TOLEDO
EDISON

A Centerior Energy Company

DONALD C. SHELTON
Vice President—Nuclear
(419) 249-2300

Docket Number 50-346

License Number NPF-3

Serial Number 1839

August 23, 1990

United States Nuclear Regulatory Commission
Document Control Desk
Washington, D. C. 20555

Subject: High Pressure Injection/Makeup Nozzle
Updated Fracture Mechanics Analysis

Gentlemen:

The Toledo Edison Company's (TE) letter to the NRC dated May 25, 1990, (Serial Number 1808) documented a May 10, 1990 meeting with the NRC Staff regarding the status of the High Pressure Injection (HPI)/Makeup Nozzle and Thermal Sleeve Program at the Davis-Besse Nuclear Power Station Unit 1 (DBNPS). Toledo Edison undertook this program of comprehensive actions to address the implications of the discovery of the failed HPI/Makeup nozzle thermal sleeve during the fifth refueling outage. Toledo Edison's May 3, 1990 letter to the NRC (Serial Number 1802) summarized the background and previous TE/NRC correspondence relating to this subject. As part of the program actions, Toledo Edison presented in letter Serial Number 1802 a fracture mechanics analysis to demonstrate the acceptability of the affected nozzle for 40 years of HPI-only service (the normal makeup flow path was re-routed to an alternate HPI nozzle during the sixth refueling outage), conservatively assuming the existence of an undetected flaw penetrating 0.125 inches into the base metal. This flaw depth is consistent with the detection capabilities of the enhanced ultrasonic testing system which was developed as part of the program.

During the May 10, 1990 meeting, the NRC Staff questioned the degree of conservatism afforded by the **pc-CRACK** fracture mechanics models used for the evaluation. The NRC Staff suggested augmenting the analysis by more conservatively modeling the nozzle configuration using a crack emanating radially from a hole in an infinite plate. Although, Toledo Edison believes that the **pc-CRACK** flaw models which were used are appropriately conservative and most accurately represented the nozzle configuration, Toledo Edison agreed in Serial Number 1808 to perform an additional analysis to assess the sensitivity of the conclusions to the suggested more conservative model. This additional analysis is now complete.

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THE TOLEDO EDISON COMPANY EDISON PLAZA 300 MADISON AVENUE TOLEDO, OHIO 43652

The enclosed letter from Structural Integrity Associates (SI) to Toledo Edison dated July 25, 1990, (EXT 90-05083) documents the results of the analysis. The additional analysis using the more conservative fracture mechanics model suggested by the NRC Staff continues to demonstrate the acceptability of the nozzle for 40 years of HPI-only service, conservatively assuming the existence of an undetected flaw penetrating 0.125 inch into the base metal. The peak stress intensity at the location of maximum stress was calculated to be approximately 56 ksi-(inch)$^{1/2}$. Based on this result, the allowable flaw depth for brittle fracture prevention is through wall because the stress intensity does not exceed the ASME Code factored fracture toughness of 63.2 ksi-(inch)$^{1/2}$ for the nozzle material. This same conclusion was supported by the previous analysis results.

Fatigue flaw growth was also projected using the more conservative model. The resultant flaw growth at the most structurally limiting location was projected to be less than 25 mils for an additional 40 years of HPI-only service. This result compares favorably with the less than 20 mils flaw growth presented in letter Serial Number 1802 and does not represent a significant increase.

Therefore, Toledo Edison believes that the additional analysis to assess the structural integrity of the nozzle using a more conservative fracture mechanics model supports the earlier conclusion that the nozzle is acceptable for continued service as discussed in letter Serial Number 1802.

If you have any questions regarding the information provided by this letter, please contact Mr. R. W. Schrauder, Manager - Nuclear Licensing, at (419) 249-2366.

Very truly yours,

DC Shelton

PWS/mmb

Enclosure

cc: P. M. Byron, DB-1 NRC Senior Resident Inspector
A. B. Davis, Regional Administrator, NRC Region III
M. D. Lynch, DB-1 NRC Senior Project Manager
Utility Radiological Safety Board of Ohio

STRUCTURAL INTEGRITY ASSOCIATES, INC.

3150 Almaden Expressway
Suite 226
San Jose, CA 95118
(408) 978-8200
FAX (408) 978-8964

Fossil Plant Operations
66 South Miller Road
Suite 10
Akron, Ohio 44313
(216) 864-8886
FAX (216) 869-5461

EXT-90-05083

July 25, 1990
PCR-90-068
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DESIGN ENGINEERING

Mr. John Nevshemal
Design Staff Engineer
Toledo Edison Company
Davis-Besse Nuclear Station
5501 North Street, Route 2
Oak Harbor, OH 43449-9760

Subject: Updated Fracture Mechanics Analysis of Davis-Besse HPI Nozzle In Response to NRC Request

References:
1. Report No. SIR-90-032, Rev. 0, "Fracture Mechanics Evaluation of Davis-Besse HPI Nozzle Considering Increased Clad Thickness and a Sharp Blend Radius Corner"
2. ASME Paper 78-PVP-91, "Fracture Mechanics Analysis of JAERI Model Pressure Vessel Test", Presented at 1978 Pressure Vessels and Piping Conference, Montreal, Canada June 25-30, 1978.

Dear John:

This letter provides a summary of updated fracture mechanics analysis performed by Structural Integrity Associates (SI) regarding the Davis-Besse HPI nozzle in response to a request made by the Nuclear Regulatory Commission (NRC) during the Toledo Edison Company presentation to the NRC on May 10.

Background

In the Reference 1 report, fracture mechanics evaluations were performed by SI to justify continued operation of the HPI nozzle in the presence of a flaw. The evaluations were based on a revised geometry of the HPI nozzle provided to SI by Toledo Edison. Two critical sections (Sections AA and BB in Figures 1 and 2) were used in the evaluations. Separate fracture mechanics models from the pc-CRACK computer software library were used for each section. For Section AA, the model used was a semi-circular crack in half space. A nozzle corner flaw model was used for Section BB. These models, together with the analyses performed in the Reference 1 report, demonstrated that the allowable flaw for brittle fracture considerations is effectively through-wall.

Therefore, ductile failure considerations prevail, resulting in a Section XI allowable flaw size of 1.6 inches. The analysis also demonstrated that a flaw through the cladding and 1/8 inch into the base metal will grow less than 20 mils for an additional 10-year design life.

During the May 10, 1990, NRC presentation, a question was raised regarding the validity of the models used in these fracture mechanics evaluations. The NRC noted that even though the models are representative of the HPI nozzle configuration, and have been validated with respect to an experimental crack growth study in Reference 2, they are not as conservative as a second model presented in Reference 2. In this model the nozzle is considered as an infinite plate with a hole in the middle and a crack emanating from this hole. This letter report provides an update of the referenced analyses, considering this second, more conservative model, and compares the results with the previous models.

The results of this new analysis demonstrate that with this new model, the conclusions of the referenced report are essentially unchanged. The allowable flaw size based on brittle fracture considerations is still through-wall and the 40-year crack growth is less than 25 mils. Details of the analysis are provided below.

Stress Analysis

The finite element model of the HPI nozzle has been described in the Reference 1 report. Details of the critical region of the model are shown in Figures 1 and 2. This model was used to determine through-wall stresses due to internal pressure and the HPI initiation thermal transient. Stresses for the most critical sections (Sections AA and BB) previously provided in Tables 2-1 and 2-2 of the Reference 1 report were used to perform a fracture mechanics evaluation to determine critical flaw size and crack growth during a 40-year period.

