TITLE WOG Upper Shelf Energy CPL Reevaluation			PAGE 1 OF 6
PROJECT WOG	AUTHOR [signature] DATE 12/14/93	CHK'D. BY N/A DATE	VERIFIED BY [signature] DATE 12/14/93
S.O. MUHP-5080	CALC. NO. SMT-008/93	FILE NO. WOG-949(5080)	GROUP MEM-SMT

Purpose:

The purpose of this analysis is to revise the information pertaining to the H.B. Robinson Plant (Plant 7) in Table 3-2 of WCAP-13587, Rev 1 (Reference 1) to incorporate the following:

1. The initial average charpy value assumed in Reference 1 for the material of Reference 2 was 50 ft-lbs. The correct value is 53.6 ft-lbs (see Reference 2). $J_{material}$ is modified to reflect this higher value.

2. The Reference 3 correlation is used for the ASTM A302 plate material. This incorparates the effect of temperature on $J_{material}$.

3. Table 3-2 of Reference 1 utilizes $J_{applied}$ for a flaw which is axially orientated with $J_{material}$ values for the transverse direction. $J_{material}$ is recalculated for both the transverse and longitudinal direction, and $J_{applied}$ for circumferential and axial flaws are compared with the transverse and longitudinal values, respectively.

Analysis:

Appendix A contains the analysis for items 1 and 2 listed above, and Appendix B contains the results for item 3.

Results:

The following table contains the $J_{material}$ parameters taken from Appendix A (note J values in in-lb/in^2 and dJ/da values in in-lb/in^3)

	Transverse	Longitudinal
$J_{material}$	299	541
$(dJ/da)_{material}$	217	392

Next, for comparison of the Transverse Orientaion to Circumferential Flaw and Longitudinal

REV NO	REV DATE	AUTHOR DATE	CHK'D BY DATE	VERIFIED BY DATE

TITLE			PAGE
WOG Upper Shelf Energy CPL Reevaluation			2 OF 6
PROJECT: WOG	AUTHOR / DATE: [signature] 12/14/93	CHK'D. BY / DATE: N/A	VERIFIED BY / DATE: [signature] 12/14/93
S.O.: MUHP-5080	CALC. NO.: SMT-008/93	FILE NO.: WOG-949(5080)	GROUP: MEM-SMT

Orientation to Axial Flaw, the $J_{applied}$ values are given below:

	Circumferential	Axial
$J_{applied}$	204	525
$(dJ/da)_{applied}$	61	222

It is shown that $J_{applied} < J_{material}$ and $(dJ/da)_{applied} < (dJ/da)_{material}$ for all cases.

References:

1. Tandon S. et al., WCAP-13587, Rev 1, "Reactor Vessel Upper Shelf Energy Bounding Evaluation for Westinghouse Pressurized Water Reactors," September 1993.

2. Hiser A. L., Terrell J. B., NUREG/CR-5265, MEA-2320, "Size Effects on J-R Curves for A302-B Plate," January 1989.

3. Memorandum for Wichman K. R. from Hiser A. L. and Malik S. N. M., "J-R Curves for Low Toughness A 302-B Plate," September 9, 1993.

4. Westinghouse Letter FDRT/SRPLO-220(93), "USE Data for H.B. Robinson Upper Shelf Plate W-10201-1," Chicots to Tandon, 12/14/93.

REV NO	REV DATE	AUTHOR	DATE	CHK'D BY	DATE	VERIFIED BY	DATE

Transverse Orientation

Using the method of Reference 3 directly (this is for info only, it is not used)

$SF := 0.749 \quad C1 := 946.82 \quad C2 := 0.1334 \quad CVN := 42 \quad a := 0.1 \quad T := 390.5$

$$f(CVN) := \frac{11.75 \cdot CVN + 108}{695.5}$$

$$f(T) := e^{\left[-0.00277 \cdot (T-180) \cdot \left(1 + 0.116 \cdot \ln(a) - 0.0092 \cdot a^{-0.409}\right)\right]}$$

$$J_R := SF \cdot C1 \cdot a^{C2} \cdot f(CVN) \cdot f(T)$$

$$J_R = 452.361$$

Using the methodology described in page 2-5 of Reference 1, adjusted for temperature with the Reference 3 factor.

