CEOG COMBUSTION ENGINEERING OWNERS GROUP

CE NPSD-906-NP

CEOG PROGRAM TO EVALUATE CHEMICAL CONTENT OF WELD DEPOSITS

FABRICATED USING

HEATS A8746 AND 34B009

CEOG TASK 747

Prepared for the
C-E OWNERS GROUP
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ABB Combustion Engineering Nuclear Power

93-02240474

ABB

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I. INTRODUCTION

This report presents the results of a task undertaken for the Combustion Engineering Owners Group (CEOG) to provide the basis for the copper and nickel content of reactor pressure vessel welds made using two specific heats of weld wire. These heats are common to beltline welds in several reactor vessels fabricated by ABB/CE in Chattanooga, Tennessee. The as-deposited welds were not always analyzed explicitly for copper or nickel during fabrication because the significance of those chemical elements to irradiation embrittlement was not then recognized. Subsequent efforts to estimate the as-deposited weld chemistry from limited data sometimes have resulted in different values for the same weld consumables. The purpose of this evaluation is to utilize a broad set of chemical analysis results in conjunction with information from material specifications to establish a consistent and viable basis for the as-deposited weld chemical content for four specific reactor pressure vessels involving two heats of weld wire.

II. BACKGROUND

Submittals were made in December 1991 to the Nuclear Regulatory Commission (NRC) in response to 10 CFR 50.61, "Fracture Toughness Requirements for Protection Against Pressurized Thermal Shock (PTS) Events" (Federal Register, v.5694, page 22304, May 15, 1991). The NRC expressed concern regarding the consistency and credibility of data used as the basis for PTS submittals, especially with respect to chemical content. Two or more licensees have reported different copper or nickel contents for reactor vessel welds for which an identical heat of weld wire was used. These differences arose in part because of the way multiple analyses were handled, the type of estimation methods used by licensees, or the degree to which data traceability was established.

The PTS submittal of one CEOG licensee was questioned by the NRC regarding the copper and nickel content of a vessel beltline weld formed using weld wire heat number A8746. This same weld wire heat was also used for two other CEOG licensees' vessel beltline welds. The same copper content (a single measurement, not an average) was reported by all three licensees, but different nickel contents were reported. An initial response to the question was prepared based on a review of fabrication records, procedures and specifications as described in the results section. This report builds upon that initial review using chemical analysis data representative of weld wire specifications and weld procedures employed by ABB/CE.

NRC guidance for determination of copper and nickel content is contained in 10 CFR 50.61, "Fracture Toughness Requirements for Protection Against Pressurized Thermal Shock Events". Four alternatives are available to obtain best-estimate copper and nickel values for the plate or forging, or for weld samples made with the weld wire heat number that matches the critical vessel weld as follows:

(1) The mean of the measured values, or, if these values are not available,

(2) the upper limiting values in the material specifications to which the vessel was built, or if not available,

(3) conservative estimates (mean plus one standard deviation) based on generic data from reactor vessels fabricated in the same time period to the same material specifications, if justification is provided.

(4) If none of the first 3 alternatives are available, 0.35% copper and 1.0% nickel must be assumed.

The preceding guidance was employed in this evaluation.

III. SCOPE

The objective of this evaluation is to provide best estimate values of copper and nickel content for weld deposits produced using the following materials:

1. [ ] weld wire heat A8746 and Linde 124 flux
2. [ ] weld wire heat 34B009 and Linde 124 or 1092 flux
3. [ ] weld wire heat 34B009 with Ni-200 cold wire feed and Linde 1092 flux

The preceding materials were used to fabricate reactor vessel beltline welds in Calvert Cliffs Unit 2, St. Lucie Unit 1, Millstone Unit 1, and Millstone Unit 2. The guidelines contained in 10 CFR 50.61 are followed to provide those best estimates. The approach taken is to review ABB/CE welding procedures and specifications, to collect chemical analysis results specific to the three weld materials noted, and to collect chemical analysis results for comparable and contrasting weld materials. This information is then evaluated to determine the best estimate value for:

1. the nickel content of [ ] wire weld deposits, specifically heats #A8746 and 34B009,
2. the copper content of [ ] wire weld deposits, specifically heat #A8746
3. the copper content of [ ] heat #34B009 weld deposits, and
4. the nickel content of [ ] heat #34B009 plus Ni-200 cold wire feed weld deposits.

