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ENGINEERING ASSESSMENT OF THE HATCH 2 AHC INDICATIONS

October .992

Prepared by: K.P. Dias
K.P. Dias, Engineer
Structural Mechanics

Ap oved by: S Ranganath
S. Ranganath, PhD., Manager
Structural Mechanics

GE Nuclear Energy

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SUMMARY

This report documents the evaluation of structural margin with regard to circumferential cracking of the Hatch-_ access hole cover (AHC) weld-to-ledge region detected during UT examination. The results of two types of structural analyses are presented in this report to assess the crack indications.

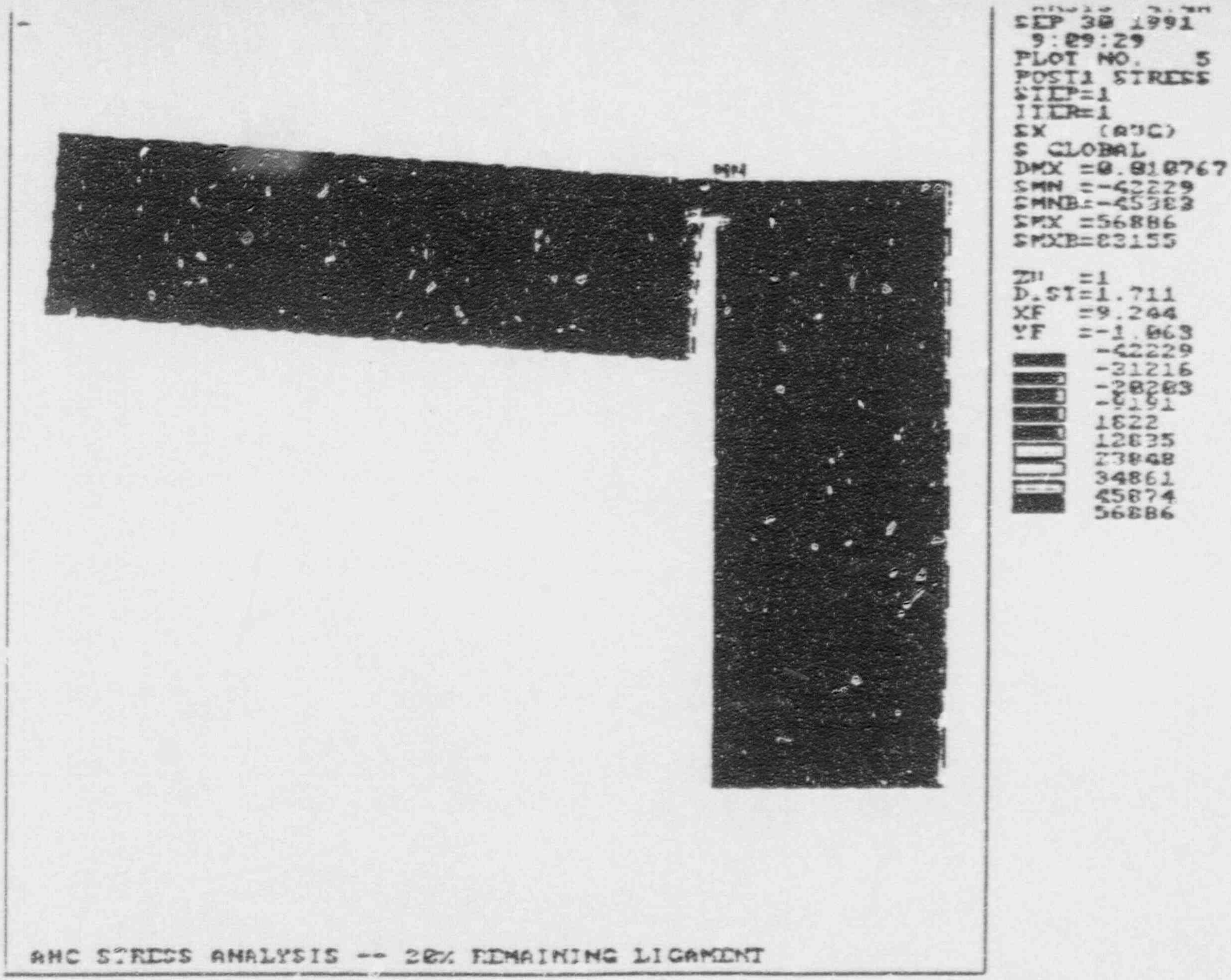
Although finite element analysis was performed to assure structural integrity of the AHC, it is important to note that the access hole cover weld does not represent a pressure boundary weld and is therefore not strictly covered by the flaw acceptance criteria of the ASME Code. Furthermore, if some through thickness cracking does occur, accompanied by leakage, there is little impact on plant performance or safety. Finally, in the limiting case where separation of the cover is postulated, the resulting core bypass flow would be readily detected as a result of the SIL 462 criteria and shutdown implemented in an orderly manner. Even if the cover lodges itself in the recirculation line and blocks flow, this is still covered by the pump seizure event which has been evaluated. Thus, separation of the cover is bounded by existing safety analysis. Therefore, the AHC cracking does not represent either a pressure boundary integrity issue or a safety concern. The NRC has implicitly accepted this in Information Notice No.88-03 (Attachment A).

Two types of structural analyses were performed to evaluate the crack indications. The first considered a crack in the AHC at the weld interface with the ledge (Figure 1). The second considered a crack entirely in the ledge with the crack tip just flush with the top of the cover. The results of the two finite element analyses are described here.

1. The analysis with the crack at the weld interface (Fig.1) showed that a ligament of 1/8 in. is sufficient to maintain the required margins against limit load and hinge formation. After accounting for potential crack growth, this translates into a ligament requirement of 0.14 inch. The available ligament of 0.26 inch is well in excess of this. The analysis was performed for normal operating differential pressure of 27 psi and a safety factor of 3. Therefore, if the remaining ligament (and crack) were to exist in the AHC weld interface, there would still be sufficient margin to assure structural integrity of the AHC.

