UCL Statistics for Data Sets with Non-Detects

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Full Precision OFF
Confidence Cc 95%
Number of Boc 2000

Chromium

General Statistics

Total Number of Observations	10	Number of Distinct Observations	10
		Number of Missing Observations	0
Minimum	1.02	Mean	4.057
Maximum	13	Median	2.785
SD	3.708	Std. Error of Mean	1.173
Coefficient of Variation	0.914	Skewness	1.811

Normal GOF Test

Shapiro Wilk Test Statistic	0.792	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.842	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.279	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.262	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	6.207	95% Adjusted-CLT UCL (Chen-1995)	6.704
		95% Modified-t UCL (Johnson-1978)	6.319

Gamma GOF Test

A-D Test Statistic	0.348	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.738	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.198	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.271	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	1.724	k star (bias corrected MLE)	1.273
Theta hat (MLE)	2.354	Theta star (bias corrected MLE)	3.186
nu hat (MLE)	34.47	nu star (bias corrected)	25.46
MLE Mean (bias corrected)	4.057	MLE Sd (bias corrected)	3.595
		Approximate Chi Square Value (0.05)	14.97
Adjusted Level of Significance	0.0267	Adjusted Chi Square Value	13.59

Assuming Gamma Distribution

95% Approximate Gamma UCL (us	6.902	95% Adjusted Gamma UCL (use when n<5(	7.604

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.958	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.842	Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.144	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.262	Data appear Lognormal at 5% Significance Level

Data appear Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	0.0198	Mean of logged Data	1.083
Maximum of Logged Data	2.565	SD of logged Data	0.823

Assuming Lognormal Distribution

95% H-UCL	8.819	90% Chebyshev (MVUE) UCL	7.199
95% Chebyshev (MVUE) UCL	8.659	97.5% Chebyshev (MVUE) UCL	10.69
99% Chebyshev (MVUE) UCL	14.67		

Nonparametric Distribution Free UCL Statistics
Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	5.986	95% Jackknife UCL	6.207
95% Standard Bootstrap UCL	5.929	95% Bootstrap-t UCL	8.081
95% Hall's Bootstrap UCL	13.59	95% Percentile Bootstrap UCL	6.029
95% BCA Bootstrap UCL	6.562		
90% Chebyshev(Mean, Sd) UCL	7.575	95% Chebyshev(Mean, Sd) UCL	9.169
97.5% Chebyshev(Mean, Sd) UCL	11.38	99% Chebyshev(Mean, Sd) UCL	15.72

Suggested UCL to Use

95% Adjusted Gamma UCL	7.604

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Uranium-234

General Statistics

Total Number of Observations	10	Number of Distinct Observations	10
		Number of Missing Observations	0
Minimum	0.523	Mean	1.141
Maximum	3.08	Median	0.871
SD	0.78	Std. Error of Mean	0.247
Coefficient of Variation	0.683	Skewness	1.987

Normal GOF Test

Shapiro Wilk Test Statistic	0.773	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk Critical Value	0.842	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.236	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.262	Data appear Normal at 5% Significance Level	

Data appear Approximate Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	1.593	95% Adjusted-CLT UCL (Chen-1995)	1.712
		95% Modified-t UCL (Johnson-1978)	1.619

Gamma GOF Test

A-D Test Statistic	0.481	**Anderson-Darling Gamma GOF Test**	
5% A-D Critical Value	0.731	Detected data appear Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.18	**Kolmogorov-Smirnov Gamma GOF Test**	
5% K-S Critical Value	0.268	Detected data appear Gamma Distributed at 5% Significance Level	

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	3.319	k star (bias corrected MLE)	2.39
Theta hat (MLE)	0.344	Theta star (bias corrected MLE)	0.478
nu hat (MLE)	66.38	nu star (bias corrected)	47.8
MLE Mean (bias corrected)	1.141	MLE Sd (bias corrected)	0.738
		Approximate Chi Square Value (0.05)	32.93
Adjusted Level of Significance	0.0267	Adjusted Chi Square Value	30.8

Assuming Gamma Distribution

95% Approximate Gamma UCL (us	1.656	95% Adjusted Gamma UCL (use when n<5(	1.771

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.924	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.842	Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.146	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.262	Data appear Lognormal at 5% Significance Level

Data appear Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-0.648	Mean of logged Data	-0.0261
Maximum of Logged Data	1.125	SD of logged Data	0.558

