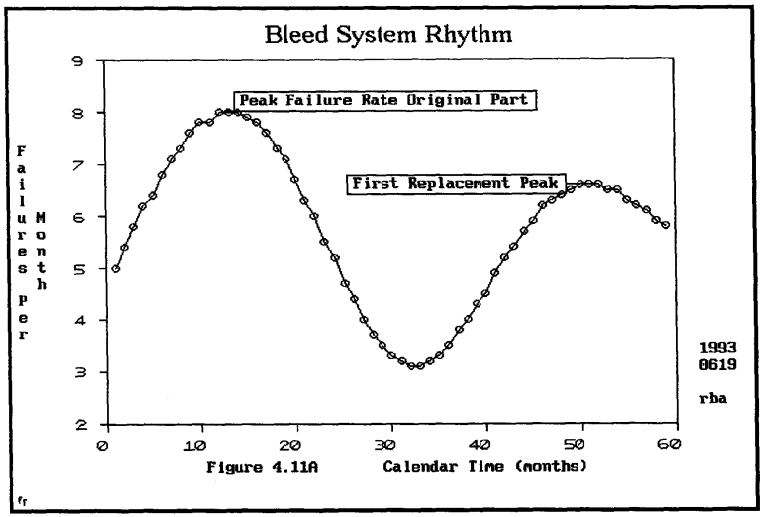

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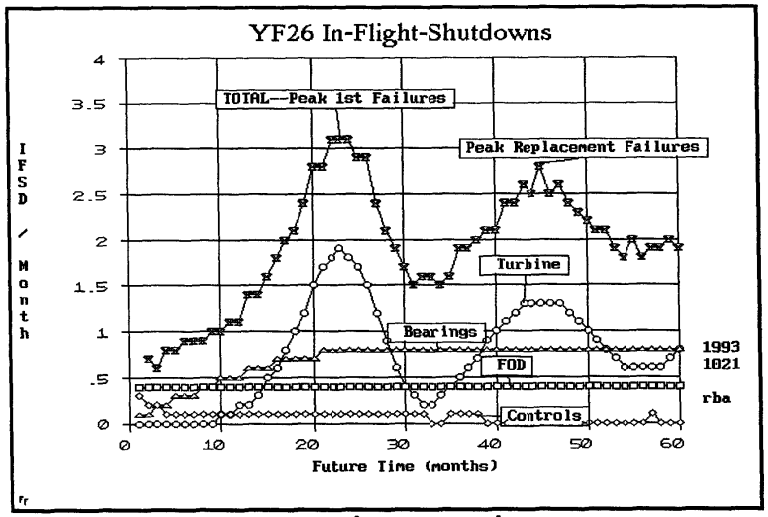

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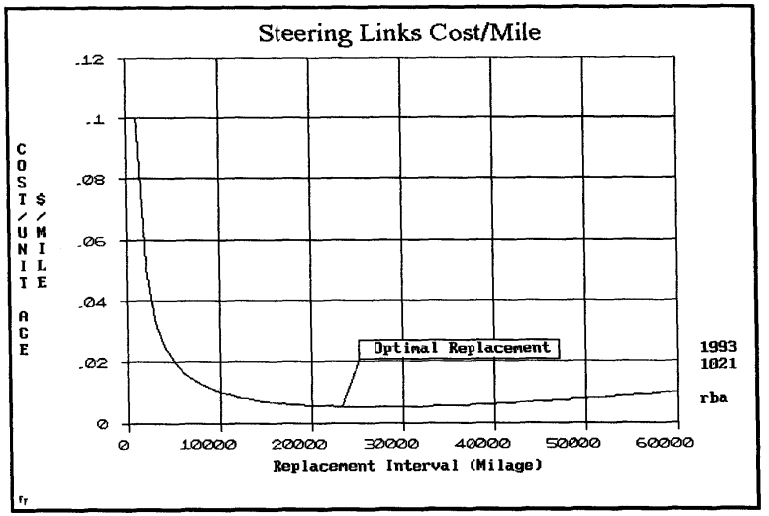

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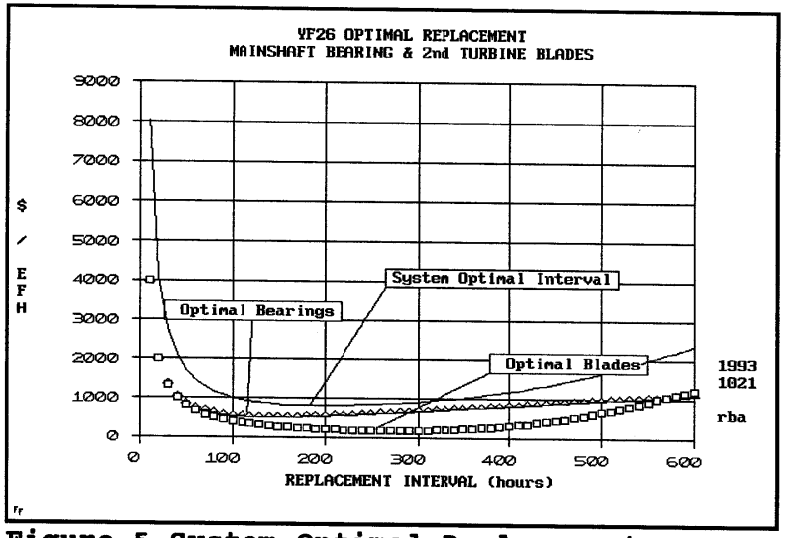

