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Diablo Canyon Units 1 and 2 Pressurized Thermal Shock and Upper-Shelf Energy Evaluations

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EXECUTIVE SUMMARY

This report presents the Pressurized Thermal Shock (PTS) and Upper-Shelf Energy (USE) evaluations for Diablo Canyon Units 1 and 2. PTS and USE evaluations must be shown to meet the applicable Nuclear Regulatory Commission (NRC) requirements through the end of the licensed operating period. Diablo Canyon Units 1 and 2 are each licensed for 40 years of operation, which pertains to 32 effective full power years (EFPY) and is deemed end-of-license (EOL). Therefore, the PTS and USE evaluations were performed at 32 EFPY in this report.

The PTS and USE evaluations were also performed at 54 EFPY, which pertains to an extended licensed operating lifetime of 60 years and is deemed end-of-license extension (EOLE). Although this extended operating license has not yet been obtained, the evaluations contained in this report demonstrate 60-year acceptability in terms of PTS and USE when reviewed against the applicable NRC requirements.

Appendix A contains the credibility evaluation for the Diablo Canyon Units 1 and 2 surveillance materials. Where applicable, surveillance data from ‘sister plants’ are used in the evaluations. Conclusions for the surveillance data credibility evaluations are contained in Appendix A of this report.

Appendix B contains the Emergency Response Guideline (ERG) limits classification for Diablo Canyon Units 1 and 2. The ERG limits were developed in order to establish guidance for operator action in the event of an emergency situation, such as a PTS event. Conclusions for the ERG limits evaluations are contained in Appendix B of this report.

The conclusions to the PTS and USE evaluations are as follows:

EOL and EOLE RT_{PTS} Values

All of the beltline and extended beltline materials in the Diablo Canyon Units 1 and 2 reactor vessels are projected to remain below the PTS screening criteria values of 270°F, for axially oriented welds and plates / forgings, and 300°F, for circumferentially oriented welds (per 10 CFR 50.61), through EOL (32 EFPY) and EOLE (54 EFPY). See Section 6 for more details.

EOL and EOLE USE Values

All of the beltline and extended beltline materials in the Diablo Canyon Units 1 and 2 reactor vessels are projected to remain above the USE screening criterion value of 50 ft-lb (per 10 CFR 50, Appendix G) through EOL (32 EFPY) and EOLE (54 EFPY). See Section 7 for more details.

1 METHOD DISCUSSION

Pressurized Thermal Shock (PTS)

The PTS Rule, 10 CFR 50.61 (Reference 1), requires that for each pressurized water nuclear power reactor for which an operating license has been issued, the licensee shall have projected pressurized thermal shock reference temperature (RT_{PTS}) values accepted by the NRC for each reactor vessel beltline material at the end-of-life fluence of the plant. This assessment must specify the basis for the projected value of RT_{PTS} for each vessel beltline material, including the assumptions regarding core-loading patterns, and must specify the copper and nickel contents and the fluence value used in the calculation. This assessment must be updated whenever there is a significant change in projected values of RT_{PTS}, or upon request for a change in the expiration date for operation of the facility. Changes to RT_{PTS} values are considered significant if either the previous value or the current value, or both values, exceed the screening criterion prior to the expiration of the operating license, including any renewed term, if applicable, for the plant.

Per Equation 1 of 10 CFR 50.61 (Reference 1), the following equations and variables are to be used for calculating RT_{PTS} values at the clad/base metal interface of the vessel. RT_{PTS} is also referred to as the EOL RT_{NDT} (reference nil-ductility transition temperature).

$$\mathbf{RT_{PTS}\ (^{o}F) = IRT_{NDT} + M + \Delta RT_{NDT}}$$

Where,

IRT_{NDT} (^{o}F) = Initial Unirradiated RT_{NDT} value

M = Margin (^{o}F) = $2\sqrt{\sigma_U^2 + \sigma_\Delta^2}$

Where,

σ_U = 0°F when Initial RT_{NDT} is a measured value

σ_U = 17°F when Initial RT_{NDT} is a generic value

For plates and forgings:

σ_Δ = 17°F when surveillance capsule data is not credible or not used**

σ_Δ = 8.5°F when credible surveillance capsule data is used**

For welds:

σ_Δ = 28°F when surveillance capsule data is not credible or not used**

σ_Δ = 14°F when credible surveillance capsule data is used**

** σ_Δ not to exceed 0.5*ΔRT_{NDT} per 10 CFR 50.61 (Reference 1)

ΔRT_{NDT} (^{o}F) = CF * FF

Where,

CF = chemistry factor (°F) calculated generically for copper (Cu) and nickel (Ni) content based on Tables 1 and 2 in Reference 1 for welds and plates, respectively (also referred to as Position 1.1). It can also be calculated using credible surveillance capsule data per Equation 5 of Reference 1 (also referred to as Position 2.1).

FF = fluence factor = $f^{(0.28 - 0.10*\log(f))}$, where the normalized neutron fluence at the clad/base metal interface on the inside surface of the vessel is $f = \Phi / (1.0 \times 10^{19})$. The units for Φ are n/cm^2, E > 1.0 MeV.

The RT_{PTS} screening criteria values are 270°F for plates, forgings and axial weld materials and 300°F for circumferential weld materials. All available surveillance data must be considered in the evaluation.

<u>Upper-Shelf Energy (USE)</u>

The predicted decrease in USE is determined as a function of fluence and copper content using either of the following:

- Figure 2 of Regulatory Guide 1.99, Revision 2 (Reference 2), Position 1.2, or
- Surveillance program test results and Figure 2 of Regulatory Guide 1.99, Revision 2, Position 2.2.

Both methods require the use of the 1/4 thickness (1/4T) vessel fluence. Per Regulatory Guide 1.99, Revision 2, the following equation and variables are to be used for calculating 1/4T fluence values, which are then used to determine the predicted decrease in USE.

$$f = f_{surf} * e^{-0.24*(x)}$$

Where:

f = Vessel 1/4T fluence [x10^{19} n/cm^2 (E > 1.0 MeV)],

f_{surf} = Vessel inner wall surface fluence [x10^{19} n/cm^2 (E > 1.0 MeV)], and

x = The depth into the vessel wall from the inner surface [inches].

Reactor Vessel/Core Inlet Temperature (T_{cold})

Regulatory Guide 1.99, Revision 2, Position 1.3 identifies limitations of applicability for the calculations of reference temperature and upper-shelf energy. Nominal irradiation temperature is one of the limitations, wherein Regulatory Guide 1.99 indicates that the nominal irradiation temperature for which the procedures are valid is 550°F. Irradiation below 525°F should be considered to produce greater embrittlement, and irradiation over 590°F may be considered to produce less embrittlement.

It is concluded that Diablo Canyon Units 1 and 2 operate within the 525°F and 590°F range. Thus, the Regulatory Guide 1.99, Revision 2 correlations are applicable.

2 CALCULATED FLUENCE

Fast neutron fluence (E > 1.0 MeV) values were calculated in WCAP-17299-NP (Reference 3) at the clad/base metal interface, in accordance with WCAP-14040-A, Revision 4 (Reference 4). The assessment was performed based on the guidance specified in Regulatory Guide 1.190 (Reference 5).

In accordance with Item IV.A2-23 of NUREG-1801, Volume 2, Revision 1 (Reference 6), any materials exceeding 1.0 x 10^{17} n/cm^2 (E > 1.0 MeV) must be monitored to evaluate the changes in fracture toughness. Reactor vessel materials that are not traditionally thought of as being plant limiting because of low levels of neutron radiation must now be evaluated to determine the accumulated fluence at EOLE (54 EFPY). Therefore, fluence calculations were performed for the Diablo Canyon Units 1 and 2 reactor vessel upper (nozzle) shell plates, nozzle forgings, along with the associated upper shell and nozzle welds, and the lower shell to lower head weld to determine if they will exceed 1.0 x 10^{17} n/cm^2 (E > 1.0 MeV) at 54 EFPY. The materials that exceed this threshold are referred to as extended beltline materials in this report and are evaluated to assure that the PTS and USE acceptance criteria are met through EOLE.

For the PTS and USE evaluations, the surface fluence values and fluence factors as well as the 1/4T fluence values are needed. These values are summarized in Tables 2.1-1 and 2.2-1 below for Diablo Canyon Units 1 and 2, respectively. For each Unit, the neutron fluence information is summarized at 32 EFPY (EOL) and 54 EFPY (EOLE).

The reactor vessel beltline thickness for Diablo Canyon Units 1 and 2 is 8.625 inches. Hence, for the 1/4T fluence calculations, the depth into the vessel wall is as follows:

$$x_{1/4T} = (0.25 * 8.625 \text{ inches}) = 2.156 \text{ inches}$$

2.1 DIABLO CANYON UNIT 1

Table 2.1-1 Diablo Canyon Unit 1 Surface Fluence and Fluence Factor Values and 1/4T Fluence Values at 32 and 54 EFPY

Reactor Vessel Material	32 EFPY			54 EFPY		
	Surface fluence, f ($x10^{19}$ n/cm^2, E > 1.0 MeV)	Surface FF	1/4T f ($x10^{19}$ n/cm^2, E > 1.0 MeV)	Surface fluence, f ($x10^{19}$ n/cm^2, E > 1.0 MeV)	Surface FF	1/4T f ($x10^{19}$ n/cm^2, E > 1.0 MeV)
Beltline Materials						
Intermediate Shell (IS) Plates B4106-1, B4106-2, B4106-3	1.23	1.0577	0.733	2.02	1.1917	1.204
Lower Shell (LS) Plates B4107-1, B4107-2, B4107-3	1.22	1.0554	0.727	2.01	1.1904	1.198
IS Longitudinal Weld 2-442A (Heat # 27204)	0.905	0.9720	0.539	1.49	1.1104	0.888
IS Longitudinal Weld 2-442B (Heat # 27204)	0.905	0.9720	0.539	1.49	1.1104	0.888
IS Longitudinal Weld 2-442C (Heat # 27204)	0.463	0.7856	0.276	0.768	0.9259	0.458
LS Longitudinal Weld 3-442A (Heat # 27204)	0.721	0.9082	0.430	1.19	1.0485	0.709
LS Longitudinal Weld 3-442B (Heat # 27204)	0.721	0.9082	0.430	1.19	1.0485	0.709
LS Longitudinal Weld 3-442C (Heat # 27204)	1.22	1.0554	0.727	2.01	1.1904	1.198
IS to LS Circumferential Weld 9-442 (Heat # 21935)	1.22	1.0554	0.727	2.01	1.1904	1.198
Extended Beltline Materials						
Upper Shell (US) Plates B4105-1, B4105-2, B4105-3	- - -	- - -	- - -	0.0341	0.2365	0.020
US Longitudinal Weld 1-442A (Heat # 27204/12008)	- - -	- - -	- - -	0.0245	0.1948	0.015
US Longitudinal Weld 1-442B (Heat # 27204/12008)	- - -	- - -	- - -	0.0149	0.1428	0.009
US Longitudinal Weld 1-442C (Heat # 27204/12008)	- - -	- - -	- - -	0.0306	0.2222	0.018
US to IS Circumferential Weld 8-442 (Heat # 13253)	- - -	- - -	- - -	0.0341	0.2365	0.020

2.2 DIABLO CANYON UNIT 2

Table 2.2-1 Diablo Canyon Unit 2 Surface Fluence and Fluence Factor Values and 1/4T Fluence Values at 32 and 54 EFPY

Reactor Vessel Material	32 EFPY			54 EFPY		
	Surface fluence, f ($x10^{19}$ n/cm^2, E > 1.0 MeV)	Surface FF	1/4T f ($x10^{19}$ n/cm^2, E > 1.0 MeV)	Surface fluence, f ($x10^{19}$ n/cm^2, E > 1.0 MeV)	Surface FF	1/4T f ($x10^{19}$ n/cm^2, E > 1.0 MeV)
Beltline Materials						
Intermediate Shell (IS) Plates B5454-1, B5454-2, B5454-3	1.35	1.0834	0.805	2.25	1.2196	1.341
Lower Shell (LS) Plates B5455-1, B5455-2, B5455-3	1.34	1.0814	0.799	2.22	1.2161	1.323
IS Longitudinal Weld 2-201A (Heat # 21935/12008)	0.751	0.9197	0.448	1.24	1.0599	0.739
IS Longitudinal Weld 2-201B (Heat # 21935/12008)	0.924	0.9778	0.551	1.53	1.1176	0.912
IS Longitudinal Weld 2-201C (Heat # 21935/12008)	0.784	0.9317	0.467	1.30	1.0730	0.775
LS Longitudinal Weld 3-201A (Heat # 33A277)	0.777	0.9292	0.463	1.28	1.0687	0.763
LS Longitudinal Weld 3-201B (Heat # 33A277)	0.744	0.9170	0.443	1.23	1.0577	0.733
LS Longitudinal Weld 3-201C (Heat # 33A277)	0.915	0.9751	0.545	1.51	1.1141	0.900
IS to LS Circumferential Weld 9-201 (Heat # 10120)	1.34	1.0814	0.799	2.22	1.2161	1.323
Extended Beltline Materials						
Upper Shell (US) Plates B5453-1, B5453-3, B5011-1R	- - -	- - -	- - -	0.0677	0.3434	0.040
US Longitudinal Weld 1-201A (Heat # 21935/12008)	- - -	- - -	- - -	0.0633	0.3317	0.038
US Longitudinal Weld 1-201B (Heat # 21935/12008)	- - -	- - -	- - -	0.0629	0.3306	0.037
US Longitudinal Weld 1-201C (Heat # 21935/12008)	- - -	- - -	- - -	0.0514	0.2971	0.031
US to IS Circumferential Weld 8-201 (Heat # 21935)	- - -	- - -	- - -	0.0677	0.3434	0.040

3 FRACTURE TOUGHNESS PROPERTIES

The fracture toughness properties of the ferritic materials in the reactor coolant pressure boundary are determined in accordance with the NRC Standard Review Plan (Reference 7). The beltline and extended beltline material properties of the Diablo Canyon Units 1 and 2 reactor vessels are presented in Tables 3.1-1 and 3.2-1, respectively.

3.1 DIABLO CANYON UNIT 1

Table 3.1-1 Material Properties for the Diablo Canyon Unit 1 Reactor Vessel[(a)]

Material Description	Chemical Composition		Fracture Toughness Properties	
Reactor Vessel Material and Identification Number	**Cu Wt. %**	**Ni Wt. %**	**Initial RT_{NDT} [(b)] (°F)**	**Initial USE (ft-lb)**
Beltline Materials				
IS Plate B4106-1	0.125	0.53	-10	116
IS Plate B4106-2	0.120	0.50	-3	114
IS Plate B4106-3[(c)]	0.086	0.476	30[(d)]	77
LS Plate B4107-1	0.13	0.56	15	110
LS Plate B4107-2	0.12	0.56	20	103
LS Plate B4107-3	0.12	0.52	-22	116
IS Longitudinal Welds 2-442A, B, C	0.203	1.018	-56[(d)]	91
LS Longitudinal Welds 3-442A, B, C	0.203	1.018	-56[(d)]	91
IS to LS Circumferential Weld 9-442	0.183	0.704	-56[(d)]	109
Diablo Canyon Unit 1 Surveillance Weld (Heat # 27204)	0.198[(e)]	0.999[(e)]	- - -	- - -
Extended Beltline Materials				
US Plate B4105-1	0.12	0.56	28[(d)]	80
US Plate B4105-2	0.12	0.57	9[(d)]	74
US Plate B4105-3	0.14	0.56	14[(d)]	81
US Longitudinal Welds 1-442A, B, C	0.19[(f)]	0.97[(f)]	-20	86
US to IS Circumferential Weld 8-442	0.25	0.73	-56[(d)]	111

Notes:

(a) All values taken from Diablo Canyon Units 1 and 2 Updated Final Safety Analysis Report (UFSAR) (Reference 8), unless otherwise noted.
(b) Initial RT_{NDT} values are measured or estimated based on experimental data, unless otherwise noted.
(c) The Diablo Canyon Unit 1 surveillance plate material pertains to IS Plate B4106-3 (Heat # C2793-1). The copper and nickel weight percents of the surveillance and vessel material are identical (Cu Wt. % = 0.086 and Ni Wt. % = 0.476).
(d) Initial RT_{NDT} values are either generic or estimated per Reference 8.
(e) Surveillance weld Cu and Ni Wt. % values taken from WCAP-15958 (Reference 9).
(f) Values taken from Diablo Canyon Pressure and Temperature Limits Report (PTLR-1), Revision 10 (Reference 10).

