Generic Letter 92-01 and RPV Integrity Assessment

Status, Schedule, and Issues

Keith R. Wichman
Matthew A. Mitchell   Allen L. Hiser

Materials and Chemical Engineering Branch
Office of Nuclear Reactor Regulation

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INTRODUCTION AND STATUS

- THE STAFF HAS PURSUED GL 92-01 ACTIVITIES TO RESOLVE QUESTIONS REGARDING CHEMISTRY VALUES FOR RPV AND SURVEILLANCE MATERIALS.

- AS A RESULT OF SUPPLEMENT 1 TO THE GL, OWNERS GROUP AND VENDOR ACTIONS WERE PERFORMED TO COLLECT AND ASSESS ALL DATA FOR RPV AND SURVEILLANCE WELD MATERIALS.

  - THIS INFORMATION WAS SUBMITTED TO THE STAFF BY FRAMATOME, THE CEOG, AND THE BWROG IN JUNE, JULY, AND DECEMBER, 1997, RESPECTIVELY.

- LICENSEES WERE EXPECTED TO REVIEW THIS INFORMATION AND NOTIFY THE STAFF OF ANY CHANGES IN THEIR LICENSING BASIS FOR RPV INTEGRITY ASSESSMENTS.

INTRODUCTION AND STATUS

- THE STAFF HAS REVIEWED THE OWNERS GROUP AND VENDOR INFORMATION AND HAS NOTED THAT NOT ALL LICENSEES HAVE NOTIFIED THE STAFF OF INFORMATION WHICH COULD CHANGE THEIR FACILITY'S LICENSING BASIS.

- AS A RESULT, THE STAFF HAS DEVELOPED RAIs TO BE ISSUED SUBSEQUENT TO THIS WORKSHOP. A DRAFT RAI WAS PROVIDED TO NEI BY LETTER DATED FEBRUARY 5, 1998.

- ADDITIONALLY, THE STAFF HAS PRESENTED TOPICS TO BE CONSIDERED WHEN ASSESSING WELD CHEMISTRY DATA AND SURVEILLANCE DATA.

  - THESE CONSIDERATIONS WERE FIRST PRESENTED AT ANNRC/NEI MEETING ON NOVEMBER 12, 1997 AND WILL BE REPRISED HERE WITH MINOR MODIFICATIONS

SCHEDULE

- IN THE MEETING SUMMARY FROM THE NOVEMBER 12, 1997 MEETING, THE STAFF PUBLISHED A PRELIMINARY SCHEDULE FOR COMPLETING GL 92-01 ACTIVITIES.

- THE SCHEDULE HAS CHANGED SLIGHTLY AS NOTED BELOW:

02/28/98 - STAFF ISSUES RAIs TO CEOG AND B&WOG LICENSEES

04/15/98 - STAFF ISSUES RAIs TO BWROG LICENSEES (IF NECESSARY)

04/30/98 - CEOG AND B&WOG LICENSEES RESPOND TO RAIs

06/15/98 - BWROG LICENSEES RESPOND TO RAIs

08/31/98 - STAFF ISSUES FINAL CLOSEOUT LETTER TO LICENSEES

02/28/99 - STAFF ISSUES REVISED NUREG-1511 AND RVID

MATERIALS ISSUES AFFECTING RPV INTEGRITY ASSESSMENTS

ISSUE 1.) THE DETERMINATION OF RPV WELD (WELD WIRE HEAT) AND SURVEILLANCE WELD BEST-ESTIMATE CHEMISTRIES

- THE EVALUATION AND PROCESSING OF DATA
- CALCULATION OF A BEST-ESTIMATE AND THE USE OF GENERIC VALUES

ISSUE 2.) THE EVALUATION AND USE OF SURVEILLANCE DATA

- THE ASSESSMENT OF CREDIBILITY
- NECESSARY DATA ADJUSTMENTS(IRRADIATION TEMPERATURE, MATERIAL CHEMISTRY)
- THE USE OF IRRADIATED DATA FROM OTHER VESSELS

STAFF ISSUES REGARDING THE DETERMINATION OF WELD CHEMISTRY

THE EXCLUSION AND GROUPING OF DATA

THE SELECTION OF A HEAT-SPECIFIC BEST-ESTIMATE METHODOLOGY

THE USE OF GENERIC VALUES

REVIEW OF BEST-ESTIMATE CHEMISTRY METHODOLOGIES

SIMPLE MEAN

GROUP OR SAMPLE MEAN (MEAN-OF-THE-MEANS)

COIL-WEIGHTED MEAN

GENERIC VALUE FOR A CLASS OF MATERIAL
(COPPER COATED WELD WIRES, NICKEL ADDITION WELDS, ETC.)

