Statistical Procedures for Assessing Surveillance Data for 10 CFR 50.61a

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ABSTRACT

In this document a procedure for use in the voluntary alternative PTS rule (10CFR50.61a) is proposed by which the plant- and heat-specific surveillance data that are collected as part of 10 CFR Part 50 Appendix H surveillance programs can be analyzed to assess how well they are represented by a generic ΔT_{30} embrittlement trend curve (ETC). If the surveillance data are "close" (closeness is assessed statistically) to the generic ETC then the predictions of the ETC are used. However, if the plant- and heat-specific surveillance data deviate significantly from the predictions of the generic ETC this is taken as an indication that alternative methods (i.e. other than, or in addition to, the ETC) *may be* needed to reliably predict ΔT_{30} trends for the conditions being assessed. Alternative methods to ΔT_{30} prediction are not addressed in this document.

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1 Treatment of Surveillance Data in 10CFR50.61a

In this document a procedure for use in the voluntary alternative PTS rule (10CFR50.61a) is proposed by which the plant- and heat-specific surveillance data that are collected as part of 10 CFR Part 50 Appendix H surveillance programs can be analyzed to assess how well they are represented by a generic ΔT_{30} embrittlement trend curve (ETC). If the surveillance data are "close" (closeness is assessed statistically) to the generic ETC then the predictions of the ETC are used. However, if the plant- and heat-specific surveillance data deviate significantly from the predictions of the generic ETC this is taken as an indication that alternative methods (i.e. other than, or in addition to, the ETC) *may be* needed to reliably predict ΔT_{30} trends for the conditions being assessed. Alternative methods to ΔT_{30} prediction are not addressed in this document. While standard and accepted procedures exist to assess the *statistical* significance of differences between individual data sets and models, similarly standard and acceptable procedures are not available to assess the *practical* importance of such differences. It is the NRC's view that the practical importance of statistically significant deviations is best assessed on a case-by-case basis. While statistically significant differences between heat specific data sets and generic ΔT_{30} trends certainly signal a situation where more focused attention is warranted, the most appropriate address of such situations may not be a heat-specific adjustment to generic ΔT_{30} trends. For this reason, alternative methods for assessing ΔT_{30} trends are not discussed herein.

The remainder of this document is divided into five sections:

- In Section 1.1 the generic ETC is described. Details on the development of this ETC appear on another document [Eason 07].
- In Section 1.2 certain entry conditions are described that must be met to use the proposed surveillance assessment procedure.
- In Section 1.3 different types of deviations between plant- and heat-specific surveillance data and the trends represented by the generic ΔT_{30} ETC are described.
- In Section 1.4 statistical procedures are described that can detect the deviations described in Section 1.3.
- In Section 1.5 the statistical tests of Section 1.4 are applied to the currently available surveillance database.

1.1 Embrittlement Trend Curve

In [Eason 07] the following generic ΔT_{30} ETC was developed. As detailed in [Eason 07], the mathematical form of these equations are motivated physically. The numerical coefficients in these equations were determined by statistically fitting them to the ΔT_{30} information collected in 10CFR50 Appendix H surveillance programs that has been reported to the NRC through (approximately) 2002. This generic ΔT_{30} ETC is being proposed for use in 10CFR50.61a.

$$\Delta T_{30} = MFterm + CRPterm \tag{1}$$

$$MF\ term = A(1 - 0.001718T_i)(1 + 6.13PMn^{2.47})\sqrt{\phi t_e} \tag{2}$$

$$A = \begin{Bmatrix} 1.140\text{x}10^{-7} & \text{for forgings} \\ 1.561\text{x}10^{-7} & \text{for plates} \\ 1.417\text{x}10^{-7} & \text{for welds} \end{Bmatrix} \tag{3}$$

$$CRP\ term = B\left(1 + 3.77Ni^{1.191}\right) f\left(Cu_e, P\right) g\left(Cu_e, Ni, \phi t_e\right) \tag{4}$$

$$B = \begin{Bmatrix} 102.3 & for\ forgings \\ 102.5 & for\ plates\ in\ non\text{-}CE\ mfg.\ vessels \\ 135.2 & for\ plates\ in\ CE\ mfg.\ vessels \\ 155.0 & for\ welds \\ 128.2 & for\ SRM\ plates \end{Bmatrix} \tag{5}$$

$$Cu_e = \begin{Bmatrix} 0 & for\ Cu \le 0.072\ wt\% \\ \min\left[Cu, Max(Cu_e)\right] & for\ Cu > 0.072\ wt\% \end{Bmatrix} \tag{6}$$

$$Max(Cu_e) = \begin{Bmatrix} 0.243 & for\ typical\ (Ni > 0.5)\ Linde\ 80\ welds \\ 0.301 & for\ all\ other\ materials \end{Bmatrix} \tag{7}$$

$$f\left(Cu_e, P\right) = \begin{Bmatrix} 0 & for\ Cu \le 0.072 \\ \left[Cu_e - 0.072\right]^{0.668} & for\ Cu > 0.072\ and\ P \le 0.008 \\ \left[Cu_e - 0.072 + 1.359(P - 0.008)\right]^{0.668} & for\ Cu > 0.072\ and\ P > 0.008 \end{Bmatrix} \tag{8}$$

$$g\left(Cu_e, Ni, \phi t_e\right) = \frac{1}{2} + \frac{1}{2}\tanh\left[\frac{\log_{10}\left(\phi t_e\right) + 1.139Cu_e - 0.448Ni - 18.120}{0.629}\right] \tag{9}$$

$$\phi t_e = \begin{Bmatrix} \phi t & for\ \phi \ge 4.39 \times 10^{10} \\ \phi t\left(\dfrac{4.39 \times 10^{10}}{\phi}\right)^{0.259} & for\ \phi < 4.39 \times 10^{10} \end{Bmatrix} \tag{10}$$

The units and descriptions of independent variables in these equations are given in Table 1-1. The dependent variable, ΔT_{30}, is estimated by Eq. (1) in degrees Fahrenheit. The standard deviation of residuals about Eq. (1) for different product forms and copper contents appears in Table 1-2.

Table 1-1. Independent variables in the embrittlement shift model and their ranges and mean values over all calibration and validation data.

Variable	Symbol	Units	Values of Surveillance Database [°F]			
			Average	Standard Deviation	Minimum	Maximum
Neutron Fluence (E>1MEv)	ϕt	n/cm^2	1.24E+19	1.19E+19	9.26E+15	1.07E+20
Neutron Flux (E>1MEv)	ϕ	n/cm^2/sec	8.69E+10	9.96E+10	2.62E+08	1.63E+12
Irradiation Temperature	*T*	°F	545	11	522	570
Copper content	*Cu*	weight %	0.140	0.084	0.010	0.410
Nickel content	*Ni*	weight %	0.56	0.23	0.04	1.26
Manganese content	*Mn*	weight %	1.31	0.26	0.58	1.96
Phosphorus content	*P*	weight %	0.012	0.004	0.003	0.031

Table 1-2. Standard deviation of residuals about Eq. (1).

Product Form	σ [°F]	
	Cu ≤ 0.072 wt %	Cu > 0.072 wt %
Forging	17.5	19.6
Plate	15.0	21.2 (this includes the correlation monitor materials)
Weld	18.6	26.4

1.2 Entry Conditions

To use this procedure, at least three ΔT_{30} values measured at a minimum of three different fluences must be available for the material heat of interest. These ΔT_{30} values should be obtained according to the analysis procedures and data quantity requirements set forth in the version of 10 CFR Part 50 Appendix H to which the reactor was granted its operating license. If this entry condition is not met then the generic equation, eq. (1), should be used to estimate ΔT_{30}.

1.3 Surveillance Tests Considered

In developing the recommended surveillance assessment procedure, consideration was given to the development of statistical tests capable of detecting the four types of deviations between heat-specific surveillance data and the generic ΔT_{30} ETC, i.e. eqs. (1-10), that are illustrated in Figure 1.1. These deviations, their potential origins, and implications, are described briefly below. Note that for Type A, B, and D deviations only situations where the data suggest that the generic ΔT_{30} ETC may provide a non-conservative prediction (i.e. where the data lies above the ETC prediction) are illustrated in Figure 1.1. The opposite situation is of course possible, i.e. where the data lies below the ETC prediction. However, from a regulatory standpoint only the former types of deviations are important, so those types of deviations are the focus of this discussion.

- Type A Deviations: For Type A deviations, measurements differ from the mean ETC prediction more-or-less uniformly at all fluences (i.e., there is no trend with fluence). Additionally, the magnitude of this deviation is larger than would be expected based on the population of data that was used to calibrate the ETC. Potential origins of Type A deviations may include, but are likely not limited to, errors in the chemical composition

values associated with the surveillance sample, or errors in the unirradiated ΔT_{30} value associated with the surveillance sample. The implication of a statistically significant Type A deviation (procedures for evaluating statistical significance are described in Section 1.4.1) is that the ETC may systematically under-estimate the value of ΔT_{30} for the heat of steel being evaluated.

- Type B Deviations: For Type B deviations, measurements differ from the mean ETC prediction by an amount that increases as fluence increases. Additionally, the magnitude of this deviation is larger than would be expected based on the population of data that was used to calibrate the ETC. Potential origins of Type B deviations may include, but are likely not limited to, errors in the temperature value associated with the surveillance sample, or the existence in the surveillance sample of an embrittlement mechanism that is not represented in the generic calibration dataset. It may be noted that a recent review of high-fluence data has revealed the possible existence of Type B deviations in a large empirical database (see Figure 1.2 and [EricksonKirk 08]). The implication of a statistically significant Type B deviation (procedures for evaluating statistical significance are described in Section 1.4.2) is that the ETC may systematically under-estimate the value of ΔT_{30} for the heat of steel being evaluated, and that the magnitude of this under-estimation will increase as the plant operation continues and the plant becomes more embrittled.
- Type C Deviations: For Type C deviations, measurements do not differ from the mean ETC by either being systematically larger than the predictions (Type A deviations) or by systematically diverting from the predictions (Type B deviations), but rather by exhibiting more scatter than would be expected based on the population of data that was used to calibrate the generic ETC. Potential origins of Type C deviations may include, but are likely not limited to, errors made in testing, labeling, or controlling the notch-orientation of surveillance specimens. The implication of statistically significant Type C deviations is not that the generic ETC may systematically under-predict the true embrittlement, but rather that the ability of the heat-specific surveillance data to provide insight into embrittlement trends is called into question for a specific heat of material.
- Type D Deviations: For Type D deviations, one or more of the ΔT_{30} measurements differs significantly from the mean ETC prediction even though all other measurements for the heat of steel being evaluated agree well with the ETC. The magnitude of the deviation of these outliers is larger than would be expected based on the population of data that was used to calibrate the generic ETC. Potential origins of Type D deviations may include, but are likely not limited to, a severe measurement error in the single data value, or the rapid emergence in the surveillance sample of an embrittlement mechanism that is not represented in the calibration dataset (i.e. rapid emergence of a Type B deviation). The implication of a statistically significant Type D deviation (procedures for evaluating statistical significance are described in Section 1.4.3) is that the ETC may systematically under-estimate the value of ΔT_{30} for the heat of steel being evaluated.

If statistically significant, Type A, B, and D deviations all give rise to concerns that the embrittlement trends predicted by the generic ETC may produce non-conservative estimates of the embrittlement experienced by materials used to construct the RPV. For this reason, methods to assess the statistical significance of these deviations are described in Sections 1.4.1 through 1.4.3. Type C deviations, if statistically significant, suggest that the surveillance program for the material in question does not provides a reliable indication of embrittlement trends for that material. As Appendix H to 10 CFR Part 50 requires the performance of surveillance on the “limiting” (meaning “most irradiation sensitive”) materials used to construct

the reactor beltline, the existence of a Type C deviation is important from a regulatory viewpoint, but it is important in the context of compliance with Appendix H to 10 CFR Part 50 rather than in the context of indicating potential non-conservatisms in the predictions of the generic ΔT_{30} ETC adopted in 10 CFR Part 50.61a. For this reason, statistical procedures to detect Type C deviations are not addressed in the main body of this document. However, they do appear, for reference and in the interest of completeness, as Appendix A.