In this evaluation, chemical analysis results were obtained from weld deposits fabricated using Linde 0091, 1092, 124 and 80 fluxes. The toughness properties of welds made using Linde 0091, 1092 and 124 fluxes have been previously shown to be

comparable[1]. [

] There is insufficient information from ABB/CE fabrication records to draw similar conclusions regarding Linde 80 flux welds. Therefore, copper and nickel analysis results from Linde 80 flux welds will be considered for information only.

IV. RESULTS

1. Welding Procedures and Specifications

ABB/CE fabricated many reactor pressure vessels using automatic submerged arc welding. [

]

2. Observed Nickel Content of [ ] Coiled Wire Electrode Weld Deposits

[

]

3. Copper Content of Weld Deposits Using Wire Heat #A8746

[

]

4. Copper Content of Weld Deposits Using Wire Heat #34B009

[

]

5. Nickel Content of Weld Deposits Using Wire Heat #34B009 and a Cold Nickel Wire Feed

[

V. CONCLUSIONS

1. [

]

2. [ ]

TABLE 1
Nickel Content for Coiled Wire Electrode Weld Deposits

Supplier Designation	Wire Supplier	Nickel Content %

3. [

]

These best estimate chemical contents are summarized in Table 9 for the welds described in Tables 2 and 5.

VI. REFERENCES

1. "Evaluation of Pressurized Thermal Shock Effects due to Small Break LOCA's with Loss of Feedwater for the Combustion Engineering NSSS," Combustion Engineering Report CEN-189, December 1981.

2. "Application of Reactor Vessel Surveillance Data for Embrittlement Management," Combustion Engineering Owners Group Report CEN-405-P (Draft Revision 2), December 1992.

TABLE 2

Weld Seams and Consumables
Using [ ] #A8746
[ ]

Reactor Vessel	Weld Seam No. (Note 1)	Weld Flux Type	Weld Procedure Specification
Calvert Cliffs Unit 2	2-203 A,B,C	Linde 124	[
St. Lucie Unit 1	2-203 A,B,C (Note 2)	Linde 124	
Millstone Unit 2	2-203 A,B,C 3-203 A,B,C	Linde 124 Linde 124	]

Note 1: All of the weld seams listed were deposited without a cold nickel wire feed.

Note 2: Weld wire heat #34B009[ ]was also used with heat #A8746 to deposit the weld seams in a single arc process.

TABLE 3

Copper Content Analysis Results
for Weld Wire Heat #A8746
[ ]

Type of Analysis	Date	Flux Type/Lot No.	Copper (%)
[			]

TABLE 4

Weld Deposit Copper Content
for [Adcom] Wire Heats

Supplier Designation	Flux Type	Copper Content (%)

[ ]

Note A - From Table 3

Note B - Combination of two Adcom heats in weld deposit

TABLE 5

Weld Seams and Consumables
Using [ ] Heat #34B009
[ ]

Reactor Vessel	Weld Seam No.	Weld Flux Type	Weld Procedure Specification
St. Lucie Unit 1	2-203 A, B, C (Note 1)	Linde 124	[
Millstone Unit 1	3-073 (Note 2)	Linde 1092	]

Note 1: Weld wire heat #A8746 [ ] was also used with heat #34B009 to deposit the weld seams in a single arc process. A cold nickel wire feed was not used.

Note 2: The weld process included the addition of a cold nickel wire feed.

TABLE 6

Copper Content Analysis Results for Weld Wire Heat #34B009

Type of Analysis	Flux Type	Copper Content (%)	Source
Weld Deposit	Linde 1092	[	
Weld Deposit	Linde 124		]
Weld Deposit	Linde 1092	0.180	HBR-2 Head Sample
Weld Deposit	Linde 1092	0.182	HBR-2 Head Sample
Weld Deposit	Linde 1092	0.183	HBR-2 Head Sample
Weld Deposit	Linde 1092	0.202	HBR-2 Head Sample
Weld Deposit	Linde 1092	0.18	MP-1 Surveillance Weld (EPRI)
Weld Deposit	Linde 1092	0.19	MP-1 Surveillance Weld (EPRI)
Weld Deposit	Linde 1092	0.18	MP-1 Surveillance Weld (GE Report NEDC-30299)

TABLE 7
Weld Deposit Nickel Content
with Cold Nickel Feed

Source	Nickel Content (%)

TABLE 8

Nickel Content for Heat #34B009
with Cold Nickel Feed and
Linde 1092 Flux

Nickel Content (%)	Source
0.75	HBR-2 Head Sample
0.32	HBR-2 Head Sample
0.84	HBR-2 Head Sample
0.43	HBR-2 Head Sample
0.81	MP-1 Surveillance Weld (EPRI)
0.98	MP-1 Surveillance Weld (EPRI)
1.03	MP-1 Surveillance Weld (GE Report NEDC-30299)