Fracture Mechanics Analysis

The fracture mechanics analyses were performed using the linear-elastic option of the **pc-CRACK** computer program. The through-wall stresses at the two critical sections from the referenced report were curve-fit utilizing a third order polynomial to account for the variation along the through-wall thickness. The curve-fit of the stresses are shown in Figures 3 through 6. For the present study, a model consisting of a hole in an infinite plate with crack emanating from the side of the hole was chosen from the **pc-CRACK** library and used to develop the stress intensity versus flaw depth curves for both Sections AA nd BB. These curves are shown in Figures 7 and 8. Also shown on these figures is the factored material fracture toughness determined previously in the Reference 1 report. The intersection of the total applied stress intensity factor curve (pressure plus thermal; curve 3) and the factored fracture toughness value (curve 4) results in the ASME Section XI allowable flaw for brittle fracture prevention. This yields an allowable flaw depth which is through-wall at both sections. For comparison purposes, the stress intensity curves from the previous analyses in the Reference 1 report are shown in Figures 9 and 10. It can be seen that the shape of the curves are essentially the same, even though this present analysis provides slightly higher stress intensity factors. Nevertheless, both models demonstrate that the Code allowable flaw depth for brittle fracture considerations is through-wall.

Crack Growth Analyses

Similar to the Reference 1 report, crack growth analyses were performed at the two critical sections to determine crack growth for a 40 year period. The bilinear law in Section XI of the ASME Code was used. Initial crack sizes of 0.325 and 1.0 inch were used for Sections AA and BB respectively. These values represent the thickness of the cladding plus 1/8 inch of the underlying base metal and are unchanged from the initial flaw depths used in the original analysis. A total of 240 startup/shutdown cycles and 80 HPI cycles, as used in Reference 1 were considered in these analyses. In the analyses of Reference 1, various combinations of the startup/shutdown and the HPI transients were investigated in the crack growth analyses, all resulting in essentially the same crack growth. Hence in this evaluation only one of the combinations was considered. This combination assumes the events to be uniformly distributed throughout the 40-year evaluation period (six startup/shutdown and two HPI transients per year). The results of the crack growth analyses are shown in Figures 11 and 12. It can be seen that the maximum crack growth is less than 25 mils compared to 20 mils in the Reference 1 report.

Conclusion

The fracture mechanics evaluations of the Davis-Besse HPI nozzle utilizing a fracture mechanics model consisting of an infinite plate with a hole in the middle and a crack emanating from the side of the hole have shown that the critical flaw size is through-wall, including the ASME Code margin. The analyses have also shown that utilizing this model, a flaw through the cladding and 1/8 inch of base metal will grow less than 25 mils for a 40-year evaluation period. These results are only slightly different than those reported in Reference 1 and produce the same general conclusions as in that report.

Structural Integrity appreciates the opportunity of being of service to Toledo Edison Company. If you have any questions or comments, do not hesitate to call.