3.2 DIABLO CANYON UNIT 2

Table 3.2-1 Material Properties for the Diablo Canyon Unit 2 Reactor Vessel[a]

Material Description	Chemical Composition		Fracture Toughness Properties	
Reactor Vessel Material and Identification Number	**Cu Wt. %**	**Ni Wt. %**	**Initial RT_{NDT} [b] (°F)**	**Initial USE (ft-lb)**
Beltline Materials				
IS Plate B5454-1[c]	0.14	0.65	52	91
IS Plate B5454-2	0.14	0.59	67	99
IS Plate B5454-3	0.15	0.62	33	90
LS Plate B5455-1	0.14	0.56	-15	112
LS Plate B5455-2	0.14	0.56	0	122
LS Plate B5455-3	0.10	0.62	15	100
IS Longitudinal Welds 2-201A, B, C	0.22	0.87	-50	118
LS Longitudinal Welds 3-201A, B, C	0.258	0.165	-56[d]	88
IS to LS Circumferential Weld 9-201	0.046	0.082	-56[d]	125
Diablo Canyon Unit 2 Surveillance Weld (Heat # 21935/12008)	0.22[e]	0.87[e]	- - -	- - -
Extended Beltline Materials				
US Plate B5453-1	0.11	0.60	28	82
US Plate B5453-3	0.11	0.60	5[d]	86.5
US Plate B5011-1R	0.11	0.65	0[d]	72
US Longitudinal Welds 1-201A, B, C	0.22[f]	0.87[f]	-50	118
US to IS Circumferential Weld 8-201	0.183	0.704	-56[d]	109

Notes:

(a) All values taken from Diablo Canyon Units 1 and 2 UFSAR (Reference 8), unless otherwise noted.
(b) Initial RT_{NDT} values are measured or estimated based on experimental data, unless otherwise noted.
(c) The Diablo Canyon Unit 2 surveillance plate material pertains to IS Plate B5454-1 (Heat # C5161-1). The copper and nickel weight percents of the surveillance and vessel material are identical (Cu Wt. % = 0.14 and Ni Wt. % = 0.65).
(d) Initial RT_{NDT} values are either generic or estimated per Reference 8.
(e) Surveillance weld Cu and Ni Wt. % values taken from WCAP-15423 (Reference 11).
(f) Values taken from Diablo Canyon Pressure and Temperature Limits Report (PTLR-1), Revision 10 (Reference 10).

4 SURVEILLANCE DATA

Per 10 CFR 50.61, calculation of Position 2.1 chemistry factors requires data from the plant-specific surveillance program. Furthermore, Regulatory Guide 1.99, Revision 2 allows the use of data from the plant-specific surveillance program in determining the decrease in USE.

In addition to the plant-specific surveillance data, 10 CFR 50.61 also requires the use of data from surveillance programs at other plants which include the same limiting beltline material when calculating Position 2.1 chemistry factors. Data from a surveillance program at another plant is often called ‘sister plant’ data.

Section 4.1 summarizes the Diablo Canyon Unit 1 surveillance data as well as surveillance data from Palisades. The Palisades surveillance program includes weld Heat # 27204, which is the same weld heat as the Diablo Canyon Unit 1 beltline longitudinal welds. Thus, the Palisades data will be used in calculation of Position 2.1 chemistry factors for Diablo Canyon Unit 1 weld Heat # 27204.

Section 4.2 summarizes the Diablo Canyon Unit 2 surveillance data as well as surveillance data from Farley Unit 1 and Calvert Cliffs Unit 1. The Farley Unit 1 and Calvert Cliffs Unit 1 surveillance programs include weld Heat # 33A277, which is the same weld heat as the Diablo Canyon Unit 2 LS longitudinal welds. Thus, the Farley Unit 1 and Calvert Cliffs Unit 1 data will be used in calculation of Position 2.1 chemistry factors for Diablo Canyon Unit 2 weld Heat # 33A277.

4.1 DIABLO CANYON UNIT 1 AND PALISADES SURVEILLANCE DATA

Table 4.1-1 Diablo Canyon Unit 1 Surveillance Capsule Data

Material[(a)]	Capsule[(a)]	Capsule Fluence[(b)] ($x10^{19}$ n/cm^2, E > 1.0 MeV)	Measured 30 ft-lb Transition Temperature Shift[(a)] (°F)	Measured USE Decrease[(a)] (%)	Inlet Temperature during Period of Irradiation (°F)	Temperature Adjustment[(f)] (°F)
IS Plate B4106-3 (Longitudinal)	S	0.283	-1.78	0	544[(c)]	+6.00
	Y	1.05	48.66	6.8	542.2[(d)]	+4.20
	V	1.36	34.32	0	541.5[(e)]	+3.50
Weld Metal (Heat # 27204)	S	0.283	110.79	11.0	544[(c)]	+6.00
	Y	1.05	232.59	34.1	542.2[(d)]	+4.20
	V	1.36	201.07	27.5	541.5[(e)]	+3.50

Notes:

(a) Taken from Table 5-10 of WCAP-15958 (Reference 9).
(b) Calculated capsule fluence values taken from Table 2-13 of WCAP-17299-NP (Reference 3).
(c) Capsule S was irradiated during Cycle 1. Therefore, this value pertains to the actual inlet operating temperature data for Cycle 1.
(d) Capsule Y was irradiated during Cycles 1-5. Therefore, this average value was determined using actual inlet operating temperature data for Cycles 1-5.
(e) Capsule V was irradiated during Cycles 1-11. Therefore, this average value was determined using actual inlet operating temperature data for Cycles 1-11.
(f) Temperature adjustment = $1.0*(T_{capsule} - T_{plant})$, where T_{plant} = 538°F for Diablo Canyon Unit 1.

Table 4.1-2 Palisades Surveillance Capsule Data for Weld Heat # 27204[a]

Material	Capsule	Capsule Fluence ($x10^{19}$ n/cm^2, E > 1.0 MeV)	Measured 30 ft-lb Transition Temperature Shift (°F)	Cu Wt. %	Ni Wt. %	Position 1.1 Chemistry Factor (°F)	Inlet Temperature during Period of Irradiation (°F)	Temperature Adjustment[b] (°F)
Weld Metal Heat # 27204 (Palisades data)	SA-60-1	1.50	253.1	0.194	1.067	227.8	535	-3.00
	SA-240-1	2.38	267.8	0.194	1.067	227.8	535.7	-2.30

Notes:

(a) All data for Palisades surveillance weld metal Heat # 27204 taken from Table A-2 of Structural Integrity Associates, Inc. Report No. 1000915.401, Rev. 1 (Reference 12), unless otherwise noted.

(b) Temperature adjustment = 1.0*($T_{capsule}$ - T_{plant}), where T_{plant} = 538°F for Diablo Canyon Unit 1 (applied to the Palisades data).

4.2 DIABLO CANYON UNIT 2, FARLEY UNIT 1, AND CALVERT CLIFFS UNIT 1 SURVEILLANCE DATA

Table 4.2-1 Diablo Canyon Unit 2 Surveillance Capsule Data

Material[a]	Capsule[a]	Capsule Fluence[b] ($x10^{19}$ n/cm^2, E > 1.0 MeV)	Measured 30 ft-lb Transition Temperature Shift[a] (°F)	Measured USE Decrease[a] (%)	Inlet Temperature during Period of Irradiation[c] (°F)	Temperature Adjustment[d] (°F)
IS Plate B5454-1 (Longitudinal)	U	0.330	65.4	11	545	+7.00
	X	0.906	100.1	20		
	Y	1.53	111.6	18		
	V	2.38	123.4	24		
IS Plate B5454-1 (Transverse)	U	0.330	73.3	0		
	X	0.906	99.5	12		
	Y	1.53	111.6	7		
	V	2.38	112.9	6		
Weld Metal (Heat # 21935/12008)	U	0.330	173.0	31		
	X	0.906	203.2	38		
	Y	1.53	211.4	40		
	V	2.38	224.5	40		

Notes:

(a) Taken from Table 5-10 of WCAP-15423 (Reference 11).
(b) Calculated capsule fluence values taken from Table 2-16 of WCAP-17299-NP (Reference 3).
(c) Diablo Canyon Unit 2 surveillance Capsules U, X, Y, and V were removed at end-of-cycle (EOC) 1, 3, 6, and 9, respectively. The inlet temperature remained at 545°F during all of those cycles for Unit 2.
(d) Temperature adjustment = 1.0*($T_{capsule}$ - T_{plant}), where T_{plant} = 538°F for Diablo Canyon Unit 2

Table 4.2-2 Farley Unit 1 and Calvert Cliffs Unit 1 Surveillance Capsule Data for Weld Heat # 33A277

Material	Capsule	Capsule Fluence ($x10^{19}$ n/cm^2, E > 1.0 MeV)	Measured 30 ft-lb Transition Temperature Shift (°F)	Cu Wt. %	Ni Wt. %	Position 1.1 Chemistry Factor[d] (°F)	Inlet Temperature during Period of Irradiation[e] (°F)	Temperature Adjustment[f] (°F)
Weld Metal Heat # 33A277 (Farley Unit 1 data)[a]	Y	0.612	66.9	0.14	0.19	78.1	544.00	+6.00
	U	1.73	75.1	0.14	0.19	78.1	540.25	+2.25
	X	3.06	87.4	0.14	0.19	78.1	540.86	+2.86
	W	4.75	98.3	0.14	0.19	78.1	541.75	+3.75
	V	7.14	117.5	0.14	0.19	78.1	541.72	+3.72
	Z	8.47	113.5	0.14	0.19	78.1	541.43	+3.43
Weld Metal Heat # 33A277 (Calvert Cliffs Unit 1 data)	263° [b]	0.62[e]	59	0.24	0.18	119.4	548.00	+10.00
	97° [c]	2.64	93	0.24	0.18	119.4	548.00	+10.00

Notes:

(a) All data for Farley Unit 1 surveillance weld metal Heat # 33A277 taken from Tables 4-1 and 5-10 of WCAP-16964-NP (Reference 13), unless otherwise noted.
(b) All Capsule 263° data for Calvert Cliffs Unit 1 surveillance weld metal Heat # 33A277 taken from Tables 13 and 17 of BMI-1280 (Reference 14), unless otherwise noted.
(c) All Capsule 97° data for Calvert Cliffs Unit 1 surveillance weld metal Heat # 33A277 taken from Tables 3-2 and 7-3 of BAW-2160 (Reference 15), unless otherwise noted.
(d) Position 1.1 chemistry factors were calculated using the Cu Wt. % and Ni Wt. % values listed and Table 1 of 10 CFR 50.61.
(e) Capsule fluence value for Calvert Cliffs Unit 1 Capsule 263° as well as inlet temperature values for each of the Farley Unit 1 and Calvert Cliffs Unit 1 surveillance capsules were obtained from Table 11-4 of the Comprehensive Reactor Vessel Surveillance Program, Revision 5 (Reference 16).
(f) Temperature adjustment = 1.0*($T_{capsule}$ - T_{plant}), where T_{plant} = 538°F for Diablo Canyon Unit 2 (applied to the Farley Unit 1 and Calvert Cliffs Unit 1 data).

5 CHEMISTRY FACTORS

As described in Section 1 of this report, Position 1.1 chemistry factors for each reactor vessel material are calculated using the best-estimate copper and nickel weight percent of the material and Tables 1 and 2 of 10 CFR 50.61. The best-estimate copper and nickel weight percents for the Diablo Canyon Units 1 and 2 reactor vessel beltline and extended beltline materials were provided in Tables 3.1-1 and 3.2-1 of this report, respectively. The Position 1.1 chemistry factors are summarized along with the Position 2.1 chemistry factors in Tables 5.1-2 and 5.2-3 for Diablo Canyon Units 1 and 2, respectively.

The Position 2.1 chemistry factors are calculated for the materials that have available surveillance program results. The calculation is performed using the method described in 10 CFR 50.61, which is also summarized in Section 1 of this report. The Diablo Canyon Units 1 and 2 surveillance data as well as any applicable sister plant data were summarized in Section 4 of this report, and will be utilized in the Position 2.1 chemistry factor calculations below.

The Position 2.1 chemistry factor calculations are presented in Tables 5.1-1 and 5.2-1 for the Diablo Canyon Units 1 and 2 reactor vessel materials contained in their respective radiation surveillance programs. These values were calculated using surveillance data taken from WCAP-15958 (Reference 9) and WCAP-15423 (Reference 11), as well as updated capsule fluence values obtained from WCAP-17299-NP (Reference 3). Additionally, surveillance data from Palisades is utilized in Table 5.1-1 as it is applicable to the Diablo Canyon Unit 1 beltline longitudinal welds (Heat # 27204).

The Position 2.1 chemistry factor calculations for weld Heat # 33A277 are presented in Table 5.2-2. This weld heat is not contained in the Diablo Canyon Unit 2 surveillance program, but is contained in the Farley Unit 1 and Calvert Cliffs Unit 1 surveillance programs. Therefore, the sister plant data as presented in Section 4 of this report is used to calculate the Position 2.1 chemistry factor for weld Heat # 33A277.

All of the surveillance data is adjusted for irradiation temperature and chemical composition differences in accordance with the guidance presented by the NRC to industry at a meeting held by the NRC on February 12 and 13, 1998 (Reference 17).

Appendix A contains the credibility evaluation for each of the surveillance materials for which a chemistry factor is calculated in this Section. Margin will be applied to the calculations of RT_{PTS} according to the conclusions of the credibility evaluation for each of the surveillance materials.

5.1 DIABLO CANYON UNIT 1

Table 5.1-1 Calculation of Diablo Canyon Unit 1 Chemistry Factors Using Surveillance Capsule Data

Material	Capsule	Capsule f(a) ($x10^{19}$ n/cm^2, E > 1.0 MeV)	FF(b)	ΔRT_{NDT}(c) (°F)	FF*ΔRT_{NDT} (°F)	FF^2
IS Plate B4106-3 (Longitudinal)	S	0.283	0.655	6.00 (0(d))	3.93	0.429
	Y	1.05	1.014	52.86 (48.66)	53.58	1.027
	V	1.36	1.085	37.82 (34.32)	41.05	1.178
				SUM:	98.56	2.635
	$CF_{IS\ Plate\ B4106\text{-}3} = \Sigma(FF * \Delta RT_{NDT}) \div \Sigma(FF^2) = (98.56) \div (2.635) = \mathbf{37.4°F}$					
Weld Metal Heat # 27204 (Diablo Canyon Unit 1 data)	S	0.283	0.655	119.13 (110.79)	78.06	0.429
	Y	1.05	1.014	241.53 (232.59)	244.82	1.027
	V	1.36	1.085	208.66 (201.07)	226.49	1.178
Weld Metal Heat # 27204 (Palisades data)	SA-60-1	1.50	1.112	250.10 (253.1)	278.18	1.237
	SA-240-1	2.38	1.234	265.50 (267.8)	327.59	1.522
				SUM :	1155.14	5.395
	$CF_{Heat\ \#\ 27204} = \Sigma(FF * \Delta RT_{NDT}) \div \Sigma(FF^2) = (1155.14) \div (5.395) = \mathbf{214.1°F}$					

Notes:

(a) f = fluence.

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

(c) ΔRT_{NDT} values are the measured 30 ft-lb shift values. All Diablo Canyon Unit 1 values are taken from Table 4.1-1 of this report. The Diablo Canyon Unit 1 ΔRT_{NDT} values have been adjusted according to the temperature adjustments summarized in Table 4.1-1 of this report. Then, the Diablo Canyon Unit 1 ΔRT_{NDT} values for the surveillance weld data are adjusted by a ratio of 1.02 (pre-adjusted values are listed in parentheses). Ratio = $CF_{Vessel\ Weld}$ / $CF_{Surv.\ Weld}$ = 226.8°F / 222.3°F = 1.02.

All Palisades values are taken from Table 4.1-2 of this report. The Palisades surveillance weld ΔRT_{NDT} values have been adjusted according to the temperature adjustments summarized in Table 4.1-2 (pre-adjusted values are listed in parentheses). No ratio is applied since the ratio was calculated to be 1.00. Ratio = $CF_{Vessel\ Weld}$ / $CF_{Surv.\ Weld}$ = 226.8°F / 227.8°F = 1.00.

(d) Measured ΔRT_{NDT} value was determined to be negative, but physically a reduction should not occur. Therefore, a conservative value of zero will be used.

Table 5.1-2 Summary of Diablo Canyon Unit 1 Positions 1.1 and 2.1 Chemistry Factors

Reactor Vessel Material	Chemistry Factor (˚F)	
	Position 1.1[a]	**Position 2.1[b]**
Beltline Materials		
IS Plate B4106-1	85.3	- - -
IS Plate B4106-2	81.0	- - -
IS Plate B4106-3	55.2	37.4
LS Plate B4107-1	89.8	- - -
LS Plate B4107-2	82.2	- - -
LS Plate B4107-3	81.4	- - -
IS Longitudinal Welds 2-442A, B, C	226.8	214.1
LS Longitudinal Welds 3-442A, B, C	226.8	214.1
IS to LS Circumferential Weld 9-442	172.2	- - -
Diablo Canyon Unit 1 Surveillance Weld (Heat # 27204)	222.3	- - -
Extended Beltline Materials		
US Plate B4105-1	82.2	- - -
US Plate B4105-2	82.4	- - -
US Plate B4105-3	98.2	- - -
US Longitudinal Welds 1-442A, B, C	215.7	- - -
US to IS Circumferential Weld 8-442	197.5	- - -

Notes:

(a) Position 1.1 Chemistry Factors were calculated using the copper and nickel weight percents presented in Table 3.1-1 of this report and Tables 1 and 2 of 10 CFR 50.61 (Reference 1).

(b) Position 2.1 Chemistry Factors taken from Table 5.1-1 of this report.

