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Pilgrim Shroud Analysis

Attached are the responses to questions raised by the NRC during a meeting on 10/4/94 concerning the Pilgrim (PNPS) Shroud Safety Assessment. Please refer any questions or comments concerning these responses to either Mr. R. V. Fairbank or me.

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ETB/nas/Rap94/Shrdsfty

Attachment

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Question 1: Provide the margin between the blowdown load calculated for PNPS and the blowdown load that results in unacceptable shroud performance.

Response 1:

The key determination in concluding shroud performance is acceptable under the blowdown load calculated for PNPS is the resulting shroud motion and displacement. The shroud in PNPS is calculated to tip under this lateral load. The worst case tipping is at the H7 weld and is limited by the jet pump riser braces. Tipping is eliminated after about one second by the restoring moment of the shroud weight (approximately 16000 kip-inch for H7). The impact of the shroud on the jet pump riser braces does not lead to buckling of the braces which could damage the jet pumps. With intact jet pumps, the reflooding of the core is assured. Also, since the tipping is limited to 1.5 inches by the braces, control rod insertion is assured. Unacceptable shroud performance could result if the jet pump riser braces bucked. The load on the jet pump riser braces is 63 kips or 16 ksi. The yield stress is 18 ksi with the Euler buckling load being 36 ksi. Therefore, the margin of safety is large.

Question 2: Provide the specific assumptions used for the PNPS TRACG analysis of the downcomer region and any benchmarking that has been performed on this model. (Confirm that the TRACG plant specific loads were the basis for the determination of the shroud response to the Recirculation Line Break).

Response 2:

The blowdown load for PNPS was calculated as stated in section 3.1.3.2, page 33 of reference 1. A TRACG Recirculation Line Break analysis was done for a large jet pump BWR plant (reference 2). The detailed modeling and benchmarking of this analysis is found in reference 2. The resulting TRACG blowdown pressure distribution around the shroud was used to calculate the lateral force and tipping moment as a function of shroud elevation for this case. The specific PNPS results are derived as follows:

- The fluid velocity distribution around the shroud, normalized to the blowdown flow and downcomer volume, is the same for PNPS as for the referenced TRACG calculation.
- The pressure distribution around the shroud is determined using the fluid velocity profile.
- The shroud lateral force is calculated using the shroud area corresponding to PNPS.
- The shroud moment is calculated for each elevation by integrating the forces above each elevation.

The blowdown flow rate for both PNPS and the referenced calculation is the same. The shroud area and annulus gap for PNPS are 90% and 91% of the referenced calculation. The resulting force and moment at the limiting H7 weld location (highest tipping displacement) for PNPS are slightly smaller when compared against those from the reference calculation. This smaller force is the result of a smaller shroud area in PNPS compared to the large BWR. The attached figures 1 and 2 show the results of the PNPS RLB analysis as a function of shroud elevation.

Question 3: Provide any data that supports the statement in section 2.6 that the PLEDGE model has been benchmarked with the Brunswick depth measurements.

Response 3:

Section 2.6 of the Pilgrim shroud analysis refers to the shroud generic safety assessment submitted by the BWR Owners' Group in August 1994 (see Reference 3). In Section 3 of Reference 3, the PLEDGE model is used to estimate the crack development that might be expected for the worst case conductivity history in a BWR. This worst case estimate is based on a conductivity history which is bounding for Pilgrim.

The PLEDGE model results are affected by a number of inputs, including material condition, ECP, chemistry and stress. Residual stress is a significant input for the shroud welds and the precise residual stress profile is not known. Therefore, the following process was followed in preparing to use the PLEDGE model:

- A residual stress profile developed from finite element analysis of the shell-to-ring geometry was scaled such that PLEDGE model results for the Brunswick 1 chemistry history would reasonably predict the cracking found at H3. Figure 3-1 from Reference 3, attached, shows the results of the Brunswick benchmarking analysis where variations in material sensitization and fluence have been considered as well. It should be noted that Figure 3-1 shows the range of cracking found at the Brunswick H3 weld. The average crack depth, which would correspond to the 360° cracking case depicted by PLEDGE, was about 1.4 inches.

- The residual stress profile, having been benchmarked with Brunswick 1 cracking data, was then used with the chemistry history for Dresden 3 and Quad Cities 1 and was shown to provide reasonable predictions of the cracking found at those plants. The Dresden 3 analysis results are shown in Figure 3-2 of Reference 3, attached.

