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SUBJECT: Response to Generic Ltr 88-11 re reactor vessel radiation embrittlement.

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H. B. ROBINSON STEAM ELECTRIC PLANT, UNIT NO. 2
DOCKET NO. 50-261/LICENSE NO. DPR-23
RESPONSE TO GENERIC LETTER 88-11

Gentlemen:

In accordance with the requirements of Generic Letter 88-11, Carolina Power & Light Company has performed the analysis of Reactor Vessel radiation embrittlement for the H. B. Robinson Steam Electric Plant, Unit No. 2 (HBR2). An extension of the due date for this response was negotiated with the Project Manager on November 17, 1988. This analysis uses the provisions of the recently issued Revision No. 2 to Regulatory Guide 1.99 to determine the radiation-induced shift in RT_{NDT} and the impact of this shift on heatup and cooldown curves and Low-Temperature-Overpressure Protection (LTOP) setpoints. The analysis also incorporates the most recent fluence determinations resulting from Cycle 11 fast fluence measurements. Revised fluence values are presented in Attachment 1.

As anticipated and discussed with members of your staff, issuance of Revision 2 to Regulatory Guide 1.99 in combination with the recent NRC acceptance of the legitimacy of the HBR2 Surveillance Weld has had a substantial favorable effect upon the Robinson Vessel embrittlement predictions. Current projections indicate that the HBR Vessel will exhibit acceptable embrittlement characteristics for more than 95 Effective Full Power Years (EFPY) with the present fluence profile.

BACKGROUND

The recent evolution of the HBR2 embrittlement issue is somewhat complicated due to the number of factors which have coincidently come into play in developing the current position. Carolina Power & Light Company has previously outlined the major steps in developing this position in meetings with the staff and subsequent submittals concerning the HBR Surveillance Weld. However, to ensure a clear understanding of the recent evolution of this issue, the following chronology of events is provided:

- o In meetings with the staff, and as subsequently documented in our January 16, 1987 submittal, CP&L established a legitimacy of the HBR2 Surveillance Weld and stated our intention to use the embrittlement data from our surveillance program in the future to evaluate the embrittlement of the upper circumferential weld.

A001 1/1

- The January 1987 submittal presented our evaluation of the upper circumferential weld embrittlement using the 10CFR50.61 PTS Rule equations. The embrittlement evaluation, based upon the copper and nickel chemistry assigned to the weld, demonstrated that the upper circumferential weld exhibited a RT_{NDT} of $269^{o}F$.

- The January 1987 submittal also identified the fact that the validity of the previously accepted nickel content of the lower circumferential weld was brought into question as a result of discoveries made while investigating the legitimacy of the HBR Surveillance Weld. Carolina Power & Light Company indicated that the final determination of the nickel content of the lower weld was the subject of an ongoing investigation; however, final resolution of lower weld chemistry was not necessary for the purpose of the PTS response since the upper weld was clearly controlling for any feasible worst case nickel content when the PTS equation was used.

- The subsequent NRC acceptance of the legitimacy of the HBR2 surveillance weld (June 19, 1987 Safety Evaluation Report) now enables CP&L to use the data from our surveillance program to evaluate the radiation-induced embrittlement for the upper circumferential beltline weld. When Revision 2 of Regulatory Guide 1.99 and the results from the surveillance capsule data are employed, the embrittlement predicted for the upper weld is substantially reduced (as demonstrated by the RT_{NDT} comparison table which follows). Attachment 2 provides the details of the evaluation of the upper weld embrittlement using the surveillance capsule data and the methodology provided in Position 2 of Regulatory Guide 1.99, Revision 2. This attachment also addresses the criteria identified in the Regulatory Guide which are used to determine whether the capsule is representative of the upper circumferential weld.

- With the substantial embrittlement margin gained on the upper weld through use of the surveillance data, the lower weld was recognized as having the potential for becoming controlling. Therefore, it was necessary to accurately establish the nickel and copper content of the lower weld in order to compute its embrittlement. The details of the investigation and the resulting chemistry determinations are presented in Attachment 3 to this submittal.

- The empirical correlations of embrittlement to weld chemistry provided in Revision 2 of Regulatory Guide 1.99 are substantially more sensitive to nickel content than previous correlations using Revision 1 of Regulatory Guide 1.99 or the equations used in the PTS rule. This factor also contributed to the lower weld embrittlement competing with the upper weld for controlling status. Attachment 3 provides the evaluation of the lower weld embrittlement using the proposed chemistry and the methodology presented in Position 1 of Regulatory Guide 1.99, Revision 2.

