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An Exelon Company

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BW010004

U. S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, D.C. 20555 - 0001

Braidwood Station, Units 1 and 2
Facility Operating License Nos. NPF-72 and NPF-77
NRC Docket Nos. STN 50-456 and STN 50-457

Subject: Response to Request for Additional Information Regarding Reactor Vessel Material Radiation Surveillance Assessment and Submittal of Credibility Evaluations

References: (1) Letter from T. J. Tulon (ComEd) to U.S. NRC, "Reactor Vessel Material Surveillance Capsule W Test Results and Information Related to Assessments of Reactor Vessel Materials Data," dated April 26, 2000.

(2) Letter from R. M. Krich (ComEd) to U.S. NRC, "Response to Request for Additional Information Regarding a License Amendment Request to Permit Uprated Power Operations at Byron and Braidwood Stations," dated November 20, 2000.

The purpose of this letter is to respond to the NRC request for additional information on the Braidwood Unit 2 Reactor Vessel Material Radiation Surveillance Assessment. In addition, we are providing additional technical reports in support of a change in the Braidwood Station, Units 1 and 2, Pressure -Temperature Limit Reports (PTLR).

In Reference 1, Braidwood Station submitted Westinghouse Topical Report WCAP-15369, Revision 0, "Analysis of Capsule W from Commonwealth Edison Company Braidwood Unit 2 Reactor Vessel Radiation Surveillance Program." This report was provided within one year of the capsule withdrawal per the requirements of Appendix H, "Reactor Vessel Material Surveillance Program Requirements," to 10 CFR 50, "Domestic Licensing of Production and Utilization Facilities." As a result of a subsequent teleconference with NRC and Commonwealth Edison Company representatives on December 13, 2000, we are providing a response to the four issues raised by the staff in their review of the WCAP. This response is contained in Attachment A.

A001

In support of a revised PTLR for Byron Station and Braidwood Station, Reference 2 transmitted a series of technical reports which provided details of how the requested power uprate will affect the pressure-temperature limits and the pressurized thermal shock evaluations. As a supplement to these reports we are enclosing the credibility evaluations of the reactor vessel surveillance capsule data for Braidwood Station, Units 1 and 2. WCAP-15366, Revision 1, "Commonwealth Edison Company Braidwood Unit 1 Surveillance Program Credibility Evaluation" is provided in Attachment B-1 and WCAP-15368, Revision 0, "Commonwealth Edison Company Braidwood Unit 2 Surveillance Program Credibility Evaluation" is provided in Attachment B-2.

Please direct any questions you may have regarding this submittal to Mr. T. W. Simpkin, Regulatory Assurance Manager, at (815) 458-2801, x2980.

Sincerely,

for T. Tulon
Site Vice President
Braidwood Station

Attachments: Attachment A, "Response to Request for Additional Information Regarding Reactor Vessel Material Radiation Surveillance Assessment WCAP-15369"

Attachment B-1, "WCAP-15366, Revision 1,Commonwealth Edison Company Braidwood Unit 1 Surveillance Program Credibility Evaluation"

Attachment B-2, "WCAP-15368, Revision 0,Commonwealth Edison Company Braidwood Unit 2 Surveillance Program Credibility Evaluation"

cc: Regional Administrator – NRC Region III
NRC Senior Resident Inspector – Braidwood Station

Attachment A

Response to Request for Additional Information Regarding Reactor Vessel Material Radiation Surveillance Assessment WCAP-15369

1. *On page 3-1 of the report, the 3rd and 4th paragraphs refer to "K_{Ic} curve" in several places; these references should be revised to "K_{Ia} curve" for accuracy, as indicated in the same section of WCAP-15316, Rev. 1.*

Yes, the references to the ASME Appendix G stress intensity factor curve should be K_{Ia}.

2. *The report does not describe the method for monitoring specimen temperature during testing of tensile specimens. Is the methodology used in this report the same as that described on page 5-2 of WCAP-15316, Rev. 1?*

The methodology used in the subject report is the same as that described on page 5-2 of WCAP 15316, Rev 1. Elevated test temperatures were obtained with a three zone electric resistance split-tube furnace with a 9-inch hot zone. All tests were conducted in air. Because of the difficulty in remotely attaching a thermocouple directly to the specimen, the following procedure was used to monitor specimen temperatures. Chromel-Alumel thermocouples were positioned at the center and at each end of the gage section of a dummy specimen and in each tensile machine gripper. In the test configuration, with a slight load on the specimen, a plot of specimen temperature versus upper and lower tensile machine gripper and controller temperatures was developed over the range from room temperature to 550°F. During the actual testing, the grip temperatures were used to obtain desired specimen temperatures. Experiments have indicated that this method is accurate to ± 2°F.

3. *Figures 5-1 to 5-12 (pages 5-17 to 5-28) indicate that the fluences for all of the plotted data are 0 (including that for the surveillance capsules). This appears to be in conflict with the fluences reported elsewhere in the report. Please indicate which is correct.*

The Capsule W fluence was not available when the plots were generated. The fluences for the four curves in Figures 5-1 through 5-12 are as follows.

Curve Number	Capsule	Fluence (x 10^{19} n/cm^2)
1	Unirradiated	0
2	U	0.400
3	X	1.23
4	W	2.25

These fluence values for the capsules are consistent with the values provided in Table 5-10 on page 5-15 of WCAP 15369, Revision 0.

4. *The recommended surveillance capsule removal schedule on page 7-1 indicates a change from that of the prior surveillance capsule report (WCAP-14228), specifically with the recommendation to place capsule Z in a standby mode. Does the licensee plan to implement this recommendation, and if so how will this*

be implemented? (This question also applies to WCAP-15316, Rev. 1, for Braidwood Unit 1.)

The schedule for the surveillance capsule removal listed in WCAP-15316 and WCAP-15368 is different from that previously provided. In both cases, the Capsule Z withdrawal status changes from a planned withdrawal at 12 Effective Full Power Years (EFPY) to a standby status. Braidwood plans on implementing this revised withdrawal schedule in a revision of the Unit 1 and Unit 2 PTLRs after NRC approval of the revised PTLR methodology as discussed in Reference 1.

As required by 10 CFR 50 Appendix H (III) (B) (3), the revised capsule withdrawal schedule was provided in the Reference 2 transmittal (Attachment E, Section 5.1.3 and Tables 5.1.3-1 and 5.1.3-2). Because of revisions to the estimated fluence levels for both Braidwood Station Units at end of life, that is, 32 EFPY, no additional capsules need be scheduled for removal and testing at this time. The change to allow Capsule W for both Braidwood Station Units to be in standby is consistent with the withdrawal schedule contained in ASTM E-185-82, "Conducting Surveillance Tests for Light-Water Cooled Nuclear Power Reactor Vessels."

References: (1) Letter from T. J. Tulon (ComEd) to U.S. NRC, "Reactor Vessel Material Radiation Surveillance Assessment," dated September 29, 2000.

(2) Letter from R. M. Krich (ComEd) to U.S. NRC, "Request for a License Amendment to Permit Uprated Power Operations at Byron and Braidwood Stations," dated July 5, 2000.

Attachment B-1

WCAP-15366, Revision 1, Commonwealth Edison Company Braidwood Unit 1 Surveillance Program Credibility Evaluation

WESTINGHOUSE NON-PROPRIETARY CLASS 3

WCAP-15366
Revision 1

Commonwealth Edison Company Braidwood Unit 1 Surveillance Program Credibility Evaluation

E. Terek

December 2000

Approved: [signature]
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PREFACE

This report has been technically reviewed and verified by:

Reviewer: T. J. Laubham

EXECUTIVE SUMMARY

The purpose of this report is to document the results of the surveillance program credibility evaluation performed using the results of the latest capsule testing from Braidwood Unit 1. Capsule W was the latest capsule removed from the Braidwood Unit 1 reactor vessel and the results of the testing are documented in WCAP-15316, Revision 1[1]. The credibility evaluation herein shows all the Braidwood Unit 1 surveillance data to be credible. In addition, the Braidwood Unit 1 and Unit 2 weld metal data is credible and applicable to the Braidwood Unit 1 Lower to intermediate shell circumferential weld seam WF-562 (Heat # 442011).

