VIRGINIA ELECTRIC AND POWER COMPANY
RICHMOND, VIRGINIA 23261

September 25, 1997

United States Nuclear Regulatory Commission
Attention: Document Control Desk
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Docket No.	50-280
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Gentlemen:

VIRGINIA ELECTRIC AND POWER COMPANY
SURRY POWER STATION UNITS 1 AND 2
GENERIC LETTER (GL) 92-01 REVISION 1, SUPPLEMENT 1
RESPONSE TO NRC REQUEST FOR ADDITIONAL INFORMATION

On May 22, 1997, the NRC provided a closeout letter for Surry Power Station's response to GL 92-01, "Reactor Vessel Structural Integrity," Revision 1, Supplement 1. This letter requested that Virginia Electric and Power Company (Virginia Power) provide an assessment of the application of the ratio procedure, as described in Position 2.1 of Regulatory Guide 1.99, Revision 2 (May 1988), to the Surry Units 1 and 2 pressure-temperature limit curves and the Low Temperature Overpressure Protection System (LTOPS) setpoints. This assessment is provided as Enclosure 1.

As described in the enclosure, the current licensing basis pressure-temperature limit curves and LTOPS setpoints remain bounding through the end of the current license period even when using the ratio procedure. However, as the enclosed evaluation documents, Virginia Power has questions regarding the statistical validity of the ratio procedure and considers an alternate method for quantifying the potential effects of chemical composition variability on the mean transition temperature shift for beltline material SA-1526 as a more technically accurate approach. The approved pressure-temperature limit curves and LTOPS setpoints also remain bounding when this alternate method is applied.

Please contact us if you have any questions or require additional information.

Very truly yours,

James P. O'Hanlon

James P. O'Hanlon
Senior Vice President - Nuclear

A028

Enclosure

Commitments made by this letter: None

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Mr. R. A. Musser
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Surry Power Station

Enclosure

Response to NRC Request for Additional Information
Generic Letter 92-01 Revision 1, Supplement 1
Reactor Vessel Structural Integrity
Surry Units 1 and 2

1.0 PURPOSE

This engineering evaluation has been prepared in response to the NRC Request for Additional Information (RAI) (1) on the Virginia Power responses (2) (6) to Generic Letter (GL) 92-01 Revision 1 Supplement 1 (3). References (2) and (6) were submitted to the NRC by References (4) and (5). In their response (1) to the Reference (4) and (5) submittals, the NRC concluded that "...the staff considers the RPV (reactor pressure vessel) integrity data for the Surry Power Station to be complete ..." but went on to discuss an April 30, 1996 meeting at which representatives of the Babcock and Wilcox Owners Group (BWOG) presented the bases for the conclusions in the Reference (2) topical report. At this meeting, the staff informed the BWOG representatives that the bases were inadequate to support the conclusion that the Regulatory Guide (RG) 1.99 Revision 2 Position 2.1 "ratio procedure" need not be applied to the class of welds fabricated with Linde 80 weld flux.

The RG 1.99 Rev. 2 Position 2.1 ratio procedure adjusts measured values of transition temperature shift for weld metal fabricated from a particular heat of weld wire to account for differences between the measured chemical composition (i.e., copper and nickel concentrations) of individual surveillance samples and the average chemical composition of the reactor vessel beltline weld material. Position 2.1 requires the ratio procedure to be performed when there is "clear evidence that the copper or nickel content of the surveillance weld differs from that of the vessel weld." At the April 30, 1996 meeting, the utility representatives indicated their understanding that this requirement was established to accommodate utilities whose plant-specific surveillance programs did not include weld metal fabricated from the same heat of weld wire as the limiting beltline material (i.e., the beltline material which is predicted to experience the most limiting transition temperature shift). The BWOG representatives disagreed with the practice of using the RG 1.99 Rev. 2 Position 1.1 correlation to modify measured transition temperature shift data obtained from samples fabricated from the same heat of weld wire as the reactor vessel beltline material. Such modification, it was argued, is unnecessary since the unmodified transition temperature shift measurements obtained from samples fabricated from a single heat of weld wire already represent unbiased estimators of the mean transition temperature shift for beltline welds fabricated from the same heat of weld wire. Application of the ratio procedure to measured transition temperature shift values obtained from surveillance specimens fabricated from the same heat of weld wire multiplies the effects of uncertainty associated with (a) the measurement of surveillance specimen chemical composition, (b) the calculation of the mean beltline weld chemical composition, (c) the determination of the initial (unirradiated) value of RT_{NDT} (i.e., the Reference Temperature for the Nil Ductility Transition) and (d) the correlation of transition temperature shift with bulk chemical composition. (There is a substantial and growing pool of evidence that transition temperature shift is more closely correlated with the concentration of copper in solid solution, rather than bulk copper.) Evidence was presented which demonstrated that the standard deviation of measured transition temperature shift data points about the best-fit line determined in accordance with RG 1.99 Rev. 2 Position 2.1, without application of the ratio procedure, is less than the standard deviation specified in the RG 1.99 Rev. 2 margin term which accounts for uncertainty in the mean transition temperature shift. Thus, the margin term included in Position 2.1 transition temperature shift calculations already accommodates the effects of chemical composition variability in surveillance specimens fabricated from the same heat of weld wire as the beltline material. If the ratio procedure were appropriately compensating for transition temperature shift variability resulting from chemical composition variability, the modified measured transition temperature shift data would converge upon the central limit defined by the best-estimate transition temperature shift line. However, the utility representatives demonstrated that application of the ratio procedure caused an increase, rather than the expected decrease, in the standard deviation of transition temperature shift data about the best-fit line. The meeting was concluded with BWOG representatives indicating that the owners group would consider performing additional work, and would consider submitting another topical report for NRC review.

On March 6, 1997, a meeting was held to further discuss NRC concerns regarding reactor vessel beltline material chemical composition variability, and to identify mutually acceptable methods for addressing the NRC's concerns. The meeting was attended by NRC staff and industry representatives from GPU Nuclear, Duke Power, Virginia Power, and Framatome Technologies, Inc. (FTI). The March 6 meeting was precipitated by the NRC's request that GPU Nuclear utilize the Regulatory Guide 1.99 Revision 2 ratio procedure in the determination of RT_{NDT} for GPU's limiting beltline material, SA-1526. RT_{NDT} is a key input to calculations of reactor coolant system pressure-temperature limit curves and Low Temperature Overpressure Protection System (LTOPS) setpoints and, hence, has a direct bearing on Technical Specification limits and operational margins. GPU Nuclear's response to this request was of particular interest to Virginia Power because SA-1526 is the second most limiting reactor vessel material for Surry Units 1 and 2 in terms of RT_{NDT}. SA-1526 is the most limiting material in the Surry vessels in terms of RT_{PTS} (i.e., the Pressurized Thermal Shock Reference Temperature). Neither GPU Nuclear, Duke Power, nor Virginia Power utilized the ratio procedure in licensing basis analyses which demonstrate compliance with 10 CFR 50.61 (i.e., the "PTS Rule") or with 10 CFR 50 Appendix G (i.e., normal operation pressure-temperature limits and LTOPS setpoints).

At this meeting, representatives from GPU Nuclear presented additional information concerning the statistical and physical validity of the RG 1.99 Revision 2 ratio procedure as a means for quantifying and accommodating the effects of variation in beltline material chemical composition in RT_{NDT} and RT_{PTS} calculations. The utility representatives were unsuccessful at ascertaining the technical basis for the applicability of the ratio procedure to materials fabricated from the same heat of weld wire, or even for the ratio procedure in general. NRC staff members concluded that some form of compensatory action is necessary to ensure that the margin of safety inherent in Regulatory Guide 1.99 Revision 2 is maintained. Mr. Barry Elliott of NRC staff suggested that licensees are expected to either apply the ratio procedure as specified in RG 1.99 Revision 2, or to provide an acceptable alternative approach for quantifying and accommodating the effects of reactor vessel beltline and surveillance weld chemical composition variability.

On May 22, 1997, the NRC issued a GL 92-01 Rev. 1 Supp. 1 "close-out letter" applicable to Surry Units 1 and 2. Although the Reference (2) report concluded that the ratio procedure need not be applied to Linde 80 weld materials, Reference (2) quantified the effects of applying the ratio procedure in 10 CFR 50.61 Pressurized Thermal Shock (PTS) screening calculations. The NRC found this evaluation to be acceptable, and concluded that application of the ratio procedure did not cause RT_{PTS} values to exceed to the 10 CFR 50.61 screening criteria. However, no evaluation of the effects of the ratio procedure on pressure-temperature limit curves and LTOPS setpoints was provided in Reference (2), so the NRC has requested that an evaluation of these effects be performed (1).

Therefore, to directly address the NRC's request for additional information on the Virginia Power response to GL 92-01 Rev. 1 Supp. 1, an assessment of the impact of the ratio procedure on Virginia Power's current licensing basis pressure-temperature limit curve and LTOPS setpoint calculations has been performed. However, because the industry continues to have questions about the validity of the RG 1.99 Revision 2 Position 2.1 ratio procedure method for modifying measured transition temperature shift data, this technical evaluation includes a critique of the ratio procedure, and proposes an alternative approach for quantifying and accommodating the effects of reactor vessel beltline and surveillance weld chemical composition variability for the Surry Units 1 and 2 Linde 80 reactor vessel weld materials.

2.0 BACKGROUND

2.1 Identification of Welds and Weld Wires

Each type of weld wire used in the fabrication of a reactor vessel or surveillance specimen is given an identification number, called the "weld wire heat" number. For example, the limiting beltline weld material for Surry Units 1 and 2 in terms of RT_{PTS} was fabricated with weld wire heat number 299L44. The limiting Surry beltline weld material in terms of RT_{NDT} was fabricated with weld wire heat number 72445.

The weld wire and welding flux combination is also identified by a number called the "weld identification number." For the Surry Unit 1 lower shell longitudinal weld fabricated with weld wire heat number 299L44, the weld identification number is SA-1526. For the Surry Unit 1 intermediate-to-lower shell circumferential weld fabricated with weld wire heat number 72445, the weld identification number is SA-1585.

Reactor vessel beltline welds fabricated with the same weld wire but with different lots of welding flux are given unique weld identification numbers. For example, the Three Mile Island Unit 1 reactor vessel beltline contains WF-25 and SA-1526; both were fabricated with weld wire heat number 299L44, but different lots of welding flux were used. The Point Beach Unit 1 reactor vessel materials surveillance program includes SA-1263, which was fabricated with the same weld wire as SA-1585, but with a different lot of welding flux. Because weld flux has been shown to be "neutral" in terms of its impact on beltline or surveillance material chemical composition and microstructure, WF-25 and SA-1526 surveillance specimens are considered to be interchangeable in terms of their ability to provide information about the material condition of reactor vessel beltline materials fabricated with weld wire heat number 299L44. Similarly, SA-1585 and SA-1263 are considered interchangeable in terms of their ability to provide information about the material condition of reactor vessel beltline materials fabricated with weld wire heat number 72445.

2.2 Chemical Composition of Beltline and Surveillance Materials

The reactor vessel materials surveillance programs required by 10 CFR 50 Appendix H were designed to provide information about the effects of radiation on reactor vessel beltline materials. The material samples included in the surveillance program capsules were selected on the basis of their chemical composition to represent the beltline material predicted to experience the largest shift in 30 ft-lb transition temperature. Surveillance materials were not extracted from the reactor vessel beltline; rather, they were fabricated from the same type of weld wire used in the fabrication of the reactor vessel beltline.

