LITERATURE REFERENCE JUSTIFICATIONS FOR TRANSFORMATIONS TO NORMALITY

Whenever a statistical method is chosen to analyze product data that has been generated by a verification or validation study, it is essential that that analysis be preceded by an evaluation of whether or not the distribution of the data violates the assumption of the statistical method. When that method's distribution assumption is normality, and when non-normality is suspected, a legitimate option is to transform the data into as close to normality as possible; subsequently, the originally chosen statistical method is used as if the transformed data were the original data, when compared to the similarly transformed study criteria. Here are several relevant quotes (all underlining below was added):

> "Most of the statistical methodology presented in this section [*"Basic Statistical Methods"*] assumes that the quality characteristic follows a known probability distribution. The analysis and conclusions that result are, of course, valid only to the extent that the distribution assumption is correct....Sometimes a set of data does not fit one of the standard distributions such as the normal distribution. One approach uses 'distribution-free' statistical methods...Some other approaches to analysis are....Make a transformation of the original characteristic to a new characteristic that is normally distributed."
> [J. M. Juran & F. M. Gryna's *Juran's Quality Control Handbook*, edition IV, 1988 by McGraw-Hill, Inc.; pages 23.91-23.92, in the section entitled "Transformations of Data"]

> "Essentially, all the standard techniques for statistical analysis and interpretation of measurement data...are based upon assumed normality of the underlying distribution involved....Real-life data do not always conform to the conditions required....When this is the case, a transformation (change of scale) applied to the raw data may put the data in such form that the appropriate conventional analysis can be performed validly."
> [M. G. Natrella, *Experimental Statistics*, 1963 by the National Bureau of Standards as "Handbook 91"; Chapter 20 (entitled "The Use of Transformations"), page 20-1]

> "After the transformation is made and the mean and standard deviation have been computed, standard methods applicable to normally distributed variables can be used to determine reliability-confidence relationships. The reliability numbers are directly applied to the original data without modification."
> [B. L. Amstadter, *Reliability Mathematics*, 1971 by McGraw-Hill, Inc., page 90]

> "Many physical situations produce data that are normally distributed; others, data that follow some other known distribution; and still others, data that can be transformed to normal data....An easy way to decide whether one of these transformations is likely to produce normality is to make use of [*a normal probability plot*]."
> [E. L. Crow, et. al., *Statistics Manual*, 1960 by Dover Publications, Inc., in a section entitled "Transformations to Obtain Normality", pages 88-90]

> [*Regarding the method of Linear Regression that is used to create a "normal probability plot", the degree of linearity of which is positively correlated with the degree of normality of a data set...*] "From a graph of the observations, it will often be obvious that the regression curve cannot be a straight line. In many cases, however, it is possible by simple transformations of the

variables to represent the regression curve as a linear relationship between transformed variables.... If the points (x, y), when transformed to points (g(x),f(y)) are grouped about a straight line such that f(y) is normally distributed...then the theory of linear regression may be applied to the transformed observations."
[A. Hald, *Statistical Theory with Engineering Applications*, 1952 by John Wiley & Sons, Inc, page 558]

"Non-normality is a way of life, since no characteristic (height, weight, etc.) will have exactly a normal distribution. One strategy to make non-normal data resemble normal data is by using a transformation....[*one such transformation is called "Box-Cox", which involves determining the best power coefficient, "λ"*].... "The criterion used to choose λ for the Box-Cox linearity plot is the value of λ that maximizes the correlation between the transformed x-values and the y-values when making a normal probability plot of the (transformed) data."
[US National Institute of Standards and Technology, NIST, *Engineering Statistics Handbook* website found (October 31, 2012) at
www.itl.nist.gov/div898/handbook/pmc/section5/pmc52.htm
in section 6.5.2, entitled "What to do when data are non-normal?"]