2. The second analysis with the crack entirely in the ledge and with the tip flush with the top surface of the plate also shows that failure is not predicted even when the crack tip is offset by just 0.125 inch from the weld interface. Although assuming a crack at the weld interface is more limiting, the UT results (Attachment B) indicate that the crack actually lies 0.125 inch or more into the ledge. Radial crack growth for a ledge crack was judged to be negligle.

Based on the results of the two finite element evaluations it is concluded that the structural integrity of the weld will be maintained. Other reasons for justifying continued operation such as low crack growth due to hydrogen water chemistry, the presence of metal path due to crack branching even with through thickness cracking and the implementation of GL 462 guidelines remain valid.



Radial Stress Distribution for 20% Remaining Ligament Case

FIGURE 1

ANALYSIS OF CRACKING WITHIN THE AHC WELD

Crack Growth Rates

Crack growth rates under sustained load IGSCC conditions in Alloy 182 are dependent on the applied stress intensity factor and the water chemistry - conductivity and electrochemical corrosion potential (ECP). But available data (Reference 1) indicate that crack growth rate is not strongly dependent on the applied stress intensity factor. In fact, beyond a threshold K value of approximately 15-20 ksi$\sqrt{in}$, the crack growth reaches a plateau value of $2\text{-}5 \times 10^{-5}$ in/hour for conductivity levels up to 0.5 μS/cm. However, the crack growth rate drops rapidly at lower conductivity values.

Similar behavior has been observed for SCC growth rate for Alloy 600 (the AHC material and the SSP material). Figure 2 shows the weekly average reactor water conductivity for Hatch-2. From the figure, it is clear that the conductivity levels at Hatch-2 were maintained below 0.2 μS/cm for almost the entire fuel cycle 9. For 0.2 μS/cm and normal water chemistry (NWC), the typical ECP is +100 mV. For NWC conditions at a relatively low conductivity, it is then reasonable to assume an expected crack growth rate of 2×10^{-5} in/hour, consistent with the observed crack growth plateau discussed above.

Hatch-2 has been operating on hydrogen water chemistry (HWC) at 0.6 ppb H_2. Since the conductivity is low, the GE CR&D "PLEDGE" model can be used to predict crack growth rates for HWC conditions. Figure 3 shows measured ECP data as a function of hydrogen injection (Reference 2) for a typical BWR. Based upon this data and a hydrogen injection rate of 0.6 ppm, the ECP is approximately -100 mV. For this ECP, the "PLEDGE" model predicts a significant decrease in crack growth rate as compared to NWC conditions at +100 mV ECP. The crack growth rate is reduced by a factor of 16.3 to 0.122×10^{-5} in/hour. The predicted ligament reduction over the next operating cycle is calculated as follows, assuming 12,000 hours of operation,

(0.22×10^{-5}) (12000) = <u>0.01464 in.</u>

or

0.01464/0.625 x 100 = <u>2.3%</u>

where the AHC through wall thickness is 0.625 inch.

Minimum Required Ligament Size

Finite element analysis has been performed to show the minimum required remaining ligament size around the AHC as a function of AHC pressure differential. From "Reactor Internal Pressure Difference Databook" (Reference 3), the following pressure differences across the AHC for Hatch-2 were obtained and adjusted by appropriate safety factors:

dP (psi)	Safety Factor	Allowable dP (psi)	Condition
26.46	3.0	79.4	Normal Op
47.7	1.5	71.6	Faulted

The limiting dP of 79.4 psi is used to determine the allowable remaining ligament size for the AHC. Figure 4 shows the finite element predictions. For dP=79.4 psi, the remaining average ligament size is approximately 20%, or 0.125 inch.

To justify continued operation through the next operating cycle, the above allowable ligament size is adjusted to account for one cycle of crack growth as follows:

Minimum Required Ligament = 0.125 + 0.01464 = 0.140 in

or, = 0.140/0.625 x 100 = 22%

That is, the measured average remaining ligament (= total thickness minus average crack depth) must be greater than 0.140 inch (or 22% of the total thickness).

Results Of UT Inspection

Due to limited access in the ledge regions around the AHC, only 67% of the circumference could be inspected, as shown in Figure 5. UT data was obtained using both 45° shear and 60° signals. These results are shown graphically in Figures 6 and 7. Although the 60° signal is

generally more reliable, the average crack depth was conservatively computed using the more limiting signal at each 5° measurement interval. The bounding crack depth profile around the circumference is shown in Figure 8.

Based upon the bounding crack depth profile (measured at 5° intervals), the average crack depth was computed to be 0.365" (or 58% of the thickness). It is assumed that the average crack depth in the ledge regions, where UT inspection was not possible, is also 0.365". Therefore, the measured remaining ligament size (assuming the crack lies within the AHC weld) is,

Measured Average Remaining Ligament = 0.625-0.365 = <u>0.26 in</u>

or, = 0.26 .625 x 100 = <u>42%</u>

Clearly the measured ligament size is well above the minimum required ligament size of 0.140 inch (or 22%). The local peak crack depth was 79.2%, which corresponds to a minimum ligament size of 0.130 inch. This value differs from the minimum required ligament by only 0.01 inch. This difference is small and occurs only over a 5° interval.

