January 09, 2001
RC-01-0010

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Gentlemen:

Subject: VIRGIL C. SUMMER NUCLEAR STATION
DOCKET NO. 50/395
OPERATING LICENSE NO. NPF-12
RESPONSE TO QUESTIONS DATED
DECEMBER 28, 2000
MSP 00-0244

South Carolina Electric & Gas Company (SCE&G) submits the attached responses to the questions provided by the NRC by letter dated December 28, 2000. These questions pertain to the cracked weld in the "A" loop of the Reactor Coolant System, specifically about Westinghouse WCAP 15615 Revision 1, which supports future operation.

Comments concerning future planned inspections represent our current thinking and may supersede statements made in previous correspondence.

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

Very truly yours,

Stephen A. Byrne

PAR/SAB/dr
Attachments

c: N. O. Lorick
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DMS (RC-01-0010)

A001

Response to NRC questions received December 28, 2000

1. The crack growth results are presented in Figure 4-4 for postulated axial flaws and in Figures 4-5 to 4-7 for postulated circumferential flaws. Please clarify the following:

   a. Confirm that the K dependent equation, Crack Growth Rate = $1.4 \times 10^{-11}(K-9)^{1.16}$ m/sec, was used in generating the above mentioned figures.

Response

The crack growth rate equation listed in the question is correct. The units of K in the equation are Mpa-rt-m.

   b. Was K constantly being updated for each increment of crack extension? If not, discuss what was done.

Response

The value of K was updated constantly during the calculation, which was performed on a spreadsheet. The time increment was one hour.

   c. If a 2-D finite element method (FEM) model was used in calculating K, justify your results by comparing them to K values from another source; e.g., closed-form solutions for a simplified but applicable case, or published influence functions based on 3-D FEM results. Do the same if your K values were not from a 2-D FEM model. Further, for staff verification, provide the K value and all input loads relevant to Figure 4-4 for an axial crack of 0.6 inch deep and the K value and all input loads relevant to Figure 4-5 for a circumferential crack of the same depth.

Response

Stresses were calculated from standard expressions for piping, using the loads in Section 2 of the report. Since there is no geometric discontinuity, no finite element model was necessary. The stress distributions used are listed below. The values of K were calculated using the Raju-Newman approach recommended in ASME Section XI, Appendix A, but using a cubic fit of the stresses, as in the original reference.

Stress distributions used in the analysis

	Axial Stress, ksi		Hoop Stress, ksi	
A/t	w/residual stress	w/out residual stress	w/ residual stress	w/out residual stress
0.0 (ID)	43.18	13.18	30.22	15.22
0.2	12.16	13.40	29.89	14.69
0.4	-0.07	13.62	29.20	14.20
0.6	2.31	13.84	28.75	13.75
0.8	12.75	14.06	28.35	13.35
1.0 (OD)	22.38	14.28	27.97	12.97

d. How were the residual stresses modeled? Did you apply the residual stress distribution directly at the crack surface?

Response

Residual stresses were taken from the recommended residual stress for pipe flaw evaluation, given in the technical basis for Section XI pipe flaw evaluation, which is reference 3 of the report. The distribution of residual stress was added directly to the other stresses. The stress distributions are listed above.

e. Figure 4-4 indicates that if the initial crack depth was assumed to be 0.6 inches (a/t=0.256), the time for the crack to reach the Section XI allowable limit would be around one cycle. Provide your comments.

Response

The statement is correct. It is clear however, that there are no flaws in the pipes of that depth.

2. In making check calculations, we find that the stress intensity factor expressions in Appendix H of Section XI are about 20% more conservative than those of Appendix A. Please explain the difference, and the justification for your stress intensity factor calculations.

Response

The stress intensity factor expressions in Appendix H were developed and put in the Code in the mid to late 1980's, and were based on expressions available at that time. The expressions in Appendix A are based on the latest available expressions, which are more accurate. We have used an expression even more accurate than the expressions in Section XI, Appendix A, and that is the Raju-Newman expression for flawed cylinders. The stress intensity factor results for several cases are attached for your information, in six different plots.

3. Where did the value for Sm used in the allowable flaw size calculations for the Alloy 182 welds come from?

Response

The value was taken from the ASME Code for the associated base metal, Alloy 600, at 600° F. The specific value used was 23.3 ksi.

4. Why is it not appropriate to assume a large flaw like the flaw missed by the UT inspection of the loop A hot leg, 0.75 inch long by 0.615 inch deep, in the other loops?