SUMMARY OF RESULTS

The table below demonstrates how the embrittlement characteristics of both the upper and lower weld are affected by application of Revision 2 of Regulatory Guide 1.99 along with the capsule data and weld chemistries presented in this submittal. Both welds are shown to be acceptable well beyond the current license of the plant with the lower weld being slightly controlling. As calculations are extended beyond the current license, the upper weld assumes the controlling status. Using current fluence projections, vessel embrittlement is considered acceptable for more than 95 EFPY.

COMPARISON OF END OF LICENSE RT_{NDT}s

	PTS Submittal	Reg. Guide 1.99 Rev. 2
Upper Circumferential Weld 10-273	269°F	237°F
Lower Circumferential Weld 11-273	*	245°F
Max. Longitudinal Welds 2-273	139°F	145°F
Max. Plate W10201-1	182°F	167°F

* Not computed. Shown to be bounded by upper circumferential weld.

IMPACT ON PLANT OPERATION

The existing heat-up and cooldown curves and LTOP setpoints are based upon the previous evaluation of the upper weld in accordance with Revision 1 of the Regulatory Guide. The maximum RT_{NDT} for the upper weld was 314°F using the Regulatory Guide 1.99, Rev. 1 methodology. When the surveillance data is considered in accordance with the provisions of Revision 2 of the Regulatory Guide, this analysis demonstrates that these embrittlement-dependent operating restrictions can be substantially relaxed.

Due to the expense involved with generating revised heatup and cooldown curves based upon the new embrittlement evaluations, CP&L has elected to defer calculation of new operating curves until NRC concurrence with the positions presented in this submittal is obtained. Because the existing, acceptable curves contain significant conservatism, CP&L is anxious to obtain the operational flexibility provided by the new analysis.

In addition, CP&L may elect to modify the current flux reduction program in light of the improved embrittlement predictions presented herein. The current Partial Length Shielded Assemblies (PLSAs) are approaching the end of their life and CP&L may need to order new PLSAs within one year. However, formal NRC concurrence with the data and methodology used in the embrittlement analysis for both the upper and lower weld is necessary before meaningful evaluation of the PLSA redesign can proceed. Submittal of revised heatup and cooldown curves may be further postponed until the impact of any changes in the flux reduction program can be incorporated. Your timely review and formal concurrence with the position delineated herein is requested in order to allow these efforts to proceed.

Finally, as a result of the recent investigation into nickel addition type welds, Carolina Power & Light Company was able to strengthen its previously docketed contention that single arc Ni-200 welds were intentionally lower in nickel than tandem arc Ni-200 welds. This position was a key element in establishing the legitimacy of the HBR2 surveillance weld. Carolina Power & Light Company's position previously relied upon a notation in the weld procedure and limited data to substantiate that contention. However, Combustion Engineering (CE) was able to provide a logical, technical reason for this "lower nickel target on single arc welds" which greatly enhances the confidence level and defendability of the CP&L position. These findings are presented for your information in Attachment 4 to this submittal.

If you have any questions concerning this request, please contact Mr. L. I. Loflin at (919) 836-6242.

Yours very truly,

R. B. Richey
Manager
Nuclear Services Department

RBR/MDM/crs (5463MDMa)

Attachments

cc: Mr. M. Ernst
Mr. R. Lo
NRC Resident Inspector - RNP

ATTACHMENT 1

CP&L's continuous monitoring of fast neutron fluence by means of reactor cavity dosimetry and iterations with neutron transport calculations provides the numbers in Figure 1. This figure provides a revision to Figure 1 of CP&L's response to the PTS rule, January 22, 1986. It includes the results of measurements and calculations for Cycle 11.

