Duke Power Company
Entergy Operations, Inc.
Florida Power Corporation

Oconee 1, 2, 3
ANO–1
Crystal River 3

The B&W Owners Group

GPU Nuclear, Inc.
Toledo Edison Company
Framatome Technologies, Inc.

TMI–1
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August 25, 2000
OG-1797

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U. S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Subject: Request for Additional Information (RAI) - B&W Owners Group Report BAW-10046, Revision 4, "Methods of Compliance With Fracture Toughness and Operational Requirements of 10 CFR Part 50, Appendix G," (TAC No. MA 8237) dated July 10, 2000

Gentlemen:

Attached is the B&W Owners Group Reactor Vessel Working Group response to the subject RAI.

Please feel free to call me at 804-832-3293 if there are further questions.

Sincerely,

DLHowell

Don L Howell
Project Manager
B&W Owners Group Services

Reactor Vessel Working Group

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W. F. Brady	- Duke Energy Corporation
R. P. Lemberger	- Florida Power Corporation
S. A. Collard	- Florida Power & Light Company
S. Leshnoff	- PECO Energy Company
D. R. Blakely	- FirstEnergy Nuclear Operating Company
J. R. Harrell	- Virginia Power
H. Hanneman	- Wisconsin Electric Power Company

c: S. N. Bailey - U.S. NRC

T010

FTI RESPONSE TO NRC STAFF COMMENTS ON

TOPICAL REPORT BAW-10046, REVISION 4

"METHODS OF COMPLIANCE WITH FRACTURE TOUGHNESS AND

OPERATIONAL REQUIREMENTS OF 10 CFR PART 50, APPENDIX G"

1. Executive Summary and Page 1-1 of the Introduction - Item No. 6 from the list on both pages states that Code Case N-640 allows the use of the K_{Ic} curve in place of the K_{Ia} curve and a revised LTOP setpoint. The wording is ambiguous in that it implies Code Case N-640 will provide two relaxations: (1) to use the K_{Ic} curve in place of the K_{Ia} curve, and (2) to set the RCS safety relief valve lift setpoint at a pressure above 100 percent of the limits set by the P-T limit curves. What the Code Case does is allow licensees to use the K_{Ic} curve in lieu of the K_{Ia} curve; however, if the K_{Ic} curve is used to establish the P-T limits, the Code Case restricts the LTOP system setpoint to 100 percent of the pressure limits established by the P-T curves. Thus, the relaxation in the 1995 Code allowing the LTOP system setpoint to be set at 110 percent of the established P-T limits may not be used if the Code Case methods are invoked. This is well explained in the body of the topical report. To avoid confusion, remove the reference to the LTOP setpoint in the sentences that read:

   "Code Case N-640 that allows the use of the K_{Ic} curve in place of the K_{Ia} curve and a revised LTOP set point."

   FTI Response

   Item No. 6 from the lists on the Executive Summary page and Page 1-1 of the Introduction will be revised to read:

   "Code Case N-640 that allows the use of the K_{Ic} curve in place of the K_{Ia} curve."

2. Page 2-4, Section 2.3.2 - Minimum temperature requirements for operating pressures above and below 20 percent of the preservice hydrostatic test pressure (PHTP) may or may not be conservative relative to the P-T limits generated in accordance with Appendix G to Section XI of the ASME Code. At this point, any NRC studies or research programs to decide whether or not to eliminate or reduce the minimum temperature requirements at operating pressures above 20 percent of the PHTP are preliminary. Thus, the sentence in Section 2.3.2 is not altogether accurate.

   FTI Response

   The sentence in Section 2.3.2 will be revised to read:

"The P-T limits generated in accordance with Appendix G to Section XI of the ASME Code are adjusted, as necessary, to ensure that the minimum temperature requirements listed in Table 1 of 10 CFR Part 50 are satisfied for all operating conditions."

3. Page 4-1, End of Section 4.1 - The tables in RG 1.99, Revision 2, "Radiation Embrittlement of Reactor Vessel Materials," should be mentioned as the basis for establishing the chemistry factor for a reactor pressure vessel beltline material when the material is not represented by a corresponding material (i.e., a material fabricated from an identical material heat) in the utility's material surveillance program.

   FTI Response

   Since the first paragraph of Section 4.1 already states that Regulatory Guide 1.99, Revision 2 is used to determine values of RT_{NDT} for irradiated materials, the last paragraph of Section 4.1 is not necessary and will be removed.

4. Pages 5-5 through 5-6, Sections 5.5.1 and 5.5.2 - Section 5.5.1 uses stress intensity methods established by Raju and Newman for evaluating longitudinal semielliptical surface flaws; Section 5.5.2 uses stress intensity methods established by Kumar for evaluating circumferential semielliptical flaws. Will the use of these methods result in conservative P-T limits relative to using the methods stated in the 1995 Edition of Appendix G to Section IX (or earlier endorsed versions)? This will determine whether an exemption is required in order to use these equations.