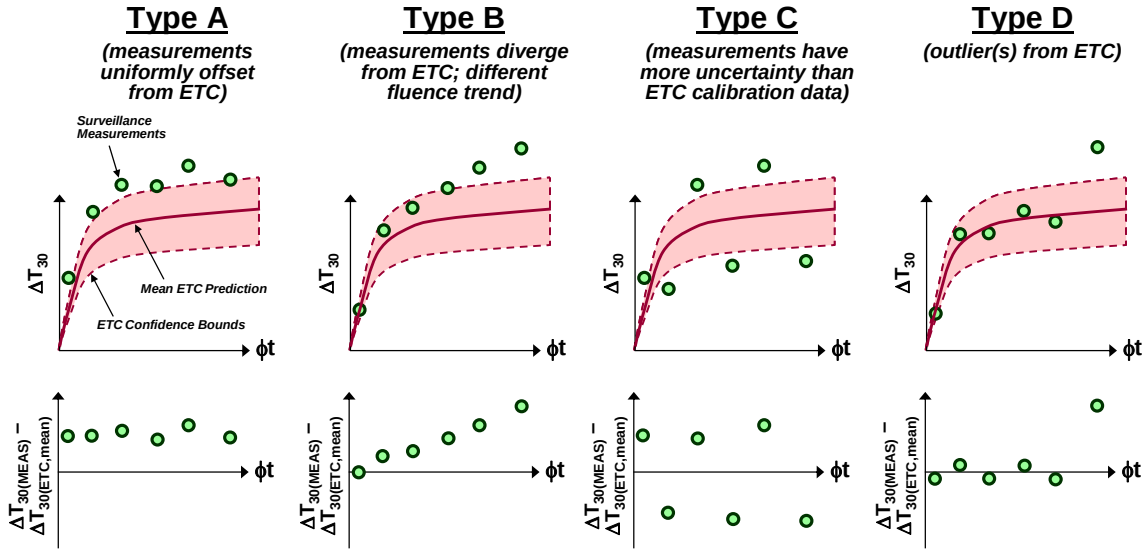

Figure 1.1. Four types of deviation between heat-specific surveillance data and the generic ΔT_{30} ETC.

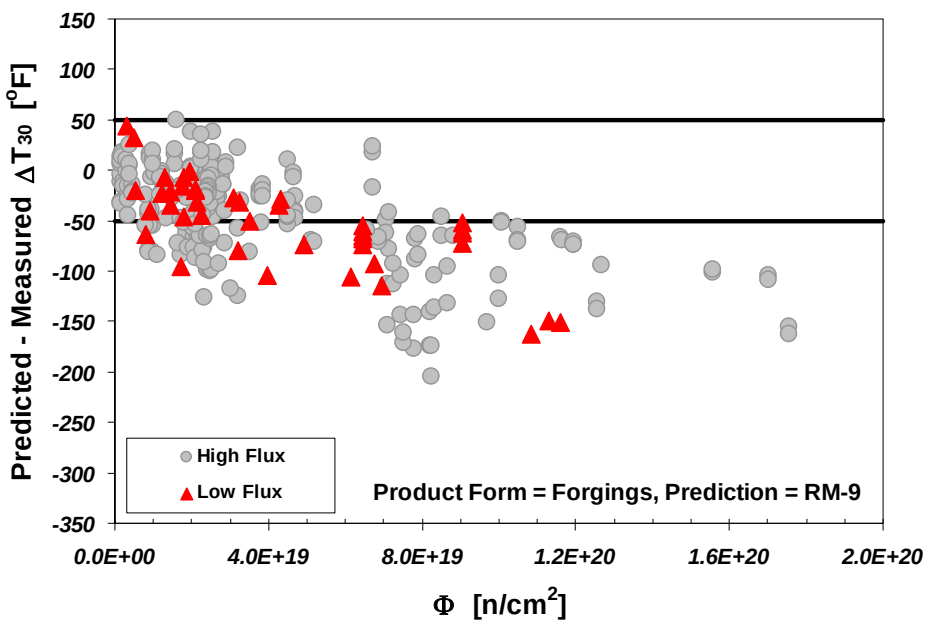

Figure 1.2. A plot of ΔT_{30} prediction residuals (residuals defined as the negative of the residuals from Figure 1.1) *vs*. fluence showing empirical evidence of Type B deviations for forgings beginning at fluences as low as $1x10^{19}$ n/cm^2 (E>1MEv). Low flux points are from power reactors while high flux points are from test reactors. Similar trends exist for both plates and for welds, see [EricksonKirk 08].

1.4 Statistical Tests to Detect Deviations of Surveillance Data from Generic ΔT_{30} Trends

1.4.1 For Type A Deviations

As illustrated by Figure 1.1, Type A deviations are characterized by measurements differ from the mean ETC prediction more-or-less uniformly at all fluences. Additionally, the magnitude of this deviation is larger than would be expected based on the population of data that was used to calibrate the ETC. The following procedure is proposed to detect Type A deviations where the ΔT_{30} measurements for a specific heat of material are uniformly under-predicted by the generic ΔT_{30} ETC. A statistical significance level of α=1% (i.e., "2.33σ") is recommended for this one-sided test; Section 1.4.4 discusses the rationale for this selection.

A-1. Ensure that the entry conditions of Section 1.2 have been met.

A-2. Estimate the mean residual (r_{mean}) for the ΔT_{30} dataset using the following formula:

$$r_{mean} = \frac{1}{n}\sum_{i=1}^{n}\left\{\Delta T_{30i(Measured)} - \Delta T_{30i(ETC-mean)}\right\}$$

where n is the number of ΔT_{30} measurements for the specific heat of material being assessed, $\Delta T_{30i(measured)}$ represents each individual measurement, and $\Delta T_{30i(ETC\text{-}mean)}$ is the value of ΔT_{30} estimated using Eq. (1).

A-3. Estimate the maximum allowable residual (r_{max}) using the following formula:

$$r_{\max} = \frac{2.33\sigma}{\sqrt{n}}$$

where n is the number of ΔT_{30} measurements for the specific heat of material being assessed and σ is the population standard deviation, which is taken from Table 1-2.

A-4. If $r_{mean} \leq r_{max}$ then the subject dataset is judged to not show a Type A deviation. However, if $r_{mean} > r_{max}$ then the subject dataset is judged to show a Type A deviation.

1.4.2 For Type B Deviations

As illustrated by Figure 1.1, Type B deviations are characterized by measurements differ from the mean ETC prediction by an amount that increases as fluence increases. Additionally, the magnitude of this deviation is larger than would be expected based on the population of data that was used to calibrate the ETC. The following procedure is proposed to detect Type B deviations where the ΔT_{30} measurements for a specific heat of material indicate a trend of increasing under-prediction by the generic ΔT_{30} ETC as fluence increases. Consistent with the test for Type A Deviations, statistical significance level of α=1% is recommended for this one-sided test; Section 1.4.4 discusses the rationale for this selection.

B-1. Ensure that the entry conditions of Section 1.2 have been met.

B-2. For each measured ΔT_{30} value, calculate the difference between the measured and predicted value of ΔT_{30}, i.e. $r = \Delta T_{30(Measured)} - \Delta T_{30(ETC\text{-}mean)}$. As illustrated in Figure 1.3, plot this difference *vs*. the value of fluence, where fluence abscissa is $Log_{10}(\phi t)$. The abscissa is expressed in this way because embrittlement, as

quantified by ΔT_{30}, increases in an approximate linear manner with the logarithm of fluence.

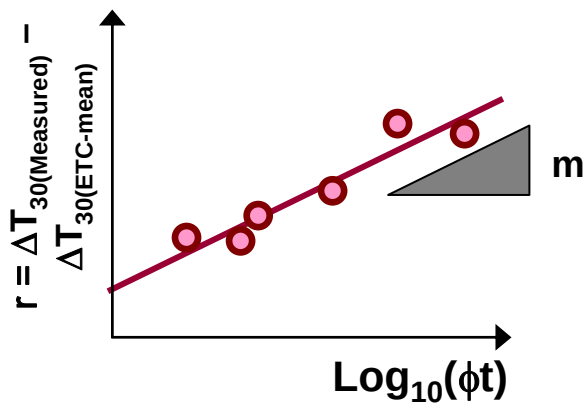

Figure 1.3. Procedure to assess Type B deviations.

B-3. Using the method of least-squares, estimate the slope (m) on Figure 1.3. Also estimate the standard-error of the estimated value of slope, i.e. se(m).

B-4. Estimate the T-statistics for both the estimates slope as follows:

$$T_m = \frac{m}{se(m)}$$

B-5. Establish the critical T-value as follows

$$T_{CRIT(\alpha)} \equiv t(\alpha, n-2)$$

where t(…) represents Student's t-distribution, α is the selected significance level, and n is the number of $\Delta T_{30(MEAS)}$ values. Adoption of α=1% is recommended for regulatory implementation of this procedure (Section 1.4.4 discusses the rationale for this selection). Table 1-3 provides values of $T_{CRIT(1\%)}$.

Table 1-3. α=1% Student's-t values.

Number of ΔT_{30} Values (n)	n-2	1 Tailed T_{CRIT} (1%,n-2)
3	1	31.82
4	2	6.96
5	3	4.54
6	4	3.75
7	5	3.36
8	6	3.14
9	7	3.00
10	8	2.90
11	9	2.82
12	10	2.76
13	11	2.72
14	12	2.68
15	13	2.65

B-6. Use the values of T_m and T_{CRIT} to determine if the heat-specific surveillance trends can be statistically distinguished from the generic trends. If $T_m \leq T_{CRIT}$

then the subject dataset is judged to not show a Type B deviation. However, if $T_m > T_{CRIT}$ then the subject dataset is judged to show a Type B deviation.

1.4.3 For Type D Deviations

As illustrated by Figure 1.1, For Type D deviations, one or more of the ΔT_{30} measurements differs significantly from the mean ETC prediction even though all other measurements for the heat of steel being evaluated agree well with the ETC. Additionally, the magnitude of the deviation of these outliers is larger than would be expected based on the population of data that was used to calibrate the generic ETC. Consistent with the tests for both Type A and B deviations, statistical significance level of α=1% is recommended for this one-sided test; Section 1.4.4 discusses the rationale for this selection.

D-1. Ensure that the entry conditions of Section 1.2 have been met.

D-2. Estimate the normalized residuals for each or the *n* observations in the ΔT_{30} dataset using the following formula:

$$R = \frac{\Delta T_{30(Measured)} - \Delta T_{30(ETC-mean)}}{\sigma}$$

where $\Delta T_{30i(measured)}$ represents each individual measurement, ad $\Delta T_{30i(ETC\text{-}mean)}$ is the value of ΔT_{30} estimated using Eq. (1), and σ is the population standard deviation taken from Table 1-2.

D-3. Find the largest and second largest of the *R* values from Step D-2; designate these $R_{(max1)}$ and $R_{(max2)}$, respectively

D-4. Find the threshold values of C_1 and C_2 corresponding to *n* in Table 1-4. These threshold values correspond to a significance level of α=1%, which is recommended for regulatory implementation of this procedure (Section 1.4.4 discusses the rationale for this selection). Appendix B of this document describes how the values of and C_2 that appear in Table 1-4 were derived.

Table 1-4. α=1% threshold value for the outlier test.

n	C_1	C_2
3	1.55	2.71
4	1.73	2.81
5	1.84	2.88
6	1.93	2.93
7	2.00	2.98
8	2.05	3.02
9	2.11	3.06
10	2.16	3.09
11	2.19	3.12
12	2.23	3.14
13	2.26	3.17
14	2.29	3.19
15	2.32	3.21
17	2.37	3.24
26	2.53	3.36
64	2.83	3.62

D-5. Use the values of C_1 and C_2 to determine if the heat-specific surveillance data contain an outlier. The surveillance dataset is judged to show a Type D deviation if the following criterion is met:

$$\left(R_{(\max 1)} > C_2\right)$$

$$OR$$

$$\left(R_{(\max 1)} > C_1\right) AND \left(R_{(\max 2)} > C_1\right)$$

If the surveillance dataset does not meet either criteria then it is judged to not show a Type D deviation.