(5463MDMa/lah)

IDENTIFICATION, LOCATION AND END OF LICENSE FLUENCE OF BELTLINE REGION MATERIAL FOR THE H. B. ROBINSON UNIT NO. 2 REACTOR VESSEL

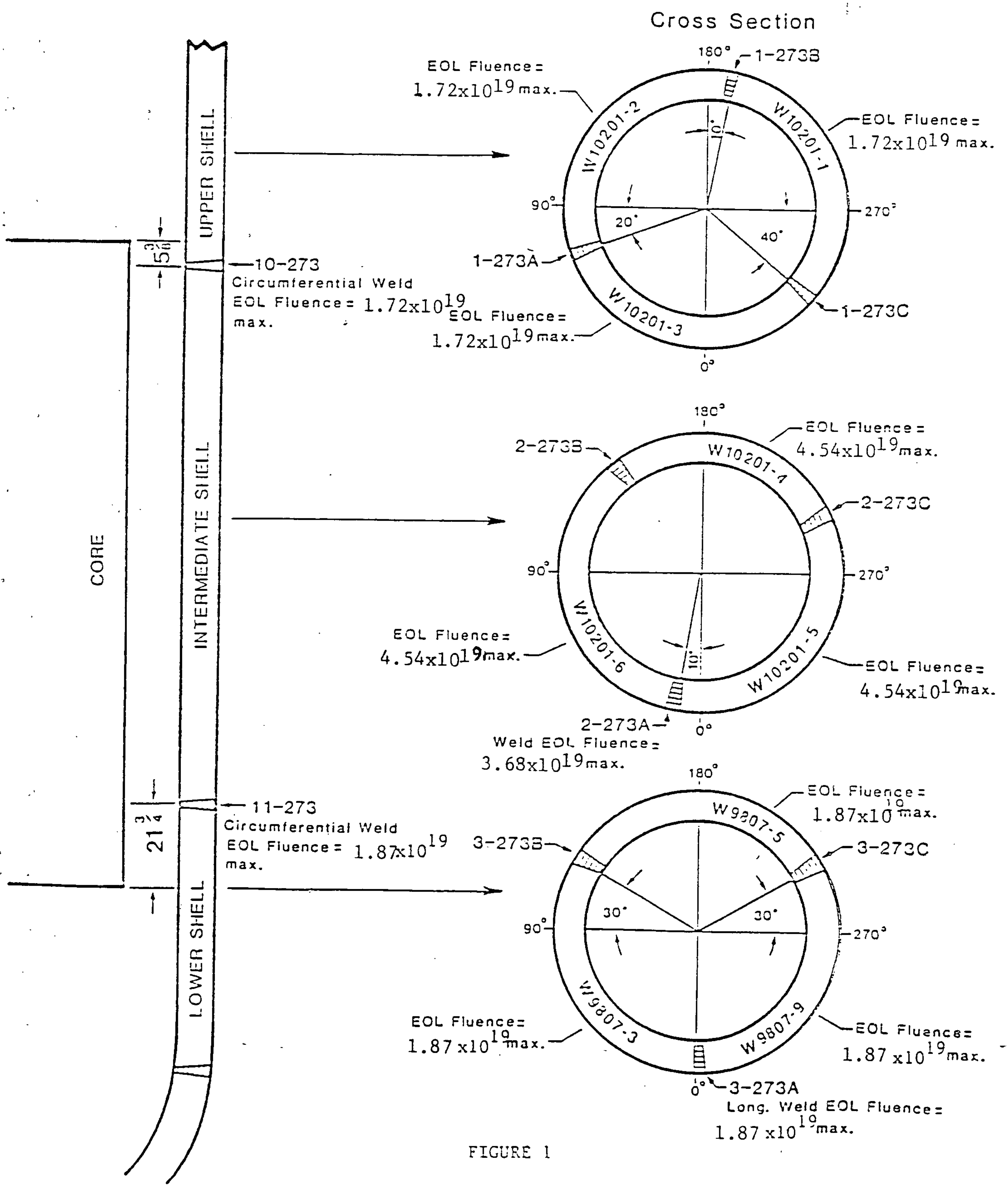


FIGURE 1

ATTACHMENT 2

EVALUATION OF EMBRITTLEMENT OF UPPER CIRCUMFERENTIAL WELD

SURVEILLANCE PROGRAM DATA

With NRC acceptance of the legitimacy of the HBR2 Surveillance Weld, the surveillance weld test results from Capsules V and T can now be used in calculation of the change in RT_{NDT}. Capsule V was tested by SWR1 and reported for Project No. 02-4397, October 19, 1976; Capsule T was tested by Westinghouse and reported in WCAP-10304, March 1983. Fracture toughness results for the two capsules are shown in Figure 1 of this attachment.