Very truly yours,

P. C. Riccardella
Associate

for A. J. Giannuzzi
Associate

sa
Enclosures
cc: TECO-01Q-102

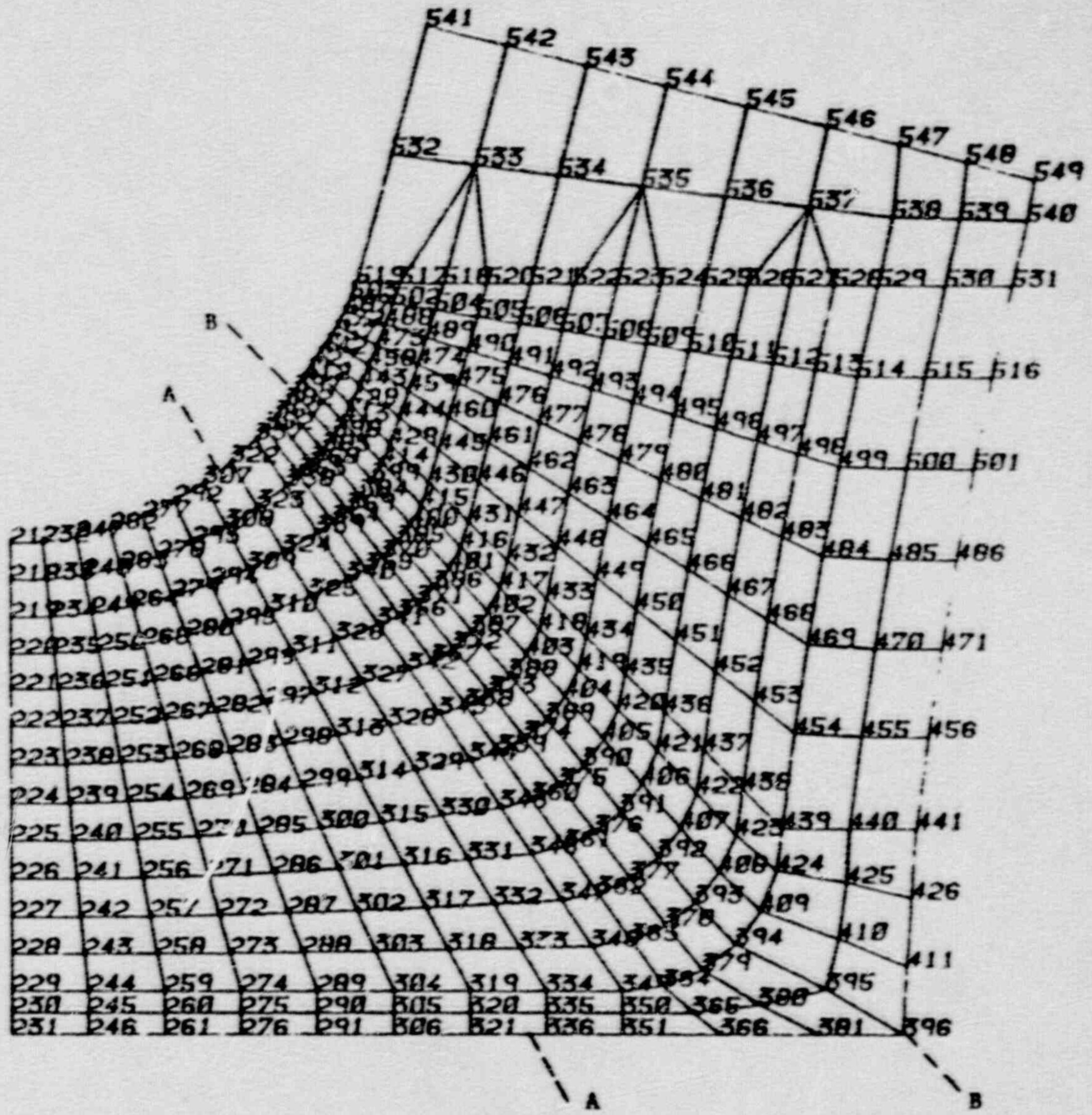

Figure 1. Finite Element Model - Node Numbers

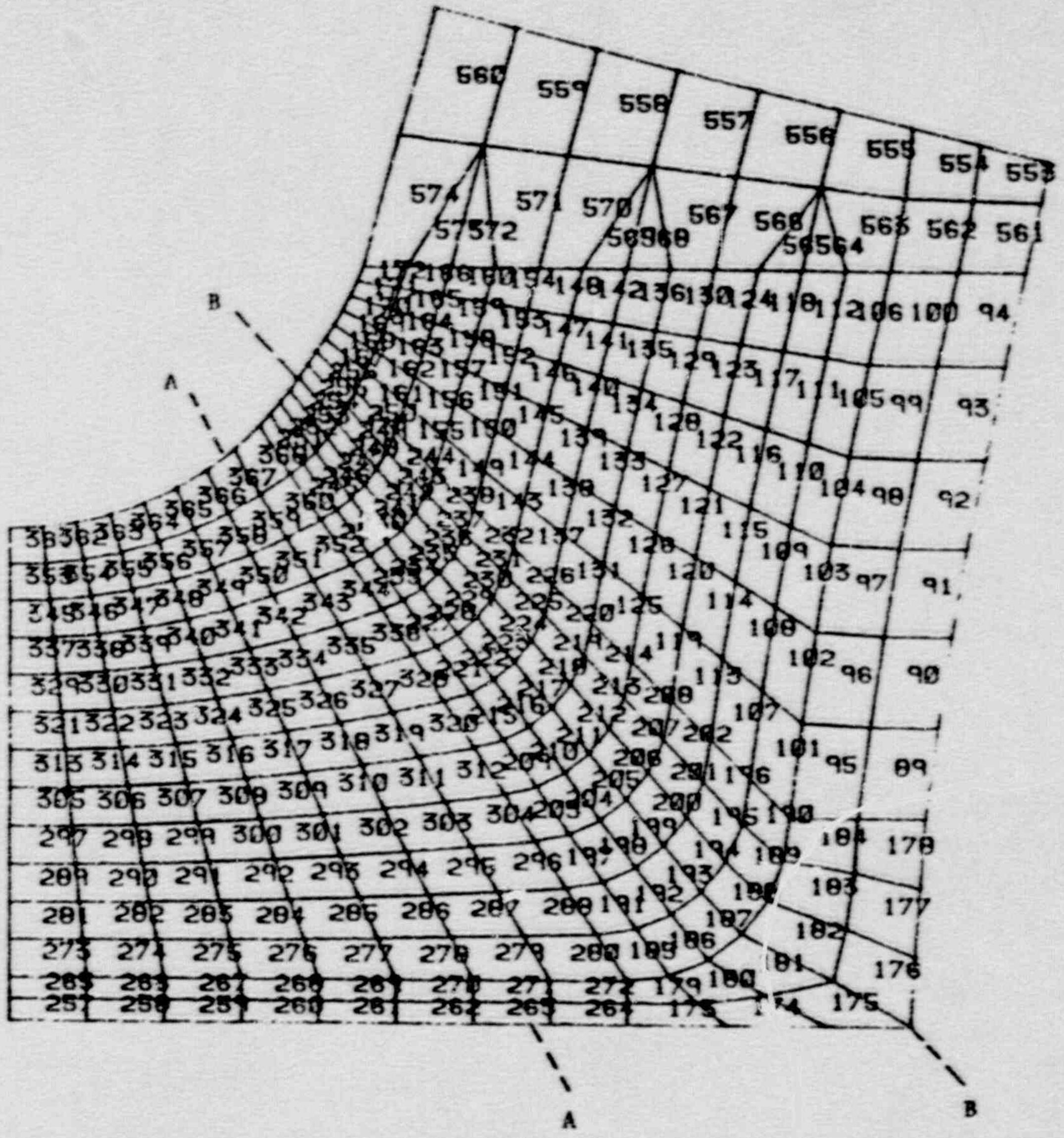

