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SUBJECT: Responds to Generic Ltr 88-11, "NRC Position on Radiation Embrittlement of Reactor Vessel Matls & Impact on Plant...."

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Iowa Electric Light and Power Company

January 30, 1989
NG-89-0213

Dr. Thomas E. Murley, Director
Office of Nuclear Reactor Regulation
U. S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, DC 20555

Subject: Duane Arnold Energy Center
Docket No: 50-331
Op. License No: DPR-49
Response to NRC Generic Letter 88-11 "NRC Position on Radiation Embrittlement of Reactor Vessel Materials and Its Impact on Plant Operation", July 12, 1988.

Reference: (1) Letter, R. McGaughy to H. Denton, dated April 7, 1986, NG-86-1245
(2) Letter, R. McGaughy to H. Denton, dated July 30, 1986, NG-86-2587
(3) "Radiation Embrittlement of Reactor Vessel Materials," USNRC Regulatory Guide 1.99, Revision 2, May 1988

File: A-101b, B-11, A-106, A-284

Dear Dr. Murley:

"NRC Position on Radiation Embrittlement of Reactor Vessel Materials" (Generic Letter 88-11) requests an evaluation of the impact of Regulatory Guide 1.99, Revision 2 on existing pressure-temperature (P-T) curves. Attachment 1 presents the results of the Revision 2 impact evaluation for the Duane Arnold Energy Center (DAEC) and describes the actions required for implementation of Revision 2. Attachment 2 provides the detailed evaluation for the DAEC.

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Although the current pressure-temperature curves assure adequate margin against brittle fracture for near-term operation, they are less conservative than curves that would be generated by Revision 2. Pressure-temperature curves, revised according to the methods of Revision 2, will be forwarded to you under separate cover. We currently expect to submit these Technical Specification changes prior to the end of 1989.

Very truly yours,

William C. Rothert
Manager, Nuclear Division

WCR/PLB/pjv+

Attachments: (1) Response to NRC Generic Letter 88-11 for the Duane Arnold Energy Center
(2) Comparison of Irradiation Embrittlement Predictions of Regulatory Guide 1.99, Revisions 1 and 2 for the Duane Arnold Energy Center

cc: P. Bell
L. Liu
L. Root
R. McGaughy
J. R. Hall (NRC-NRR)
A. Bert Davis (Region III)
NRC Resident Office
Commitment Control No. 880339

ATTACHMENT 1

Response to NRC Generic Letter 88-11

FOR

THE DUANE ARNOLD ENERGY CENTER

BACKGROUND

The pressure-temperature (P-T) curves in the Technical Specifications are established to the requirements of 10CFR50, Appendix G [1] to assure that brittle fracture of the reactor vessel is prevented. Part of the analysis involved in developing the P-T curves is to account for neutron irradiation embrittlement effects in the core region, or beltline. In the past, Regulatory Guide 1.99, Revision 1 [2] has been used to predict the shift in nil-ductility reference temperature (RT_{NDT}) as a function of neutron fluence in the beltline region. Regulatory Guide 1.99, Revision 1 was developed assuming that copper (Cu) and phosphorus (P) were the key chemical elements influencing embrittlement.

Regulatory Guide 1.99, Revision 2 [3] was issued in May 1988. Rev 2 represents the results of a statistical evaluation of commercial reactor surveillance test data accumulated through 1984. There are two basic factors used in the calculations to predict the shift in RT_{NDT} shown in the regulatory guide: a chemistry factor and a fluence factor. Both of these factors remained the same from Rev 1 to Rev 2. However, the method used to calculate each factor has been significantly changed. The chemistry factor (CF) has been changed from an equation based on Cu and P in Rev 1 to tables of CF values based on Cu and nickel (Ni), with separate values for plate material and for weld material. The overall effect of the changes in the fluence factor calculation from Rev 1 to Rev 2 has generally been to increase RT_{NDT} shift predictions for relatively low fluences (below 10^{19} n/cm^2) and to decrease RT_{NDT} shift predictions for higher fluences.