TANDEM-WIRE WELD DECONVOLUTION

OTHERS

Conclusions of the Combustion Engineering Report and Framatome Inspection

Combustion Engineering

- Additional data relevant to the determination of best-estimate chemistries was integrated into and evaluated during the review process

- Several methodologies for the determination of best-estimate chemistries were considered given the available data. For the purposes of the report, a method was chosen to represent the "best-estimate" for each heat

- In some cases, generic values were chosen for either, copper, nickel, or both

CONCLUSIONS OF THE COMBUSTION ENGINEERING REPORT AND FRAMATOME INSPECTION (CONT.)

FRAMATOME

- ADDITIONAL DATA RELEVANT TO THE DETERMINATION OF BEST-ESTIMATE CHEMISTRIES WERE EVALUATED DURING THE REVIEW PROCESS

- IT WAS DETERMINED THAT THE BEST-ESTIMATE VALUES WHICH HAD BEEN USED PREVIOUSLY TO CHARACTERIZE SPECIFIC WELD-WIRE HEATS WERE ACCEPTABLE

RESULTS OF THE STAFF'S PRELIMINARY REVIEW

- IN GENERAL, THE STAFF HAS CONCLUDED THAT THE ANALYSES PRESENTED BY CEOG AND FRAMATOME PROVIDE ACCURATE OR CONSERVATIVE METHODOLOGIES FOR THE DETERMINATION OF RPV WELD BEST-ESTIMATE CHEMISTRIES

- HOWEVER, QUESTIONS NEED TO BE ADDRESSED REGARDING SOME ASPECTS OF THE CEOG AND FRAMATOME EVALUATIONS (DATA EXCLUSION, DATA GROUPING, USE OF GENERIC VALUES)

- THE ISSUES WHICH FOLLOW SHOULD BE CONSIDERED WHEN DETERMINING BEST-ESTIMATE VALUES

ACCEPTABLE METHODS OR REASONS FOR EXCLUDING DATA

A. IF THERE EXISTS AN IDENTIFIED AND RECORDED DEFICIENCY IN A DATAPOINT

- A DUPLICATE OR UNTRACEABLE RECORD, A RECORD WHICH IDENTIFIES AN ATYPICAL CONDITION OR SAMPLE LOCATION

B. IF A DATAPOINT IS IDENTIFIED AS A STATISTICAL OUTLIER AND A PHYSICAL BASIS EXISTS FOR BELIEVING THE DATAPOINT TO BE ATYPICAL

- ALL DATA NOT EXCLUDED IN (A.) SHOULD BE USED AS THE DATASET

- A PRIORI EXCLUSION OF SOME DATA BASED ON "INCONSISTENCY" WITH EXPECTED NORMS SHOULD NOT BE USED BEFORE ANALYSIS FOR STATISTICAL OUTLIERS IS CONDUCTED

ACCEPTABLE METHODS OR REASONS FOR EXCLUDING DATA (CONT.)

B. IF A DATAPOINT IS IDENTIFIED AS A STATISTICAL OUTLIER AND A PHYSICAL BASIS EXISTS FOR BELIEVING THE DATAPOINT TO BE ATYPICAL

- TESTS FOR STATISTICAL OUTLIERS SHOULD BE MORE STATISTICALLY RIGOROUS THAN CHAUVENET'S CRITERION

- IF A DATAPOINT IS SCREENED AS AN OUTLIER, ADDITIONAL PHYSICAL EVIDENCE SHOULD BE AVAILABLE BEFORE THE DATAPOINT IS REMOVED FROM THE DATASET

GROUPING OF WELD DATA

- RECENTLY AN ADDITIONAL QUESTION WAS RAISED REGARDING THE GROUPING OF WELD DATA WHEN A MEAN-OF-THE-MEANS OR COIL-WEIGHTED AVERAGE APPROACH IS USED

  - IF A WELD (OR WELDS) WERE FABRICATED AS WELD QUALIFICATION SPECIMENS BY THE SAME MANUFACTURER, WITHIN A SHORT TIME SPAN, USING SIMILAR WELDING INPUT PARAMETERS, AND USING THE SAME COIL OF WELD CONSUMABLES, IT MAY BE APPROPRIATE TO CONSIDER ALL CHEMISTRY DATA FROM THE SAMPLES FROM "ONE WELD" FOR DETERMINING "BEST-ESTIMATE" CHEMISTRIES

  - IF INFORMATION IS NOT ABLE TO CONFIRM THESE DETAILS, BEST-ESTIMATE CHEMISTRY SHOULD BE EVALUATED BOTH BY ASSUMING THE DATA CAME FROM "ONE WELD" OR FROM AN APPROPRIATE NUMBER OF "MULTIPLE WELDS"