Except in a few rare instances, reactor vessel beltline materials have not been sampled to obtain direct information about their chemical composition. If a reactor vessel beltline weld were repeatedly sampled and subjected to chemical analysis, the chemical composition of the reactor vessel beltline weld could be assumed to be described by the resulting distribution (mean and standard deviation) of copper and nickel concentrations. RG 1.99 Revision 2 Position 1.1 specifies that the reactor vessel beltline material should be inferred to be *the mean* (i.e., average) *of the measured values for a plate or forging or for weld samples made with the weld wire heat number that matches the critical vessel weld.* This engineering approximation of a beltline material's chemical composition simplifies RG 1.99 Revision 2 Position 1.1 transition temperature shift calculations. The margin of safety inherent in RG 1.99 Rev. 2 Position 1.1 calculations is maintained so long as the standard deviation of chemical composition measurements does not exceed that which is accommodated by the Position 1.1 margin term.

2.3 Copper Variation Within and Among Spools of Weld Wire

Weld wire is coated with copper to prevent oxidation of the wire during storage. The thickness of the copper coating on a particular spool of weld wire heat number, e.g. 299L44, may differ from the copper coating on another spool of weld wire heat number 299L44. Moreover, the thickness of copper coating on a particular spool of weld wire heat number 299L44 may vary along the length of the weld wire. Depending on the size of the weld, more than one spool of wire may be used in the fabrication of a particular reactor vessel weld. More than one spool of wire may have been used in the fabrication of a particular surveillance weld. Even if the surveillance specimen weld and the reactor vessel weld were both fabricated from a single spool of wire, variation in copper coating thickness along the length of the wire could introduce a difference between the measured copper concentration of the surveillance material and the beltline material. The implications of this postulated variation are clear: (a) a particular surveillance weld specimen may not have the same copper concentration as a particular sample of beltline material fabricated from the same weld wire heat number, and (b) the measured values of radiation-induced 30 ft-lb transition temperature shift obtained from a particular surveillance specimen may not be representative of the transition temperature shift experienced by a particular sample of beltline material fabricated from the same weld wire heat number.

2.4 Determination of RT_{NDT} Per RG 1.99 Revision 2

ASME Section XI Appendix G correlates the fracture toughness of a reactor pressure vessel steel with the Reference Temperature for the Nil Ductility Transition, RT_{NDT}. RT_{NDT} may be thought of as a conservative estimate of the temperature at which a material transitions from brittle failure at lower material temperatures to ductile failure at higher test temperatures. RT_{NDT} is defined as:

$$RT_{NDT} = I + \Delta RT_{NDT} + M$$

where I is the initial value of RT_{NDT} determined in accordance with Paragraph NB-2331 of Section III of the ASME Boiler and Pressure Vessel Code; ΔRT_{NDT} is the change in RT_{NDT} due to irradiation; and M is a margin term which accounts for uncertainty in the initial value of RT_{NDT} and in the correlation which predicts ΔRT_{NDT}. M is defined as:

$$M = 2\,(\sigma_I^2 + \sigma_\Delta^2)^{1/2}$$

where σ_I is the standard deviation for the initial RT_{NDT}, based either on the precision of the test method or on the standard deviation obtained from the set of data used to establish the mean value of initial RT_{NDT}. σ_Δ is a conservative estimate of the standard deviation of transition temperature shift (i.e., ΔRT_{NDT}) estimates obtained from the RG 1.99 Rev. 2 Position 1.1 transition temperature shift correlation (described below). Position 1.1 specifies that σ_Δ is 28°F for welds and 17°F for base metal, but further specifies that σ_Δ need not exceed 0.50 times the mean value of ΔRT_{NDT}.

2.5 Transition Temperature Shift Correlation (RG 1.99 Rev. 2 Position 1.1)

ΔRT_{NDT} is calculated as the difference between the temperature at which an irradiated material specimen absorbs 30 ft-lb of energy in a Charpy impact test, and the temperature at which an unirradiated Charpy specimen absorbs 30 ft-lb of energy. The temperature at which a tested surveillance specimen absorbs 30 ft-lb of energy is often called the 30 ft-lb transition temperature, where "transition" is referring to the relatively abrupt transition between brittle failure at lower test temperatures, and ductile failure at higher test temperatures.

Regulatory Guide 1.99 Revision 2 Position 1.1 presents a correlation of the change in 30 ft-lb transition temperature of reactor pressure vessel steels (i.e., ΔRT_{NDT}) as a function of neutron fluence (E > 1 MeV), copper concentration, and nickel concentration. In the absence of measured values of 30 ft-lb transition temperature shift, a licensee can estimate the change in 30 ft-lb transition temperature for a particular reactor vessel beltline material by providing the correlation with estimates of the neutron fluence, and the mean copper and nickel concentrations of the reactor vessel beltline material. The actual value of ΔRT_{NDT} for a beltline material will be within $\pm 2\sigma_\Delta$, or 56°F, of the predicted value of ΔRT_{NDT} with 95% probability and confidence when measurement and calculational uncertainties associated with neutron fluence, copper concentration, and nickel concentration for the beltline material are no greater than those associated with the ΔRT_{NDT} data which constitute the RG 1.99 Revision 2 ΔRT_{NDT} correlation. The standard deviations for the fluence and chemical composition of surveillance data which constitute the RG 1.99 Rev. 2 Position 1.1 transition temperature shift correlation have been historically assumed to be 20% fluence (DG-1053, "Calculational and Dosimetry Methodology for Determination of Pressure Vessel Fluence") and 0.03 wt% copper or nickel (SECY 82-465, "Pressurized Thermal Shock," Section E-4.1, "Determination of RT_{NDT} for Plant for Comparison with Screening Criteria").

2.6 Use of Surveillance Data (RG 1.99 Rev. 2 Position 2.1)

If two or more credible measured values of 30 ft-lb transition temperature shift are available from a reactor vessel materials surveillance program, RG 1.99 Revision 2 provides guidance for using this data to derive a material-specific best-estimate 30 ft-lb transition temperature shift correlation. A chemistry factor (CF) for credible surveillance data is obtained by performing a least squares fit with the following functional form:

$$\Delta RT_{NDT} = (CF)\ f^{(0.28 - 0.1 \log f)}$$

where f is the neutron fluence (E > 1 MeV, $x10^{19}$ n/cm^2). The credibility of surveillance data is determined on the basis of the proximity of the measured 30 ft-lb transition temperature shift value to the best-estimate (i.e., least squares fit) ΔRT_{NDT} line determined in the manner described above. The margin of safety inherent in RG 1.99 Rev. 2 is maintained when variation in measured values of transition temperature shift about the best estimate ΔRT_{NDT} line is no greater than that accommodated by the RG 1.99 Rev. 2 margin terms (i.e., standard deviations for measured ΔRT_{NDT} values about the best-estimate line of 28°F for welds, and 17°F for base metal). This requirement is satisfied by the RG 1.99 Rev. 2 Section B "credibility criteria," which stipulate that the scatter of ΔRT_{NDT} values about a best-fit line drawn as described in Position 2.1 normally should be less than one standard deviation (i.e., less than 28°F for welds and 17°F for base metal), and certainly less than two standard deviations when the fluence range of the data is large (i.e., two or more orders of magnitude). These requirements are consistent with standard statistical evaluation practices for distributions of data which may be assumed to be normal. (When statistics are derived from a normal distribution, 66% of the values will fall within one standard deviation (1σ) of the mean, and 95% of the values will fall within two standard deviations (2σ) of the mean.)

If the material from which the 30 ft-lb transition temperature shift data were derived is the "same material" as the reactor vessel beltline material which the licensee is attempting to describe with the surveillance data, the material-specific best-estimate 30 ft-lb transition temperature shift correlation is independent of the beltline material chemical composition, and is a function of neutron fluence alone. Surveillance materials have historically been assumed to be the "same material" as the reactor vessel beltline material when they were fabricated with weld wire of the same weld wire heat number. This assumption has been called into question by NRC staff after observing that surveillance welds fabricated with a particular heat of weld wire exhibited variations in chemical composition in excess of what staff expected. As a result, NRC staff is concerned that measured values of ΔRT_{NDT} from a particular surveillance specimen may not be indicative of, or may not conservatively represent, the actual value of ΔRT_{NDT} experienced by the beltline material. Such concerns may be well-founded if (a) the chemical composition distribution (mean and standard deviation) of a sample of surveillance materials fabricated from a particular heat of weld wire is not representative of the chemical composition distribution for a reactor vessel beltline material fabricated from the same heat of weld wire, (b) the difference between the beltline and surveillance weld chemical composition distributions results in a difference in transition temperature shift, and (c) the resulting difference in transition temperature shift reduces the margin of safety inherent in RG 1.99 Rev. 2 estimates of 30 ft-lb transition temperature for a given heat of weld wire.

2.7 Chemistry Factor Ratio Procedure

RG 1.99 Rev. 2 Position 2.1 provides guidance for the use of reactor vessel materials surveillance program data (i.e., measured values of 30 ft-lb transition temperature shift) when there is clear evidence that the chemical composition of the surveillance material is different from the chemical composition of the reactor vessel beltline material which the licensee is attempting to describe with the surveillance data. If the measured copper and nickel concentrations of surveillance material are lower than the copper and nickel concentrations of the beltline material, the transition temperature shift predicted by the RG 1.99 Revision 2 Position 1.1 correlation for the surveillance material will be less than the transition temperature shift predicted by the correlation for the beltline material. Conversely, if the measured chemical compositions of the surveillance material are higher than the chemical composition of the beltline material, the predicted transition temperature shift for the surveillance material will be greater than the predicted shift for the beltline material. A measure of predicted transition temperature shift as a function of copper and nickel concentrations is provided by RG 1.99 Revision 2 Position 1.1 in the form of tabulated Chemistry Factors (CFs). These CFs are the "fitting coefficients" for the transition temperature shift data which constitute the RG 1.99 Revision 2 Position 1.1 ΔRT_{NDT} correlation. The CF values are numerically equivalent to the predicted mean transition temperature shift at an accumulated neutron fluence (E > 1 MeV) of $1x10^{19}$ n/cm^2. Chemistry factors for the Surry Units 1 and 2 surveillance weld materials are presented in Attachments 1 and 2 in order of descending predicted transition temperature shift (i.e., in order of descending CF).

The RG 1.99 Revision 2 Position 2.1 ratio procedure directs the licensee to "scale up" or "scale down" the measured transition temperature shift value obtained from surveillance specimens by multiplying each value by the ratio of the tabulated CF *for the reactor vessel beltline weld material average copper and nickel concentrations* to the tabulated CF *for the surveillance specimen copper and nickel concentrations.* Typically, a chemical analysis is performed for each analyzed surveillance capsule. Therefore, the measured value of transition temperature shift from each surveillance capsule is scaled by a "capsule-specific CF ratio" based on the measured chemical composition for the surveillance specimens and the mean chemical composition of the reactor vessel beltline weld material. Once adjusted, the measured values of transition temperature shift are used to obtain the material-specific CF as previously described in Section 2.6.

Position 2.1 does not provide guidance regarding what constitutes "clear evidence" of a difference between the chemical compositions of a surveillance and beltline material. The broadest interpretation of what constitutes "clear evidence" is any difference between a point estimate of a beltline material's chemical composition (i.e., a chemical composition measurement for a surveillance specimen fabricated from a particular heat of weld wire) and the mean chemical composition of the beltline material (i.e., the average of available surveillance specimen chemical composition measurements). Under this interpretation, there are virtually no circumstances under which the ratio procedure would not be required by Position 2.1 to be applied, since measured surveillance specimen chemical compositions will rarely be identical to the mean chemical composition determined for a beltline material fabricated from a particular heat of weld wire.