1 INTRODUCTION

Regulatory Guide 1.99, Revision 2, describes general procedures acceptable to the NRC staff for calculating the effects of neutron radiation embrittlement of the low-alloy steels currently used for light-water-cooled reactor vessels. Position C.2 of Regulatory Guide 1.99, Revision 2, describes the method for calculating the adjusted reference temperature and Charpy upper-shelf energy of reactor vessel beltline materials using surveillance capsule data. The methods of Position C.2 can only be applied when two or more credible surveillance data sets become available from the reactor in question. Note: These criteria are also given in 10 CFR 50.61.

To date there has been three surveillance capsules removed from the Braidwood Unit 1 reactor vessel. To use these surveillance data sets, they must be shown to be credible. In accordance with the discussion of Regulatory Guide 1.99, Revision 2 (or 10 CFR 50.61), there are five requirements that must be met for the surveillance data to be judged credible.

The purpose of this evaluation is to apply the credibility requirements of Regulatory Guide 1.99, Revision 2 (or 10 CFR 50.61), to the Braidwood Unit 1 reactor vessel surveillance data. The Braidwood Units 1 and 2 surveillance weld data are also evaluated for credibility, and applicability to the Braidwood Unit 1 intermediate to lower shell girth weld.

2 EVALUATION:

Criterion 1: Materials in the capsules should be those judged most likely to be controlling with regard to radiation embrittlement.

The beltline region of the reactor vessel is defined in Appendix G to 10 CFR Part 50, "Fracture Toughness Requirements", as follows:

> "the reactor vessel (shell material including welds, heat affected zones, and plates or forgings) that directly surrounds the effective height of the active core and adjacent regions of the reactor vessel that are predicted to experience sufficient neutron radiation damage to be considered in the selection of the most limiting material with regard to radiation damage."

The Braidwood Unit 1 reactor vessel consists of the following beltline region materials:

- Intermediate shell forging [49D383/49C344]-1-1,
- Lower shell forging [49D867/49C813]-1-1,
- Nozzle shell forging 5P-7016,
- The intermediate shell forging to lower shell forging circumferential weld seam WF-562 fabricated with weld wire heat number 442011, Linde 80, Flux Lot 8061, and
- The nozzle shell forging to intermediate shell forging circumferential weld seam WF-645 fabricated with weld wire heat number H4498, Linde 80, Flux Lot 0261.
- The remaining vessel forging and weld materials are predicted to experience less than 10^{17} n/cm^2 fluences.

The Braidwood Unit 1 surveillance program utilizes tangential and axial test specimens from the lower shell forging [49D867/49C813]-1-1. The surveillance weld metal was fabricated with weld wire heat number 442011, Flux Type Linde 80, Lot Number 8061.

At the time when the surveillance program material was selected it was believed that copper and phosphorus were the elements most important to embrittlement of reactor vessel steels and the nozzle shell was not considered a "beltline" material. The lower shell forging had an initial RT_{NDT} that was 10°F higher than the intermediate shell forging initial RT_{NDT}. In addition, the lower and intermediate shell forgings had essentially the same copper and phosphorous content. Based on this evaluation of the beltline forging materials, the lower shell forging was chosen for the surveillance program. Weld seam WF-562, on the other hand, was considered the only weld in the beltline region and therefore was representative of all the beltline welds. Hence, the surveillance program weld was fabricated with the

same weld wire heat, the same type of flux, and the same flux lot number as the intermediate to lower shell forging circumferential weld seam WF-562.

Based on the above discussion and the methodology in use at the time the program was developed, the Braidwood Unit 1 surveillance material meets this criteria.

Criterion 2: Scatter in the plots of Charpy energy versus temperature for the irradiated and unirradiated conditions should be small enough to permit the determination of the 30 ft-lb temperature and upper shelf energy unambiguously.

Plots of Charpy energy versus temperature for the unirradiated and irradiated condition are presented Appendix C of WCAP-15316, Revision 1[1].

Based on engineering judgment, the scatter in the data presented in these plots is small enough to permit the determination of the 30 ft-lb temperature and the upper shelf energy of the Braidwood Unit 1 surveillance materials unambiguously. Hence, the Braidwood Unit 1 surveillance data meets this criterion.

Criterion 3: When there are two or more sets of surveillance data from one reactor, the scatter of ΔRT_{NDT} values about a best-fit line drawn as described in Regulatory Position 2.1 normally should be less than 28°F for welds and 17°F for base metal. Even if the fluence range is large (two or more orders of magnitude), the scatter should not exceed twice those values. Even if the data fail this criterion for use in shift calculations, they may be credible for determining decrease in upper shelf energy if the upper shelf can be clearly determined, following the definition given in ASTM E185-82.

The functional form of the least squares method as described in Regulatory Position 2.1 will be utilized to determine a best-fit line for this data and to determine if the scatter of these ΔRT_{NDT} values about this line is less than 28°F for welds and less than 17°F for the plate. Following is the calculation of the best fit line as described in Regulatory Position 2.1 of Regulatory Guide 1.99, Revision 2.

Following is the calculation of the best fit line as described in Regulatory Position 2.1 of Regulatory Guide 1.99, Revision 2.

Braidwood Unit 1 has one circumferential weld that will be evaluated for credibility. This weld is Weld WF-562 (Intermediate to lower Shell forging Circ. Weld) and is made from weld wire heat 442011, Linde 80 type flux, Lot Number 8061. This weld metal is contained in both the Braidwood Unit 1 and the Braidwood Unit 2 surveillance programs. Since the welds in question utilize data from other surveillance

programs, the recommended NRC methods for determining credibility will be followed. The NRC methods were presented to industry at a meeting held by the NRC on February 12 and 13, 1998. At this meeting the NRC presented five cases. Of the five cases Case 4 most closely represents the situation listed above for Braidwood Unit 1 surveillance weld metal. Note, for the forging materials, the straight forward method of Regulatory Guide 1.99, Revision 2 will be followed.

From Section 6.3.1.2 of this calcnote, the Braidwood Unit 1 and Braidwood Unit 2 average inlet temperatures are 553°F. Therefore, no temperature adjustment is needed.

First, NRC Case 4 will be evaluated for the Braidwood Unit 1 surveillance weld metal, "Surveillance Data Available from Plant and Other Sources".

TABLE 1
Surveillance Data - Normalization for Credibility Determination (when all data is being used)

Capsule	Cu (%)	Ni (%)	Irradiation Temperature ($T_{capsule}$)	Fluence (x 10^{19})	Fluence Factor (FF)	Measured ΔRT_{NDT}	Temperature Adjusted (553°F)(1)	Ratio Chemistry Adjusted (553°F) ΔRT_{NDT}(2)
U-Braid. 1	0.03	0.67	553°F	0.387	0.737	17.06°F	17.06°F	17.06°F
X-Braid. 1	0.03	0.67	553°F	1.24	1.060	30.15°F	30.15°F	30.15°F
W-Braid. 1	0.03	0.67	553°F	2.09	1.201	49.68°F	49.68°F	49.68°F
U-Braid. 2	0.03	0.71	553°F	0.352	0.712	0.0°F	0.0°F	0.0°F
X-Braid. 2	0.03	0.71	553°F	1.075	1.020	20.0°F	20.0°F	20.0°F

Notes:

(1) No temperature adjustment required.