Assuming Lognormal Distribution

95% H-UCL	1.747	90% Chebyshev (MVUE) UCL	1.724
95% Chebyshev (MVUE) UCL	1.997	97.5% Chebyshev (MVUE) UCL	2.378
99% Chebyshev (MVUE) UCL	3.125		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	1.547	95% Jackknife UCL	1.593
95% Standard Bootstrap UCL	1.528	95% Bootstrap-t UCL	2.028
95% Hall's Bootstrap UCL	3.238	95% Percentile Bootstrap UCL	1.562
95% BCA Bootstrap UCL	1.717		
90% Chebyshev(Mean, Sd) UCL	1.881	95% Chebyshev(Mean, Sd) UCL	2.216
97.5% Chebyshev(Mean, Sd) UCL	2.682	99% Chebyshev(Mean, Sd) UCL	3.595

Suggested UCL to Use

95% Student's-t UCL	1.593

When a data set follows an approximate (e.g., normal) distribution passing one of the GOF test
When applicable, it is suggested to use a UCL based upon a distribution (e.g., gamma) passing both GOF tests in ProUCL

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Uranium-235/236

General Statistics

Total Number of Observations	10	Number of Distinct Observations	10
Number of Detects	5	Number of Non-Detects	5
Number of Distinct Detects	5	Number of Distinct Non-Detects	5
Minimum Detect	0.0606	Minimum Non-Detect	0.021
Maximum Detect	0.177	Maximum Non-Detect	0.0407
Variance Detects	0.00205	Percent Non-Detects	50%
Mean Detects	0.102	SD Detects	0.0452
Median Detects	0.096	CV Detects	0.445
Skewness Detects	1.516	Kurtosis Detects	2.668
Mean of Logged Detects	-2.356	SD of Logged Detects	0.406

Normal GOF Test on Detects Only

Shapiro Wilk Test Statistic	0.862	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.762	Detected Data appear Normal at 5% Significance Level
Lilliefors Test Statistic	0.306	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.343	Detected Data appear Normal at 5% Significance Level

Detected Data appear Normal at 5% Significance Level

Kaplan-Meier (KM) Statistics using Normal Critical Values and other Nonparametric UCLs

KM Mean	0.0613	KM Standard Error of Mean	0.0175
KM SD	0.0494	95% KM (BCA) UCL	0.0965
95% KM (t) UCL	0.0934	95% KM (Percentile Bootstrap) UCL	0.0902
95% KM (z) UCL	0.0901	95% KM Bootstrap t UCL	0.0833
90% KM Chebyshev UCL	0.114	95% KM Chebyshev UCL	0.138
97.5% KM Chebyshev UCL	0.17	99% KM Chebyshev UCL	0.235

Gamma GOF Tests on Detected Observations Only

A-D Test Statistic	0.331	**Anderson-Darling GOF Test**
5% A-D Critical Value	0.68	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.258	**Kolmogorov-Smirnov GOF**
5% K-S Critical Value	0.358	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics on Detected Data Only

k hat (MLE)	7.334	k star (bias corrected MLE)	3.067
Theta hat (MLE)	0.0139	Theta star (bias corrected MLE)	0.0331
nu hat (MLE)	73.34	nu star (bias corrected)	30.67
Mean (detects)	0.102		

Gamma ROS Statistics using Imputed Non-Detects

GROS may not be used when data set has > 50% NDs with many tied observations at multiple DLs
GROS may not be used when kstar of detects is small such as <1.0, especially when the sample size is small (e.g., <15-20)
For such situations, GROS method may yield incorrect values of UCLs and BTVs
This is especially true when the sample size is small.
For gamma distributed detected data, BTVs and UCLs may be computed using gamma distribution on KM estimates

Minimum	0.01	Mean	0.0558
Maximum	0.177	Median	0.0353
SD	0.0569	CV	1.02
k hat (MLE)	0.973	k star (bias corrected MLE)	0.748
Theta hat (MLE)	0.0574	Theta star (bias corrected MLE)	0.0746
nu hat (MLE)	19.47	nu star (bias corrected)	14.96
Adjusted Level of Significance (β)	0.0267		
Approximate Chi Square Value (14.96	7.233	Adjusted Chi Square Value (14.96, β)	6.322
95% Gamma Approximate UCL (use v	0.115	95% Gamma Adjusted UCL (use when n<50)	0.132

Estimates of Gamma Parameters using KM Estimates

Mean (KM)	0.0613	SD (KM)	0.0494
Variance (KM)	0.00244	SE of Mean (KM)	0.0175
k hat (KM)	1.539	k star (KM)	1.144
nu hat (KM)	30.77	nu star (KM)	22.87
theta hat (KM)	0.0399	theta star (KM)	0.0536
80% gamma percentile (KM)	0.0975	90% gamma percentile (KM)	0.137
95% gamma percentile (KM)	0.175	99% gamma percentile (KM)	0.264