1.4.4 Comments on the Proposed Tests

The significance level recommended for regulatory implementation of all of the Type A, B, and D tests is α=1%. At this significance level there is less than a 1 in 100 chance that the underlying cause of the detected difference (Type A, B, or D) between the heat- or plant-specific surveillance data and the generic ΔT_{30} embrittlement trends has occurred due to chance alone. The following considerations informed this recommendation:

- A 1% significance level makes it more difficult for heat- and plant-specific surveillance data to be declared "different" from the generic ΔT_{30} ETC than has traditionally been the case. For example, both 10CFR50.61 and Regulatory Guide 1.99 Revision 2 use a "2σ" criterion which, for a 1-sided test, implies an α=2.5% significance level [10CFR50.61, RG1.99R2]. The staff views this change in significance level (from the 2.5% to 1%) as appropriate in view of the much greater physical and empirical support of the generic ΔT_{30} ETC than was available at the time both 10CFR50.61 and Regulatory Guide 1.99 Revision 2 were adopted.
- The selection of the α=1% significance level represents a conscious trade off between the competing goals of providing high confidence in the determination **(a)** of a statistically significant difference between heat- and plant-specific surveillance data and the generic ΔT_{30} ETC versus **(b)** limiting the risk of judging that a particular set of heat- or plant-specific surveillance data are similar to the generic ΔT_{30} ETC when, in fact, they are not. The former goal is achieved by adopting a small value for α whereas the latter goal is achieved by increasing the α value.
- If a heat- or plant-specific data set is determined, by these statistical tests, to be "different" from the generic ΔT_{30} embrittlement trend the alternatives that are then available to licensees to either troubleshoot the cause of the difference, or to develop new/replacement data are one, or all, of the following: limited, expensive, have long lead times. Consequently, while the NRC feels it is important to compare heat- and plant-specific data to generic trends, and to take action when such comparisons show differences, the NRC feels it is technically justified to reserve alternative action for those cases where the differences are most egregious, are most clear, and are most practically significant,

Considering all of these factors a significance level for Type A, B, and D tests of α=1% is recommended.

1.4.5 Combination of Type A, B, and D Tests for Use in 10CFR50.61a

Failure of heat- or plant-specific surveillance data to pass either the Type A , B, or D deviation tests indicates a situation where the generic ΔT_{30} ETC may under-estimate the embrittlement trends for the subject material. Use of the generic ΔT_{30} ETC is therefore not advised in this situation. It is recommended that failure of heat- or plant-specific surveillance data to pass ***any*** of the three deviation tests outlined in this document should trigger a need for the licensee to prepare, for the consideration of the NRC, a document describing alternative methods (i.e. other than, or in addition to, the ETC) that can be used to reliably predict ΔT_{30} trends for the conditions being assessed.

1.5 Evaluation of Currently Available Plant Data Relative to these Statistical Tests

The plant surveillance data used in [Eason 07] to calibrate eq. (1) were evaluated according to the statistical tests detailed in Section 1.4 and, for information, also according to the statistical test detailed in Appendix A. After filtering to remove heats having less than three ΔT_{30} observations at three different fluence values 159 data sets remained for evaluation. These sets included data from both PWRs and BWRs, and from plants that are no longer in operation. While the BWR and ex-plant data are not directly pertinent to 10CFR50.61a, they were retained in the analysis for information. The results of all of these analyses are provided in Appendix C, while Table 1-5 summarizes the proportion of heats in the surveillance database that exhibit statistically significant deviations at the α=1% level. The information in Table 1-5 demonstrates that both the mean and the outlier tests exhibit a rate of deviation above the expected value for a population of 159 data sets (i.e., Count=1.6) while the deviation rates of the slope and variance tests are both close to the expected value of 1.6. These observations suggest that for the mean and outlier tests the assumption that the residuals are distributed normally about the generic ETC model expressed by eq. (1) may be incorrect. One possible explanation for this situation (i.e., the apparent lack of normalcy of the mean outlier residuals tests coupled with the apparent normalcy of the slope and variance residuals) could be the presence of systematic biases in some of the un-irradiated T_{30} values (arising from, for example, measurement error or imprecision). Such biases, if present, would have no effect on the detection rate of the slope and variance tests because both tests operate on the ***differences*** between ΔT_{30} residuals, not on their absolute values. Thus, any systematic biases in the un-irradiated T_{30} values would be subtracted out of the ΔT_{30} difference values that are used to perform the slope and variance tests and, consequently, could have no effect on the outcome of the test. Conversely, the mean and variance tests both operate on the ***absolute values*** of ΔT_{30} residuals. Consequently, systematic biases in the un-irradiated values of ΔT_{30} could effect the normalcy of the ΔT_{30} residuals and, thereby, on the detection rate of the mean and outlier tests.

Table 1-6 list the nine heats of material from seven currently operating PWRs that show a statistically significant deviation of Type A, B, or D. While these tests suggest that the surveillance data for these heats exhibit a statistically significant deviation (at α=1%) from the expected embrittlement trends, they ***do not*** determine if these differences are practically important. It is suggested that the practical importance of these deviations be assessed by a more thorough review of the plant specific data than is possible within the scope of this document.

Table 1-5. Proportion of material heats in the current surveillance database operating PWRs that exhibit statistically significant deviations (α=1%) of Type A, B, C, or D (details appear in Appendix C).

Test Type		Data Sets that Show Statistically Significant (α=1%) Deviation	
		Count	Percent
A	Mean Test	11	6.9%
B	Slope Test	2	1.3%
C	Variance Test	3	1.9%
D	Outlier Test	7	4.4%

Table 1-6. Heats of material in currently operating PWRs that exhibit statistically significant deviations (α=1%) of Type A, B, or D (details appear in Appendix C).

Plant Name	Heat ID	Product Form	Population σ [°F]	Number of ΔT_{30} Values	Heat Fails these Deviation Tests		
					A - Mean Test	B - Slope Test	D - Outlier Test
San Onofre 3	PSO301	Plate	18.6	3	FAIL		FAIL
D.C. Cook 2	PCK201	Plate	21.2	8	FAIL		
Beaver Valley 1	PBV101	Plate	21.2	8	FAIL		FAIL
Callaway	WCL101	Weld	18.6	4	FAIL		FAIL
Surry 1	WSU101	Weld	26.4	3	FAIL		FAIL
Indian Point 2	PIP203	Plate	21.2	3	FAIL		
Sequoyah 1	FSQ101	Forging	19.6	8	FAIL		
Sequoyah 1	WSQ101	Weld	26.4	4	FAIL		
Sequoyah 1	WSQ201	Weld	26.4	4			FAIL

1.6 Summary and Conclusions

This document discusses four different statistical tests that were considered by the NRC for implementation in 10CFR50.61a. The aim of performing these tests is to determine if the surveillance data are sufficiently "close" to the predictions of a generic embrittlement trend curve (ETC) that the predictions of the ETC may be used. From a regulatory perspective, it is of particular interest is to determine if plant- and heat-specific surveillance data deviate significantly from the predictions of the generic ETC in a manner that suggests that the generic ETC is very likely to under-predict plant- and heat-specific data trends. To this end it was decided to adopt a statistical significance level of α=1%. The selection of the α=1% significance level represents a conscious trade off between the competing goals of providing high confidence in the determination **(a)** of a statistically significant difference between heat- and plant-specific surveillance data and the generic ΔT_{30} ETC versus **(b)** limiting the risk of judging that a particular set of heat- or plant-specific surveillance data are similar to the generic ΔT_{30} ETC when, in fact, they are not. The α=1% tests will show fewer statistically significant deviations than did either 10CFR50.61 or Regulatory Guide 1.99 Revision 2, both of which use a "2σ" criterion which, for a 1-sided test, implies an α=2.5% significance level. The staff views this change in significance level (from the 2.5% to 1%) as appropriate in view of the much

greater physical and empirical support of the generic ΔT_{30} ETC than was available at the time both 10CFR50.61 and Regulatory Guide 1.99 Revision 2 were adopted.

Of the four statistical tests considered, three are recommended for adoption in 10CFR50.61a because these three tests indicate when an under prediction of embrittlement magnitude by the generic ETC is very likely to have occurred. In appendices to this document these statistical tests are applied to the entirety of the currently available surveillance database. Of all the heats of material that exist in currently operating PWRs, only ten heats from eight plants fail one or more of the three recommended statistical tests. While these tests suggest that the surveillance data for these heats exhibit a statistically significant deviation (at α=1%) from the expected embrittlement trends, they ***do not*** determine if these differences are practically important. It is suggested that the practical importance of these deviations be assessed by a more thorough review of the plant specific data than is possible within the scope of this document.

1.7 References

10CFR50.61 — Title 10, Section 50.61, of the *Code of Federal Regulations*, "Fracture Toughness Requirements for Protection against Pressurized Thermal Shock Events," promulgated June 26, 1984.

Eason 07 — Eason, E.D., G.R. Odette, R.K. Nanstad, and T. Yamamoto, "A Physically Based Correlation of Irradiation-Induced Transition Temperature Shifts for RPV Steels," Oak Ridge National Laboratory, ORNL/TM-2006/530, ADAMS Accession Numbers ML081000629 and ML081000630.

EricksonKirk 08 — Information regarding embrittlement trend curve development , work in progress: ADAMS Accession Numbers ML081120253, ML081120289, and ML081120600.

RG1.99R2 — Regulatory Guide 1.99, "Radiation Embrittlement of Reactor Vessel Materials," Rev. 2, U.S. Nuclear Regulatory Commission, Washington, DC, May 1988.

Appendix A – Statistical Test for Type C Deviations

As illustrated by Figure 1.1 of the main body of this document, Type C deviations are characterized by measurements do not differ from the mean ETC by either being systematically larger than the predictions (Type A deviations) or by systematically diverting from the predictions (Type B deviations), but rather by exhibiting more scatter than would be expected based on the population of data that was used to calibrate the generic ETC. Additionally, the magnitude of this deviation is larger than would be expected based on the population of data that was used to calibrate the ETC. The following procedure can be used to detect Type C deviations. Consistent with the tests for both Type A and B deviations, a statistical significance level of α=1% is adopted for this one-sided test; Section 1.4.4 of the main body of this document discusses the rationale for this selection.

C-1. Ensure that the entry conditions of Section 1.2 have been met.

C-2. Estimate the standard deviation for the ΔT_{30} dataset.

C-3. Estimate the F statistic for this dataset using the following formula

$$F_{DATA} = \frac{s^2}{\sigma^2}$$

where σ is the population standard deviation, which is taken from Table 1-2.

C-4. Establish the critical F-value as follows

$$F_{CRIT(\alpha)} \equiv F(\alpha, n-1)$$

where F(…) represents F-distribution, α is the selected significance level, and n is the number of $\Delta T_{30(MEAS)}$ values. Adoption of α=1% is recommended for regulatory implementation of this procedure (Section 1.4.4 of the main body of this document discusses the rationale for this selection). Table 1-4 provides values of $F_{CRIT(1\%)}$.

Table A-1. α=1% F values.

Number of ΔT_{30} Values (n)	n-1	1 Tailed F_{CRIT} (1%,n-1)
3	2	4.63
4	3	3.80
5	4	3.34
6	5	3.04
7	6	2.82
8	7	2.66
9	8	2.53
10	9	2.43
11	10	2.34
12	11	2.27
13	12	2.20
14	13	2.15
15	14	2.10

C-5. Use the values of F_{DATA} and F_{CRIT} to determine if the heat-specific surveillance data exhibits a variability that can be statistically distinguished from the generic variability described in Table 1-2. If $F_{DATA} \leq F_{CRIT}$ then the subject dataset is not judged to not show a Type C deviation. However, if $F_{DATA} > F_{CRIT}$ then the subject dataset is judged to show a Type C deviation.