Figure 2. Finite Element Model - Element Numbers

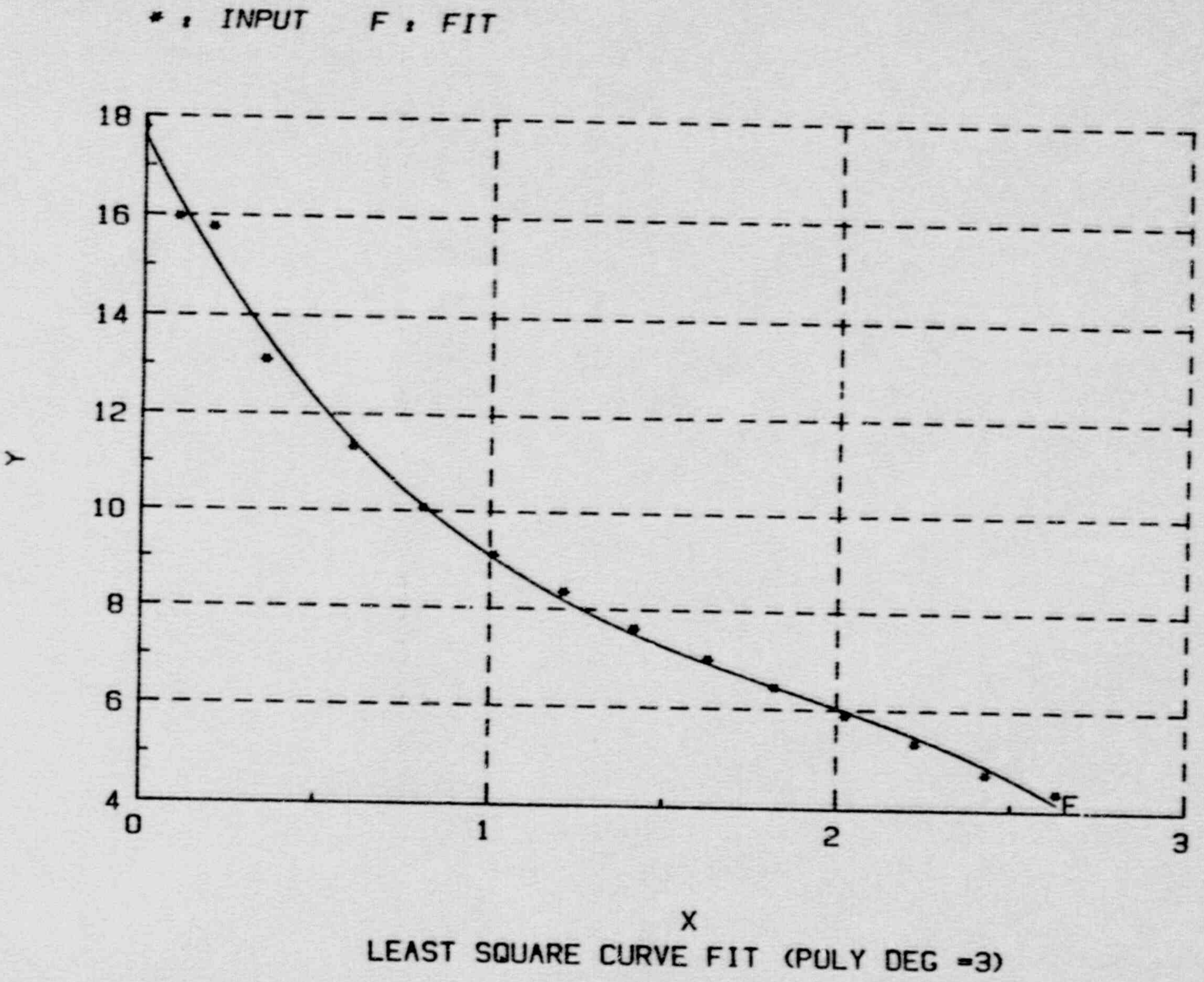

Figure 3. Curve-fit of Through-wall Pressure Stresses for Section AA

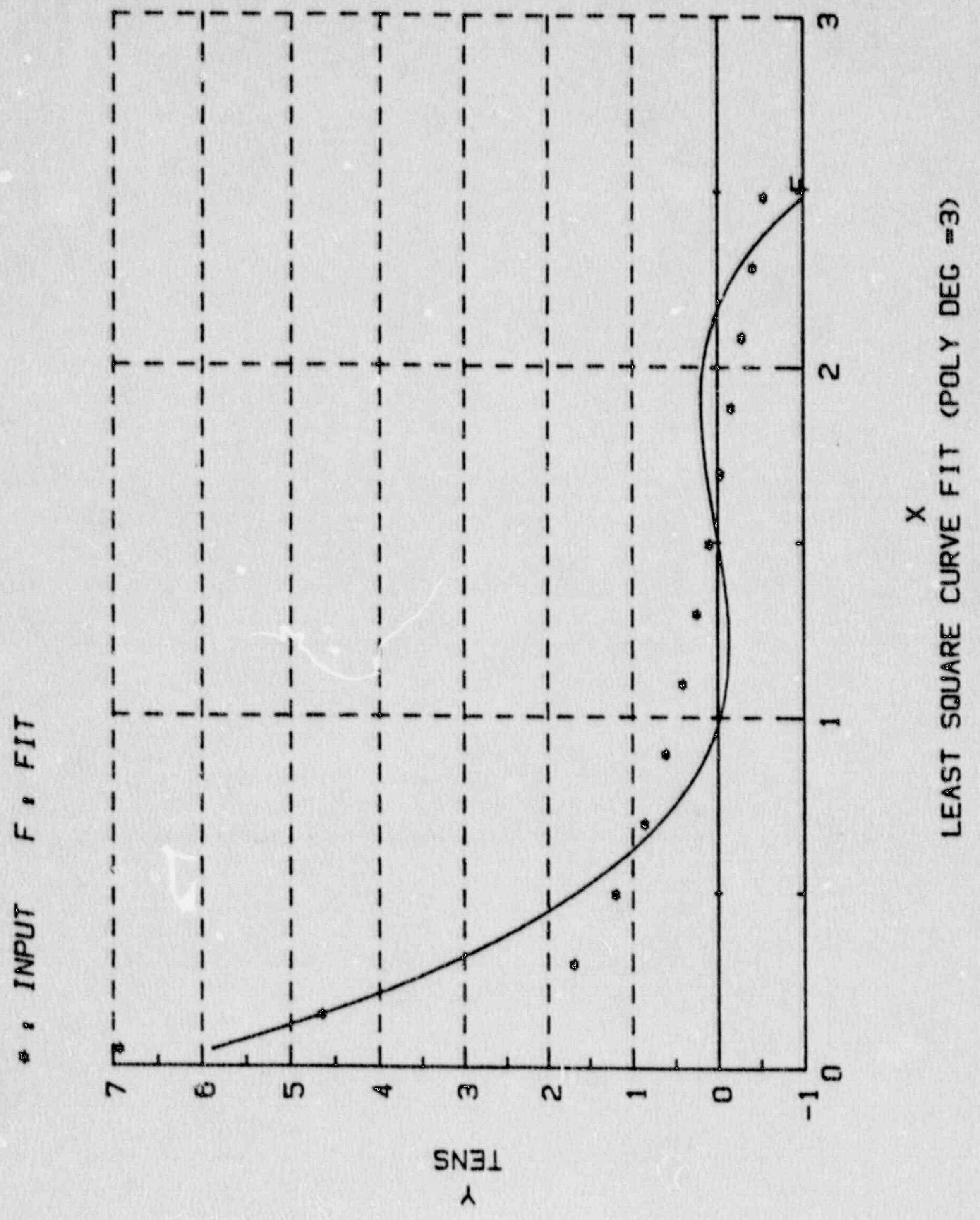

Figure 4. Curve-fit of Through-wall HPI Initiation Transient Stressses for Section AA