Point 1(taken @ a=0.1") See attached table taken from Reference 2

$a := 0.1$

$$f(T) := e^{\left[-0.00277 \cdot (T-180) \cdot \left(1 + 0.116 \cdot \ln(a) - 0.0092 \cdot a^{-0.409}\right)\right]}$$

$f(T) = 0.661$

$\%Drop := 0.03$

$INITJ := 694$

$Drop := 53.6 - 42$

$J_{mat1} := INITJ \cdot f(T) \cdot (1 - (\%Drop \cdot Drop))$

$J_{mat1} = 299.219$

Point 2(taken @ a=0.0563") See attached table taken from Reference 2

$f(T) = 0.661$

$\%Drop := 0.03$

$INITJ := 672$

$Drop := 53.6 - 42$

$J_{mat2} := INITJ \cdot f(T) \cdot (1 - (\%Drop \cdot Drop))$

$J_{mat2} = 289.733$

$$delJ := \frac{J_{mat1} - J_{mat2}}{(0.1 - 0.0563)}$$

$delJ = 217.055$

Note: f(T) is actually a function of both a and T. However, since it is only a estimation technique used to adjust Jmat for different tempertures the value of f(T) for 0.1" crack extension will be utilized. This represents a lower bound to the values of f(T) at 0.1" and 0.0563" crack extension. If 0.0563" crack extension was to be utilized, f(T) would equal 0.69, allowing Jmaterial to be higher which is non-conservative

Longitudinal Orientation

Using the method of Reference 3 directly (for info only)

$SF := 0.749 \quad C1 := 946.82 \quad C2 := 0.1334 \quad CVN := 63.7 \quad a := 0.1 \quad T := 390.5$

$$f(CVN) := \frac{11.75 \cdot CVN + 108}{695.5}$$

Note, 63.7 value contained in Reference 4

[signature] 12/14/93
[signature] 12/14/93

$$f(T) := e^{\left[-0.00277\cdot(T-180)\cdot\left(1+0.116\cdot\ln(a)-0.0092\cdot a^{-0.409}\right)\right]}$$

$$J_R := SF\cdot C1\cdot a^{C2}\cdot f(CVN)\cdot f(T)$$

$$J_R = 433.48$$

Using the methodology described in page 2-5 of Reference 1, adjusted for temperature with the Reference 3 factor.

Note, for this case, a 1.5% increase in Jmaterial is assumed as opposed to a 3% increase for conservatism.

Point 1(taken @ a=0.1") See attached table taken from Reference 2

$$a := 0.1$$

$$f(T) := e^{\left[-0.00277\cdot(T-180)\cdot\left(1+0.116\cdot\ln(a)-0.0092\cdot a^{-0.409}\right)\right]}$$

$$f(T) = 0.661$$

$$\%Inc := 0.015$$

$$INITJ := 694$$

$$Inc := 63.7 - 53.6$$

$$J_{mat1} := \frac{INITJ\cdot f(T)}{1-(\%Inc\cdot Inc)}$$

$$J_{mat1} = 540.866$$

Point 2(taken @ a=0.0563") See attached table taken from Reference 2

$$f(T) = 0.661$$

$$\%Inc := 0.015$$

$$INITJ := 672$$

$$Inc := 63.7 - 53.6$$

$$J_{mat2} := \frac{INITJ\cdot f(T)}{1-(\%Inc\cdot Inc)}$$

$$J_{mat2} = 523.72$$

$$delJ := \frac{J_{mat1} - J_{mat2}}{(0.1 - 0.0563)}$$

$$delJ = 392.348$$

Specimen V50-103 (Taken from Ref. 2)

Material Type : STEEL
Side Groove : 20%
Thickness : 4 in.
Temperature : 180°F
Width : 8 in.
Ao : 4.1058 in.
Af : 6.7132 in.
Flow Stress : 75700 psi.
Young's Mod : 29336000 psi.
Initial Slope : 3.5325E-7 in./lbs.
Razor Spacing : .1 in.
Hold-Load Dis : 2.2 in.
Razor-LL Dis : 0 in.