Appendix B – Derivation of the Statistical Test for Type D Deviations

C_2 is defined so that the probability that all the normalized residuals are less than C_2 is 1-α = 0.99, assuming the embrittlement shift model is correct. Under this assumption, the normalized residuals all have a standard normal distribution with mean 0 and standard deviation 1. Denote the cumulative distribution function of the standard normal distribution by F. Then

(a) $C_2 = F^{-1}([0.99]^{1/n})$

For any n and C_2 as determined above, define

(b) $p = \text{Prob}\{C_1 < X \leq C_2\}$

for any $C_1 < C_2$ and where X has a standard normal distribution. Then

(c) $1-p = \text{Prob}\{X \leq C_1\} + \text{Prob}\{X > C_2\}$

However, the second term in (1-p) is negligible compared to the first term. In fact, from Table 1-4 in the main body of the text, $C_2 \geq 2.71$ for $n \geq 3$ and therefore $\text{Prob}\{X > C_2\} < 0.0034$ for $n \geq 3$. Thus

(d) $1-p \approx \text{Prob}\{X \leq C_1\}$

The probability that the subject dataset does not show a Type D deviation can be expressed in terms of p. Because all of the n normalized residuals must be less than or equal to C_1 to pass the Outlier Test, we may write:

(e) $\text{Prob}\{x_{[1]} \leq C_1\} = (1-p)^n$

Also, the Outlier test states that it is acceptable to have a single normalized residual lies between C_1 and C_2 and the other (n–1) are all < C_1. Therefore

(f) $\text{Prob}\{x_{[2]} < C_1 \leq x_{[1]} \leq C_2\} = np\,(1-p)^{n-1}$

Because (e) and (f) are mutually exclusive, the sum of their probabilities is the probability of a Type D deviation, or 1-α = 0.99. Denote this sum by G(p). Then

$$G(p) = (1-p)^n + np\,(1-p)^{n-1} = (1-p)^{n-1}\,[\,1+(n-1)p\,]$$

By iteration, find p_0 such that $G(p_0) = 0.99$. To calculate C_1 in Table 1-4 set $\text{Prob}\{X \leq C_1\} = 1-p_0$. Then

$$C_1 = F^{-1}(1-p_0)$$

Appendix C – Results of Statistical Assessment of Existing Plant Surveillance Database

Table C-1. Type A Deviations (Mean Test)

General Information							Type A Deviation (Mean Test)		
Plant Name	Unit	Reactor Type	Heat	Product Form	n	σ [°F]	r_{mean} [°F]	r_{max} [°F]	Fails Test?
Davis Besse		PWR	FDB102	F	4	19	-7	22	
Ginna		PWR	FGIN02	F	4	19	-18	22	
Kewaunee		PWR	FKWE02	F	4	19	-7	22	
Point Beach	2	PWR	FPB202	F	4	20	19	23	
Turkey Point	3	PWR	FTP302	F	3	20	10	26	
Connecticut Yankee		ex-PWR	PCTY04	P	3	21	-4	29	
Oyster Creek		BWR	PGG_01	P	4	19	2	22	
Indian Point	2	PWR	PIP202	P	3	21	-1	29	
Indian Point	2	PWR	PIP203	P	3	21	32.6	28.5	Yes
Indian Point	3	PWR	PIP304	P	5	21	13	22	
Oconee	1	PWR	POC102	P	6	21	5	20	
Point Beach	1	PWR	PPB102	P	4	21	-28	25	
Salem	1	PWR	PSA103	P	3	21	-30	29	
Dresden	3	BWR	WDR302	W	3	26	-17	36	
Crystal River & Surry	3 & 2	PWR	WHSS65	W	3	26	3	36	
Arkansas Nuclear	1	PWR	PAN101	P	6	21	-13	20	
Arkansas Nuclear	1	PWR	WAN101	W	3	26	6	36	
Arkansas Nuclear	2	PWR	PAN201	P	3	21	-3	29	
Braidwood	1	PWR	FBD101	F	6	19	-7	18	
Braidwood	1	PWR	WBD101	W	3	19	3	25	
Braidwood	2	PWR	FBD201	F	6	19	-9	18	
Braidwood	2	PWR	WBD201	W	3	19	-8	25	
Brunswick	1	BWR	PBR_01	P	5	21	31.3	22.1	Yes
Brunswick	1	BWR	WBR_01	W	3	26	35	36	
Beaver Valley	1	PWR	PBV101	P	8	21	23.0	17.5	Yes
Beaver Valley	1	PWR	WBV101	W	4	26	-3	31	

General Information							Type A Deviation (Mean Test)		
Plant Name	Unit	Reactor Type	Heat	Product Form	n	σ [°F]	r_{mean} [°F]	r_{max} [°F]	Fails Test?
Beaver Valley	2	PWR	PBV201	P	6	19	-7	18	
Beaver Valley	2	PWR	WBV201	W	3	26	-37	36	
Byron	1	PWR	FBY101	F	6	19	15	18	
Byron	1	PWR	WBY101	W	3	19	0	25	
Byron	2	PWR	FBY201	F	6	19	-5	18	
Byron	2	PWR	WBY201	W	3	19	-1	25	
Catawba	1	PWR	FCB101	F	6	20	-16	19	
Catawba	1	PWR	WCB101	W	3	19	-8	25	
Catawba	2	PWR	PCB201	P	6	21	-1	20	
Catawba	2	PWR	WCB201	W	3	19	1	25	
Calvert Cliffs	1	PWR	PCC103	P	3	21	-6	29	
Calvert Cliffs	1	PWR	WCC101	W	3	26	-17	36	
Calvert Cliffs	2	PWR	PCC202	P	3	21	-7	29	
D.C. Cook	1	PWR	PCK101	P	8	21	-4	17	
D.C. Cook	1	PWR	WCK101	W	3	26	-103	36	
D.C. Cook	2	PWR	PCK201	P	8	21	24.6	17.5	Yes
D.C. Cook	2	PWR	WCK201	W	4	19	17	22	
Callaway		PWR	PCL101	P	8	19	-2	15	
Callaway		PWR	WCL101	W	4	19	27.0	21.7	Yes
Comanche Peak	1	PWR	PCP101	P	4	19	-5	22	
Crystal River	3	PWR	PCR301	P	4	21	17	25	
Crystal River	3	PWR	WCR301	W	4	26	12	31	
Crystal River	3	PWR	WHSS66	W	4	26	-20	31	
Crystal River	3	PWR	WHSSCR	W	3	26	-6	36	
Connecticut Yankee		ex-PWR	PCTY02	P	3	21	-13	29	
Duane Arnold		BWR	PDAC01	P	3	21	10	29	
Duane Arnold		BWR	WDAC01	W	3	19	-4	25	
Davis Besse		PWR	WDB101	W	5	26	1	28	
Diablo Canyon	1	PWR	PDC103	P	3	21	-24	29	
Diablo Canyon	1	PWR	WDC101	W	3	26	-2	36	
Diablo Canyon	2	PWR	PDC201	P	8	21	-5	17	
Diablo Canyon	2	PWR	WDC201	W	4	26	-3	31	

General Information							Type A Deviation (Mean Test)		
Plant Name	Unit	Reactor Type	Heat	Product Form	n	σ [°F]	r_{mean} [°F]	r_{max} [°F]	Fails Test?
Dresden	2	BWR	PDR201	P	5	21	-32	22	
Dresden	3	BWR	PDR301	P	6	21	-10	20	
Dresden	3	BWR	WDR301	W	5	26	-5	28	
Farley	1	PWR	PFA101	P	8	21	13	17	
Farley	1	PWR	WFA101	W	4	26	-7	31	
Farley	2	PWR	PFA201	P	8	21	15	17	
Farley	2	PWR	WFA201	W	4	19	-51	22	
Fort Calhoun		PWR	PFC101	P	5	21	-10	22	
Fort Calhoun		PWR	WFC101	W	4	26	-1	31	
FitzPatrick		BWR	PFTZ01	P	6	21	-11	20	
Ginna		PWR	FGIN01	F	4	19	17	22	
Ginna		PWR	WGIN01	W	4	26	13	31	
H.B. Robinson	2	PWR	WHB201	W	3	26	6	36	
Indian Point	3	PWR	WIP301	W	3	26	33	36	
Kewaunee		PWR	FKWE01	F	4	19	-9	22	
Kewaunee		PWR	WKWE01	W	4	26	16	31	
McGuire	1	PWR	PMC101	P	8	21	13	17	
McGuire	1	PWR	WMC101	W	4	26	-11	31	
McGuire	2	PWR	FMC201	F	8	20	1	16	
McGuire	2	PWR	WMC201	W	4	19	3	22	
Millstone	1	ex-BWR	PML101	P	4	21	-6	25	
Millstone	2	PWR	PML201	P	5	21	13	22	
Millstone	2	PWR	WML201	W	3	26	-27	36	
Maine Yankee		ex-PWR	PMY_01	P	6	21	28.5	20.2	Yes
Maine Yankee		ex-PWR	SHSS01	SRM	17	21	1	12	
Maine Yankee		ex-PWR	WMY_01	W	4	26	-8	31	
North Anna	1	PWR	FNA101	F	6	20	-14	19	
North Anna	1	PWR	WNA101	W	3	26	21	36	
North Anna	2	PWR	FNA201	F	6	20	-18	19	
North Anna	2	PWR	WNA201	W	3	26	-23	36	
Nine Mile Point	1	BWR	PNM101	P	5	21	-10	22	
Oconee	1	PWR	SHSS02	SRM	64	21	-14	6	

General Information							Type A Deviation (Mean Test)		
Plant Name	Unit	Reactor Type	Heat	Product Form	n	σ [°F]	r_{mean} [°F]	r_{max} [°F]	Fails Test?
Oconee	1	PWR	WOC101	W	3	26	5	36	
Oconee	2	PWR	FOC201	F	5	19	-3	19	
Oconee	2	PWR	WOC201	W	3	26	-23	36	
Oconee	3	PWR	FOC301	F	4	19	2	22	
Oconee	3	PWR	FOC302	F	3	19	21	25	
Oconee	3	PWR	WOC301	W	4	26	-28	31	
Oyster Creek		BWR	PCPR02	P	4	21	-3	25	
Oyster Creek		BWR	PEP2JP	P	5	19	-3	19	
Oyster Creek		BWR	WGG_01	W	4	19	-8	22	
Oyster Creek		BWR	WML101	W	6	26	-23	25	
Oyster Creek		BWR	WQC102_1	W	4	26	26	31	
Oyster Creek		BWR	WQC201_1	W	4	26	17	31	
Oyster Creek		BWR	WRB_01	W	3	19	34.6	25.0	Yes
Palisades		PWR	PPAL01	P	7	21	-33	19	
Palisades		PWR	WPAL01	W	4	26	-5	31	
Point Beach	1	PWR	PPB101	P	4	21	9	25	
Point Beach	1	PWR	WPB101	W	4	26	-42	31	
Point Beach	2	PWR	FPB201	F	4	19	16	22	
Point Beach	2	PWR	WPB201	W	4	26	6	31	
Prairie Island	1	PWR	FPI101	F	8	19	-2	15	
Prairie Island	1	PWR	WPI101	W	4	26	-19	31	
Prairie Island	2	PWR	FPI201	F	8	20	-4	16	
Prairie Island	2	PWR	WPI201	W	4	26	-11	31	
Quad Cities	1	BWR	PQC101	P	6	21	1	20	
Quad Cities	1	BWR	WQC101	W	4	26	-16	31	
Quad Cities	2	BWR	PQC201	P	4	21	-18	25	
Quad Cities	2	BWR	WQC201	W	4	26	18	31	
Davis Besse		PWR	PRS101	P	3	21	-6	29	
Davis Besse		PWR	WRS101	W	3	26	-14	36	
Salem	1	PWR	PSA101	P	3	21	6	29	
Salem	2	PWR	PSA201	P	8	21	10	17	
Salem	2	PWR	WSA201	W	4	26	-18	31	

General Information							Type A Deviation (Mean Test)		
Plant Name	Unit	Reactor Type	Heat	Product Form	n	σ [°F]	r_{mean} [°F]	r_{max} [°F]	Fails Test?
Seabrook	1	PWR	PSB101	P	4	19	19	22	
Saint Lucie	1	PWR	PSL101	P	5	21	-19	22	
Saint Lucie	1	PWR	WSL101	W	3	26	-18	36	
Saint Lucie	2	PWR	PSL201	P	3	21	14	29	
San Onofre	2	PWR	PSO201	P	3	21	-7	29	
San Onofre	3	PWR	PSO301	P	3	19	40.1	25.0	Yes
Sequoyah	1	PWR	FSQ101	F	8	20	18.3	16.1	Yes
Sequoyah	1	PWR	WSQ101	W	4	26	32.4	30.8	Yes
Sequoyah	2	PWR	FSQ201	F	8	20	7	16	
Sequoyah	2	PWR	WSQ201	W	4	26	23	31	
South Texas	1	PWR	PST101	P	4	19	3	22	
South Texas	2	PWR	PST201	P	4	19	4	22	
Surry	1	PWR	PSU101	P	3	21	5	29	
Surry	1	PWR	WSU101	W	3	26	43.5	35.5	Yes
Surry	2	PWR	PSU201	P	6	21	0	20	
Surry	2	PWR	WSU201	W	3	26	-14	36	
Three Mile Island	1	PWR	PTM101	P	3	21	-17	29	
Turkey Point	3	PWR	SASTM	SRM	26	21	5	10	
Turkey Point	3	PWR	WTP301	W	4	26	13	31	
Trojan		ex-PWR	PTRO01	P	6	21	1	20	
Trojan		ex-PWR	WTRO01	W	3	19	8	25	
Votgle	1	PWR	PVO101	P	6	19	-1	18	
Votgle	1	PWR	WVO101	W	3	19	-4	25	
Votgle	2	PWR	PVO201	P	6	19	-14	18	
Votgle	2	PWR	WVO201	W	3	19	-13	25	
Virgil Summer	1	PWR	PVS101	P	8	21	-20	17	
Virgil Summer	1	PWR	WVS101	W	4	19	0	22	
Watts Bar	1	PWR	FWB101	F	4	20	-6	23	
Wolf Creek	1	PWR	PWC101	P	8	19	8	15	
Wolf Creek	1	PWR	WWC101	W	4	19	17	22	
Waterford	3	PWR	PWF301	P	3	19	-13	25	
Zion	1	ex-PWR	PZN101	P	8	21	-2	17	