Until recently, both NRC and industry held a narrower interpretation of what constituted "clear evidence." Specifically, if chemical composition measurements were obtained from surveillance materials fabricated from a particular heat of weld wire, then these chemical composition measurements were assumed to be unbiased estimators of the average chemical composition of a beltline material fabricated from the same heat of weld wire. Under this assumption, there would be virtually no circumstances under which the ratio procedure would need to be applied. However, if surveillance and beltline materials were fabricated from different heats of weld wire, then it could not be assumed that transition temperature shift measurements obtained from the surveillance materials could be applied to the limiting beltline material without some kind of "translation." The ratio procedure was originally instituted in RG 1.99 Rev. 2 Position 2.1 as an attempt to facilitate translation of plant-specific reactor vessel materials surveillance program results to the limiting beltline material when the plant-specific surveillance program did not include the most limiting beltline material. This historical perspective suggests that the narrower interpretation of what constitutes "clear evidence" is more consistent with the original intent of RG 1.99 than more recent interpretations.

3.0 IMPACT OF RATIO PROCEDURE ON SURRY REACTOR VESSEL MATERIALS

3.1 Surry Unit 1 Circumferential Weld Material SA-1585

The most limiting material for Surry Units 1 and 2 in terms of RT_{NDT} is the Surry Unit 1 circumferential weld material SA-1585. Available surveillance data for this material are presented in Attachment 1. There is little evidence of chemical composition differences between beltline and surveillance materials fabricated with weld wire heat number 72445. Therefore, the ratio procedure need not be applied to these materials. However, as the following evaluation demonstrates, the ratio procedure would provide an analytical benefit if it were applied to these materials.

Application of the RG 1.99 Revision 2 ratio procedure to available surveillance data for SA-1585 causes the chemistry factor to decrease from 149.2°F to 141.4°F; the associated end-of-license (EOL) value of RT_{NDT} at the ¼-T location decreases from 228.4°F to 218.7°F. Because the 228.4°F value of RT_{NDT} was utilized in the development of pressure-temperature limit curves and LTOPS setpoints valid to EOL, application of the ratio procedure (with other analytical inputs constant) would permit an increase in the cumulative neutron fluence (n/cm^2), and hence the cumulative core burnup (in units of Effective Full Power Years; EFPY) to which the Surry Unit 1 pressure-temperature limit curves and LTOPS setpoints are valid. For example, the existing Surry Unit 1 pressure-temperature limit curves and LTOPS setpoints are based on an RT_{NDT} of 228.4°F, and are valid to a cumulative neutron fluence of 3.96×10^{19} n/cm^2, which corresponds to a cumulative core burnup of 28.8 EFPY. Application of the ratio procedure to SA-1585 results in an RT_{NDT} of 228.4°F at a cumulative neutron fluence of 5.25×10^{19} n/cm^2, which corresponds to a cumulative core burnup of 38.5 EFPY. These calculations do not include the effects of Surry Unit 1 flux reduction implemented beginning with Surry 1 Cycle 13.

Application of the ratio procedure causes the end-of-license-renewal (EOLR) RT_{PTS} value for SA-1585 to decrease from 276.6°F (based on an estimate of the EOLR fluence which does not include the effects of flux reduction) to 264.5°F; the applicable screening criterion is 300°F.

3.2 Surry Unit 1 Longitudinal Weld Material SA-1526

Available surveillance data for SA-1526 are presented in Attachment 2. Application of the ratio procedure causes the chemistry factor for SA-1526 to increase from 217.0°F to 232.7°F. This causes the end-of-license (EOL) RT_{NDT} at the ¼-T location for SA-1526 to increase from 203.9°F to 215.5°F. Application of the ratio procedure does not cause the EOL RT_{NDT} at the ¼-T location for SA-1526 to exceed that of SA-1585 (i.e., 228.4°F). Therefore, SA-1585 continues to be the most limiting material for Surry Units 1 and 2 pressure-temperature limits and LTOPS setpoint considerations. These calculations do not consider the effects of Surry Unit 1 flux reduction implemented beginning with Surry 1 Cycle 13.

Application of the ratio procedure causes the end-of-license (EOL) RT_{PTS} value for SA-1526 to increase from 248.8°F (based on an estimate of the EOL fluence which does not include the effects flux reduction) to 262.5°F; the applicable screening criterion is 270°F. The end-of-license-renewal (EOLR)

RT_{PTS} value for SA-1526 increases from approximately 261.7°F (based on an estimate of the EOLR fluence which *includes* the effects flux reduction) to 276.3°F; the applicable screening criterion is 270°F. Thus, if the ratio procedure is not applied and credit is taken for Surry Unit 1 fluence reduction, SA-1526 is projected to meet the applicable PTS screening criterion at EOLR.

3.3 Surry Unit 2 Circumferential Weld Material R-3008

The most limiting material for Surry Unit 2 in terms of RT_{NDT} at the ¼-T location is the Rotterdam weld material R-3008 (weld wire heat number 0227). As the Reference (6) evaluation demonstrates, there is little evidence of chemical composition differences between beltline and surveillance materials fabricated with weld wire heat number 0227. (See Table 2-6 of Reference (6).) Therefore, the ratio procedure need not be applied to these materials. Application of the ratio procedure to these materials would not cause the Surry Unit 2 weld material R-3008 to become more limiting than the Surry Unit 1 circumferential weld material SA-1585.

4.0 EVALUATION OF THE RG 1.99 REVISION 2 RATIO PROCEDURE

When there are observed differences between the *measured chemical composition of surveillance materials fabricated from a particular heat of weld wire* and the *inferred mean chemical composition of a beltline material fabricated from the same heat of weld wire*, there are four alternative approaches for quantifying and accommodating the impact of these differences on transition temperature shift assessments for the beltline material:

1. **Apply the Ratio Procedure:** Modify measured values of transition temperature shift to accommodate differences in beltline and surveillance material chemical composition on the basis of general trends in transition temperature shift with chemical composition documented in RG 1.99 Rev. 1 Position 1.1.

2. **Apply Selection Criteria:** Apply selection criteria to eliminate surveillance results obtained from surveillance specimens which are considered to not be representative of the beltline material.

3. **Use All Data But Assess Margin of Safety:** Use all surveillance specimens fabricated from the same heat of weld wire as the beltline material, regardless of chemical composition variability, but demonstrate that the margin of safety inherent in RG 1.99 Rev. 2 calculations is not diminished by the observed variability.

4. **Rank Surveillance Results Per Position 1.1:** Rank surveillance results (i.e., measured values of transition temperature shift) in order of descending RG 1.99 Rev. 2 Position 1.1 Chemistry Factor (CF). Calculate the highest CF implied by surveillance data in the manner prescribed by RG 1.99 Rev. 2 Position 2.1 by first considering only those surveillance results which are projected by Position 1.1 to experience the highest transition temperature shift (i.e., highest CF). Incorporate surveillance results with lower projected transition temperature shift (i.e., lower CF) only if the results cause the CF calculated in accordance with Position 2.1 to be higher.

Although the ratio procedure appears to provide a straight-forward means of accommodating chemical composition differences, significant problems with the underlying assumptions of the ratio procedure have been identified which call into question the statistical validity of the procedure. These problems, as well as the alternative approaches, are described below.

4.1 Application of the Ratio Procedure

The ratio procedure assumes that, because transition temperature shift has been correlated with bulk chemical composition, bulk chemical composition is the cause of transition temperature shift. Application of the ratio procedure under this assumption introduces the effects of chemical composition measurement and sampling uncertainty, and uncertainty in RG 1.99 Rev. 2 Position 1.1 predictions of transition temperature shift into measured values of transition temperature shift. The ratio procedure gives undue consideration to the statistical relationship between changes in transition temperature and bulk chemical composition, while it gives insufficient consideration to the physical relationship between surveillance and beltline materials fabricated from the same heat of weld wire.

The RG 1.99 Revision 2 Position 1.1 shift correlation is based on transition temperature shift data from surveillance materials with a broad spectrum of chemical compositions. The ratio procedure invokes the correlation's general trend with chemical composition to make adjustments to measured values of transition temperature for welds made from a particular heat of weld wire. Ostensibly, this procedure is performed to "correct," or at least "reduce," biases in measured values of transition temperature shift introduced by chemical composition differences by driving measured values of transition temperature shift toward the true mean transition temperature shift. However, the procedure erroneously assumes that, because transition temperature shift has been *correlated* with bulk chemical composition, bulk chemical composition is the *cause* of observed transition temperature shift. Although the Position 1.1 correlation can be used to obtain *conservative* estimates of transition temperature shift (through application of a margin term to achieve a desired degree of conservatism), the correlation cannot be used to make *accurate* corrections to measured values of transition temperature shift. Such treatment of measured data is contrary to accepted statistical practices.

The ratio procedure introduces error into measured values of transition temperature shift through its reliance on bulk chemical composition as the sole predictor of radiation-induced transition temperature shift. There is a substantial and growing pool of evidence which suggests that transition temperature shift of high-copper-content Linde 80 weld materials is governed by the concentration of copper in "solid solution" rather than by the bulk chemical composition (which includes precipitates and other microstructural formations). Thus, the ratio procedure diminishes the predictive capability of surveillance data by introducing an embrittlement theory not necessarily supported by surveillance data. If the Surry Units 1 and 2 surveillance materials contain a lower proportion of copper in solid solution (vs. bulk copper) than other materials considered in the development of the RG 1.99 Rev. 2 Position 1.1 transition temperature shift correlation, application of the ratio procedure could amplify the effect of bulk chemical composition differences, when these chemical composition differences had little effect on transition temperature shift behavior. Figures 1 and 2 in Attachment 4 illustrate the tendency of the RG 1.99 Rev. 2 Position 1.1 transition temperature shift calculations, which are based on the best-estimate bulk copper and nickel concentrations, to over-estimate transition temperature shift for the Surry Units 1 and 2 surveillance materials at higher fluences. This tendency has been observed for other B&W Owners Group integrated surveillance program materials, and is suggestive of the phenomena related to copper in solid solution described above.

The ratio procedure introduces the uncertainty and/or bias associated with RG 1.99 Revision 2 Position 1.1 transition temperature shift predictions into measured values of transition temperature shift. For example, the tabulated chemistry factor values presented in RG 1.99 Rev. 2 represent the predicted transition temperature shift at $1x10^{19}$ n/cm^2. The appropriateness of applying the ratio procedure to measured values of transition temperature shift at fluences other than $1x10^{19}$ n/cm^2 has not been demonstrated. Without application of the ratio procedure, surveillance specimens fabricated from the same heat of weld wire as the reactor vessel beltline material are unbiased estimators of the mean transition temperature shift of the beltline material.

The ratio procedure makes two erroneous assumptions concerning surveillance and beltline material chemical composition. First, it assumes that a surveillance material's copper and nickel concentrations are *identical* to the single measurements performed as part of the surveillance capsule analysis. Thus, ratio procedure introduces uncertainty associated with the measurement technique and with limited sampling (i.e., uncertainty due to variation in the spatial distribution of copper within a specimen). Second, the ratio procedure assumes that a beltline material's copper and nickel concentrations are *identical* to the average copper and nickel concentrations for the weld wire heat number associated with the vessel weld and surveillance weld. This simplifying assumption introduces an additional source of uncertainty which is not inherent in measured values of transition temperature shift. The effects of these uncertainties are compounded by the uncertainty associated with the Position 1.1 transition temperature shift correlation when chemistry differences (i.e., between beltline and surveillance materials) are translated into transition temperature shift differences.

As Figures 3 through 6 in Attachment 4 demonstrate, application of the ratio procedure increases the standard deviation of the ΔRT_{NDT} function based on surveillance data. Thus, there is no corroborating evidence that transition temperature shift measurements which have been adjusted by the ratio procedure are converging upon the mean transition temperature shift. For the reasons described above, this behavior is not unexpected, and is indicative that the ratio procedure fails to account for differences in transition temperature shift between surveillance and beltline materials that are attributable to differences in chemical composition between the surveillance and beltline materials.