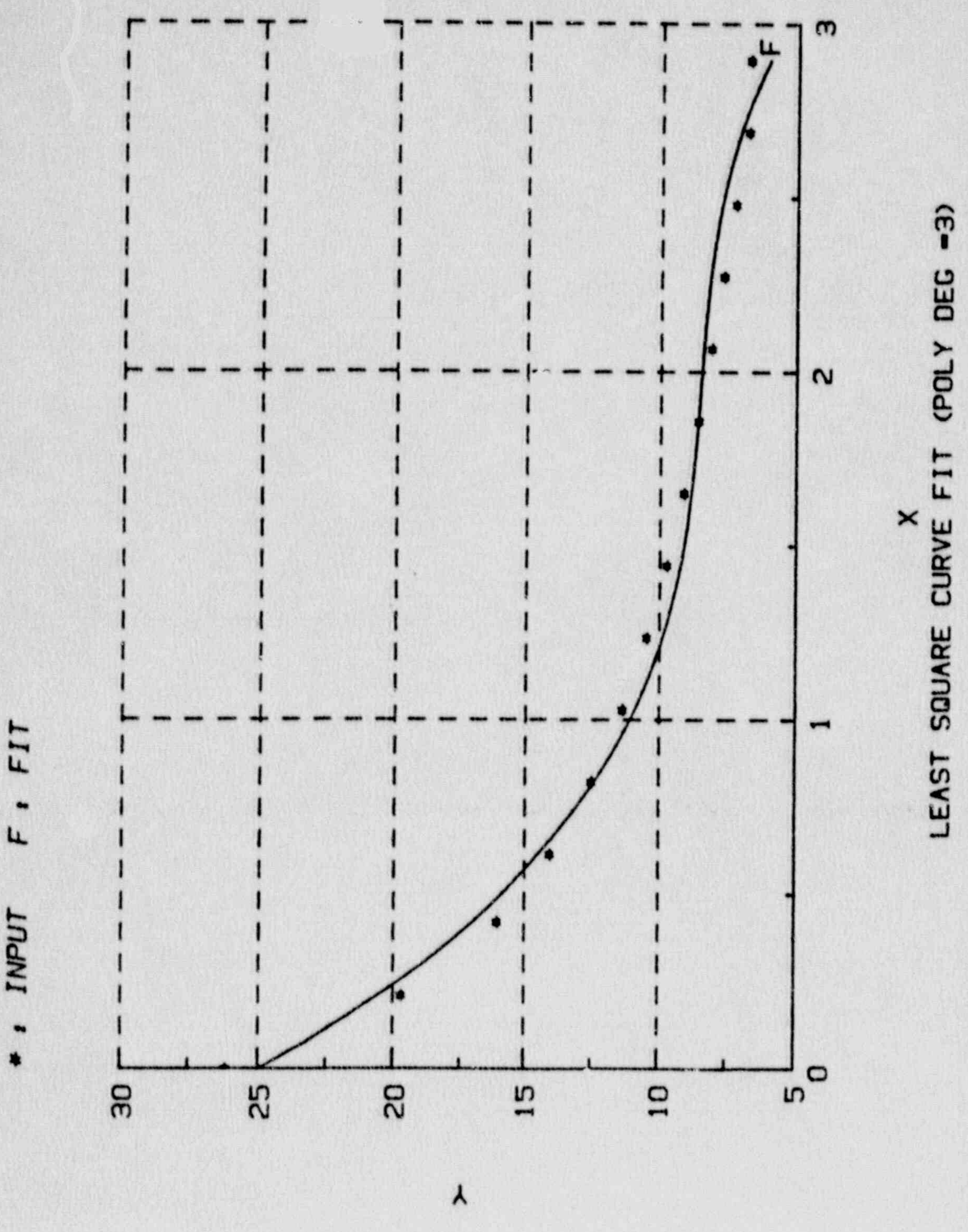

Figure 5. Curve-fit of Through-wall Pressure Stresses for Section BB

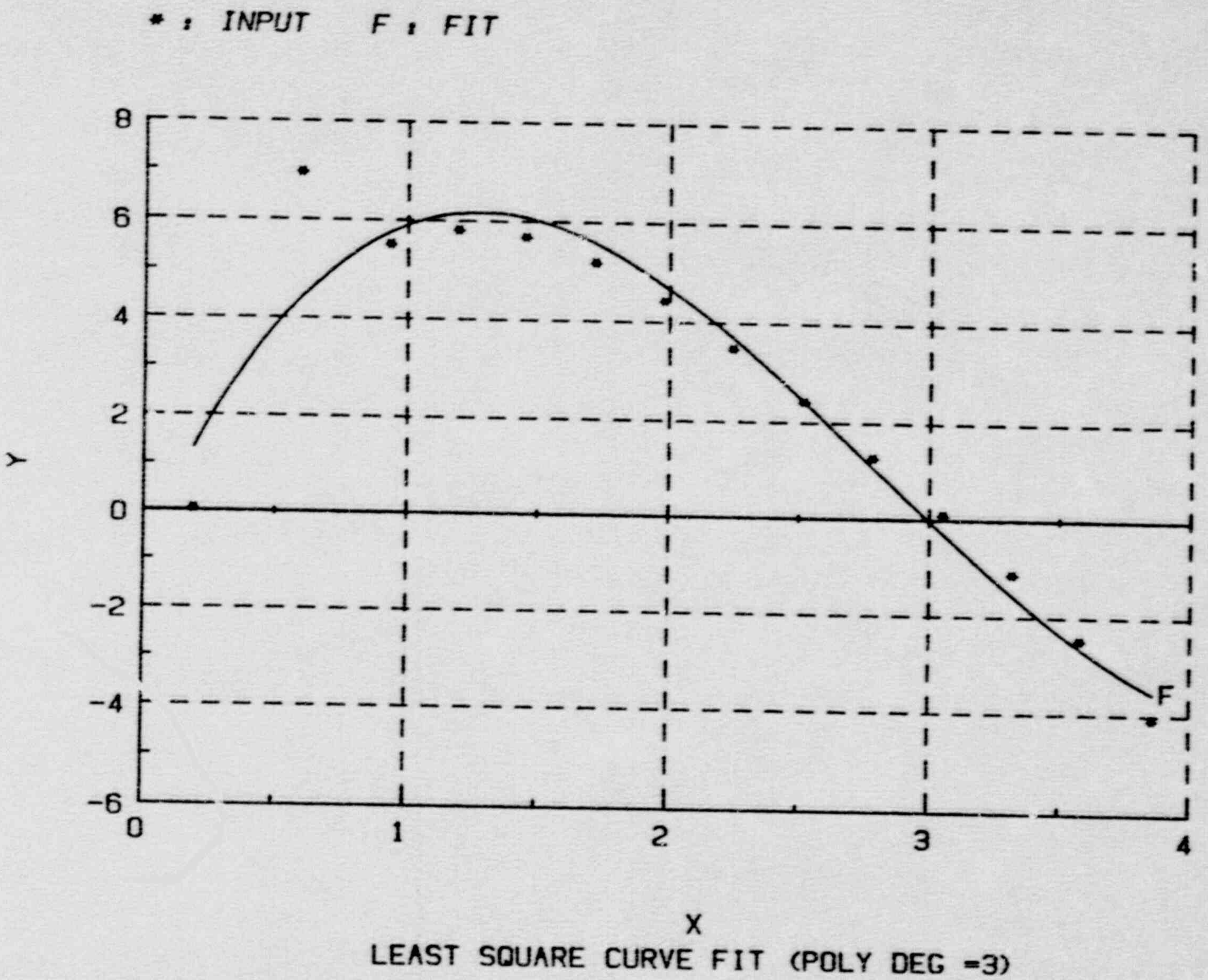

Figure 6. Curve-fit of Through-wall HPI Initiation Transient Stressses for Section BB

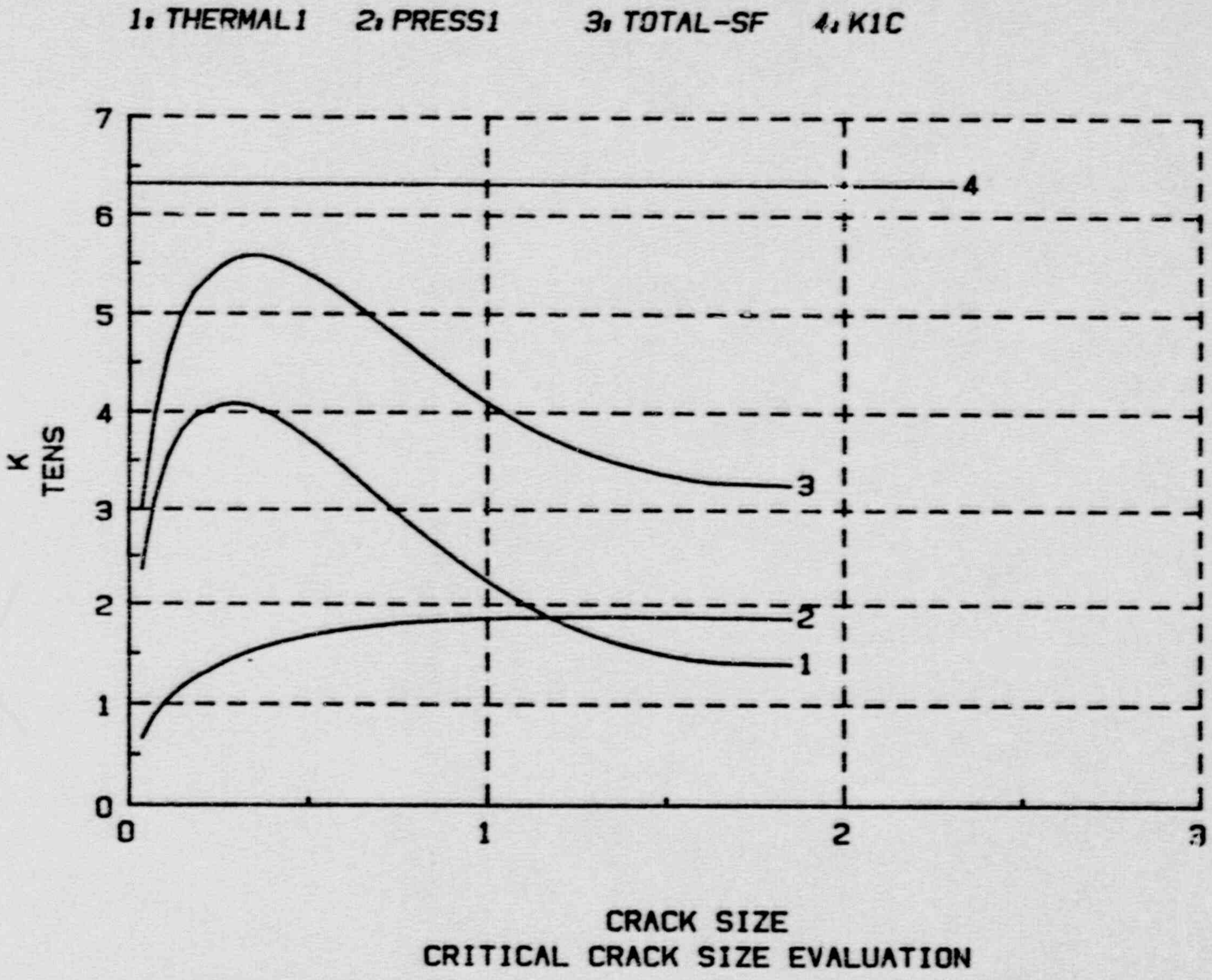

Figure 7. Applied Versus Allowable Stress Intensity for Section AA - Crack Emanating from a Hole in an Infinite Plate Model