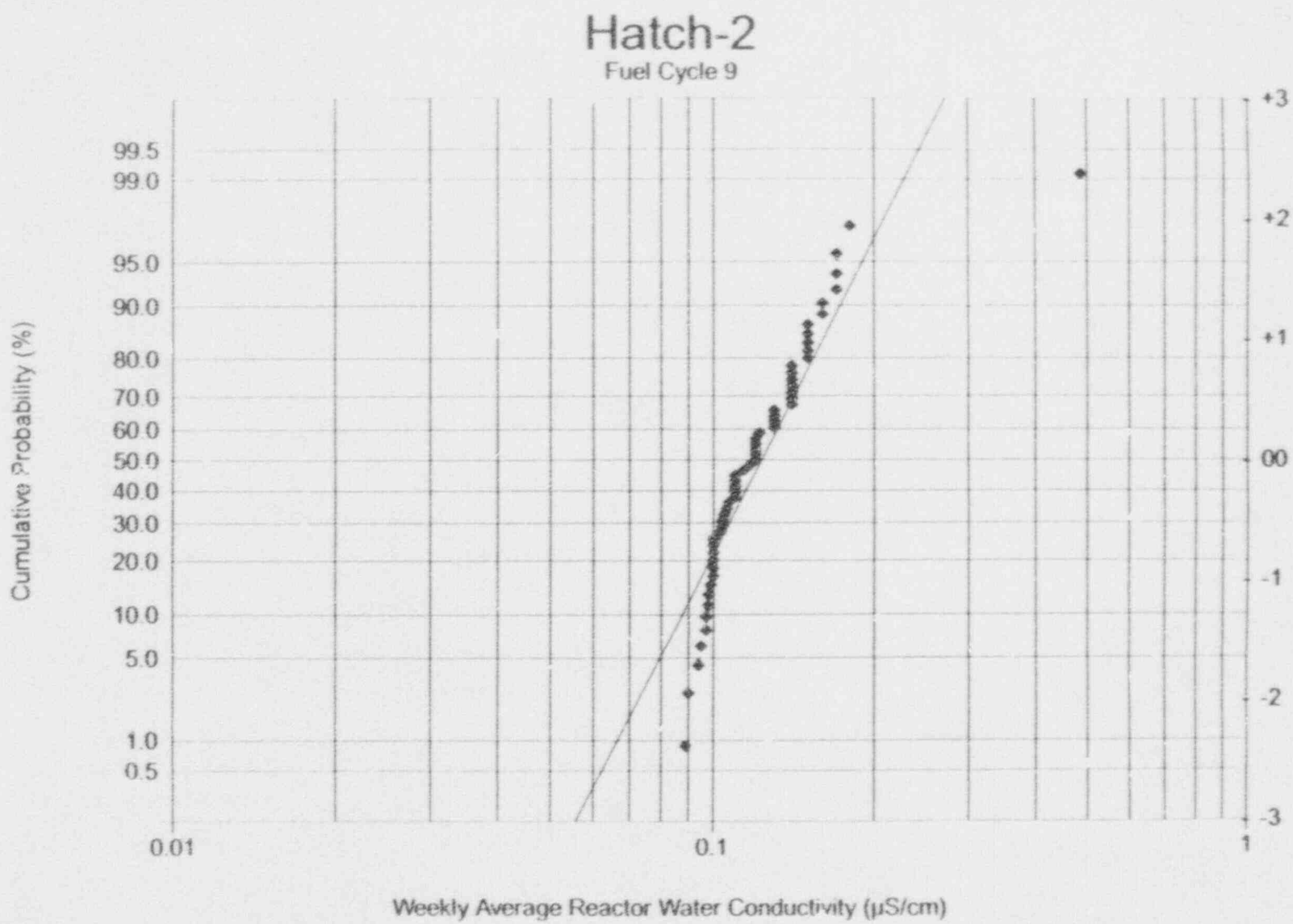

Hatch-2
Fuel Cycle 9
99.5
99.0
95.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
5.0
1.0
0.5
Cumulative Probability (%)
+3
+2
+1
00
-1
-2
-3
0.01
0.1
1
Weekly Average Reactor Water Conductivity (µS/cm)