In summary, Virginia Power concludes that the ratio procedure introduces additional uncertainty from several sources into measured values of transition temperature shift as a result of assuming that, because transition temperature shift is *correlated* with bulk chemical composition, bulk chemical composition is the *cause* of transition temperature shift. These sources include chemical composition measurement uncertainty, chemical composition sampling uncertainty, simplifying analysis assumptions, and uncertainty in the RG 1.99 Revision 2 transition temperature shift correlation. Although the Regulatory Guide 1.99 Revision 2 ΔRT_{NDT} correlation's tendency toward higher transition temperature shift for higher copper and nickel concentrations is undisputed, use of the correlation to modify measured values of transition temperature shift is inappropriate.

4.2 Application of Selection Criteria

RG 1.99 Revision 2 Position 2.1 states that the ratio procedure should be applied *if there is clear evidence that the copper and nickel content of the surveillance weld differs from that of the vessel weld.* However, if there is clear evidence that the copper and nickel content of the surveillance weld differs from that of the vessel weld, the surveillance weld is not representative of the vessel weld, and should not be used to assess its material condition.

Accepted statistical practices recommend the exclusion of data points which are not considered to be randomly selected observations constituting a subset of the total population under observation. In essence, this principle states that the probability of making an incorrect inference about a population when a data point has been retained, but is believed to not be representative of the population under observation, is greater than the probability of making an incorrect inference about the population under observation when the suspect data point has been eliminated from the set of observations. On this basis, one would conclude that transition temperature shift data obtained from surveillance specimens which are not representative of the reactor vessel beltline material should not be utilized to infer the material condition of the beltline material.

Position 2.1 provides no guidance for licensees to determine what constitutes *clear evidence* that *the copper or nickel content of the surveillance weld differs from the average for the weld wire heat number associated with the vessel weld and surveillance weld.* However, the Position 2.1 directive could be interpreted to require either:

(a) statistical evidence that *individual* surveillance material copper and nickel concentration measurements are significantly different from the *mean* copper and nickel concentrations of a reactor vessel beltline weld,

(b) statistical evidence that the *mean* copper and nickel concentrations of a set of surveillance materials are significantly different from the *mean* copper and nickel concentrations of a reactor vessel beltline weld,

(c) statistical evidence that the *mean* copper and nickel concentrations of a *subset* of the available surveillance data are significantly different from the *mean* copper and nickel concentrations of a reactor vessel beltline weld,

(d) statistical evidence that the *standard deviations* of copper and nickel concentration measurements for a set of surveillance materials are significantly different from the *standard deviations* of copper and nickel concentration measurements for a reactor vessel beltline weld (even if there is insufficient evidence to conclude that the surveillance and beltline weld mean chemical compositions are not significantly different, as described in (b) above), or

(e) anecdotal evidence that differences in the weld wire, coating, welding procedure, specimen fabrication, or any other relevant weld feature may have resulted in differences between the beltline and surveillance material chemical compositions.

If there is insufficient evidence, from any of the above perspectives, to conclude that surveillance specimens fabricated from a particular heat of weld wire are not representative of a beltline material fabricated from the same heat of weld wire, it must be concluded that there is no "clear evidence" of differences in chemical composition as required by RG 1.99 Rev. 2 Position 2.1, and that the ratio procedure need not be applied. Under these circumstances, data from surveillance specimens may be used, unmodified, to assess the material condition of the beltline material.

Application of selection criteria is not proposed for Surry Units 1 and 2. However, a statistical evaluation has been performed using the approach described in (a) above to demonstrate how a statistical basis might be documented to support the exclusion of non-representative data. This evaluation is presented in Attachment 2 for SA-1526. The evaluation suggests that the Surry Unit 1 Capsules T and V SA-1526 surveillance specimens may not be representative of the larger population of SA-1526 weld material on the basis of their observed chemical compositions. The hypothesis that the mean copper concentration for SA-1526 (excluding Surry Unit 1 Capsules T and V) is significantly different from that previously determined (on the basis of surveillance weld and nozzle belt dropout measurements) could not be conclusively rejected on the basis of the surveillance data presented in Attachment 2. Regardless of these statistical evaluations, Virginia Power has concluded that differences in bulk chemical composition, by themselves, provide insufficient evidence to reject the hypothesis that measured values of transition temperature shift from available surveillance materials are unbiased estimators of the mean 30 ft-lb transition temperature shift for a beltline material fabricated from the same heat of weld wire.

4.3 Assessment of RG 1.99 Rev. 2 Margin of Safety When All Data is Used

As described in Section 2.5 of this technical evaluation, the conservatism of Position 1.1 ΔRT_{NDT} calculations (i.e., based on the ΔRT_{NDT} correlation) is contingent upon the standard deviation of chemical composition measurements being within the margin accommodated by the Position 1.1 margin term. Section 2.6 of this technical evaluation describes the manner by which measured values of 30 ft-lb transition temperature shift obtained from surveillance materials fabricated from a particular heat of weld wire may be used to derive a best-estimate 30 ft-lb transition temperature shift function which is a function of fluence only ($\Delta RT_{NDT}(f)$). When surveillance results are used in this manner to perform RG 1.99 Revision 2 Position 2.1 transition temperature shift calculations, the margin of safety inherent in RG 1.99 Rev. 2 calculations is maintained so long as the variation (i.e., standard deviation) of measured transition temperature shift data points about the best-fit line determined in accordance with RG 1.99 Rev. 2 Position 2.1 is less than the standard deviation specified in the RG 1.99 Rev. 2 margin term to account for uncertainty in the mean transition temperature shift (i.e., σ_Δ). This determination is typically made by application of the RG 1.99 Rev. 2 Section B credibility criteria. The credibility criteria are independent of surveillance material chemical composition. Therefore, chemical composition variability among surveillance specimens fabricated from a particular heat of weld wire directly impacts the conservatism of Position 1.1 calculations, whereas it is only of secondary importance to Position 2.1 calculations. Application of the credibility criteria is sufficient to ensure the conservatism of Position 2.1 ΔRT_{NDT} calculations, provided there is insufficient evidence to reject the hypothesis that measured values of transition temperature shift obtained from specimens fabricated from a particular heat of weld wire are unbiased estimators of the mean transition temperature shift for a beltline material fabricated from the same heat of weld wire. Again, measurements of surveillance specimen bulk chemical composition provide insufficient evidence to reject this hypothesis.

4.4 Observation of Transition Temperature Shift Data

Sections 2.6 and 4.3 demonstrate that the margin of safety inherent in RG 1.99 Revision 2 Position 2.1 calculations of transition temperature shift is maintained by application of the RG 1.99 Rev. 2 Section B credibility criteria. Despite what is claimed to be higher-than-expected variability among measured values of chemical composition for a particular heat of weld wire, the standard deviation of transition temperature shift data about a best-fit ΔRT_{NDT} line determined in accordance with RG 1.99 Revision 2 Position 2.1 is significantly less than the standard deviation associated with the RG 1.99 Revision 2 Position 1.1 transition temperature shift correlation (i.e., 28°F). (See Figures 3 through 6 in Attachment 4. The standard deviation of transition temperature shift data about a best-fit ΔRT_{NDT} line is calculated as the sum of the squares of the differences between the data points and the best-fit line, divided by the number of data points used in the determination of the best fit line minus 1.) Thus, the transition temperature shift behavior of the surveillance materials used to assess the material condition of the Surry Units 1 and 2 beltline welds suggests that the surveillance and beltline materials are, in fact, the "same material." Application of the ratio procedure to measured values of transition temperature shift for SA-1526 causes the standard deviation of the data to exceed the 28°F standard deviation specified in the RG 1.99 Rev. 2 Section B credibility criteria. Therefore, it is concluded that application of the ratio procedure reduces the predictive capability of measured transition temperature shift data with no corroborating evidence that the procedure is appropriately accounting for differences in transition temperature shift which result from chemical composition variability.

5.0 ALTERNATIVE APPROACH TO ADDRESS DIFFERENCES IN CHEMISTRY

The foregoing sections demonstrate that there are significant technical questions regarding the statistical validity of the ratio procedure, and that standard statistical practices would suggest elimination, rather than modification, of non-representative data. Further, measurements of surveillance specimen bulk chemical composition provide insufficient evidence to reject the hypothesis that measured values of transition temperature shift obtained from the surveillance specimens are representative of the mean transition temperature shift for Surry Units 1 and 2 beltline welds fabricated from the same heats of weld wire. If this hypothesis is not rejected, the margin of safety inherent in RG 1.99 Rev. 2 Position 2.1 transition temperature shift calculations performed for the limiting Surry Units 1 and 2 beltline materials is maintained without inclusion of additional margins or adjustments to compensate for observed chemical composition variability. Despite these conclusions, Virginia Power was informed at the March 6, 1997 meeting with NRC staff that the issue of chemical variability within welds fabricated from a particular heat of weld wire could not be simply ignored, and that some form of compensatory action is necessary to ensure that the margin of safety inherent in Regulatory Guide 1.99 Revision 2 is maintained.

On recommendation by NRC staff, Virginia Power proposes an alternate method to compensate for the potential impact of observed surveillance material chemical composition variation on measured values of transition temperature shift. The approach preferentially considers transition temperature shift measurements obtained from surveillance specimens with the highest copper and nickel concentrations and, hence, the highest predicted transition temperature shift. Transition temperature shift measurements obtained from surveillance specimens with lower copper and nickel concentrations are incorporated into Position 2.1 transition temperature shift calculations only if such incorporation results in a higher calculated chemistry factor. Given the general trend of increasing transition temperature shift with increasing Position 1.1 chemistry factor, this procedure conservatively accounts for the potential effects on transition temperature shift of chemical composition variability among surveillance specimens fabricated from a particular heat of weld wire. The proposed procedure is as follows:

1. A best-fit line through the unmodified transition temperature shift data for surveillance materials fabricated from a particular heat of weld wire is determined in accordance with RG 1.99 Revision 2 Position 2.1. *(The RG 1.99 Revision 2 Position 2.1 calculational procedure for determining a best-fit ΔRT_{NDT} line is described in Section 2.6 of this evaluation. The best-fit line is presented in Figure 3 for SA-1526. No evaluation is performed for SA-1585 or for R-3008 because there is little evidence of chemical composition variation for these materials.)*

2. The estimated standard deviation of unmodified transition temperature shift data about the best-fit ΔRT_{NDT} line is calculated and verified to be less than the standard deviation associated with the RG 1.99 Revision 2 Position 1.1 transition temperature shift correlation (i.e., 28°F). *(The estimated standard deviation of transition temperature shift data about this best-fit line is calculated as the sum of the squares of the differences between the data points and the best-fit line, divided by the number of data points used in the determination of the best fit line minus 1. The standard deviation for unmodified data points is presented on Figure 3 for SA-1526.)*

3. If the estimated standard deviation of transition temperature shift data for a particular surveillance material is greater than 28°F, the value of σ_Δ used to calculate the margin term, M, is increased to that which is implied by the transition temperature shift data. *(The standard deviation for unmodified values of transition temperature shift about the best-fit line is much less than 28°F. See Figure 3.)*

4. Surveillance material test results (i.e., measured copper content, nickel content, neutron fluence, and transition temperature shift) are ranked in order of descending RG 1.99 Rev. 2 Position 1.1 Chemistry Factor (CF). If two or more surveillance results have the same Position 1.1 CF, these surveillance results are ranked in order of descending neutron fluence. *(The performance of this step is documented in the table presented in Attachment 2 for SA-1526.)*

5. Beginning with the surveillance material test results with the two highest calculated Position 1.1 CFs, the Position 2.1 CF is calculated in the manner described in Section 2.6. *(The performance of this step is documented in Attachment 3.)*

6. If additional surveillance results are available, the surveillance result with the next highest Position 1.1 CF is included in the data set used to determine a second CF in accordance with Position 2.1. Similarly, a third, fourth, fifth, etc. Position 2.1 CF will be determined by sequentially including the surveillance result with the next highest Position 1.1 CF, until all data have been considered. *(The performance of this step is documented in Attachment 3.)*

7. The maximum Position 2.1 CF calculated in the manner described above will be used to assess the material condition of beltline materials fabricated from the same heat of weld wire as the surveillance materials whose data was used in the CF calculations.