5.2 DIABLO CANYON UNIT 2

Table 5.2-1 Calculation of Diablo Canyon Unit 2 Chemistry Factors Using Surveillance Capsule Data

Material	Capsule	Capsule f[a] ($x10^{19}$ n/cm^2, E > 1.0 MeV)	FF[b]	ΔRT_{NDT}[c] (°F)	FF*ΔRT_{NDT} (°F)	FF^2
IS Plate B5454-1 (Longitudinal)	U	0.330	0.695	72.4 (65.4)	50.32	0.483
	X	0.906	0.972	107.1 (100.1)	104.14	0.945
	Y	1.53	1.118	118.6 (111.6)	132.55	1.249
	V	2.38	1.234	130.4 (123.4)	160.89	1.522
IS Plate B5454-1 (Transverse)	U	0.330	0.695	80.3 (73.3)	55.81	0.483
	X	0.906	0.972	106.5 (99.5)	103.55	0.945
	Y	1.53	1.118	118.6 (111.6)	132.55	1.249
	V	2.38	1.234	119.9 (112.9)	147.94	1.522
				SUM:	887.76	8.400
	$CF_{IS\ Plate\ B5454-1} = \Sigma(FF * \Delta RT_{NDT}) \div \Sigma(FF^2) = (887.76) \div (8.400) = \mathbf{105.7°F}$					
Diablo Canyon Unit 2 Weld Metal (Heat # 21935/12008)	U	0.330	0.695	180.0 (173.0)	125.10	0.483
	X	0.906	0.972	210.2 (203.2)	204.38	0.945
	Y	1.53	1.118	218.4 (211.4)	244.09	1.249
	V	2.38	1.234	231.5 (224.5)	285.64	1.522
				SUM :	859.22	4.200
	$CF_{Heat\ \#\ 21935/12008} = \Sigma(FF * \Delta RT_{NDT}) \div \Sigma(FF^2) = (859.22) \div (4.200) = \mathbf{204.6°F}$					

Notes:

(a) f = fluence.

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

(c) ΔRT_{NDT} values are the measured 30 ft-lb shift values. All values are taken from Table 4.2-1 of this report. The Diablo Canyon Unit 2 ΔRT_{NDT} values have been adjusted according to the temperature adjustments summarized in Table 4.2-1 of this report (pre-adjusted values are listed in parentheses). No ratio is applied to the ΔRT_{NDT} values for the surveillance weld data since the beltline weld and surveillance weld chemistry factors are identical.

Table 5.2-2 Calculation of Diablo Canyon Unit 2 Weld Heat # 33A277 Chemistry Factors Using Surveillance Capsule Data from Farley Unit 1 and Calvert Cliffs Unit 1

Material	Capsule	Capsule f[a] ($x10^{19}$ n/cm^2, E > 1.0 MeV)	FF[b]	ΔRT_{NDT}[c] (°F)	FF*ΔRT_{NDT} (°F)	FF^2
Weld Metal Heat # 33A277 (Farley Unit 1 data)	Y	0.612	0.862	118.1 (66.9)	101.86	0.744
	U	1.73	1.151	125.3 (75.1)	144.20	1.324
	X	3.06	1.295	146.2 (87.4)	189.42	1.678
	W	4.75	1.392	165.3 (98.3)	230.15	1.938
	V	7.14	1.466	196.4 (117.5)	287.90	2.149
	Z	8.47	1.492	189.4 (113.5)	282.59	2.225
Weld Metal Heat # 33A277 (Calvert Cliffs Unit 1 data)	263°	0.62	0.866	73.1 (59)	63.35	0.750
	97°	2.64	1.260	109.2 (93)	137.54	1.587
				SUM :	1436.99	12.396
	$CF_{Heat\ \#\ 33A277} = \Sigma(FF * \Delta RT_{NDT}) \div \Sigma(FF^2) = (1436.99) \div (12.396) =$ **115.9°F**					

Notes:

(a) f = fluence.

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

(c) ΔRT_{NDT} values are the measured 30 ft-lb shift values. All values are taken from Table 4.2-2 of this report. ΔRT_{NDT} values for the surveillance weld data are adjusted first by the difference in operating temperature then using the ratio procedure to account for differences in the surveillance weld chemistry and the beltline weld chemistry (pre-adjusted values are listed in parentheses). The temperature adjustments and ratios applied are as follows:

Farley Unit 1:
Temperature adjustment per Table 4.2-2 (on a capsule-by-capsule basis)
Ratio = $CF_{Vessel\ Weld} / CF_{Surv.\ Weld}$ = 126.3°F / 78.1°F = 1.62

Calvert Cliffs Unit 1:
Temperature adjustment per Table 4.2-2 (+10.00°F for each capsule)
Ratio = $CF_{Vessel\ Weld} / CF_{Surv.\ Weld}$ = 126.3°F / 119.4°F = 1.06

Table 5.2-3 Summary of Diablo Canyon Unit 2 Positions 1.1 and 2.1 Chemistry Factors

Reactor Vessel Material	Chemistry Factor (˚F)	
	Position 1.1[a]	Position 2.1
Beltline Materials		
IS Plate B5454-1	101.3	105.7[b]
IS Plate B5454-2	99.6	- - -
IS Plate B5454-3	110.5	- - -
LS Plate B5455-1	98.2	- - -
LS Plate B5455-2	98.2	- - -
LS Plate B5455-3	65.2	- - -
IS Longitudinal Welds 2-201A, B, C	211.2	204.6[b]
LS Longitudinal Welds 3-201A, B, C	126.3	115.9[c]
IS to LS Circumferential Weld 9-201	34.0	- - -
Diablo Canyon Unit 2 Surveillance Weld (Heat # 21935/12008)	211.2	- - -
Extended Beltline Materials		
US Plate B5453-1	74	- - -
US Plate B5453-3	74	- - -
US Plate B5011-1R	74.8	- - -
US Longitudinal Welds 1-201A, B, C	211.2	204.6[b]
US to IS Circumferential Weld 8-201	172.2	- - -

Notes:

(a) Position 1.1 Chemistry Factors were calculated using the copper and nickel weight percents presented in Table 3.2-1 of this report and Tables 1 and 2 of 10 CFR 50.61 (Reference 1).
(b) Position 2.1 Chemistry Factors taken from Table 5.2-1 of this report.
(c) Position 2.1 Chemistry Factors were calculated using Farley Unit 1 and Calvert Cliffs Unit 1 surveillance data and are taken from Table 5.2-2 of this report.

6 PRESSURIZED THERMAL SHOCK CALCULATIONS

A limiting condition on reactor vessel integrity known as Pressurized Thermal Shock (PTS) may occur during a severe system transient such as a loss-of-coolant accident (LOCA) or steam line break. Such transients may challenge the integrity of the reactor vessel under the following conditions: severe overcooling of the inside surface of the vessel wall followed by high repressurization; significant degradation of vessel material toughness caused by radiation embrittlement; and the presence of a critical-size defect anywhere within the vessel wall.

In 1985, the U.S. NRC issued a formal ruling (10 CFR 50.61) on PTS (Reference 1) that established screening criteria on reactor vessel embrittlement, as measured by the maximum reference nil-ductility transition temperature in the limiting beltline component at the end-of-license, termed RT_{PTS}. RT_{PTS} screening values were set by the U.S. NRC for beltline axial welds, forgings or plates, and for beltline circumferential weld seams for plant operation to the end of plant license. All domestic PWR vessels have been required to evaluate vessel embrittlement in accordance with the criteria through the end-of-license. The U.S. NRC revised 10 CFR 50.61 in 1991 and 1995 to change the procedure for calculating radiation embrittlement. These revisions make the procedure for calculating the reference temperature for pressurized thermal shock (RT_{PTS}) values consistent with the methods given in Regulatory Guide 1.99, Revision 2 (Reference 2).

These accepted methods were used with the surface fluence of Section 2 to calculate the following RT_{PTS} values for the Diablo Canyon Units 1 and 2 reactor vessel materials at 32 EFPY (EOL) and 54 EFPY (EOLE). The EOL and EOLE RT_{PTS} calculations are summarized below in Tables 6.1-1 and 6.1-2 for Diablo Canyon Unit 1 and in Tables 6.2-1 and 6.2-2 for Diablo Canyon Unit 2.

PTS Conclusion

For Diablo Canyon Unit 1, the limiting RT_{PTS} values at 32 EFPY and 54 EFPY are 214°F (see Table 6.1-1) and 243°F (see Table 6.1-2), respectively; these values correspond to LS Longitudinal Weld 3-442C (Position 2.1). For Diablo Canyon Unit 2, the limiting RT_{PTS} values at 32 EFPY and 54 EFPY are 209°F (see Table 6.2-1) and 222°F (see Table 6.2-2), respectively; these values correspond to IS Plate B5454-2. Therefore, all of the beltline and extended beltline materials in the Diablo Canyon Units 1 and 2 reactor vessels are below the RT_{PTS} screening criteria values of 270°F, for axially oriented welds and plates / forgings, and 300°F, for circumferentially oriented welds through EOL (32 EFPY) and EOLE (54 EFPY).

The Alternate PTS Rule (10 CFR 50.61a (Reference 18)) was final approved by the NRC early in 2010. This alternate rule is less restrictive than the Mandatory PTS Rule (10 CFR 50.61) and is intended to be used for situations where the 10 CFR 50.61 criteria cannot be met. Diablo Canyon Units 1 and 2 currently meet the criteria for the Mandatory PTS Rule through EOL and EOLE and therefore do not need to utilize the Alternate PTS Rule at this time.

6.1 DIABLO CANYON UNIT 1

Table 6.1-1 RT_{PTS} Calculations for the Diablo Canyon Unit 1 Reactor Vessel Beltline Materials at 32 EFPY[a]

Reactor Vessel Material	R.G. 1.99, Rev. 2 Position	CF[b] (°F)	Fluence[c] ($x10^{19}$ n/cm^2, E > 1.0 MeV)	FF[c]	IRT_{NDT} [d] (°F)	ΔRT_{NDT} (°F)	σ_U[d] (°F)	σ_Δ[f] (°F)	Margin (°F)	RT_{PTS} (°F)
Beltline Materials										
IS Plate B4106-1	1.1	85.3	1.23	1.0577	-10	90.2	0	17	34	114
IS Plate B4106-2	1.1	81.0	1.23	1.0577	-3	85.7	0	17	34	117
IS Plate B4106-3	1.1	55.2	1.23	1.0577	30	58.4	17[e]	17	48.1	136
→ Using non-credible surveillance data	2.1	37.4	1.23	1.0577	30	39.6	17[e]	17	48.1	118
LS Plate B4107-1	1.1	89.8	1.22	1.0554	15	94.8	0	17	34	144
LS Plate B4107-2	1.1	82.2	1.22	1.0554	20	86.8	0	17	34	141
LS Plate B4107-3	1.1	81.4	1.22	1.0554	-22	85.9	0	17	34	98
IS Longitudinal Weld 2-442A & B	1.1	226.8	0.905	0.9720	-56[e]	220.5	17[e]	28	65.5	230
→ Using credible surveillance data	2.1	214.1	0.905	0.9720	-56[e]	208.1	17[e]	14	44.0	196
IS Longitudinal Weld 2-442C	1.1	226.8	0.463	0.7856	-56[e]	178.2	17[e]	28	65.5	188
→ Using credible surveillance data	2.1	214.1	0.463	0.7856	-56[e]	168.2	17[e]	14	44.0	156
LS Longitudinal Weld 3-442A & B	1.1	226.8	0.721	0.9082	-56[e]	206.0	17[e]	28	65.5	216
→ Using credible surveillance data	2.1	214.1	0.721	0.9082	-56[e]	194.5	17[e]	14	44.0	183
LS Longitudinal Weld 3-442C	1.1	226.8	1.22	1.0554	-56[e]	239.4	17[e]	28	65.5	249
→ Using credible surveillance data	2.1	214.1	1.22	1.0554	-56[e]	226.0	17[e]	14	44.0	**214**
IS to LS Circ. Weld 9-442	1.1	172.2	1.22	1.0554	-56[e]	181.7	17[e]	28	65.5	191

Notes (continued on next page):

(a) The 10 CFR 50.61 methodology was utilized in the calculation of the RT_{PTS} values. See Section 1 of this report for details.

(b) Taken from Table 5.1-2 of this report.

Table 6.1-1 RT_{PTS} Calculations for the Diablo Canyon Unit 1 Reactor Vessel Beltline Materials at 32 EFPY[(a)]

Notes (continued from previous page):

(c) Taken from Table 2.1-1 of this report.

(d) Initial RT_{NDT} values are taken from Table 3.1-1 of this report and are measured values, unless otherwise noted.

(e) Initial RT_{NDT} values are either generic or estimated; therefore, σ_U = 17°F.

(f) Per Appendix A of this report, the surveillance plate data was deemed <u>non-credible</u>. Per the guidance of 10 CFR 50.61, the base metal σ_Δ = 17°F for Position 1.1 and for Position 2.1 with <u>non-credible</u> surveillance data. Per Appendix A, the surveillance weld data was deemed <u>credible</u>. Per the guidance of 10 CFR 50.61, the weld metal σ_Δ = 28°F for Position 1.1 and with <u>credible</u> surveillance data σ_Δ = 14°F for Position 2.1. However, σ_Δ need not exceed $0.5*\Delta RT_{NDT}$.

Table 6.1-2 RT_{PTS} Calculations for the Diablo Canyon Unit 1 Reactor Vessel Beltline and Extended Beltline Materials at 54 EFPY[a]

Reactor Vessel Material	R.G. 1.99, Rev. 2 Position	CF[b] (°F)	Fluence[c] ($x10^{19}$ n/cm^2, E > 1.0 MeV)	FF[c]	IRT_{NDT} [d] (°F)	ΔRT_{NDT} (°F)	σ_U[d] (°F)	σ_Δ[f] (°F)	Margin (°F)	RT_{PTS} (°F)
Beltline Materials										
IS Plate B4106-1	1.1	85.3	2.02	1.1917	-10	101.7	0	17	34	126
IS Plate B4106-2	1.1	81.0	2.02	1.1917	-3	96.5	0	17	34	128
IS Plate B4106-3	1.1	55.2	2.02	1.1917	30	65.8	17[e]	17	48.1	144
→ Using non-credible surveillance data	2.1	37.4	2.02	1.1917	30	44.6	17[e]	17	48.1	123
LS Plate B4107-1	1.1	89.8	2.01	1.1904	15	106.9	0	17	34	156
LS Plate B4107-2	1.1	82.2	2.01	1.1904	20	97.9	0	17	34	152
LS Plate B4107-3	1.1	81.4	2.01	1.1904	-22	96.9	0	17	34	109
IS Longitudinal Weld 2-442A & B	1.1	226.8	1.49	1.1104	-56[e]	251.8	17[e]	28	65.5	261
→ Using credible surveillance data	2.1	214.1	1.49	1.1104	-56[e]	237.7	17[e]	14	44.0	226
IS Longitudinal Weld 2-442C	1.1	226.8	0.768	0.9259	-56[e]	210.0	17[e]	28	65.5	220
→ Using credible surveillance data	2.1	214.1	0.768	0.9259	-56[e]	198.2	17[e]	14	44.0	186
LS Longitudinal Weld 3-442A & B	1.1	226.8	1.19	1.0485	-56[e]	237.8	17[e]	28	65.5	247
→ Using credible surveillance data	2.1	214.1	1.19	1.0485	-56[e]	224.5	17[e]	14	44.0	213
LS Longitudinal Weld 3-442C	1.1	226.8	2.01	1.1904	-56[e]	270.0	17[e]	28	65.5	280
→ Using credible surveillance data	2.1	214.1	2.01	1.1904	-56[e]	254.9	17[e]	14	44.0	**243**
IS to LS Circ. Weld 9-442	1.1	172.2	2.01	1.1904	-56[e]	205.0	17[e]	28	65.5	215

Table 6.1-2 RT_{PTS} Calculations for the Diablo Canyon Unit 1 Reactor Vessel Beltline and Extended Beltline Materials at 54 EFPY[(a)]

Reactor Vessel Material	R.G. 1.99, Rev. 2 Position	CF[(b)] (°F)	Fluence[(c)] ($x10^{19}$ n/cm^2, E > 1.0 MeV)	FF[(c)]	IRT_{NDT} [(d)] (°F)	ΔRT_{NDT} (°F)	σ_U[(d)] (°F)	σ_Δ[(f)] (°F)	Margin (°F)	RT_{PTS} (°F)
Extended Beltline Materials										
US Plate B4105-1	1.1	82.2	0.0341	0.2365	28	19.4	17[(e)]	9.7	39.2	87
US Plate B4105-2	1.1	82.4	0.0341	0.2365	9	19.5	17[(e)]	9.7	39.2	68
US Plate B4105-3	1.1	98.2	0.0341	0.2365	14	23.2	17[(e)]	11.6	41.2	78
US Longitudinal Weld 1-442A	1.1	215.7	0.0245	0.1948	-20	42.0	0	21.0	42.0	64
US Longitudinal Weld 1-442B	1.1	215.7	0.0149	0.1428	-20	30.8	0	15.4	30.8	42
US Longitudinal Weld 1-442C	1.1	215.7	0.0306	0.2222	-20	47.9	0	24.0	47.9	76
US to IS Circ. Weld 8-442	1.1	197.5	0.0341	0.2365	-56[(e)]	46.7	17[(e)]	23.4	57.8	48

Notes:

(a) The 10 CFR 50.61 methodology was utilized in the calculation of the RT_{PTS} values. See Section 1 of this report for details.

(b) Taken from Table 5.1-2 of this report.

(c) Taken from Table 2.1-1 of this report.

(d) Initial RT_{NDT} values are taken from Table 3.1-1 of this report and are measured values, unless otherwise noted.

(e) Initial RT_{NDT} values are either generic or estimated; therefore, σ_U = 17°F.