Response

The 0.75 inch flaw in the A hot leg was not evaluated by UT examinations due to a specific pipe/weld irregular geometry coincident with the specific size and location of the flaw. If the flaw was incrementally longer or incrementally displaced in the axial direction, Wesdyne indicated that this flaw would have been seen in two sequential scans and therefore evaluated. The other nozzle welds appeared much more regular in geometry in the remote visual examination (video), thus decreasing the chance that a flaw was hidden in a specific geometric and axial location.

To provide further assurance that indications in the other nozzles are evaluated, ET has been performed. Although ET is not useful in determining Code compliance, the results may provide additional insight. Referring to Table 3-1 of WCAP 15615, three ET indications in the A hot leg were indeed undersized when comparing the length as defined by ET to that actually measured by destructive testing. All of these were 0.75 inches or longer in total length. However, five other indications defined by ET were either over estimated or had an exact correlation to the measured lengths. All of these indications were in the size range of less than or equal to 0.6 inches in length. One of these five examined destructively was not a crack (iron/titanium deposits). The analysis of this data does provide some reasonable correlation in the identification and sizing of actual PWSCC flaws in the size range of 0.6 inches and below. Based on this analysis, it is reasonable to assess the indications in the other loops as evaluated in the WCAP.

5. There is some concern that you have not addressed uncertainties in your evaluation of the eddy current results. In reviewing Table 3-1, it is seen that in some cases the eddy current results were unconservative relative to the destructively determined flaw sizes. The following scenario is suggested: The hot legs are the locations of concern, because of the higher temperature. Since the largest flaw of concern in the hot legs has a length of 0.25 inches, start with this length and increase it by a margin equal to the largest undercall by ECT. This would be the indication at 11-14 degrees, which was called as 1.0 inches long, but was actually 1.6 inches long. Thus the flaw length becomes 0.25 x 1.6 = 0.4 inches. The depth can be estimated conservatively by taking the smallest aspect ratio, which was 1.0, and using the aforementioned length. The depth then becomes 0.4 inched as well. Please evaluate this flaw.

Response

The methodology used to postulate a flaw size from a surface ET indication is described in the WCAP. This method was deliberately chosen taking into account the hot cell data and grouping the flaws into categories with similar characteristics of orientation (axial versus circumferential), length, and depth. We feel this is an appropriate and sound approach to conservatively postulate flaw sizes given that even further conservatism is applied to calculate potential growth rates.

However, as the NRC has pointed out, there are other assumptions that can be made. We feel the example provided does not have a sound technical basis nor does it provide good correlation to data found in the hot cell. Specifically, taking the worst case ET under-call from a hot cell flaw, applying an aspect ratio from the through wall flaw, and applying this uncertainty to the small ET indications, provides a different result. In evaluating this example, using an axial flaw in a hot leg pipe, and using figure 4-4 of the report, it was found that the allowable service time is 1.9 years, well beyond our presently scheduled Refuel 13 date.

We believe the assumed flaw sizes and shapes described in the WCAP report are realistic and sufficiently conservative, so the true allowable service time should be in excess of 3.2 years. We realize that the nature of these arguments contains a mixture of theory and empirical data and that absolute certainty is not possible. To compensate for this, a discussion on future inspections to provide additional assurance that uncertainty in the theoretical flaw growth rates and initial sizes are conservative is warranted. Please refer to the conclusion for this discussion.

6. Please provide the values for Pm and Pb as used in the analyses, and explain why Pe was not used.

Response

The values are listed below, for the axial stresses. For the hoop stresses, the only stress of importance is the pressure stress, and this is calculated using the nominal hoop stress equation, PD/2t, as shown in IWB 3640. The Pe is required only for flux welds, where the fracture toughness can be low. The only weld in this region is the Alloy 82/182 weld, which has very high fracture toughness. This is also the reason that no Z factors are needed for this evaluation. Even if Pe were to be added in, the results would not change.

Condition	Pm(ksi)	Pb(ksi)	Pe(ksi)
Normal/Upset	7.74	4.44	7.25
Emergency/Faulted	8.39	6.37	7.25

Conclusion

Much discussion has taken place internally to SCE&G and the NRC on what are appropriate inspection methods for future outages at V. C. Summer. Although V. C. Summer accepts the position of being the first nuclear facility in the United States to have such an issue with the reactor vessel nozzles, we feel that the question has become a generic industry issue. The EPRI Materials Reliability Project (MRP) has therefore accepted the challenge of better defining the most appropriate NDE methods based on the information gained from V. C. Summer and other plants throughout the world. Additionally, many domestic and international units will be inspected between this date and the V. C. Summer Refuel 13 in 2002. The industry will become much better informed on techniques and methods for detecting and sizing small cracks in large bore piping.