General Information							Type A Deviation (Mean Test)		
Plant Name	Unit	Reactor Type	Heat	Product Form	n	σ [^{o}F]	r_{mean} [^{o}F]	r_{max} [^{o}F]	Fails Test?
Zion	1	ex-PWR	WZN101	W	5	26	-6	28	
Zion	2	ex-PWR	PZN201	P	6	21	3	20	
Zion	2	ex-PWR	WZN201	W	3	26	3	36	

Table C-2. Type B Deviations (Slope Test)

General Information							Type B Deviation (Slope Test)				
Plant Name	Unit	Reactor Type	Heat	Product Form	n	σ [^{o}F]	m	se(m)	T_m	$T_{crit(\alpha)}$	Fails Test?
Davis Besse		PWR	FDB102	F	4	19	33.72	23.70	1.42	6.96	
Ginna		PWR	FGIN02	F	4	19	39.26	74.20	0.53	6.96	
Kewaunee		PWR	FKWE02	F	4	19	5.09	6.32	0.81	6.96	
Point Beach	2	PWR	FPB202	F	4	20	41.30	12.36	3.34	6.96	
Turkey Point	3	PWR	FTP302	F	3	20	52.36	70.45	0.74	31.82	
Connecticut Yankee		ex-PWR	PCTY04	P	3	21	-63.22	2.55	-24.79	31.82	
Oyster Creek		BWR	PGG_01	P	4	19	21.14	22.39	0.94	6.96	
Indian Point	2	PWR	PIP202	P	3	21	-59.41	46.88	-1.27	31.82	
Indian Point	2	PWR	PIP203	P	3	21	-17.19	2.14	-8.05	31.82	
Indian Point	3	PWR	PIP304	P	5	21	2.30	29.72	0.08	4.54	
Oconee	1	PWR	POC102	P	6	21	-19.62	25.32	-0.77	3.75	
Point Beach	1	PWR	PPB102	P	4	21	-76.91	8.77	-8.77	6.96	
Salem	1	PWR	PSA103	P	3	21	-6.76	19.49	-0.35	31.82	
Dresden	3	BWR	WDR302	W	3	26	-25.60	231.23	-0.11	31.82	
Crystal River & Surry	3 & 2	PWR	WHSS65	W	3	26	2.10	14.59	0.14	31.82	
Arkansas Nuclear	1	PWR	PAN101	P	6	21	-26.06	10.09	-2.58	3.75	
Arkansas Nuclear	1	PWR	WAN101	W	3	26	-37.69	19.02	-1.98	31.82	
Arkansas Nuclear	2	PWR	PAN201	P	3	21	-5.72	16.85	-0.34	31.82	
Braidwood	1	PWR	FBD101	F	6	19	26.30	21.44	1.23	3.75	
Braidwood	1	PWR	WBD101	W	3	19	8.25	8.49	0.97	31.82	
Braidwood	2	PWR	FBD201	F	6	19	14.24	22.91	0.62	3.75	
Braidwood	2	PWR	WBD201	W	3	19	6.66	19.20	0.35	31.82	
Brunswick	1	BWR	PBR_01	P	5	21	67.73	13.28	5.10	4.54	Yes
Brunswick	1	BWR	WBR_01	W	3	26	41.69	45.09	0.92	31.82	

General Information							Type B Deviation (Slope Test)				
Plant Name	Unit	Reactor Type	Heat	Product Form	n	σ [^{o}F]	m	se(m)	T_m	$T_{crit(\alpha)}$	Fails Test?
Beaver Valley	1	PWR	PBV101	P	8	21	-37.91	21.46	-1.77	3.14	
Beaver Valley	1	PWR	WBV101	W	4	26	-56.91	15.54	-3.66	6.96	
Beaver Valley	2	PWR	PBV201	P	6	19	4.78	6.63	0.72	3.75	
Beaver Valley	2	PWR	WBV201	W	3	26	-50.14	20.08	-2.50	31.82	
Byron	1	PWR	FBY101	F	6	19	7.34	15.79	0.46	3.75	
Byron	1	PWR	WBY101	W	3	19	26.54	8.12	3.27	31.82	
Byron	2	PWR	FBY201	F	6	19	0.03	19.60	0.00	3.75	
Byron	2	PWR	WBY201	W	3	19	27.60	8.32	3.32	31.82	
Catawba	1	PWR	FCB101	F	6	20	24.31	20.63	1.18	3.75	
Catawba	1	PWR	WCB101	W	3	19	7.91	2.47	3.20	31.82	
Catawba	2	PWR	PCB201	P	6	21	0.93	10.27	0.09	3.75	
Catawba	2	PWR	WCB201	W	3	19	91.48	9.59	9.54	31.82	
Calvert Cliffs	1	PWR	PCC103	P	3	21	13.74	2.75	4.99	31.82	
Calvert Cliffs	1	PWR	WCC101	W	3	26	37.90	2.00	18.95	31.82	
Calvert Cliffs	2	PWR	PCC202	P	3	21	11.27	12.00	0.94	31.82	
D.C. Cook	1	PWR	PCK101	P	8	21	-8.31	11.44	-0.73	3.14	
D.C. Cook	1	PWR	WCK101	W	3	26	-27.17	98.72	-0.28	31.82	
D.C. Cook	2	PWR	PCK201	P	8	21	1.58	17.98	0.09	3.14	
D.C. Cook	2	PWR	WCK201	W	4	19	-14.88	17.64	-0.84	6.96	
Callaway		PWR	PCL101	P	8	19	-8.04	14.97	-0.54	3.14	
Callaway		PWR	WCL101	W	4	19	-41.68	12.80	-3.26	6.96	
Comanche Peak	1	PWR	PCP101	P	4	19	-19.21	15.89	-1.21	6.96	
Crystal River	3	PWR	PCR301	P	4	21	22.02	11.98	1.84	6.96	
Crystal River	3	PWR	WCR301	W	4	26	46.92	13.65	3.44	6.96	
Crystal River	3	PWR	WHSS66	W	4	26	-110.03	117.85	-0.93	6.96	
Crystal River	3	PWR	WHSSCR	W	3	26	-116.65	31.01	-3.76	31.82	
Connecticut Yankee		ex-PWR	PCTY02	P	3	21	-47.44	1.52	-31.24	31.82	
Duane Arnold		BWR	PDAC01	P	3	21	-2.02	13.71	-0.15	31.82	
Duane Arnold		BWR	WDAC01	W	3	19	20.21	6.54	3.09	31.82	
Davis Besse		PWR	WDB101	W	5	26	10.23	58.55	0.17	4.54	
Diablo Canyon	1	PWR	PDC103	P	3	21	-2.29	33.31	-0.07	31.82	
Diablo Canyon	1	PWR	WDC101	W	3	26	23.50	74.96	0.31	31.82	

General Information							Type B Deviation (Slope Test)				
Plant Name	Unit	Reactor Type	Heat	Product Form	n	σ [^{o}F]	m	se(m)	T_m	$T_{crit(\alpha)}$	Fails Test?
Diablo Canyon	2	PWR	PDC201	P	8	21	-1.49	7.64	-0.19	3.14	
Diablo Canyon	2	PWR	WDC201	W	4	26	-34.17	7.34	-4.66	6.96	
Dresden	2	BWR	PDR201	P	5	21	2.15	5.51	0.39	4.54	
Dresden	3	BWR	PDR301	P	6	21	-2.52	4.90	-0.51	3.75	
Dresden	3	BWR	WDR301	W	5	26	7.60	7.66	0.99	4.54	
Farley	1	PWR	PFA101	P	8	21	21.46	8.51	2.52	3.14	
Farley	1	PWR	WFA101	W	4	26	-27.48	10.40	-2.64	6.96	
Farley	2	PWR	PFA201	P	8	21	20.33	15.54	1.31	3.14	
Farley	2	PWR	WFA201	W	4	19	-25.24	19.69	-1.28	6.96	
Fort Calhoun		PWR	PFC101	P	5	21	-22.33	33.89	-0.66	4.54	
Fort Calhoun		PWR	WFC101	W	4	26	-73.25	49.46	-1.48	6.96	
FitzPatrick		BWR	PFTZ01	P	6	21	8.83	10.75	0.82	3.75	
Ginna		PWR	FGIN01	F	4	19	-33.49	29.11	-1.15	6.96	
Ginna		PWR	WGIN01	W	4	26	13.77	24.57	0.56	6.96	
H.B. Robinson	2	PWR	WHB201	W	3	26	7.86	33.97	0.23	31.82	
Indian Point	3	PWR	WIP301	W	3	26	-0.18	79.92	0.00	31.82	
Kewaunee		PWR	FKWE01	F	4	19	-3.54	28.08	-0.13	6.96	
Kewaunee		PWR	WKWE01	W	4	26	-15.96	19.26	-0.83	6.96	
McGuire	1	PWR	PMC101	P	8	21	24.92	19.19	1.30	3.14	
McGuire	1	PWR	WMC101	W	4	26	-43.26	13.24	-3.27	6.96	
McGuire	2	PWR	FMC201	F	8	20	4.68	13.50	0.35	3.14	
McGuire	2	PWR	WMC201	W	4	19	-34.72	13.01	-2.67	6.96	
Millstone	1	ex-BWR	PML101	P	4	21	-46.63	28.45	-1.64	6.96	
Millstone	2	PWR	PML201	P	5	21	23.17	31.56	0.73	4.54	
Millstone	2	PWR	WML201	W	3	26	-56.09	3.80	-14.77	31.82	
Maine Yankee		ex-PWR	PMY_01	P	6	21	-6.49	15.82	-0.41	3.75	
Maine Yankee		ex-PWR	SHSS01	SRM	17	21	-4.95	15.22	-0.33	2.60	
Maine Yankee		ex-PWR	WMY_01	W	4	26	10.14	12.08	0.84	6.96	
North Anna	1	PWR	FNA101	F	6	20	8.37	20.75	0.40	3.75	
North Anna	1	PWR	WNA101	W	3	26	-40.22	70.03	-0.57	31.82	
North Anna	2	PWR	FNA201	F	6	20	18.17	12.92	1.41	3.75	
North Anna	2	PWR	WNA201	W	3	26	-5.18	23.10	-0.22	31.82	

General Information							Type B Deviation (Slope Test)				
Plant Name	Unit	Reactor Type	Heat	Product Form	n	σ [^{o}F]	m	se(m)	T_m	$T_{crit(\alpha)}$	Fails Test?
Nine Mile Point	1	BWR	PNM101	P	5	21	41.45	22.11	1.87	4.54	
Oconee	1	PWR	SHSS02	SRM	64	21	1.87	4.39	0.43	2.39	
Oconee	1	PWR	WOC101	W	3	26	41.08	14.09	2.92	31.82	
Oconee	2	PWR	FOC201	F	5	19	-15.62	13.86	-1.13	4.54	
Oconee	2	PWR	WOC201	W	3	26	30.52	12.69	2.41	31.82	
Oconee	3	PWR	FOC301	F	4	19	-2.79	5.78	-0.48	6.96	
Oconee	3	PWR	FOC302	F	3	19	-21.76	32.80	-0.66	31.82	
Oconee	3	PWR	WOC301	W	4	26	41.81	33.82	1.24	6.96	
Oyster Creek		BWR	PCPR02	P	4	21	-8.62	42.21	-0.20	6.96	
Oyster Creek		BWR	PEP2JP	P	5	19	-32.14	8.29	-3.88	4.54	
Oyster Creek		BWR	WGG_01	W	4	19	39.71	61.15	0.65	6.96	
Oyster Creek		BWR	WML101	W	6	26	10.03	20.07	0.50	3.75	
Oyster Creek		BWR	WQC102_1	W	4	26	6.48	11.60	0.56	6.96	
Oyster Creek		BWR	WQC201_1	W	4	26	57.46	59.89	0.96	6.96	
Oyster Creek		BWR	WRB_01	W	3	19	20.94	63.55	0.33	31.82	
Palisades		PWR	PPAL01	P	7	21	-77.49	15.02	-5.16	3.36	
Palisades		PWR	WPAL01	W	4	26	-42.23	5.32	-7.93	6.96	
Point Beach	1	PWR	PPB101	P	4	21	-55.54	23.06	-2.41	6.96	
Point Beach	1	PWR	WPB101	W	4	26	-12.46	53.53	-0.23	6.96	
Point Beach	2	PWR	FPB201	F	4	19	-0.70	8.03	-0.09	6.96	
Point Beach	2	PWR	WPB201	W	4	26	38.35	27.60	1.39	6.96	
Prairie Island	1	PWR	FPI101	F	8	19	-0.54	17.08	-0.03	3.14	
Prairie Island	1	PWR	WPI101	W	4	26	57.84	38.91	1.49	6.96	
Prairie Island	2	PWR	FPI201	F	8	20	8.36	9.37	0.89	3.14	
Prairie Island	2	PWR	WPI201	W	4	26	-40.19	12.22	-3.29	6.96	
Quad Cities	1	BWR	PQC101	P	6	21	7.70	2.14	3.59	3.75	
Quad Cities	1	BWR	WQC101	W	4	26	10.12	7.81	1.30	6.96	
Quad Cities	2	BWR	PQC201	P	4	21	-10.04	3.17	-3.17	6.96	
Quad Cities	2	BWR	WQC201	W	4	26	-3.89	4.21	-0.92	6.96	
Davis Besse		PWR	PRS101	P	3	21	19.87	18.23	1.09	31.82	
Davis Besse		PWR	WRS101	W	3	26	24.78	24.12	1.03	31.82	
Salem	1	PWR	PSA101	P	3	21	5.06	24.98	0.20	31.82	

