

2018 Fall Technical Conference, West Palm Beach, FL  
Plenary Talk on Receiving the Gerald J. Hahn Award of the  
Quality and Productivity Section of the American Statistical Assoc.

# COLLABORATION

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# INTRODUCTION

What to Offer to this Knowledgeable Audience ?

- New Methodology ?
- Applications ? Award Criteria.
- Useful Skills ?
- Collaborators – Colleagues and Clients ?

We are all collaborators.

My favorite collaborator Anne.

# TALK PURPOSES

Acknowledge valuable contributions of collaborators and clients.

Review statistical SKILLS and practices.

Offer entertaining applications.

# **OVERVIEW**

**GERRY HAHN – MEASUREMENT ERROR**

**BILL MEEKER -- ACCELERATED TESTING**

**JOE KUZAWINSKI -- HAZARD PLOTTING**

**NECIP DOGANAKSOY -- REPAIR DATA ANALYSIS**

**CONCLUDING REMARKS**



**GERRY HAHN –**

**ESTIMATE MEASUREMENT ERROR**

AWARD DISCLAIMER.

PRODUCTIVITY: 24 Years, *Intervals* book, Reliability book, Speed Typist, Tsunami Generator, Devil Says.

HUMOR.

COLLABORATION. Estimate a standard deviation with one measurement.

# COMPARE INSTRUMENTS X AND Y: $\mu_X - \mu_Y, \sigma_X / \sigma_Y$

<b>Crater Depth Measurements with Two Instruments</b>			
<b>Crater <math>i</math></b>	<b>Instrument X costly <math>X_i</math></b>	<b>Instrument Y cheap</b>	
		<b>1st <math>Y_i</math></b>	<b>2nd <math>Y_i'</math></b>
1	71	77	80
2	108	105	96
3	72	71	74
4	140	152	146
5	61	88	83
6	97	117	120
7	90	93	103
8	127	130	119
9	101	112	108
10	114	105	115

Estimate  $\sigma_X$  with one measurement ?!

## Our Solution:

Hahn, Gerald J. and Nelson, Wayne (1970), "A Problem in the **Statistical Comparison of Measuring Devices**," *Technometrics* **12**, (Feb. 1970) 126-149.

Jack Youden Prize of ASQ for best expository 1970 paper in *Technometrics*.

**SKILL:** Cultivate collaborators who do the hard, tedious work.

**SKILL:** Acknowledge clients who let us publish their data.

## **Further thoughts on this application :**

SKILL: Train clients to consult before running any experiment.

SKILL: Randomize everything. Was the order of depth measurements randomized?

SKILL: Plan the data analysis before the experiment.

