SCE&G
A SCANA COMPANY

August 19, 1999
RC-99-0152

Document Control Desk
U. S. Nuclear Regulatory Commission
Washington, DC 20555

Attention: Ms. K. R. Cotton

Gentlemen:

Gary J. Taylor
Vice President
Nuclear Operations

Subject: VIRGIL C. SUMMER NUCLEAR STATION
DOCKET NO. 50/395
OPERATING LICENSE NO. NPF-12
EXEMPTION REQUEST FROM 10 CFR 50 APPENDIX G
REQUIREMENTS TO BE USED FOR GENERATION OF
PRESSURE – TEMPERATURE LIMITS CURVES
(NRR 990009)

Reference: Gary J. Taylor, SCE&G, to NRC, RC-99-0154, August 19, 1999

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10 CFR 50, Appendix G, specifies fracture toughness requirements for ferritic materials of the reactor coolant boundary. It requires that Pressure-Temperature (P-T) limits for the Reactor Coolant System (RCS) be at least as conservative as those obtained by the methodology in the 1989 edition of Appendix G to Section XI of the American Society of Mechanical Engineers (ASME) code. 10 CFR 50.60 also states that alternatives to the requirements of 10 CFR 50, Appendix G may be used when the alternative has been approved via an exemption granted by the NRC.

South Carolina Electric and Gas Company (SCE&G) seeks an exemption under 10 CFR 0.12a(2)ii from 10 CFR 50 Appendix G requirements to establish Pressure-Temperature Limits Curves using the methodology presented in 1989 ASME Section XI, Appendix G. SCE&G requests, as an alternate requirement to utilize the methodology presented in the 1996 ASME Section XI, Appendix G and ASME Code Case N-640, "Alternative Reference Fracture Toughness for Development of P-T Curves for Section XI, Division I", dated February 1999 (Attachment 3). Additionally, SCE&G requests to utilize a reduced flange temperature requirement based on the use of K_{IC}, similar to ASME Code Case N-640.

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The primary reason for incorporating this change in methodology is to provide more realistic limits than the current Appendix G methodology. This exemption is necessary to assure there is sufficient margin inherent in the generation of the V. C. Summer Nuclear Station Heatup/Cooldown curves, yet not impact normal operation of the plant.

SCE&G has determined this methodology of generating the P-T curves provides an increase in operating margin while maintaining an equivalent level of safety for the reactor vessel. This change does not present an undue risk to the public health and safety nor does it endanger common defense and security, as the underlying purpose of the regulation is still achieved.

SCE&G requests the review and approval of this exemption request as expeditiously as practical to support the implementation of the new P-T curves, requested in Technical Specification Change Request, dated August 19, 1999 (Reference 1).

Should you have any questions, please call Mr. Philip Rose at (803) 345-4052.

Very truly yours,

Gary J. Taylor

Gary J. Taylor

PAR/GJT/dr
Attachments

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DMS (RC-99-0152)

Request for Exemption from 10 CFR 50, Appendix G Requirements to be Used for Generation Of Pressure–Temperature Limits Curves

This exemption request changes the methodology utilized in the generation of the Pressure-Temperature Limits Curves located in the Virgil. C. Summer Nuclear Station Technical Specifications. The current methodology utilizes the guidance found in the 1989 ASME Boiler and Pressure Vessel Code (B&PV Code, or Code), Section XI, Appendix G, and Regulatory Guide 1.99, Revision 2. The new methodology utilizes the guidance found in the 1996 ASME Code, Section XI, Appendix G, Regulatory Guide 1.99, Revision 2, along with Code Case N-640 and a reduced flange temperature requirement.

The current methodology uses the reference stress intensity factor K_{IA} in calculating the fracture toughness curve. The updated methodology to be employed is based on the K_{IC} approach.

Basis for Exemption:

Appendix G to the ASME Boiler and Pressure Vessel Code, Section XI, Division 1, "Fracture Toughness Criteria for Protection Against Failure" was updated in 1996 and ASME Code Case N-640, "Alternate Reference Fracture Toughness for Development of P-T Limit Curves for Section XI, Division 1" was approved in February of 1999. The 1996 ASME Section XI, Appendix G, provides a more accurate methodology for calculating stress intensity factors due to thermal and pressure stresses at the 1/4T and 3/4T locations, while Code Case N-640 allows the use of the K_{IC} methodology rather than the K_{IA} methodology. Use of these industry accepted methods increases plant operating margins while maintaining an equivalent level of safety relative to current regulations.