(2) The normalized chemical composition for this weld heat (442011) is 0.03%Cu and 0.67%Ni. This produces a chemistry factor of 41, which identical to the chemistry factor for both the Braidwood 1 and 2 surveillance data. Therefore the surveillance weld metal ΔRT_{NDT} values were not adjusted to normalize chemical composition.

The vessel being analyzed is Braidwood Unit 1.

The best estimate chemistry for weld heat 442011 is:

0.03% Cu and 0.67% Ni ➔ Table CF_{Vessel} = 41°F

Weld heat number 442011 is in the surveillance program and in the vessel, and T_{plant} = 553°F

Credibility assessment - Braidwood Unit 1 Data Only:

The data most representative for Braidwood Unit 1 is that from Braidwood Unit 1 since the irradiation environment of the surveillance capsules and the vessel are the same. The data requires the least adjustments.

No temperature adjustment is needed.

Following is the determination of the CF using only Braidwood Unit 1 surveillance data.

TABLE 2

Determination of Surveillance Weld CF Braidwood Unit 1 Data Only

Material	Capsule	Capsule f(1)	FF(2)	ΔRT_{NDT}(3)	FF*ΔRT_{NDT}	FF^2
Braidwood Unit 1 Surveillance Weld Metal	U	0.387	0.737	17.06°F	12.57°F	0.543
	X	1.24	1.060	30.15°F	31.96°F	1.124
	W	2.09	1.201	49.68°F	59.67°F	1.442
				SUM:	104.2°F	3.109
	$CF = \Sigma(FF * RT_{NDT}) \div \Sigma(FF^2) = (104.2°F) \div (3.109) =$ **33.5°F**					

Notes: (1) f = fluence ($f * 10^{19}$, n/cm^2 (E > 1.0 MeV))

(2) $FF = f^{(0.28 - 0.1*\log(f))}$

(3) ΔRT_{NDT} is the measured value.

Slope of best fit line = 33.5°F

TABLE 3

Braidwood Unit 1 Surveillance Capsule Data Only

Capsule	Cu (%)	Ni (%)	Irradiation Temperature ($T_{capsule}$)	Fluence (x 10^{19})	Fluence Factor (FF)	Measured ΔRT_{NDT}	Predicted ΔRT_{NDT} from Best Fit Line	(Measured - Predicted) ΔRT_{NDT}
U-Braid. 1	0.03	0.67	553°F	0.387	0.737	17.06°F	24.7°F	-7.6°F
X-Braid. 1	0.03	0.67	553°F	1.24	1.060	30.15°F	35.5°F	-5.4°F
W-Braid. 1	0.03	0.67	553°F	2.09	1.201	49.68°F	40.2°F	9.5°F

Where predicted ΔRT_{NDT} = ($Slope_{best\ fit}$) * (Fluence Factor)

Data are credible since the scatter is less than 28°F for all surveillance specimens.

Determination of CF - Braidwood Unit 1 data only

No temperature adjustments are necessary since $T_{capsule} = T_{plant}$

Adjust measure values of ΔRT_{NDT} for chemical composition differences (normalize data to best estimate of vessel weld):

Ratio = (CF_{VW} ÷ CF_{SW})= (41.0 ÷ 41.0) =1.0

Therefore no chemistry adjustment needed.

Following is the determination of the best fit line relating adjusted ("ratio and temperature" adjusted) ΔRT_{NDT} to FF. The slope of this best fit line is the $CF_{Surv.}$ Data.

Since no temperature or chemistry adjustments were required, the adjusted ΔRT_{NDT} is the same as the "ratio and temperature" adjusted ΔRT_{NDT}. From Table 2 the CF is:

$CF_{Surv.\ Data}$ = 33.5°F

Credibility Assessment - All Data:

The data from all sources should also be considered

Since data are from multiple sources the data must be adjusted for chemical composition and irradiation environment differences and then plot the "ratio and temperature" adjusted ΔRT_{NDT} values versus FF and determine the best fit line.

For credibility determination, data are normalized to the mean chemical composition and temperature of the Braidwood Unit 1 surveillance specimens.

TABLE 4

Braidwood Unit 1 and Unit 2 Surveillance Capsule Data

Material	Capsule	Capsule f(a)	FF(b)	Ratio Temperature Adjusted ΔRT_{NDT}(c)	FF*ΔRT_{NDT}	FF^2
Braidwood 1 Surveillance Weld	U	0.387	0.737	17.06°F	12.57°F	0.543
	W	1.24	1.060	30.15°F	31.96°F	1.124
	X	2.09	1.201	49.68°F	59.67°F	1.442
Braidwood 2 Surveillance Weld	U	0.352	0.712	0.0°F	0.0°F	0.507
	X	1.075	1.020	20.0°F	20.4°F	1.040
				SUM:	124.60°F	4.56
	$CF_{Weld} = \Sigma(FF * RT_{NDT}) \div \Sigma(FF^2) = (124.60) \div (4.56) =$ **26.8°F**					

Notes:

(a) Calculated fluence (x 10^{19} n/cm^2, E > 1.0 MeV).

(b) FF = fluence factor = $f^{(0.28 - 0.1*\log f)}$.

(c) The surveillance weld metal ΔRT_{NDT} values have not been adjusted (Ratio Procedure: (Ratio = 1.0 for Unit 1 & 2) and irradiation temperature is 553°F (See Table 1)).

The slope of the best fit line = 26.8°F

TABLE 5

Best Fit of all Weld Metal Surveillance Data Available

Capsule	Cu (%)	Ni (%)	Irradiation Temperature ($T_{capsule}$)	Fluence (x 10^{19})	Fluence Factor (FF)	Ratio Temperature Adjusted (553°F) ΔRT_{NDT}	Predicted ΔRT_{NDT} from Best Fit Line	(Measured - Predicted) ΔRT_{NDT}
U-Braid. 1	0.03	0.67	553°F	0.387	0.737	17.06°F	19.8°F	-2.7°F
X-Braid. 1	0.03	0.67	553°F	1.24	1.060	30.15°F	28.4°F	1.8°F
W-Braid. 1	0.03	0.67	553°F	2.09	1.201	49.68°F	32.2°F	17.5°F
U-Braid. 2	0.03	0.71	553°F	0.352	0.712	0.0°F	19.1°F	-19.1°F
X- Braid. 2	0.03	0.71	553°F	2.075	1.020	20.0°F	27.3°F	-7.3°F

Where predicted ΔRT_{NDT} = ($Slope_{best\ fit}$) * (Fluence Factor)

Data are credible since the scatter is less than 28°F for all surveillance specimens.

Therefore, the surveillance program weld metal CF to be used in calculations is 26.8°F and is based on all available surveillance data.

Now that the Weld Metal has been evaluated for credibility, the Forging material must be evaluated. The calculated CF from surveillance data for the lower shell forging [49D867/49C813]-1-1 is 23.9°F.

TABLE 6

Predicted Versus Best-Estimate ΔRT_{NDT} Values for the Braidwood Unit 1 Forging Surveillance Data

Material	Capsule	CF	FF	Best Estimate ΔRT_{NDT}	Measured ΔRT_{NDT}	Change in ΔRT_{NDT} (B.E. - Measured)
Lower Shell Forging [49D867/49C813]-1-1 (Tangential)	U	23.9°F	0.737	17.6°F	5.78°F	11.8
	X	23.9°F	1.060	25.3°F	38.23°F	-12.9
	W	23.9°F	1.201	28.7°F	24.14°F	4.6
Lower Shell Forging [49D867/49C813]-1-1 (Axial)	U	23.9°F	0.737	17.6°F	0.0°F	17.6
	X	23.9°F	1.060	25.3°F	28.75°F	-3.5
	W	23.9°F	1.201	28.7°F	37.11°F	-8.4

From Table 7 above, the Braidwood Unit 1 Forging Data has five out of six data points within the 17°F scatter band. With six data points it can be expected that one would be out of the 17°F scatter band. The lower shell axial data point for capsule U is only out by 0.6°F and the measured data point is being over predicted by the best fit CF. Hence, based on engineering judgment, the forging surveillance data is considered credible.