General Information							Type B Deviation (Slope Test)				
Plant Name	Unit	Reactor Type	Heat	Product Form	n	σ [^{o}F]	m	se(m)	T_m	$T_{crit(\alpha)}$	Fails Test?
Salem	2	PWR	PSA201	P	8	21	-3.87	21.39	-0.18	3.14	
Salem	2	PWR	WSA201	W	4	26	-45.51	9.34	-4.87	6.96	
Seabrook	1	PWR	PSB101	P	4	19	-6.15	14.03	-0.44	6.96	
Saint Lucie	1	PWR	PSL101	P	5	21	-5.59	16.17	-0.35	4.54	
Saint Lucie	1	PWR	WSL101	W	3	26	-46.07	12.84	-3.59	31.82	
Saint Lucie	2	PWR	PSL201	P	3	21	49.57	1.95	25.45	31.82	
San Onofre	2	PWR	PSO201	P	3	21	11.38	26.39	0.43	31.82	
San Onofre	3	PWR	PSO301	P	3	19	15.75	21.22	0.74	31.82	
Sequoyah	1	PWR	FSQ101	F	8	20	31.83	17.01	1.87	3.14	
Sequoyah	1	PWR	WSQ101	W	4	26	-8.36	4.54	-1.84	6.96	
Sequoyah	2	PWR	FSQ201	F	8	20	12.09	14.40	0.84	3.14	
Sequoyah	2	PWR	WSQ201	W	4	26	-71.71	89.12	-0.80	6.96	
South Texas	1	PWR	PST101	P	4	19	-9.15	21.18	-0.43	6.96	
South Texas	2	PWR	PST201	P	4	19	16.33	4.60	3.55	6.96	
Surry	1	PWR	PSU101	P	3	21	10.46	20.36	0.51	31.82	
Surry	1	PWR	WSU101	W	3	26	9.51	7.62	1.25	31.82	
Surry	2	PWR	PSU201	P	6	21	-2.98	13.63	-0.22	3.75	
Surry	2	PWR	WSU201	W	3	26	7.37	24.69	0.30	31.82	
Three Mile Island	1	PWR	PTM101	P	3	21	-41.07	2.89	-14.23	31.82	
Turkey Point	3	PWR	SASTM	SRM	26	21	10.59	8.87	1.19	2.49	
Turkey Point	3	PWR	WTP301	W	4	26	15.55	35.61	0.44	6.96	
Trojan		ex-PWR	PTRO01	P	6	21	-2.31	12.00	-0.19	3.75	
Trojan		ex-PWR	WTRO01	W	3	19	-14.97	10.82	-1.38	31.82	
Votgle	1	PWR	PVO101	P	6	19	20.85	19.05	1.09	3.75	
Votgle	1	PWR	WVO101	W	3	19	-41.81	19.81	-2.11	31.82	
Votgle	2	PWR	PVO201	P	6	19	15.57	10.12	1.54	3.75	
Votgle	2	PWR	WVO201	W	3	19	25.29	19.30	1.31	31.82	
Virgil Summer	1	PWR	PVS101	P	8	21	-12.14	16.33	-0.74	3.14	
Virgil Summer	1	PWR	WVS101	W	4	19	-20.29	23.75	-0.85	6.96	
Watts Bar	1	PWR	FWB101	F	4	20	41.28	90.57	0.46	6.96	
Wolf Creek	1	PWR	PWC101	P	8	19	-8.38	9.54	-0.88	3.14	
Wolf Creek	1	PWR	WWC101	W	4	19	4.70	8.95	0.53	6.96	

General Information							Type B Deviation (Slope Test)				
Plant Name	Unit	Reactor Type	Heat	Product Form	n	σ [°F]	m	se(m)	T_m	$T_{crit(\alpha)}$	Fails Test?
Waterford	3	PWR	PWF301	P	3	19	-87.52	64.25	-1.36	31.82	
Zion	1	ex-PWR	PZN101	P	8	21	14.89	14.97	0.99	3.14	
Zion	1	ex-PWR	WZN101	W	5	26	43.23	8.52	5.07	4.54	Yes
Zion	2	ex-PWR	PZN201	P	6	21	19.41	15.57	1.25	3.75	
Zion	2	ex-PWR	WZN201	W	3	26	17.59	31.94	0.55	31.82	

Table C-3. Type C Deviations (Variance Test)

General Information							Type C Deviation (Variance Test)			
Plant Name	Unit	Reactor Type	Heat	Product Form	n	σ [°F]	s [°F]	F_{DATA}	$F_{CRIT(a)}$	Fails Test?
Davis Besse		PWR	FDB102	F	4	19	17.10	0.85	3.80	
Ginna		PWR	FGIN02	F	4	19	37.24	4.01	3.80	Yes
Kewaunee		PWR	FKWE02	F	4	19	3.47	0.03	3.80	
Point Beach	2	PWR	FPB202	F	4	20	14.49	0.55	3.80	
Turkey Point	3	PWR	FTP302	F	3	20	12.98	0.44	4.63	
Connecticut Yankee		ex-PWR	PCTY04	P	3	21	22.85	1.16	4.63	
Oyster Creek		BWR	PGG_01	P	4	19	5.68	0.09	3.80	
Indian Point	2	PWR	PIP202	P	3	21	24.51	1.34	4.63	
Indian Point	2	PWR	PIP203	P	3	21	5.64	0.07	4.63	
Indian Point	3	PWR	PIP304	P	5	21	13.68	0.42	3.34	
Oconee	1	PWR	POC102	P	6	21	22.37	1.11	3.04	
Point Beach	1	PWR	PPB102	P	4	21	22.09	1.09	3.80	
Salem	1	PWR	PSA103	P	3	21	7.50	0.13	4.63	
Dresden	3	BWR	WDR302	W	3	26	33.22	1.58	4.63	
Crystal River & Surry	3 & 2	PWR	WHSS65	W	3	26	3.98	0.02	4.63	
Arkansas Nuclear	1	PWR	PAN101	P	6	21	21.01	0.98	3.04	
Arkansas Nuclear	1	PWR	WAN101	W	3	26	30.08	1.30	4.63	
Arkansas Nuclear	2	PWR	PAN201	P	3	21	9.66	0.21	4.63	
Braidwood	1	PWR	FBD101	F	6	19	17.17	0.85	3.04	
Braidwood	1	PWR	WBD101	W	3	19	4.52	0.06	4.63	
Braidwood	2	PWR	FBD201	F	6	19	16.58	0.79	3.04	
Braidwood	2	PWR	WBD201	W	3	19	7.85	0.18	4.63	

General Information							Type C Deviation (Variance Test)			
Plant Name	Unit	Reactor Type	Heat	Product Form	n	σ [°F]	s [°F]	F_{DATA}	$F_{CRIT(a)}$	Fails Test?
Brunswick	1	BWR	PBR_01	P	5	21	49.28	5.40	3.34	Yes
Brunswick	1	BWR	WBR_01	W	3	26	36.36	1.90	4.63	
Beaver Valley	1	PWR	PBV101	P	8	21	21.94	1.07	2.66	
Beaver Valley	1	PWR	WBV101	W	4	26	22.31	0.71	3.80	
Beaver Valley	2	PWR	PBV201	P	6	19	5.11	0.08	3.04	
Beaver Valley	2	PWR	WBV201	W	3	26	21.87	0.69	4.63	
Byron	1	PWR	FBY101	F	6	19	12.09	0.42	3.04	
Byron	1	PWR	WBY101	W	3	19	11.57	0.39	4.63	
Byron	2	PWR	FBY201	F	6	19	13.19	0.50	3.04	
Byron	2	PWR	WBY201	W	3	19	10.85	0.34	4.63	
Catawba	1	PWR	FCB101	F	6	20	17.95	0.84	3.04	
Catawba	1	PWR	WCB101	W	3	19	3.47	0.03	4.63	
Catawba	2	PWR	PCB201	P	6	21	7.93	0.14	3.04	
Catawba	2	PWR	WCB201	W	3	19	39.63	4.54	4.63	
Calvert Cliffs	1	PWR	PCC103	P	3	21	5.09	0.06	4.63	
Calvert Cliffs	1	PWR	WCC101	W	3	26	11.99	0.21	4.63	
Calvert Cliffs	2	PWR	PCC202	P	3	21	3.43	0.03	4.63	
D.C. Cook	1	PWR	PCK101	P	8	21	9.59	0.20	2.66	
D.C. Cook	1	PWR	WCK101	W	3	26	44.44	2.83	4.63	
D.C. Cook	2	PWR	PCK201	P	8	21	14.80	0.49	2.66	
D.C. Cook	2	PWR	WCK201	W	4	19	10.54	0.32	3.80	
Callaway		PWR	PCL101	P	8	19	15.02	0.65	2.66	
Callaway		PWR	WCL101	W	4	19	19.65	1.12	3.80	
Comanche Peak	1	PWR	PCP101	P	4	19	11.20	0.36	3.80	
Crystal River	3	PWR	PCR301	P	4	21	12.58	0.35	3.80	
Crystal River	3	PWR	WCR301	W	4	26	21.82	0.68	3.80	
Crystal River	3	PWR	WHSS66	W	4	26	27.98	1.12	3.80	
Crystal River	3	PWR	WHSSCR	W	3	26	30.53	1.34	4.63	
Connecticut Yankee		ex-PWR	PCTY02	P	3	21	18.82	0.79	4.63	
Duane Arnold		BWR	PDAC01	P	3	21	4.06	0.04	4.63	
Duane Arnold		BWR	WDAC01	W	3	19	6.36	0.12	4.63	
Davis Besse		PWR	WDB101	W	5	26	33.51	1.61	3.34	
Diablo Canyon	1	PWR	PDC103	P	3	21	11.92	0.32	4.63	

General Information							Type C Deviation (Variance Test)			
Plant Name	Unit	Reactor Type	Heat	Product Form	n	σ [°F]	s [°F]	F_{DATA}	$F_{CRIT(a)}$	Fails Test?
Diablo Canyon	1	PWR	WDC101	W	3	26	28.04	1.13	4.63	
Diablo Canyon	2	PWR	PDC201	P	8	21	5.97	0.08	2.66	
Diablo Canyon	2	PWR	WDC201	W	4	26	12.25	0.22	3.80	
Dresden	2	BWR	PDR201	P	5	21	15.88	0.56	3.34	
Dresden	3	BWR	PDR301	P	6	21	15.14	0.51	3.04	
Dresden	3	BWR	WDR301	W	5	26	22.83	0.75	3.34	
Farley	1	PWR	PFA101	P	8	21	10.34	0.24	2.66	
Farley	1	PWR	WFA101	W	4	26	11.64	0.19	3.80	
Farley	2	PWR	PFA201	P	8	21	15.99	0.57	2.66	
Farley	2	PWR	WFA201	W	4	19	15.04	0.65	3.80	
Fort Calhoun		PWR	PFC101	P	5	21	9.94	0.22	3.34	
Fort Calhoun		PWR	WFC101	W	4	26	16.85	0.41	3.80	
FitzPatrick		BWR	PFTZ01	P	6	21	8.84	0.17	3.04	
Ginna		PWR	FGIN01	F	4	19	17.64	0.90	3.80	
Ginna		PWR	WGIN01	W	4	26	13.75	0.27	3.80	
H.B. Robinson	2	PWR	WHB201	W	3	26	17.51	0.44	4.63	
Indian Point	3	PWR	WIP301	W	3	26	21.44	0.66	4.63	
Kewaunee		PWR	FKWE01	F	4	19	13.45	0.52	3.80	
Kewaunee		PWR	WKWE01	W	4	26	10.65	0.16	3.80	
McGuire	1	PWR	PMC101	P	8	21	17.76	0.70	2.66	
McGuire	1	PWR	WMC101	W	4	26	17.00	0.41	3.80	
McGuire	2	PWR	FMC201	F	8	20	12.83	0.43	2.66	
McGuire	2	PWR	WMC201	W	4	19	16.30	0.77	3.80	
Millstone	1	ex-BWR	PML101	P	4	21	21.31	1.01	3.80	
Millstone	2	PWR	PML201	P	5	21	19.71	0.86	3.34	
Millstone	2	PWR	WML201	W	3	26	18.68	0.50	4.63	
Maine Yankee		ex-PWR	PMY_01	P	6	21	16.10	0.58	3.04	
Maine Yankee		ex-PWR	SHSS01	SRM	17	21	16.04	0.57	2.02	
Maine Yankee		ex-PWR	WMY_01	W	4	26	9.12	0.12	3.80	
North Anna	1	PWR	FNA101	F	6	20	16.97	0.75	3.04	
North Anna	1	PWR	WNA101	W	3	26	36.19	1.88	4.63	
North Anna	2	PWR	FNA201	F	6	20	13.32	0.46	3.04	
North Anna	2	PWR	WNA201	W	3	26	11.16	0.18	4.63	