Gamma Kaplan-Meier (KM) Statistics

Approximate Chi Square Value (22.87	13	Adjusted Chi Square Value (22.87, β)	11.72
95% Gamma Approximate KM-UCL	0.108	95% Gamma Adjusted KM-UCL (use when r	0.12

Lognormal GOF Test on Detected Observations Only

Shapiro Wilk Test Statistic	0.945	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.762	Detected Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.238	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.343	Detected Data appear Lognormal at 5% Significance Level

Detected Data appear Lognormal at 5% Significance Level

Lognormal ROS Statistics Using Imputed Non-Detects

Mean in Original Scale	0.0649	Mean in Log Scale	-2.964

SD in Original Scale	0.0491	SD in Log Scale	0.696
95% t UCL (assumes normality of R	0.0933	95% Percentile Bootstrap UCL	0.0916
95% BCA Bootstrap UCL	0.0964	95% Bootstrap t UCL	0.106
95% H-UCL (Log ROS)	0.118		

Statistics using KM estimates on Logged Data and Assuming Lognormal Distribution

KM Mean (logged)	-3.11	KM Geo Mean	0.0446
KM SD (logged)	0.796	95% Critical H Value (KM-Log)	2.703
KM Standard Error of Mean (logged)	0.281	95% H-UCL (KM -Log)	0.125
KM SD (logged)	0.796	95% Critical H Value (KM-Log)	2.703
KM Standard Error of Mean (logged)	0.281		

DL/2 Statistics

DL/2 Normal		**DL/2 Log-Transformed**	
Mean in Original Scale	0.0593	Mean in Log Scale	-3.23
SD in Original Scale	0.0539	SD in Log Scale	0.976
95% t UCL (Assumes normality)	0.0905	95% H-Stat UCL	0.172

DL/2 is not a recommended method, provided for comparisons and historical reasons

Nonparametric Distribution Free UCL Statistics
Detected Data appear Normal Distributed at 5% Significance Level

Suggested UCL to Use

95% KM (t) UCL	0.0934

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Uranium-238

General Statistics

Total Number of Observations	10	Number of Distinct Observations	10
		Number of Missing Observations	0
Minimum	0.558	Mean	1.188
Maximum	3.17	Median	0.835
SD	0.809	Std. Error of Mean	0.256
Coefficient of Variation	0.681	Skewness	1.883

Normal GOF Test

Shapiro Wilk Test Statistic	0.776	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.842	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.224	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.262	Data appear Normal at 5% Significance Level

Data appear Approximate Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	1.657	95% Adjusted-CLT UCL (Chen-1995)	1.771
		95% Modified-t UCL (Johnson-1978)	1.682

Gamma GOF Test

A-D Test Statistic	0.549	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.731	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.226	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.268	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	3.26	k star (bias corrected MLE)	2.349
Theta hat (MLE)	0.364	Theta star (bias corrected MLE)	0.506
nu hat (MLE)	65.2	nu star (bias corrected)	46.97
MLE Mean (bias corrected)	1.188	MLE Sd (bias corrected)	0.775
		Approximate Chi Square Value (0.05)	32.25
Adjusted Level of Significance	0.0267	Adjusted Chi Square Value	30.14

Assuming Gamma Distribution

95% Approximate Gamma UCL (use	1.73	95% Adjusted Gamma UCL (use when n<50	1.851

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.905	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk Critical Value	0.842	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.21	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.262	Data appear Lognormal at 5% Significance Level	

Data appear Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-0.583	Mean of logged Data	0.0109
Maximum of Logged Data	1.154	SD of logged Data	0.566

Assuming Lognormal Distribution

95% H-UCL	1.836	90% Chebyshev (MVUE) UCL	1.805
95% Chebyshev (MVUE) UCL	2.094	97.5% Chebyshev (MVUE) UCL	2.496
99% Chebyshev (MVUE) UCL	3.286		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	1.609	95% Jackknife UCL	1.657
95% Standard Bootstrap UCL	1.584	95% Bootstrap-t UCL	2.092
95% Hall's Bootstrap UCL	2.959	95% Percentile Bootstrap UCL	1.642
95% BCA Bootstrap UCL	1.752		
90% Chebyshev(Mean, Sd) UCL	1.955	95% Chebyshev(Mean, Sd) UCL	2.303
97.5% Chebyshev(Mean, Sd) UCL	2.786	99% Chebyshev(Mean, Sd) UCL	3.734

Suggested UCL to Use

95% Student's-t UCL	1.657

When a data set follows an approximate (e.g., normal) distribution passing one of the GOF test
When applicable, it is suggested to use a UCL based upon a distribution (e.g., gamma) passing both GOF tests in ProUCL

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
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