Load (lbs)	Defl. (in.)	Area (in.-lbs)	Slope (in./lbs)	Post-a (in.)	Delta-a (in.)	Jmc	Jd	Jm	Jd*	Jm*	Je
						|<- - -	- - -	(in.-lbs/in.²)	- - -	- - ->|
22269.8	0.0079	88.1	3.54163E-07	4.1101	0.0043	16.0	15.9	15.9	15.3	15.3	15.3
30543.0	0.0109	166.8	3.54699E-07	4.1126	0.0068	30.2	30.1	30.1	29.0	29.0	29.0
38972.5	0.0140	273.2	3.54279E-07	4.1110	0.0052	49.5	49.4	49.4	47.6	47.6	47.6
46832.5	0.0169	397.1	3.53685E-07	4.1085	0.0027	72.0	71.9	71.9	69.2	69.2	69.2
54785.0	0.0198	547.3	3.53173E-07	4.1064	0.0006	99.2	99.2	99.2	95.5	95.5	95.5
62832.5	0.0228	725.8	3.53212E-07	4.1068	0.0010	131.5	131.5	131.5	126.6	126.6	126.6
70712.5	0.0259	927.9	3.53131E-07	4.1065	0.0007	168.2	168.1	168.1	161.8	161.8	161.8
78252.5	0.0288	1147.7	3.53335E-07	4.1076	0.0018	208.0	207.7	207.7	200.1	200.1	200.1
85775.0	0.0318	1394.7	3.53274E-07	4.1075	0.0017	252.7	252.4	252.4	243.2	243.2	243.2
93012.5	0.0348	1659.1	3.53315E-07	4.1078	0.0020	300.6	300.3	300.3	289.4	289.4	289.4
100032.5	0.0378	1945.4	3.53402E-07	4.1084	0.0026	352.5	352.0	352.0	339.4	339.4	339.4
106982.5	0.0408	2260.4	3.53712E-07	4.1099	0.0041	409.6	408.8	408.8	394.3	394.4	394.3
113607.5	0.0439	2597.2	3.54177E-07	4.1121	0.0063	470.7	469.4	469.5	453.0	453.1	453.0
119350.0	0.0468	2936.5	3.54730E-07	4.1147	0.0089	532.1	530.4	530.6	512.1	512.2	512.1
124402.5	0.0497	3299.0	3.56285E-07	4.1217	0.0159	597.8	594.6	595.1	574.3	574.7	574.3
126485.0	0.0514	3501.3	3.57966E-07	4.1292	0.0234	634.5	629.7	630.5	608.2	608.8	608.2
126712.5	0.0519	3571.7	3.59092E-07	4.1341	0.0283	647.2	641.4	642.4	619.4	620.3	619.5
126572.5	0.0524	3635.8	3.60693E-07	4.1411	0.0353	658.9	651.4	652.8	629.0	630.2	629.1
126307.5	0.0529	3695.3	3.62444E-07	4.1487	0.0429	669.6	660.5	662.3	637.6	639.1	637.6
125762.5	0.0532	3735.3	3.63723E-07	4.1542	0.0484	676.9	666.5	668.6	643.4	645.2	643.4
125082.5	0.0535	3774.8	3.65553E-07	4.1621	0.0563	684.0	671.8	674.4	648.4	650.6	648.4
124767.5	0.0539	3819.9	3.68116E-07	4.1730	0.0672	692.2	677.5	680.7	653.3	656.0	653.3
123742.5	0.0542	3861.2	3.70406E-07	4.1826	0.0768	699.7	682.7	686.6	658.1	661.5	658.2
123200.0	0.0546	3906.6	3.73025E-07	4.1936	0.0878	707.9	688.4	693.0	663.2	667.1	663.2
122235.0	0.0549	3946.7	3.76227E-07	4.2069	0.1011	715.2	692.5	698.0	666.6	671.4	666.7
121530.0	0.0552	3979.4	3.78738E-07	4.2172	0.1114	721.1	695.9	702.2	669.6	675.0	669.7
120962.5	0.0555	4018.8	3.81006E-07	4.2264	0.1206	728.3	700.9	707.9	674.1	680.1	674.2
120642.5	0.0559	4062.5	3.84416E-07	4.2401	0.1343	736.2	705.5	713.5	677.8	684.7	677.9
120122.5	0.0563	4110.1	3.87236E-07	4.2514	0.1456	744.8	711.5	720.4	683.2	690.8	683.2
119635.0	0.0567	4163.2	3.90777E-07	4.2654	0.1596	754.4	717.8	727.8	688.6	697.2	688.7
119002.5	0.0572	4225.3	3.94241E-07	4.2789	0.1731	765.7	725.9	737.0	696.0	705.5	696.1
118337.5	0.0576	4270.2	3.96857E-07	4.2890	0.1832	773.8	731.6	743.6	701.2	711.5	701.4
118105.0	0.0581	4324.5	4.00150E-07	4.3016	0.1958	783.7	738.5	751.5	707.3	718.5	707.4
117517.5	0.0591	4439.7	4.06408E-07	4.3252	0.2194	804.5	753.7	768.9	721.1	734.2	721.2
117137.5	0.0601	4561.7	4.11622E-07	4.3445	0.2387	826.6	771.5	788.5	737.6	752.3	737.8
116977.5	0.0611	4679.9	4.16569E-07	4.3625	0.2567	848.1	788.8	807.6	753.7	770.0	753.9
115422.5	0.0631	4912.9	4.29601E-07	4.4088	0.3030	890.3	819.4	843.2	781.8	802.4	782.1
112500.0	0.0642	5029.3	4.39253E-07	4.4418	0.3360	911.4	831.6	859.3	793.3	817.4	793.7
110777.5	0.0651	5138.0	4.46470E-07	4.4659	0.3601	931.1	845.2	876.0	806.1	832.9	806.6
108937.5	0.0662	5255.2	4.56219E-07	4.4977	0.3919	952.3	857.9	892.9	817.7	848.2	818.2
107137.5	0.0672	5365.8	4.65064E-07	4.5257	0.4199	972.4	870.5	909.4	829.5	863.5	830.1
104975.0	0.0683	5476.6	4.76167E-07	4.5599	0.4541	992.4	881.0	925.0	839.0	877.5	839.7
102995.0	0.0694	5587.5	4.85095E-07	4.5867	0.4809	1012.5	894.1	942.2	851.7	893.9	852.4
101657.5	0.0704	5696.5	4.93259E-07	4.6106	0.5048	1032.3	907.7	959.8	864.7	910.4	865.4
100552.5	0.0715	5800.5	5.01995E-07	4.6356	0.5298	1051.1	920.0	976.2	876.0	925.5	876.8
99362.5	0.0726	5911.0	5.08889E-07	4.6550	0.5492	1071.1	935.6	995.3	891.3	943.9	892.1
97845.0	0.0737	6018.4	5.18846E-07	4.6823	0.5765	1090.6	947.5	1012.2	902.5	959.6	903.4