Therefore, the surveillance program forging material CF to be used in calculations is 23.9°F and is based on all available surveillance data.

Criterion 4: The irradiation temperature of the Charpy specimens in the capsule should match the vessel wall temperature at the cladding/base metal interface within +/- 25°F.

The capsule specimens are located in the reactor between the core barrel and the vessel wall and are positioned opposite the center of the core. The test capsules are in baskets attached to the neutron pads. The location of the specimens with respect to the reactor vessel beltline provides assurance that the reactor vessel wall and the specimens experience equivalent operating conditions such that the temperatures will not differ by more than 25°F. Hence, this criteria is met.

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

The Braidwood Unit 1 surveillance program does not contain correlation monitor material. Therefore, this criterion is not applicable to the Braidwood Unit 1 surveillance program.

3 CONCLUSION

Based on the preceding responses to all five criteria of Regulatory Guide 1.99, Revision 2, Section B and 10 CFR 50.61, the Braidwood Unit 1 surveillance data is credible. In addition, the Braidwood Unit 1 and 2 weld data is credible and applicable to the Byron Unit 2 nozzle to intermediate shell circumferential weld seam WF-501 (Heat # 442011).

4 REFERENCES

1 WCAP-15316, Revision 1 "Analysis of Capsule W from the Commonwealth Edison Co. Braidwood Unit 1 Reactor Vessel Radiation Surveillance Program", E. Terek, et al., December 1999.

2 Regulatory Guide 1.99, Revision 2, "Radiation Embrittlement of Reactor Vessel Materials", U.S. Nuclear Regulatory Commission, May, 1988.

3 10 CFR 50.61, "Fracture Toughness Requirements for Protection Against Pressurized Thermal Shock Events", Federal Register, Volume 60, No. 243, dated December 19, 1995.

APPENDIX A

NRC CASE 4 FROM NOVEMBER INDUSTRY MEETING

CASE 4 - SURVEILLANCE DATA AVAILABLE FROM PLANT AND OTHER SOURCES

Surveillance data

Capsule Designation	NSSS Vendor	Cu	Ni	Irradiation Temperature ($T_{Capsule}$)	Fluence ($x10^{19}$)	Fluence Factor (FF)	Measured ΔRT_{NDT}	Temperature Adjusted (550°F) ΔRT_{NDT}	Ratio, Temperature Adjusted (550°F) ΔRT_{NDT}
Plant a - 1	B&W	0.37	0.70	556.0	0.779	0.930	214.0	220.0	196.0
Plant b - 1	B&W	0.33	0.67	556.0	0.107	0.431	124.0	130.0	126.0
Plant b - 2	B&W	0.33	0.67	556.0	0.866	0.960	203.0	209.0	202.5
Plant c - 1	B&W	0.33	0.67	556.0	0.830	0.948	182.0	188.0	182.2
Plant c - 2	B&W	0.33	0.67	556.0	0.968	0.991	222.0	228.0	221.0
Plant x - 1	West.	0.24	0.66	536.0	0.281	0.653	165.0	151.0	172.1
Plant x - 2	West.	0.24	0.66	536.0	1.940	1.181	240.0	226.0	257.6

Normalization for credibility determination (when all data are being used)

Data normalized to mean chemical composition (i.e., copper and nickel) of surveillance specimens

Cu = 0.31%
Ni = 0.67%

Data normalized to mean temperature of surveillance specimens

$T_{Normalize}$ = 550°F

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

Assume the following for Plant "x" (the plant whose vessel is being assessed)

Weld heat 299L44 is in the surveillance program and in the vessel

T_{Plant} = 536°F

Surveillance data for heat 299L44 is also available from other sources

Best estimate for heat

Weld metal

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

Credibility assessment - Plant "x" data only

The data most representative for Plant "x" is that from Plant "x" since the irradiation environment of the surveillance capsules and the vessel are very similar. This data requires the least adjustment (e.g., no temperature correction)

Plant "x" data should be examined independently to determine credibility

Since all data are from one source (Plant "x"), plot measured ΔRT_{NDT} versus FF and determine best fit line

Slope of best fit line = 214.8°F

Capsule	Cu	Ni	Irradiation Temperature ($T_{Capsule}$)	Fluence ($x10^{19}$)	Fluence Factor (FF)	Measured ΔRT_{NDT}	Predicted ΔRT_{NDT} from best fit line	(Measured - Predicted) ΔRT_{NDT}
Plant x - 1	0.24	0.66	536.0	0.281	0.653	165.0	140.3	24.7
Plant x - 2	0.24	0.66	536.0	1.940	1.181	240.0	253.6	-13.6

where predicted ΔRT_{NDT} = ($Slope_{best fit}$)*(Fluence Factor)

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

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

Determination of CF - Plant "x" data only

No temperature adjustments are necessary since $T_{Capsule} = T_{Plant}$

Adjust measured values of ΔRT_{NDT} for chemical composition differences as follows (normalize data to best estimate of <u>vessel</u> being assessed):

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

$CF_{Table,\ Surv.\ chem.} = 182.9°F$

Determine best fit line relating adjusted ("ratio and temperature" adjusted) ΔRT_{NDT} to FF. The slope of this best fit line is the $CF_{Surv.\ Data}$.

Since no temperature adjustments were required in this case the ratio adjusted ΔRT_{NDT} is the same as the "ratio and temperature" adjusted ΔRT_{NDT}

$CF_{Surv.\ Data} = 259.0°F$

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

Credibility assessment - All data

The data from all sources should also be considered

Since data are from multiple sources, must adjust data for chemical composition and irradiation environment differences and then plot the "ratio and temperature" adjusted ΔRT_{NDT} values versus FF and determine best fit line

For credibility determination, data are normalized to the mean chemical composition and temperature of the <u>surveillance specimens</u>

Slope of best fit line = 218.4°F

Capsule	Cu	Ni	Irradiation Temperature ($T_{Capsule}$)	Fluence ($x10^{19}$)	Fluence Factor (FF)	Ratio and Temperature (550) Adjusted ΔRT_{NDT}	Predicted ΔRT_{NDT} from best fit line	(Adjusted - Predicted) ΔRT_{NDT}
Plant a - 1	0.37	0.70	556.0	0.779	0.930	196.0	203.1	-7.1
Plant b - 1	0.33	0.67	556.0	0.107	0.431	126.0	94.1	31.9
Plant b - 2	0.33	0.67	556.0	0.866	0.960	202.5	209.6	-7.1
Plant c - 1	0.33	0.67	556.0	0.830	0.948	182.2	207.0	-24.8
Plant c - 2	0.33	0.67	556.0	0.968	0.991	221.0	216.4	4.5
Plant x - 1	0.24	0.66	536.0	0.281	0.653	172.1	142.8	29.4
Plant x - 2	0.24	0.66	536.0	1.940	1.181	257.6	258.0	-0.4

where predicted ΔRT_{NDT} = ($Slope_{best\ fit}$)*(Fluence Factor)

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

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

Determination of CF - All Data

If data were credible, the CF would be determined as follows

Must make irradiation temperature and chemical composition adjustments since the irradiation temperature and chemistry differ between the capsules and the plant being assessed

For capsules with $T_{Capsule}$ greater than 536°F (i.e., T_{Plant}), must increase $\Delta RT_{NDT,\ measured}$ by 1.0°F for each degree difference in irradiation temperature to get the temperature adjusted ΔRT_{NDT} (i.e., $\Delta RT_{NDT,\ T\ adjusted}$)

To obtain the "ratio and temperature" adjusted ΔRT_{NDT}, apply the ratio procedure as follows:

$$Ratio/Temperature\ Adjusted\ \Delta RT_{NDT} = \left(\frac{CF_{Table,\ Vessel\ Chem.}}{CF_{Table,\ Surv.\ Chem.}}\right) * \Delta RT_{NDT,\ T\ adjusted}$$