Using the procedure described above to account for variation in surveillance material chemical composition, a CF of 221.5°F was calculated for SA-1526. (The ratio procedure produced a CF of 232.7°F for SA-1526.) If the benefits of flux reduction are considered, the CF for SA-1526 could increase to 266.1°F without causing SA-1526 to become more limiting than SA-1585 in terms of the (EOL) value of RT_{NDT} at the ¼-T location (i.e., RT_{NDT} = 228.4°F). Even if flux reduction is not considered, the CF for SA-1526 could increase to 250.1°F, and SA-1585 would continue to be the limiting Surry 1 and 2 reactor vessel beltline material in terms of EOL RT_{NDT}. On the basis of these calculations, no modification of existing Surry Units 1 and 2 pressure-temperature limits or LTOPS setpoints is required at this time to accommodate the postulated effects of chemical composition variability.

6.0 RESULTS AND CONCLUSIONS

Virginia Power has performed an assessment of the impact of applying the ratio procedure to the limiting Surry Units 1 and 2 reactor vessel beltline materials. The limiting Surry Units 1 and 2 beltline material in terms of EOL RT_{NDT} is SA-1585, which was fabricated with weld wire heat number 72445. There is little evidence of chemical composition differences between the beltline and surveillance materials fabricated with weld wire heat number 72445. Therefore, the ratio procedure need not be applied to these materials. If the ratio procedure is applied to these materials, the chemistry factor (CF) decreases from 149.2°F to 141.4°F. Thus, application of the ratio procedure produces an analytical benefit for SA-1585. Application of the ratio procedure to SA-1526 (weld wire heat number 299L44) causes the CF for this material to increase from 217.0°F to 232.7°F. Even if the effects of flux reduction (implemented beginning with Surry Unit 1 Cycle 13) are not considered, the CF for SA-1526 could increase to 250.1°F, and SA-1585 would continue to be the limiting Surry 1 and 2 reactor vessel beltline material in terms of EOL RT_{NDT} (i.e., RT_{NDT} = 228.4°F).

Virginia Power has also performed an evaluation of the applicability of the RG 1.99 Revision 2 Position 2.1 ratio procedure to Surry Units 1 and 2 beltline weld materials. A series of technical considerations have been identified which challenge the statistical validity of the ratio procedure, and which call into question the need for Virginia Power to apply the ratio procedure. These considerations are summarized below:

1. Virginia Power has concluded that the ratio procedure introduces uncertainty from various sources into measured values of transition temperature shift as a result of assuming that, because transition temperature shift is *correlated* with bulk chemical composition, bulk chemical composition is the *cause* of transition temperature shift. Although the RG 1.99 Rev. 2 Position 1.1 correlation can be used to make *conservative estimates* of transition temperature shift on the basis of weld material bulk chemical composition, it cannot be used to make *accurate corrections* to measured values of transition temperature shift on the basis of bulk chemical composition. Application of the ratio procedure reduces the predictive capability of surveillance specimens, and introduces the effects of chemical composition measurement uncertainty, chemical composition sampling uncertainty, simplifying analysis assumptions, and uncertainty or bias in the RG 1.99 Revision 2 transition temperature shift correlation. The figures presented in Attachment 4 demonstrate that application of the ratio procedure increases the standard deviation of the ΔRT_{NDT} function based on surveillance data. These figures suggest that transition temperature shift measurements which have been adjusted by the ratio procedure are not converging as expected upon the mean transition temperature shift.

2. RG 1.99 Revision 2 Position 2.1 states that the ratio procedure should be applied *if there is clear evidence that the copper and nickel content of the surveillance weld differs from that of the vessel weld.* There are several problems with this requirement. First, RG 1.99 Revision 2 does not provide guidance regarding what constitutes "clear evidence" of a difference between the chemical compositions of a surveillance and beltline material. Second, accepted statistical practices suggest that surveillance materials which are not representative of the beltline material should be not be used to assess the material condition of the beltline weld. Finally, for

surveillance and beltline weld materials fabricated from the same heat of weld wire, differences in bulk chemical composition are insufficient basis to reject the hypothesis that measured values of transition temperature shift are unbiased estimators of the mean beltline material transition temperature shift.

3. The margin of safety inherent in RG 1.99 Rev. 2 Position 2.1 transition temperature shift calculations performed for the limiting Surry Units 1 and 2 beltline materials is maintained without inclusion of additional margins or adjustments to compensate for observed chemical composition variability. The standard deviation of transition temperature shift data about a best-fit ΔRT_{NDT} line determined in accordance with Position 2.1 of RG 1.99 Revision 2 is significantly less than the standard deviation associated with the RG 1.99 Revision 2 Position 1.1 transition temperature shift correlation (i.e., 28°F).

4. There is no evidence to reject the hypothesis that measured values of transition temperature shift obtained from available surveillance materials fabricated from a particular heat of weld wire are unbiased estimators of the mean transition temperature shift for beltline weld materials fabricated from the same heat of weld wire. On the contrary, the observed transition temperature shift behavior of the surveillance materials used to assess the material condition of the Surry Units 1 and 2 beltline welds suggests that surveillance and beltline materials are, in fact, the "same material."

It is Virginia Power's position that the unmodified measured values of transition temperature shift obtained from surveillance specimens fabricated from weld wire heat number 299L44 are unbiased estimators of the mean transition temperature shift for beltline material SA-1526. As such, it is not necessary to apply the ratio procedure, or any other procedure, to compensate for the potential effects of chemical composition variation on measured values of transition temperature shift. If NRC staff should determine that, despite the evidence presented herein, that a correction for chemical composition variation is necessary, Virginia Power proposes an alternate methodology to account for the potential effects of observed surveillance specimen chemical composition variability on the mean beltline material transition temperature shift for SA-1526. Specifically, Virginia Power proposes that measured values of transition temperature shift be considered sequentially, in order of descending Position 1.1 chemistry factor, in Position 2.1 chemistry factor calculations. This procedure conservatively maximizes the chemistry factor implied by surveillance data, and provides a conservative estimate of the mean transition temperature shift for the beltline material under consideration. The criticisms of the ratio procedure outlined above do not apply to this proposed alternate procedure.

Using the alternate procedure described above to account for the potential effects of chemical composition variation in surveillance materials, a CF value of 221.5°F was calculated for SA-1526. This value is slightly higher than that previously calculated for SA-1526 (217.0°F). This slight increase in CF does not cause SA-1526 to become more limiting than SA-1585 in terms of EOL RT_{NDT}. Because there is little evidence of chemical composition variability for SA-1585, and because application of the ratio procedure to SA-1585 would provide an analytical benefit, no modification of existing Surry Units 1 and 2 pressure-temperature limits or LTOPS setpoints is required at this time.

7.0 REFERENCES

(1) Letter from G. E. Edison (USNRC) to J. P. O'Hanlon (Virginia Power), "Closeout for Virginia Electric and Power Company Response to Generic Letter 92-0, Revision 1, Supplement 1 for Surry Power Station, Units 1 and 2 (TAC Nos. M92737 and M92738)," (Virginia Power Serial No. 97-338), dated May 22, 1997.

(2) Topical Report BAW-2257, Revision 1, "B&W Owners Group Reactor Vessel Working Group Response to Generic Letter 92-01, Revision 1, Supplement 1," Prepared by B&W Nuclear Technologies (now Framatome Technologies), dated October, 1995.

(3) NRC Generic Letter 92-01 Revision 1, Supplement 1, "Reactor Vessel Structural Integrity," dated May 19, 1995.

(4) Letter from J. P. O'Hanlon to USNRC, "Virginia Electric and Power Company, North Anna Power Station Units 1 and 2, Surry Power Station Units 1 and 2, 90-Day Response to Generic Letter 92-01, Revision 1, Supplement 1, Reactor Vessel Structural Integrity," Serial No. 95-270, dated August 10, 1995.

(5) Letter from J. P. O'Hanlon to USNRC, "Virginia Electric and Power Company, Surry Power Station Units 1 and 2, North Anna Power Station Units 1 and 2, Six-Month Response to Generic Letter 92-01, Revision 1, Supplement 1, Reactor Vessel Structural Integrity," Serial No. 95-270A, dated November 20, 1995.

(6) Topical Report BAW-2260, Revision 0, "Response to Generic Letter 92-01, Revision 1, Supplement 1, for Virginia Power's North Anna Units 1 and 2 Beltline Materials and Surry Units 1 and 2 Rotterdam Beltline Weld Materials," Prepared by B&W Nuclear Technologies (now Framatome Technologies), dated October, 1995.

(7) Topical Report BAW-1799, "B&W 177-FA Reactor Vessel Beltline Weld Chemistry Study," dated July, 1983.

Attachment 1

SA-1585 Surveillance Data

SA-1585 Surveillance Data

Pages B-42 and B-43 of BAW-1799 (7) present the results of chemical analyses performed on 30 SA-1585 nozzle belt dropout samples. Exhibit B5 on page B-46 documents that the mean copper concentration for welds fabricated with weld wire heat number 72445 is 0.21 wt% with a standard deviation of 0.03 wt%; the mean nickel concentration is 0.59 wt% with a standard deviation of 0.01 wt%. The lowest observed copper concentration in this data set was 0.18 wt%, and the highest observed copper concentration was 0.29 wt%. The lowest observed nickel concentration was 0.58 wt%, and the highest observed nickel concentration was 0.61 wt%.

The following chemical compositions and measured transition temperatures shifts were obtained surveillance specimens fabricated with weld wire heat number 72445.

IDENTIFIER	MATERIAL	Φ *	ΔTT	CU(%)	NI(%)	CF **	REFERENCE
B&WOG/PB1-T	SA-1263	2.42	180	0.22	0.66	176.9	WCAP-10736/BAW-2257 Rev. 2
B&WOG/PB1-R	SA-1263	2.38	165	0.22[1]	0.66	176.9	WCAP-10736/BAW-2257 Rev. 1
B&WOG/PB1-S	SA-1263	0.829	165	0.22[1]	0.66	176.9	WCAP-10736/BAW-2257 Rev. 1
B&WOG/PB1-V	SA-1263	0.502	110	0.22[1]	0.66	176.9	WCAP-10736/BAW-2257 Rev. 1
B&WOG/CR3-LG2	SA-1585	1.67	168	0.21	0.59	162.5	BAW-2257, Rev. 1, Page B-9
B&WOG/CR3-LG1	SA-1585	0.51	148	0.21	0.59	162.5	BAW-2257, Rev. 1, Page B-9
		MEAN EST:		0.22	0.64	***	
		STD DEV EST:		0.005	0.04		

* Fluence values are in units of 10^{19} n/cm^2

** Per RG 1.99 Revision 2 Position 1.1. Units of °F.

*** The estimated mean copper and nickel concentration for welds fabricated from weld wire heat number are 0.21 wt% and 0.59 wt%, respectively, per BAW-2257, Rev. 1, Page B-7 (2). The RG 1.99 Revision 2 Position 1.1 CF for these chemistry values is 162.5°F

[1] WCAP-10736 reports a measured chemical composition of 0.22 wt% copper and 0.66 wt% Ni for Point Beach Unit 1 Capsule T specimen WW23. Until the issuance of WCAP-10736, a copper concentration range of 0.18 wt% to 0.24 wt%, and a nickel concentration of 0.57 wt% had been reported for Point Beach Unit 1 surveillance weld SA-1263 (weld wire heat number 72445). The measured copper and nickel concentrations reported in SA-10736 for Point Beach Unit 1 Capsule T specimen WW23 have been applied herein to the four Point Beach Unit 1 surveillance capsules.