IMPACT EVALUATION

The beltline region in the DAEC consists of two lower shell plates (Shell 1), two lower-intermediate shell plates (Shell 2), and their associated longitudinal and girth welds. Attachment 2 provides the detailed evaluation for the DAEC. The process followed for each beltline material is described below.

Chemistry

The chemistry data for the beltline region plates and beltline weld filler material shown in Attachment 2 were taken from the DAEC surveillance test report [5] and the GE design record file that supports it. The Reference [5] work was supplemented with more specific information from Chicago Bridge & Iron on the weld materials that went into the beltline longitudinal and girth welds.

Initial RT_{NDT}

The values of initial RT_{NDT} shown in Attachment 2 were also taken from the DAEC surveillance test report and the GE design record file material that supports it. These values were based on 30 ft-lb impact energy verification testing, with longitudinal Charpy specimens used for plate, done at the time of vessel fabrication. The calculations of these initial RT_{NDT} values in Reference [5] were based on a GE procedure which established conservative values of RT_{NDT} from the fabrication test data. Since these RT_{NDT} values are conservative, the term in the Rev 2 margin expression σ_I is assumed to be zero.

Fluence

The values of neutron fluence for 32 effective-full-power-years (EFPY) shown in Attachment 2 are based on dosimetry results. For the DAEC, the dosimetry tested as part of the first surveillance capsule test [5], combined with computed lead factors, was used as the basis for determining the 32 EFPY fluence at the 1/4 thickness into the vessel wall from the inside surface (1/4 T) as well as the vessel inside surface, f_{surf} .

The Rev 1 calculations of RT_{NDT} shift are based on a calculated value of fluence at 1/4 T as noted above. The Rev 2 method takes the calculated fluence at the vessel inside surface, f_{surf} , and attenuates that value at depth x according to the relationship:

$$f_x = f_{surf} (e^{-0.24x}).$$

This method results in a slightly lower fluence at the 1/4 T location than the Rev 1 methodology.

Surveillance Test Correction Factor

Rev 1 allows for consideration of surveillance data when it becomes available. If the actual RT_{NDT} shift seen in the surveillance data is larger than initial predictions, Rev 1 shift predictions are increased by this factor. As discussed in the DAEC surveillance test report [5], the RT_{NDT} shift seen in the surveillance plate material was larger than predicted by Rev 1 by a factor of 1.31. Rev 1 shift predictions for plate were increased by this factor. For the weld material, the surveillance testing showed that the measured shift for the weld metal was less than the predicted shift. Based on this result, the correction factor for the welds is set to 1.0.

SHIFT and Adjusted Reference Temperature (ART)

The RT_{NDT} shift calculations in Attachment 2 are based on the procedures in Rev 1 and Rev 2. For Rev 1, the value of SHIFT is computed with the equation:

$$SHIFT = (STF)*[40 + 1000(\%Cu - .08) + 5000(\%P - .008)]*(f)^{.5}$$

where STF = surveillance test correction factor

f = fluence for the given EFPY / 10^{19} .

For Rev 2, the value of SHIFT consists of two terms:

$$SHIFT = \Delta RT_{NDT} + Margin$$

$$\text{where } \Delta RT_{NDT} = [CF]*f^{(.28 - 0.10 \log f)}$$

$$Margin = 2(\sigma_I{}^2 + \sigma_\Delta{}^2)^{.5}$$

Chemistry factors (CF) are tabulated for weld material and plate material in Tables 1 and 2, respectively, in Rev 2. The margin term σ_Δ has set values in Rev 2 of 17°F for plate and 28°F for weld. However, σ_Δ need not be greater than $0.5*\Delta RT_{NDT}$.

The values of ART in the attachments are computed by adding the SHIFT terms to the values of initial RT_{NDT} :

$$ART = \text{initial } RT_{NDT} + SHIFT$$

Results Summary

The impact of implementing Rev 2 can best be determined by comparing the ART values based on Rev 1 and Rev 2. Table 1 shows the ART values at 8, 12, and 32 EFPY for each beltline material in the DAEC. The following conclusions are drawn from the results in this table:

1. The Rev 2 ART values at 32 EFPY for the DAEC are below 200°F, which is the allowable limit in 10CFR50, Appendix G. Therefore, implementation of Rev 2 will not result in any additional analysis, testing or provisions for thermal annealing.