Determine best fit line relating adjusted ("ratio and temperature" adjusted) ΔRT_{NDT} to FF. The slope of this best fit line is the $CF_{Surv.\ Data}$. $CF_{Surv.\ Data}$ = 247.2°F

Appropriate CF

Data from the plant being assessed were evaluated and the data were credible

When all of the data were evaluated, the data were determined to be not credible

Since the data from the plant being assessed is the most appropriate and requires the least amount of adjustment, the CF determined from evaluation of the Plant "x" data is the most appropriate.
$CF_{Surv.\ Data}$ = 259.0°F

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

Effects of data analysis technique (Ratio procedure and using plant-specific data)

Previous analyses

Ratio procedure not applied, temperature correction to data from other sources not made, All data used

$RT_{NDT(U)}$ = -7.0°F; M = 49.8; CF = 217.0°F; FF = 0.8745

$RT_{NDT,\ previous}$ = -7.0 + 49.8 + (217.0 * 0.8745) = 232.6°F

Current analyses

Ratio procedure applied, No temperature correction necessary, Only Plant "x" data used

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

Attachment B-2

WCAP-15368, Revision 0
Commonwealth Edison Company Braidwood Unit 2
Surveillance Program Credibility Evaluation

WESTINGHOUSE NON-PROPRIETARY CLASS 3

WCAP-15368

Commonwealth Edison Company Braidwood Unit 2 Surveillance Program Credibility Evaluation

T. J. Laubham

September 2000

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TABLE 1

PREFACE

This report has been technically reviewed and verified by:

Reviewer: Ed Terek

EXECUTIVE SUMMARY

The purpose of this report is to document the results of the surveillance program credibility evaluation performed using the results of the latest capsule testing from Braidwood Unit 2. Capsule W was the latest capsule removed from the Braidwood Unit 2 reactor vessel and the results of the testing are documented in WCAP-15369[1]. The credibility evaluation herein shows all the Braidwood Unit 2 surveillance weld data to be credible and the forging data to be non-credible. The Braidwood Unit 1 beltline weld metal (Heat # 442011) surveillance data is applicable to the Braidwood Unit 2 beltline weld and was shown to be credible.

1 INTRODUCTION

Regulatory Guide 1.99, Revision 2, describes general procedures acceptable to the NRC staff for calculating the effects of neutron radiation embrittlement of the low-alloy steels currently used for light-water-cooled reactor vessels. Position C.2 of Regulatory Guide 1.99, Revision 2, describes the method for calculating the adjusted reference temperature and Charpy upper-shelf energy of reactor vessel beltline materials using surveillance capsule data. The methods of Position C.2 can only be applied when two or more credible surveillance data sets become available from the reactor in question. Note: These criteria are also given in 10 CFR 50.61.

To date there has been three surveillance capsules removed from the Braidwood Unit 2 reactor vessel. To use these surveillance data sets, they must be shown to be credible. In accordance with the discussion of Regulatory Guide 1.99, Revision 2 (or 10 CFR 50.61), there are five requirements that must be met for the surveillance data to be judged credible.

The purpose of this evaluation is to apply the credibility requirements of Regulatory Guide 1.99, Revision 2 (or 10 CFR 50.61), to the Braidwood Unit 2 reactor vessel surveillance data.

2 EVALUATION:

Criterion 1: Materials in the capsules should be those judged most likely to be controlling with regard to radiation embrittlement.

The beltline region of the reactor vessel is defined in Appendix G to 10 CFR Part 50, "Fracture Toughness Requirements", as follows:

> "the reactor vessel (shell material including welds, heat affected zones, and plates or forgings) that directly surrounds the effective height of the active core and adjacent regions of the reactor vessel that are predicted to experience sufficient neutron radiation damage to be considered in the selection of the most limiting material with regard to radiation damage."

The Braidwood Unit 2 reactor vessel consists of the following beltline region materials:

- Intermediate shell forging 49D963-1/49C904-1
- Lower shell forging 50D102-1/50C97-1
- Nozzle shell forging 5P-7056
- The intermediate shell forging to lower shell forging circumferential weld seam WF-562 fabricated with weld wire heat number 442011, Linde 80, Flux Lot 8061.
- The nozzle shell forging to intermediate shell forging circumferential weld seam WF-645 fabricated with weld wire heat number H4498, Linde 80, Flux Lot 0261.

The Braidwood Unit 2 surveillance program utilizes tangential and axial test specimens from lower shell forging 50D102-1/50C97-1. The surveillance weld metal was fabricated with weld wire heat number 442011, Flux Type Linde 80, Lot Number 8061.

At the time when the surveillance program material was selected it was believed that copper and phosphorus were the elements most important to embrittlement of reactor vessel steels and the nozzle shell was not considered a "beltline" material. The lower shell forging had an initial RT_{NDT} that was equal to the intermediate shell forging initial RT_{NDT} but a higher copper content. Based on this evaluation of the beltline forging materials, the lower shell forging was chosen for the surveillance program. Weld seam WF-562, on the other hand, was considered the only weld in the beltline region and therefore was representative of all the beltline welds. Hence, the surveillance program weld was fabricated with the same weld wire heat, the same type of flux, and the same flux lot number as the intermediate to lower shell forging circumferential weld seam WF-562.

Based on the above discussion and the methodology in use at the time the program was developed, the Braidwood Unit 2 surveillance material meets this criteria.

Criterion 2: Scatter in the plots of Charpy energy versus temperature for the irradiated and unirradiated conditions should be small enough to permit the determination of the 30 ft-lb temperature and upper shelf energy unambiguously.

Plots of Charpy energy versus temperature for the unirradiated and irradiated condition are presented in Appendix C of WCAP-15369[1].

From WCAP-15369, one can see the scatter in the data presented in the Charpy plots is small enough to permit the determination of the 30 ft-lb temperature and the upper shelf energy of the Braidwood Unit 2 surveillance materials unambiguously. Hence, the Braidwood Unit 2 surveillance data meets this criterion.

Criterion 3: When there are two or more sets of surveillance data from one reactor, the scatter of ΔRT_{NDT} values about a best-fit line drawn as described in Regulatory Position 2.1 normally should be less than 28°F for welds and 17°F for base metal. Even if the fluence range is large (two or more orders of magnitude), the scatter should not exceed twice those values. Even if the data fail this criterion for use in shift calculations, they may be credible for determining decrease in upper shelf energy if the upper shelf can be clearly determined, following the definition given in ASTM E185-82.

The functional form of the least squares method as described in Regulatory Position 2.1 will be utilized to determine a best-fit line for this data and to determine if the scatter of these ΔRT_{NDT} values about this line is less than 28°F for welds and less than 17°F for the forging. Following is the calculation of the best fit line as described in Regulatory Position 2.1 of Regulatory Guide 1.99, Revision 2.

Braidwood Unit 2 has one circumferential weld that will be evaluated for credibility. This weld is Weld WF-562 (Intermediate to lower Shell forging Circ. Weld) and is made from weld wire heat 442011, Linde 80 type flux, Lot Number 8061. This weld metal is contained in both the Braidwood Unit 1 and the Braidwood Unit 2 surveillance programs. Since the welds in question utilize data from other surveillance programs, the recommended NRC methods for determining credibility will be followed. The NRC methods were presented to industry at a meeting held by the NRC on February 12 and 13, 1998. At this meeting the NRC presented five cases. Of the five cases Case 4 most closely represents the situation listed above for

Braidwood Unit 2 surveillance weld metal. Note, for the forging materials, the straight forward method of Regulatory Guide 1.99, Revision 2 will be followed.