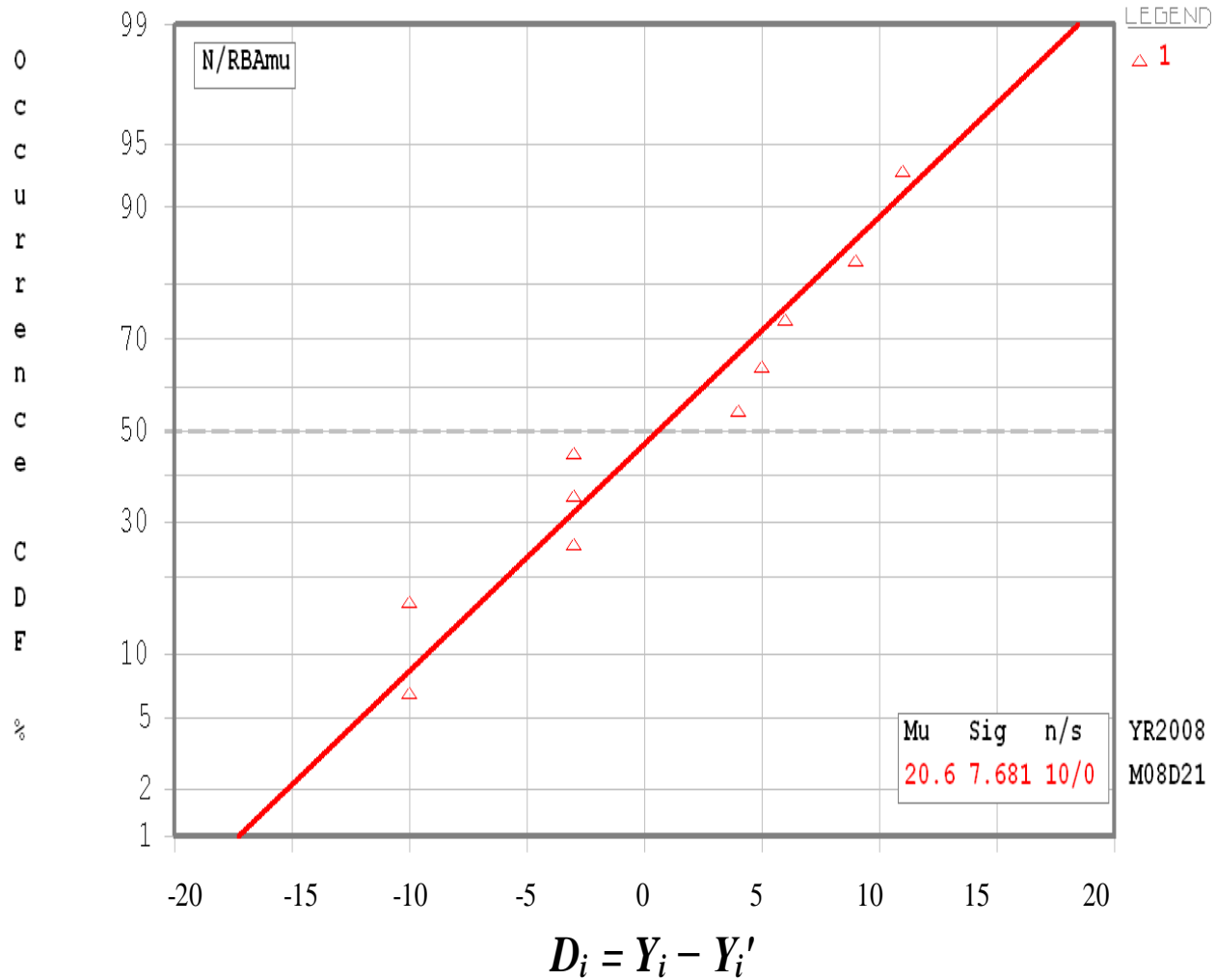
SKILL: With a new test, run a small preliminary test to learn your mistakes and can avoid them in the big experiment.

SKILL: Always plot the data many ways.

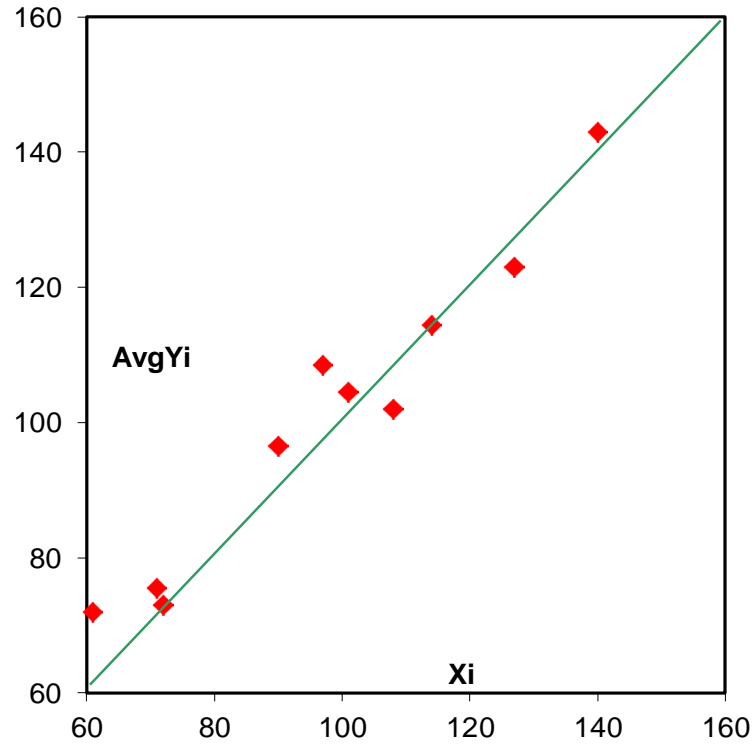
SKILL: Always develop additional analyses, e.g., plots of the crater measurements.