The process above provided a basis to use the PLEDGE model, with worst case chemistry and material condition assumptions, to estimate the bounding cracking that might be present in an operating BWR which had not inspected. The results of that bounding analysis were used, however, in a somewhat qualitative manner in Reference 3 and in Pilgrim analysis. The main conclusion drawn from the PLEDGE model results was that crack growth, with the current low conductivity and the self-relieving nature of the residual stresses, would be very small if a deep crack were present. As seen from the attached figures, this conclusion would be true even if the inputs were adjusted slightly to make the PLEDGE predictions more conservative.

<u>References:</u>

1) GENE-523-A119-0894, PNPS Shroud Safety Assessment, August 1994
2) GENE-112-00819-05, "Core Shroud Blowdown Load Calculation During Recirculation Line Break by TRACG Analysis for Dresden 2 and 3, and Quad Cities 1 and 2", September 1994
3) GENE-523-A107-0794, "BWR Shroud Cracking Generic Safety Assessment" Revision 1, July 1994

Figure 1: Shear Force vs. Elevation for Pilgrim Blowdown Analysis

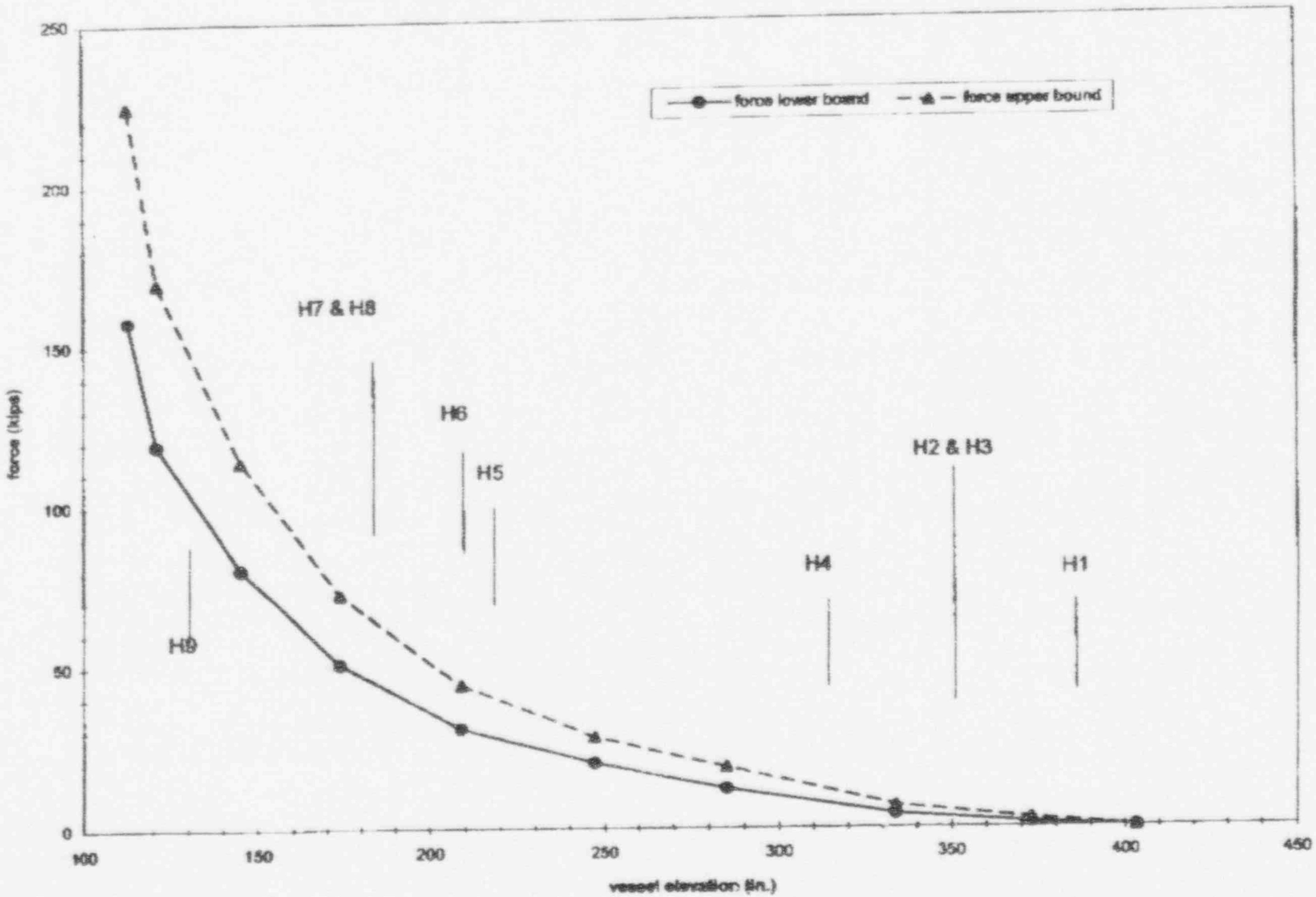
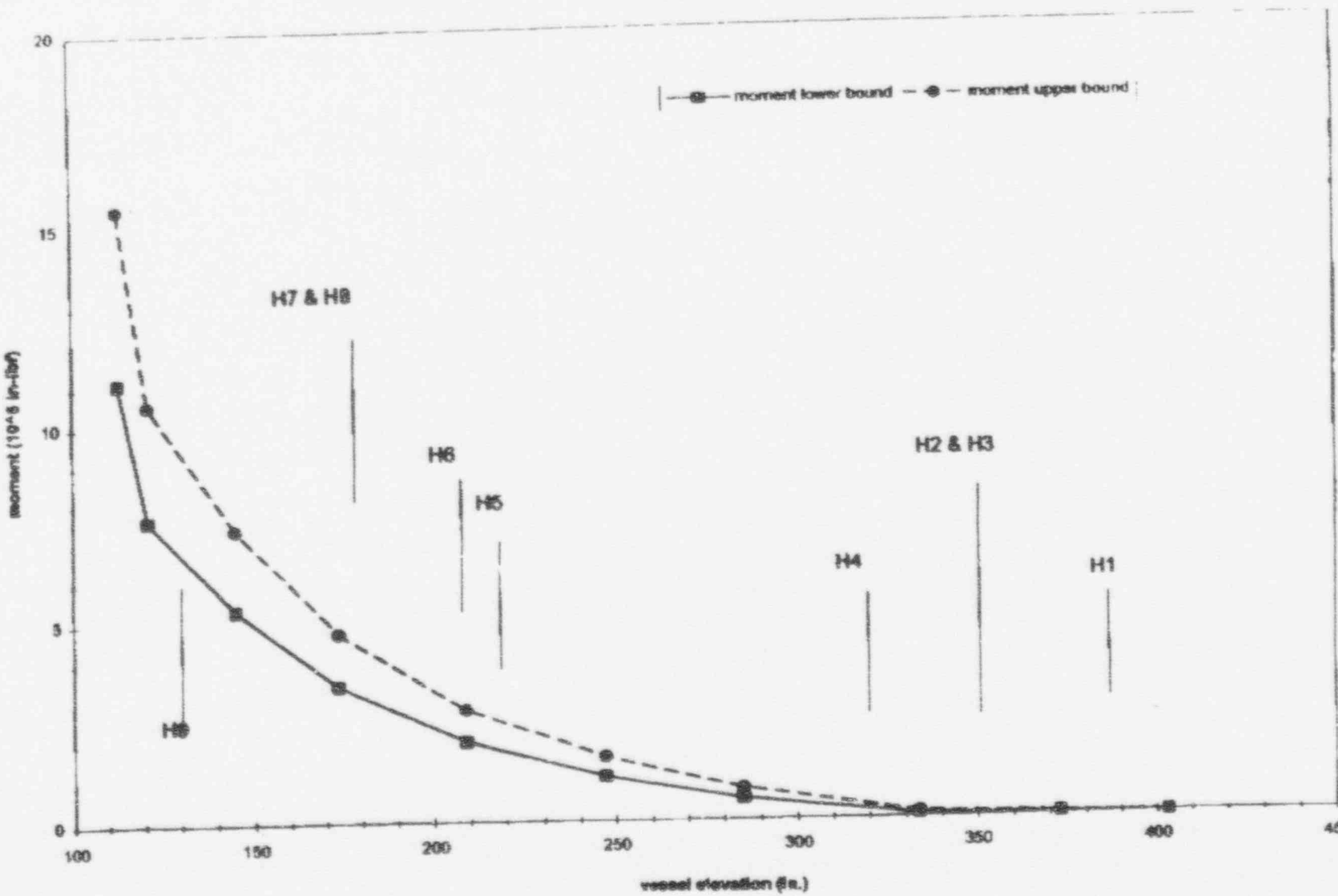