2. The Rev 1 ART value which applies to the current P-T curves in the Technical Specifications at 12 EFPY is 92.9°F (see Table 1). The maximum Rev 2 ART value at 12 EFPY is 115.2°F. Therefore, the current Technical Specification 12 EFPY P-T curves (Figure 3.6-1) based on Rev 1 are less conservative than 12 EFPY curves that would be generated with Rev 2.

IMPLEMENTATION OF REV 2

Generic Letter 88-11 requires that Rev 2 be implemented within two refueling outages of the published date of Rev 2. Based on the results on the previous page, the following conclusions are made concerning Rev 2 implementation:

While the current Technical Specification P-T curves provide adequate margin for plant operation, they are non-conservative when compared to curves based on Rev 2. For example, "Curve C-Core Critical Operation" in Figure 3.6-1 has a margin of 200-275°F to the steam-water saturation curve where the BWR normally operates. Using Rev 2 methodology, this margin will only be reduced approximately 25°F.

We have authorized the revision of the P-T curves according to the methods of Rev 2. The P-T curves will include the Rev 2 shift corresponding to an appropriate value of EFPY. This revision will require changes to both the Technical Specifications and Section 5.3 of the UFSAR.

Table 1

COMPARISON OF REV 1 AND REV 2 ART VALUES

FOR THE DUANE ARNOLD ENERGY CENTER

	8 EFPY		12 EFPY		32 EFPY	
	Rev 1	Rev 2	Rev 1	Rev 2	Rev 1	Rev 2
Beltline Component	ART (°F)	ART (°F)	ART (°F)	ART (°F)	ART (°F)	ART (°F)
Plates:						
C6439-2	67.5	85.3	73.7	94.9	95.0	115.2
B0402-1	83.2	108.0	92.9	115.2	126.5	135.8
B0436-2	53.2	87.3	62.9	96.5	96.5	122.8
B0673-1	59.1	87.D	70.2	96.2	108.3	122.3
Beltline Welds:						
09L853, Lot LD17A27A	-29.0	-18.D	-24.3	-11.2	-8.0	8.2
07L669, Lot K004A27A	-29.D	-18.D	-24.3	-11.2	-8.0	8.2
CTY538, Lot A027A27A	-20.0	-18.0	-13.3	-11.2	10.0	8.2
432Z4521, Lot B020A27A	-23.0	-34.4	-16.9	-31.1	4.0	-21.1
432Z0471, Lot B003A27A	-24.5	-18.D	-18.8	-11.2	1.D	8.2