Check  $Y_i - Y_i'$  for normality and centered on zero:



**Crossplot  $X_i$  vs.  $(Y_i+Y_i')/2$  -- Correlated and No Outliers**



SKILL: Avoid publishing , you'll be asked to review.

Grubbs, Frank E. (1973), "Errors of Measurement, Precision, Accuracy and the Statistical Comparison of Measuring Instruments," *Technometrics* **15**, 53-66.

Bullet velocities at the Aberdeen Proving Ground.



**BILL MEEKER --**

**ACCELERATED TESTING**

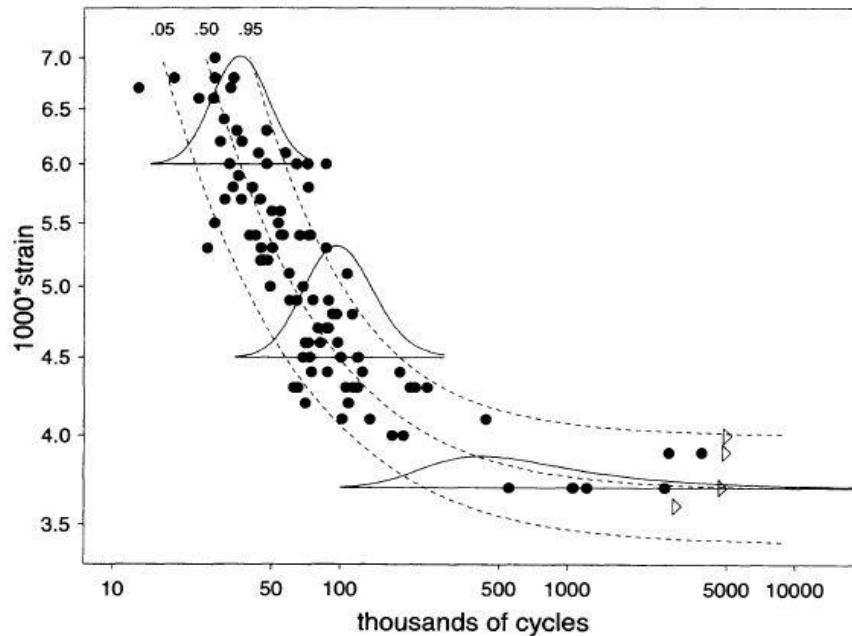
GRAD STUDENT At Union College. Summers at GE.

PRODUCTIVITY Prodigious output in diverse areas. Snee on Giants. His positive reviews of my books.

SKILL: Cultivate colleagues who generously promote your work.

COLLABORATION First Weibull accelerated life test plans. Bill did the hard part – programming the calculations. Today Nelson (2015) lists near 300 references. Yili Hong's new plans at FTC.

FATIGUE LIMIT Pascual, F.G. and Meeker, W.Q. (1999), "Estimating Fatigue Curves with the Random Fatigue-Limit Model," *Technometrics* **41**, 277-290.



This won Jack Youden and Frank Wilcoxon Prizes among *Technometrics* articles in 1999. In the article, Bill graciously acknowledged my suggestion.

SKILL: Always generously acknowledge all who contributed.

## **JOE KUZAWINSKI -- HAZARD PLOTTING**

Suggested **hazard plotting** to estimate a life distribution.