CONSIDERATIONS WHEN DETERMINING BEST-ESTIMATE CHEMISTRIES

IN ACCORDANCE WITH THE CURRENT REGULATORY FRAMEWORK OF 10CFR50.61, THE GUIDANCE IN REGULATORY GUIDE 1.99 REVISION 2, AND PREVIOUS STAFF EVALUATIONS:

- A HEAT-SPECIFIC CHEMISTRY DETERMINATION CAN BE MADE WITH 1 OR MORE VALID DATAPOINTS FROM A WELD WIRE HEAT

- IF ONLY A LIMITED AMOUNT OF DATA ARE AVAILABLE, THE STAFF WILL CONSIDER AS PART OF IT REVIEW PROCESS THE IMPACT OF USING GENERIC COPPER AND/OR NICKEL VALUES OF THE SUBJECT CLASS OF MATERIAL

- IF NO VALID DATA ARE AVAILABLE TO DEFINE EITHER THE COPPER OR NICKEL CONTENT OF A WELD WIRE HEAT, A GENERIC MEAN VALUE PLUS ONE STANDARD DEVIATION SHOULD BE USED

CONSIDERATIONS WHEN DETERMINING BEST-ESTIMATE CHEMISTRIES (CONT.)

- SURVEILLANCE WELD CHEMISTRY SHOULD CONTINUE TO BE BASED ON THE CHEMISTRY DATA FOR THAT SPECIFIC WELD RATHER THAN THE HEAT BEST-ESTIMATE CHEMISTRY

FINALLY, THE STAFF HAS DETERMINED THAT WHEN SUFFICIENT DATA EXIST FROM MORE THAN ONE SOURCE (WELD), COIL-WEIGHTED AND MEAN-OF-THE MEANS METHODS MAY PROVIDE A MORE RELIABLE ESTIMATION OF THE HEAT-SPECIFIC CHEMISTRY. HOWEVER, JUSTIFICATION MUST BE PROVIDED FOR WHATEVER METHOD IS CHOSEN FOR THE PARTICULAR WELD WIRE HEAT.

Regulatory Impact of Changing Best-Estimate Chemistries Without Involving Surveillance Data

- **Case #1 - The limiting material remains the same but the current RT_{PTS} is nonconservative.**

Facility: XXXXXX
Surveillance Weld Heat: XXXXX [Heat is present in vessel, but does not affect limiting material]

RVID Evaluation of Limiting Materials					CEOG Evaluation of Limiting Materials				
Heat (orientation)	Cu	Ni	CF	RT_{pts}	Heat (orientation)	Cu	Ni	CF	RT_{pts}
Circ. Weld	0.170	0.920	197.8	**244.9**	Circ. Weld	0.192	1.038	224.2	**276.3**

Note: All CFs are based on RG 1.99 Rev. 2 Table determinations.

- **Case #2 - A new material becomes limiting and the RT_{PTS} value for the vessel increases.**

Facility: YYYYYY
Surveillance Weld Heat: YYYYYY [Heat not present in vessel]

RVID Evaluation of Limiting Materials					CEOG Evaluation of Limiting Materials				
Heat (orientation)	Cu	Ni	CF	RT_{pts}	Heat (orientation)	Cu	Ni	CF	RT_{pts}
Axial Weld 1	0.210	1.000	229.0	**263.7**	Axial Weld 1	0.203	1.018	226.8	261.3
Axial Weld 2	0.190	0.970	215.7	248.9	Axial Weld 2	0.219	0.996	231.1	**266.0**

Note: All CFs are based on RG 1.99 Rev. 2 Table determinations.

ALTERNATIVE METHODS FOR EVALUATION AND USE OF SURVEILLANCE DATA

- Basic Methodology for Evaluating RT_{NDT}/RT_{PTS}
- Adjustments to Surveillance Data
  - Chemical composition adjustments
  - Irradiation environment (temperature) adjustments
- Assessing Credibility
  - Data from one source
  - Data from multiple sources
- Effects of Credibility
  - Credible data
  - Non-credible data
    - Non-conservative Table CF
- Five Example Cases

BACKGROUND

- According to 10 CFR 50.61 and Reg. Guide 1.99, Rev. 2:

$$RT_{NDT} = RT_{NDT(U)} + M + \Delta RT_{NDT}$$

$RT_{NDT(U)}$ = reference temperature in unirradiated condition

M = margin term to account for uncertainties

ΔRT_{NDT} = mean value of irradiation temperature shift

$$\Delta RT_{NDT} = (CF)^{*}FF$$

where: CF = chemistry factor

FF = fluence factor = $f^{(0.28 - 0.10^{*}\log f)}$

f = best estimate neutron fluence

- 2 methods for determining CF (described in RG 1.99, Rev. 2)

Position 1.1 [Table CF]: determined from generic tables (weld and base metal) using the best-estimate copper and nickel contents for the material.