FIGURE 2

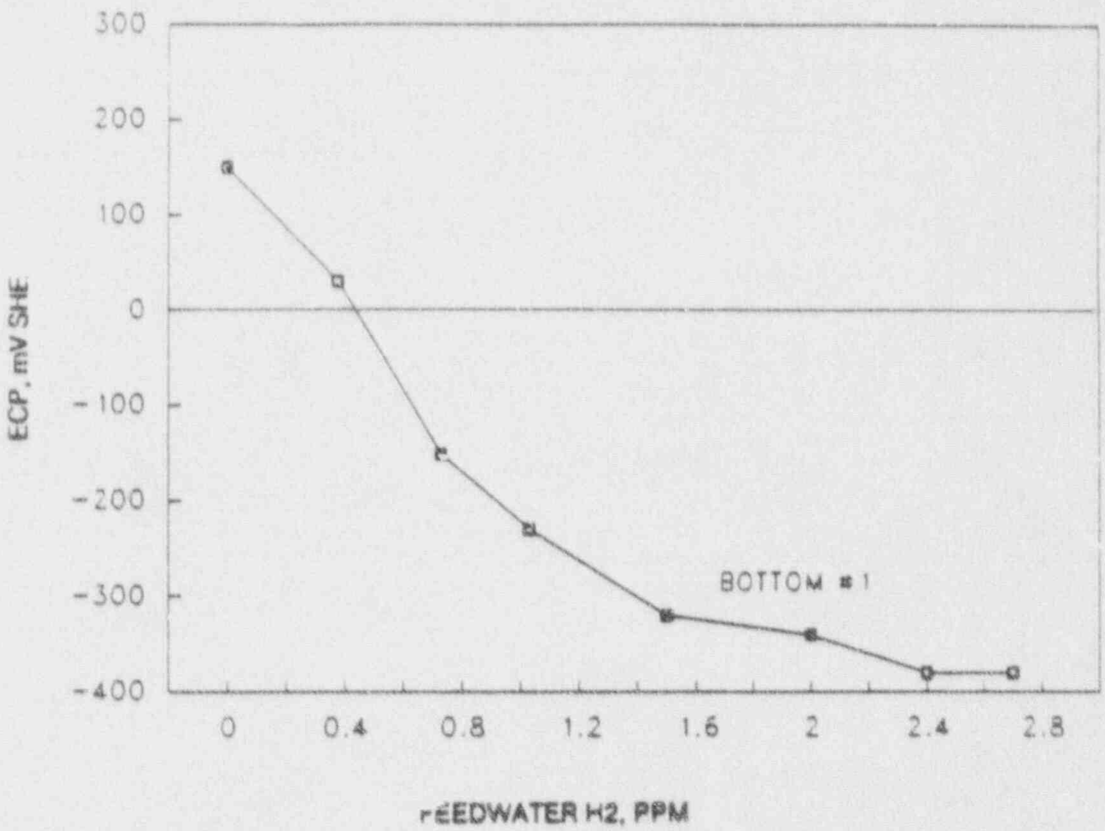