(f) Per Appendix A of this report, the surveillance plate data was deemed non-credible. Per the guidance of 10 CFR 50.61, the base metal σ_Δ = 17°F for Position 1.1 and for Position 2.1 with non-credible surveillance data. Per Appendix A, the surveillance weld data was deemed credible. Per the guidance of 10 CFR 50.61, the weld metal σ_Δ = 28°F for Position 1.1 and with credible surveillance data σ_Δ = 14°F for Position 2.1. However, σ_Δ need not exceed $0.5*\Delta RT_{NDT}$.

6.2 DIABLO CANYON UNIT 2

Table 6.2-1 RT_{PTS} Calculations for the Diablo Canyon Unit 2 Reactor Vessel Beltline Materials at 32 EFPY[a]

Reactor Vessel Material	R.G. 1.99, Rev. 2 Position	CF[b] (°F)	Fluence[c] ($x10^{19}$ n/cm^2, E > 1.0 MeV)	FF[c]	IRT_{NDT} [d] (°F)	ΔRT_{NDT} (°F)	σ_U[d] (°F)	σ_Δ[f] (°F)	Margin (°F)	RT_{PTS} (°F)
Beltline Materials										
IS Plate B5454-1	1.1	101.3	1.35	1.0834	52	109.7	0	17	34	196
→ Using credible surveillance data	2.1	105.7	1.35	1.0834	52	114.5	0	8.5	17	184
IS Plate B5454-2	1.1	99.6	1.35	1.0834	67	107.9	0	17	34	**209**
IS Plate B5454-3	1.1	110.5	1.35	1.0834	33	119.7	0	17	34	187
LS Plate B5455-1	1.1	98.2	1.34	1.0814	-15	106.2	0	17	34	125
LS Plate B5455-2	1.1	98.2	1.34	1.0814	0	106.2	0	17	34	140
LS Plate B5455-3	1.1	65.2	1.34	1.0814	15	70.5	0	17	34	120
IS Longitudinal Weld 2-201A	1.1	211.2	0.751	0.9197	-50	194.2	0	28	56	200
→ Using credible surveillance data	2.1	204.6	0.751	0.9197	-50	188.2	0	14	28	166
IS Longitudinal Weld 2-201B	1.1	211.2	0.924	0.9778	-50	206.5	0	28	56	213
→ Using credible surveillance data	2.1	204.6	0.924	0.9778	-50	200.1	0	14	28	178
IS Longitudinal Weld 2-201C	1.1	211.2	0.784	0.9317	-50	196.8	0	28	56	203
→ Using credible surveillance data	2.1	204.6	0.784	0.9317	-50	190.6	0	14	28	169
LS Longitudinal Weld 3-201A	1.1	126.3	0.777	0.9292	-56[e]	117.4	17[e]	28	65.5	127
→ Using credible surveillance data	2.1	115.9	0.777	0.9292	-56[e]	107.7	17[e]	14	44.0	96
LS Longitudinal Weld 3-201B	1.1	126.3	0.744	0.9170	-56[e]	115.8	17[e]	28	65.5	125
→ Using credible surveillance data	2.1	115.9	0.744	0.9170	-56[e]	106.3	17[e]	14	44.0	94

Table 6.2-1 RT_{PTS} Calculations for the Diablo Canyon Unit 2 Reactor Vessel Beltline Materials at 32 EFPY[a]

Reactor Vessel Material	R.G. 1.99, Rev. 2 Position	CF[b] (°F)	Fluence[c] ($x10^{19}$ n/cm^2, E > 1.0 MeV)	FF[c]	IRT_{NDT} [d] (°F)	ΔRT_{NDT} (°F)	σ_U[d] (°F)	σ_Δ[f] (°F)	Margin (°F)	RT_{PTS} (°F)
LS Longitudinal Weld 3-201C	1.1	126.3	0.915	0.9751	-56[e]	123.2	17[e]	28	65.5	133
→ Using credible surveillance data	2.1	115.9	0.915	0.9751	-56[e]	113.0	17[e]	14	44.0	101
IS to LS Circ. Weld 9-201	1.1	34.0	1.34	1.0814	-56[e]	36.8	17[e]	18.4	50.1	31

Notes:

(a) The 10 CFR 50.61 methodology was utilized in the calculation of the RT_{PTS} values. See Section 1 of this report for details.

(b) Taken from Table 5.2-3 of this report.

(c) Taken from Table 2.2-1 of this report.

(d) Initial RT_{NDT} values are taken from Table 3.2-1 of this report and are measured values, unless otherwise noted.

(e) Initial RT_{NDT} values are generic; therefore, $\sigma_U = 17°F$.

(f) Per Appendix A of this report, the surveillance data of the plate and weld materials were deemed credible. Per the guidance of 10 CFR 50.61, the base metal $\sigma_\Delta = 17°F$ for Position 1.1 and with credible surveillance data $\sigma_\Delta = 8.5°F$ for Position 2.1; the weld metal $\sigma_\Delta = 28°F$ for Position 1.1 and with credible surveillance data $\sigma_\Delta = 14°F$ for Position 2.1. However, σ_Δ need not exceed $0.5*\Delta RT_{NDT}$.

Table 6.2-2 RT_{PTS} Calculations for the Diablo Canyon Unit 2 Reactor Vessel Beltline and Extended Beltline Materials at 54 EFPY[(a)]

Reactor Vessel Material	R.G. 1.99, Rev. 2 Position	CF[(b)] (°F)	Fluence[(c)] ($x10^{19}$ n/cm^2, E > 1.0 MeV)	FF[(c)]	IRT_{NDT} [(d)] (°F)	ΔRT_{NDT} (°F)	σ_U[(d)] (°F)	σ_Δ[(f)] (°F)	Margin (°F)	RT_{PTS} (°F)
Beltline Materials										
IS Plate B5454-1	1.1	101.3	2.25	1.2196	52	123.5	0	17	34	210
→ Using credible surveillance data	2.1	105.7	2.25	1.2196	52	128.9	0	8.5	17	198
IS Plate B5454-2	1.1	99.6	2.25	1.2196	67	121.5	0	17	34	**222**
IS Plate B5454-3	1.1	110.5	2.25	1.2196	33	134.8	0	17	34	202
LS Plate B5455-1	1.1	98.2	2.22	1.2161	-15	119.4	0	17	34	138
LS Plate B5455-2	1.1	98.2	2.22	1.2161	0	119.4	0	17	34	153
LS Plate B5455-3	1.1	65.2	2.22	1.2161	15	79.3	0	17	34	128
IS Longitudinal Weld 2-201A	1.1	211.2	1.24	1.0599	-50	223.9	0	28	56	230
→ Using credible surveillance data	2.1	204.6	1.24	1.0599	-50	216.9	0	14	28	195
IS Longitudinal Weld 2-201B	1.1	211.2	1.53	1.1176	-50	236.0	0	28	56	242
→ Using credible surveillance data	2.1	204.6	1.53	1.1176	-50	228.7	0	14	28	207
IS Longitudinal Weld 2-201C	1.1	211.2	1.30	1.0730	-50	226.6	0	28	56	233
→ Using credible surveillance data	2.1	204.6	1.30	1.0730	-50	219.5	0	14	28	198
LS Longitudinal Weld 3-201A	1.1	126.3	1.28	1.0687	-56[(e)]	135.0	17[(e)]	28	65.5	144
→ Using credible surveillance data	2.1	115.9	1.28	1.0687	-56[(e)]	123.9	17[(e)]	14	44.0	112
LS Longitudinal Weld 3-201B	1.1	126.3	1.23	1.0577	-56[(e)]	133.6	17[(e)]	28	65.5	143
→ Using credible surveillance data	2.1	115.9	1.23	1.0577	-56[(e)]	122.6	17[(e)]	14	44.0	111
LS Longitudinal Weld 3-201C	1.1	126.3	1.51	1.1141	-56[(e)]	140.7	17[(e)]	28	65.5	150
→ Using credible surveillance data	2.1	115.9	1.51	1.1141	-56[(e)]	129.1	17[(e)]	14	44.0	117
IS to LS Circ. Weld 9-201	1.1	34.0	2.22	1.2161	-56[(e)]	41.3	17[(e)]	20.7	53.5	39

Table 6.2-2 RT_{PTS} Calculations for the Diablo Canyon Unit 2 Reactor Vessel Beltline and Extended Beltline Materials at 54 EFPY[(a)]

Reactor Vessel Material	R.G. 1.99, Rev. 2 Position	CF[(b)] (°F)	Fluence[(c)] ($x10^{19}$ n/cm^2, E > 1.0 MeV)	FF[(c)]	IRT_{NDT} [(d)] (°F)	ΔRT_{NDT} (°F)	σ_U[(d)] (°F)	σ_Δ[(f)] (°F)	Margin (°F)	RT_{PTS} (°F)
Extended Beltline Materials										
US Plate B5453-1	1.1	74	0.0677	0.3434	28	25.4	0	12.7	25.4	79
US Plate B5453-3	1.1	74	0.0677	0.3434	5	25.4	17[(e)]	12.7	42.4	73
US Plate B5011-1R	1.1	74.8	0.0677	0.3434	0	25.7	17[(e)]	12.8	42.6	68
US Longitudinal Weld 1-201A	1.1	211.2	0.0633	0.3317	-50	70.1	0	28	56	76
→ Using <u>credible</u> surveillance data	2.1	204.6	0.0633	0.3317	-50	67.9	0	14	28	46
US Longitudinal Weld 1-201B	1.1	211.2	0.0629	0.3306	-50	69.8	0	28	56	76
→ Using <u>credible</u> surveillance data	2.1	204.6	0.0629	0.3306	-50	67.6	0	14	28	46
US Longitudinal Weld 1-201C	1.1	211.2	0.0514	0.2971	-50	62.7	0	28	56	69
→ Using <u>credible</u> surveillance data	2.1	204.6	0.0514	0.2971	-50	60.8	0	14	28	39
US to IS Circ. Weld 8-201	1.1	172.2	0.0677	0.3434	-56[(e)]	59.1	17[(e)]	28	65.5	69

Notes:

(a) The 10 CFR 50.61 methodology was utilized in the calculation of the RT_{PTS} values. See Section 1 of this report for details.
(b) Taken from Table 5.2-3 of this report.
(c) Taken from Table 2.2-1 of this report.
(d) Initial RT_{NDT} values are taken from Table 3.2-1 of this report and are measured values, unless otherwise noted.
(e) Initial RT_{NDT} values are either generic or estimated; therefore, σ_U = 17°F.
(f) Per Appendix A of this report, the surveillance data of the plate and weld materials were deemed <u>credible</u>. Per the guidance of 10 CFR 50.61, the base metal σ_Δ = 17°F for Position 1.1 and with <u>credible</u> surveillance data σ_Δ = 8.5°F for Position 2.1; the weld metal σ_Δ = 28°F for Position 1.1 and with <u>credible</u> surveillance data σ_Δ = 14°F for Position 2.1. However, σ_Δ need not exceed 0.5*ΔRT_{NDT}.

7 UPPER-SHELF ENERGY CALCULATIONS

The requirements for upper-shelf energy (USE) are contained in 10 CFR 50, Appendix G (Reference 19). 10 CFR 50, Appendix G requires utilities to submit an analysis at least 3 years prior to the time that the USE of any reactor vessel material is predicted to drop below 50 ft-lb.

Regulatory Guide 1.99, Revision 2 defines two methods that can be used to predict the decrease in USE due to irradiation. The method to be used depends on the availability of credible surveillance capsule data. For vessel beltline materials that are not in the surveillance program or are not credible, the Charpy USE (Position 1.2) is assumed to decrease as a function of fluence and copper content, as indicated in Regulatory Guide 1.99, Revision 2 (Reference 2).

When two or more credible surveillance data sets become available from the reactor vessel, they may be used to determine the Charpy USE of the surveillance materials. The surveillance data are then used in conjunction with Figure 2 of the Regulatory Guide to predict the decrease in USE (Position 2.2) of the reactor vessel materials due to irradiation. If the EOL and/or EOLE USE values calculated using Position 2.2 are most limiting, then they must be used regardless of the credibility of the surveillance data.

The 32 EFPY (EOL) and 54 EFPY (EOLE) Position 1.2 USE values of the vessel materials can be predicted using the corresponding 1/4T fluence projection, the copper content, and Figure 2 in Regulatory Guide 1.99, Revision 2.

The predicted Position 2.2 USE values are determined for the beltline and extended beltline materials that are contained in the surveillance program by using the reduced plant surveillance data along with the corresponding 1/4T fluence projection. The reduced plant surveillance data from Table 5-10 of WCAP-15958 (Reference 9) for Diablo Canyon Unit 1 and Table 5-10 of WCAP-15423 (Reference 11) for Diablo Canyon Unit 2 were plotted on Reg. Guide 1.99, Revision 2, Figure 2 (see Figures 7.1-1 and 7.2-1 of this report) using the updated surveillance capsule fluence values documented in WCAP-17299-NP (Reference 3). This data was fitted by drawing a line parallel to the existing lines as the upper bound of all the surveillance data. These reduced lines were used instead of the existing lines to determine the Position 2.2 EOL and EOLE USE values.

The projected USE values were calculated to determine if the Diablo Canyon Units 1 and 2 reactor vessel materials remain above the 50 ft-lb limit at EOL and EOLE. These calculations are summarized in Tables 7.1-1 and 7.1-2 for Diablo Canyon Unit 1 and in Tables 7.2-1 and 7.2-2 for Diablo Canyon Unit 2.

USE Conclusion

For Diablo Canyon Unit 1, the limiting USE values at 32 EFPY and 54 EFPY are 62.3 ft-lb (see Table 7.1-1) and 59.2 ft-lb (see Table 7.1-2), respectively; these values correspond to LS Longitudinal Weld 3-442C (Position 2.2). For Diablo Canyon Unit 2, the limiting USE values at 32 EFPY and 54 EFPY are 57.2 ft-lb (see Table 7.2-1) and 53.7 ft-lb (see Table 7.2-2), respectively; these values correspond to LS Longitudinal Weld 3-201C. Therefore, all of the beltline and extended beltline materials in the Diablo Canyon Units 1 and 2 reactor vessels are projected to remain above the USE screening criterion value of 50 ft-lb (per 10 CFR 50, Appendix G) through EOL (32 EFPY) and EOLE (54 EFPY).

7.1 DIABLO CANYON UNIT 1

Table 7.1-1 Diablo Canyon Unit 1 Predicted Positions 1.2 and 2.2 USE Values at 32 EFPY

Reactor Vessel Material	Wt. % Cu[(a)]	1/4T EOL Fluence[(b)] ($x10^{19}$ n/cm^2, E > 1.0 MeV)	Unirradiated USE[(a)] (ft-lb)	Projected USE Decrease (%)	Projected EOL USE (ft-lb)
Beltline Materials					
IS Plate B4106-1	0.125	0.733	116	20	92.8
IS Plate B4106-2	0.120	0.733	114	20	91.2
IS Plate B4106-3	0.086	0.733	77	18[(c)]	63.1
→ Using surveillance data	0.086	0.733	77	6.4[(d)]	72.1
LS Plate B4107-1	0.13	0.727	110	21	86.9
LS Plate B4107-2	0.12	0.727	103	20	82.4
LS Plate B4107-3	0.12	0.727	116	20	92.8
IS Longitudinal Weld 2-442A & B	0.203	0.539	91	31	62.8
→ Using surveillance data	0.203	0.539	91	29.5[(d)]	64.2
IS Longitudinal Weld 2-442C	0.203	0.276	91	26	67.3
→ Using surveillance data	0.203	0.276	91	25[(d)]	68.3
LS Longitudinal Weld 3-442A & B	0.203	0.430	91	29	64.6
→ Using surveillance data	0.203	0.430	91	28[(d)]	65.5
LS Longitudinal Weld 3-442C	0.203	0.727	91	32	61.9
→ Using surveillance data	0.203	0.727	91	31.5[(d)]	**62.3**
IS to LS Circ. Weld 9-442	0.183	0.727	109	30	76.3

Notes:

(a) From Table 3.1-1 of this report.

(b) From Table 2.1-1 of this report.

(c) Percentage USE decrease is conservatively based on lowest Cu Wt. % chemistry line (0.05% for weld and 0.10% for base metal) delineated in Figure 2 of Regulatory Guide 1.99, Revision 2.

(d) Percentage USE decrease is based on Position 2.2 of Regulatory Guide 1.99, Revision 2, using data from Table 4.1-1 of this report. Credibility Criterion 3 in the Discussion section of Regulatory Guide 1.99, Revision 2, indicates that even if the surveillance data are not considered credible for determination of ΔRT_{NDT}, "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." Regulatory Guide 1.99, Revision 2, Position 2.2 indicates that an upper-bound line drawn parallel to the existing lines (in Figure 2 of the Guide) through the surveillance data points should be used in preference to the existing graph lines for determining the decrease in USE.