   FTI Response

   The introduction to Section 5.5, and Sections 5.5.1 and 5.5.2 will be revised as shown in Attachment 1 to this letter. In addition, all mention of the Raju and Newman solution the Kumar solution (in Item No. 2 from the lists on the Executive Summary page and Page 1-1, Item No. 1 from the list on Page 7-1, and Reference Nos. 15 and 16) will be removed.

5. Page 5-7, Section 5.5.3 - Provide a reference for the equation:

$$F = 2.5 - 6.108(a/r_n) + 12(a/r_n)^2 - 9.1664(a/r_n)^3$$

   FTI Response

   This cubic equation was developed as a curve fit to the finite element results which serve as the basis for the proposed curve for stress intensity factors for nozzle corner flaws in Fig. A5-1 of WRC Bulletin 175. As demonstrated by Attachment 2, the equation on Page 5-7 provides a very good representation of

the data points in Fig. A5-1 for a/r_n ratios up to at least 0.25, which is the maximum flaw size considered for nozzle corner flaws.

6. In general, use of Code Case N-640 and Code Case N-588 will yield P-T limit curves that are not as conservative as those that would be generated if Appendix G to Section XI of the ASME Code were used to generate the curves. The report needs to state that exemptions against the requirements of 10 CFR 50.60 and 10 CFR Part 50, Appendix G, need to be submitted if licensees wish to use either Code Case N-640 or Code Case N-588 (or both) as the bases for generating their P-T limit curves. Any exemption requests will be approved or denied by the staff on a case-by-case basis pursuant to the requirements and criteria stated in 10 CFR 50.12.

FTI Response

The last paragraph of Section 7 will be revised to read:

> "It is concluded that the use of the changes noted above reduces excessive conservatism in application of 10 CFR 50, Appendix G, without decreasing overall safety margins. It is also noted, however, that the use of either Code Case N-640 or Code Case N-588 (or both) as a basis for generating P-T limit curves obligates the licensee to submit a request for exemptions against the requirements of 10 CFR 50.60 and 10 CFR Part 50, Appendix G."

Attachment 1

Proposed Changes to BAW-10046, Revision 4 for
Longitudinal and Circumferential Stress Intensity Factor Solutions
(in Response to Comment No. 4)

5.5 Stress Intensity Factors, K_I

Stress intensity factors are obtained using K_I solutions from Appendix G to the 1995 edition of Section XI, as modified by Code Case N-588.

5.5.1 Longitudinal Semielliptical Surface Flaw

The stress intensity factor solution for a longitudinal semielliptical surface flaw can be expressed in terms of pressure and bending components, as follows:

$$K_I = K_{Im} + K_{It}$$

where

K_I = total stress intensity factor
K_{Im} = membrane term due to pressure
K_{It} = bending term due to a radial thermal gradient

K_I due to pressure (membrane tension)

$$K_{Im} = M_m \times (pR_i/t)$$

where

p = internal pressure, ksi
R_i = vessel inner radius, in.
t = vessel wall thickness, in.

For an inside surface flaw,

$$\begin{aligned} M_m &= 1.85 \text{ for } \sqrt{t} < 2 \\ &= 0.926\sqrt{t} \text{ for } 2 \le \sqrt{t} \le 3.464 \\ &= 3.21 \text{ for } \sqrt{t} > 3.464 \end{aligned}$$

For an outside surface flaw,

$$\begin{aligned} M_m &= 1.77 \text{ for } \sqrt{t} < 2 \\ &= 0.893\sqrt{t} \text{ for } 2 \le \sqrt{t} \le 3.464 \\ &= 3.09 \text{ for } \sqrt{t} > 3.464 \end{aligned}$$

K_I due to bending (radial thermal gradient)

For a thermal stress distribution described by

$$\sigma(x) = C_0 + C_1 (x/a) + C_2 (x/a)^2 + C_3 (x/a)^3 ,$$

thermal stress intensity factors are defined by the following relationships:

For an inside 1/4-thickness surface flaw during cooldown,

$$K_{It} = (1.0359\ C_0 + 0.6322\ C_1 + 0.4753\ C_2 + 0.3855\ C_3)\sqrt{\pi a} ,$$

For an outside 1/4-thickness surface flaw during heatup,

$$K_{It} = (1.043\ C_0 + 0.630\ C_1 + 0.481\ C_2 + 0.401\ C_3)\sqrt{\pi a} ,$$

where

x = is a dummy variable that represents the radial distance from the appropriate (i.e., inside or outside) surface, in.
a = the flaw depth, in.

Stress intensity factors K_{Im} and K_{It} may also calculated from pre-1995 versions of Appendix G to Section XI.