TABLE 9

Best Estimate Copper and Nickel Content for Vessel Welds

Reactor Vessel	Weld Seam No.	Content (%) Cu	Content (%) Ni
Calvert Cliffs Unit 2	2-203 A,B,C		
St. Lucie Unit 1	2-203 A,B,C(1)		
	2-203 A,B,C(2)		
Millstone Unit 2	2-203 A,B,C		
	3-203 A,B,C		
Millstone Unit 1	3-073		

Notes

(1) Chemical content contribution from wire heat #A8746

(2) Chemical content contribution from wire heat #34B009

September 28, 1993
F-MECH-93-050
L-MECH-93-015

Mr. R. Scott Boggs
Florida Power & Light Company
P.O. Box 1400
Juno Beach, FL 33408-0420

Subject: Upper Shelf Energy Information Pertaining to the St. Lucie Unit 1 and Unit 2 Reactor Vessel Welds.

Appendices: A) Certified Material Test Reports Pertinent to St. Lucie Unit 2

Attachments: "Atypical Weld Material In Reactor Pressure Vessel Welds; Information Requested by Nuclear Regulatory Commission Inspection & Enforcement Bulletin No. 78-12", Prepared By Combustion Engineering Inc., dated June 8, 1979.

Dear Mr. Boggs:

The purpose of this report is to provide upper shelf energy (USE) information on beltline welds for Florida Power and Light Company (FP&L), St. Lucie Units 1 and 2 reactor vessels. This information is required by FP&L in order to respond to a NRC request for additional information associated with Generic Letter 92-01 (Ref 1) as described in References 2 and 3. Additionally, two copies of the Combustion Engineering Document "Atypical Weld Material In Reactor Pressure Vessel Welds" are included as requested in Reference 3.

Please recognize that this letter report, including Appendix A, contains proprietary information and is not to be transmitted or reproduced without specific written approval from Combustion Engineering, Inc. The Attachment "Atypical Weld Material In Reactor Pressure Vessels", is not proprietary because it was publicly released in the past.

This letter report is a non-proprietary version.

1.0 St. Lucie Unit 1:

1.1 Background

The St. Lucie Unit 1 reactor vessel intermediate shell longitudinal seam welds (2-203 A,B,C) were fabricated using wire heat numbers A8746 and 34B009 and Linde 124 Flux lots 3878 and 3688 respectively based upon input provided by FP&L and repeated in Reference 2. The initial Charpy upper shelf energy (USE) for this weld was not

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determined at the time of manufacture, nor is such data known to be available from other sources (e.g., surveillance program welds) for the aforementioned welding consumables. The NRC has stated that an acceptable approach for satisfaction of 10CFR50, Appendix G requirements for initial USE is to use the average value from similarly fabricated welds (Ref 1); in this case, from USE measurements on submerged arc welds produced using MIL-B4 wire and Linde 124 Flux.

1.2 Scope

This report provides a basis for the initial upper shelf energy for weld wire heat numbers A8746 and 34B009 fabricated with Linde 124 flux using USE data from welds fabricated with Linde 124 flux.

1.3 Procedure

Weld material certifications (WMC) (Ref 4) at the ABB Combustion Engineering facility in Chattanooga, Tennessee were searched to obtain Charpy impact test data specific to Linde 124 flux welds. The WMCs were compiled and the initial USE determined from the Charpy impact data in accordance with the definitions provided in ASTM E185-82 (Ref 5). The primary definitions necessary to establish the upper shelf energy are provided as follows:

1.3.1 Upper Shelf Energy is defined as the average energy value for all Charpy specimens (normally three) whose test temperature is above the upper end of the transition region. For specimens tested in sets of three at each test temperature, the set having the highest average may be regarded as defining the upper shelf energy (Ref 5).

1.3.2 Charpy Transition Curve is defined as a graphic presentation of Charpy data, including absorbed energy, lateral expansion and fracture appearance, extending over a range including the lower shelf energy (<5% shear), transition region and the upper shelf energy (>95% shear) (Ref 5).

1.3.3 Transition Region is defined as the region on the transition temperature curve in which toughness increases rapidly with rising temperature. In terms of fracture appearance, it is characterized by a rapid change from a primarily cleavage (crystalline) fracture mode to primarily shear fracture mode (Ref 5).