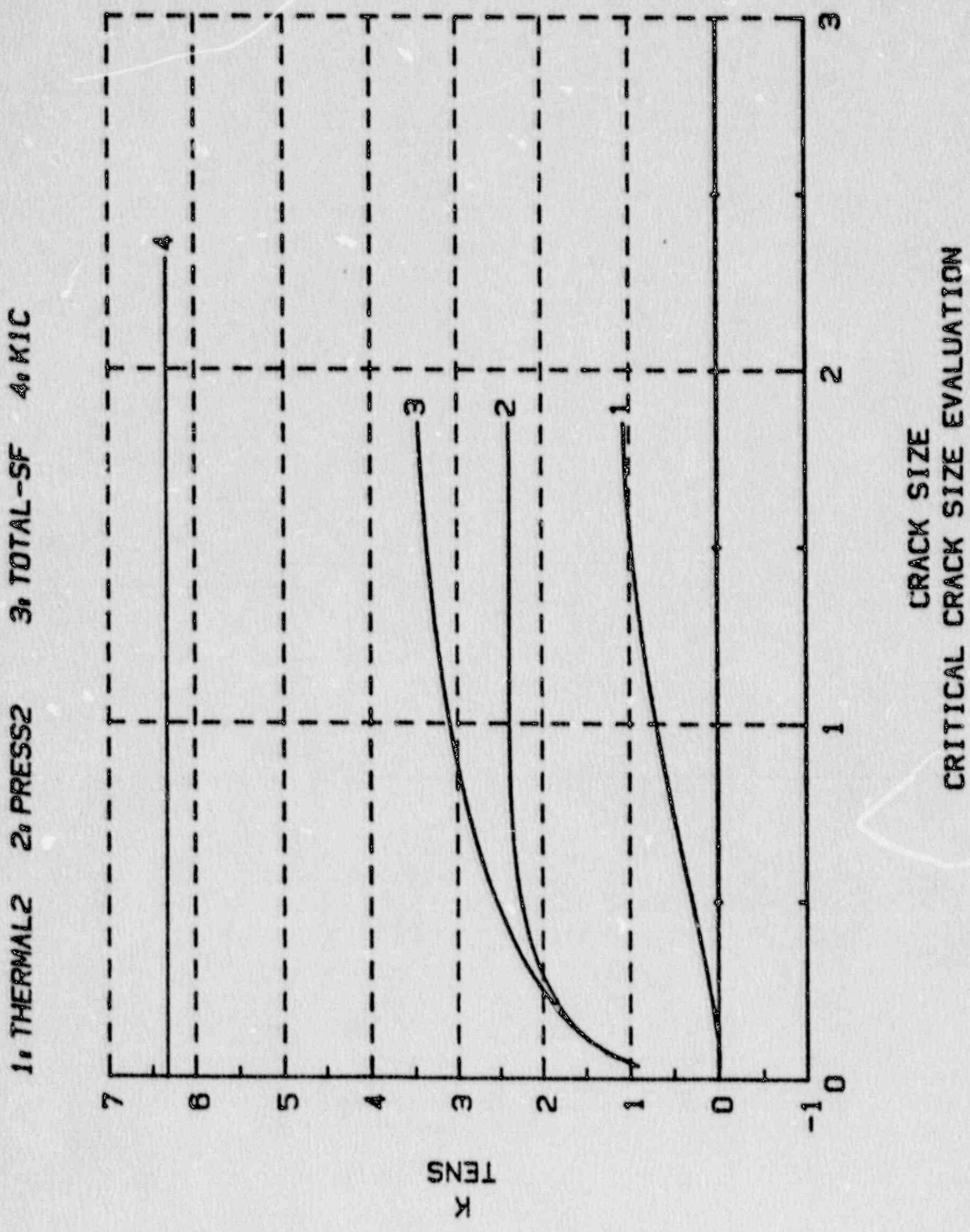

Figure 8. Applied Versus Allowable Stress Intensity for Section BB - Crack Emanating from a Hole in an Infinite Plate Model

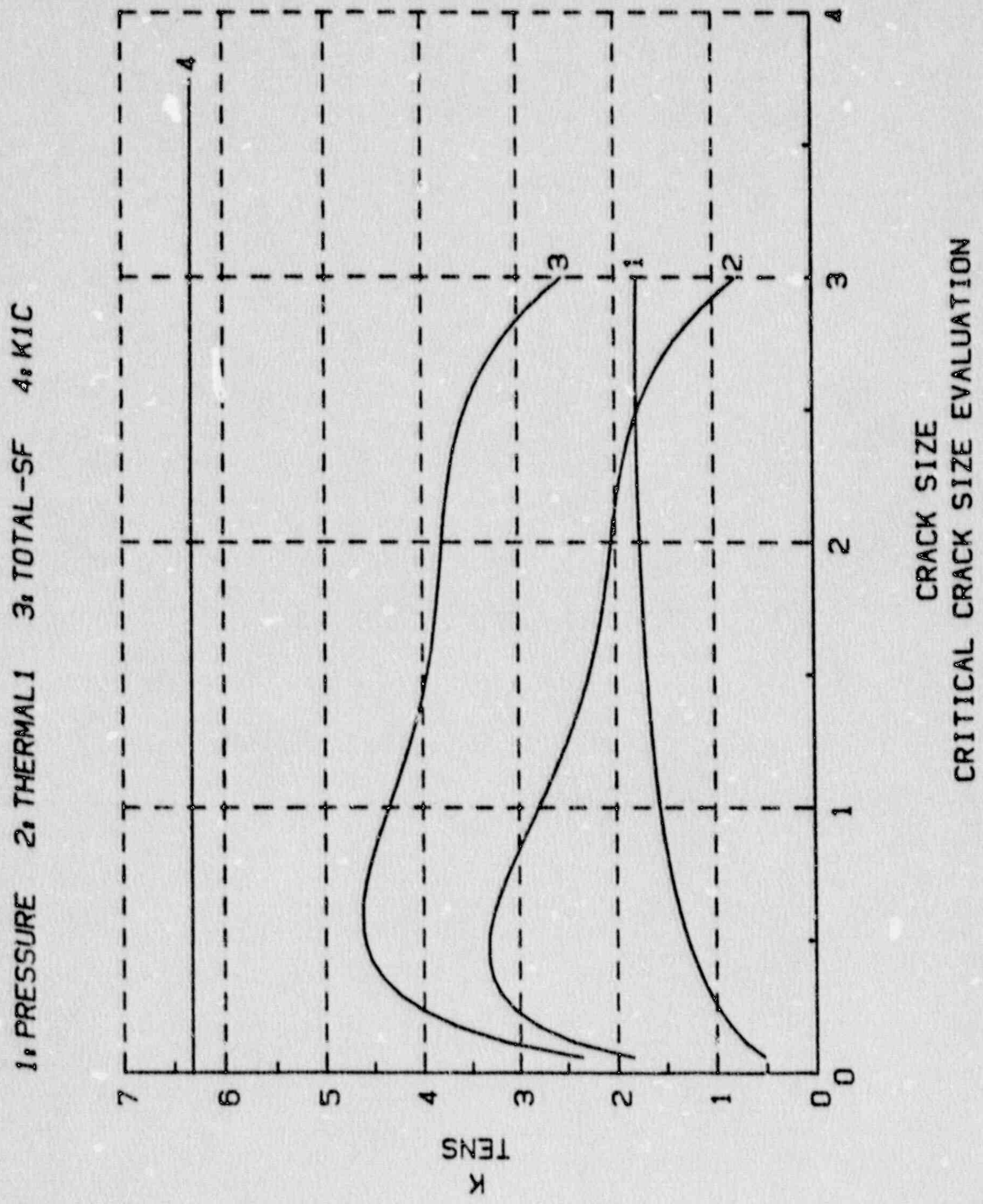

Figure 9. Applied Versus Allowable Stress Intensity for Section AA - Semi-Circular Crack in Half Space Model