Figure 2: Moment vs. Elevation in Primary Plane for Pilgrim Blowdown Analysis



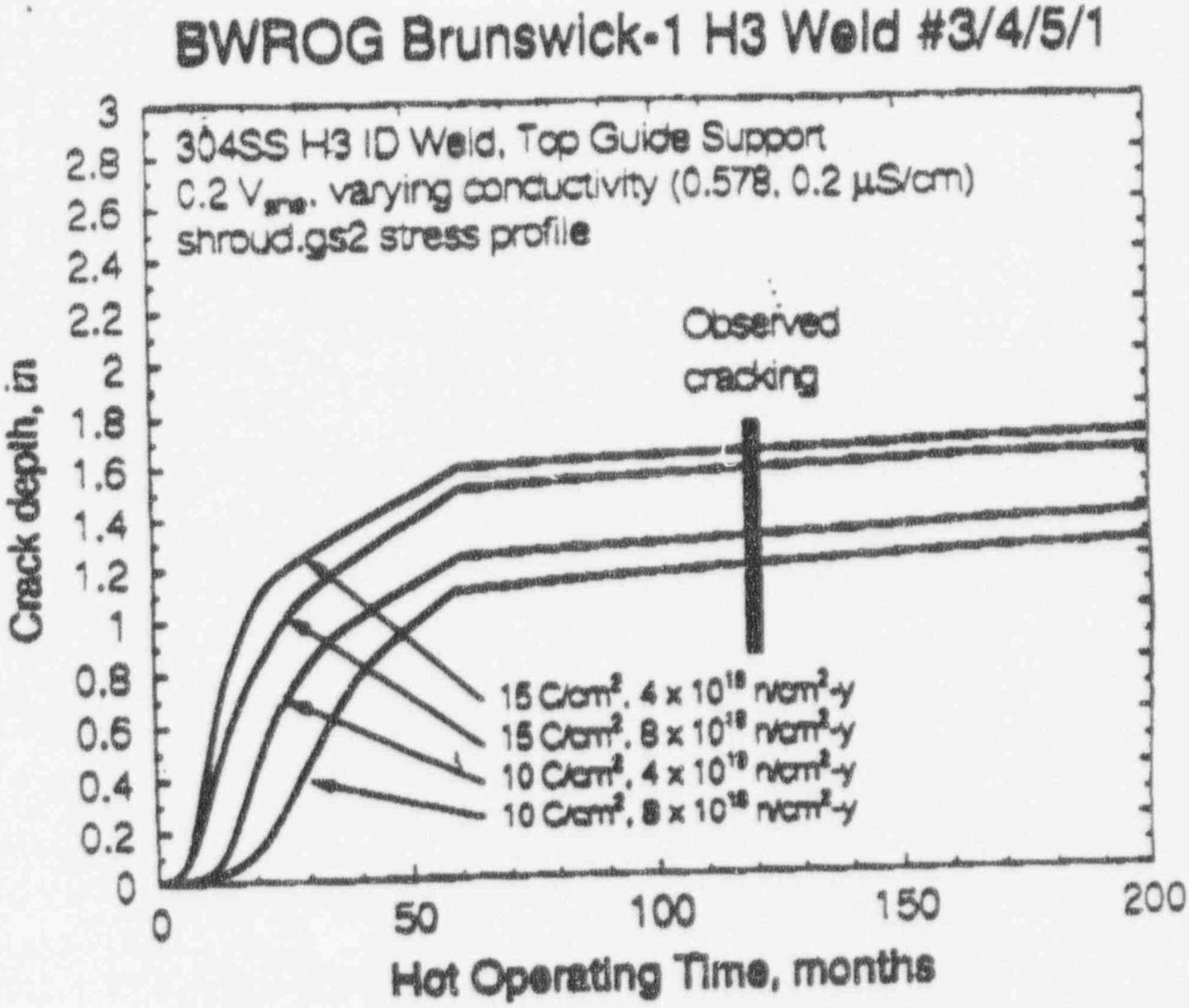


Figure 3-1. PLEDGE Model