Attachment 2

Statistical Evaluation of SA-1526 Chemical Composition Data

Statistical Evaluation of SA-1526 Chemical Composition Data

The purpose of this section is to provide an example of a statistical evaluation of surveillance data applicable to the Surry Unit 1 SA-1526 beltline material. First, the evaluation applies Chauvenet's criterion to eliminate suspicious data points (i.e., measured values of transition temperature shift) on the basis of differences between individual and the average surveillance specimen chemical composition. Then the evaluation performs a hypothesis test to determine if the observed copper concentration of the remaining data points provide sufficient evidence to reject the hypothesis that the mean copper content is equal to the hypothesized value. It is recognized that Chauvenet's criterion is highly restrictive for small samples of data, and that it may reject suspicious data points too easily. A less restrictive selection criterion would result in fewer data points being identified as outliers, and would increase the likelihood that the hypothesis test, as described above, would result in a rejection of the null hypothesis. In any case, the purpose of the statistical evaluation provided in this section is only to provide an example of how selection criteria might be applied to eliminate suspicious data points. For surveillance and beltline materials fabricated from the same heat of weld wire, variation among measured values of surveillance material bulk chemical composition, by itself, provides insufficient evidence to conclude that a particular measured value of transition temperature shift is not an unbiased estimator of the mean transition temperature shift for the beltline material. For this reason, the application of selection criteria to eliminate suspicious data points is not proposed for Surry Units 1 and 2.

Application of Selection Criteria to SA-1526 Surveillance Data

Pages B-39 and B-40 of BAW-1799 (7) present the results of chemical analyses performed on 7 WF-25 surveillance welds, 41 WF-25 nozzle belt dropout samples, and 11 SA-1526 nozzle belt dropout samples. Both WF-25 and SA-1526 were fabricated with weld wire heat number 299L44. Exhibit B5 on page B-46 documents that the mean copper concentration for welds fabricated with weld wire heat number 299L44 is 0.35 wt% with a standard deviation of 0.03 wt%; the mean nickel concentration is 0.68 wt% with a standard deviation of 0.04. The lowest observed copper concentration in this data set was 0.29 wt%, and the highest observed copper concentration was 0.40 wt%. The lowest observed nickel concentration was 0.59 wt%, and the highest observed nickel concentration was 0.71 wt%.

The following chemical compositions and measured transition temperatures shifts were obtained from surveillance specimens fabricated with weld wire heat number 299L44.

IDENTIFIER	MATERIAL	Φ *	ΔTT	CU(%)	NI(%)	CF **	REFERENCE
B&WOG/TMI2-LG1	SA-1526	0.83	182	0.37	0.70	234.0	BAW-2257, Rev. 1, Page B-7
B&WOG/CR3-LG1	WF-25	0.779	214	0.35	0.70	226.5	BAW-2257, Rev. 1, Page B-7
B&WOG/TMI2-LG1	WF-25	0.968	222	0.35	0.67	222.2	BAW-2257, Rev. 1, Page B-7
B&WOG/TMI1-C	WF-25	0.866	203	0.33	0.66	213.7	BAW-2257, Rev. 1, Page B-7
B&WOG/TMI1-E	WF-25	0.107	124	0.33	0.66	213.7	BAW-2257, Rev. 1, Page B-7
B&WOG/S1-T	SA-1526	0.281	165	0.25	0.68	189.2	WCAP-11415/BAW-2257 Rev. 1
B&WOG/S1-V	SA-1526	1.94	240	0.243	0.643	181.0	WCAP-11415/BAW-2257 Rev. 1
		MEAN EST:		0.32	0.67 ***		
		STD DEV EST:		0.05	0.02		

* Fluence values are in units of 10^{19} n/cm^2

** Per RG 1.99 Revision 2 Position 1.1. Units of °F.

*** The estimated mean copper and nickel concentrations for welds fabricated from weld wire heat number 299L44 are 0.35 wt% and 0.68 wt%, respectively, per BAW-2257, Rev. 1, Page B-7 (2). The RG 1.99 Revision 2 Position 1.1 CF for these chemistry values is 223.6°F

Two of the surveillance material copper concentration data points appear to not be representative of the larger population. The mean and standard deviation of the larger population of copper concentration data for welds fabricated with weld wire heat number 299L44 may be used to determine the probability that a given observation of will deviate by a certain amount from the mean. Chauvenet's Criterion specifies that an observation may be rejected if the probability of obtaining the particular deviation from the mean is less than 1/2n, where n is the number of observations in the data set under consideration. This process of evaluation and elimination is performed only once.

For n = 7, the ratio of maximum acceptable deviation to the standard deviation, d_{MAX}/σ, is 1.80. The maximum deviations from the mean copper concentration are experienced by surveillance capsules B&WOG/S1-V (0.35-0.243)/0.03 = 3.56) and B&WOG/S1-T (0.35-0.25)/0.03 = 3.33). After elimination of these suspicious data points, estimates of the mean and standard deviation of the copper concentration for the remaining surveillance materials are calculated to be 0.346 wt% and 0.02 wt%, respectively. The observed copper concentration data provide insufficient evidence to reject the hypothesis that the mean copper concentration for SA-1526 is 0.35 wt%. (See hypothesis test on the pages which follow.) The CF for the remaining 5 data points is calculated to be 218.0°F (vs. 217.0°F for n = 7).

On the pages which follow, the selected (i.e., reduced) dataset is used to test the following hypothesis:

The mean copper concentration for SA-1526 beltline and surveillance materials is 0.35 wt%.

Hypothesis Testing for SA-1526 (Copper Concentration; Selected Dataset)

	Parameter	Description	Value
Purpose	N/A	A statistical test is being performed to reach a decision on whether to accept or reject the null hypothesis.	N/A
Type 1 Error	Alpha	A value of Alpha is selected to establish the maximum acceptable probability of a Type 1 Error. A Type 1 Error is committed if we reject the null hypothesis when it is true.	0.05
z-Alpha	ZAlpha	ZAlpha is the number of standard deviations beyond which the integrated area under a standard normal distribution equals Alpha	1.645
Rejection Region	RR	Reject the null hypothesis if the estimate of the research data mean lies more than ZAlpha standard deviations beyond the mean value represented in the null hypothesis.	N/A
Null Hypothesis	Ho	**The mean copper concentration for SA-1526 beltline and surveillance materials is 0.35 wt%.**	Ho: mean = 0.35 wt%
Alternate Hypothesis	Ha	**The mean copper concentration for SA-1526 beltline and surveillance materials is less than 0.35 wt%, based on research data.**	Ha: mean < 0.35 wt%
Standard Deviation	SD	Because it is known, the standard deviation of copper concentration is assumed to be that which was obtained for the larger population of data.	SD = 0.03 wt %
Sample Size	N	The mean of the research data was determined on the basis of 5 data points.	N = 5
Standard Deviation of the Mean	SDM	The standard deviation of the mean copper concentration is the standard deviation of the population (SD) divided by the square root of N.	SDM = 0.0134
Calculate	z	z is the number of standard deviations the estimate of the research data mean is from the mean represented in the null hypothesis.	z = (0.346 - 0.35)/0.0134 = -0.30
Type 1 Conclusion	N/A	Since the observed estimate of the research data mean lies less than 1.645 standard deviations below the mean value represented in the null hypothesis, we accept Ho and conclude that the mean copper content is equal to 0.35 wt% for SA-1526.	mean = 0.35 wt%

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Hypothesis Testing for SA-1526 (Copper Concentration; Selected Dataset)

Type 2 Error	Beta	A Type 2 Error is committed if we accept the null hypothesis when it is false and the alternate hypothesis is true. The value of Beta is calculated for each hypothesis test.	N/A
Mean under Ho	Mo	Mo denotes the hypothesized mean under the null hypothesis.	Mo = 0.35 wt%
Mean under Ha	Ma	Ma denotes the hypothesized mean under the alternate hypothesis.	Ma = 0.346 wt%
Test Statistic for Beta	TS	Beta is the probability that z is less than ZAlpha - (|Mo - Ma|)/SDM]	N/A
Calculate TS	TS	N/A	1.645 - 0.004/0.0134 = 1.35
Calculate	Beta	Beta = P[z < TS]	0.0885
Type 2 Conclusion	Beta	The probability of accepting the null hypothesis when it is false and the alternate hypothesis is true is calculated to be 8.85%.	N/A

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Summary of Chemical Composition Statistical Evaluation

The foregoing application of selection criteria to surveillance data suggest that the SA-1526 surveillance specimens from Surry Unit 1 may not be representative of the larger population of SA-1526 weld materials on the basis of their observed bulk chemical compositions. The remaining SA-1526 surveillance material chemical composition data provides insufficient evidence to conclusively reject the hypothesis that the mean copper content of the surveillance specimens is equal to the hypothesized mean copper content for the beltline weld material. There is no evidence to reject the hypothesis that measured values of transition temperature shift from available SA-1526 surveillance materials are unbiased estimators of the mean 30 ft-lb transition temperature shift for beltline materials fabricated from the same heat of weld wire.

Attachment 3

Chemistry Factor Calculations for SA-1526
in Consideration of Surveillance Material Chemical Composition Variability

SA-1526: Highest Cu and Ni Concentration

IDENTIFIER	MATERIAL	Φ	ΔTT	CU(%)	NI(%)	REFERENCE
B&WOG/TMI2-LG1	SA-1526	0.83	182	0.37	0.70	BAW-2257, Rev. 1, Page B-7
B&WOG/CR3-LG1	WF-25	0.779	214	0.35	0.70	BAW-2257, Rev. 1, Page B-7
			CF:	210.7		

SA-1526: Add Next Point In Order of Descending Cu Conc., Ni Conc, and Fluence

IDENTIFIER	MATERIAL	Φ	ΔTT	CU(%)	NI(%)	REFERENCE
B&WOG/TMI2-LG1	SA-1526	0.83	182	0.37	0.70	BAW-2257, Rev. 1, Page B-7
B&WOG/CR3-LG1	WF-25	0.779	214	0.35	0.70	BAW-2257, Rev. 1, Page B-7
B&WOG/TMI2-LG1	WF-25	0.968	222	0.35	0.67	BAW-2257, Rev. 1, Page B-7
			CF:	215.5		

SA-1526: Add Next Point In Order of Descending Cu Conc., Ni Conc, and Fluence

IDENTIFIER	MATERIAL	Φ	ΔTT	CU(%)	NI(%)	REFERENCE
B&WOG/TMI2-LG1	SA-1526	0.83	182	0.37	0.70	BAW-2257, Rev. 1, Page B-7
B&WOG/CR3-LG1	WF-25	0.779	214	0.35	0.70	BAW-2257, Rev. 1, Page B-7
B&WOG/TMI2-LG1	WF-25	0.968	222	0.35	0.67	BAW-2257, Rev. 1, Page B-7
B&WOG/TMI1-C	WF-25	0.866	203	0.33	0.66	BAW-2257, Rev. 1, Page B-7
			CF:	214.5		