Table 7.1-2 Diablo Canyon Unit 1 Predicted Positions 1.2 and 2.2 USE Values at 54 EFPY

Reactor Vessel Material	Wt. % Cu[(a)]	1/4T EOLE Fluence[(b)] (x10^{19} n/cm^2, E > 1.0 MeV)	Unirradiated USE[(a)] (ft-lb)	Projected USE Decrease (%)	Projected EOLE USE (ft-lb)
Beltline Materials					
IS Plate B4106-1	0.125	1.204	116	23	89.3
IS Plate B4106-2	0.120	1.204	114	22	88.9
IS Plate B4106-3	0.086	1.204	77	20[(c)]	61.6
→ Using surveillance data	0.086	1.204	77	7.2[(d)]	71.5
LS Plate B4107-1	0.13	1.198	110	23	84.7
LS Plate B4107-2	0.12	1.198	103	22	80.3
LS Plate B4107-3	0.12	1.198	116	22	90.5
IS Longitudinal Weld 2-442A & B	0.203	0.888	91	34	60.1
→ Using surveillance data	0.203	0.888	91	33[(d)]	61.0
IS Longitudinal Weld 2-442C	0.203	0.458	91	29	64.6
→ Using surveillance data	0.203	0.458	91	28.5[(d)]	65.1
LS Longitudinal Weld 3-442A & B	0.203	0.709	91	32	61.9
→ Using surveillance data	0.203	0.709	91	31[(d)]	62.8
LS Longitudinal Weld 3-442C	0.203	1.198	91	36	58.2
→ Using surveillance data	0.203	1.198	91	35[(d)]	**59.2**
IS to LS Circ. Weld 9-442	0.183	1.198	109	34	71.9
Extended Beltline Materials					
US Plate B4105-1	0.12	0.020	80	8.6	73.1
US Plate B4105-2	0.12	0.020	74	8.6	67.6
US Plate B4105-3	0.14	0.020	81	9.4	73.4
US Longitudinal Weld 1-442A	0.19	0.015[(e)]	86	14	74.0
US Longitudinal Weld 1-442B	0.19	0.009[(e)]	86	14	74.0
US Longitudinal Weld 1-442C	0.19	0.018[(e)]	86	14	74.0
US to IS Circ. Weld 8-442	0.25	0.020	111	17	92.1

Notes:

(a) From Table 3.1-1 of this report.
(b) From Table 2.1-1 of this report.
(c) Percentage USE decrease is conservatively based on lowest Cu Wt. % chemistry line (0.05% for weld and 0.10% for base metal) delineated in Figure 2 of Regulatory Guide 1.99, Revision 2.
(d) Percentage USE decrease is based on Position 2.2 of Regulatory Guide 1.99, Revision 2, using data from Table 4.1-1 of this report. Credibility Criterion 3 in the Discussion section of Regulatory Guide 1.99, Revision 2, indicates that even if the surveillance data are not considered credible for determination of ΔRT_{NDT}, "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." Regulatory Guide 1.99, Revision 2, Position 2.2 indicates that an upper-bound line drawn parallel to the existing lines (in Figure 2 of the Guide) through the surveillance data points should be used in preference to the existing graph lines for determining the decrease in USE.
(e) The minimum fluence value (2 x 10^{19} n/cm^2) displayed on Figure 2 of Regulatory Guide 1.99, Revision 2 was conservatively used to determine the projected USE decrease.

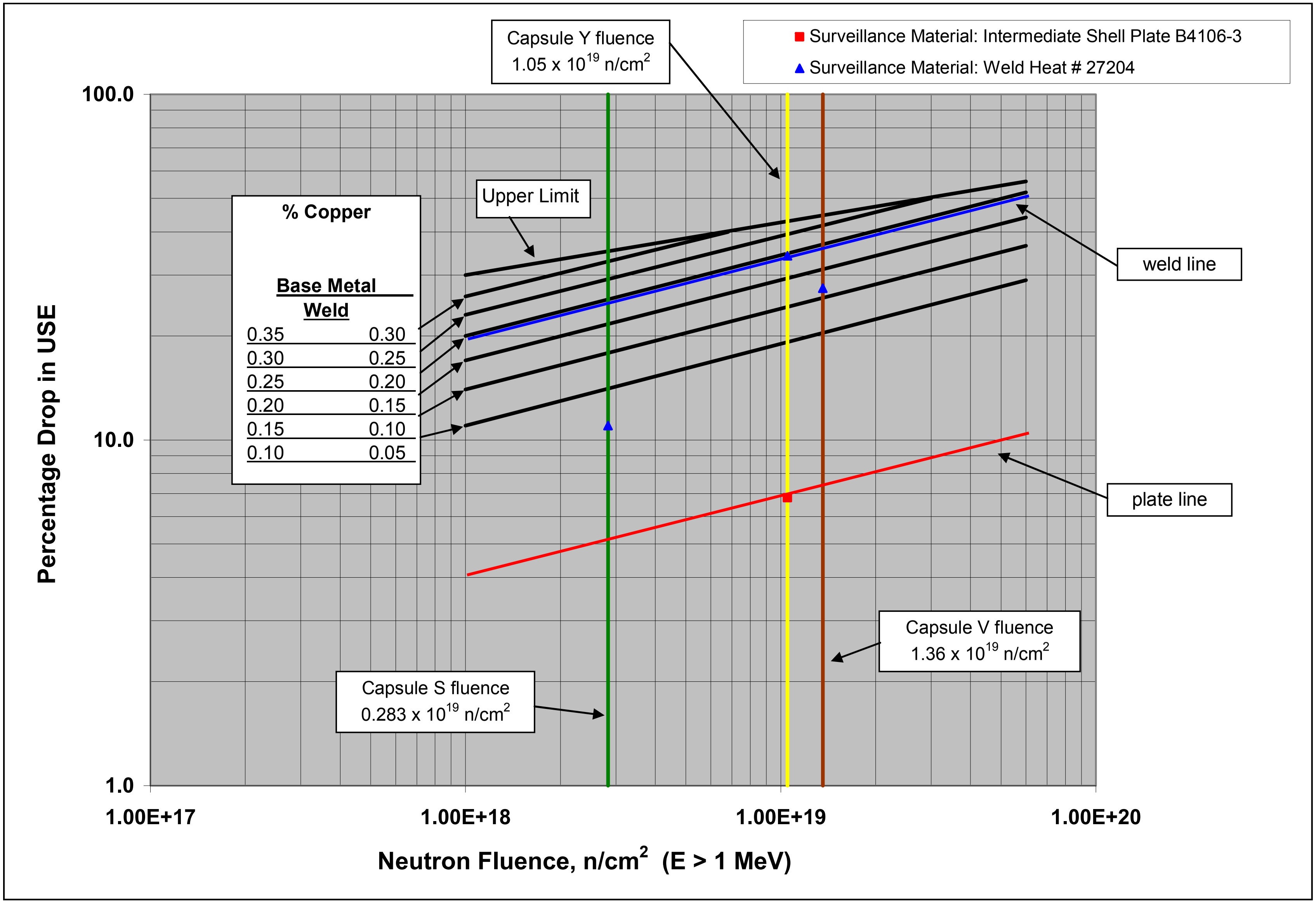

Figure 7.1-1 Regulatory Guide 1.99, Revision 2 Predicted Decrease in USE as a Function of Copper and Fluence for Diablo Canyon Unit 1

7.2 DIABLO CANYON UNIT 2

Table 7.2-1 Diablo Canyon Unit 2 Predicted Positions 1.2 and 2.2 USE Values at 32 EFPY

Reactor Vessel Material	Wt. % Cu[(a)]	1/4T EOL Fluence[(b)] ($x10^{19}$ n/cm^2, E > 1.0 MeV)	Unirradiated USE[(a)] (ft-lb)	Projected USE Decrease (%)	Projected EOL USE (ft-lb)
Beltline Materials					
IS Plate B5454-1	0.14	0.805	91	22	71.0
→ Using surveillance data	0.14	0.805	91	19.5[(d)]	73.3
IS Plate B5454-2	0.14	0.805	99	22	77.2
IS Plate B5454-3	0.15	0.805	90	23	69.3
LS Plate B5455-1	0.14	0.799	112	22	87.4
LS Plate B5455-2	0.14	0.799	122	22	95.2
LS Plate B5455-3	0.10	0.799	100	18	82.0
IS Longitudinal Weld 2-201A	0.22	0.448	118	30	82.6
→ Using surveillance data	0.22	0.448	118	33.5[(d)]	78.5
IS Longitudinal Weld 2-201B	0.22	0.551	118	32	80.2
→ Using surveillance data	0.22	0.551	118	35[(d)]	76.7
IS Longitudinal Weld 2-201C	0.22	0.467	118	31	81.4
→ Using surveillance data	0.22	0.467	118	34[(d)]	77.9
LS Longitudinal Weld 3-201A	0.258	0.463	88	34	58.1
LS Longitudinal Weld 3-201B	0.258	0.443	88	34	58.1
LS Longitudinal Weld 3-201C	0.258	0.545	88	35	**57.2**
IS to LS Circ. Weld 9-201	0.046	0.799	125	18[(c)]	102.5

Notes:

(a) From Table 3.2-1 of this report.
(b) From Table 2.2-1 of this report.
(c) Percentage USE decrease is conservatively based on lowest Cu Wt. % chemistry line (0.05% for weld and 0.10% for base metal) delineated in Figure 2 of Regulatory Guide 1.99, Revision 2.
(d) Percentage USE decrease is based on Position 2.2 of Regulatory Guide 1.99, Revision 2, using data from Table 4.2-1 of this report. Credibility Criterion 3 in the Discussion section of Regulatory Guide 1.99, Revision 2, indicates that even if the surveillance data are not considered credible for determination of ΔRT_{NDT}, "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." Regulatory Guide 1.99, Revision 2, Position 2.2 indicates that an upper-bound line drawn parallel to the existing lines (in Figure 2 of the Guide) through the surveillance data points should be used in preference to the existing graph lines for determining the decrease in USE.

Table 7.2-2 Diablo Canyon Unit 2 Predicted Positions 1.2 and 2.2 USE Values at 54 EFPY

Reactor Vessel Material	Wt. % Cu[a]	1/4T EOLE Fluence[b] ($x10^{19}$ n/cm^2, E > 1.0 MeV)	Unirradiated USE[a] (ft-lb)	Projected USE Decrease (%)	Projected EOLE USE (ft-lb)
Beltline Materials					
IS Plate B5454-1	0.14	1.341	91	25	68.3
→ Using surveillance data	0.14	1.341	91	22[d]	71.0
IS Plate B5454-2	0.14	1.341	99	25	74.3
IS Plate B5454-3	0.15	1.341	90	26	66.6
LS Plate B5455-1	0.14	1.323	112	25	84.0
LS Plate B5455-2	0.14	1.323	122	25	91.5
LS Plate B5455-3	0.10	1.323	100	21	79.0
IS Longitudinal Weld 2-201A	0.22	0.739	118	34	77.9
→ Using surveillance data	0.22	0.739	118	37.5[d]	73.8
IS Longitudinal Weld 2-201B	0.22	0.912	118	36	75.5
→ Using surveillance data	0.22	0.912	118	39.5[d]	71.4
IS Longitudinal Weld 2-201C	0.22	0.775	118	35	76.7
→ Using surveillance data	0.22	0.775	118	38[d]	73.2
LS Longitudinal Weld 3-201A	0.258	0.763	88	38	54.6
LS Longitudinal Weld 3-201B	0.258	0.733	88	38	54.6
LS Longitudinal Weld 3-201C	0.258	0.900	88	39	**53.7**
IS to LS Circ. Weld 9-201	0.046	1.323	125	21[c]	98.8
Extended Beltline Materials					
US Plate B5453-1	0.11	0.040	82	9.4	74.3
US Plate B5453-3	0.11	0.040	86.5	9.4	78.4
US Plate B5011-1R	0.11	0.040	72	9.4	65.2
US Longitudinal Weld 1-201A	0.22	0.038	118	18	96.8
→ Using surveillance data	0.22	0.038	118	20[d]	94.4
US Longitudinal Weld 1-201B	0.22	0.037	118	18	96.8
→ Using surveillance data	0.22	0.037	118	20[d]	94.4
US Longitudinal Weld 1-201C	0.22	0.031	118	17	97.9
→ Using surveillance data	0.22	0.031	118	19[d]	95.6
US to IS Circ. Weld 8-201	0.183	0.040	109	16	91.6

Notes (continued on next page):

(a) From Table 3.2-1 of this report.
(b) From Table 2.2-1 of this report.

Notes (continued from previous page):

(c) Percentage USE decrease is conservatively based on lowest Cu Wt. % chemistry line (0.05% for weld and 0.10% for base metal) delineated in Figure 2 of Regulatory Guide 1.99, Revision 2.

(d) Percentage USE decrease is based on Position 2.2 of Regulatory Guide 1.99, Revision 2, using data from Table 4.2-1 of this report. Credibility Criterion 3 in the Discussion section of Regulatory Guide 1.99, Revision 2, indicates that even if the surveillance data are not considered credible for determination of ΔRT_{NDT}, "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." Regulatory Guide 1.99, Revision 2, Position 2.2 indicates that an upper-bound line drawn parallel to the existing lines (in Figure 2 of the Guide) through the surveillance data points should be used in preference to the existing graph lines for determining the decrease in USE.

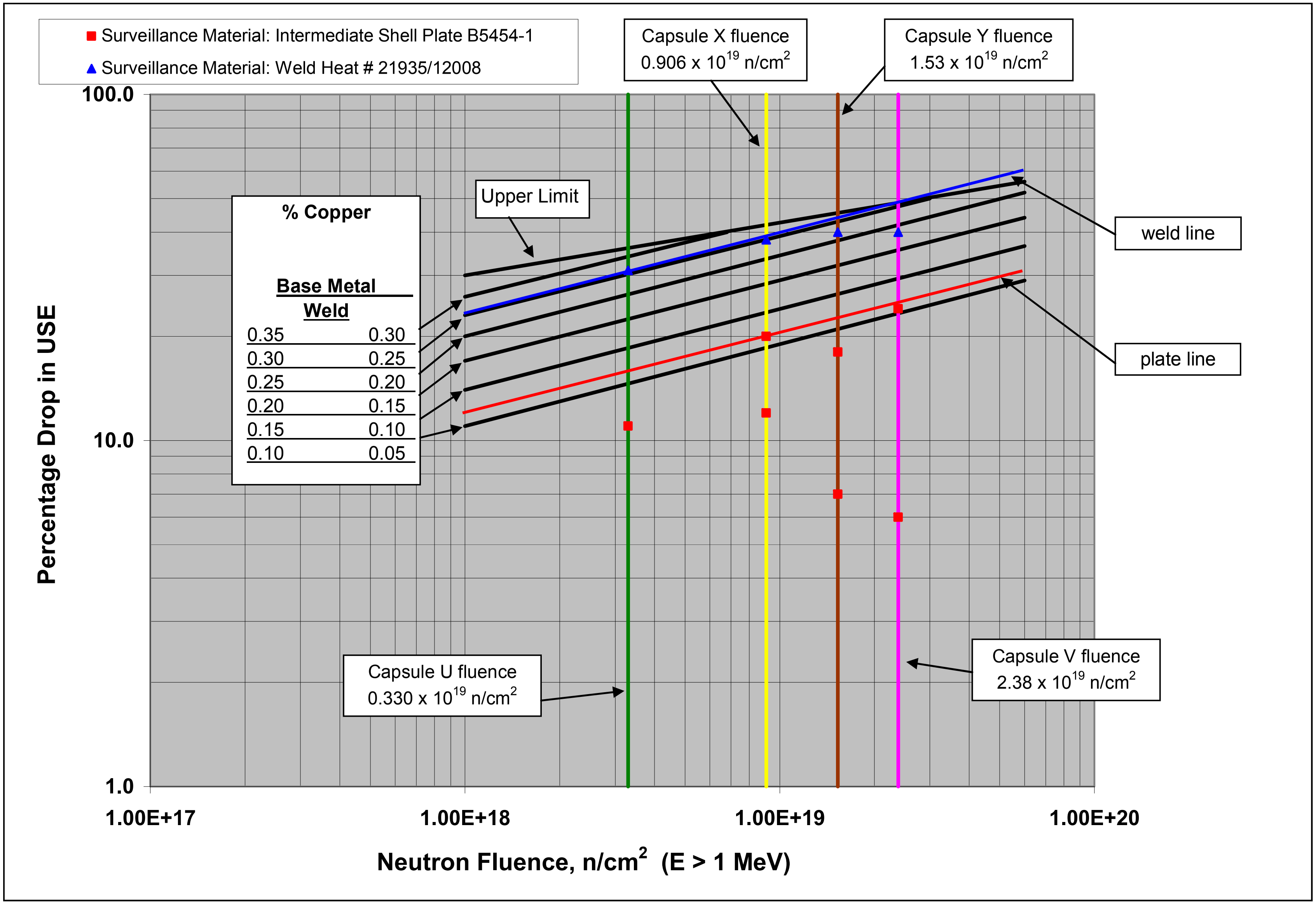

Figure 7.2-1 Regulatory Guide 1.99, Revision 2 Predicted Decrease in USE as a Function of Copper and Fluence for Diablo Canyon Unit 2

8 REFERENCES

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APPENDIX A
SURVEILLANCE DATA CREDIBILITY EVALUATION

A.1 DIABLO CANYON UNIT 1

Introduction

Regulatory Guide 1.99, Revision 2 (Reference A.1-1) 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.

To date there have been three surveillance capsules removed and tested from the Diablo Canyon Unit 1 reactor vessel. To use these surveillance data sets, they must be shown to be credible. In accordance with Regulatory Guide 1.99, Revision 2, the credibility of the surveillance data will be judged based on five criteria.

The purpose of this evaluation is to apply the credibility requirements of Regulatory Guide 1.99, Revision 2, to the Diablo Canyon Unit 1 reactor vessel surveillance data and determine if that surveillance data is credible.