Use of surveillance capsule data is predicated upon demonstrating that the surveillance weld is "representative" of the vessel weld that it is intended to represent.

The judgement criteria for the surveillance weld as listed in Position 2 of Revision 2 the regulatory guide are considered in order as follows:

Criterion 1 - Materials in the capsules should be those judged most likely to be controlling with regard to radiation embrittlement according to the recommendations of this guide.

Response:

The surveillance weld is representative of the upper circumferential weld in the region of the vessel. As was established in our January 1987 PTS response, both welds were fabricated using identical weld metal, flux, and weld procedures.

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-foot-pound temperature and the upper-shelf unambiguously.

Response:

Scatter in the Charpy V test results for the unirradiated Capsule V and Capsule T conditions is small except for one data point each from Capsules V and T. The test results were analyzed with cubic spline and generalized cross validation methods to obtain the best Charpy V curves. The methods yielded a more conservative ΔRT_{NDT} than hyperbolic tangent or other methods for Capsule V. The test points for Capsule T were closely bunched in the transition region in order to obtain the most reliable Charpy V curve for the 30-foot-pound impact loading at the highest fast neutron flux exposure.

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 $28^{o}F$ for welds and $17^{o}F$ 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 E 185-82 (Ref. 1).

Response:

The best fit line for the surveillance weld test results from Capsules V and T is shown in Figure 1 of this attachment. Scatter is not a problem.

Criterion 4 - The irradiation temperature of the Charpy specimens in the capsule should match vessel wall temperature at the cladding/base metal interface within $\pm 25^{\circ}F$.

Response:

The H. B. Robinson 2 surveillance program is standard for the early Westinghouse NSSS. As suspended on the outside of the thermal shield and centered on the core center line, the contents of the capsules are cooled by the same annulus water as the inside vessel surface with stainless steel at the water interface. The temperature limits of ± 25°F are understood to be easily met under steady state conditions.

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.

Response:

The surveillance data for the correlation monitor material falls within the scatter band for the material as shown in Figure 2 of this attachment which was copied from ORNL's report on the surveillance plate. By their location in the upper half of the scatter band, the data demonstrates that the HBR2 surveillance capsule results are conservative.

EVALUATION RESULTS

Calculation of End of License RT_{NDT} for Upper Circumferential Weld Using Position 2 of Regulatory Guide 1.99, Revision 2, and Surveillance Data at I.D.

ΔRT_{NDT} (Capsule V) = 200
ΔRT_{NDT} (Capsule T) = 285

Where:

$$f_1 = .593^{.28-.1 \log .593} = .85370$$
$$f_2 = 4.1^{.28-.1 \log 4.1} = 1.36153$$
$$CF_1 = 200 \times .8537 = 170.7$$
$$CF_2 = 285 \times 1.36153 = 388.0$$
$$CF_1 + CF_2 = 170.7 + 388 = 559$$