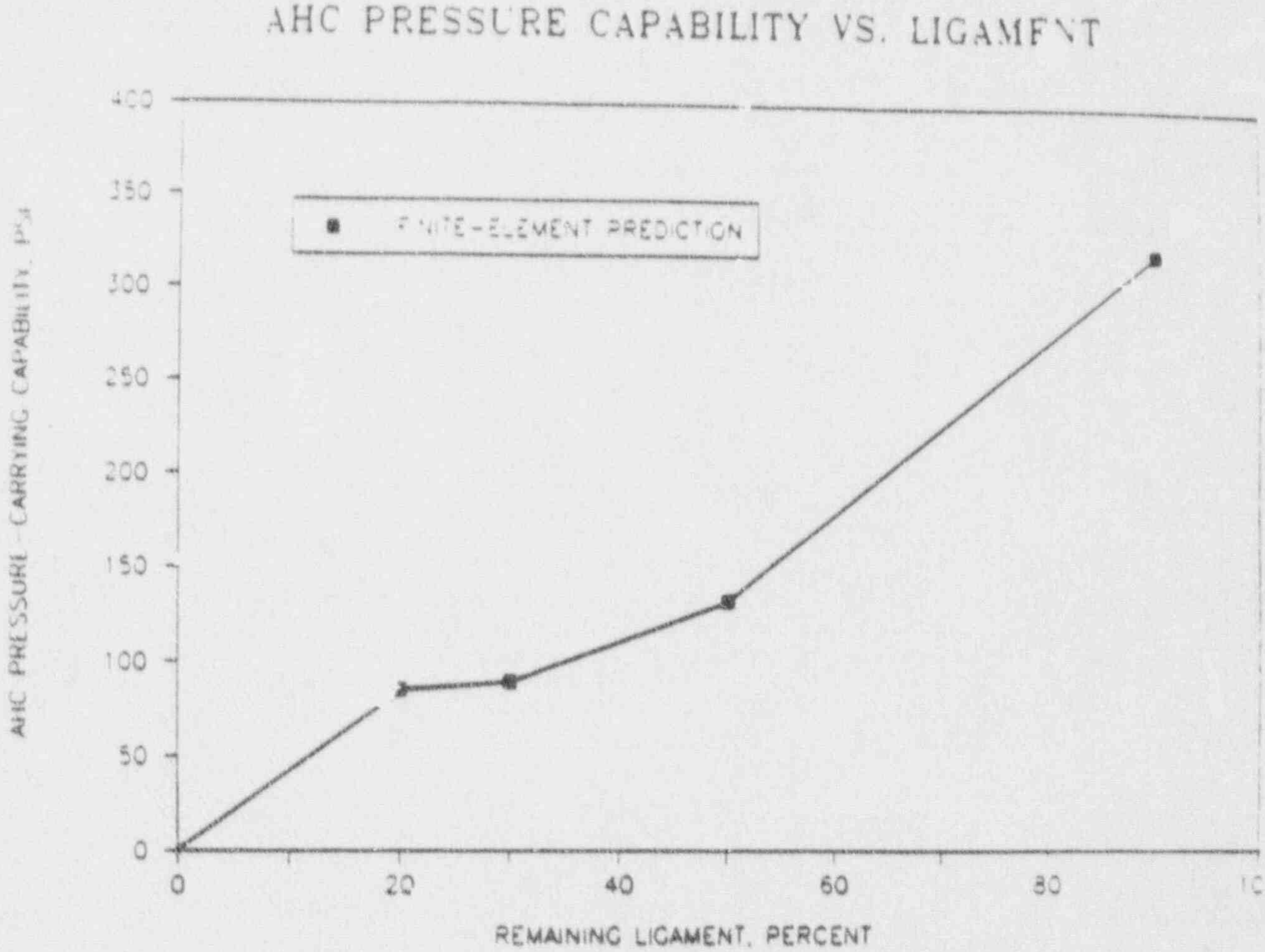
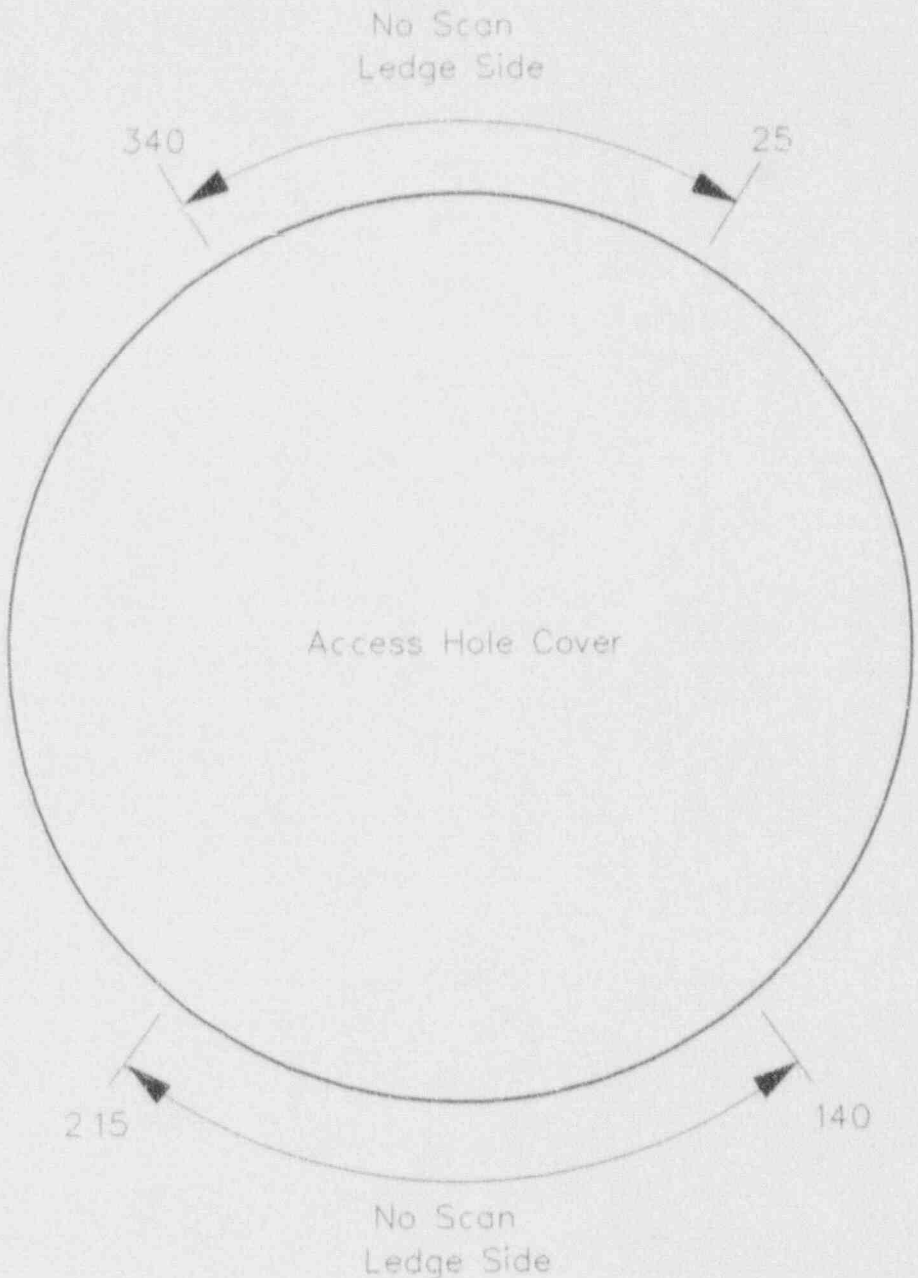