The ASME approach for calculating the allowable limit curves for various heatup and cooldown rates specifies that the total stress intensity factor, K_I, for the combined thermal and pressure stresses at any time during heatup or cooldown cannot be greater than the reference stress intensity factor, K_{IC}, for the metal temperature at that time. K_{IC} is obtained from the reference fracture toughness curve, defined in Appendix G to Section XI of the 1996 ASME Code. The K_{IC} curve is based on the lower bound of static critical K_I values measured as a function of temperature on specimens of SA-533 Grade B Class 1, SA-508-2, and SA-508-3 steels.

According to WCAP 14040-NP-A, Revision 2, it is appropriate to utilize the steady state Appendix G limits for the Cold Overpressure Mitigation System (COMS) setpoint, since most overpressure events are likely to occur during isothermal conditions in the RCS.

Since the RCS fluid heatup and cooldown process is very slow, with the fastest rate being 100 °F per hour, the rate of change of pressure and temperature of the reactor vessel is essentially constant. Both heatup and cooldown correspond to static loading, with regard to fracture toughness.

The proposed heatup and cooldown curves are based on Code Case N-640 and use the reference stress intensity factor K_{IC}. K_{IA} is a fracture toughness curve, which is a lower bound on all static, dynamic, and arrest fracture toughness data, and K_{IC} is the lower bound on static fracture toughness only.

The only time when dynamic loading can occur and where K_{IA} should be used for the reactor pressure vessel is when a crack is running. This may occur during a Pressurized Thermal Shock event, but not during normal heatup and cooldown. Therefore the static toughness K_{IC} lower bound toughness is used to generate the heatup and cooldown curves. This reduces some of the excess conservatism in the current Appendix G approach.

A justification for the reduction of flange temperature requirements was prepared for Virgil C. Summer Nuclear Station by Westinghouse. The conclusion presented by this evaluation is that the utilization of the K_{IC} methodology provides an equivalent level of safety as the current methodology, while providing additional operating margin. A detailed discussion is provided in Attachment 2 to this letter.

Closure Head/Vessel Flange requirements for V. C. Summer Nuclear Station

Introduction

10 CFR Part 50, Appendix G contains the requirements for the metal temperature of the closure head flange and vessel flange regions. This rule states that the metal temperature of the closure flange regions must exceed the material unirradiated RT_{NDT} by at least 120 °F for normal operation when the pressure exceeds 20 percent of the pre-service hydrostatic test pressure (3106 psig), which is 621 psig for the Virgil C. Summer Nuclear Station reactor vessel.

This requirement was originally based on concerns about the fracture margin in the closure flange region. During the boltup process, outside surface stresses in this region typically reach over 70 percent of the steady state stress, without being at steady state temperature. The margin of 120 °F and the pressure limitation of 20 percent of hydrotest pressure were developed using the K_{IA} fracture toughness methodology, in the mid 1970's.

Improved knowledge of fracture toughness and other issues which affect the integrity of the reactor vessel, have led to the recent change to allow the use of K_{IC} in the development of pressure-temperature curves, as contained in Code Case N-640, "Alternate Reference Fracture Toughness for Development of P-T Limit Curves for Section XI, Division 1". The following discussion uses a similar approach (i.e., using K_{IC}) to provide a technical basis for elimination of these flange requirements.

Comparing Flange Requirements

The geometry of the closure head flange region for a typical Westinghouse four loop plant reactor vessel, which is more conservative (i.e., bounding) than the geometry of a three loop plant such as the V. C. Summer Nuclear Station reactor vessel, is shown in Figure 1. All the other plant designs have a smaller closure head thickness, so the boltup stresses will be lower, and this case will conservatively bracket the others. The stresses in this region are highest near the outside surface of the head. Hence, an outside reference flaw of 25 percent of the wall thickness parallel to the dome to flange weld (i.e., in the direction of welding) was postulated in this region. To be consistent with ASME Section XI, Appendix G, a safety factor of two was applied for the fracture calculation.