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," (Reference A.1-2) as follows:

> *"the region of 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 Diablo Canyon Unit 1 reactor vessel beltline region consists of the following materials:

1. Intermediate Shell Plates B4106-1, B4106-2, and B4106-3
2. Lower Shell Plates B4107-1, B4107-2, and B4107-3
3. Intermediate and Lower Shell Longitudinal Weld Seams (Heat # 27204, Linde 1092 Flux)
4. Intermediate to Lower Shell Circumferential Weld Seam (Heat # 21935, Linde 1092 Flux)

Per WCAP-8465 (Reference A.1-3), the Diablo Canyon Unit 1 surveillance program was based on ASTM E185-70. Per Section 3.1 of ASTM E185-70, "*Sample shall represent one heat of the base metal and one butt weld if a weld occurs in the irradiated region*."

At the time that the Diablo Canyon Unit 1 surveillance capsule program was developed, the intermediate shell plates were judged to be most limiting. Therefore, specimens from each intermediate shell plate are included in the surveillance program. However, to date, the three capsules removed and tested contained only specimens from intermediate shell plate B4106-3. This plate material may be considered the most limiting base metal because it has the lowest initial upper-shelf energy value and highest initial RT_{NDT}. Hence intermediate shell plate B4106-3 was utilized in the surveillance program.

The weld material in the Diablo Canyon Unit 1 surveillance program was made of the same wire heat as the reactor vessel intermediate and lower shell longitudinal weld seams (Heat # 27204, Linde 1092 Flux). This represents six of the seven welds in the beltline region. The seventh weld, the intermediate to lower shell circumferential weld, was made from Heat # 21935. This weld had a higher initial USE and lower copper content than Heat # 27204. Thus, Heat # 27204 was chosen as the surveillance weld. ASTM E185-70 only requires that the surveillance material represent a weld in the irradiated region. Since the surveillance weld Heat # 27204 is the same as the intermediate and lower shell longitudinal welds, this criterion is met.

<u>Based on the discussion above, Criterion 1 is met for the Diablo Canyon Unit 1 surveillance program.</u>

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 conditions are presented in Section 5 and Appendix C of the latest surveillance capsule report, WCAP-15958 (Reference A.1-4).

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 Diablo Canyon Unit 1 surveillance materials unambiguously.

<u>Hence, Criterion 2 is met for the Diablo Canyon Unit 1 surveillance program.</u>

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 (Reference A.1-5).

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 the weld 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. In addition, 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 (Reference A.1-6). At this meeting the NRC presented five cases. Of the five cases, Case 1 ("Surveillance data available from plant but no other source") most closely represents the situation for the Diablo Canyon Unit 1 surveillance plate material. However, Diablo Canyon Unit 1 has a weld that will be evaluated for credibility using the guidance for the appropriate case as explained in Reference A.1-6. Each surveillance material and the respective evaluation method are described below:

1. IS Plate B4106-3 (Case 1) – This plate material will be evaluated using the NRC Case 1 guidelines as described above.
2. Heat # 27204 (Case 4) – This weld heat pertains to IS and LS longitudinal welds 3-442A, B, and C and 2-442A, B, and C in the Diablo Canyon Unit 1 reactor vessel. This weld heat is contained in the Diablo Canyon Unit 1 surveillance program as well as the Palisades surveillance program. NRC Case 4 per Reference A.1-6 is entitled "Surveillance Data from Plant and Other Sources" and most closely represents the situation for Diablo Canyon Unit 1 weld Heat # 27204.

Case 1: IS Plate B4106-3 and
Case 4: Weld Heat # 27204 (Diablo Canyon Unit 1 data only)

Following the NRC Case 1 and Case 4 guidelines, the Diablo Canyon Unit 1 surveillance plate and weld metal (Heat # 27204) will be evaluated using Diablo Canyon Unit 1 data only. First, the data is adjusted to the mean operating temperature for the surveillance capsules. The mean operating temperature of the Diablo Canyon Unit 1 surveillance capsules is calculated in Table A.1-1 below:

Table A.1-1 Mean Operating Temperature for Diablo Canyon Unit 1

Capsule	Inlet Temperature during Period of Irradiation (°F)
S	544[a]
Y	542.2[a]
V	541.5[a]
MEAN	**542.6**

Note:
(a) Values taken from Table 4.1-1 of this report.

The capsule-specific temperature adjustments are as shown in Table A.1-2 below:

Table A.1-2 Operating Temperature Adjustments for the Diablo Canyon Unit 1 Surveillance Capsule Data

Capsule	Inlet Temperature during Period of Irradiation (°F)	Mean Operating Temperature (°F)	Temperature Adjustment (°F)
S	544	542.6	+1.4
Y	542.2		-0.4
V	541.5		-1.1

Thus, the temperature adjustments calculated above in Table A.1-2 will be used to adjust the ΔRT_{NDT} values for the Diablo Canyon Unit 1 surveillance materials in Table A.1-3, which contains the calculation of interim chemistry factors for the credibility evaluation.

Table A.1-3 Calculation of Interim Chemistry Factors for the Credibility Evaluation Using Diablo Canyon Unit 1 Surveillance Capsule Data Only

Material	Capsule	Capsule f[(a)] ($x10^{19}$ n/cm^2, E > 1.0 MeV)	FF[(b)]	ΔRT_{NDT}[(c)] (°F)	FF*ΔRT_{NDT} (°F)	FF^2
IS Plate B4106-3 (Longitudinal)	S	0.283	0.655	-0.38 (-1.78)	-0.25	0.429
	Y	1.05	1.014	48.26 (48.66)	48.92	1.027
	V	1.36	1.085	33.22 (34.32)	36.06	1.178
				SUM:	84.73	2.635
	$CF_{IS\ Plate\ B4106\text{-}3} = \Sigma(FF * \Delta RT_{NDT}) \div \Sigma(FF^2) = (84.73) \div (2.635) = \mathbf{32.2°F}$					
Diablo Canyon Unit 1 Weld Metal (Heat # 27204)	S	0.283	0.655	112.19 (110.79)	73.52	0.429
	Y	1.05	1.014	232.19 (232.59)	235.36	1.027
	V	1.36	1.085	199.97 (201.07)	217.06	1.178
				SUM :	525.93	2.635
	$CF_{Heat\ \#\ 27204} = \Sigma(FF * \Delta RT_{NDT}) \div \Sigma(FF^2) = (525.93) \div (2.635) = \mathbf{199.6°F}$					

Notes:

(a) f = capsule fluence taken from Table 4.1-1 of this report.
(b) FF = fluence factor = $f^{(0.28 - 0.10*\log f)}$.
(c) ΔRT_{NDT} values are the measured 30 ft-lb shift values taken from Table 4.1-1 of this report. These measured ΔRT_{NDT} values for the surveillance weld metal do not include the adjustment ratio procedure of Reg. Guide 1.99, Revision 2, Position 2.1 since this calculation is based on the actual surveillance weld metal measured shift values. However, as shown in Table A.1-1, the Diablo Canyon Unit 1 surveillance capsules were irradiated at different temperatures. Therefore, the ΔRT_{NDT} values for both the surveillance weld and plate materials are adjusted by the temperature adjustment values summarized in Table A.1-2 (pre-adjusted values are listed in parentheses).

The scatter of ΔRT_{NDT} values about the functional form of a best-fit line drawn as described in Regulatory Position 2.1 is presented in Table A.1-4.

Table A.1-4 Best-Fit Evaluation for Diablo Canyon Unit 1 Surveillance Materials Only

Material	Capsule	CF ($Slope_{best-fit}$) (°F)	Capsule f ($x10^{19}$ n/cm^2, E > 1.0 MeV)	FF	Measured ΔRT_{NDT} (°F)[(a)]	Predicted ΔRT_{NDT} (°F)[(b)]	Scatter ΔRT_{NDT} (°F)[(c)]	<17°F (Base Metal) <28°F (Weld)
IS Plate B4106-3 (Longitudinal)	S	32.2	0.283	0.655	-0.38	21.07	21.5	No
	Y	32.2	1.05	1.014	48.26	32.59	15.7	Yes
	V	32.2	1.36	1.085	33.22	34.90	1.7	Yes
Diablo Canyon Unit 1 Weld Metal (Heat # 27204)	S	199.6	0.283	0.655	112.19	130.79	18.6	Yes
	Y	199.6	1.05	1.014	232.19	202.31	29.9	No
	V	199.6	1.36	1.085	199.97	216.64	16.7	Yes

Notes:

(a) Measured ΔRT_{NDT} values are the adjusted values taken from Table A.1-3.
(b) Predicted $\Delta RT_{NDT} = CF_{best-fit} * FF$.
(c) Scatter ΔRT_{NDT} = Absolute Value [Predicted ΔRT_{NDT} – Measured ΔRT_{NDT}].

The scatter of ΔRT_{NDT} values about the best-fit line, drawn as described in Regulatory Guide 1.99, Revision 2, Position 2.1, should be less than 17°F for base metal. Table A.1-4 indicates that one of the three surveillance data points falls outside the +/- 1σ of 17°F scatter band for surveillance base metals; therefore, the IS Plate B4106-3 data is deemed "non-credible" per the third criterion.

The scatter of ΔRT_{NDT} values about the best-fit line, drawn as described in Regulatory Guide 1.99, Revision 2, Position 2.1, should be less than 28°F for weld metal. Table A.1-4 indicates that one of the three surveillance data points falls outside the +/- 1σ of 28°F scatter band for surveillance weld materials; therefore, the weld metal (Heat # 27204) is deemed "non-credible" per the third criterion.

Hence, Criterion 3 is not met for the Diablo Canyon Unit 1 surveillance plate material. Criterion 3 is also not met for the surveillance weld material when only Diablo Canyon Unit 1 data is considered. However, the surveillance data may still be used in determining the upper-shelf energy decrease in accordance with Regulatory Guide 1.99, Revision 2, Position 2.2. Furthermore, the surveillance weld material will be evaluated using the Palisades surveillance data to determine if it is credible when considering all available data.

Case 4: Weld Heat # 27204 (All data)

In accordance with the NRC Case 4 guidelines, the data from Diablo Canyon Unit 1 and Palisades will now be analyzed together. Data is adjusted to the mean chemical composition and operating temperature of the surveillance capsules. This is performed in Table A.1-5 below:

Table A.1-5 Mean Chemical Composition and Operating Temperature for Diablo Canyon Unit 1 and Palisades

Material	Capsule	Cu Wt. %	Ni Wt. %	Inlet Temperature during Period of Irradiation (°F)
Weld Metal Heat # 27204 (Diablo Canyon Unit 1 data)	S	0.198	0.999	544[a]
	Y	0.198	0.999	542.2[b]
	V	0.198	0.999	541.5[c]
Weld Metal Heat # 27204 (Palisades data)	SA-60-1	0.194	1.067	535
	SA-240-1	0.194	1.067	535.7
MEAN		**0.196**	**1.026**	**539.7**

Notes:

(a) Capsule S was irradiated during Cycle 1. Therefore, this value pertains to the actual inlet operating temperature data for Cycle 1.

(b) Capsule Y was irradiated during Cycles 1-5. Therefore, this average value was determined using actual inlet operating temperature data for Cycles 1-5.

(c) Capsule V was irradiated during Cycles 1-11. Therefore, this average value was determined using actual inlet operating temperature data for Cycles 1-11.

Therefore, the Diablo Canyon Unit 1 and Palisades surveillance capsule data will be adjusted to the mean chemical composition and operating temperature calculated in Table A.1-5.

Diablo Canyon Unit 1 data

CF_{Mean} = 224.5°F (calculated per Table 1 of Regulatory Guide 1.99, Revision 2 using Cu Wt. % = 0.196 and Ni Wt. % = 1.026 per Table A.1-5)

$CF_{Surv.\ Weld\ (Diablo\ Canyon\ Unit\ 1)}$ = 222.3°F (per Table 5.1-2 of this report)

Ratio = 224.5 ÷ 222.3 = 1.01 (applied to Diablo Canyon Unit 1 surveillance data for weld Heat # 27204 in the credibility evaluation)

Palisades data

CF_{Mean} = 224.5°F

$CF_{Surv.\ Weld\ (Palisades)}$ = 227.8°F (per Table 4.1-2 of this report)

Ratio = 224.5 ÷ 227.8 = 0.99 (applied to Palisades surveillance data for weld Heat # 27204 in the credibility evaluation)

The capsule-specific temperature adjustments are as shown in Table A.1-6 below:

Table A.1-6 Operating Temperature Adjustments for the Diablo Canyon Unit 1 and Palisades Surveillance Capsule Data

Material	Capsule	Inlet Temperature during Period of Irradiation (°F)	Mean Operating Temperature (°F)	Temperature Adjustment (°F)
Weld Metal Heat # 27204 (Diablo Canyon Unit 1 data)	S	544	539.7	+4.3
	Y	542.2	539.7	+2.5
	V	541.5	539.7	+1.8
Weld Metal Heat # 27204 (Palisades data)	SA-60-1	535	539.7	-4.7
	SA-240-1	535.7	539.7	-4.0

Using the chemical composition and operating temperature adjustments described and calculated above, an interim chemistry factor is calculated for weld Heat # 27204 using the Diablo Canyon Unit 1 and Palisades data. This calculation is shown in Table A.1-7 below.

Table A.1-7 Calculation of Weld Heat # 27204 Interim Chemistry Factor for the Credibility Evaluation Using Diablo Canyon Unit 1 and Palisades Surveillance Capsule Data

Material	**Capsule**	**Capsule f[(a)] ($x10^{19}$ n/cm^2, E > 1.0 MeV)**	**FF[(b)]**	**ΔRT_{NDT}[(c)] (°F)**	**FF*ΔRT_{NDT} (°F)**	**FF^2**
Weld Metal Heat # 27204 (Diablo Canyon Unit 1 data)	S	0.283	0.655	116.24 (110.79)	76.17	0.429
	Y	1.05	1.014	237.44 (232.59)	240.68	1.027
	V	1.36	1.085	204.90 (201.07)	222.41	1.178
Weld Metal Heat # 27204 (Palisades data)	SA-60-1	1.50	1.112	245.92 (253.1)	273.52	1.237
	SA-240-1	2.38	1.234	261.16 (267.8)	322.23	1.522
				SUM :	1135.02	5.395
	$CF_{Heat\ \#\ 27204} = \Sigma(FF * \Delta RT_{NDT}) \div \Sigma(FF^2) = (1135.02) \div (5.395) =$ **210.4°F**					

Notes:

(a) f = capsule fluence taken from Tables 4.1-1 and 4.1-2 of this report for Diablo Canyon Unit 1 and Palisades, respectively.

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

(c) ΔRT_{NDT} values are the measured 30 ft-lb shift values. Pre-adjusted values are taken from Tables 4.1-1 and 4.1-2 for Diablo Canyon Unit 1 and Palisades, respectively. ΔRT_{NDT} values for the surveillance weld data are adjusted first by the difference in operating temperature then using the ratio procedure to account for differences in the surveillance weld chemistry and the beltline weld chemistry (pre-adjusted values are listed in parentheses). The temperature adjustments are shown in Table A.1-6 of this report. The ratios applied are 1.01 for Diablo Canyon Unit 1 and 0.99 for Palisades.

The scatter of ΔRT_{NDT} values about the functional form of a best-fit line drawn as described in Regulatory Position 2.1 is presented in Table A.1-8.

Table A.1-8 Best-Fit Evaluation for Surveillance Weld Metal Heat # 27204 Using Diablo Canyon Unit 1 and Palisades Data

Material	Capsule	CF ($Slope_{best-fit}$) (°F)	Capsule f ($x10^{19}$ n/cm^2, E > 1.0 MeV)	FF	Measured ΔRT_{NDT} (°F)[(a)]	Predicted ΔRT_{NDT} (°F)[(b)]	Scatter ΔRT_{NDT} (°F)[(c)]	<28°F (Weld)
Weld Metal Heat # 27204 (Diablo Canyon Unit 1 data)	S	210.4	0.283	0.655	116.24	137.88	21.6	Yes
	Y	210.4	1.05	1.014	237.44	213.27	24.2	Yes
	V	210.4	1.36	1.085	204.90	228.38	23.5	Yes
Weld Metal Heat # 27204 (Palisades data)	SA-60-1	210.4	1.50	1.112	245.92	234.02	11.9	Yes
	SA-240-1	210.4	2.38	1.234	261.16	259.60	1.6	Yes

Notes:

(a) ΔRT_{NDT} values are the adjusted values taken from Table A.1-7.
(b) Predicted $\Delta RT_{NDT} = CF_{best-fit} * FF$.
(c) Scatter ΔRT_{NDT} = Absolute Value [Predicted ΔRT_{NDT} – Measured ΔRT_{NDT}].

The scatter of ΔRT_{NDT} values about the best-fit line, drawn as described in Regulatory Guide 1.99, Revision 2, Position 2.1, should be less than 28°F for weld metal. Table A.1-8 indicates that all five surveillance data points fall within the +/- 1σ of 28°F scatter band for surveillance weld materials; therefore, the weld material (Heat # 27204) is deemed "credible" per the third criterion when all available data is considered.

In conclusion, the combined surveillance data from Diablo Canyon Unit 1 and Palisades for weld Heat # 27204 may be applied to the Diablo Canyon Unit 1 reactor vessel weld. The chemistry factor calculation as applicable to the Diablo Canyon Unit 1 reactor vessel weld is contained in Table 5.1-1 of this report.