SA-1526: Add Next Point In Order of Descending Cu Conc., Ni Conc, and Fluence

IDENTIFIER	MATERIAL	Φ	ΔTT	CU(%)	NI(%)	REFERENCE
B&WOG/TMI2-LG1	SA-1526	0.83	182	0.37	0.70	BAW-2257, Rev. 1, Page B-7
B&WOG/CR3-LG1	WF-25	0.779	214	0.35	0.70	BAW-2257, Rev. 1, Page B-7
B&WOG/TMI2-LG1	WF-25	0.968	222	0.35	0.67	BAW-2257, Rev. 1, Page B-7
B&WOG/TMI1-C	WF-25	0.866	203	0.33	0.66	BAW-2257, Rev. 1, Page B-7
B&WOG/TMI1-E	WF-25	0.107	124	0.33	0.66	BAW-2257, Rev. 1, Page B-7
			CF:	218.0		

SA-1526: Add Next Point In Order of Descending Cu Conc., Ni Conc, and Fluence

IDENTIFIER	MATERIAL	Φ	ΔTT	CU(%)	NI(%)	REFERENCE
B&WOG/TMI2-LG1	SA-1526	0.83	182	0.37	0.70	BAW-2257, Rev. 1, Page B-7
B&WOG/CR3-LG1	WF-25	0.779	214	0.35	0.70	BAW-2257, Rev. 1, Page B-7
B&WOG/TMI2-LG1	WF-25	0.968	222	0.35	0.67	BAW-2257, Rev. 1, Page B-7
B&WOG/TMI1-C	WF-25	0.866	203	0.33	0.66	BAW-2257, Rev. 1, Page B-7
B&WOG/TMI1-E	WF-25	0.107	124	0.33	0.66	BAW-2257, Rev. 1, Page B-7
B&WOG/S1-T	SA-1526	0.281	165	0.25	0.68	WCAP-11415/BAW-2257 Rev. 1
			CF:	221.5		

SA-1526: No Ratio Procedure, All Data

IDENTIFIER	MATERIAL	Φ	ΔTT	CU(%)	NI(%)	REFERENCE
B&WOG/TMI2-LG1	SA-1526	0.83	182	0.37	0.70	BAW-2257, Rev. 1, Page B-7
B&WOG/CR3-LG1	WF-25	0.779	214	0.35	0.70	BAW-2257, Rev. 1, Page B-7
B&WOG/TMI2-LG1	WF-25	0.968	222	0.35	0.67	BAW-2257, Rev. 1, Page B-7
B&WOG/TMI1-C	WF-25	0.866	203	0.33	0.66	BAW-2257, Rev. 1, Page B-7
B&WOG/TMI1-E	WF-25	0.107	124	0.33	0.66	BAW-2257, Rev. 1, Page B-7
B&WOG/S1-T	SA-1526	0.281	165	0.25	0.68	WCAP-11415/BAW-2257 Rev. 1
B&WOG/S1-V	SA-1526	1.94	240	0.243	0.643	WCAP-11415/BAW-2257 Rev. 1
			CF:	217.0		

Attachment 4

Figures

FIGURE 1
SA-1585 Measured Shift vs. Fluence (No Ratio Procedure)
(Curve based on Position 1.1, Best Est. [Cu]=0.21 wt%, [Ni]=0.59 wt%, CF=162.5 degrees F)

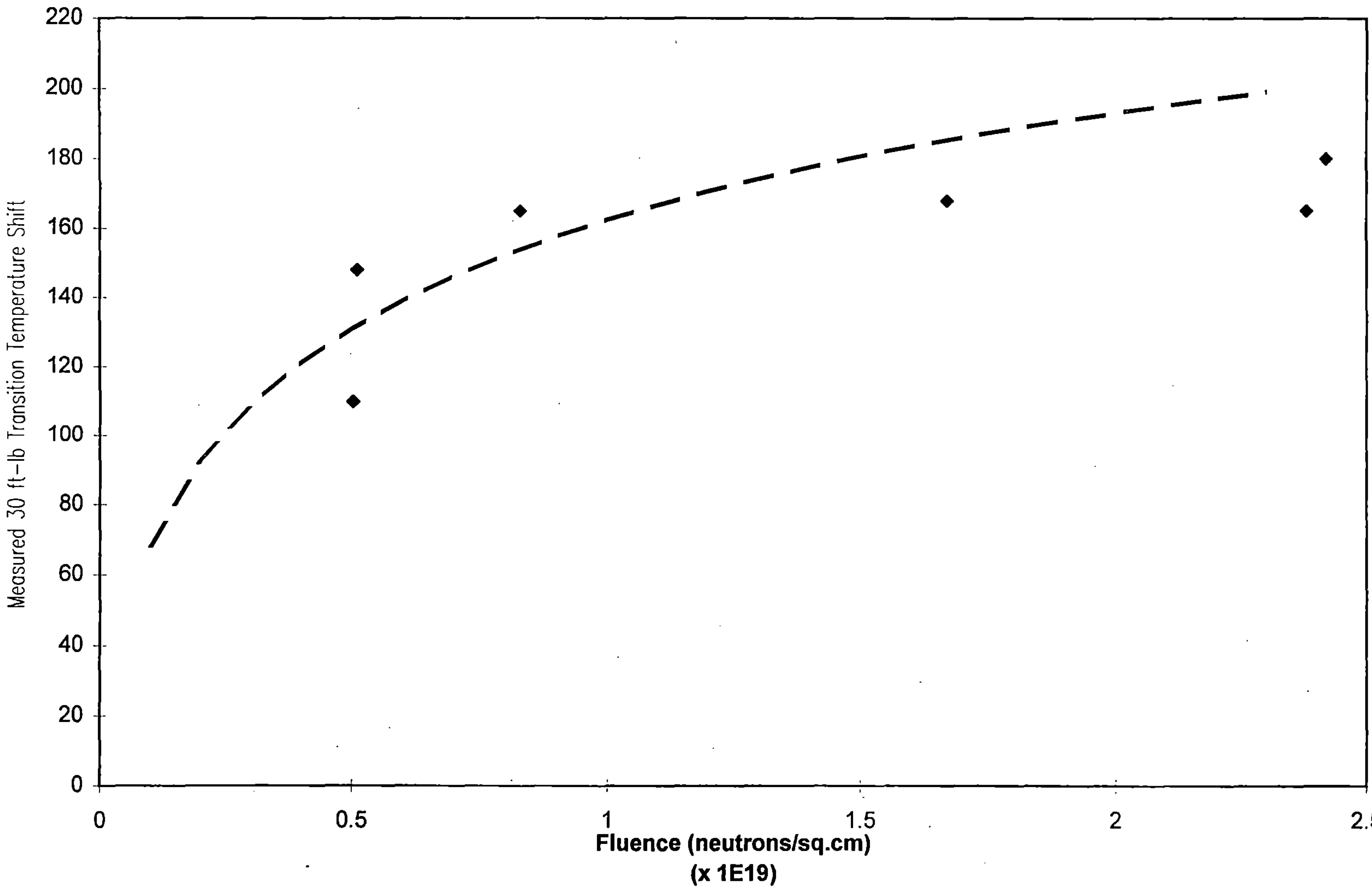

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FIGURE 2
SA-1526 Measured Shift vs. Fluence (No Ratio Procedure)
(Curve based on Position 1.1, Best Est. [Cu]=0.35 wt%, [Ni]=0.68 wt%, CF=223.6 degrees F)

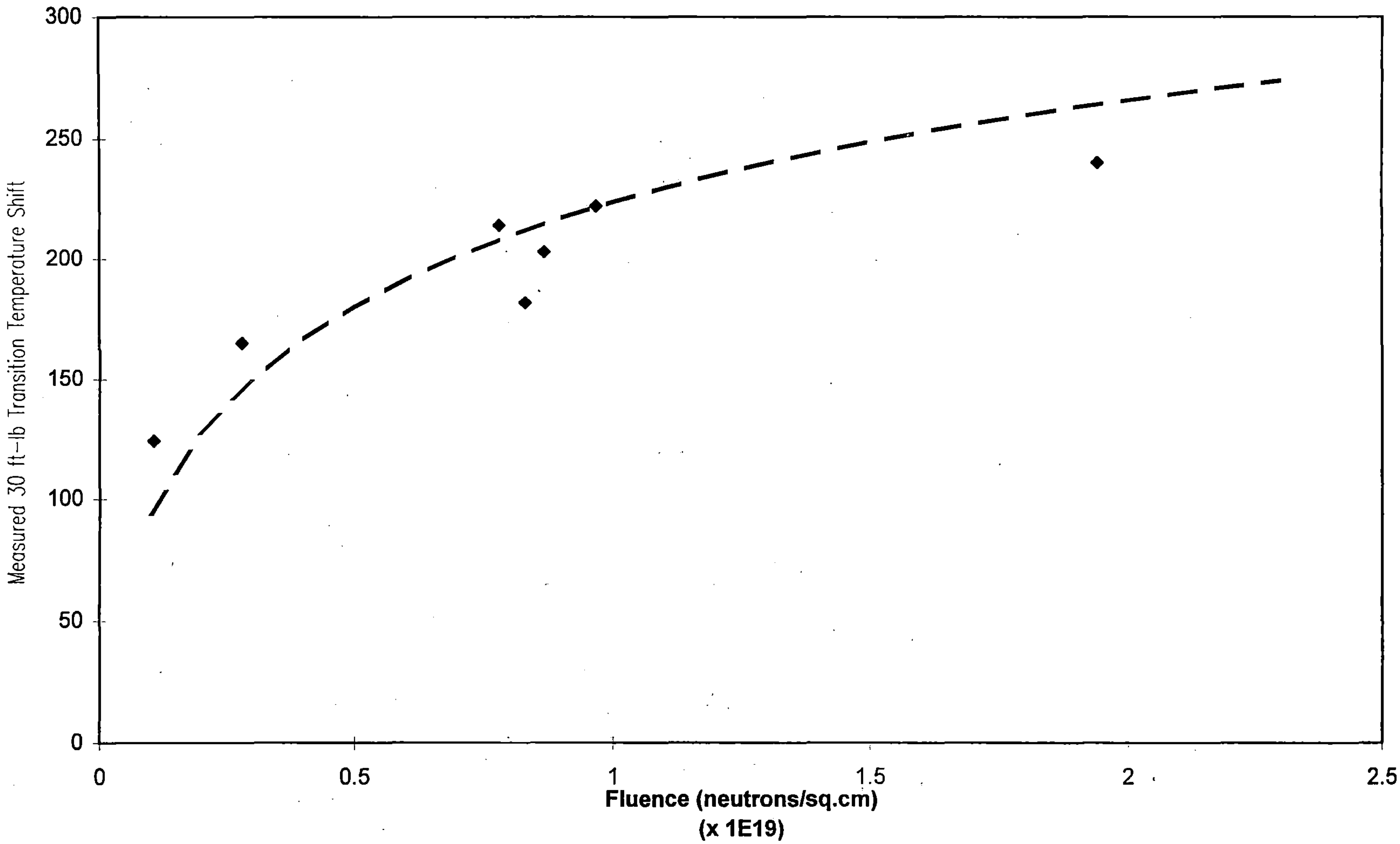

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FIGURE 3
SA-1526 Measured Shift vs. Fluence (No Ratio Procedure)
(Std. Dev. of Estimate = 20.5 degrees F)
(Curve based on Position 2.1, CF=217.0 degrees F)