Figure 2 shows the crack driving force or stress intensity factor for the postulated flaw in this region, along with a second curve which incorporates the safety factor of two. Note that the stress intensity factor with a safety factor of one for this region does not exceed 55 ksi$\sqrt{\text{in}}$., even for a postulated flaw of 50 percent of the wall thickness. For the reference flaw, with the safety factor of two, the applied stress intensity factor is 85.15

ksi√in. at 25 percent of the wall thickness. The appropriate result for a three loop plant is 70.4 ksi√in. for the same case, as shown in figure 4. Since the head thickness of the V. C. Summer Nuclear Station reactor vessel is only 5.75 inches, the stresses are lower, resulting in a lower applied stress intensity factor. For two loop plants the geometry is similar and the head thickness is 5.5 inches, so the three loop results apply conservatively to the two loop plants.

Alternative Flange Requirement

The determination of the boltup, or flange requirement, is shown in Figure 3, where the fracture toughness is plotted as a function of the temperature. In this figure, the intersection between the stress intensity factor and the K_{IC} toughness curve occurs at a value slightly higher than $T - RT_{NDT} = 45$ °F, which is significantly lower than the existing temperature requirement of 120 °F, determined using the K_{IA} toughness curve. The value of $T - RT_{NDT}$ for a three loop plant is even lower, at 29 °F, as shown in Figure 5.

The alternate flange requirement for use with the K_{IC} curve will be based on the governing case for all Westinghouse plants (i.e., 4-loop geometry) and will preserve current implementing pressure requirements. Therefore, based on the above, the alternate flange requirement is:

> The pressure in the vessel should not exceed 20 percent of the pre-service hydrostatic test pressure (3106 psig) until the temperature exceeds $T - RT_{NDT} = 45$ °F.

Margins of Safety

Using the K_{IC} curve can support not only a significantly relaxed temperature for implementing the flange requirement, but also a potential elimination of the flange requirement. This can be illustrated by examining the stress intensity factor change for a quarter thickness postulated flaw as the vessel is pressurized after boltup, progressing up to steady state operation.

> The stresses at the region of interest are shown in Table 1, for steady state operation. Included here are the stresses at the outside surface, which is the highest stress location for this region, as well as the membrane and bending stresses. Note that the OD stresses, as well as the membrane and bending stresses, are very similar for the four designs shown in the table. Table 2 shows a comparison of the boltup and steady state stresses for the same plant designs. Again the results are similar for the designs shown, which bracket all plants in service. No comparisons are available for three or two loop Westinghouse plants; they are conservatively covered by the four loop plant results, as discussed above.

As the vessel is pressurized, the stresses in the closure flange region gradually change from mostly bending stresses to mostly membrane stresses. As a result the stress intensity factor, or driving force, increases for a postulated flaw at the outside surface. Table 3 shows the change in stress intensity factor from boltup to steady state operation. Due to differences in geometry, the results are slightly different for the designs shown, but the key conclusion is that the change is small, in all cases less than 13 ksi$\sqrt{in}$.

There is also a toughness change between K_{IA} and K_{IC}, and, as seen for example in Figure 3, the difference in toughness depends on the temperature chosen for comparison. The most appropriate comparison is at boltup, since that is the lowest temperature of concern for each plant design. To obtain this temperature, the calculated stress intensity factor at boltup was obtained (column 2 of Table 3), and a safety factor of two applied. The temperature was then determined from the value of K_{IA} toughness that matched the stress intensity factor discussed above. The difference in toughness was obtained at that temperature.

Based on the above, the gain in toughness in going to K_{IC} for the flange considerations is shown to be significantly more than the difference in applied stress intensity factor between boltup and steady state operation. Therefore, there is no need for any special considerations for the flange when using the K_{IC} toughness. Even if the comparison is made at T - RT_{NDT}, the change in toughness exceeds the change in applied stress intensity factor, as seen in Table 3. Therefore, it may be concluded that fracture considerations for the reactor vessel closure flange are no longer necessary and that maintenance of the alternate flange requirements provides adequate margins of safety to support operation of Virgil C. Summer Nuclear Station.