Position 2.1 [Surveillance CF]: used when 2 or more credible surveillance data points are available. CF is determined from best fit line of surveillance data (ΔRT_{NDT} versus fluence).

$$CF = \frac{\sum_{i=1}^{n}\left[A_i \times f_i^{(0.28 - 0.10 \log f_i)}\right]}{\sum_{i=1}^{n}\left[f_i^{(0.56 - 0.20 \log f_i)}\right]}$$

REQUIREMENTS AND RECOMMENDATIONS IN 10 CFR 50.61 & RG 1.99 REV. 2

Per 10 CFR 50.61(c)(2):

> "To verify that RT_{NDT} for each vessel beltline material is a ***bounding value*** for the specific reactor vessel, licensees shall consider plant-specific information that could affect the level of embrittlement. This information includes but is not limited to the ***reactor vessel operating temperature*** and any ***related surveillance program[5] results***."

Per Footnote 5:

> [5] Surveillance program results means any data that demon-strates the embrittlement trends for the limiting beltline material, including but not limited to data from test reactors or from surveillance programs at other plants with or without surveil-lance program integrated per 10 CFR Part 50 , Appendix H.

Per RG 1.99 Rev. 2 Position 2.1 and 10 CFR 50.61(c)(2)(ii)(B):

> "if there is ***clear evidence that the copper or nickel content of the surveillance weld differs from that of the vessel weld***, i.e., differs from the average for the weld wire heat number associated with the vessel weld and the surveillance weld, ***the measured values of ΔRT_{NDT} should be adjusted by multiplying them by the ratio of the chemistry factor for the vessel weld to that for the surveillance weld***"

$$Ratio\ Adjusted\ \Delta RT_{NDT} = \left(\frac{Table\ CF_{Vessel\ Chem.}}{Table\ CF_{Surv.\ Chem.}}\right) * Measured\ \Delta RT_{NDT}$$

IRRADIATION ENVIRONMENT ADJUSTMENTS

- Irradiation temperature and fluence are first order environmental variables in assessing irradiation damage
  - Other variables are believed to be less significant contributors
  - Must account for differences in temperature between surveillance specimens and vessel
- Studies have shown that for temperatures near 550°F, a 1°F decrease in irradiation temperature will result in approximately a 1°F increase in ΔRT_{NDT}

RECENT ISSUES ON USE OF SURVEILLANCE DATA

- "Best-fit line" through surveillance data (plot of ΔRT_{NDT} vs. fluence) must go through origin
- Using a CF determined from non-credible surveillance data
- Correcting for chemical composition (ratio procedure)
- Correcting for irradiation environment (temperature)
- Appropriate chemical composition for multiple surveillance capsules from a single source (i.e., mean value for all capsules from that source)
- Appropriate normalizing parameters for surveillance data when assessing credibility (i.e., mean of surveillance data) and determining CF (i.e., best estimate of vessel)

ASSESSING CREDIBILITY

Credibility Criteria from RG 1.99, Rev. 2, and 10 CFR 50.61

"...the use of surveillance data from a given reactor (in place of the calculative procedures given in this guide) requires considerable engineering judgment to evaluate the credibility of the data and assign suitable margins."

"When surveillance data from the reactor in question become available, the weight given to them relative to the information in this guide will depend on the credibility of the surveillance data as judged by the following criteria:"

1. Materials in the capsules should be those judged controlling

2. Scatter in the Charpy curves should be small enough to permit the determination of 30-ft-lb temperature and upper shelf energy unambiguously

3. **When there are 2 or more sets of data from *one reactor*, the scatter of ΔRT_{NDT} values about a best-fit line should be less than 28°F for welds and 17°F for base metal. Even if the fluence range is large (2 or more orders of magnitude), the scatter should not exceed twice those values**

4. The irradiation temperature of the Charpy specimens should match the vessel wall temperature at the cladding/base metal interface within ±25°F

5. The surveillance data from the correlation monitor material in the capsule should fall within the scatter band of the data base for that material

CASE 1: CREDIBLE SURVEILLANCE DATA FROM PLANT AND NO OTHER SOURCE

Surveillance data are available from plant and not any other source

Best estimate for heat (Weld metal)