From Table 1 below, the Braidwood Unit 1 and Braidwood Unit 2 average inlet temperatures are 553°F and 552°F. Note, however that Capsules U and X were exposed to the same average operating temperature of 553°F for the first four cycles and Capsule W was exposed to the same average operating temperature of 553°F for five of the seven cycles. Only the temperature difference in cycles six and seven cause the overall 1°F drop in average operating temperature for Unit 2. Thus it can be concluded that for the majority of operating history, the inlet operating temperature of both Braidwood Unit 1 and Unit 2 are essentially the same for the time of interest and no temperature adjustments are required.

TABLE 1

Braidwood Units 1 and 2 Average Operating Temperature History

Fuel Cycle	Braidwood 1	Capsule	Braidwood 2	Capsule
1	557°F[3]	U	557°F[3]	U
2	551°F[3]	- -	551°F[3]	- -
3	551°F[3]	- -	551°F[3]	- -
4	551°F[3]	X	551°F[3]	X
5	551-554°F[3]	- -	551°F[4]	- -
6	554°F[3]	- -	551°F[4]	- -
7	554°F[4]	W	550°F[5]	W
Average Temp.	553°F		552°F	

First, NRC Case 4 will be evaluated for the Braidwood Unit 2 surveillance weld metal, "Surveillance Data Available from Plant and Other Sources".

TABLE 2
Surveillance Data - Normalization for Credibility Determination (when all data is being used)

Capsule	Cu (%)	Ni (%)	Irradiation Temperature ($T_{capsule}$)	Fluence (x 10^{19})	Fluence Factor (FF)	Measured ΔRT_{NDT}	Temperature Adjusted (553°F)(1)	Ratio Chemistry Adjusted (553°F) ΔRT_{NDT}(2)
U-Braid. 1	0.03	0.67	553°F	0.387	0.737	17.06°F	17.06°F	17.06°F
X-Braid. 1	0.03	0.67	553°F	1.24	1.060	30.15°F	30.15°F	30.15°F
W-Braid. 1	0.03	0.67	553°F	2.09	1.201	49.68°F	49.68°F	49.68°F
U-Braid. 2	0.03	0.71	553°F	0.400	0.746	0.0°F	0.0°F	0.0°F
X-Braid. 2	0.03	0.71	553°F	1.23	1.058	26.3°F	26.3°F	26.3°F
W-braid. 2	0.03	0.71	552°F(1)	2.25	1.220	23.9°F	23.9°F	23.9°F

Notes:

(1) Per Table 1 and discussion herein, no temperature adjustment required.

(2) The normalized chemical composition for this weld heat (442011) is 0.03%Cu and 0.67%Ni. This produces a chemistry factor of 41, which identical to the chemistry factor for both the Braidwood 1 and 2 surveillance data. Therefore the surveillance weld metal ΔRT_{NDT} values were not adjusted to normalize chemical composition.

The vessel being analyzed is Braidwood Unit 2.

The best estimate chemistry for weld heat 442011 is:

0.03% Cu and 0.67% Ni ➔ Table CF_{Vessel} = 41°F

Weld heat number 442011 is in the surveillance program and in the vessel, and T_{plant} = 553°F

Credibility assessment - Braidwood Unit 2 Data Only:

The data most representative for Braidwood Unit 2 is that from Braidwood Unit 2 since the irradiation environment of the surveillance capsules and the vessel are the same. The data requires the least adjustments.

No temperature adjustment is needed.

Following is the determination of the CF using only Braidwood Unit 2 surveillance data.

TABLE 3
Determination of Surveillance Weld CF Braidwood Unit 2 Data Only

Material	Capsule	Capsule f	FF	ΔRT_{NDT}	$FF*\Delta RT_{NDT}$	FF^2
Braidwood Unit 2 Surveillance Weld Metal	U	0.400	0.746	0.0	0.0	0.557
	X	1.23	1.058	26.3	27.83	1.119
	W	2.25	1.220	23.9	29.16	1.488
				SUM:	56.99	3.164
	$CF = \Sigma(FF * RT_{NDT}) \div \Sigma(FF^2) = (56.99) \div (3.164) =$ **18.0°F**					

Slope of best fit line = 18.0°F

TABLE 4
Braidwood Unit 2 Surveillance Capsule Data Only

Capsule	Cu (%)	Ni (%)	Irradiation Temperature ($T_{capsule}$)	Fluence (x 10^{19})	Fluence Factor (FF)	Measured ΔRT_{NDT}	Predicted ΔRT_{NDT} from Best Fit Line	(Measured - Predicted) ΔRT_{NDT}
U-Braid. 2	0.03	0.71	553°F	0.400	0.746	0.0°F	13.4°F	-13.4°F
X-Braid. 2	0.03	0.71	553°F	1.23	1.058	26.3°F	19.0°F	-7.3°F
W-Braid. 2	0.03	0.71	552°F	2.25	1.220	23.9°F	22.0°F	1.9°F

Where predicted ΔRT_{NDT} = $(Slope_{best\ fit})$ * (Fluence Factor)

Data are credible since the scatter is less than 28°F for all surveillance specimens.

Determination of CF - Braidwood Unit 2 data only

No temperature adjustments are necessary since $T_{capsule} = T_{plant}$

Adjust measure values of ΔRT_{NDT} for chemical composition differences (normalize data to best estimate of vessel weld):

Ratio = $(CF_{VW} \div CF_{SW})$= $(41.0 \div 41.0) = 1.0$

Therefore no chemistry adjustment needed.

Following is the determination of the best fit line relating adjusted ("ratio and temperature" adjusted) ΔRT_{NDT} to FF. The slope of this best fit line is the $CF_{Surv. Data.}$

Since no temperature or chemistry adjustments were required, the adjusted ΔRT_{NDT} is the same as the "ratio and temperature" adjusted ΔRT_{NDT}. From Table 2 the CF is:

$CF_{Surv. Data} = 18.0°F$

Credibility Assessment - All Data:

The data from all sources should also be considered

Since data are from multiple sources the data must be adjusted for chemical composition and irradiation environment differences and then plot the "ratio and temperature" adjusted ΔRT_{NDT} values versus FF and determine the best fit line.

For credibility determination, data are normalized to the mean chemical composition and temperature of the Braidwood Unit 2 surveillance specimens.

TABLE 5

Braidwood Unit 1 and Unit 2 Surveillance Capsule Data Chemistry Factor

Material	Capsule	Capsule $f^{(a)}$	$FF^{(b)}$	Ratio Temperature Adjusted $\Delta RT_{NDT}^{(c)}$	$FF*\Delta RT_{NDT}$	FF^2
Braidwood 1 Surveillance Weld	U	0.387	0.737	17.06°F	12.57°F	0.543
	W	1.24	1.060	30.15°F	31.96°F	1.124
	X	2.09	1.201	49.68°F	59.67°F	1.442
Braidwood 2 Surveillance Weld	U	0.400	0.746	0.0°F	0.0°F	0.557
	X	1.23	1.058	26.3°F	27.82°F	1.119
	W	2.25	1.220	23.9°F	29.16°F	1.488
				SUM:	161.19°F	6.273
	$CF_{Weld} = \Sigma(FF * RT_{NDT}) \div \Sigma(FF^2) = (161.19) \div (6.273) =$ **25.7°F**					

Notes:

(a) Calculated fluence (x 10^{19} n/cm^2, E > 1.0 MeV).

(b) FF = fluence factor = $f^{(0.28 - 0.1*\log f)}$.

(c) The surveillance weld metal ΔRT_{NDT} values have not been adjusted (Ratio Procedure: (Ratio = 1.0 for Unit 1 & 2) and irradiation temperature is 553°F for all capsules except Unit 2 W, which is 552°F (See Table 1)).