FIGURE 3 Measured ECP at bottom electrode positions (Ref. 2).



Pressure Capability as a Function of Remaining Ligament

FIGURE 4



Total Circumference Scanned = 240 degrees (67%)

Avg. Remaining Ligament = 0.26" (42%)

FIGURE 5

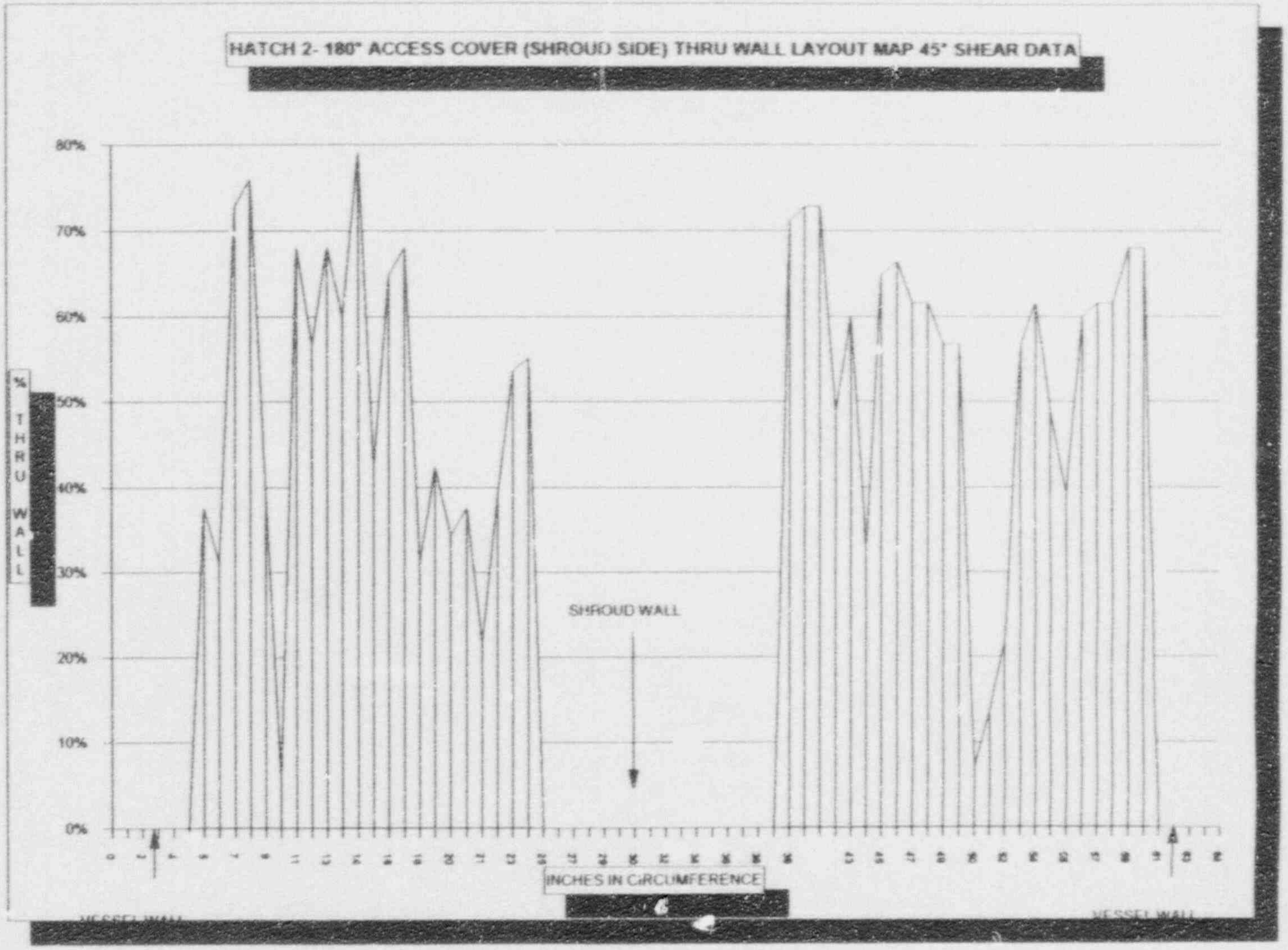
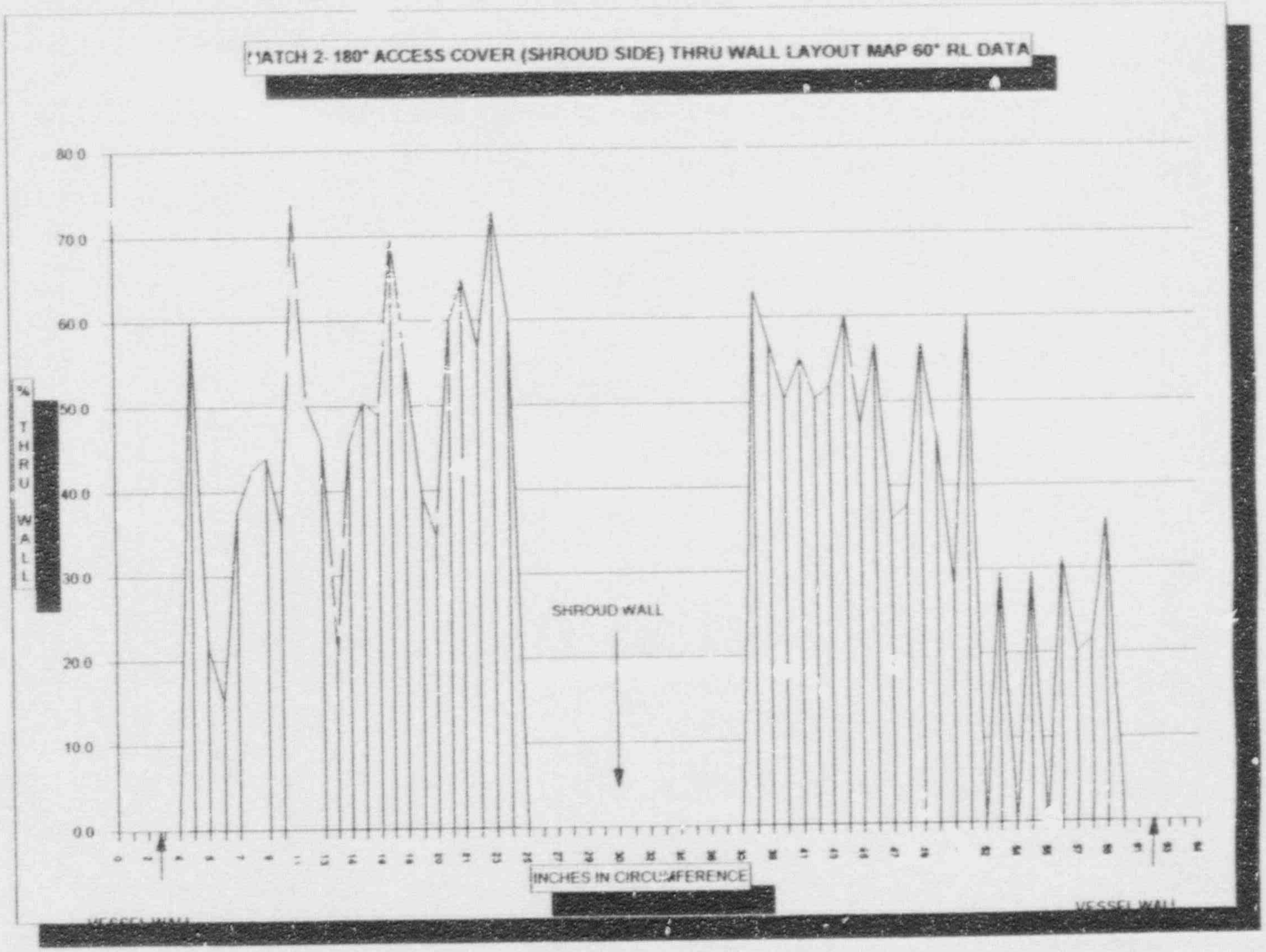

HATCH 2- 180° ACCESS COVER (SHROUD SIDE) THRU WALL LAYOUT MAP 45° SHEAR DATA
% THRU WALL
80%
70%
60%
50%
40%
30%
20%
10%
0%
SHROUD WALL
INCHES IN CIRCUMFERENCE

FIGURE 6



ATCH 2- 180" ACCESS COVER (SHROUD SIDE) THRU WALL LAYOUT MAP 60" RL DATA
% THRU WALL
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
SHROUD WALL
INCHES IN CIRCUMFERENCE