I published

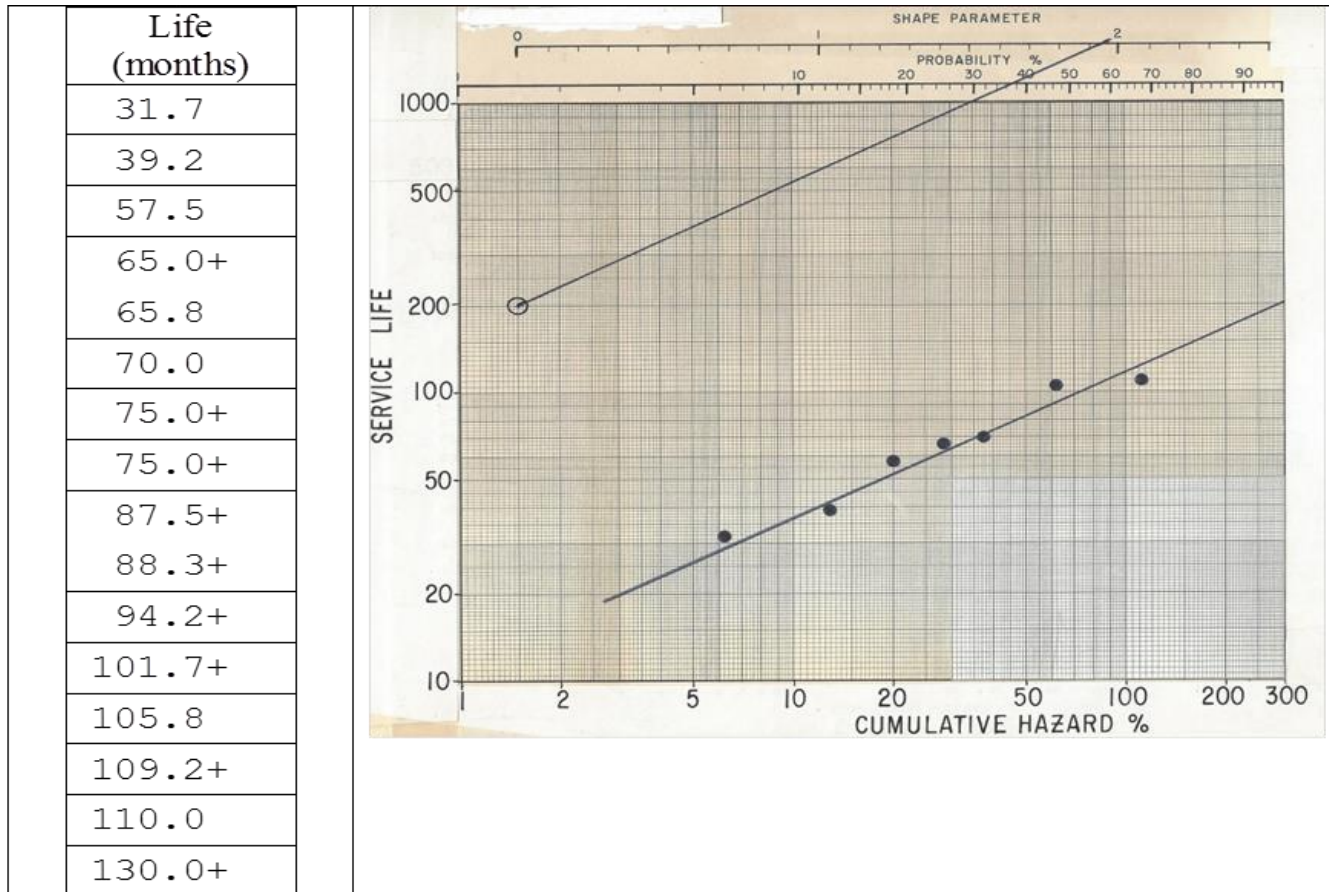
Nelson, Wayne, "Theory and Applications of Hazard Plotting for Censored Failure Data," *Technometrics* **14** (Nov.1972) 945-966.