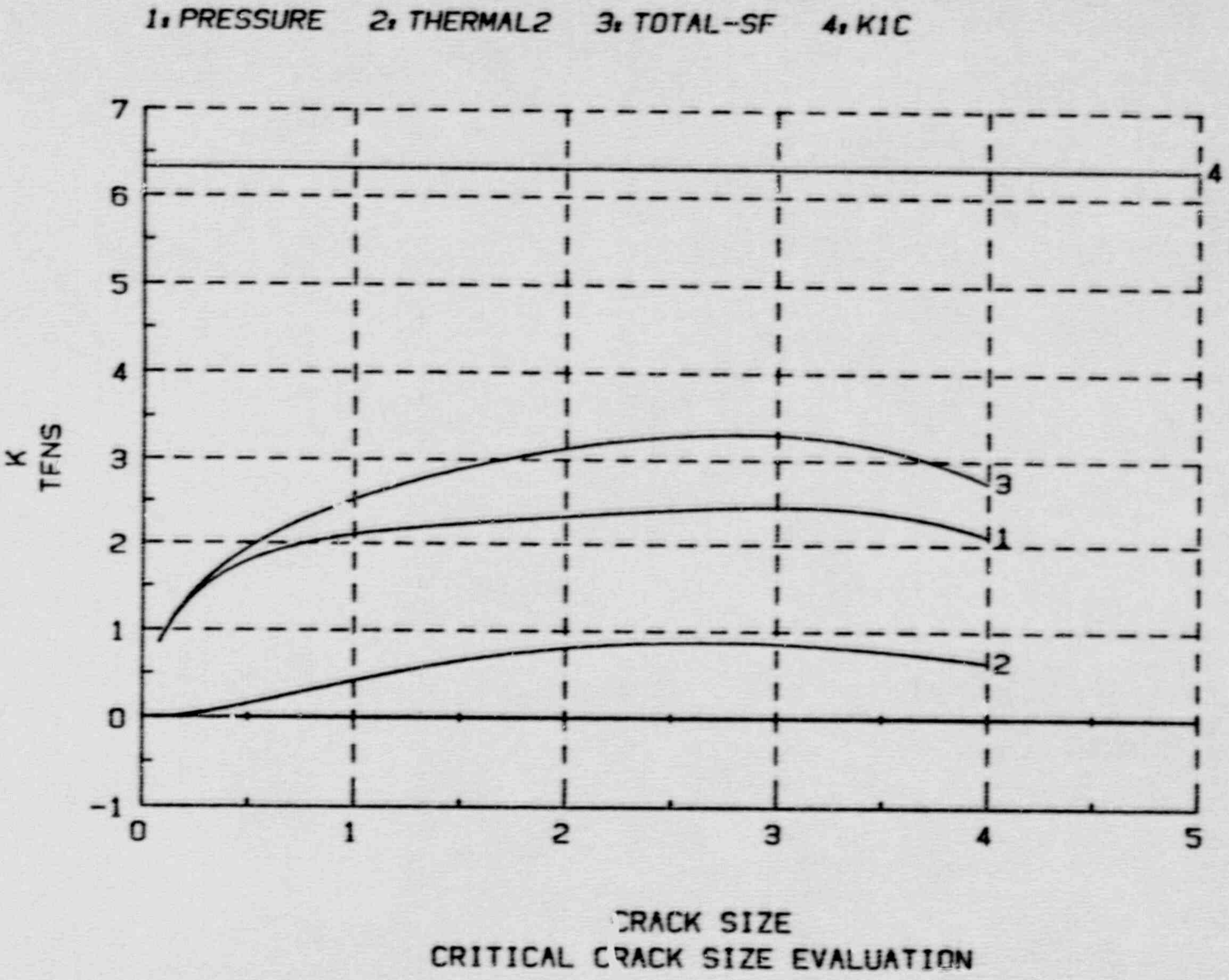

Figure 10. Applied Versus Allowable Stress Intensity for Section BB - Corner Crack Model Nozzle