FIGURE 7

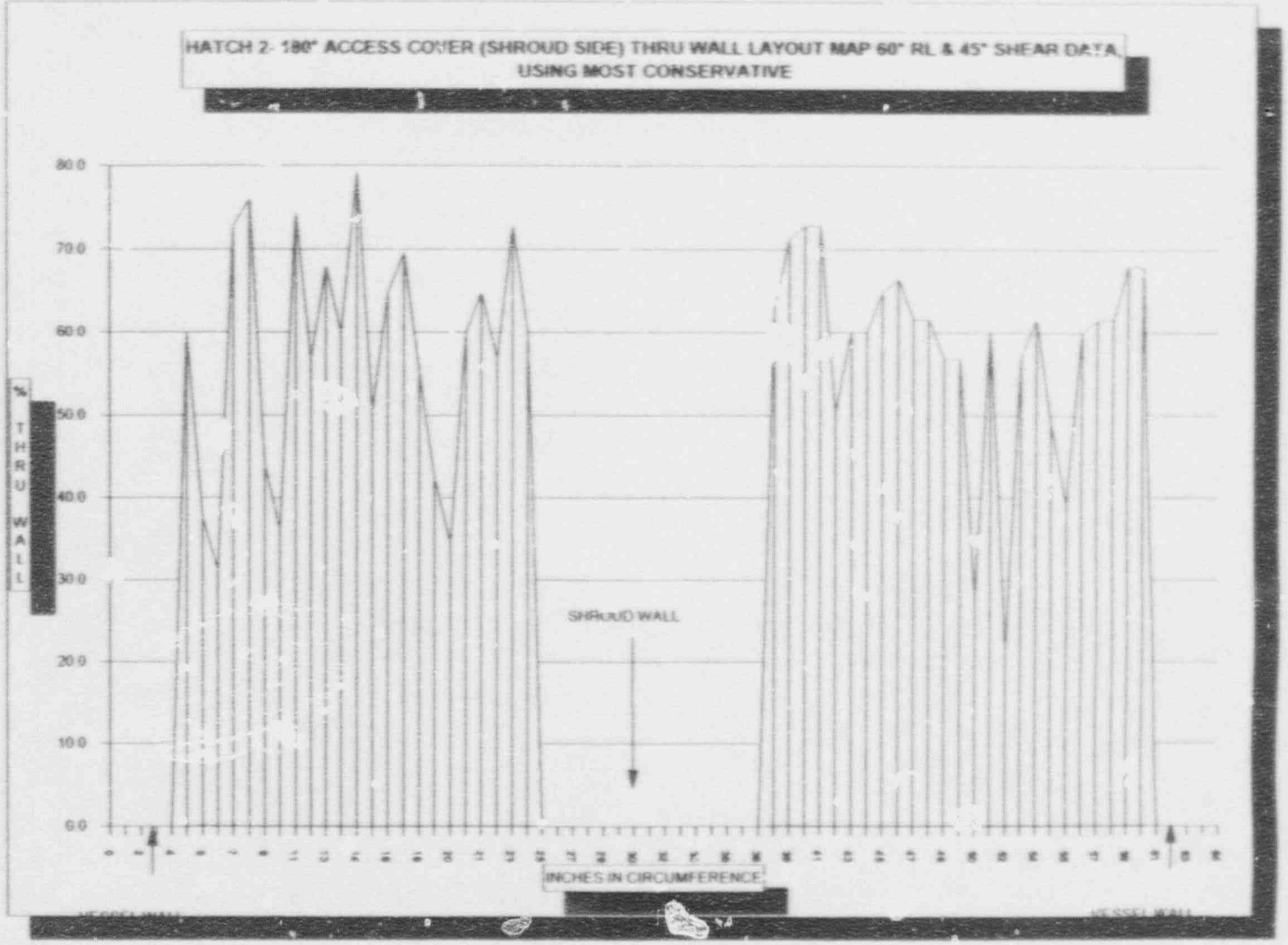

HATCH 2- 180° ACCESS COVER (SHROUD SIDE) THRU WALL LAYOUT MAP 60° RL & 45° SHEAR DATA
USING MOST CONSERVATIVE
% THRU WALL
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
SHROUD WALL
INCHES IN CIRCUMFERENCE

FIGURE 8

ANALYSIS OF CRACKING IN THE AHC LEDGE

The previous analysis conservatively assumes that the cracking is within the AHC-to-ledge weld. However, a careful review of the UT plots confirms that the crack is entirely in the ledge. In most cases, the tip of the crack is at least 1/8 inch or more from the vertical weld interface. Therefore, even if the tip of the crack extends to the top surface of the cover, there is still a remaining ligament since the crack is in the ledge.

Based on the above findings, a second finite element analysis was performed for the special case of when the crack tip is just at level of the top of the cover, but 1/8 inch into the ledge. The analysis was performed for a normal operating pressure equal to 27 psi. The structural integrity of the remaining 1/8 inch horizontal ligament is evaluated based upon the axial stress distribution results (Figure 9) of this special finite element analysis. The maximum stress is 17.6 ksi. Assuming a value of $3S_m = 70$ ksi for limit load failure, there is still a factor of 4 margin remaining. For the limited faulted condition (approximately 48 ksi pressure), the peak stress at the ligament/hinge is scaled up to 17.6 x (48/27) = 31 ksi. Therefore, for faulted conditions there is approximately a factor of 2 margin remaining.

For this analysis, where a ledge crack was considered, radial crack growth across the horizontal ligament was neglected for the following two reasons:

1. At Hatch 2 hydrogen water chemistry (HWC) will be maintained with high availability.

2. Crack growth in the radial direction is not likely unless significant branching exists.

Therefore, the results of the FEM analysis (ledge cracking) are sufficient to justify continued operation for one more fuel cycle.

For the vertical ligament, the previous AHC cracking analysis is bounding and has shown that the remaining vertical ligament of 0.26" is sufficient to maintain required margin for continued operation.