General Information							Type C Deviation (Variance Test)			
Plant Name	Unit	Reactor Type	Heat	Product Form	n	σ [°F]	s [°F]	F_{DATA}	$F_{CRIT(a)}$	Fails Test?
Nine Mile Point	1	BWR	PNM101	P	5	21	10.43	0.24	3.34	
Oconee	1	PWR	SHSS02	SRM	64	21	15.64	0.54	1.48	
Oconee	1	PWR	WOC101	W	3	26	20.00	0.57	4.63	
Oconee	2	PWR	FOC201	F	5	19	12.94	0.48	3.34	
Oconee	2	PWR	WOC201	W	3	26	17.75	0.45	4.63	
Oconee	3	PWR	FOC301	F	4	19	5.16	0.08	3.80	
Oconee	3	PWR	FOC302	F	3	19	24.73	1.77	4.63	
Oconee	3	PWR	WOC301	W	4	26	36.77	1.94	3.80	
Oyster Creek		BWR	PCPR02	P	4	21	9.35	0.19	3.80	
Oyster Creek		BWR	PEP2JP	P	5	19	13.61	0.54	3.34	
Oyster Creek		BWR	WGG_01	W	4	19	14.44	0.60	3.80	
Oyster Creek		BWR	WML101	W	6	26	14.02	0.28	3.04	
Oyster Creek		BWR	WQC102_1	W	4	26	3.14	0.01	3.80	
Oyster Creek		BWR	WQC201_1	W	4	26	17.29	0.43	3.80	
Oyster Creek		BWR	WRB_01	W	3	19	7.62	0.17	4.63	
Palisades		PWR	PPAL01	P	7	21	26.10	1.52	2.82	
Palisades		PWR	WPAL01	W	4	26	13.38	0.26	3.80	
Point Beach	1	PWR	PPB101	P	4	21	18.26	0.74	3.80	
Point Beach	1	PWR	WPB101	W	4	26	21.75	0.68	3.80	
Point Beach	2	PWR	FPB201	F	4	19	3.68	0.04	3.80	
Point Beach	2	PWR	WPB201	W	4	26	17.69	0.45	3.80	
Prairie Island	1	PWR	FPI101	F	8	19	16.10	0.75	2.66	
Prairie Island	1	PWR	WPI101	W	4	26	33.19	1.58	3.80	
Prairie Island	2	PWR	FPI201	F	8	20	9.67	0.24	2.66	
Prairie Island	2	PWR	WPI201	W	4	26	18.70	0.50	3.80	
Quad Cities	1	BWR	PQC101	P	6	21	11.89	0.31	3.04	
Quad Cities	1	BWR	WQC101	W	4	26	25.47	0.93	3.80	
Quad Cities	2	BWR	PQC201	P	4	21	18.08	0.73	3.80	
Quad Cities	2	BWR	WQC201	W	4	26	11.61	0.19	3.80	
Davis Besse		PWR	PRS101	P	3	21	7.48	0.12	4.63	
Davis Besse		PWR	WRS101	W	3	26	9.60	0.13	4.63	
Salem	1	PWR	PSA101	P	3	21	11.83	0.31	4.63	
Salem	2	PWR	PSA201	P	8	21	17.26	0.66	2.66	

General Information							Type C Deviation (Variance Test)			
Plant Name	Unit	Reactor Type	Heat	Product Form	n	σ [°F]	s [°F]	F_{DATA}	$F_{CRIT(a)}$	Fails Test?
Salem	2	PWR	WSA201	W	4	26	16.82	0.41	3.80	
Seabrook	1	PWR	PSB101	P	4	19	6.41	0.12	3.80	
Saint Lucie	1	PWR	PSL101	P	5	21	6.14	0.08	3.34	
Saint Lucie	1	PWR	WSL101	W	3	26	10.41	0.16	4.63	
Saint Lucie	2	PWR	PSL201	P	3	21	25.47	1.44	4.63	
San Onofre	2	PWR	PSO201	P	3	21	10.58	0.25	4.63	
San Onofre	3	PWR	PSO301	P	3	19	7.47	0.16	4.63	
Sequoyah	1	PWR	FSQ101	F	8	20	18.32	0.87	2.66	
Sequoyah	1	PWR	WSQ101	W	4	26	3.98	0.02	3.80	
Sequoyah	2	PWR	FSQ201	F	8	20	13.75	0.49	2.66	
Sequoyah	2	PWR	WSQ201	W	4	26	57.76	4.79	3.80	Yes
South Texas	1	PWR	PST101	P	4	19	12.21	0.43	3.80	
South Texas	2	PWR	PST201	P	4	19	6.69	0.13	3.80	
Surry	1	PWR	PSU101	P	3	21	10.61	0.25	4.63	
Surry	1	PWR	WSU101	W	3	26	5.56	0.04	4.63	
Surry	2	PWR	PSU201	P	6	21	12.57	0.35	3.04	
Surry	2	PWR	WSU201	W	3	26	13.20	0.25	4.63	
Three Mile Island	1	PWR	PTM101	P	3	21	21.40	1.02	4.63	
Turkey Point	3	PWR	SASTM	SRM	26	21	17.53	0.68	1.79	
Turkey Point	3	PWR	WTP301	W	4	26	14.24	0.29	3.80	
Trojan		ex-PWR	PTRO01	P	6	21	8.75	0.17	3.04	
Trojan		ex-PWR	WTRO01	W	3	19	7.49	0.16	4.63	
Votgle	1	PWR	PVO101	P	6	19	14.95	0.65	3.04	
Votgle	1	PWR	WVO101	W	3	19	17.80	0.92	4.63	
Votgle	2	PWR	PVO201	P	6	19	8.40	0.20	3.04	
Votgle	2	PWR	WVO201	W	3	19	11.70	0.40	4.63	
Virgil Summer	1	PWR	PVS101	P	8	21	14.00	0.44	2.66	
Virgil Summer	1	PWR	WVS101	W	4	19	14.20	0.58	3.80	
Watts Bar	1	PWR	FWB101	F	4	20	30.04	2.35	3.80	
Wolf Creek	1	PWR	PWC101	P	8	19	10.13	0.30	2.66	
Wolf Creek	1	PWR	WWC101	W	4	19	5.95	0.10	3.80	
Waterford	3	PWR	PWF301	P	3	19	21.97	1.40	4.63	
Zion	1	ex-PWR	PZN101	P	8	21	11.50	0.29	2.66	

General Information							Type C Deviation (Variance Test)			
Plant Name	Unit	Reactor Type	Heat	Product Form	n	σ [°F]	s [°F]	F_{DATA}	$F_{CRIT(a)}$	Fails Test?
Zion	1	ex-PWR	WZN101	W	5	26	15.65	0.35	3.34	
Zion	2	ex-PWR	PZN201	P	6	21	12.16	0.33	3.04	
Zion	2	ex-PWR	WZN201	W	3	26	13.51	0.26	4.63	

Table C-4. Type D Deviations (Outlier Test)

General Information							Type D Deviation (Outlier Test)				
Plant Name	Unit	Reactor Type	Heat	Product Form	n	σ [°F]	$R_{(max1)}$	$R_{(max2)}$	C_1	C_2	Fails Test?
Davis Besse		PWR	FDB102	F	4	19	0.98	-0.60	1.73	2.81	
Ginna		PWR	FGIN02	F	4	19	1.35	-0.34	1.73	2.81	
Kewaunee		PWR	FKWE02	F	4	19	-0.08	-0.43	1.73	2.81	
Point Beach	2	PWR	FPB202	F	4	20	1.64	1.35	1.73	2.81	
Turkey Point	3	PWR	FTP302	F	3	20	1.05	0.67	1.55	2.71	
Connecticut Yankee		ex-PWR	PCTY04	P	3	21	1.02	-0.60	1.55	2.71	
Oyster Creek		BWR	PGG_01	P	4	19	0.23	-0.05	1.73	2.81	
Indian Point	2	PWR	PIP202	P	3	21	1.26	-0.57	1.55	2.71	
Indian Point	2	PWR	PIP203	P	3	21	1.81	1.53	1.55	2.71	
Indian Point	3	PWR	PIP304	P	5	21	1.41	1.11	1.84	2.88	
Oconee	1	PWR	POC102	P	6	21	1.53	1.41	1.93	2.93	
Point Beach	1	PWR	PPB102	P	4	21	-0.37	-0.52	1.73	2.81	
Salem	1	PWR	PSA103	P	3	21	-1.09	-1.33	1.55	2.71	
Dresden	3	BWR	WDR302	W	3	26	0.74	-1.02	1.55	2.71	
Crystal River & Surry	3 & 2	PWR	WHSS65	W	3	26	0.23	0.18	1.55	2.71	
Arkansas Nuclear	1	PWR	PAN101	P	6	21	0.98	-0.13	1.93	2.93	
Arkansas Nuclear	1	PWR	WAN101	W	3	26	1.47	0.03	1.55	2.71	
Arkansas Nuclear	2	PWR	PAN201	P	3	21	0.36	-0.32	1.55	2.71	
Braidwood	1	PWR	FBD101	F	6	19	0.41	0.23	1.93	2.93	
Braidwood	1	PWR	WBD101	W	3	19	0.42	0.03	1.55	2.71	
Braidwood	2	PWR	FBD201	F	6	19	0.85	0.41	1.93	2.93	
Braidwood	2	PWR	WBD201	W	3	19	0.04	-0.59	1.55	2.71	
Brunswick	1	BWR	PBR_01	P	5	21	4.09	2.99	1.84	2.88	Yes
Brunswick	1	BWR	WBR_01	W	3	26	2.56	1.53	1.55	2.71	
Beaver Valley	1	PWR	PBV101	P	8	21	2.52	2.26	2.05	3.02	Yes
Beaver Valley	1	PWR	WBV101	W	4	26	0.83	0.14	1.73	2.81	