Therefore, we are compelled to perform the best and most meaningful NDE inspection available to ensure the integrity of the two susceptible hot legs at V. C. Summer. At a minimum, we will perform the best available ultrasonic inspection method on the B and C hot leg nozzle-to-pipe welds during V. C. Summer's Refuel

13, presently scheduled for the spring of 2002. Our calculations determined that the aggressive nature of SCC would not propagate a crack to unacceptable depth for approximately 3.2 years. Even using the extreme conservatism suggested by the NRC staff, we would not expect an unacceptable depth before 1.9 years. Therefore, Refuel 13 is an opportunistic time to use the best sizing method available to assure ourselves that the WCAP calculations and the methodology is appropriately conservative to operate cycle 14 to Refuel 14, presently scheduled for the fall of 2003.

In Refuel 14, SCE&G plans on performing the full 10-year inservice inspection, again using the best available, approved methodology and techniques. To commit to future ET examinations would be premature since much research and development must be done in order to make it a meaningful method. The ET data taken during the current outage was to research the extent of condition, not determine Code compliance. At present, we have evaluated extent of condition in the WCAP and now must continue to assure Code compliance in future inspections. The ET technique is not capable, in the absence of standards and acceptance criteria, of determining Code compliance. The industry initiative is focused on understanding and resolving the Code compliance issue regarding NDE techniques. If ET is developed to the point of having appropriate standards and procedures to compliment and assure Code compliance, then this falls into our commitment to use the best available, industry developed NDE techniques to characterize and evaluate potential flaws at V. C. Summer.

Finally, SCE&G recognizes the need to mitigate the effects of PWSCC. We will therefore be working on development of a mitigation strategy in conjunction with the MRP to implement in future outages

Stress Intensity Factor Plots

Various Cases

Curve Fit for Inside Axial Flaw Function 2:1 ratio (S=0 ksi)

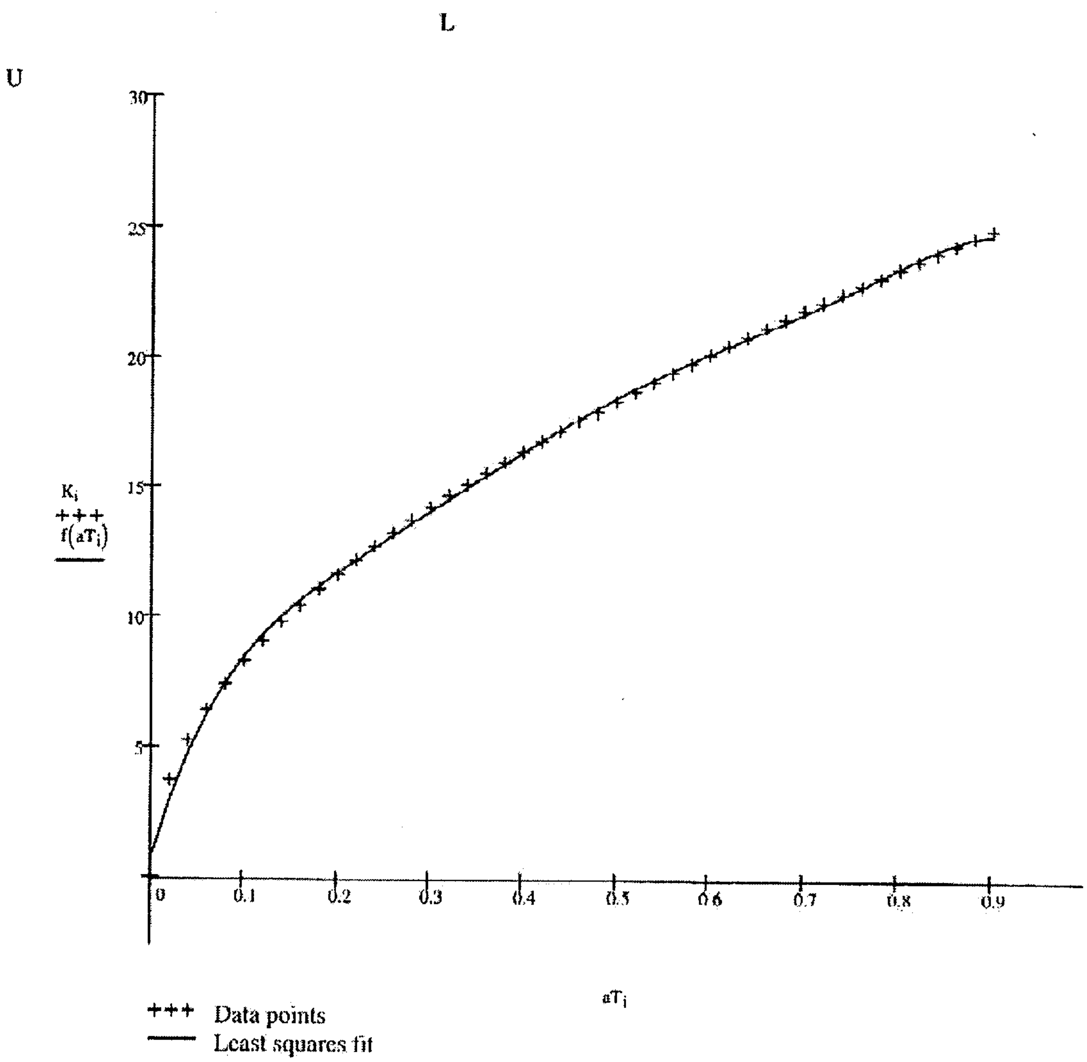
Choose degree of polynomial ------------> D := 6