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APPENDIX B

$p := 2.485 \quad R_i := 77.97 \quad CR := 100$

$t := 9.875 \quad SF := 1.15 \cdot 1.1 \quad s := \frac{1.25}{1.15}$ **(safety factor adjustment for dJ/da)**

$\sigma_y := 43.8 \quad E := 2.64 \cdot 10^4 \quad \nu := 0.3 \quad E_c := \frac{E}{(1-\nu^2)}$

$$F_1(a) := 0.982 + 1.006 \cdot \left(\frac{a}{t}\right)^2 \qquad K_{Ipa}(a) := SF \cdot p \cdot \left[1 + \left(\frac{R_i}{t}\right)\right] \cdot \sqrt{\pi \cdot a} \cdot F_1(a)$$

$$F_2(a) := 0.885 + 0.233 \cdot \left(\frac{a}{t}\right) + 0.345 \cdot \left(\frac{a}{t}\right)^2 \qquad K_{Ipc}(a) := SF \cdot p \cdot \left(1 + \frac{R_i}{2 \cdot t}\right) \cdot \sqrt{\pi \cdot a} \cdot F_2(a)$$

$$F_3(a) := \left[\left[0.690 + 3.127 \cdot \left(\frac{a}{t}\right)\right] - 7.435 \cdot \left(\frac{a}{t}\right)^2\right] + 3.532 \cdot \left(\frac{a}{t}\right)^3$$