Charpy test data for each weld wire heat and flux lot combination showing a fracture appearance of 95% shear or greater were compiled. The Charpy tests tended to be conducted in sets of three over a range of test temperatures. This allowed each set of

three tests to be averaged to determine the USE at a given temperature. The highest averaged USE for each weld wire heat and flux lot combination was taken to be the initial USE for the material and used to determine the best estimate (mean) and standard deviation for welds fabricated using Linde 124 flux. This best estimate can then be used as input for projecting USE after irradiation.

1.4 Results

Charpy impact energy data was assessed for 68 different weld wire heat / flux lot combinations to determine the initial upper shelf energy in accordance with ASTM E185-82 definitions (Ref 5). 67 USE values represented the average of three Charpy impact specimens usually tested at a single temperature. The remaining one USE value comes from an average of two Charpy specimens tested at 100°F. This USE value was judged to be adequate for the purposes of this analysis and would not significantly alter the results if omitted. All fracture specimens have a fracture appearance showing no less than 95% shear.

The average upper shelf energy for the Linde 124 flux welds is [.] The data ranges from [.] This represents an average of 68 different weld wire heat / Linde 124 flux lot combinations presented in Table 1.

Table 1: Initial Upper Shelf Energy Values for Linde 124 Welds.

Count	Wire Heat / Flux Lot	Initial USE ft-lb
1	[	[
2		
3		
4		
5		
6		
7		
8		
9		
10		
11	]	]

Count	Wire Heat / Flux Lot	Initial USE ft-lb
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
23		
24		
25		
26		
27		
28		
29		
30		
31		
32		
33		
34		
35		
36		
37		
38		
39		

Count	Wire Heat / Flux Lot	Initial USE ft-lb
40		
41		
42		
43		
44		
45		
46		
47		
48		
49		
50		
51		
52		
53		
54		
55		
56		
57		
58		
59		
60		
61		
62		
63		
64		
65		
66		
67		

Count	Wire Heat / Flux Lot	Initial USE ft-lb
68	[ ]	[
	Average USE:	
	Standard Deviation:	]

2.0 St. Lucie Unit 2:

2.1 Background

The St. Lucie Unit 2 reactor vessel beltline welds were fabricated using the consumable presented in Table 2 based upon input provided by FP&L and repeated in Reference 2. The basis for the initial upper shelf energy for these welds was weld material certification tests performed at the time of vessel manufacture (Ref 4).

Table 2: Beltline Weld Wire Consumable used in St. Lucie Unit 2

Seam No.	Wire Heat No.	Flux Type	Flux Lot No.
101-124 A,B,C	83642	Linde 0091	3536
101-124 C (Repair)	83637	Linde 0091	1122
101-142 A,B,C	83637	Linde 0091	1122
101-171	83637	Linde 124	0951
101-171	3P7317	Linde 124	0951

2.2 Scope

Weld material certification test reports (WMCs) for the following weld wire heat and flux lots are provided: Wire heat 83642, Linde 0091 flux lot 3536; wire heat 83637, Linde 0091 flux lot 1122; wire heat 83637, Linde 124 flux lot 0951; and wire heat 3P7317, Linde 124 flux lot 0951. Upper shelf energy values for the aforementioned wire/flux combinations will be determined if sufficient information is presented in the WMC. Where fully applicable information is not available, the degree of applicability will be addressed as per the project proposal (Ref 2).

2.3 Procedure

Weld material certifications (WMC) at the ABB Combustion Engineering facility in Chattanooga, Tennessee were searched to obtain Charpy impact test data specific to the consumable presented in Table 2. The WMCs were compiled and the initial USE determined, when possible, from the Charpy impact data in accordance with the definitions provided in ASTM E185-82 (Ref 5) and presented in sections 1.3.1 - 1.3.3. Where fully applicable information was not available in the WMC (e.g., where percent shear fracture was not reported) the degree of applicability to the Unit 2 weld seam USE is addressed.