Enter name of data file ---------------> A := READPRN("inside axial flaw, 21, S=0.prn")

Number of data points: 46

Polynomial Coefficients ----------> Coefficients of ^{d}

d =	$coeff_d$ =
0	0.799
1	123.052
2	-632.441
3	$2.035 \cdot 10^3$
4	$-3.467 \cdot 10^3$
5	$2.942 \cdot 10^3$
6	-978.639



Stress Intensity Factor K as a function of (a/t)

Calculated Mean Square Error: $MSE_p = 0.049$

$a_0 = 0.242$

Curve Fit for Inside Axial Flaw Function 2:1 ratio (S=30 ksi)

Choose degree of polynomial -----------> $D := 6$

Enter name of data file ---------------> A := READPRN("inside axial flaw, 21, S=30.prn")

Number of data points: 46

Polynomial Coefficients ----------> Coefficients of ^{d}

d =	$coeff_d$ =
0	1.584
1	244.769
2	$-1.248\cdot10^{3}$
3	$4.025\cdot10^{3}$
4	$-6.862\cdot10^{3}$
5	$5.824\cdot10^{3}$
6	$-1.938\cdot10^{3}$

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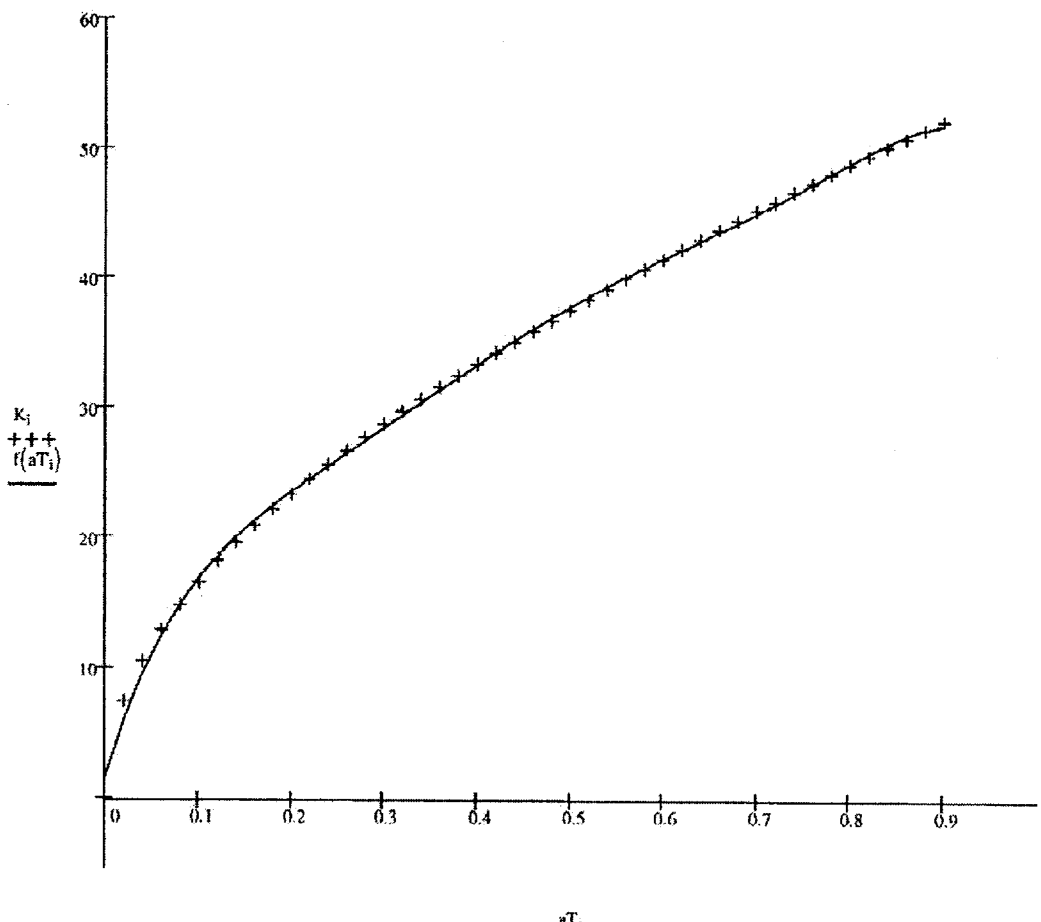