The slope of the best fit line = 25.7°F

TABLE 6

Best Fit of all Weld Metal Surveillance Data Available

Capsule	Cu (%)	Ni (%)	Irradiation Temperature ($T_{capsule}$)	Fluence (x 10^{19})	Fluence Factor (FF)	Ratio Temperature Adjusted (553°F) ΔRT_{NDT}	Predicted ΔRT_{NDT} from Best Fit Line	(Measured - Predicted) ΔRT_{NDT}
U-Braid. 1	0.03	0.67	553°F	0.387	0.737	17.06°F	18.9°F	-1.8°F
X-Braid. 1	0.03	0.67	553°F	1.24	1.060	30.15°F	27.2°F	3.0°F
W-Braid. 1	0.03	0.67	553°F	2.09	1.201	49.68°F	30.9°F	18.8°F
U-Braid. 2	0.03	0.71	553°F	0.40	0.746	0.0°F	19.2°F	-19.2°F
X- Braid. 2	0.03	0.71	553°F	1.23	1.058	26.3°F	27.2°F	0.9°F
W-Braid. 2	0.03	0.71	552°F	2.25	1.220	23.9°F	31.4°F	7.5°F

Where predicted ΔRT_{NDT} = ($Slope_{best\ fit}$) * (Fluence Factor)

Data are credible since the scatter is less than 28°F for all surveillance specimens.

Therefore, the surveillance program weld metal CF to be used in calculations is 25.7°F and is based on all available surveillance data.

Now that the Weld Metal has been evaluated for credibility, the Forging material must be evaluated. Table 7 calculates the CF from surveillance data for the lower shell forging 50D102-1/50C97-1.

TABLE 7

Calculation of Chemistry Factors for the Lower Shell Forging using Surveillance Capsule Data

Material	Capsule	Capsule f[(a)]	FF[(b)]	ΔRT_{NDT}[(c)]	FF*ΔRT_{NDT}	FF^2
Lower Shell Forging 50D102-1/50C97-1 (Tangential)	U	0.400	0.746	0.0[(d)]	0	0.557
	X	1.23	1.058	0.0[(d)]	0	1.119
	W	2.25	1.220	4.53	5.53	1.488
Lower Shell Forging 50D102-1/50C97-1 (Axial)	U	0.400	0.746	0.0[(d)]	0	0.557
	X	1.23	1.058	33.94	35.91	1.119
	W	2.25	1.220	33.2	40.50	1.488
				SUM:	81.94	6.328
	$CF = \Sigma(FF * RT_{NDT}) \div \Sigma(FF^2) = (81.94) \div (6.328) = 12.9°F$					

Notes:

(a) Braidwood Unit 2 capsule fluences were updated as a part of the capsule W dosimetry analysis (Ref. 1), (x 10^{19} n/cm^2, E > 1.0 MeV).

(b) FF = fluence factor = $f^{(0.28 - 0.1*\log f)}$.

(c) ΔRT_{NDT} values are the measured 30 ft-lb shift values taken from Ref. 1.

(d) Actual values of ΔRT_{NDT} are -9.73 (Cap U Tang.), -9.42 (Cap. X Tang.), -0.13 (Cap. U Axial). This physically should not occur, therefore for conservatism (i.e. higher chemistry factor) a value of zero will be used.

TABLE 8

Predicted Versus Best-Estimate ΔRT_{NDT} Values for the Braidwood Unit 2 Forging Surveillance Data

Material	Capsule	CF	FF	Best Estimate ΔRT_{NDT}	Measured ΔRT_{NDT}	Change in ΔRT_{NDT} (B.E. - Measured)
Lower Shell Forging	U	12.9°F	0.746	9.6°F	0.0°F[(a)]	9.6
50D102-1/50C97-1	X	12.9°F	1.058	13.6°F	0.0°F[(a)]	-13.6
(Tangential)	W	12.9°F	1.220	15.7°F	4.53°F	11.2
Lower Shell Forging	U	12.9°F	0.746	9.6°F	0.0°F[(a)]	9.6
50D102-1/50C97-1	X	12.9°F	1.058	13.6°F	33.94°F	-20.3
(Axial)	W	12.9°F	1.220	15.7°F	33.2°F	-17.5

NOTE:

(a) Actual values of ΔRT_{NDT} are -9.73 (Cap U Tang.), -9.42 (Cap. X Tang.), -0.13 (Cap. U Axial). This physically should not occur, therefore for conservatism a value of zero will be used.

From Table 8 above, the Braidwood Unit 2 Forging Data has four out of six data points within the 17°F scatter band. Since one of the points is out only 0.5 from the 17°F cut-off, then an argument could be made that this is actually within the scatter band due to how the data is plotted (i.e. symmetric versus asymmetric), measured and/or rounding error. This would leave one of six outside the scatter band. This condition would be considered credible, however for conservatism, **the forging surveillance data is considered non-credible.**

Since the forging material is deemed non-credible, a check for conservatism will be performed. This is done by comparing the chemistry factor using Position 1.1 of Regulatory Guide 1.99, Revision 2 to the chemistry factor using Position 2.1 of Regulatory Guide 1.99, Revision 2. The copper and nickel weight percent for the Braidwood Unit 2 Surveillance forging material is 0.06, 0.76, respectively. Using Table 2 from the Regulatory Guide 1.99, Revision 2, the chemistry factor is 37.0°F

TABLE 9

Lower Shell Forging 50D102-1/50C97-1 Position 1.1 Table Chemistry Factor Conservatism Assessment

Material	Capsule	CF	FF	Best Estimate ΔRT_{NDT}	Measured ΔRT_{NDT}	Change in ΔRT_{NDT} (B.E. - Measured)
Lower Shell Forging 50D102-1/50C97-1 (Tangential)	U	37.0°F	0.746	27.6°F	0.0°F[(a)]	27.6
	X	37.0°F	1.058	39.1°F	0.0°F[(a)]	39.1
	W	37.0°F	1.220	45.1°F	4.53°F	40.6
Lower Shell Forging 50D102-1/50C97-1 (Axial)	U	37.0°F	0.746	27.6°F	0.0°F[(a)]	27.6
	X	37.0°F	1.058	39.1°F	33.94°F	5.2
	W	37.0°F	1.220	45.1°F	33.2°F	11.9

NOTE:

(a) Actual values of ΔRT_{NDT} are -9.73 (Cap U Tang.), -9.42 (Cap. X Tang.), -0.13 (Cap. U Axial). This physically should not occur, therefore for conservatism a value of zero will be used.

Since the scatter is greater than 2*σ (σ_Δ = 17°F) for two out of six points, the Table CF is non-conservative. Therefore, the surveillance program forging material CF to be used in calculations is 12.9°F along with a full margin.

Criterion 4: The irradiation temperature of the Charpy specimens in the capsule should match the vessel wall temperature at the cladding/base metal interface within +/- 25°F.

The capsule specimens are located in the reactor between the core barrel and the vessel wall and are positioned opposite the center of the core. The test capsules are in baskets attached to the neutron pads. The location of the specimens with respect to the reactor vessel beltline provides assurance that the reactor vessel wall and the specimens experience equivalent operating conditions such that the temperatures will not differ by more than 25°F. Hence, this criteria is met.

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

The Braidwood Unit 2 surveillance program does not contain correlation monitor material. Therefore, this criterion is not applicable to the Braidwood Unit 2 surveillance program.

CONCLUSION:

Based on the preceding responses to all five criteria of Regulatory Guide 1.99, Revision 2, Section B and 10 CFR 50.61, the Braidwood Unit 2 surveillance weld data is credible, while the surveillance forging data is considered non-credible.

3 REFERENCES

1 WCAP-15369, "Analysis of Capsule W from the Commonwealth Edison Co. Braidwood Unit 2 Reactor Vessel Radiation Surveillance Program", T. J. Laubham, et al., February 2000.

2 Regulatory Guide 1.99, Revision 2, "Radiation Embrittlement of Reactor Vessel Materials", U.S. Nuclear Regulatory Commission, May, 1988.