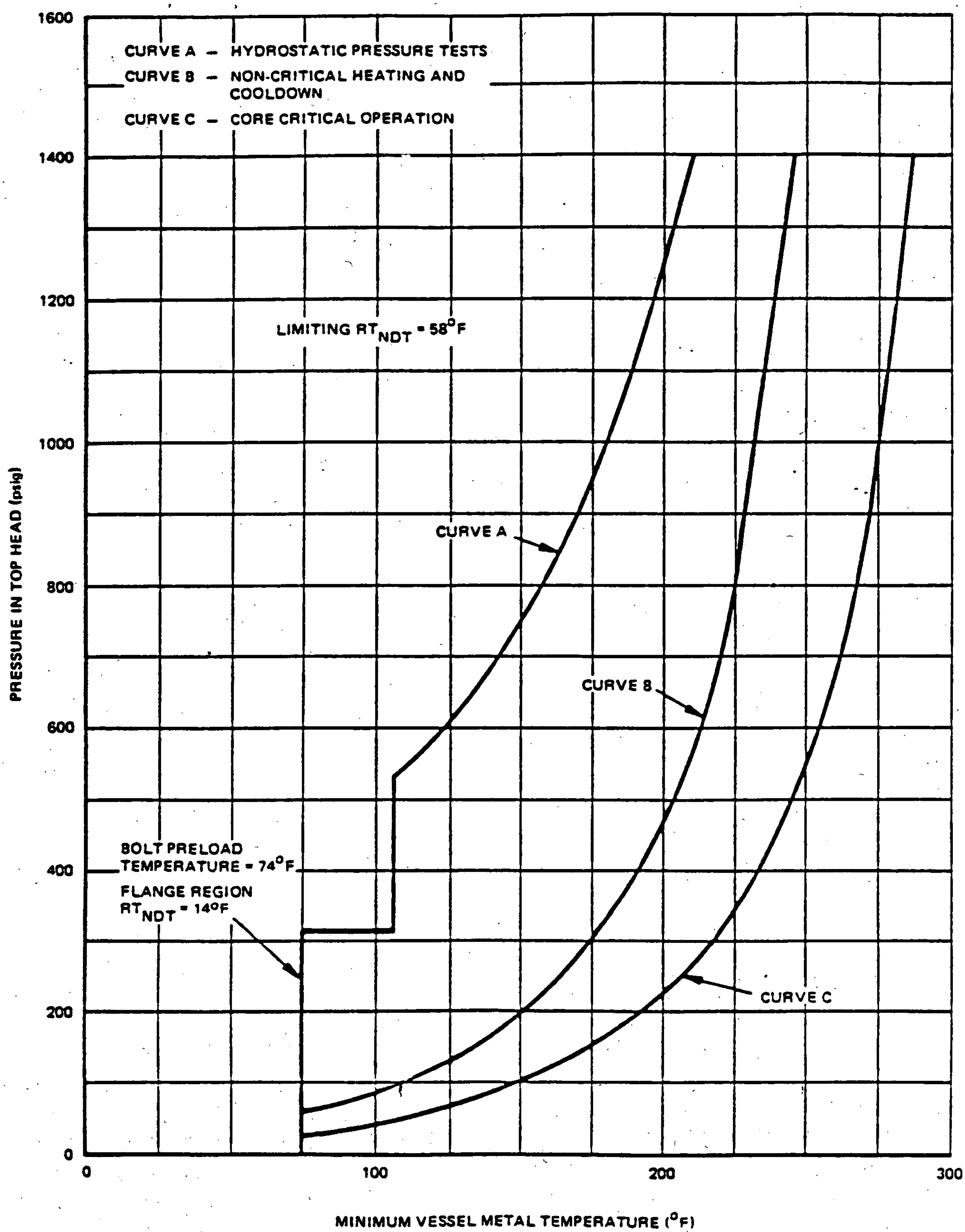

Figure 3.6.1. Pressure versus Minimum Temperature Valid to Twelve Full Power Years, per Appendix G of 10CFR50

REFERENCES

[1] "Fracture Toughness Requirements," Appendix G to Part 50 of Title 10 of the Code of Federal Regulations, July 1983.

[2] "Effects of Residual Elements on Predicted Radiation Damage to Reactor Vessel Materials," USNRC Regulatory Guide 1.99, Revision 1, April 1977.

[3] "Radiation Embrittlement of Reactor Vessel Materials," USNRC Regulatory Guide 1.99, Revision 2, May 1988.

[4] "NRC Position on Radiation Embrittlement of Reactor Vessel Material and Its Impact of Plant Operations," USNRC Generic Letter 88-11, July 1988.

[5] Iowa Electric Letter NG-86-2587 dated July 30, 1986 from R. McGaughy to NRC's H. Denton, Subject - "Reactor Pressure Vessel Surveillance Material Summary Technical Report, Revision 1," with attachment GE Report NEDC-31166 Revision 1 "Duane Arnold Energy Center Reactor Pressure Vessel Surveillance Materials Testing."

ATTACHMENT 2

COMPARISON OF IRRADIATION EMBRITTLEMENT PREDICTIONS OF REGULATORY GUIDE 1.99, REVISIONS 1 AND 2

FOR

THE DUANE ARNOLD ENERGY CENTER

COMPARISON OF REG. GUIDE 1.99 REVISIONS 1 AND 2
FOR DUANE ARNOLD BELTLINE MATERIALS

Lower Plate (Shell 1) : 1-18 Thickness 4.47 inches

Material Heat: C6439-2

Chemistry:

C	Mn	P	S	Si	Cu	Ni	Mo
0.21	1.25	0.012	0.012	0.18	0.09	0.51	0.48

Initial RTndt: RTndt-I = 40 F, Sigma-I = 0 F

32 EFPY Fluence (f):
Calculated Peak 1/4T f = 3.6E+18 n/cm^2 (used with Rev 1)
Calculated Peak I.D. f = 4.6E+18 n/cm^2
Rev 2 Attenuated 1/4T f = 3.5E+18 n/cm^2 (basis for Rev 2 delta RT)

Surveillance Testing Affecting Rev 1 Shift Calculation:

Tests of surveillance plate showed shift of 42 F instead of predicted shift of 32 F. Correction factor applied of 42/32= 1.31

Chemistry Factor for Rev 2 Shift: CF= 58

Comparison of Rev 1 and Rev 2 SHIFT and ART (degrees F) versus EFPY:

EFPY	Rev 2 Delta RT	Rev 2 Margin	Rev 2 SHIFT	Rev 2 ART	Rev 1 SHIFT	Rev 1 ART
4	15.8	15.8	31.5	71.5	19.5	59.5
8	22.6	22.6	45.3	85.3	27.5	67.5
12	27.4	27.4	54.9	94.9	33.7	73.7
16	31.2	31.2	62.4	102.4	38.9	78.9
20	34.3	34.0	68.3	108.3	43.5	83.5
24	36.9	34.0	70.9	110.9	47.6	87.6
28	39.2	34.0	73.2	113.2	51.5	91.5
32	41.2	34.0	75.2	115.2	55.0	95.0

COMPARISON OF REG. GUIDE 1.99 REVISIONS 1 AND 2 FOR DUANE ARNOLD BELTLINE MATERIALS

Lower Plate (Shell 1) : 1-19 Thickness 4.47 inches

Material Heat: B0402-1

Chemistry:

C	Mn	P	S	Si	Cu	Ni	Mo
0.2	1.35	0.012	0.015	0.16	0.13	0.47	0.45

Initial RTndt: RTndt-I = 40 F, Sigma-I = 0 F

32 EFPY Fluence (f):
Calculated Peak 1/4T f = 3.6E+18 n/cm^2 (used with Rev 1)
Calculated Peak I.D. f = 4.6E+18 n/cm^2
Rev 2 Attenuated 1/4T f = 3.5E+18 n/cm^2 (basis for Rev 2 delta RT)

Surveillance Testing Affecting Rev 1 Shift Calculation:

Tests of surveillance plate showed shift of 42 F instead of predicted shift of 32 F. Correction factor applied of 42/32= 1.31

Chemistry Factor for Rev 2 Shift: CF= 87.1

Comparison of Rev 1 and Rev 2 SHIFT and ART (degrees F) versus EFPY:

EFPY	Rev 2 Delta RT	Rev 2 Margin	Rev 2 SHIFT	Rev 2 ART	Rev 1 SHIFT	Rev 1 ART
4	23.7	23.7	47.4	87.4	30.6	70.6
8	34.0	34.0	68.0	108.0	43.2	83.2
12	41.2	34.0	75.2	115.2	52.9	92.9
16	46.8	34.0	80.8	120.8	61.1	101.1
20	51.4	34.0	85.4	125.4	68.4	108.4
24	55.4	34.0	89.4	129.4	74.9	114.9
28	58.8	34.0	92.8	132.8	80.9	120.9
32	61.8	34.0	95.8	135.8	86.5	126.5

COMPARISON OF REG. GUIDE 1.99 REVISIONS 1 AND 2 FOR DUANE ARNOLD BELTLINE MATERIALS

Low-Inter. Plate (Shell 2): 1-20 Thickness 4.47 inches

Material Heat: B0436-2

Chemistry:

C	Mn	P	S	Si	Cu	Ni	Mo
0.19	1.33	0.008	0.01	0.18	0.15	0.64	0.5

Initial RTndt: RTndt-I = 10 F, Sigma-I = 0 F

32 EFPY Fluence (f):
Calculated Peak 1/4T f = 3.6E+18 n/cm^2 (used with Rev 1)
Calculated Peak I.D. f = 4.6E+18 n/cm^2
Rev 2 Attenuated 1/4T f = 3.5E+18 n/cm^2 (basis for Rev 2 delta RT)