+++ Data points
—— Least squares fit

Stress Intensity Factor K as a function of (a/t)

Calculated Mean Square Error: $MSE_p = 0.192$

$a_o = 0.08$

Curve Fit for Inside Circumferential Flaw Function, 2:1 ratio (S=0 ksi)

Choose degree of polynomial ------------> $D := 6$

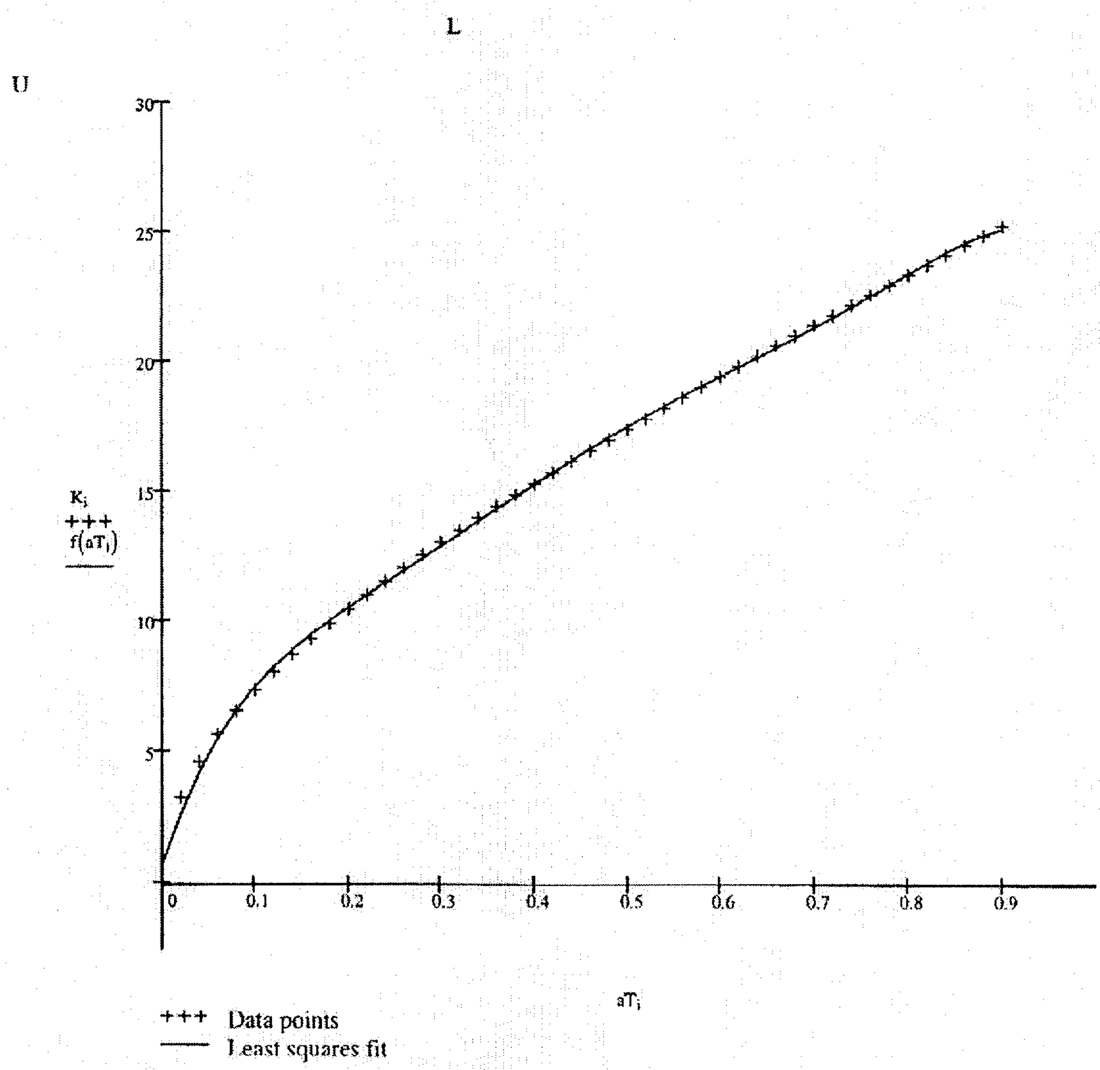
Enter name of data file ---------------> A := READPRN("inside circumferential flaw, 21, S=0.prn")