General Information							Type D Deviation (Outlier Test)				
Plant Name	Unit	Reactor Type	Heat	Product Form	n	σ [°F]	$R_{(max1)}$	$R_{(max2)}$	C_1	C_2	Fails Test?
Beaver Valley	2	PWR	PBV201	P	6	19	-0.04	-0.06	1.93	2.93	
Beaver Valley	2	PWR	WBV201	W	3	26	-0.61	-1.39	1.55	2.71	
Byron	1	PWR	FBY101	F	6	19	1.67	1.58	1.93	2.93	
Byron	1	PWR	WBY101	W	3	19	0.38	0.37	1.55	2.71	
Byron	2	PWR	FBY201	F	6	19	0.46	0.36	1.93	2.93	
Byron	2	PWR	WBY201	W	3	19	0.59	-0.10	1.55	2.71	
Catawba	1	PWR	FCB101	F	6	20	0.14	0.05	1.93	2.93	
Catawba	1	PWR	WCB101	W	3	19	-0.27	-0.46	1.55	2.71	
Catawba	2	PWR	PCB201	P	6	21	0.30	0.26	1.93	2.93	
Catawba	2	PWR	WCB201	W	3	19	1.75	0.74	1.55	2.71	
Calvert Cliffs	1	PWR	PCC103	P	3	21	-0.10	-0.19	1.55	2.71	
Calvert Cliffs	1	PWR	WCC101	W	3	26	-0.14	-0.71	1.55	2.71	
Calvert Cliffs	2	PWR	PCC202	P	3	21	-0.14	-0.38	1.55	2.71	
D.C. Cook	1	PWR	PCK101	P	8	21	0.57	0.28	2.05	3.02	
D.C. Cook	1	PWR	WCK101	W	3	26	-2.30	-3.73	1.55	2.71	
D.C. Cook	2	PWR	PCK201	P	8	21	2.27	1.68	2.05	3.02	
D.C. Cook	2	PWR	WCK201	W	4	19	1.47	1.28	1.73	2.81	
Callaway		PWR	PCL101	P	8	19	1.06	0.70	2.05	3.02	
Callaway		PWR	WCL101	W	4	19	3.03	0.98	1.73	2.81	Yes
Comanche Peak	1	PWR	PCP101	P	4	19	0.38	-0.15	1.73	2.81	
Crystal River	3	PWR	PCR301	P	4	21	1.46	1.03	1.73	2.81	
Crystal River	3	PWR	WCR301	W	4	26	1.12	1.00	1.73	2.81	
Crystal River	3	PWR	WHSS66	W	4	26	0.71	-0.78	1.73	2.81	
Crystal River	3	PWR	WHSSCR	W	3	26	0.77	0.06	1.55	2.71	
Connecticut Yankee		ex-PWR	PCTY02	P	3	21	0.17	-0.45	1.55	2.71	
Duane Arnold		BWR	PDAC01	P	3	21	0.66	0.39	1.55	2.71	
Duane Arnold		BWR	WDAC01	W	3	19	0.14	-0.32	1.55	2.71	
Davis Besse		PWR	WDB101	W	5	26	2.01	0.32	1.84	2.88	
Diablo Canyon	1	PWR	PDC103	P	3	21	-0.53	-1.24	1.55	2.71	
Diablo Canyon	1	PWR	WDC101	W	3	26	1.14	-0.69	1.55	2.71	
Diablo Canyon	2	PWR	PDC201	P	8	21	0.21	-0.04	2.05	3.02	
Diablo Canyon	2	PWR	WDC201	W	4	26	0.54	-0.15	1.73	2.81	
Dresden	2	BWR	PDR201	P	5	21	-0.23	-1.56	1.84	2.88	

General Information							Type D Deviation (Outlier Test)				
Plant Name	Unit	Reactor Type	Heat	Product Form	n	σ [°F]	$R_{(max1)}$	$R_{(max2)}$	C_1	C_2	Fails Test?
Dresden	3	BWR	PDR301	P	6	21	0.49	-0.20	1.93	2.93	
Dresden	3	BWR	WDR301	W	5	26	1.01	0.43	1.84	2.88	
Farley	1	PWR	PFA101	P	8	21	1.39	1.20	2.05	3.02	
Farley	1	PWR	WFA101	W	4	26	0.38	-0.46	1.73	2.81	
Farley	2	PWR	PFA201	P	8	21	1.92	1.22	2.05	3.02	
Farley	2	PWR	WFA201	W	4	19	-2.12	-2.13	1.73	2.81	
Fort Calhoun		PWR	PFC101	P	5	21	0.03	-0.11	1.84	2.88	
Fort Calhoun		PWR	WFC101	W	4	26	0.59	0.32	1.73	2.81	
FitzPatrick		BWR	PFTZ01	P	6	21	-0.03	-0.16	1.93	2.93	
Ginna		PWR	FGIN01	F	4	19	2.19	1.10	1.73	2.81	
Ginna		PWR	WGIN01	W	4	26	1.17	0.58	1.73	2.81	
H.B. Robinson	2	PWR	WHB201	W	3	26	0.96	0.05	1.55	2.71	
Indian Point	3	PWR	WIP301	W	3	26	1.90	1.54	1.55	2.71	
Kewaunee		PWR	FKWE01	F	4	19	-0.04	-0.05	1.73	2.81	
Kewaunee		PWR	WKWE01	W	4	26	1.10	0.74	1.73	2.81	
McGuire	1	PWR	PMC101	P	8	21	1.98	1.16	2.05	3.02	
McGuire	1	PWR	WMC101	W	4	26	0.54	-0.68	1.73	2.81	
McGuire	2	PWR	FMC201	F	8	20	1.52	0.13	2.05	3.02	
McGuire	2	PWR	WMC201	W	4	19	1.32	0.14	1.73	2.81	
Millstone	1	ex-BWR	PML101	P	4	21	0.43	0.18	1.73	2.81	
Millstone	2	PWR	PML201	P	5	21	1.94	1.09	1.84	2.88	
Millstone	2	PWR	WML201	W	3	26	-0.27	-1.13	1.55	2.71	
Maine Yankee		ex-PWR	PMY_01	P	6	21	2.36	1.58	1.93	2.93	
Maine Yankee		ex-PWR	SHSS01	SRM	17	21	1.48	0.96	2.37	3.24	
Maine Yankee		ex-PWR	WMY_01	W	4	26	0.05	-0.12	1.73	2.81	
North Anna	1	PWR	FNA101	F	6	20	0.88	-0.65	1.93	2.93	
North Anna	1	PWR	WNA101	W	3	26	2.07	0.94	1.55	2.71	
North Anna	2	PWR	FNA201	F	6	20	-0.12	-0.17	1.93	2.93	
North Anna	2	PWR	WNA201	W	3	26	-0.59	-0.63	1.55	2.71	
Nine Mile Point	1	BWR	PNM101	P	5	21	0.05	-0.24	1.84	2.88	
Oconee	1	PWR	SHSS02	SRM	64	21	1.47	1.40	2.83	3.62	
Oconee	1	PWR	WOC101	W	3	26	0.87	0.31	1.55	2.71	
Oconee	2	PWR	FOC201	F	5	19	0.94	0.00	1.84	2.88	

General Information							Type D Deviation (Outlier Test)				
Plant Name	Unit	Reactor Type	Heat	Product Form	n	σ [°F]	$R_{(max1)}$	$R_{(max2)}$	C_1	C_2	Fails Test?
Oconee	2	PWR	WOC201	W	3	26	-0.09	-1.17	1.55	2.71	
Oconee	3	PWR	FOC301	F	4	19	0.37	0.16	1.73	2.81	
Oconee	3	PWR	FOC302	F	3	19	2.53	0.98	1.55	2.71	
Oconee	3	PWR	WOC301	W	4	26	0.89	-1.03	1.73	2.81	
Oyster Creek		BWR	PCPR02	P	4	21	0.48	-0.17	1.73	2.81	
Oyster Creek		BWR	PEP2JP	P	5	19	0.86	0.12	1.84	2.88	
Oyster Creek		BWR	WGG_01	W	4	19	0.62	-0.32	1.73	2.81	
Oyster Creek		BWR	WML101	W	6	26	0.07	-0.70	1.93	2.93	
Oyster Creek		BWR	WQC102_1	W	4	26	1.14	1.02	1.73	2.81	
Oyster Creek		BWR	WQC201_1	W	4	26	1.16	1.03	1.73	2.81	
Oyster Creek		BWR	WRB_01	W	3	19	2.27	1.87	1.55	2.71	Yes
Palisades		PWR	PPAL01	P	7	21	0.11	-0.48	2	2.98	
Palisades		PWR	WPAL01	W	4	26	0.21	0.07	1.73	2.81	
Point Beach	1	PWR	PPB101	P	4	21	1.08	1.03	1.73	2.81	
Point Beach	1	PWR	WPB101	W	4	26	-0.46	-1.58	1.73	2.81	
Point Beach	2	PWR	FPB201	F	4	19	1.06	0.94	1.73	2.81	
Point Beach	2	PWR	WPB201	W	4	26	0.00	0.00	1.73	2.81	
Prairie Island	1	PWR	FPI101	F	8	19	0.77	0.77	2.05	3.02	
Prairie Island	1	PWR	WPI101	W	4	26	0.89	-0.43	1.73	2.81	
Prairie Island	2	PWR	FPI201	F	8	20	0.56	0.11	2.05	3.02	
Prairie Island	2	PWR	WPI201	W	4	26	0.57	-0.47	1.73	2.81	
Quad Cities	1	BWR	PQC101	P	6	21	0.74	0.60	1.93	2.93	
Quad Cities	1	BWR	WQC101	W	4	26	0.63	-0.63	1.73	2.81	
Quad Cities	2	BWR	PQC201	P	4	21	-0.11	-0.38	1.73	2.81	
Quad Cities	2	BWR	WQC201	W	4	26	1.07	0.81	1.73	2.81	
Davis Besse		PWR	PRS101	P	3	21	-0.05	-0.12	1.55	2.71	
Davis Besse		PWR	WRS101	W	3	26	-0.26	-0.36	1.55	2.71	
Salem	1	PWR	PSA101	P	3	21	0.91	0.01	1.55	2.71	
Salem	2	PWR	PSA201	P	8	21	1.58	1.20	2.05	3.02	
Salem	2	PWR	WSA201	W	4	26	-0.12	-0.24	1.73	2.81	
Seabrook	1	PWR	PSB101	P	4	19	1.39	1.19	1.73	2.81	
Saint Lucie	1	PWR	PSL101	P	5	21	-0.55	-0.72	1.84	2.88	
Saint Lucie	1	PWR	WSL101	W	3	26	-0.28	-0.68	1.55	2.71	

General Information							Type D Deviation (Outlier Test)				
Plant Name	Unit	Reactor Type	Heat	Product Form	n	σ [°F]	$R_{(max1)}$	$R_{(max2)}$	C_1	C_2	Fails Test?
Saint Lucie	2	PWR	PSL201	P	3	21	2.02	-0.01	1.55	2.71	
San Onofre	2	PWR	PSO201	P	3	21	0.02	-0.10	1.55	2.71	
San Onofre	3	PWR	PSO301	P	3	19	2.43	2.34	1.55	2.71	Yes
Sequoyah	1	PWR	FSQ101	F	8	20	2.37	1.73	2.05	3.02	
Sequoyah	1	PWR	WSQ101	W	4	26	1.39	1.31	1.73	2.81	
Sequoyah	2	PWR	FSQ201	F	8	20	1.57	1.36	2.05	3.02	
Sequoyah	2	PWR	WSQ201	W	4	26	3.62	1.44	1.73	2.81	Yes
South Texas	1	PWR	PST101	P	4	19	0.71	0.59	1.73	2.81	
South Texas	2	PWR	PST201	P	4	19	0.67	0.39	1.73	2.81	
Surry	1	PWR	PSU101	P	3	21	0.80	0.02	1.55	2.71	
Surry	1	PWR	WSU101	W	3	26	1.88	1.58	1.55	2.71	Yes
Surry	2	PWR	PSU201	P	6	21	0.55	0.47	1.93	2.93	
Surry	2	PWR	WSU201	W	3	26	0.00	-0.58	1.55	2.71	
Three Mile Island	1	PWR	PTM101	P	3	21	0.38	-1.29	1.55	2.71	
Turkey Point	3	PWR	SASTM	SRM	26	21	1.98	1.94	2.53	3.36	
Turkey Point	3	PWR	WTP301	W	4	26	1.30	0.36	1.73	2.81	
Trojan		ex-PWR	PTRO01	P	6	21	0.74	0.14	1.93	2.93	
Trojan		ex-PWR	WTRO01	W	3	19	0.77	0.55	1.55	2.71	
Votgle	1	PWR	PVO101	P	6	19	0.70	0.56	1.93	2.93	
Votgle	1	PWR	WVO101	W	3	19	0.67	-0.02	1.55	2.71	
Votgle	2	PWR	PVO201	P	6	19	-0.17	-0.23	1.93	2.93	
Votgle	2	PWR	WVO201	W	3	19	-0.17	-0.49	1.55	2.71	
Virgil Summer	1	PWR	PVS101	P	8	21	0.12	-0.15	2.05	3.02	
Virgil Summer	1	PWR	WVS101	W	4	19	0.95	0.16	1.73	2.81	
Watts Bar	1	PWR	FWB101	F	4	20	0.94	0.85	1.73	2.81	
Wolf Creek	1	PWR	PWC101	P	8	19	1.10	0.88	2.05	3.02	
Wolf Creek	1	PWR	WWC101	W	4	19	1.20	1.20	1.73	2.81	
Waterford	3	PWR	PWF301	P	3	19	0.53	-0.87	1.55	2.71	
Zion	1	ex-PWR	PZN101	P	8	21	0.43	0.33	2.05	3.02	
Zion	1	ex-PWR	WZN101	W	5	26	0.31	0.02	1.84	2.88	
Zion	2	ex-PWR	PZN201	P	6	21	1.20	0.27	1.93	2.93	
Zion	2	ex-PWR	WZN201	W	3	26	0.66	0.04	1.55	2.71	