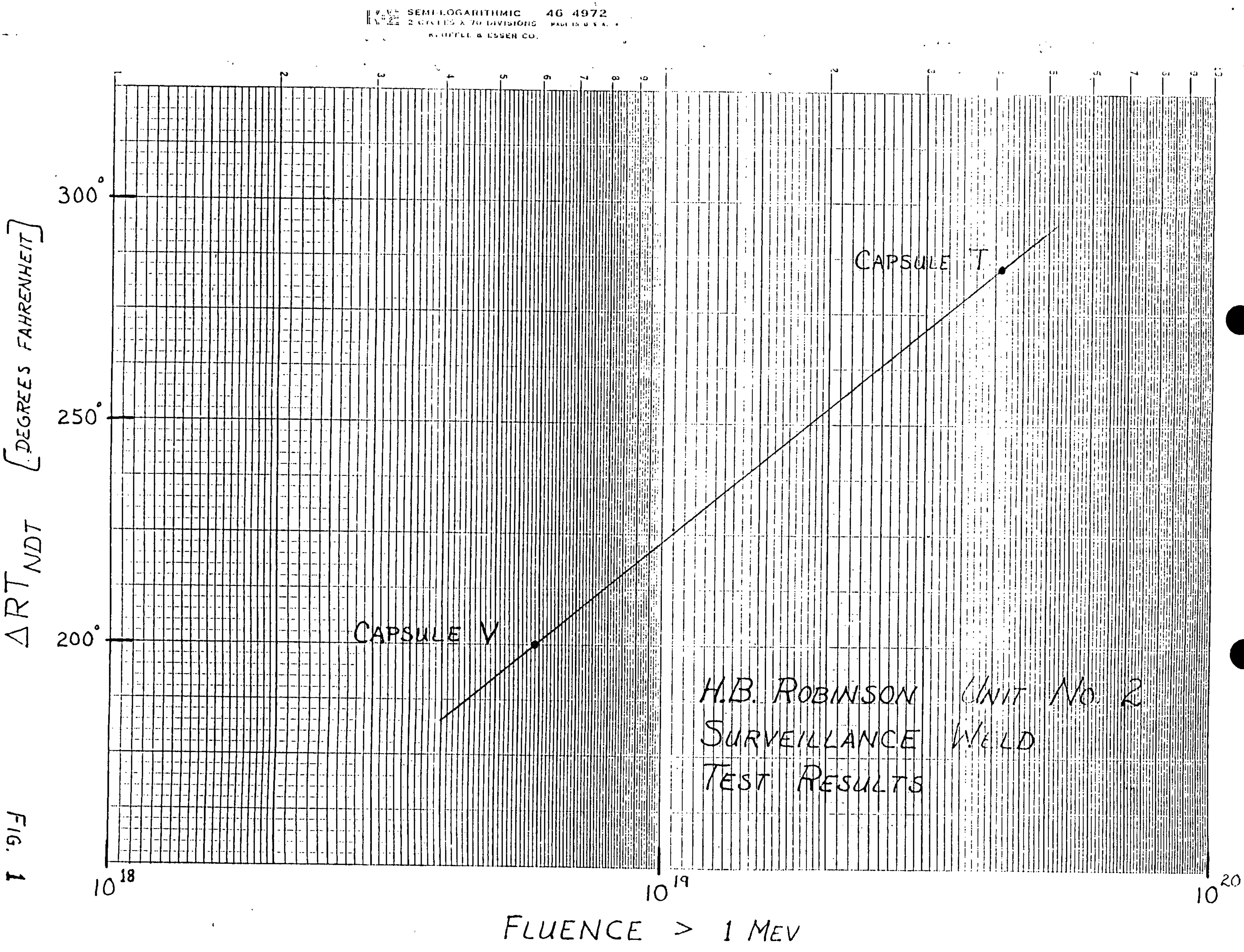
Divide by $.85370^2 + 1.36153^2 = .7288 + 1.85376 = 2.582$

$$\frac{CF_1 + CF_2}{2.582} = \frac{170.7 + 388}{2.582} = 816.4$$

$$\Delta RT_{NDT} = (216.4)\ f^{.28 - .1 \log f} = (216.4)\ 1.715^{.28 - .1 \log 1.715}$$
$$= (216.4)\ 1.1484 = 248.5$$

$$\sigma_\Delta = \frac{28}{2} = 14 \qquad \text{Margin} = 2\sqrt{\sigma_i^2 + \sigma_\Delta^2} = 2\sqrt{17^2 + 14^2} = 44$$

$$RT_{NDT} = -56 + 248.5 + 44 = 237°F$$



K&E SEMI-LOGARITHMIC 46 4972
2 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO.
300°
250°
200°
ΔRT NDT [DEGREES FAHRENHEIT]
CAPSULE T
CAPSULE V
H.B. ROBINSON UNIT NO. 2
SURVEILLANCE WELD
TEST RESULTS
10^18
10^19
10^20
FLUENCE > 1 MEV