Number of data points: 46

Polynomial Coefficients ---------->

Coefficients of ^{d}

d =	$coeff_d$ =
0	0.691
1	107.172
2	-538.26
3	$1.743 \cdot 10^3$
4	$-2.974 \cdot 10^3$
5	$2.525 \cdot 10^3$
6	-840.589



Stress Intensity Factor K as a function of (a/t)

Calculated Mean Square Error: $MSE_p = 0.037$

$a_o = 0.308$

Curve Fit for Inside Circumferential Flaw Function, 6:1 ratio (S=0 ksi)

Choose degree of polynomial ------------> $D := 6$

Enter name of data file ----------------> A := READPRN("inside circumferential flaw, 61, S=0.prn")

Number of data points: 46

Polynomial Coefficients ----------> Coefficients of ^{d}

d =	$coeff_d$ =
0	1.089
1	159.773
2	-815.752
3	$2.74 \cdot 10^3$
4	$-4.703 \cdot 10^3$
5	$4.018 \cdot 10^3$
6	$-1.348 \cdot 10^3$

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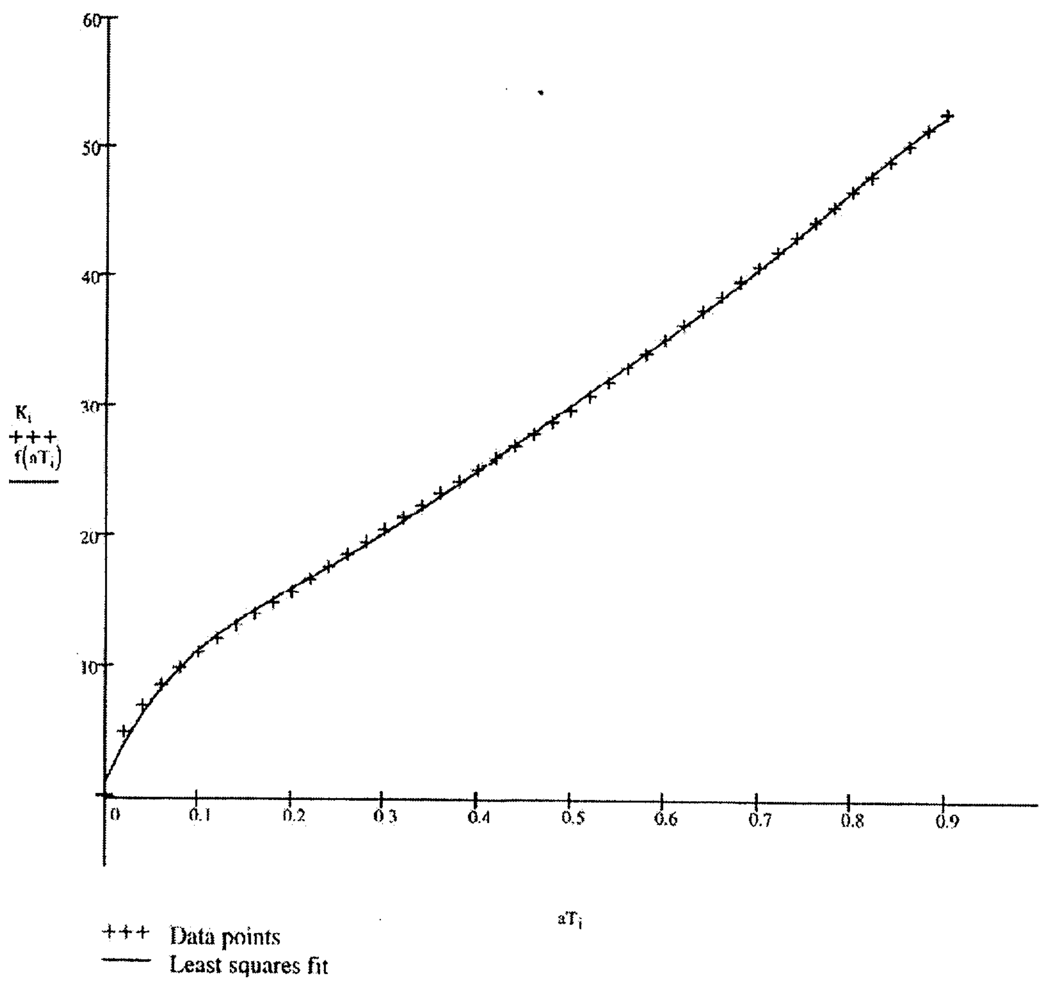