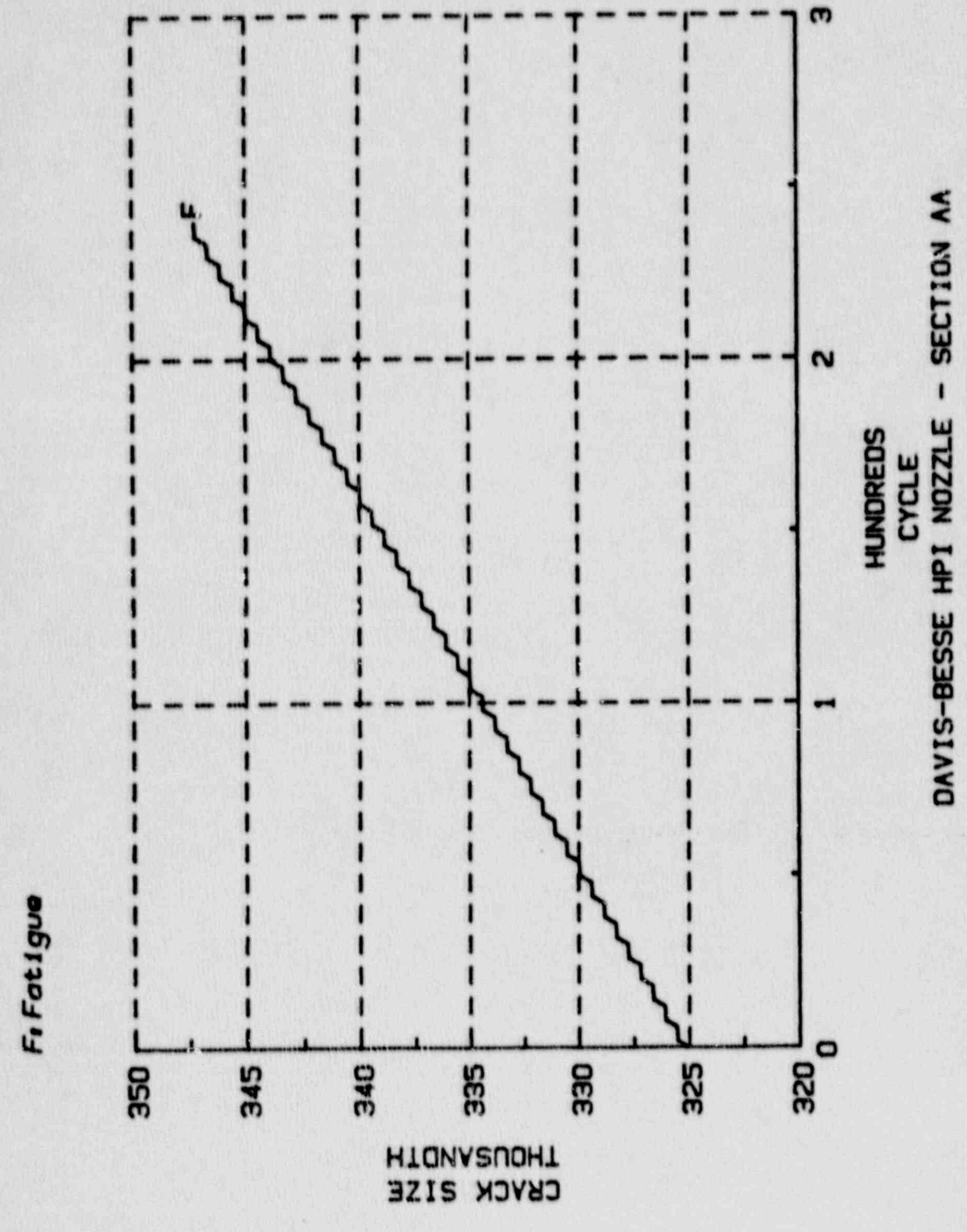

Figure 11. Fatigue Crack Growth for Section AA

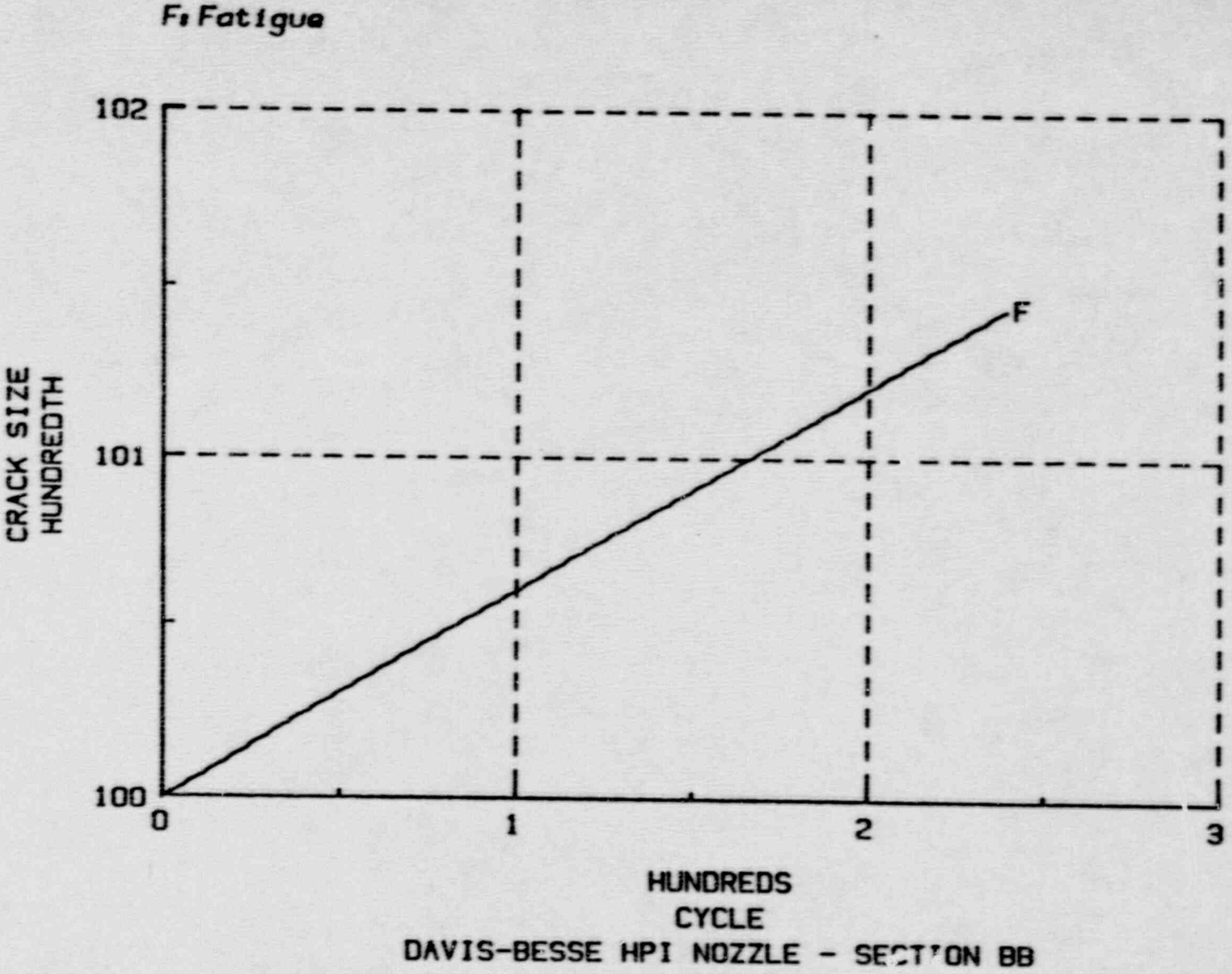

Figure 12. Fatigue Crack Growth for Section BB

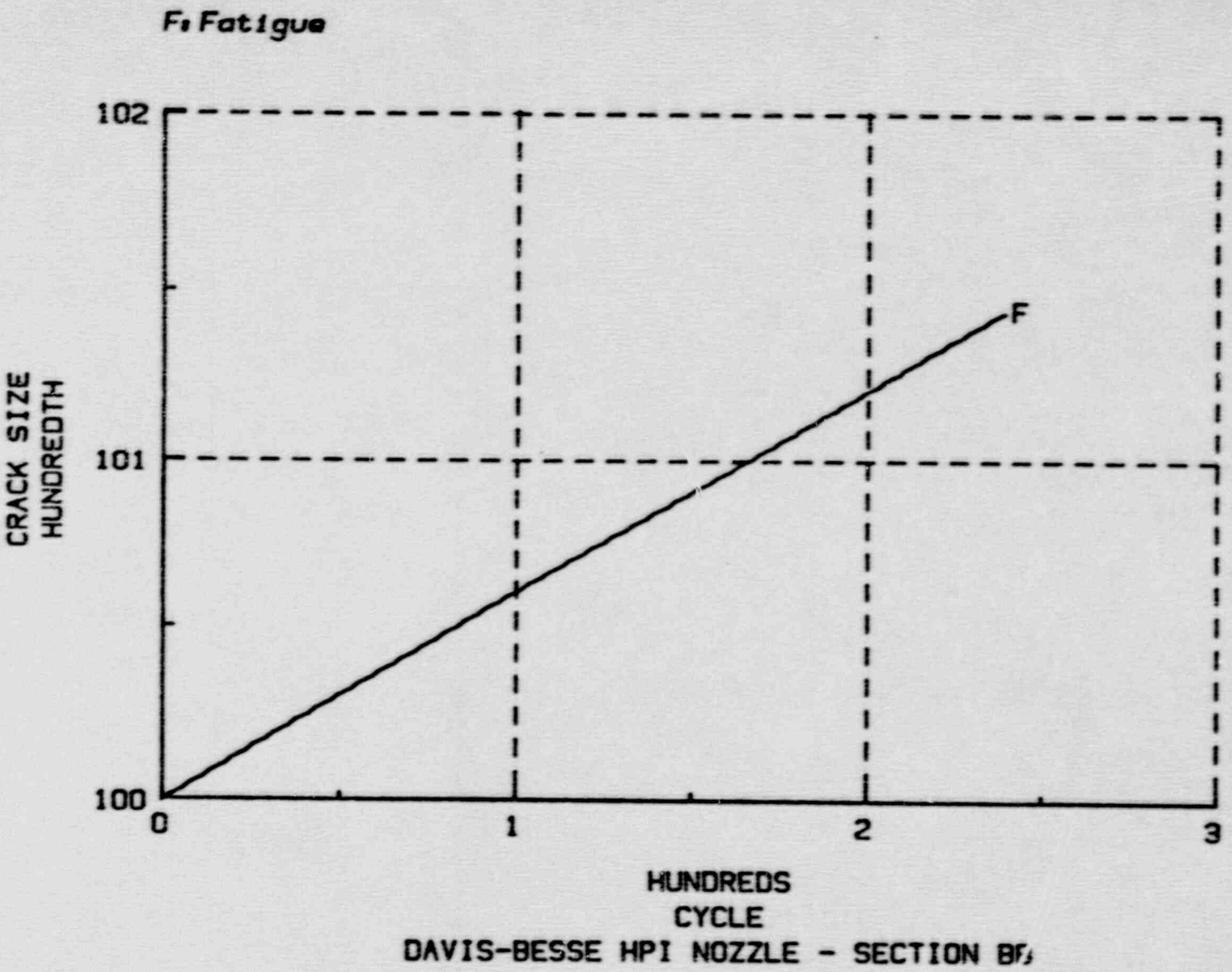

Figure 12. Fatigue Crack Growth for Section BB