0.283% Cu, 0.755% Ni ⇒ Table $CF_{Vessel\ Chem.}$ = 212.2°F

Credibility assessment

Since all data from one source, determine interim CF

Interim CF = 191.3°F

Capsule	Cu (Wt. %)	Ni (Wt. %)	Fluence (10^{19} n/cm^2)	Fluence Factor (FF)	Measured ΔRT_{NDT} (°F)	Predicted ΔRT_{NDT} (°F)	(Measured - Predicted) ΔRT_{NDT} (°F)
Plant X - 1	0.2294	0.7391	0.559	0.837	175	160.2	14.8
Plant X - 2	0.2294	0.7391	2.070	1.198	235	229.2	5.8
Plant X - 3	0.2294	0.7391	2.890	1.282	230	245.2	-15.2

Data are credible since scatter is less than σ_Δ (28°F) for all capsules

- Reduced σ_Δ = 14°F is used

CASE 1: CREDIBLE SURVEILLANCE DATA FROM PLANT AND NO OTHER SOURCE (cont'd)

Determination of CF

No temperature adjustments needed

Adjust measured ΔRT_{NDT} to chemical composition of VESSEL

Table $CF_{Surv.\ Chem.}$ = 192.5°F

Determine Surveillance CF using ratio adjusted ΔRT_{NDT}

With no temp. adjustment, the ratio adjusted ΔRT_{NDT} are the same as the "ratio and temperature" adjusted ΔRT_{NDT}

Surveillance CF = 191.3 * (212.2/192.5) = 210.9°F

Final Result: assuming $RT_{NDT(U)}$ = -56.0°F; M = 44.0°F; FF = 1.307

RT_{NDT} = -56.0 + 44.0 + (210.9*1.307) = 263.6°F

CASE 2: SURVEILLANCE DATA FROM PLANT - NON-CREDIBLE DATA AND TABLE CF IS CONSERVATIVE

Surveillance data are available from plant and not any other source

Best estimate for heat (Base metal)

0.14% Cu, 0.55% Ni ⇒ Table $CF_{Vessel\ Chem.}$ = 97.8°F

Credibility assessment

Since all data from one source, determine interim CF (95.9°F)

Capsule	Cu	Ni	Fluence (10^{19} n/cm^2)	Fluence Factor (FF)	Measured ΔRT_{NDT} (°F)	Predicted ΔRT_{NDT} (°F)	(Measured - Predicted) ΔRT_{NDT} (°F)
1L	0.14	0.55	0.58	0.848	85	81.3	3.7
1T	0.14	0.55	0.58	0.848	55	81.3	-26.3
2L	0.14	0.55	1.69	1.144	105	109.8	-4.8
2T	0.14	0.55	1.69	1.144	90	109.8	-19.8
3L	0.14	0.55	2.95	1.287	135	123.4	11.6
3T	0.14	0.55	2.95	1.287	105	123.4	-18.4
4L	0.14	0.55	3.82	1.346	155	129.1	25.9
4T	0.14	0.55	3.82	1.346	145	129.1	15.9

Data are not credible since scatter is greater than σ_Δ (17°F) for several surveillance capsules - must use σ_Δ = 17°F

CASE 2: SURVEILLANCE DATA FROM PLANT - NON-CREDIBLE DATA AND TABLE CF IS CONSERVATIVE (cont'd)

Determination of CF

Since data are not credible, evaluate whether CF should be determined from the Tables

Determine if Table CF is conservative:

No temperature adjustments necessary

No chemical composition adjustments - base metal

Evaluate Surveillance CF from measured ΔRT_{NDT} (95.9°F)

- With no chemical composition or temperature adjustments needed, measured ΔRT_{NDT} is the same as the "ratio and temperature" adjusted ΔRT_{NDT}

Since Table CF is greater than Surveillance CF, the Table CF is conservative

Final Result: assuming $RT_{NDT(U)}$ = 15.0°F; M = 34°F; FF = 1.35

RT_{NDT} = 15.0 + 34.0 + (97.8*1.35) = 181.0°F

CASE 3: NON-CREDIBLE SURVEILLANCE DATA AND TABLE CF IS NON-CONSERVATIVE

Surveillance data are available from plant and not any other source

Best estimate for heat

Base metal

0.20% Cu, 0.54% Ni $\Rightarrow$ Table $CF_{Vessel\ Chem.}$ = 141.8°F

Credibility assessment

Since all data from one source, evaluate interim CF (159.9°F)

