Dosimeter Batch Calibration "Curve Fit" Analysis

GEX Doc #100-215

SCOPE

GEX regression analysis (curve fitting) of calibration data sets for customers using the Terastat "Calibrate!" software program.

PURPOSE

This document provides an explanation of the process of how GEX analyzes customer calibration data and the explains the statistical tests that are performed on the curve fitting data. This document should help customers to develop some acceptance criteria for their internal procedures and serves as a reference for future questions that may arise.

METHOD

Data Set Preparation and Review:
GEX staff reviews customer provided dosimeter measurement data and the calibration laboratory certificate for general completion upon receipt from the customers. The completed data sets are evaluated by determining a mean, standard deviation, and coefficient of variation to verify that data sets satisfy specified precision requirements, and for the identification of any potential outlier data prior to undertaking the curve fitting process. In addition, the data sets are plotted and evaluated to verify that the response plot is appropriate based on the expectations for a particular dosimeter and dosimetry system.

Curve Fitting:
GEX utilizes the Terastat "Calibrate!" software program to perform regression analysis (curve fitting) of calibration data sets in order to derive mathematical response functions used to estimate dose from a measured response value. Response functions are generated for each set of measurement instruments and/or instrument data in combination.

The "Calibrate!" software used by GEX was developed by Terastat specifically for use in performing calibration of dosimetry systems and operates as an "add-in" to the Microsoft Excel spreadsheet software program. The software program performs curve-fitting and fit analysis of the calibration data sets by using built-in MS Excel functions.

The "Calibrate!" software performs regression analysis curve fitting of dosimeter response as a function of dose, performing up to five simultaneous curve fits of the data (dependent on the quantity of dose levels).

- Log-linear
- Linear (1^{st} order)
- Quadratic (2^{nd} Order)
- Cubic (3^{rd} Order)
- Quartic (4^{th} Order)

Individual equations derived for each curve fit along with statistical analysis of fit are provided for review and evaluation by the customer. Analysis of fit involves evaluation of the difference between values derived from the regression model against actual values.

This software compares the fit analysis results of all the generated response functions and determines a "best fit" response function based on internal software criteria. It should be noted, however, that the customer or GEX can select a different fit based on personal analysis.

Goodness of Fit Testing:
The "Calibrate!" software provides the following quantitative curve fit statistical analysis functions and displays the results for each of the generated curves:

- **r-Square:** value from the regression equation used to fit the data. It can be read as the fraction of variability in the response due to changes in the standard value. For almost all calibrations, r-square will be 0.990 or greater and is not a sensitive analysis statistic for determining the best fit.

- **Regression F Statistic:** the F value of the regression equation. A larger F statistic value indicates the model fits the data well.

- **Significance of Regression:** probability that the observed regression F statistic may have occurred by chance. For almost all calibrations, the p-value will be near zero.

- **Lack of Fit F Statistic:** the F-value of the lack of fit component of the residual variability. This statistic is used to evaluate whether a better fit to the data can be obtained by using a higher order polynomial. The lowest value typically indicates that a higher order fit is not better.

- **Lack of Fit Significance:** probability that the observed lack of fit F statistic may have occurred by chance. If this value is greater than 0.05 then the software decides that the lack of fit is not significant.

- **MSE:** Mean Square Error - the variability remaining after fitting the regression equation. The lowest value is typically best.

- **Estimated MDL at 95% confidence:** refers to "minimum descriptive length". The MDL principle is used in selecting a best model from a group of possible candidate models. The MDL algorithm takes personal preference out and uses specially determined weighting factors so the software can automatically select a so called "best fit" function curves generated by the software. For example, it weights the F Statistic far higher than the r-square. The algorithm applies a set of criteria developed specifically to evaluate the sensitivity of the various response functions in order to determine the curve with the "best fit". The lower the value, typically the better the fit.

Plot of Residuals Analysis:
The "Calibrate!" software also provides a plot of residuals that is used for qualitative analysis of the "best fit" regression model. The residuals plot is an invaluable tool used to verify the quality of fit of the

selected response function. Residual plots should demonstrate generally distributed results around zero without a detectable pattern, which is reviewed by trained GEX technical staff conducting the calibration for the customer. Residual plots also provide a means to verify absence of outlier data that should have been resolved prior to determination of the best curve fit.

Determining the Usable Dose Range of the "Best Fit" Response Function:
Once the "best fit" curve has been determined, the "Calibrate!" software is used by trained GEX staff to create a table of dose values covering the calibrated range derived from the calibration response function. The software estimates a dose for each designated response value, and also generates 95% lower and upper prediction limit values for each dose.

A percent uncertainty value with a 95% confidence level is calculated for each dose estimate value using these prediction limits *(upper prediction limit - lower prediction limit) / (2 * dose estimate * 100)*. The uncertainty limits can be used to select the minimum and maximum allowable dose limits of the calibration using a maximum allowable uncertainty value.

Determining the Uncertainty of the Calibration Curve:
Once the calibration curve dose range limits have been established, a median or average value for the usable portion of the calibration range can be calculated. This 'Type A' calibration uncertainty aggregate captures the measurement variability and uncertainty in the fitting. The overall calibration uncertainty is determined by adding the all additional components (Type A and/or Type B) in quadrature. Please refer to GEX Technical Memo 100-209 for discussion and ISO/ASTM 51707 for guidance, see References section below.

LIMITATIONS/PRECAUTIONS

Regarding curve fitting and "best-fit", it should be noted that the customer or GEX can select a different fit based on personal analysis. See 'Curve Fitting' section above for additional detail.

REFERENCES

References:

- *ISO/ASTM 51707: Standard Guide for Estimation of Measurement Uncertainty in Dosimetry for Radiation Processing*
- *GEX Technical Information and Usage Report (TIR) #100-209, Developing and Using Uncertainty Statements*

REVISION CONTROL HISTORY

DATE	CHANGE DESCRIPTION	REVISION
12/13/16	Initial release.	A

To learn more about GEX products and services, go to www.gexcorp.com or contact a GEX representative at +1 303 400-9640.