Benchmarked to Brunswick 1 H3 Cracking

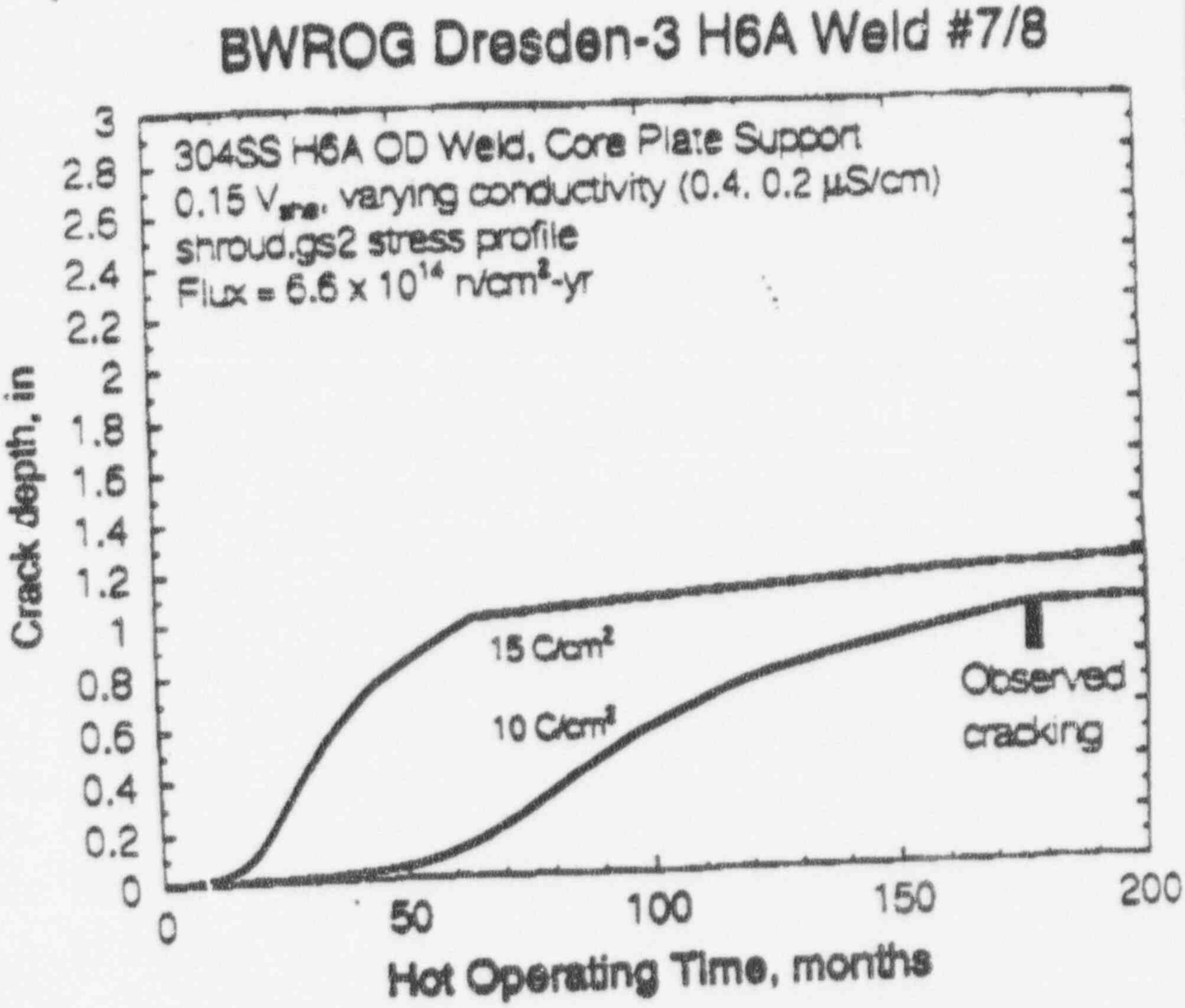


Figure 3-2. Benchmarked PLEDGE Model Confirmed with Dresden-3 H6A Cracking