Surveillance Testing Affecting Rev 1 Shift Calculation:

Tests cf surveillance plate showed shift of 42 F instead of predicted shift of 32 F. Correction factor applied of 42/32= 1.31

Chemistry Factor for Rev 2 Shift: CF= 111

Comparison of Rev 1 and Rev 2 SHIFT and ART (degrees F) versus EFPY:

EFPY	Rev 2 Delta RT	Rev 2 Margin	Rev 2 SHIFT	Rev 2 ART	Rev 1 SHIFT	Rev 1 ART
4	30.2	30.2	60.4	70.4	30.6	40.6
8	43.3	34.0	77.3	87.3	43.2	53.2
12	52.5	34.0	86.5	96.5	52.9	62.9
16	59.7	34.0	93.7	103.7	61.1	71.1
20	65.6	34.0	99.6	109.6	68.4	78.4
24	70.6	34.0	104.6	114.6	74.9	84.9
28	74.9	34.0	108.9	118.9	80.9	90.9
32	78.8	34.0	112.8	122.8	86.5	96.5

COMPARISON OF REG. GUIDE 1.99 REVISIONS 1 AND 2
FOR DUANE ARNOLD BELTLINE MATERIALS

Low-Inter. Plate (Shell 2): 1-21 Thickness 4.47 inches

Material Heat: B0673-1

Chemistry:

C	Mn	P	S	Si	Cu	Ni	Mo
0.2	1.37	0.011	0.014	0.18	0.15	0.61	0.55

Initial RTndt: RTndt-I = 10 F, Sigma-I = 0 F

32 EFPY Fluence (f):

Calculated Peak 1/4T f = 3.6E+18 n/cm^2 (used with Rev 1)
Calculated Peak I.D. f = 4.6E+18 n/cm^2
Rev 2 Attenuated 1/4T f = 3.5E+18 n/cm^2 (basis for Rev 2 delta RT)

Surveillance Testing Affecting Rev 1 Shift Calculation:

Tests of surveillance plate showed shift of 42 F instead of predicted shift of 32 F. Correction factor applied of 42/32= 1.31

Chemistry Factor for Rev 2 Shift: CF= 110.25

Comparison of Rev 1 and Rev 2 SHIFT and ART (degrees F) versus EFPY:

EFPY	Rev 2 Delta RT	Rev 2 Margin	Rev 2 SHIFT	Rev 2 ART	Rev 1 SHIFT	Rev 1 ART
4	30.0	30.0	59.9	69.9	34.7	44.7
8	43.0	34.0	77.0	87.0	49.1	59.1
12	52.2	34.0	86.2	96.2	60.2	70.2
16	59.3	34.0	93.3	103.3	69.5	79.5
20	65.1	34.0	99.1	109.1	77.7	87.7
24	70.1	34.0	104.1	114.1	85.1	95.1
28	74.4	34.0	108.4	118.4	91.9	101.9
32	78.3	34.0	112.3	122.3	98.3	108.3

COMPARISON OF REG. GUIDE 1.99 REVISIONS 1 AND 2 FOR DUANE ARNOLD BELTLINE MATERIALS

Beltline Girth Weld : Thickness 4.47 inches

Material Heat: 09L853 , Lot L017A27A

Chemistry:

C	Mn	P	S	Si	Cu	Ni	Mo
0.036	1.07	0.014	0.017	0.44	0.03	0.88	0.55

Initial RTndt: RTndt-I = -50 F, Sigma-I = 0 F

32 EFPY Fluence (f):
Calculated Peak 1/4T f = 3.6E+18 n/cm^2 (used with Rev 1)
Calculated Peak I.D. f = 4.6E+18 n/cm^2
Rev 2 Attenuated 1/4T f = 3.5E+18 n/cm^2 (basis for Rev 2 delta RT)

Surveillance Testing Affecting Rev 1 Shift Calculation:

Surveillance testing showed that the measured shift for the weld metal was less than the predicted shift. Correction factor applied = 1

Chemistry Factor for Rev 2 Shift: CF= 41

Comparison of Rev 1 and Rev 2 SHIFT and ART (degrees F) versus EFPY:

EFPY	Rev 2 Delta RT	Rev 2 Margin	Rev 2 SHIFT	Rev 2 ART	Rev 1 SHIFT	Rev ART
4	11.1	11.1	22.3	-27.7	14.8	-35.2
8	16.0	16.0	32.0	-18.0	21.0	-29.0
12	19.4	19.4	38.8	-11.2	25.7	-24.3
16	22.0	22.0	44.1	-5.9	29.7	-20.3
20	24.2	24.2	48.4	-1.6	33.2	-16.8
24	26.1	26.1	52.1	2.1	36.4	-13.6
28	27.7	27.7	55.4	5.4	39.3	-10.7
32	29.1	29.1	58.2	8.2	42.0	-8.0

COMPARISON OF REG. GUIDE 1.99 REVISIONS 1 AND 2
FOR DUANE ARNOLD BELTLINE MATERIALS

Beltline Girth Weld : Thickness 4.47 inches

Material Heat: 07L669 , Lot K004A27A

Chemistry:

C	Mn	P	S	Si	Cu	Ni	Mo
0.05	1.24	0.014	0.016	0.48	0.03	1.02	0.54

Initial RTndt: RTndt-I = -50 F, Sigma-I = 0 F

32 EFPY Fluence (f):
Calculated Peak 1/4T f = 3.6E+18 n/cm^2 (used with Rev 1)
Calculated Peak I.D. f = 4.6E+18 n/cm^2
Rev 2 Attenuated 1/4T f = 3.5E+18 n/cm^2 (basis for Rev 2 delta RT)

Surveillance Testing Affecting Rev 1 Shift Calculation:

Surveillance testing showed that the measured shift for the weld metal was less than the predicted shift. Correction factor applied = 1

Chemistry Factor for Rev 2 Shift: CF= 41

Comparison of Rev 1 and Rev 2 SHIFT and ART (degrees F) versus EFPY:

EFPY	Rev 2 Delta RT	Rev 2 Margin	Rev 2 SHIFT	Rev 2 ART	Rev 1 SHIFT	Rev 1 ART
4	11.1	11.1	22.3	-27.7	14.8	-35.2
8	16.0	16.0	32.0	-18.0	21.0	-29.0
12	19.4	19.4	38.8	-11.2	25.7	-24.3
16	22.0	22.0	44.1	-5.9	29.7	-20.3
20	24.2	24.2	48.4	-1.6	33.2	-16.8
24	26.1	26.1	52.1	2.1	36.4	-13.6
28	27.7	27.7	55.4	5.4	39.3	-10.7
32	29.1	29.1	58.2	8.2	42.0	-8.0

COMPARISON OF REG. GUIDE 1.99 REVISIONS 1 AND 2 FOR DUANE ARNOLD BELTLINE MATERIALS

Beltline Girth Weld : Thickness 4.47 inches

Material Heat: CTY538 , Lot A027A27A

Chemistry:

C	Mn	P	S	Si	Cu	Ni	Mo
0.066	1.06	0.02	0.018	0.46	0.03	0.83	0.49

Initial RTndt: RTndt-I = -50 F, Sigma-I = 0 F

32 EFPY Fluence (f):
Calculated Peak 1/4T f = 3.6E+18 n/cm^2 (used with Rev 1)
Calculated Peak I.D. f = 4.6E+18 n/cm^2
Rev 2 Attenuated 1/4T f = 3.5E+18 n/cm^2 (basis for Rev 2 delta RT)

Surveillance Testing Affecting Rev 1 Shift Calculation:

Surveillance testing showed that the measured shift for the weld metal was less than the predicted shift. Correction factor applied = 1

Chemistry Factor for Rev 2 Shift: CF= 41

Comparison of Rev 1 and Rev 2 SHIFT and ART (degrees F) versus EFPY:

EFPY	Rev 2 Delta RT	Rev 2 Margin	Rev 2 SHIFT	Rev 2 ART	Rev 1 SHIFT	Rev ART
4	11.1	11.1	22.3	-27.7	21.2	-28.8
8	16.0	16.0	32.0	-18.0	30.0	-20.0
12	19.4	19.4	38.8	-11.2	36.7	-13.3
16	22.0	22.0	44.1	-5.9	42.4	-7.6
20	24.2	24.2	48.4	-1.6	47.4	-2.6
24	26.1	26.1	52.1	2.1	52.0	2.0
28	27.7	27.7	55.4	5.4	56.1	6.1
32	29.1	29.1	58.2	8.2	60.0	10.0