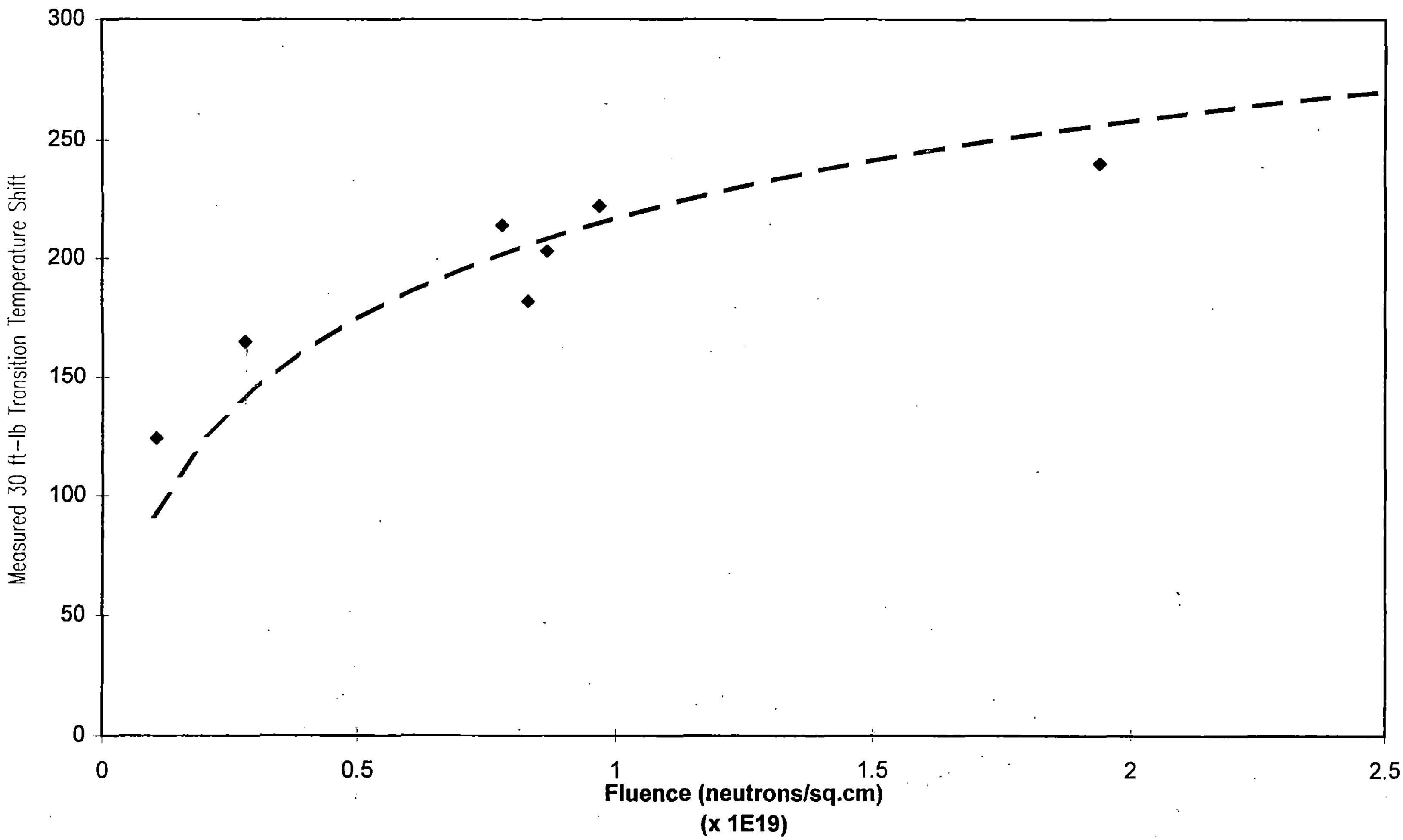

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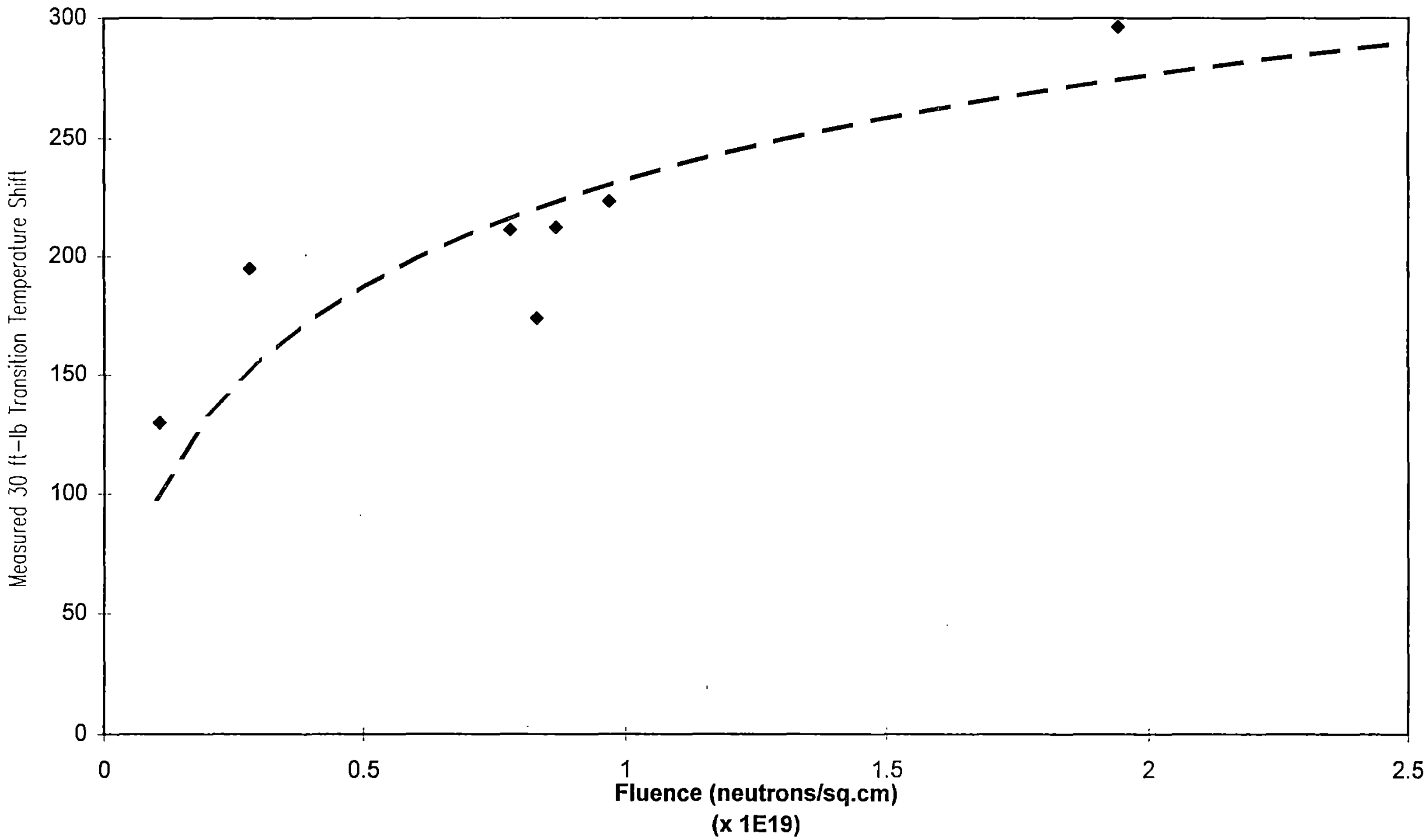
FIGURE 4
SA-1526 Measured Shift vs. Fluence (Ratio Procedure)
(Std. Dev. of Estimate = 30.4 degrees F)
(Curve based on Position 2.1, CF=232.7 degrees F)



FILE2.XLS

Figure 5 (SA-1585)

FIGURE 5
SA-1585 Measured Shift vs. Fluence (No Ratio Procedure)
(Std. Dev. of Estimate = 18.9 degrees F)
(Curve based on Position 2.1, CF=149.8 degrees F)

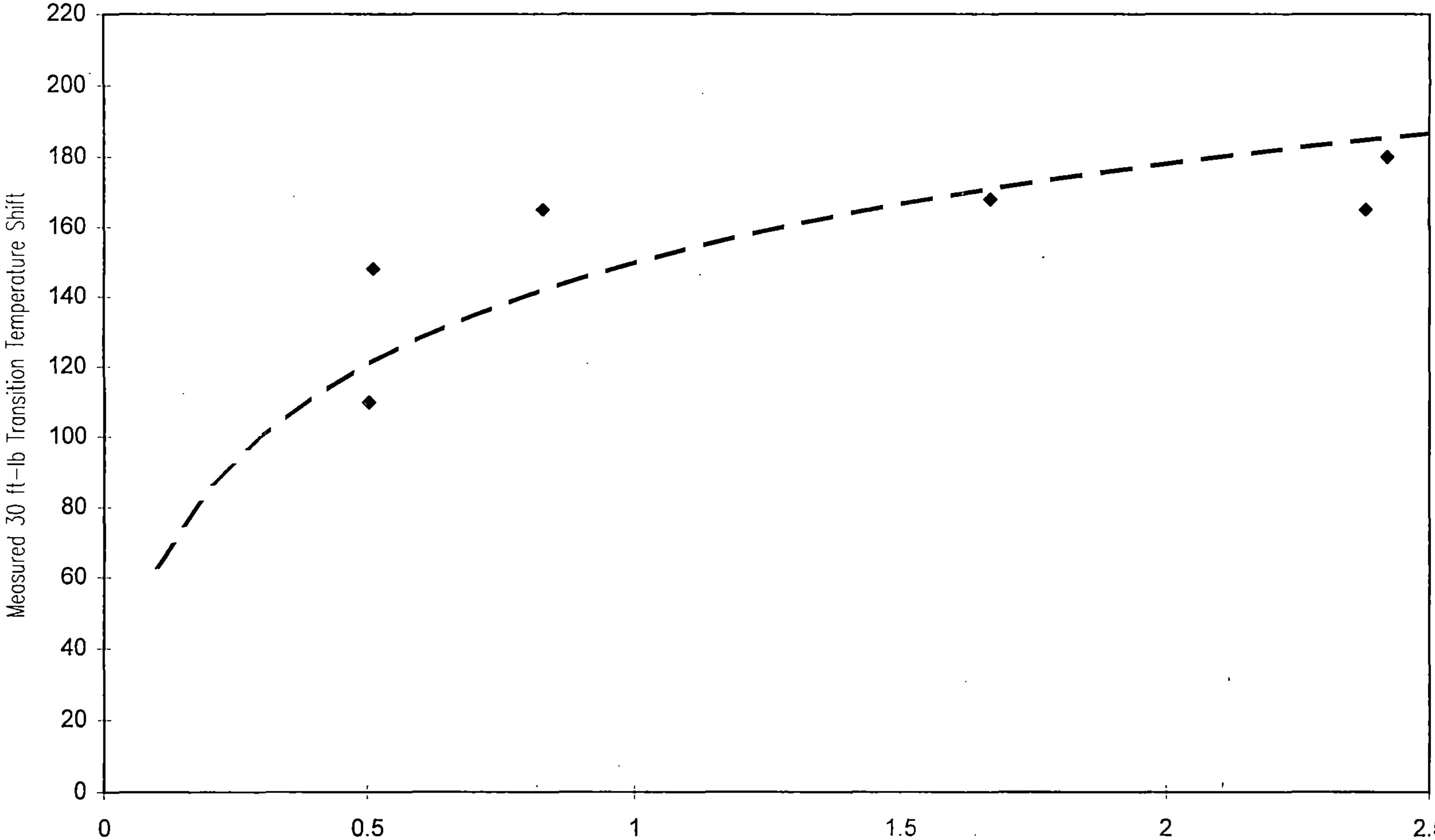


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FIGURE 6
SA-1585 Measured Shift vs. Fluence (Ratio Procedure)
(Std. Dev. of Estimate = 21.2 degrees F)
(Curve based on Position 2.1, CF=141.4 degrees F)