$$K_{It}(a) := \left(\frac{CR}{1000}\right) \cdot t^{2.5} \cdot F_3(a) \qquad a_o := \frac{t}{4} + 0.1 \qquad a_d := \frac{t}{4}$$

$$a_{effa} := (a_o) + \left(\frac{1}{6 \cdot \pi}\right) \cdot \left(\frac{K_{Ipa}(a_o) + K_{It}(a_o)}{\sigma_y}\right)^2 \qquad a_{effc} := (a_o) + \left(\frac{1}{6 \cdot \pi}\right) \cdot \left(\frac{K_{Ipc}(a_o) + K_{It}(a_o)}{\sigma_y}\right)^2$$

$$J_a := \frac{1000 \cdot \left(K_{Ipa}(a_{effa}) + K_{It}(a_{effa})\right)^2}{E_c} \qquad J_c := \frac{1000 \cdot \left(K_{Ipc}(a_{effc}) + K_{It}(a_{effc})\right)^2}{E_c}$$

$$a_{effao} := (a_o) + \left(\frac{1}{6 \cdot \pi}\right) \cdot \left(\frac{K_{Ipa}(a_o) \cdot s + K_{It}(a_o)}{\sigma_y}\right)^2 \qquad a_{effco} := (a_o) + \left(\frac{1}{6 \cdot \pi}\right) \cdot \left(\frac{K_{Ipc}(a_o) \cdot s + K_{It}(a_o)}{\sigma_y}\right)^2$$

$$J_{ao} := \frac{1000 \cdot \left(K_{Ipa}(a_{effao}) \cdot s + K_{It}(a_{effao})\right)^2}{E_c} \qquad J_{co} := \frac{1000 \cdot \left(K_{Ipc}(a_{effco}) \cdot s + K_{It}(a_{effco})\right)^2}{E_c}$$

$$a_{effad} := (a_d) + \left(\frac{1}{6 \cdot \pi}\right) \cdot \left(\frac{K_{Ipa}(a_d) \cdot s + K_{It}(a_d)}{\sigma_y}\right)^2 \qquad a_{effcd} := (a_d) + \left(\frac{1}{6 \cdot \pi}\right) \cdot \left(\frac{K_{Ipc}(a_d) \cdot s + K_{It}(a_d)}{\sigma_y}\right)^2$$

$$J_{ad} := \frac{1000 \cdot \left(K_{Ipa}(a_{effad}) \cdot s + K_{It}(a_{effad})\right)^2}{E_c} \qquad J_{cd} := \frac{1000 \cdot \left(K_{Ipc}(a_{effcd}) \cdot s + K_{It}(a_{effcd})\right)^2}{E_c}$$

$$dJ_a := J_{ao} - J_{ad} \qquad da := a_o - a_d \qquad dJ_c := J_{co} - J_{cd}$$

Results:

$J_a = 524.734 \qquad J_c = 203.926$

$\frac{dJ_a}{da} = 221.783 \qquad \frac{dJ_c}{da} = 61.421$

Westinghouse Electric Corporation **Energy Systems**

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93-CPL-072
ET-NSL-OPL-II-93-557
December 16, 1993

CAROLINA POWER & LIGHT COMPANY
H. B. ROBINSON UNIT 2
Reactor Vessel Upper Shelf Energy Re-Evaluation

Reference:

1) Tandon S., et al., WCAP-13587, Revision 1, "Reactor Vessel Upper Shelf Energy Bounding Evaluation for Westinghouse Pressurized Water Reactors", September 1993.

Dear Mr. Kozyra:

Please find attached the revised information prepared by Westinghouse pertaining to the H. B. Robinson Unit 2 (Plant 7) reactor vessel upper shelf energy data presented in Table 3-2 of WCAP-13587, Revision 1 (Reference 1). The revised information is being supplied per our telephone conversation (Westinghouse and CP&L) with the NRC on December 12, 1993.

Please contact either Mr. S. Tandon (412) 374-6634, Mr. S. A. Swamy (412) 374-6513 or Mr. B. A. Bishop (412) 374-4593, if you have any questions.