TABLE 1
AXIAL STRESS COMPARISON
STEADY STATE OPERATION @ 2250 PSI

Plant	OD Stress (ksi)	Membrane Stress (ksi)	Bending Stress (ksi)
W 4 Loop	23.0	15.4	7.6
W 3 Loop	21.5	13.3	8.3
CE	22.7	13.1	9.6
B&W	23.8	16.2	7.6

TABLE 2
STRESS COMPARISON
BOLTUP VS STEADY STATE

Plant	Boltup Membrane (ksi)	Boltup Bending (ksi)	SS Membrane (ksi)	SS Bending (ksi)
W 4 Loop	2.1	14.5	15.4	7.6
W 3 Loop	-	-	13.3	8.3
CE	2.1	21.5	13.1	9.6
B&W	4.95	15.4	16.2	7.6

TABLE 3

COMPARISON OF STRESS INTENSITY FACTOR CHANGE
VS FRACTURE TOUGHNESS GAIN

Plant	K (Boltup)	K (Steady State)	ΔK	K_{IA} to K_{IC} Change at Boltup	K_{IA} to K_{IC} at $T = RT_{NDT}$
W 4 Loop	29.5	42.6	13.1	50.0	14.6
W 3 Loop	-	35.2	-	-	14.6
CE	37.8	49.3	11.5	93.0	14.6
B&W	49.5	46.3	-3.2	101.0	14.6