Frank Wilcoxon Prize of ASQ for best practical application in *Technometrics* in 1972. Lawless (2000) calls it a “classic in reliability theory.”

The **Nelson-Aalen estimate** should be called the **Kuzawinski estimate** or Joe estimate.

I now prefer the Herd (1960) plotting positions and probability paper.

Weibull hazard plot of field winding life of large power generators. Is preventive replaced needed? Is  $\beta > 1$  ?





**NECIP DOGANAKSOY --**

**REPAIR AND RECURRENCE DATA ANALYSIS**

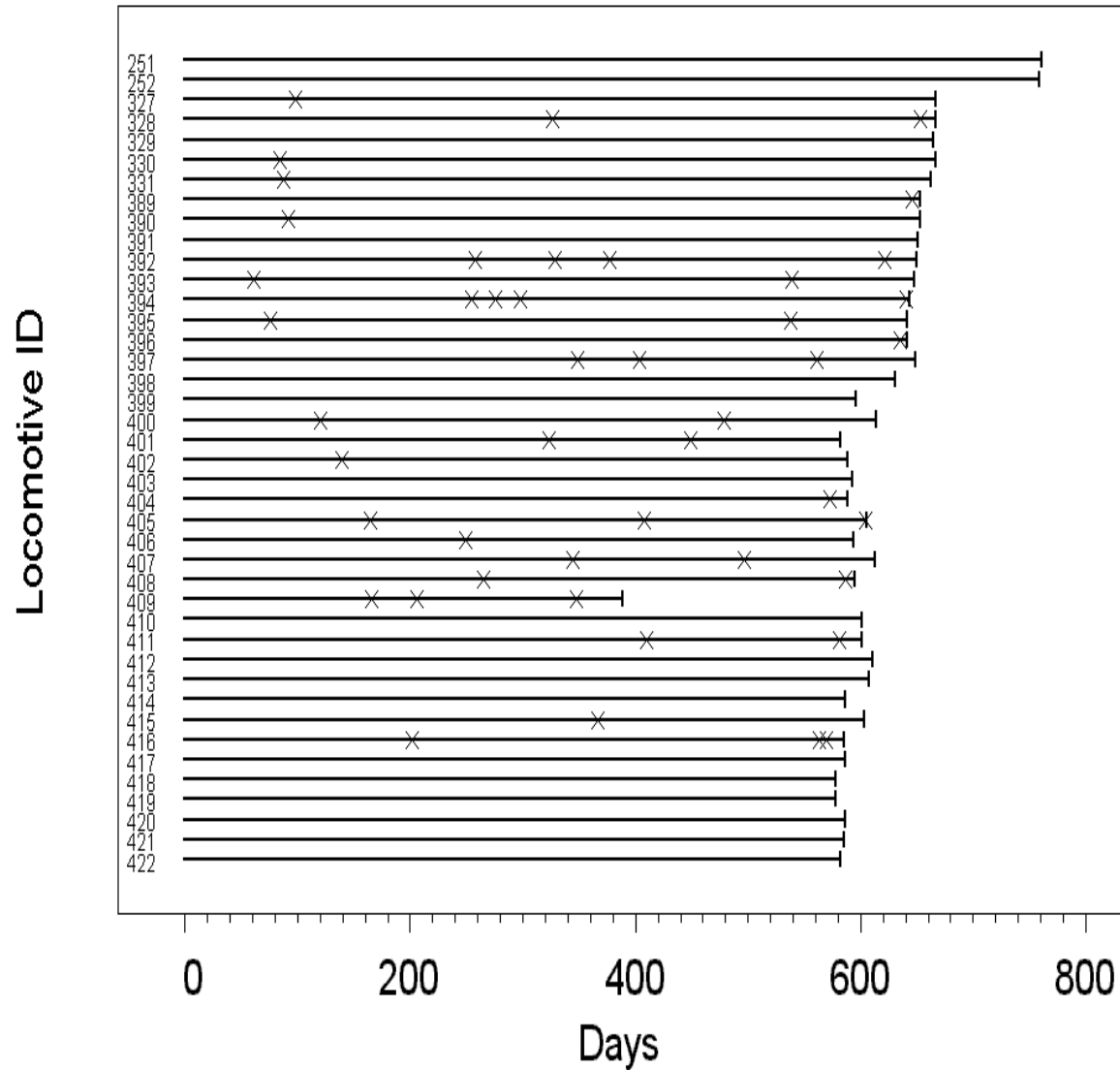
Grad student at Union College and talented colleague at GE.