Capsule	Cu	Ni	Fluence (10^{19} n/cm^2)	Fluence Factor (FF)	Measured ΔRT_{NDT} (°F)	Predicted ΔRT_{NDT} (°F)	(Measured - Predicted) ΔRT_{NDT} (°F)
Plant X - 1L	0.20	0.54	0.340	0.703	128.1	112.4	15.7
Plant X - 1T	0.20	0.54	0.340	0.703	137.8	112.4	25.4
Plant X - 2L	0.20	0.54	0.688	0.895	118.9	143.1	-24.2
Plant X - 2T	0.20	0.54	0.688	0.895	131.8	143.1	-11.3
Plant X - 3L	0.20	0.54	1.058	1.016	147.7	162.4	-14.7
Plant X - 3T	0.20	0.54	1.058	1.016	179.9	162.4	17.5

Data are not credible since scatter is greater than σ_Δ (17°F) for several surveillance capsules - must use σ_Δ = 17°F

CASE 3: NON-CREDIBLE SURVEILLANCE DATA AND TABLE CF IS NON-CONSERVATIVE (cont'd)

Determination of CF

Since data are not credible, evaluate whether CF should be determined from the Tables or if Table CF is non-conservative

Compare measured ΔRT_{NDT} to that predicted using Table CF

Capsule	Measured ΔRT_{NDT} (°F)	Predicted ΔRT_{NDT} (°F)	(Measured - Predicted) ΔRT_{NDT} (°F)
Plant X - 1L	128.1	99.7	28.4
Plant X - 1T	137.8	99.7	38.1
Plant X - 2L	118.9	126.9	-8.0
Plant X - 2T	131.8	126.9	4.9
Plant X - 3L	147.7	144.1	3.6
Plant X - 3T	179.9	144.1	35.8

Since the scatter for two capsules exceeds 2 * σ_Δ (σ_Δ=17°F), the Table CF is non-conservative, and the Surveillance CF should be used with σ_Δ=17°F instead of the reduced σ_Δ=8.5°F

Evaluate Surveillance CF:

No temperature adjustments needed

No chemical composition adjustments needed (base metal)

With no chemical composition or temperature adjustments needed, the measured ΔRT_{NDT} is the same as the "ratio and temperature" adjusted ΔRT_{NDT}

Surveillance CF = 159.9°F

Final Result: assuming $RT_{NDT(U)}$ = 27.0°F; M = 34.0°F; FF = 1.293

RT_{NDT} = 27.0 + 34.0 + (159.9*1.293) = 267.8°F

CASE 4: SURVEILLANCE DATA FROM PLANT AND OTHER SOURCES

Surveillance data (Weld metal)

Capsule	NSSS Vendor	Cu	Ni	Irrad. Temp. (°F)	Fluence (10^{19} n/cm^2)	Measured ΔRT_{NDT} (°F)	Adjusted ΔRT_{NDT} [using Ratio and Temperature (550°F)] (°F)
Plant A - 1	B&W	0.37	0.70	556.0	0.779	214.0	196.0
Plant B - 1	B&W	0.33	0.67	556.0	0.107	124.0	126.0
Plant B - 2	B&W	0.33	0.67	556.0	0.866	203.0	202.5
Plant C - 1	B&W	0.33	0.67	556.0	0.830	182.0	182.2
Plant C - 2	B&W	0.33	0.67	556.0	0.968	222.0	221.0
Plant X - 1	West.	0.24	0.66	536.0	0.281	165.0	172.1
Plant X - 2	West.	0.24	0.66	536.0	1.940	240.0	257.6

Vessel being analyzed is Plant X

Best estimate chemistry for heat (Weld metal)

0.34% Cu, 0.68% Ni ⇒ Table $CF_{\text{Vessel Chem.}}$ = 220.6°F

Credibility assessment - Using Plant "X" data only

No temperature adjustment needed

Determine Surveillance CF for Plant X data only (214.8°F)

Capsule	Cu	Ni	Irrad. Temp. (°F)	Fluence (10^{19} n/cm^2)	Measured ΔRT_{NDT} (°F)	Predicted ΔRT_{NDT} (°F)	(Measured - Predicted) ΔRT_{NDT} (°F)
Plant x - 1	0.24	0.66	536.0	0.281	165.0	140.3	24.7
Plant x - 2	0.24	0.66	536.0	1.940	240.0	253.6	-13.6

Data are credible since scatter is less than σ_Δ (28°F) for all surveillance specimens

CASE 4: SURVEILLANCE DATA FROM PLANT AND OTHER SOURCES (cont'd)