3 WCAP14824, Rev. 2, "Byron Unit1 Heatup and Cooldown Limit Curves for Normal Operation and Surveillance Weld Metal Integration For Byron and Braidwood", T.J. Laubham, et. al., November 1997.

4 NDIT No. BRW-DIT-97-321, Rev. 0, "Braidwood Station Historical Tcold Data for Units 1 and 2", M.A. Gorski (ComEd), 10-22-97.

5 NDIT No. BRW-DIT-2000-0010, Rev. 0, "Braidwood Station Historical Tcold Data for Units 1 and 2 Cycle 7", M.A. Gorski (ComEd), 1-20-2000.

APPENDIX A

NRC CASES 4 & 5 FROM NOVEMBER INDUSTRY MEETING

CASE 4 - SURVEILLANCE DATA AVAILABLE FROM PLANT AND OTHER SOURCES

Surveillance data

Capsule Designation	NSSS Vendor	Cu	Ni	Irradiation Temperature ($T_{Capsule}$)	Fluence ($x10^{19}$)	Fluence Factor (FF)	Measured ΔRT_{NDT}	Temperature Adjusted (550°F) ΔRT_{NDT}	Ratio, Temperature Adjusted (550°F) ΔRT_{NDT}
Plant a - 1	B&W	0.37	0.70	556.0	0.779	0.930	214.0	220.0	196.0
Plant b - 1	B&W	0.33	0.67	556.0	0.107	0.431	124.0	130.0	126.0
Plant b - 2	B&W	0.33	0.67	556.0	0.866	0.960	203.0	209.0	202.5
Plant c - 1	B&W	0.33	0.67	556.0	0.830	0.948	182.0	188.0	182.2
Plant c - 2	B&W	0.33	0.67	556.0	0.968	0.991	222.0	228.0	221.0
Plant x - 1	West.	0.24	0.66	536.0	0.281	0.653	165.0	151.0	172.1
Plant x - 2	West.	0.24	0.66	536.0	1.940	1.181	240.0	226.0	257.6

Normalization for credibility determination (when all data are being used)

Data normalized to mean chemical composition (i.e., copper and nickel) of surveillance specimens

Cu = 0.31%
Ni = 0.67%

Data normalized to mean temperature of surveillance specimens

$T_{Normalize} = 550°F$

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

Assume the following for Plant "x" (the plant whose vessel is being assessed)

Weld heat 299L44 is in the surveillance program and in the vessel

T_{Plant} = 536°F

Surveillance data for heat 299L44 is also available from other sources

Best estimate for heat

Weld metal

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

Credibility assessment - Plant "x" data only

The data most representative for Plant "x" is that from Plant "x" since the irradiation environment of the surveillance capsules and the vessel are very similar. This data requires the least adjustment (e.g., no temperature correction)

Plant "x" data should be examined independently to determine credibility

Since all data are from one source (Plant "x"), plot measured ΔRT_{NDT} versus FF and determine best fit line

Slope of best fit line = 214.8°F

Capsule	Cu	Ni	Irradiation Temperature ($T_{Capsule}$)	Fluence ($x10^{19}$)	Fluence Factor (FF)	Measured ΔRT_{NDT}	Predicted ΔRT_{NDT} from best fit line	(Measured - Predicted) ΔRT_{NDT}
Plant x - 1	0.24	0.66	536.0	0.281	0.653	165.0	140.3	24.7
Plant x - 2	0.24	0.66	536.0	1.940	1.181	240.0	253.6	-13.6

where predicted ΔRT_{NDT} = ($Slope_{best\ fit}$)*(Fluence Factor)

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

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

Determination of CF - Plant "x" data only

No temperature adjustments are necessary since $T_{Capsule} = T_{Plant}$

Adjust measured values of ΔRT_{NDT} for chemical composition differences as follows (normalize data to best estimate of vessel being assessed):

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

$CF_{Table,\ Surv.\ chem.} = 182.9°F$

Determine best fit line relating adjusted ("ratio and temperature" adjusted) ΔRT_{NDT} to FF. The slope of this best fit line is the $CF_{Surv.\ Data}$.

Since no temperature adjustments were required in this case the ratio adjusted ΔRT_{NDT} is the same as the "ratio and temperature" adjusted ΔRT_{NDT}

$CF_{Surv.\ Data} = 259.0°F$

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

Credibility assessment - All data

The data from all sources should also be considered

Since data are from multiple sources, must adjust data for chemical composition and irradiation environment differences and then plot the "ratio and temperature" adjusted ΔRT_{NDT} values versus FF and determine best fit line

For credibility determination, data are normalized to the mean chemical composition and temperature of the surveillance specimens

Slope of best fit line = 218.4°F

Capsule	Cu	Ni	Irradiation Temperature ($T_{Capsule}$)	Fluence ($x10^{19}$)	Fluence Factor (FF)	Ratio and Temperature (550) Adjusted ΔRT_{NDT}	Predicted ΔRT_{NDT} from best fit line	(Adjusted - Predicted) ΔRT_{NDT}
Plant a - 1	0.37	0.70	556.0	0.779	0.930	196.0	203.1	-7.1
Plant b - 1	0.33	0.67	556.0	0.107	0.431	126.0	94.1	31.9
Plant b - 2	0.33	0.67	556.0	0.866	0.960	202.5	209.6	-7.1
Plant c - 1	0.33	0.67	556.0	0.830	0.948	182.2	207.0	-24.8
Plant c - 2	0.33	0.67	556.0	0.968	0.991	221.0	216.4	4.5
Plant x - 1	0.24	0.66	536.0	0.281	0.653	172.1	142.8	29.4
Plant x - 2	0.24	0.66	536.0	1.940	1.181	257.6	258.0	-0.4

where predicted $\Delta RT_{NDT} = (Slope_{best\ fit})*(Fluence\ Factor)$

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

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

Determination of CF - All Data

If data were credible, the CF would be determined as follows

Must make irradiation temperature and chemical composition adjustments since the irradiation temperature and chemistry differ between the capsules and the plant being assessed

For capsules with $T_{Capsule}$ greater than 536°F (i.e., T_{Plant}), must increase $\Delta RT_{NDT,\ measured}$ by 1.0°F for each degree difference in irradiation temperature to get the temperature adjusted ΔRT_{NDT} (i.e., $\Delta RT_{NDT,\ T\ adjusted}$)

To obtain the "ratio and temperature" adjusted ΔRT_{NDT}, apply the ratio procedure as follows:

$$Ratio/Temperature\ Adjusted\ \Delta RT_{NDT} = \left(\frac{CF_{Table,\ Vessel\ Chem.}}{CF_{Table,\ Surv.\ Chem.}}\right) * \Delta RT_{NDT,\ T\ adjusted}$$

Determine best fit line relating adjusted ("ratio and temperature" adjusted) ΔRT_{NDT} to FF. The slope of this best fit line is the $CF_{Surv.\ Data}$. $CF_{Surv.\ Data}$ = 247.2°F

Appropriate CF

Data from the plant being assessed were evaluated and the data were credible

When all of the data were evaluated, the data were determined to be not credible

Since the data from the plant being assessed is the most appropriate and requires the least amount of adjustment, the CF determined from evaluation of the Plant "x" data is the most appropriate.
$CF_{Surv.\ Data}$ = 259.0°F

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

Effects of data analysis technique (Ratio procedure and using plant-specific data)

Previous analyses

Ratio procedure not applied, temperature correction to data from other sources not made, All data used

$RT_{NDT(U)} = -7.0°F$; $M = 49.8$; $CF = 217.0°F$; $FF = 0.8745$

$$RT_{NDT,\ previous} = -7.0 + 49.8 + (217.0 * 0.8745) = 232.6°F$$

Current analyses

Ratio procedure applied, No temperature correction necessary, Only Plant "x" data used

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