Persisted in nominating me for the Hahn Award.

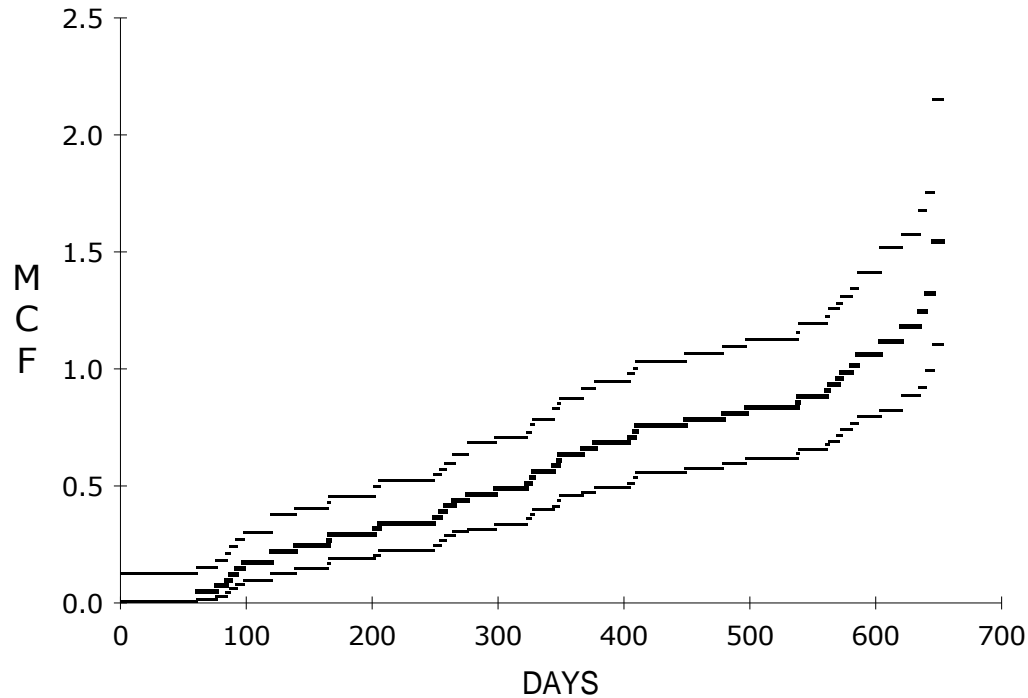
COLLABORATION. Funded by the GE Locomotive Dept., Necip programmed my confidence limits for the MCF for repair data, the hard tedious work. NIST work.



# Display of valve seat replacements on 41 locomotives.



## MCF for Number of Replacements with 95% Confidence Limits



Plots predict need for component replacements. The Locomotive Dept. used such plots before the automotive industry.