2.4 Results

Weld material certification (WMC) reports for the weld wire heat / flux lot number combinations presented in Table 2 were obtained from records in possession of Combustion Engineering. The WMCs pertaining to the Linde 124 welds contained enough information to fully determine the initial upper shelf energy values for the consumable used. The WMCs pertaining to the Linde 0091 welds did not contain sufficient information; however, enough information was available to determine a conservative (lower bound) upper shelf energy value relevant to the consumables used. A copy of the WMCs for the consumables listed in Table 2 are provided in Appendix A. A description of the process used to determine the USE is described for each weld wire heat / flux lot combination as follows:

2.4.1 Wire Heat 83637, Flux Type Linde 124, Flux Lot No. 0951: The WMC pertaining to this combination of weld consumables contains a full array of Charpy tests over a range of temperatures. [

]

2.4.2 Wire Heat 3P7317, Flux Type Linde 124, Flux Lot No. 0951: The WMC pertaining to this combination of weld consumables contains a full array of Charpy tests over a range of temperatures. [

]

2.4.3 Wire Heat 83642, Flux Type Linde 0091, Flux Lot No. 3536: The WMC pertaining to this combination of weld consumables contains limited Charpy tests at two test temperatures and fracture appearance is not recorded. [

]
This value does not represent an "official" upper shelf energy for these weld consumables because no measurement of the fracture appearance (i.e., % shear fracture) is available. However, this value suggests very good fracture toughness characteristics for the material at 10°F and, therefore, may be used as a lower bound approximation to the initial USE.

2.4.4 Wire Heat 83637, Flux Type Linde 0091, Flux Lot No. 1122: The WMC pertaining to this combination of weld consumables contains limited Charpy tests at 10°F and fracture appearance is not recorded. [ ] This value does not represent an official upper shelf energy for these weld consumables because no measurement of the fracture appearance (i.e., % shear failure) is available. However, this value suggests very good fracture toughness characteristics for the material at 10°F and, therefore, may be used as a lower bound approximation to the initial USE.

3.0 CONCLUSIONS:

No information is available to determine the initial upper shelf energy specific to the weld consumables used in the St. Lucie Unit 1 reactor vessel 2-203 A,B,C weldments. As an alternate approach, a best estimate value of initial USE was calculated using 68 welds fabricated with Linde 124 flux. The best estimate initial USE of these welds fabricated with MIL-B4 wire and Linde 124 flux was calculated to be [.] This best estimate value can be used as input for projecting USE after irradiation.

Complete or partial information is available to determine the initial upper shelf energy specific to the consumable used in the St. Lucie Unit 2 beltline welds. Weld material certification reports for these materials are provided in Appendix A. Weld wire heat 3P7317 with Linde 124 flux lot 0951 has a calculated initial upper shelf energy value of [.] Weld wire heat 83637 with Linde 124 flux lot 0951 has a calculated initial upper shelf energy value of [.] Weld wire heat 83637 with Linde 0091 flux lot 1122 has an average Charpy energy at 10°F of [;] weld wire heat 83642 with Linde 0091 flux lot 3536 has an average Charpy energy at 10°F of [.] These average energies can be conservatively assumed to be a lower bound approximation of the initial upper shelf energy for the two Linde 0091 flux welds.

If you have any questions or concerns regarding this information, please feel free to contact me at (203) 285-3794 or Steve Byrne at (203) 285-3469.

Sincerely,

COMBUSTION ENGINEERING, INC

David J. Woodilla
Project Engineer

Enclosure

References:

1. Letter from J. A. Norris (NRC) to J. H. Goldberg (FP&L), dated July 28, 1993, Docket No. 50-335, 50-389. Subject: St. Lucie Units 1 and 2 - Request for Additional Information - Generic Letter 92-01, Revision 1 (TAC NOS. M83505 and M83506).

2. ABB/CE Letter No. F-MECH-93-042, "St. Lucie Upper Shelf Energy Evaluation, Proposal No. 93-241-A6A," S. T. Byrne, dated August 27, 1993.

3. Florida Power and Light Company Purchase Order No. B93633-30016, dated August 31, 1993.

4. ABB/CE Letter No. MECH-93-1214, "Weld Material Certification Reports", S. T. Byrne, dated October 14, 1993.

5. ASTM Designation E 185-82, "Standard Practice for Conducting Surveillance Tests for Light-Water Cooled Nuclear Power Reactor Vessels," Annual Book of ASTM Standards, Vol. 12.02, ASTM, Philadelphia, PA.

APPENDIX A

**Certified Material Test Reports
Pertinent to St. Lucie Unit 2**

Contents of Appendix A

Certified Material Test Report for Weld Wire Heat No. 83637, Linde Flux Type 124, Flux Lot No. 0951

Certified Material Test Report for Wire Heat
No. 3P7317, Linde Flux Type 124, Flux Lot No. 0951

Certified Material Test Report for Weld Wire Heat No. 83642, Linde Flux Type 0091, Flux Lot No. 3536

Certified Material Test Report for Weld Wire Heat No. 83637, Linde Flux Type 0091, Flux Lot No. 1122.

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