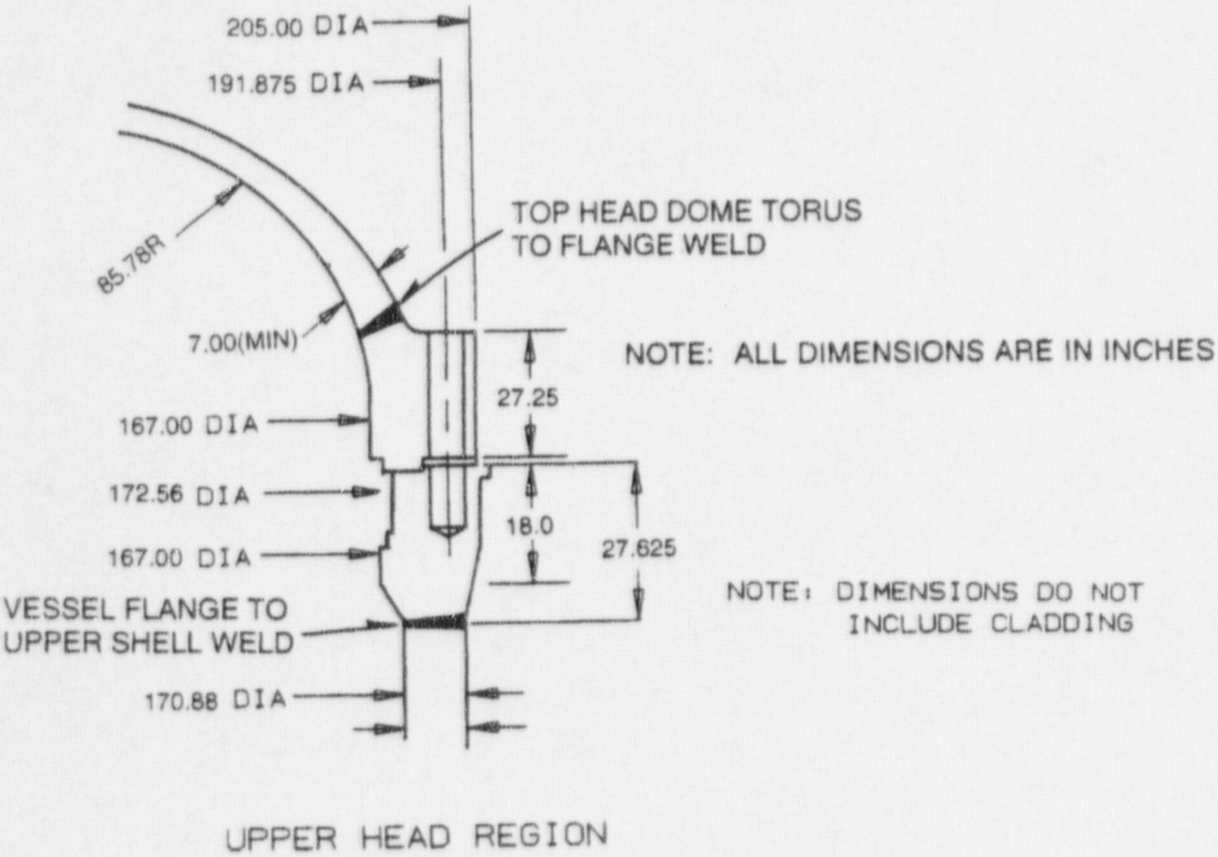

Figure 1. Geometry of the Upper Head/Flange Region of a Typical Westinghouse Four Loop Plant Reactor Vessel

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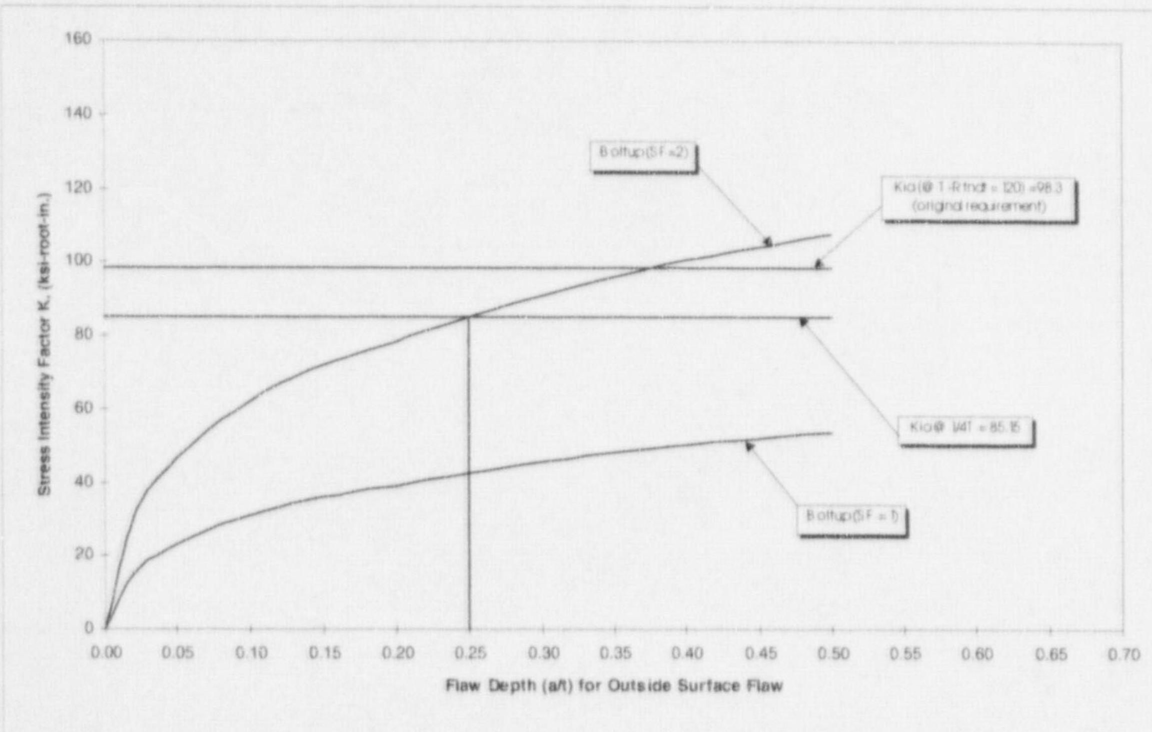

Figure 2. Crack Driving Force as a Function of Flaw Size: Outside Surface Flaw in the Closure Head to Flange Region Weld