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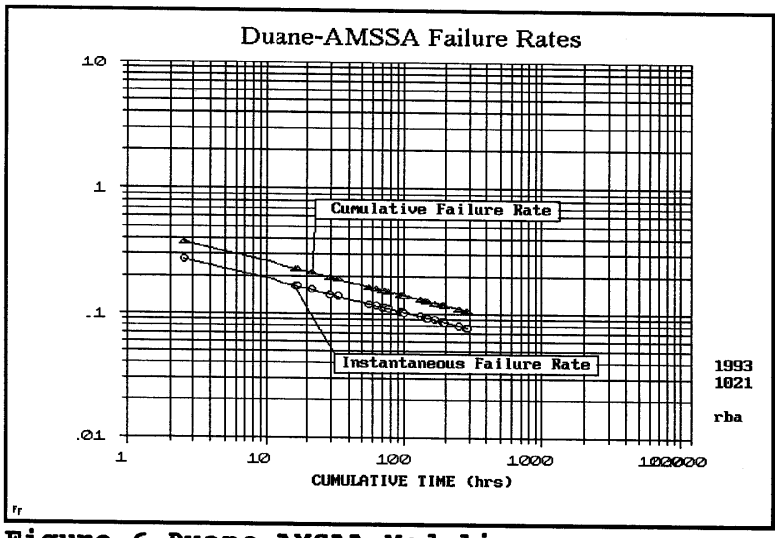

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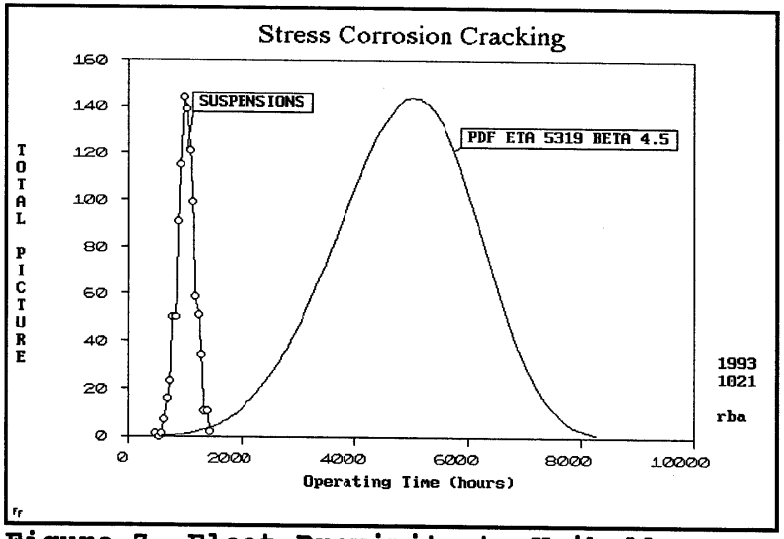

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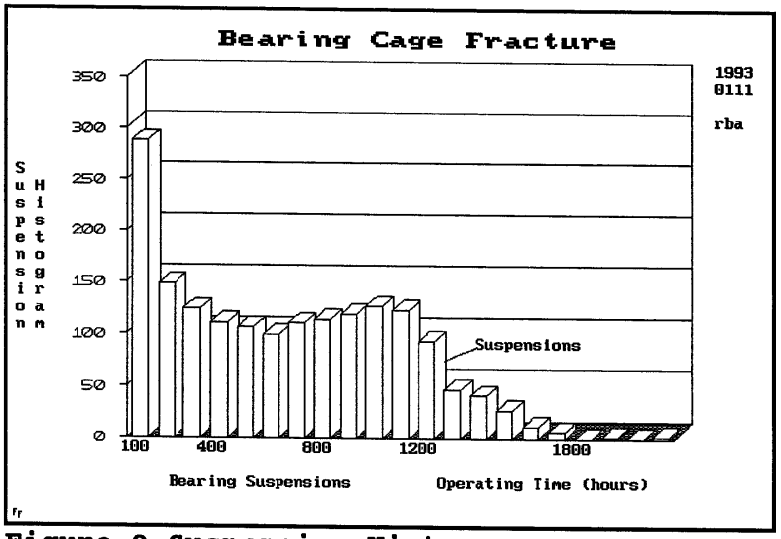

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