Determination of CF - Plant "X" data only

No temperature adjustments needed

Adjust measured ΔRT_{NDT} to chemical composition of VESSEL

Table $CF_{Surv.\ chem.} = 182.9°F$

Determine Surveillance CF

No temperature adjustment needed

Surveillance CF = 259.0°F

Final Result: assuming $RT_{NDT(U)} = -7.0°F$; M = 49.8; F = 0.8745

$$RT_{NDT} = -7.0 + 49.8 + (259.0 * 0.8745) = 269.2°F$$

CASE 4: SURVEILLANCE DATA FROM PLANT AND OTHER SOURCES (cont'd)

Credibility assessment - All data

Data adjusted to mean chemical comp. of surveillance capsules

Cu = 0.31%
Ni = 0.67%

Data adjusted to mean temperature of surveillance capsules

Temp. = 550°F

Determine Surveillance CF (218.4°F)

Capsule	Cu	Ni	Irrad. Temp. (°F)	Fluence (10^{19} n/cm^2)	Adjusted ΔRT_{NDT} [using Ratio and Temperature (550°F)] (°F)	Predicted ΔRT_{NDT} (°F)	(Adjusted - Predicted) ΔRT_{NDT} (°F)
Plant A - 1	0.37	0.70	556.0	0.779	196.0	203.1	-7.1
Plant B - 1	0.33	0.67	556.0	0.107	126.0	94.1	31.9
Plant B - 2	0.33	0.67	556.0	0.866	202.5	209.6	-7.1
Plant C - 1	0.33	0.67	556.0	0.830	182.2	207.0	-24.8
Plant C - 2	0.33	0.67	556.0	0.968	221.0	216.4	4.5
Plant X - 1	0.24	0.66	536.0	0.281	172.1	142.8	29.4
Plant X - 2	0.24	0.66	536.0	1.940	257.6	258.0	-0.4

Data are not credible since scatter is greater than σ_Δ (28°F) for several surveillance specimens

CASE 5: SURVEILLANCE DATA FROM OTHER SOURCES ONLY

Surveillance data (Weld metal)

Capsule	NSSS Vendor	Cu	Ni	Irrad. Temp. (°F)	Fluence (10^{19} n/cm^2)	Measured ΔRT_{NDT} (°F)
Plant A - 1	West.	0.23	0.62	542.0	0.502	110.0
Plant A - 2	West.	0.23	0.62	542.0	0.829	165.0
Plant A - 3	West.	0.23	0.62	542.0	2.380	165.0
Plant A - 4	West.	0.23	0.62	542.0	2.420	180.0
Plant B - 1	B&W	0.22	0.58	556.0	0.510	148.0
Plant B - 2	B&W	0.22	0.58	556.0	1.670	168.0

Assume that the vessel is in Plant "Y":

Westinghouse is NSSS vendor

Plant operating temperature = 536°F

Best estimate chemistry for heat (Weld metal)

0.22% Cu, 0.58% Ni ⇒ Table $CF_{Vessel\ Chem.}$ = 164.0°F

CASE 5: SURVEILLANCE DATA FROM OTHER SOURCES ONLY (cont'd)

Credibility assessment - Plant "A" data only

If irradiation environment for Plant "A" is judged closer to that of Plant "Y" than Plant "B", then start the evaluation using Plant "A" data only

Both Plant "A" and Plant "Y" are from the same NSSS vendor

Determine Surveillance CF (145.8°F)

Capsule	Cu	Ni	Irrad. Temp. (°F)	Fluence (10^{19} n/cm^2)	Measured ΔRT_{NDT} (°F)	Predicted ΔRT_{NDT} (°F)	(Measured - Predicted) ΔRT_{NDT} (°F)
Plant A - 1	0.23	0.62	542.0	0.502	110.0	117.8	-7.8
Plant A - 2	0.23	0.62	542.0	0.829	165.0	138.2	26.8
Plant A - 3	0.23	0.62	542.0	2.380	165.0	179.9	-14.9
Plant A - 4	0.23	0.62	542.0	2.420	180.0	180.6	-0.6

Data are credible since scatter is less than σ_{Δ} (28°F) for all surveillance capsules

CASE 5: SURVEILLANCE DATA FROM OTHER SOURCES ONLY (cont'd)

Determination of CF - Plant "A" data only

Need adjustments for irradiation temperature and chemical composition adjustments to match the VESSEL

Capsule	NSSS Vendor	Cu	Ni	Irrad. Temp. (°F)	Fluence (10^{19} n/cm^2)	Measured ΔRT_{NDT} (°F)	Adjusted ΔRT_{NDT} [using Ratio and Temperature (536°F)] (°F)
Plant A - 1	West.	0.23	0.62	542.0	0.502	110.0	110.3
Plant A - 2	West.	0.23	0.62	542.0	0.829	165.0	162.7
Plant A - 3	West.	0.23	0.62	542.0	2.380	165.0	162.7
Plant A - 4	West.	0.23	0.62	542.0	2.420	180.0	176.9