Stress Intensity Factor K as a function of (a/t)

Calculated Mean Square Error: $MSE_p = 0.1$ $a_0 = 0.151$

Curve Fit for Inside Circumferential Flaw Function, 2:1 ratio (S=30 ksi)

Choose degree of polynomial ----------> $D := 6$

Enter name of data file --------------> A := READPRN("inside circumferential flaw, 21, S=30.prn")

Number of data points: 46

Polynomial Coefficients ----------> Coefficients of ^{d}

d =	coeff$_d$ =
0	2.396
1	312.092
2	$-2.275 \cdot 10^3$
3	$7.231 \cdot 10^3$
4	$-1.19 \cdot 10^4$
5	$9.911 \cdot 10^3$
6	$-3.266 \cdot 10^3$

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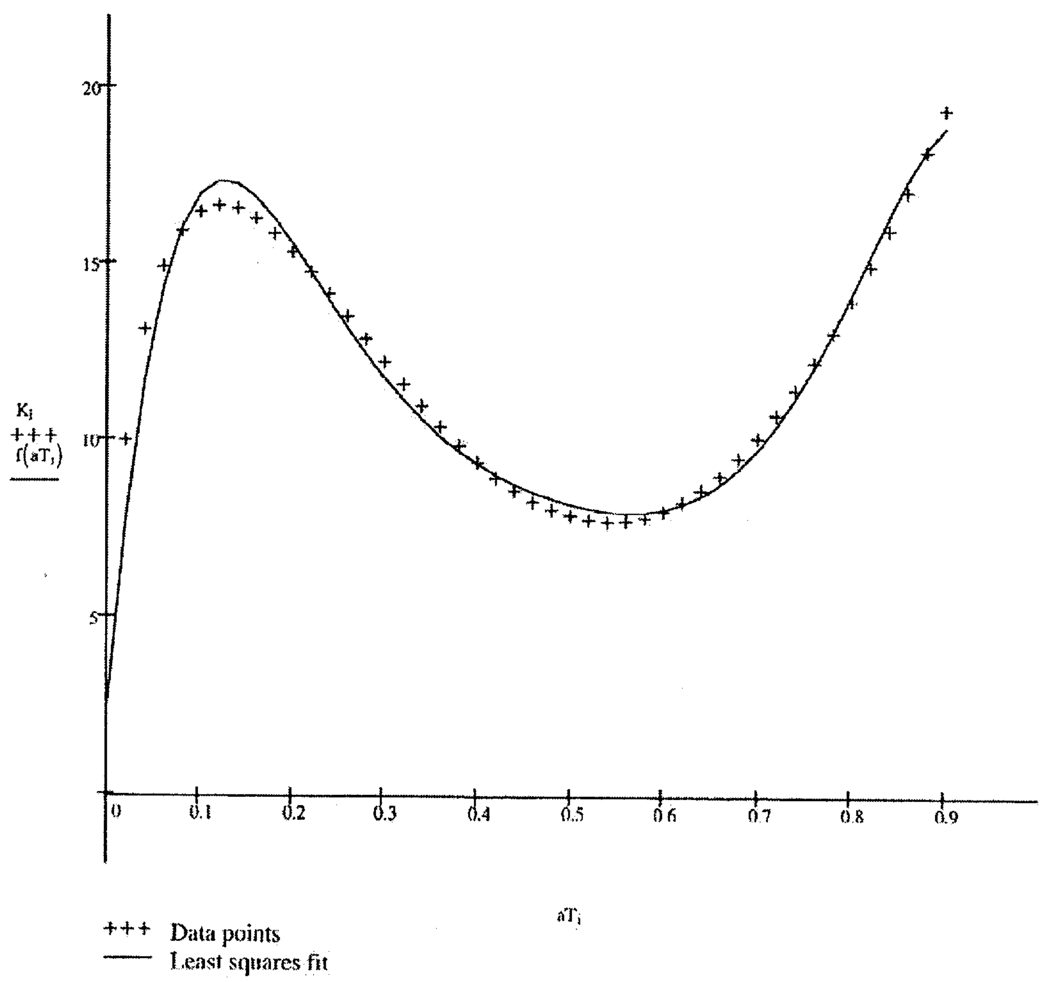