Very truly yours,

W. J. Rinkacs for
Gary S. Weingarten
Special Representative
Carolina Area

WJR
Attachment

cc:	D. B. Waters (HBR)	1L, 1A	C. Griffin (CP&L)	1L, 1A
	R. J. Muth (W-HBR)	1L, 1A		
	G. S. Weingarten (W- Raleigh)	1L, 1A		
	Document Control (CP&L)	1L, 1A		

H. B. Robinson Upper Shelf Energy Re-Evaluation

The purpose of this attachment is to revise the information pertaining to the H.B. Robinson Unit 2 (Plant 7) in Table 3-2 of WCAP-13587, Rev 1 (Reference 1) to incorporate the following. Note that this table corresponds to the Level A and B condition analysis of Reference 1.

1. The initial average charpy value assumed in Reference 1 for the material of Reference 2 was 50 ft-lbs. $J_{material}$ is modified to reflect the actual initial value of 53.6 ft-lbs.

2. Reference 3 contains a relationship to adjust the $J_{material}$ value of the Reference 2 ASTM A 302B plate material for different temperature values. The technique described in Reference 1 along with this temperature correction is used to calculate $J_{material}$ for this plant.

3. Table 3-2 of Reference 1 conservatively utilizes $J_{applied}$ for a flaw which is axially orientated with $J_{material}$ values for the transverse direction. $J_{material}$ is recalculated for both the transverse and longitudinal direction, and $J_{applied}$ for circumferential and axial flaws are compared with the transverse and longitudinal values, respectively as depicted in the attached figure.

Based on the items listed above, the following table contains the $J_{material}$ parameters applicable to the H. B. Robinson Unit 2 vessel.

Parameter	Transverse	Longitudinal
$J_{material}$ (in-lb/in^2)	299	541
$(dJ/da)_{material}$	217	392

Next, for comparison of the transverse orientation to circumferential flaw and longitudinal orientation to axial flaw, the $J_{applied}$ values are given below:

Parameter	Circumferential	Axial
$J_{applied}$ (in-lb/in^2)	204	525
$(dJ/da)_{applied}$	61	222

It is shown that $J_{applied} < J_{material}$ and $(dJ/da)_{applied} < (dJ/da)_{material}$ in each respective direction. Note that longitudinal/axial values are supplied for information only as irradiated Charpy Energy is predicted to remain well above 50 ft-lbs in that direction.

<u>References:</u>

1. Tandon S. et al., WCAP-13587, Rev 1, "Reactor Vessel Upper Shelf Energy Bounding Evaluation for Westinghouse Pressurized Water Reactors," September 1993.

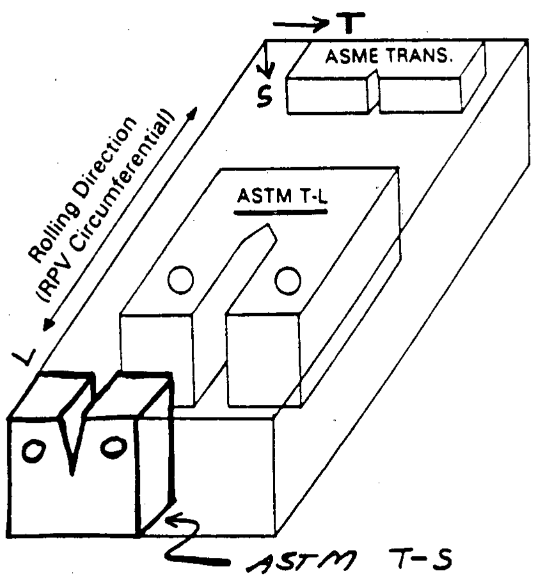
2. Hiser A. L., Terrell J. B., NUREG/CR-5265, MEA-2320, "Size Effects on J-R Curves for A302-B Plate," January 1989.

3. Memorandum for Wichman K. R. from Hiser A. L. and Malik S. N. M., "J-R Curves for Low Toughness A 302-B Plate," September 9, 1993.

DEFINITION OF ASME AND ASTM ORIENTATIONS

"WEAK" DIRECTION

ASME TRANSVERSE
ASTM T-L
RPV CIRC. FLAW



"STRONG" DIRECTION

ASME LONGITUDINAL
ASTM L-T
RPV AXIAL FLAW