Determine Surveillance CF (144.0°F)

Final Result: assuming $RT_{NDT(U)}$ = -5.0°F; M = 48.3; FF = 1.354

$$RT_{NDT} = -5.0 + 48.3 + (144.0 * 1.354) = 238.3°F$$

CASE 5: SURVEILLANCE DATA FROM OTHER SOURCES ONLY (cont'd)

Credibility Determination - All data

Adjust data to mean chemical composition and operating temperature of surveillance capsules

Cu = 0.23%
Ni = 0.61%
Temp. = 547°F

Evaluate interim CF (150.3°F)

Capsule	Cu	Ni	Irrad. Temp. (°F)	Fluence (10^{19} n/cm^2)	Adjusted ΔRT_{NDT} [using Ratio and Temperature (547°F)] (°F)	Predicted ΔRT_{NDT} (°F)	(Measured - Adjusted) ΔRT_{NDT} (°F)
Plant A - 1	0.23	0.62	542.0	0.502	104.0	121.4	-17.4
Plant A - 2	0.23	0.62	542.0	0.829	158.4	142.4	16.0
Plant A - 3	0.23	0.62	542.0	2.380	158.4	185.4	-27.0
Plant A - 4	0.23	0.62	542.0	2.420	173.3	186.1	-12.8
Plant B - 1	0.22	0.58	556.0	0.510	163.4	122.1	41.3
Plant B - 2	0.22	0.58	556.0	1.670	184.2	171.5	12.7

5 of the 6 data points are credible (scatter less than 28°F), the data set could be considered credible

Determination of CF - All data

Adjust measured ΔRT_{NDT} to chemistry and operating temperature of the VESSEL

Evaluate Surveillance CF (154.4°F)

Final Result: assuming $RT_{NDT(U)}$ = -5.0°F; M = 48.3; FF = 1.354

$$RT_{NDT} = -5.0 + 48.3 + (154.4 * 1.354) = 252.4°F$$

EITHER RESULT MEETS THE APPLICABLE CRITERIA

ADDITIONAL GUIDANCE ON ISSUES DISCUSSED AT NOVEMBER 12, 1997

Best fit line through surveillance data

Question: Should the scatter of the surveillance data about the least squares fit of the surveillance data be determined using a linear equation in which the increase in transition temperature (Δ) has a value of zero at a fluence factor (FF) of zero or should the scatter of the surveillance data about the least squares fit of the surveillance data be determined using a linear equation in which Δ can have a nonzero value when FF is zero?

Answer: The general linear equation describing the relationship between the chemistry factor, CF, Δ and FF is $\Delta = (CF)(FF) + b$, where CF is the slope of the line and b is the value of Δ when FF is zero. Based on this general equation, from Reference 1 the least squares estimate of the chemistry factor from surveillance data (FF_i,Δ_i) is given by

$$CF = \frac{\sum FF_i \Delta_i - (\sum FF_i)(\sum \Delta_i)/n}{\sum FF_i^2 - (\sum FF_i)^2/n} \qquad \text{(Eq 1)}$$

Eq. 1, however, is not the formula for CF used in RG 1.99, Revision 2, or 10 CFR 50.61. Credibility Criterion 3 in RG 1.99, Revision 2 indicates that the scatter of the surveillance data should be calculated using the best-fit line described in Regulatory Position 2.1. Regulatory Position 2.1 in RG 1.99, Revision 2, indicates that the CF is determined by multiplying each adjusted Δ_i by its corresponding FF_i, summing the products, and dividing by the sum of the squares of the FF_i. This results in Eq. 2:

$$CF = \frac{\sum FF_i \Delta_i}{\sum FF_i^2} \qquad \text{(Eq. 2)}$$

By minimizing the sum of the squares of the deviations of data from the linear equation $\Delta = (CF)\,FF$, the chemistry factor CF is given by Eq. 2. To minimize the sum of the squares of the deviations from a linear equation, the sum of the squares of the deviations are differentiated and set to zero. The resultant equation is solved for the chemistry factor.

Hence, the reason for using Eq. 2 instead of Eq. 1 to determine CF is that, implicit in the equations contained in RG 1.99, Revision 2, the least squares fit of the surveillance data should be performed using a linear equation in which Δ has a value of zero when the FF is zero. Since Credibility Criterion 3 specifies that Eq. 2 should be used to determine the scatter of the surveillance data, the scatter of the surveillance data must be fit to a linear equation with b equal to zero to satisfy RG 1.99, Revision 2.

Reference 1: "Applied Regression Analysis," N. R. Draper, and H. Smith, 1966