5.5.2 Circumferential Semielliptical Surface Flaw

The membrane and bending stress intensity factor solutions for a circumferential semielliptical surface flaw are identical to those for a longitudinal semielliptical surface flaw except for the M_m coefficients in the membrane solution.

For an inside surface flaw,

$$\begin{aligned} M_m &= 0.89 \text{ for } \sqrt{t} < 2 \\ &= 0.443\ \sqrt{t} \text{ for } 2 \le \sqrt{t} \le 3.464 \\ &= 1.53 \text{ for } \sqrt{t} > 3.464 \end{aligned}$$

For an outside surface flaw,

$$\begin{aligned} M_m &= 0.89 \text{ for } \sqrt{t} < 2 \\ &= 0.443\ \sqrt{t} \text{ for } 2 \le \sqrt{t} \le 3.464 \\ &= 1.53 \text{ for } \sqrt{t} > 3.464 \end{aligned}$$

Attachment 2

Demonstration that the Equation on Page 5-7 of BAW-10046, Revision 4 Provides a Proper Curve Fit to Data Points in Fig. A5-1 of WRC Bulletin 175 (in Response to Comment No. 5)

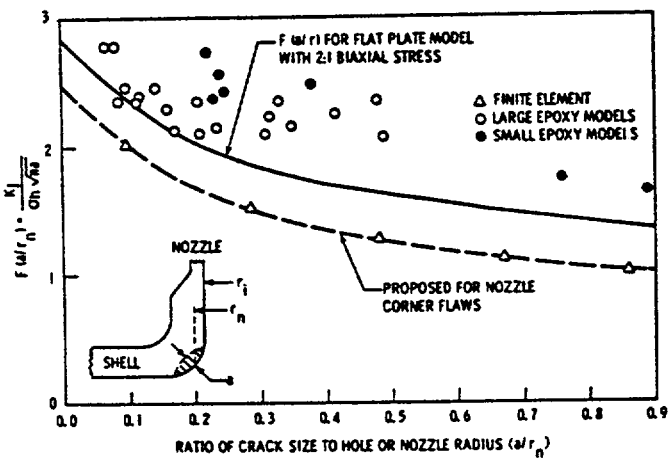
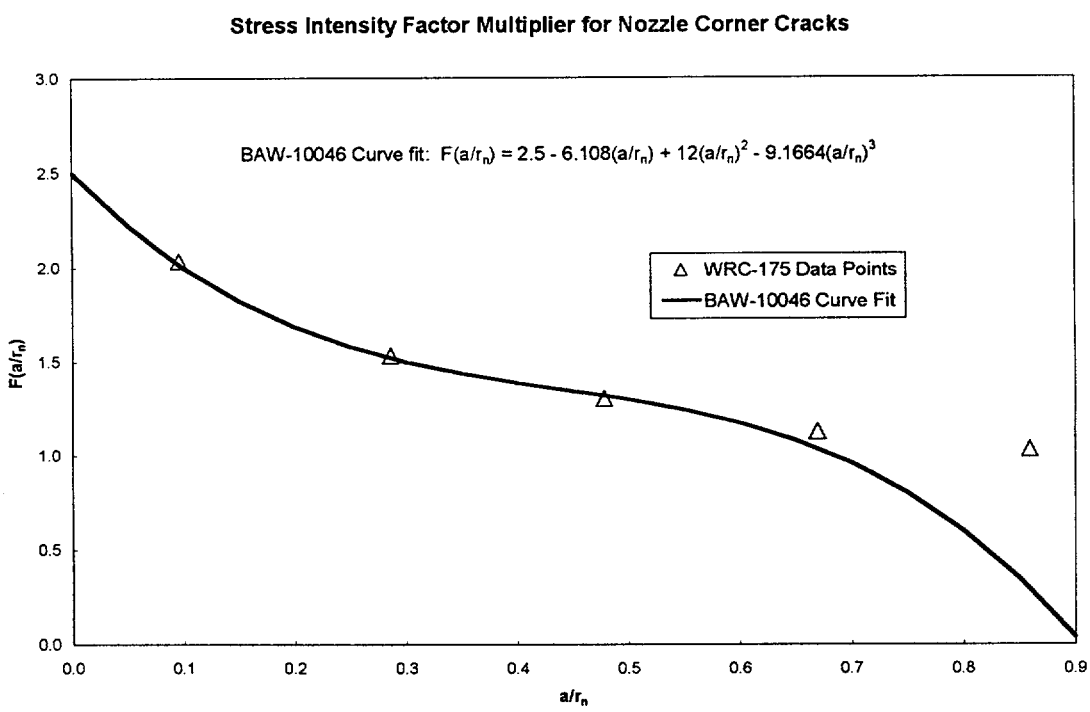


Fig. A5-1 from WRC Bulletin 175



Comparison of Data Points in Fig. A5-1 with Curve Fit Equation