FIG. 1

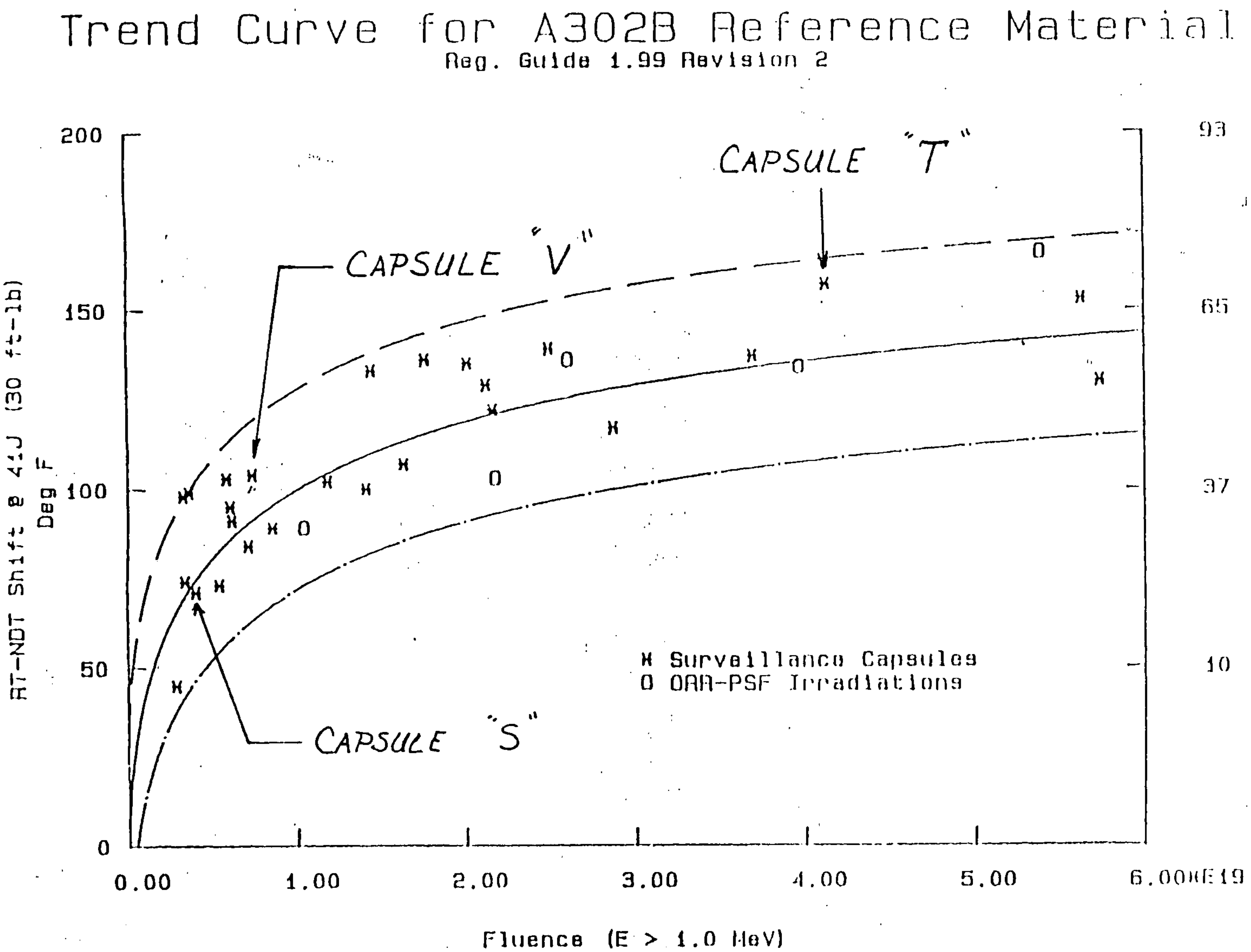


Fig. 2 Embrittlement of the A302B reference material relative to the Reg. Guide 1.99, Rev. 2. The upper and lower curves are the 28°F uncertainty bounds (2σ) specified by Reg. Guide 1.99.

ATTACHMENT 3

HBR2 LOWER CIRCUMFERENTIAL WELD

NICKEL CHEMISTRY

As a result of CP&L's previous investigation into the legitimacy of the HBR2 surveillance weld, it was recognized that the tandem arc welds which make up the great majority of the nickel addition (Ni-200) welds produced by Combustion Engineering in the mid-1960's were procedurally quite different than the Ni-200 welds produced using the single arc process. These procedural differences were expected to have caused the unexpectedly low nickel content of the HBR2 surveillance weld and all other single arc welds.