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 Diablo Canyon Unit 1 capsule specimens are located in the reactor between the thermal shield and the vessel wall and are positioned opposite the center of the core. The test capsules are in baskets attached to the thermal shield. 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, Criterion 4 is met for the Diablo Canyon Unit 1 surveillance program.

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

The Diablo Canyon Unit 1 surveillance program does contain Correlation Monitor Material (CMM). The material was obtained from a 12-inch-thick A533 Grade B, Class 1 plate (HSST Plate 02). NUREG/CR-6413, ORNL/TM-13133 (Reference A.1-7) contains a plot of residual vs. Fast Fluence for the CMM (Figure 11 in the report). This Figure shows a 2σ uncertainty of 50°F. The data used for this plot is contained in Table 14 in the report. However, the NUREG Report does not consider the recalculated fluence values as documented herein nor does it include data pertaining to Capsule V. Thus, Table A.1-9 contains an updated calculation of Residual vs. Fast fluence, considering the recalculated capsule fluence values as well as data from Capsule V.

Table A.1-9 Calculation of Residual vs. Fast Fluence for Diablo Canyon Unit 1

Capsule	Capsule f ($x10^{19}$ n/cm^2, E > 1.0 MeV)	FF	Measured Shift (˚F)[(a)]	RG 1.99 Shift (˚F)[(b)]	Residual (˚F)[(c)]
S	0.283	0.655	67.02 (65.62)	83.88	-16.9
Y	1.05	1.014	115.39 (115.79)	129.75	-14.4
V	1.36	1.085	115.51 (116.61)	138.94	-23.4

Notes:

(a) Measured ΔT_{30} values for the CMM were taken from Table B-13 of WCAP-15958 (Reference A.1-4). The measured ΔT_{30} values for the CMM were then adjusted by the temperature adjustment values summarized in Table A.1-2 (pre-adjusted values are listed in parentheses).

(b) Per NUREG/CR-6413, ORNL/TM-13133, the Cu and Ni values for the correlation monitor material (HSST Plate 02) are 0.17 and 0.64, respectively. This equates to a chemistry factor value of 128˚F based on Regulatory Guide 1.99, Revision 2, Position 1.1. The calculated shift is thus equal to CF * FF.

(c) Residual = Measured Shift – RG 1.99 Shift.

Table A.1-9 shows a 2σ uncertainty of less than 50˚F, which is the allowable scatter in NUREG/CR-6413, ORNL/TM-13133.

Hence, Criterion 5 is met for the Diablo Canyon Unit 1 surveillance program.

Conclusion

Based on the preceding responses to the five criteria of Regulatory Guide 1.99, Revision 2, Section B, and the application of engineering judgment, the Diablo Canyon Unit 1 surveillance plate data is deemed non-credible.

The combined Diablo Canyon Unit 1 and Palisades surveillance weld data (Heat # 27204) is deemed credible.

Appendix A.1 References

A.1-1 U.S. Nuclear Regulatory Commission, Office of Nuclear Regulatory Research, Regulatory Guide 1.99, Revision 2, "Radiation Embrittlement of Reactor Vessel Materials," May 1988.

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A.1-5 ASTM E185-82, Annual Book of ASTM Standards, Section 12, Volume 12.02, "Standard Practice for Conducting Surveillance Tests for Light-Water Cooled Nuclear Power Reactor Vessels," American Society of Testing and Materials, Philadelphia, PA, 1982.

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A.2 DIABLO CANYON UNIT 2

Introduction

Regulatory Guide 1.99, Revision 2 (Reference A.2-1) 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.

To date there have been four surveillance capsules removed and tested from the Diablo Canyon Unit 2 reactor vessel. To use these surveillance data sets, they must be shown to be credible. In accordance with Regulatory Guide 1.99, Revision 2, the credibility of the surveillance data will be judged based on five criteria.

The purpose of this evaluation is to apply the credibility requirements of Regulatory Guide 1.99, Revision 2, to the Diablo Canyon Unit 2 reactor vessel surveillance data and determine if that surveillance data is credible.

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," (Reference A.2-2) as follows:

> "*the region of 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 Diablo Canyon Unit 2 reactor vessel beltline region consists of the following materials:

1. Intermediate Shell Plates B5454-1, B5454-2, and B5454-3
2. Lower Shell Plates B5455-1, B5455-2, and B5455-3
3. Intermediate Shell Axial Welds (Heat # 21935/12008)
4. Intermediate to Lower Shell Circumferential Weld (Heat # 10120)
5. Lower Shell Axial Welds (Heat # 33A277)

Per WCAP-8783 (Reference A.2-3), the Diablo Canyon Unit 2 surveillance program was developed to the requirements of ASTM E185-73. Intermediate shell plate B5454-1 had one of the highest initial RT_{NDT} values and one of the lowest initial USE values of the beltline plate materials. In addition, intermediate shell plate B5454-1 had one of the highest Cu contents and the highest Ni content of the beltline plates. Hence, it was chosen as the most limiting material.

The intermediate shell longitudinal welds had the highest initial RT_{NDT} and the highest Ni and P contents of all the beltline weld materials. Hence, weld Heat # 21935/12008 was chosen as the most limiting weld.

Based on the discussion above, Criterion 1 is met for the Diablo Canyon Unit 2 surveillance program.

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 conditions are presented in Section 5 and Appendix C of the latest surveillance capsule report, WCAP-15423 (Reference A.2-4).

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 Diablo Canyon Unit 2 surveillance materials unambiguously.

Hence, Criterion 2 is met for the Diablo Canyon Unit 2 surveillance program.

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 (Reference A.2-5).

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 the weld 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. In addition, 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 (Reference A.2-6). At this meeting the NRC presented five cases. Of the five cases, Case 1 ("Surveillance data available from plant but no other source") most closely represents the situation for the Diablo Canyon Unit 2 surveillance plate material. However, Diablo Canyon Unit 2 has two welds that will be evaluated for credibility. These welds will be evaluated using the guidance for the appropriate case as explained in Reference A.2-6. Each weld and the respective evaluation method are described below:

1. <u>IS Plate B5454-1 (Case 1)</u> – This plate material will be evaluated using the NRC Case 1 guidelines as described above.
2. <u>Heat # 21935/12008 (Case 1)</u> – This weld heat pertains to IS longitudinal welds 2-201A, B, and C and US longitudinal welds 1-201A, B, and C in the Diablo Canyon Unit 2 reactor vessel. NRC Case 1 per Reference A.2-6 is entitled "Surveillance data available from plant but no other source" and most closely represents the situation for Diablo Canyon Unit 2 weld Heat # 21935/12008.
3. <u>Heat # 33A277 (Case 5)</u> – This weld heat pertains to LS longitudinal welds 3-201A, B, and C in the Diablo Canyon Unit 2 reactor vessel. This weld heat is not contained in the Diablo Canyon Unit 2 surveillance program. However, it is contained in the Farley Unit 1 and Calvert Cliffs Unit 1 surveillance programs. NRC Case 5 per Reference A.2-6 is entitled "Surveillance Data from Other Sources Only" and most closely represents the situation for Diablo Canyon Unit 2 weld Heat # 33A277.

Case 1: IS Plate B5454-1 and Weld Heat # 21935/12008

Following the NRC Case 1 guidelines, the Diablo Canyon Unit 2 surveillance plate and weld metal (Heat # 21935/12008) will be evaluated using the Diablo Canyon Unit 2 data. This evaluation is contained in Table A.2-1. First, the data is adjusted to the mean operating temperature for the surveillance capsules. Per Table 4.2-1 of this report, all of the Diablo Canyon Unit 2 surveillance capsules were irradiated at 545°F. Therefore, no temperature adjustments are required for the interim chemistry factor calculations presented in Table A.2-1.

Table A.2-1 Calculation of Interim Chemistry Factors for the Credibility Evaluation Using Diablo Canyon Unit 2 Surveillance Capsule Data Only

Material	Capsule	Capsule f[(a)] ($x10^{19}$ n/cm^2, E > 1.0 MeV)	FF[(b)]	ΔRT_{NDT}[(c)] (°F)	FF*ΔRT_{NDT} (°F)	FF^2
IS Plate B5454-1 (Longitudinal)	U	0.330	0.695	65.4	45.45	0.483
	X	0.906	0.972	100.1	97.33	0.945
	Y	1.53	1.118	111.6	124.73	1.249
	V	2.38	1.234	123.4	152.26	1.522
IS Plate B5454-1 (Transverse)	U	0.330	0.695	73.3	50.95	0.483
	X	0.906	0.972	99.5	96.75	0.945
	Y	1.53	1.118	111.6	124.73	1.249
	V	2.38	1.234	112.9	139.30	1.522
				SUM:	831.49	8.400
	$CF_{IS\ Plate\ B5454-1} = \Sigma(FF * \Delta RT_{NDT}) \div \Sigma(FF^2) = (831.49) \div (8.400) =$ **99.0°F**					
Diablo Canyon Unit 2 Weld Metal (Heat # 21935/12008)	U	0.330	0.695	173.0	120.24	0.483
	X	0.906	0.972	203.2	197.58	0.945
	Y	1.53	1.118	211.4	236.27	1.249
	V	2.38	1.234	224.5	277.00	1.522
				SUM :	831.08	4.200
	$CF_{Heat\ \#\ 21935/12008} = \Sigma(FF * \Delta RT_{NDT}) \div \Sigma(FF^2) = (831.08) \div (4.200) =$ **197.9°F**					

Notes:

(a) f = capsule fluence taken from Table 4.2-1 of this report.
(b) FF = fluence factor = $f^{(0.28 - 0.10*\log f)}$.
(c) ΔRT_{NDT} values are the measured 30 ft-lb shift values taken from Table 4.2-1 of this report. These measured ΔRT_{NDT} values for the surveillance weld metal do not include the adjustment ratio procedure of Reg. Guide 1.99, Revision 2, Position 2.1, since this calculation is based on the actual surveillance weld metal measured shift values. In addition, all of the Diablo Canyon Unit 2 surveillance capsules were irradiated at the same temperature; therefore, no temperature adjustments are required.

The scatter of ΔRT_{NDT} values about the functional form of a best-fit line drawn as described in Regulatory Position 2.1 is presented in Table A.2-2.

Table A.2-2 Best-Fit Evaluation for Diablo Canyon Unit 2 Surveillance Materials Only

Material	Capsule	CF ($Slope_{best-fit}$) (°F)	Capsule f ($x10^{19}$ n/cm^2, E > 1.0 MeV)	FF	Measured ΔRT_{NDT} (°F)	Predicted ΔRT_{NDT} (°F)[(a)]	Scatter ΔRT_{NDT} (°F)[(b)]	<17°F (Base Metal) <28°F (Weld)
IS Plate B5454-1 (Longitudinal)	U	99.0	0.330	0.695	65.4	68.80	3.4	Yes
	X	99.0	0.906	0.972	100.1	96.25	3.9	Yes
	Y	99.0	1.53	1.118	111.6	110.63	1.0	Yes
	V	99.0	2.38	1.234	123.4	122.14	1.3	Yes
IS Plate B5454-1 (Transverse)	U	99.0	0.330	0.695	73.3	68.80	4.5	Yes
	X	99.0	0.906	0.972	99.5	96.25	3.3	Yes
	Y	99.0	1.53	1.118	111.6	110.63	1.0	Yes
	V	99.0	2.38	1.234	112.9	122.14	9.2	Yes
Diablo Canyon Unit 2 Weld Metal (Heat # 21935/12008)	U	197.9	0.330	0.695	173.0	137.53	35.5	No
	X	197.9	0.906	0.972	203.2	192.40	10.8	Yes
	Y	197.9	1.53	1.118	211.4	221.16	9.8	Yes
	V	197.9	2.38	1.234	224.5	244.15	19.7	Yes

Notes:

(a) Predicted $\Delta RT_{NDT} = CF_{best-fit} * FF$.
(b) Scatter ΔRT_{NDT} = Absolute Value [Predicted ΔRT_{NDT} – Measured ΔRT_{NDT}].

The scatter of ΔRT_{NDT} values about the best-fit line, drawn as described in Regulatory Guide 1.99, Revision 2, Position 2.1, should be less than 17°F for base metal. Table A.2-2 indicates that all eight surveillance data points fall within the +/- 1σ of 17°F scatter band for surveillance base metals; therefore, the IS Plate B5454-1 data is deemed "credible" per the third criterion.

The scatter of ΔRT_{NDT} values about the best-fit line, drawn as described in Regulatory Guide 1.99, Revision 2, Position 2.1, should be less than 28°F for weld metal. Table A.2-2 indicates that three of the four surveillance data points fall within the +/- 1σ of 28°F scatter band for surveillance weld materials; therefore, the weld material (Heat # 21935/12008) is deemed "credible" per the third criterion.

Case 5: Weld Heat # 33A277 (Farley Unit 1 and Calvert Cliffs Unit 1 data)

Following the NRC Case 5 guidelines, the Farley Unit 1 and Calvert Cliffs Unit 1 surveillance weld metal (Heat # 33A277) will be evaluated for credibility. Weld Heat # 33A277 pertains to Diablo Canyon Unit 2 reactor vessel LS Longitudinal Welds 3-201A, B, and C, but is not contained in the Diablo Canyon Unit 2 surveillance program.

In accordance with the NRC Case 5 guidelines, the data from only Farley Unit 1 will be analyzed first. First, the data is adjusted to the mean operating temperature for the surveillance capsules. The mean operating temperature of the Farley Unit 1 surveillance capsules is calculated in Table A.2-3 below:

Table A.2-3 Mean Operating Temperature for Farley Unit 1

Material	Capsule	Inlet Temperature during Period of Irradiation (°F)
Weld Metal Heat # 33A277 (Farley Unit 1 data)[a]	Y	544.00
	U	540.25
	X	540.86
	W	541.75
	V	541.72
	Z	541.43
MEAN		**541.67**

Note:
(a) Values taken from Table 4.2-2 of this report.

The capsule-specific temperature adjustments are as shown in Table A.2-4 below:

Table A.2-4 Operating Temperature Adjustments for the Farley Unit 1 Surveillance Capsule Data

Material	Capsule	Inlet Temperature during Period of Irradiation (°F)	Mean Operating Temperature (°F)	Temperature Adjustment (°F)
Weld Metal Heat # 33A277 (Farley Unit 1 data)	Y	544.00	541.67	+2.33
	U	540.25		-1.42
	X	540.86		-0.81
	W	541.75		+0.08
	V	541.72		+0.05
	Z	541.43		-0.24

Thus, the temperature adjustments calculated above in Table A.2-4 will be used to adjust the ΔRT_{NDT} values for the Farley Unit 1 surveillance materials in Table A.2-5, which contains the calculation of interim chemistry factors for the credibility evaluation.

Table A.2-5 Calculation of Interim Chemistry Factor for Weld Heat # 33A277 Using Farley Unit 1 Surveillance Data Only

Material	Capsule	Capsule f[(a)] ($x10^{19}$ n/cm^2, E > 1.0 MeV)	FF[(b)]	ΔRT_{NDT}[(c)] (°F)	FF*ΔRT_{NDT} (°F)	FF^2
Weld Metal Heat # 33A277 (Farley Unit 1 data)	Y	0.612	0.862	69.2 (66.9)	59.71	0.744
	U	1.73	1.151	73.7 (75.1)	84.79	1.324
	X	3.06	1.295	86.6 (87.4)	112.17	1.678
	W	4.75	1.392	98.4 (98.3)	136.96	1.938
	V	7.14	1.466	117.6 (117.5)	172.34	2.149
	Z	8.47	1.492	113.3 (113.5)	168.96	2.225
				SUM :	734.92	10.059
	$CF_{Heat\ \#\ 33A277} = \Sigma(FF * \Delta RT_{NDT}) \div \Sigma(FF^2) = (734.92) \div (10.059) = \mathbf{73.1^{\circ}F}$					

Notes:

(a) f = capsule fluence taken from Table 4.2-2 of this report for Farley Unit 1.

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

(c) ΔRT_{NDT} values are the measured 30 ft-lb shift values taken from Table 4.2-2 of this report for Farley Unit 1. These measured ΔRT_{NDT} values do not include the adjustment ratio procedure of Reg. Guide 1.99, Revision 2, Position 2.1 since this calculation is based on the actual surveillance weld metal measured shift values. However, as shown in Table A.2-3, the Farley Unit 1 surveillance capsules were irradiated at different temperatures. Therefore, the ΔRT_{NDT} values for the Farley Unit 1 surveillance weld material are adjusted by the temperature adjustment values summarized in Table A.2-4 (pre-adjusted values are listed in parentheses).

The scatter of ΔRT_{NDT} values about the functional form of a best-fit line drawn as described in Regulatory Position 2.1 is presented in Table A.2-6.

Table A.2-6 Best-Fit Evaluation for Weld Heat # 33A277 Using Farley Unit 1 Data Only

Material	Capsule	CF ($Slope_{best-fit}$) (°F)	Capsule f ($x10^{19}$ n/cm^2, E > 1.0 MeV)	FF	Measured ΔRT_{NDT} (°F)[(a)]	Predicted ΔRT_{NDT} (°F)[(b)]	Scatter ΔRT_{NDT} (°F)[(c)]	<28°F (Weld)
Weld Metal Heat # 33A277 (Farley Unit 1 data)	Y	73.1	0.612	0.862	69.2	63.01	6.2	Yes
	U	73.1	1.73	1.151	73.7	84.08	10.4	Yes
	X	73.1	3.06	1.295	86.6	94.64	8.1	Yes
	W	73.1	4.75	1.392	98.4	101.71	3.3	Yes
	V	73.1	7.14	1.466	117.6	107.11	10.4	Yes
	Z	73.1	8.47	1.492	113.3	108.99	4.3	Yes

Notes:

(a) Measured ΔRT_{NDT} values are the adjusted values taken from Table A.2-5.
(b) Predicted $\Delta RT_{NDT} = CF_{best-fit} * FF$.
(c) Scatter ΔRT_{NDT} = Absolute Value [Predicted ΔRT_{NDT} – Measured ΔRT_{NDT}].