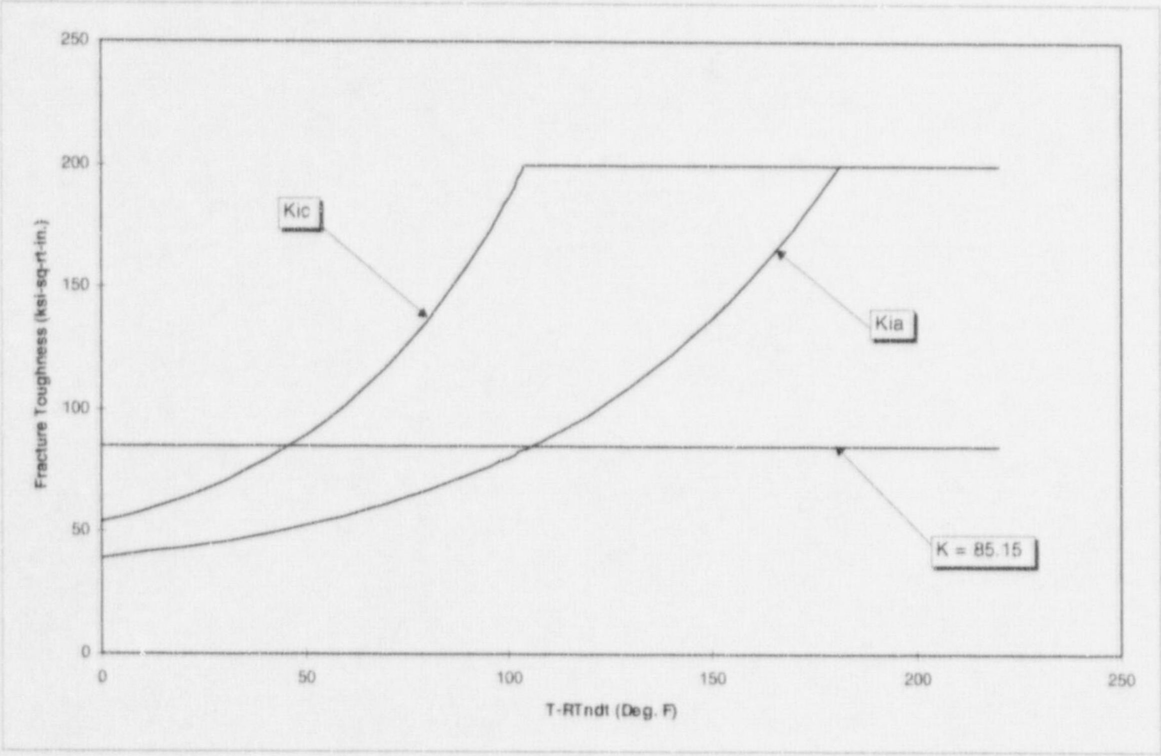

Figure 3. Determination of Boltup Requirement, Four Loop plant, using K_{IC}

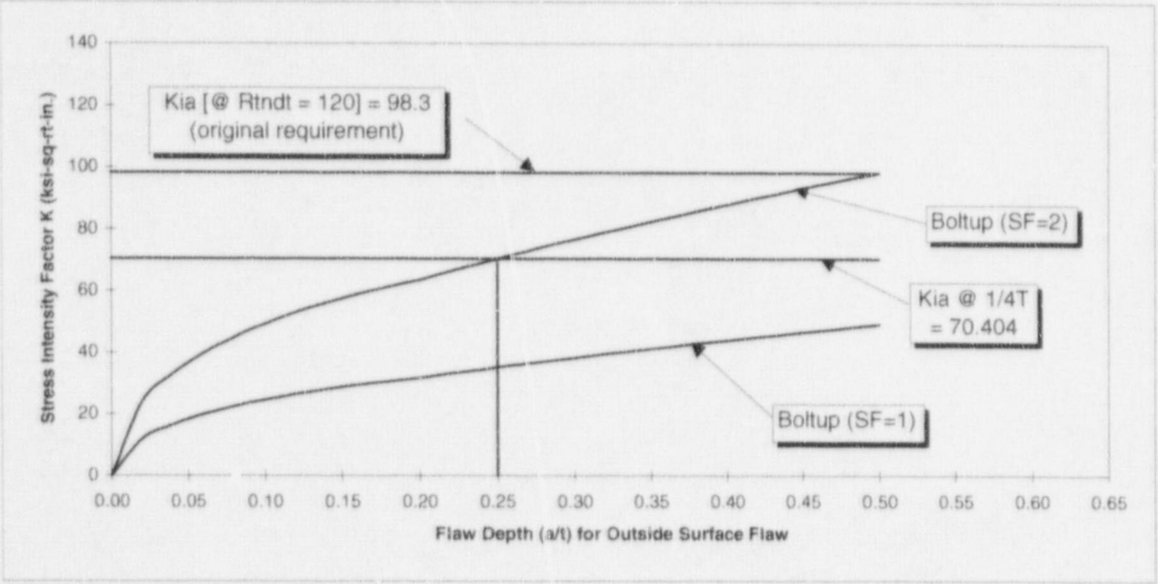

Figure 4. Crack Driving Force as a Function of Flaw Size: Outside Surface Flaw in the Closure Head to Flange Region Weld, Three Loop plant

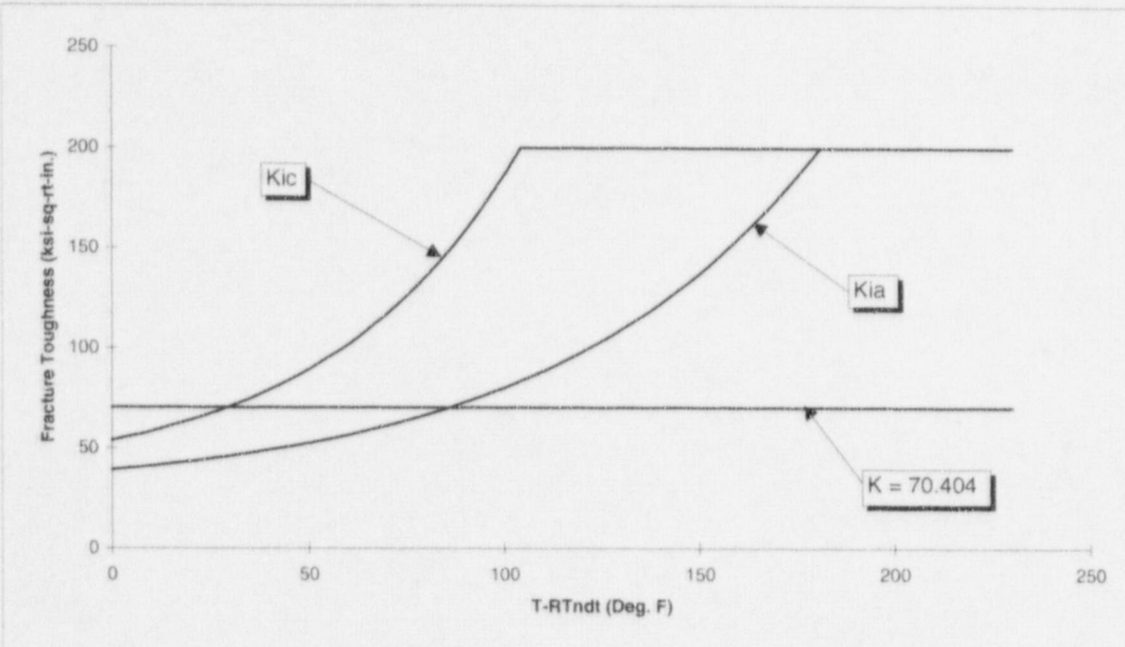

Figure 5. Determination of Boltup Requirement, Three Loop plant, using K_{IC}

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ISI 94-004
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CASE
N-640

CASES OF ASME BOILER AND PRESSURE VESSEL CODE

Approval Date: February 26, 1999
See Numeric Index for expiration and any reaffirmation dates.

Case N-640
Alternative Reference Fracture Toughness for Development of P-T Limit Curves
Section XI, Division 1

Inquiry: May the reference fracture toughness curve K_{IC}, as found in Appendix A of Section XI, be used in lieu of Fig. G-2210-1 in Appendix G for the developement of P-T Limit Curves?

Reply: It is the opinion of the Committee that the reference fracture toughness K_{IC} of Fig. A-4200- 1 of Appendix A may be used in lieu of Fig. G-2210-1 in Appendix G for the development of P-T Limit Curves. When this Case is employed LTOP Systems shall limit the maximum pressure in the vessel to 100% of the pressure allowed by the the P-T Limit Curves.