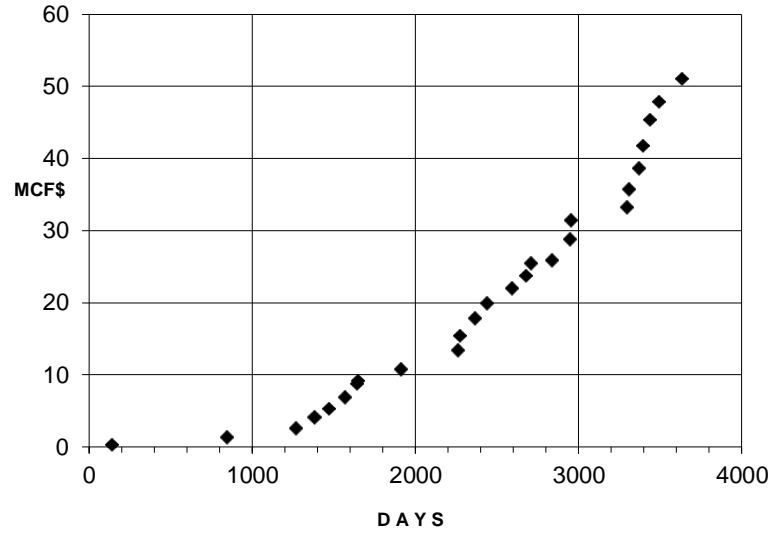
**SKILL:** Seek clients who fund advances in Statistics.

**SERVICE CONTRACT DATA:** Alabama Electric Power.

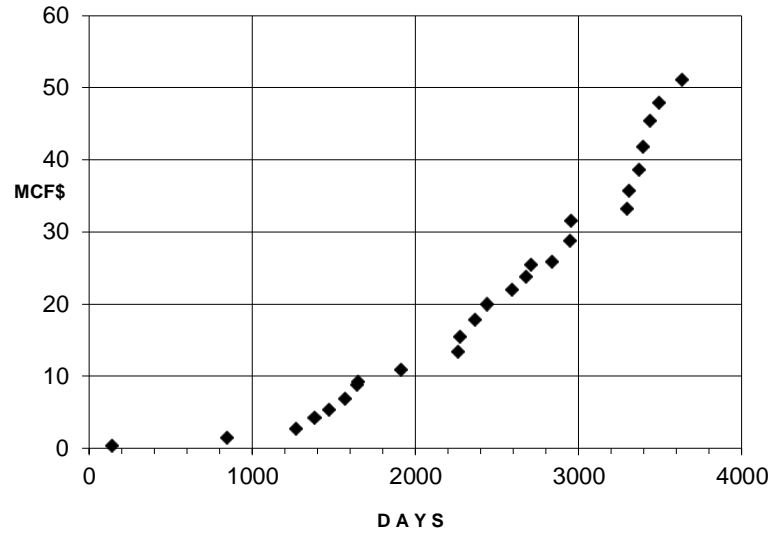
AEP wanted confidence limits for the MCF for costs.

**SKILL:** Cultivate clients who advance Statistics.

**MCF of *cost* of fan motor repairs.**



**MCF of *number* of fan motor repairs.**



## **CONCLUDING REMARKS**

We generously acknowledge our colleagues and clients for helping us.

We and our colleagues and clients will benefit more when we use SKILLS.

What else do you think is a key SKILL?

Many thanks for your collaboration.

## REFERENCES

Herd, O.R. (1960). "Estimation of Reliability from Incomplete Data," *Proceedings of the Sixth National Symposium on Reliability and Quality Control*, 202-217.

Lawless, J.F. (2000), "Two Classics in Reliability Theory," *Technometrics* **42**, 5-6.

Meeker, William Q ., Hahn, Gerald J., and Escobar, Luís A. (2017), *Statistical Intervals: A Guide for Practitioners and Researchers*, Second Edition, Wiley.

Nelson, Wayne (1995), "Confidence Limits for Recurrence Data -- Applied to Cost or Number of Product Repairs," *Technometrics* **37**, 147-157.

Nelson, Wayne B. (2003), *Recurrent Events Data Analysis for Product Repairs, Disease Recurrences, and Other Applications*, SIAM, Philadelphia, ASA/SIAM, [www.siam.org/books/sa10/](http://www.siam.org/books/sa10/)

Nelson, Wayne B. (2015), "An Updated Bibliography of Accelerated Test Plans," *Proceedings of the Reliability and Maintainability Symp.*, 177-182. Request a searchable Word file of an updated bibliography from WNconsult@aol.com.