The scatter of ΔRT_{NDT} values about the best-fit line, drawn as described in Regulatory Guide 1.99, Revision 2, Position 2.1, should be less than 28°F for weld metal. Table A.2-6 indicates that all six surveillance data points fall within the +/- 1σ of 28°F scatter band for surveillance base metals; therefore, the weld metal Heat # 33A277 data is deemed "credible" per the third criterion when only the Farley Unit 1 data is considered.

In accordance with the NRC Case 5 guidelines, the data from Farley Unit 1 and Calvert Cliffs Unit 1 will now be analyzed together. Data is adjusted to the mean chemical composition and operating temperature of the surveillance capsules. This is performed in Table A.2-7 below:

Table A.2-7 Mean Chemical Composition and Operating Temperature for Farley Unit 1 and Calvert Cliffs Unit 1

Material	Capsule	Cu Wt. %	Ni Wt. %	Inlet Temperature during Period of Irradiation (°F)
Weld Metal Heat # 33A277 (Farley Unit 1 data)	Y	0.14	0.19	544.00
	U	0.14	0.19	540.25
	X	0.14	0.19	540.86
	W	0.14	0.19	541.75
	V	0.14	0.19	541.72
	Z	0.14	0.19	541.43
Weld Metal Heat # 33A277 (Calvert Cliffs Unit 1 data)	263°	0.24	0.18	548.00
	97°	0.24	0.18	548.00
MEAN		**0.17**	**0.19**	**543.25**

Therefore, the Farley Unit 1 and Calvert Cliffs Unit 1 surveillance capsule data will be adjusted to the mean chemical composition and operating temperature calculated in Table A.2-7.

Farley Unit 1 data

CF_{Mean} = 91.2°F (calculated per Table 1 of Regulatory Guide 1.99, Revision 2 using Cu Wt. % = 0.17 and Ni Wt. % = 0.19 per Table A.2-7)

$CF_{Surv.\ Weld\ (Farley\ Unit\ 1)}$ = 78.1°F (per Table 4.2-2 of this report)

Ratio = 91.2 ÷ 78.1 = 1.17 (applied to Farley Unit 1 surveillance data for weld Heat # 33A277 in the credibility evaluation)

Calvert Cliffs Unit 1 data

CF_{Mean} = 91.2°F

$CF_{Surv.\ Weld\ (Calvert\ Cliffs\ Unit\ 1)}$ = 119.4°F (per Table 4.2-2 of this report)

Ratio = 91.2 ÷ 119.4 = 0.76 (applied to Calvert Cliffs Unit 1 surveillance data for weld Heat # 33A277 in the credibility evaluation)

The capsule-specific temperature adjustments are as shown in Table A.2-8 below:

Table A.2-8 Operating Temperature Adjustments for the Farley Unit 1 and Calvert Cliffs Unit 1 Surveillance Capsule Data

Material	Capsule	Inlet Temperature during Period of Irradiation (°F)	Mean Operating Temperature (°F)	Temperature Adjustment (°F)
Weld Metal Heat # 33A277 (Farley Unit 1 data)	Y	544.00	543.25	+0.75
	U	540.25	543.25	-3.00
	X	540.86	543.25	-2.39
	W	541.75	543.25	-1.50
	V	541.72	543.25	-1.53
	Z	541.43	543.25	-1.82
Weld Metal Heat # 33A277 (Calvert Cliffs Unit 1 data)	263°	548.00	543.25	+4.75
	97°	548.00	543.25	+4.75

Using the chemical composition and operating temperature adjustments described and calculated above, an interim chemistry factor is calculated for weld Heat # 33A277 using the Farley Unit 1 and Calvert Cliffs Unit 1 data. This calculation is shown in Table A.2-9 below.

Table A.2-9 Calculation of Weld Heat # 33A277 Interim Chemistry Factor for the Credibility Evaluation Using Farley Unit 1 and Calvert Cliffs Unit 1 Surveillance Capsule Data

Material	Capsule	Capsule f[(a)] ($x10^{19}$ n/cm^2, E > 1.0 MeV)	FF[(b)]	ΔRT_{NDT}[(c)] (°F)	FF*ΔRT_{NDT} (°F)	FF^2
Weld Metal Heat # 33A277 (Farley Unit 1 data)	Y	0.612	0.862	79.2 (66.9)	68.26	0.744
	U	1.73	1.151	84.4 (75.1)	97.08	1.324
	X	3.06	1.295	99.5 (87.4)	128.84	1.678
	W	4.75	1.392	113.3 (98.3)	157.67	1.938
	V	7.14	1.466	135.7 (117.5)	198.92	2.149
	Z	8.47	1.492	130.7 (113.5)	194.93	2.225
Weld Metal Heat # 33A277 (Calvert Cliffs Unit 1 data)	263°	0.62	0.866	48.5 (59)	41.96	0.750
	97°	2.64	1.260	74.3 (93)	93.58	1.587
				SUM :	981.25	12.396
	$CF_{Heat\ \#\ 33A277} = \Sigma(FF * \Delta RT_{NDT}) \div \Sigma(FF^2) = (981.25) \div (12.396) =$ **79.2°F**					

Notes:

(a) f = capsule fluence taken from Table 4.2-2 of this report.
(b) FF = fluence factor = $f^{(0.28 - 0.10*\log f)}$.
(c) ΔRT_{NDT} values are the measured 30 ft-lb shift values. Pre-adjusted values are taken from Table 4.2-2 of this report. ΔRT_{NDT} values for the surveillance weld data are adjusted first by the difference in operating temperature then using the ratio procedure to account for differences in the surveillance weld chemistry and the beltline weld chemistry (pre-adjusted values are listed in parentheses). The temperature adjustments are shown in Table A.2-8 of this report. The ratios applied are 1.17 and 0.76 for Farley Unit 1 and Calvert Cliffs Unit 1, respectively.

The scatter of ΔRT_{NDT} values about the functional form of a best-fit line drawn as described in Regulatory Position 2.1 is presented in Table A.2-10.

Table A.2-10 Best-Fit Evaluation for Surveillance Weld Metal Heat # 33A277 Using Farley Unit 1 and Calvert Cliffs Unit 1 Data

Material	Capsule	CF ($Slope_{best-fit}$) (°F)	Capsule f ($x10^{19}$ n/cm^2, E > 1.0 MeV)	FF	Measured ΔRT_{NDT} (°F)[(a)]	Predicted ΔRT_{NDT} (°F)[(b)]	Scatter ΔRT_{NDT} (°F)[(c)]	<28°F (Weld)
Weld Metal Heat # 33A277 (Farley Unit 1 data)	Y	79.2	0.612	0.862	79.2	68.27	10.9	Yes
	U	79.2	1.73	1.151	84.4	91.09	6.7	Yes
	X	79.2	3.06	1.295	99.5	102.54	3.1	Yes
	W	79.2	4.75	1.392	113.3	110.20	3.1	Yes
	V	79.2	7.14	1.466	135.7	116.05	19.6	Yes
	Z	79.2	8.47	1.492	130.7	118.09	12.6	Yes
Weld Metal Heat # 33A277 (Calvert Cliffs Unit 1 data)	263°	79.2	0.62	0.866	48.5	68.56	20.1	Yes
	97°	79.2	2.64	1.260	74.3	99.72	25.4	Yes

Notes:

(a) ΔRT_{NDT} values are the adjusted values taken from Table A.2-9.
(b) Predicted $\Delta RT_{NDT} = CF_{best-fit} * FF$.
(c) Scatter ΔRT_{NDT} = Absolute Value [Predicted ΔRT_{NDT} – Measured ΔRT_{NDT}].

The scatter of ΔRT_{NDT} values about the best-fit line, drawn as described in Regulatory Guide 1.99, Revision 2, Position 2.1, should be less than 28°F for weld metal. Table A.2-10 indicates that all eight surveillance data points fall within the +/- 1σ of 28°F scatter band for surveillance weld materials; therefore, the weld material (Heat # 33A277) is deemed "credible" per the third criterion when all available data is considered.

In conclusion, the combined surveillance data from Farley Unit 1 and Calvert Cliffs Unit 1 for weld Heat # 33A277 may be applied to the Diablo Canyon Unit 2 reactor vessel weld. The chemistry factor calculation as applicable to the Diablo Canyon Unit 2 reactor vessel weld is contained in Table 5.2-2 of this report.

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 Diablo Canyon Unit 2 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.

<u>Hence, Criterion 4 is met for the Diablo Canyon Unit 2 surveillance program.</u>

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

The Diablo Canyon Unit 2 surveillance program does not contain correlation monitor material; therefore, this criterion is not applicable to the Diablo Canyon Unit 2 surveillance program.

Conclusion

Based on the preceding responses to the five criteria of Regulatory Guide 1.99, Revision 2, Section B, and the application of engineering judgment, the Diablo Canyon Unit 2 surveillance weld and plate data as well as the combined Farley Unit 1 and Calvert Cliffs Unit 1 surveillance weld data for use at Diablo Canyon Unit 2 are deemed credible.

Appendix A.2 References

A.2-1 U.S. Nuclear Regulatory Commission, Office of Nuclear Regulatory Research, Regulatory Guide 1.99, Revision 2, "Radiation Embrittlement of Reactor Vessel Materials," May 1988.

A.2-2 10 CFR 50, Appendix G, "Fracture Toughness Requirements," Federal Register, Volume 60, No. 243, December 19, 1995.

A.2-3 WCAP-8783, Revision 0, "Pacific Gas and Electric Company Diablo Canyon Unit No. 2 Reactor Vessel Radiation Surveillance Program," J. A. Davidson and S. E. Yanichko, December 1976.

A.2-4 WCAP-15423, Revision 0, "Analysis of Capsule V from Pacific Gas and Electric Company Diablo Canyon Unit 2 Reactor Vessel Radiation Surveillance Program," E. Terek et al., September 2000.

A.2-5 ASTM E185-82, Annual Book of ASTM Standards, Section 12, Volume 12.02, "Standard Practice for Conducting Surveillance Tests for Light-Water Cooled Nuclear Power Reactor Vessels," American Society of Testing and Materials, Philadelphia, PA, 1982.

A.2-6 K. Wichman, M. Mitchell, and A. Hiser, USNRC, Generic Letter 92-01 and RPV Integrity Workshop Handouts, *NRC/Industry Workshop on RPV Integrity Issues,* February 12, 1998.

APPENDIX B
EMERGENCY RESPONSE GUIDELINE LIMITS

The Emergency Response Guideline (ERG) limits (Reference B-1) were developed in order to establish guidance for operator action in the event of an emergency situation, such as a PTS event. Generic categories of limits were developed for the guidelines based on the limiting inside surface RT_{NDT}. These generic categories were conservatively generated for the Westinghouse Owners Group (WOG) to be applicable to all Westinghouse plants.

The highest EOL (or EOLE) RT_{NDT} for which the generic category ERG limits were developed is 250°F for a longitudinal flaw and 300°F for a circumferential flaw. Therefore, if the limiting vessel material has an RT_{NDT} that exceeds 250°F for a longitudinal flaw or 300°F for a circumferential flaw, plant-specific ERG P-T limits must be developed.

The ERG category is determined by the magnitude of the limiting RT_{NDT} value, which is calculated the same way as the RT_{PTS} values are calculated in Section 6 of this report. The material with the highest RT_{NDT} defines the limiting material, which for Diablo Canyon Unit 1 is LS Longitudinal Weld 3-442C (Position 2.1) and for Diablo Canyon Unit 2 is IS Plate B5454-2. Table B-1 identifies ERG category limits and the limiting material RT_{NDT} values at 32 and 54 EFPY for Diablo Canyon Units 1 and 2.

Table B-1 Evaluation of Diablo Canyon Units 1 and 2 ERG Limit Category

ERG Pressure-Temperature Limits (Reference B-1)			
Applicable RT_{NDT} Value[a]		**ERG P-T Limit Category**	
RT_{NDT} < 200°F		Category I	
200°F < RT_{NDT} < 250°F		Category II	
250°F < RT_{NDT} < 300°F		Category III b	
Limiting RT_{NDT} Values			
Reactor Vessel Material		**Unit 1 RT_{NDT} Value[b]**	
Unit 1	LS Longitudinal Weld 3-442C (Position 2.1)	32 EFPY	214˚F
		54 EFPY	243˚F
Reactor Vessel Material		**Unit 2 RT_{NDT} Value[c]**	
Unit 2	IS Plate B5454-2	32 EFPY	209˚F
		54 EFPY	222˚F

Notes:

(a) Longitudinally oriented flaws are applicable only up to 250°F; circumferentially oriented flaws are applicable up to 300°F.
(b) Unit 1 values taken from Tables 6.1-1 and 6.1-2 for 32 and 54 EFPY, respectively.
(c) Unit 2 values taken from Tables 6.2-1 and 6.2-2 for 32 and 54 EFPY, respectively.

Assuming that Diablo Canyon Units 1 and 2 are currently in ERG Category I, it is necessary to calculate the EFPY at which each Unit will change from ERG Category I to Category II. Thus, RT_{NDT} values for the limiting material are calculated at 21.77 EFPY in Table B-2 for Diablo Canyon Unit 1 and at 21.85 EFPY in Table B-3 for Diablo Canyon Unit 2. 21.77 and 21.85 EFPY are chosen based on the fluence information given in Tables 2-5 and 2-6 of WCAP-17299-NP (Reference B-2).

All of the Diablo Canyon Unit 1 longitudinal welds have identical margin, initial RT_{NDT}, and chemistry factor values per Table 6.1-1 of this report. Thus, the limiting RT_{NDT} value at 21.77 EFPY is the longitudinal weld that is at the highest fluence location, which pertains to LS Longitudinal Weld 3-442C. Therefore, based on the calculation shown below in Table B-2 and the calculations provided in Table 6.1-1 of this report, it can be concluded that LS Longitudinal Weld 3-442C (Position 2.1) is the limiting material for Diablo Canyon Unit 1 at both 21.77 EFPY and 32 EFPY.

Table B-2 RT_{NDT} Calculation at 21.77 EFPY for Diablo Canyon Unit 1 LS Longitudinal Weld 3-442C (Position 2.1)

CF[a] (°F)	Fluence[b] ($x10^{19}$ n/cm^2, E > 1.0 MeV)	FF	IRT_{NDT} [a] (°F)	ΔRT_{NDT} (°F)	σ_U[a] (°F)	σ_Δ[a] (°F)	Margin[a] (°F)	RT_{NDT} (°F)
214.1	0.863	0.9587	-56	205.3	17	14	44.0	193

Notes:
(a) Values taken from Table 6.1-2 of this report.
(b) 21.77 EFPY fluence value pertains to the 45° azimuthal location and is taken from Table 2-5 of WCAP-17299-NP (Reference B-2).

Based on the calculation shown below in Table B-3 and the calculations provided in Table 6.2-1 of this report, it can be concluded that IS Plate B5454-2 is the limiting material for Diablo Canyon Unit 2 at both 21.85 EFPY and 32 EFPY.

Table B-3 RT_{NDT} Calculation at 21.85 EFPY for Diablo Canyon Unit 2 IS Plate B5454-2

CF[a] (°F)	Fluence[b] ($x10^{19}$ n/cm^2, E > 1.0 MeV)	FF	IRT_{NDT} [a] (°F)	ΔRT_{NDT} (°F)	σ_U[a] (°F)	σ_Δ[a] (°F)	Margin[a] (°F)	RT_{NDT} (°F)
99.6	0.942	0.9833	67	97.9	0	17	34	199

Notes:
(a) Values taken from Table 6.2-2 of this report.
(b) 21.85 EFPY fluence value pertains to the 45° azimuthal location and is taken from Table 2-6 of WCAP-17299-NP (Reference B-2).

Emergency Response Guideline Limits Conclusion

Interpolation of the 32 and 21.77 EFPY RT_{NDT} values shown in Tables B-1 and B-2 concludes that Diablo Canyon Unit 1 will transition from ERG Category I to Category II at approximately 24.7 EFPY. Interpolation of the 32 and 21.85 EFPY RT_{NDT} values shown in Tables B-1 and B-3 concludes that Diablo Canyon Unit 2 will transition from ERG Category I to Category II at approximately 22.8 EFPY.

Following the transition from ERG Category I to Category II, comparison of the ERG limit categories with the RT_{NDT} values at 32 and 54 EFPY provided in Table B-1 indicates that Diablo Canyon Units 1 and 2 will then remain in ERG Category II through EOLE (54 EFPY).

Appendix B References

B-1 HF04BG, "Background Information for Westinghouse Owner's Group Emergency Response Guidelines, Critical Safety Function Status Tree, F-0.4 Integrity, HP/LP-Rev. 2," Westinghouse Owner's Group, April 30, 2005.

B-2 WCAP-17299-NP, Revision 0, "Fast Neutron Fluence Update for Diablo Canyon Unit 1 and 2 Pressure Vessels," F. A. Alpan, February 2011.