As a consequence of this discovery, the previously accepted chemistry of the vessel lower circumferential weld was brought into question. This tandem arc Ni-200 lower vessel weld had previously been assigned a nickel chemistry from a single arc Ni-200 weld of the same heat in the head of the HBR2 vessel. In light of the difference discovered between tandem and single arc weld procedures, this was considered inappropriate. At the time of the January 1987 PTS response, the upper weld was clearly the controlling weld for any feasible nickel content that might ultimately be assigned to the lower weld. Therefore, CP&L deferred assigning a revised chemistry to the lower vessel weld until a thorough investigation of tandem arc welds could be completed. The results of that investigation are presented below:

On December 18, 1987, CP&L met with key representatives of the Combustion Engineering at their plant in Chattanooga, Tennessee to obtain information relevant to the welding of the H. B. Robinson vessel at that facility in and around 1966. The CE representatives consisted of Welding, QA, and Engineering personnel involved in the manufacture of vessels at the time of the HBR2 vessel fabrication. Due to the vintage of the HBR2 plant and the nature of the issues discussed, some of the information discussed was not originally documented and therefore resides solely within the memories and expertise of those associated with the program at the time. This report documents the aspects of that meeting which have proved important to establishing the chemistry of circumferential welds in the H. B. Robinson plant vessel beltline region.

The following is a synopsis of the crucial aspects of that discussion and their immediate impact upon the HBR2 project.

- Previously CP&L had been concerned about a notation on the official weld "Traveler" document which directed the fabrication of the lower circumferential weld in CE's welding shop. The note alluded to possible use of non-standard weld parameters on that seam. CE allayed these concerns and provided an explanation of the notation which was logical and consistent with both the documentation and their shop practices. As a result, CP&L was satisfied that the lower girth seam was indeed fabricated using the standard tandem arc weld procedure and parameters.

- No evidence has been found to support previous CP&L speculation that the variability of nickel content observed within tandem arc, Ni-200 welds could be due to minor procedural variations of the weld parameters used to produce these welds. Therefore, CP&L will assume that all Ni-200 tandem arc welds were produced from the identical, procedurally controlled weld parameters and should exhibit similar weld chemistries.

- Having established that

  (1) the HBR2 lower girth weld is indeed a "standard" tandem arc, Ni-200 weld, and

  (2) all CE tandem arc, Ni-200 welds are procedurally identical.

  Carolina Power and Light Company can now use the data base of tandem arc, Ni-200 welds as representative of the nickel chemistry of the lower circumferential weld. CE was able to supplement the existing data base of tandem arc, Ni-200 weld with records from laboratory analyses of such welds performed during the 1966 time frame. The data base used to establish the nickel content of the lower vessel weld consists of welds identified by EPRI and Westinghouse in their previous reports on HBR2 weld chemistry, additional measurements available on the Palisades surveillance weld, and the data recently provided by CE lab reports.

A compilation of that data base is presented in Table A3-1. The overall average of 1.06 percent Ni had been assigned to represent the lower weld of the HBR2 vessel. This average does not take credit for any dilution effect attributable to unusually low nickel content of the HBR2 vessel plates. Although some lower nickel content of the weld is expected due to this dilution factor, CP&L was unable to quantify this effect at this time and elected to simply note this as an additional conservatism in the evaluation.

COPPER CHEMISTRY

The previous CP&L investigation concerning the identity of the HBR2 surveillance weld indicates that the most appropriate means of assigning a copper value to any specific weld would be to determine the average copper value exhibited by a large number of weld samples of the same heat of wire. Lacking sufficient data for a specific heat of weld wire, the data base can be legitimately expanded to include other heats of wire fabricated and copper coated by the same vendor (RACO) during the same time period. Inclusion of other heats in the data base is appropriate as long as the bare wire itself did not contain an unusually high or low copper content which could bias the measurements.

In this case, the heat of interest (34B009) is considered to have a slightly below average copper content in the bare wire. Therefore, the average copper content of RACO wire samples fabricated during the time frame in question is considered slightly conservative in assigning the copper content to the lower circumferential weld.

Here again the data base is primarily composed of data compiled from previous EPRI and Westinghouse reports on the subject and various miscellaneous measurements obtained through other sources. As recognized in previous CP&L submittals on this subject, all data from a single surveillance weld has been averaged to produce one independent data entry. The data demonstrates a 0.197 percent average copper content for this family of RACO weld wires and is tabulated in Table A3-2.

INITIAL RT_{NDT}

Combustion Engineering made both the HBR2 Lower Circumferential Weld and the Millstone 1 surveillance weld in 1967 using the same weld metal, flux, and tandem arc procedure. Specifically:

Weld metal	-	RACO 3 & Ni 200 Heat 34B009
Flux	-	Linde 1092
Procedure	-	SAA-33J(1)

Therefore, the initial RT_{NDT} of the Millstone Surveillance weld has been used in the evaluation of the HBR2 lower circumferential weld. The initial RT_{NDT} of the Millstone surveillance weld has been determined to be -80°F by General Electric in NEDC-30299, "Fracture Toughness of Reactor Vessel Steel Welds."