Stress Intensity Factor K as a function of (a/t)

Calculated Mean Square Error: $MSE_p = 0.439$ $a_o = 0.056$

Curve Fit for Inside Circumferential Flaw Function, 6:1 ratio (S=30 ksi)

Choose degree of polynomial ------------> $D := 6$

Enter name of data file ----------------> A := READPRN("inside circumferential flaw, 61, S=30.prn")

Number of data points: 46

Polynomial Coefficients ----------> Coefficients of T^d

d =	$coeff_d$ =
0	3.665
1	475.663
2	$-3.378 \cdot 10^3$
3	$1.1 \cdot 10^4$
4	$-1.849 \cdot 10^4$
5	$1.56 \cdot 10^4$
6	$-5.177 \cdot 10^3$

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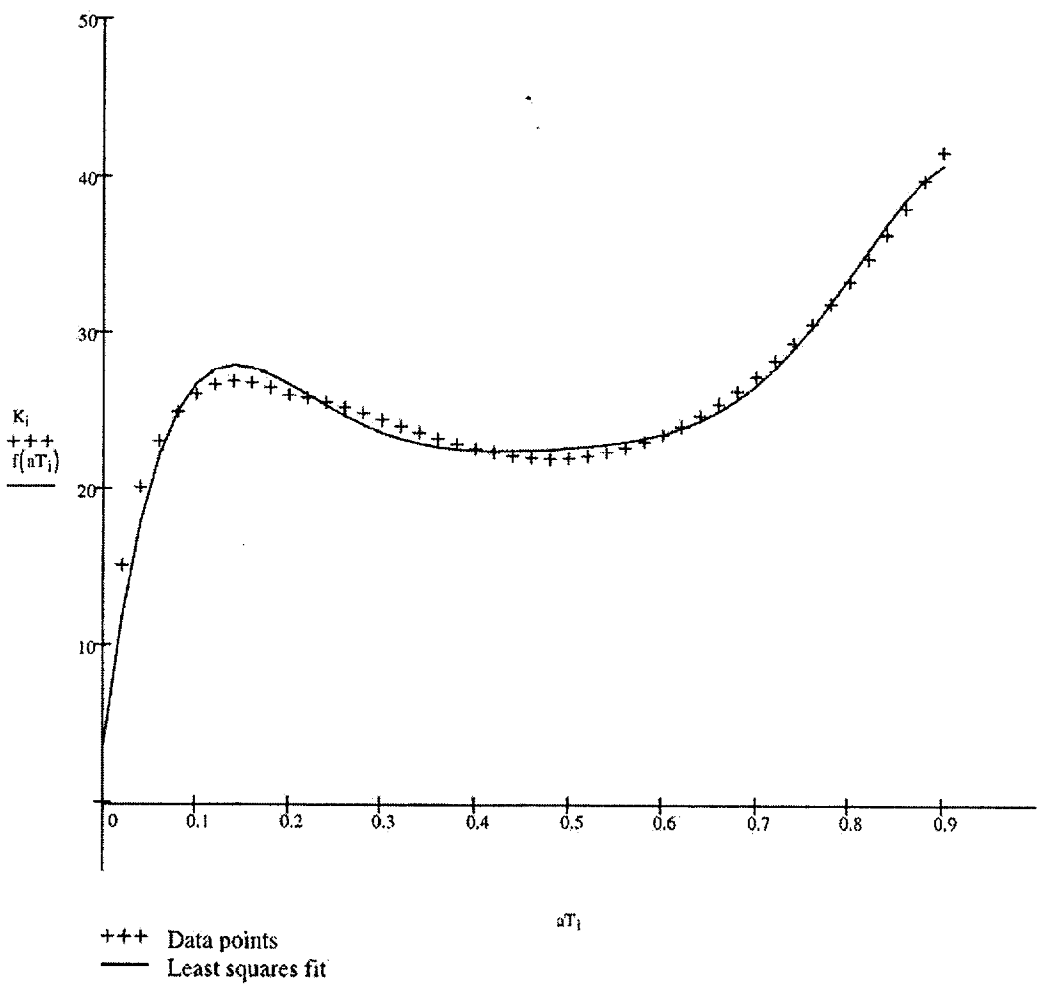

Stress Intensity Factor K as a function of (a/t)

Calculated Mean Square Error: $MSE_p = 1.062$ $a_o = 0.027$