COMPARISON OF REG. GUIDE 1.99 REVISIONS 1 AND 2
FOR DUANE ARNOLD BELTLINE MATERIALS

Beltline Longitudinal Weld : Thickness 4.47 inches

Material Heat: 432Z4521 , Lot B020A27A

Chemistry:

C	Mn	P	S	Si	Cu	Ni	Mo
0.06	1.2	0.018	0.017	0.42	0.01	0.98	0.54

Initial RTndt: RTndt-I = -50 F, Sigma-I = 0 F

32 EFPY Fluence (f):
Calculated Peak 1/4T f = 3.6E+18 n/cm^2 (used with Rev 1)
Calculated Peak I.D. f = 4.6E+18 n/cm^2
Rev 2 Attenuated 1/4T f = 3.5E+18 n/cm^2 (basis for Rev 2 delta RT)

Surveillance Testing Affecting Rev 1 Shift Calculation:

Surveillance testing showed that the measured shift for the weld metal was less than the predicted shift. Correction factor applied = 1

Chemistry Factor for Rev 2 Shift: CF= 20

Comparison of Rev 1 and Rev 2 SHIFT and ART (degrees F) versus EFPY:

EFPY	Rev 2 Delta RT	Rev 2 Margin	Rev 2 SHIFT	Rev 2 ART	Rev 1 SHIFT	Rev 1 ART
4	5.4	5.4	10.9	-39.1	19.1	-30.9
8	7.8	7.8	15.6	-34.4	27.0	-23.0
12	9.5	9.5	18.9	-31.1	33.1	-16.9
16	10.8	10.8	21.5	-28.5	38.2	-11.8
20	11.8	11.8	23.6	-26.4	42.7	-7.3
24	12.7	12.7	25.4	-24.6	46.8	-3.2
28	13.5	13.5	27.0	-23.0	50.5	0.5
32	14.2	14.2	28.4	-21.6	54.0	4.0

COMPARISON OF REG. GUIDE 1.99 REVISIONS 1 AND 2 FOR DUANE ARNOLD BELTLINE MATERIALS

Beltline Longitudinal Weld : Thickness 4.47 inches

Material Heat: 432Z0471 , Lot B003A27A

Chemistry:

C	Mn	P	S	Si	Cu	Ni	Mo
0.077	0.92	0.017	0.019	0.33	0.03	0.91	0.52

Initial RTndt: RTndt-I = -50 F, Sigma-I = 0 F

32 EFPY Fluence (f):
Calculated Peak 1/4T f = 3.6E+18 n/cm^2 (used with Rev 1)
Calculated Peak I.D. f = 4.6E+18 n/cm^2
Rev 2 Attenuated 1/4T f = 3.5E+18 n/cm^2 (basis for Rev 2 delta RT)

Surveillance Testing Affecting Rev 1 Shift Calculation:

Surveillance testing showed that the measured shift for the weld metal was less than the predicted shift. Correction factor applied = 1

Chemistry Factor for Rev 2 Shift: CF= 41

Comparison of Rev 1 and Rev 2 SHIFT and ART (degrees F) versus EFPY:

EFPY	Rev 2 Delta RT	Rev 2 Margin	Rev 2 SHIFT	Rev 2 ART	Rev 1 SHIFT	Rev 1 ART
4	11.1	11.1	22.3	-27.7	18.0	-32.0
8	16.0	16.0	32.0	-18.0	25.5	-24.5
12	19.4	19.4	38.8	-11.2	31.2	-18.8
16	22.0	22.0	44.1	-5.9	36.1	-13.9
20	24.2	24.2	48.4	-1.6	40.3	-9.7
24	26.1	26.1	52.1	2.1	44.2	-5.8
28	27.7	27.7	55.4	5.4	47.7	-2.3
32	29.1	29.1	58.2	8.2	51.0	1.0