EVALUATION RESULTS

Using the fluence presented in Attachment 1 and the embrittlement parameters specified above in accordance with the provisions of Section 1 of Regulatory Guide 1.99, Revision 2, the lower weld is predicted to exhibit acceptable embrittlement characteristics well beyond the current end of license. The computation of RT_{NDT} at end of license for the Lower Circumferential Weld is presented below:

Cu = 0.20%
Ni = 1.06%
CF = 230
FF = 1.17
Initial RT_{NDT} = -80

$$\Delta RT_{NDT} = CF \times FF = 230 \times 1.17 = 269$$

$$RT_{NDT} = -80 + 269 + 56 = 245°F$$

At the present fluence profile, the lower weld is controlling throughout the current license. The upper weld would become controlling for significant life extension and eventually limit vessel life after more than 95 EFPY.

Table A3-1

Ni Content
Ni-200 Tandem Arc Welds

Source	Identification		Ni Content
EPRI Report	Millstone 1		.98
EPRI Report	Salem 1		1.26
EPRI Report	IP3-SW		1.02
EPRI Report	IP3-Longitude		1.09
EPRI Report	IP2-SW		1.15
EPRI Report	CE Lab Record		1.09 [5]*
HBR2 Head Grinding Samples			.99
	Palisades SW	1.38	
	Palisades SW	1.60	1.31**
EPRI Irradiated Steel Handbook	Palisades SW	.95	
CE Lab	D4494		.98
	D4577		.93
	D4604		1.07
	D4660		.96
	D4674		1.12
	D4687		.92
	D4673		1.05
	D4686		.97
	D4688		.99
Westinghouse Report	CE Analysis		1.20
		Average =	1.06

* Considered to be five independent samples.

** Three measurements of the same surveillance weld were averaged and considered to represent one independent sample.

(5463MDMa/lah)

Table A3-2

Cu Content
RACO 3 Weld Wire

		Cu Content (percent)
EPRI REPORT		
Humbolt	SW	0.22
Zorita	SW	0.22
Big Rock Pt.	SW	0.26
Tarapur	SW	0.16
Conn. Yankee	SW	0.22
San Onofre	SW	0.19
Millstone	SW	0.19
IP 2	SW	0.20
IP 3	SW	0.15
Salem 1	SW	0.16
IP 3	Longitude Seam	0.15
Lab Rec		0.20
Lab Rec		0.15
HBR2 MEASUREMENTS		
HBR2	SW	0.33
HBR2	Boat Sample(s)	0.19
HBR2	Grinding Samples	0.16
WESTINGHOUSE REPORT		
1/8" RACO/34B009		0.28
1/8" RACO/34B009		0.15
1/8" RACO/34B009		0.17
	AVERAGE	0.197

ATTACHMENT 4

EVOLUTION OF NICKEL ADDITION WELD PROCESS

The following information was obtained from CE personnel cognizant of CE's welding procedures and practices during the time of the HBR vessel fabrication.

Until mid-1965, CE was using RACO 3 welding wire and ARCOS flux without any nickel addition. In mid-1965 due to problems with this combination, CE switched to the Linde 1092 flux. However, this combination reduced the manganese content of the weldment.

Due to the reduced manganese content, the Linde 1092 welds did not exhibit sufficient strength to meet code requirements. Therefore, nickel was added to the weld via the cold wire feed process to enable the weld to achieve the required strength properties. The procedural target value for the amount of nickel to be added to the weld was established at a value which had demonstrated the required code strength in previous tests.

The perspective that the nickel was added to bring the weld up to the required strength properties is significant to understanding why the single arc Ni-200 welds apparently had a lower targeted nickel content than the tandem arc Ni-200 weld. Although both tandem and single arc welds were fabricated using the same flux/weld metal combinations, the tandem arc was obviously a much hotter weld. This additional heat input would have reduced the weld strength of the tandem arc in comparison to the single arc process. Therefore, it was been completely consistent with existing welding engineering practice to add more nickel to the tandem arc welds in comparison to the single arc welds to compensate for heat effects. In this way, both types of welds could exhibit the required strength properties while conserving relatively expensive nickel wire.