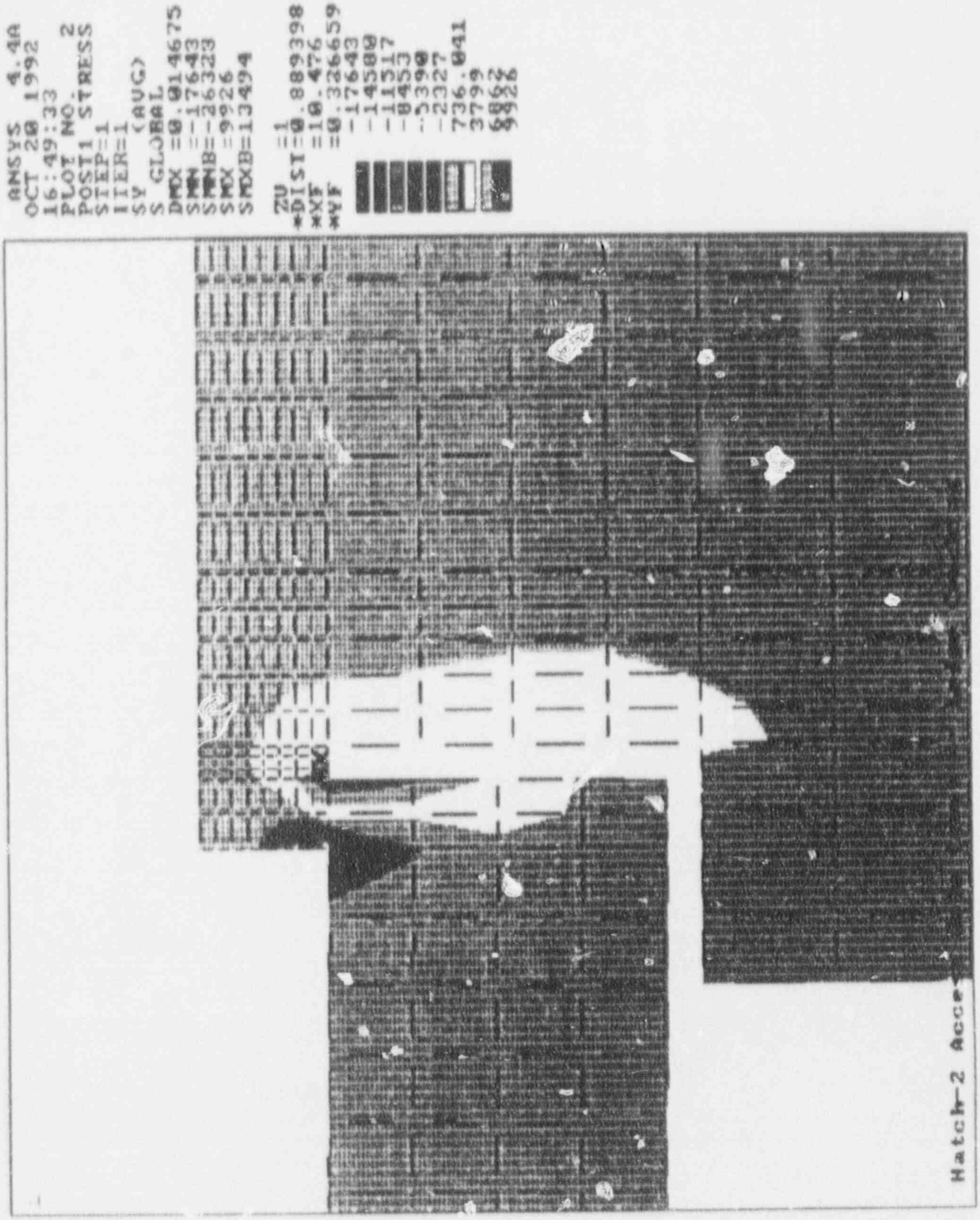

ANSYS 4.4A
OCT 20 1992
16:49:33
PLOT NO. 2
POST1 STRESS
STEP=1
ITER=1
SY (AVG)
S GLOBAL
DMX =0.014675
SMN =-17643
SMNB=-26323
SMX =9926
SMXB=13494
ZV =1
*DIST=0.889398
*XF =10.476
*YF =0.326659
-17643
-14580
-11517
-8453
-5390
-2327
736.041
3799
6862
9926
Hatch-2 Acce

FIGURE 9

CONCLUSIONS AND RECOMMENDATIONS

Based upon the preceding analysis and discussion, the following conclusions and recommendations are offered.

1. Based on the stresses in the vicinity (1/16 in.) of the crack tip, limit load failure (due to hinge formation) is not predicted even with the crack tip close to the vertical weld interface. Even if the highest stressed region (1/8" horizontal ligament) were to form a hinge, tearing will not occur because of the inherent ductility of the material. In any case the cover would be restrained by the ledge.

2. Even if through thickness cracking occurs over 50 percent of the weld circumference, analysis shows that separation of the cover will not occur.

3. Hatch Unit 2 is operating under hydrogen water chemistry. The injection level is sufficient to lower the ECP in the region below the cover to -100mV. This will reduce IGSCC growth rates significantly.

4. Because of the extensive crack branching in the weld metal under IGSCC, even if through thickness cracking is visually confirmed, there appears to be sufficient metal holding the cover in place. No gross deformation or incipient failure condition has been observed even in AHCs (in other plants) with much more severe cracking. On the other hand, at Hatch 2 there are no visual indications, confirming that there is no through thickness cracking.

5. The separation of an AHC would result in the introduction of a new flow path in parallel with the reactor core. The hydraulic resistance of the recirculation system would decrease and this would lead to an increase in the total recirculation (jet pump loop) flow. However, because a portion of the jet pump loop flow would bypass the core (through the access hole), the actual core flow would decrease and lead to a reduction in core power consistent with the normal power flow map. Since the access hole is approximately 20 inches in diameter, the impact on recirculation flow and core power would be significant enough that it would be readily

apparent to the operator, who would be expected to take corrective action. Attachment B describes the consequences of a loose AHC getting separated and approaching the recirculation pump. It concludes that there are no safety consequences for such a postulated event.

6. The recommendations of SIL 462 will be fully implemented. Even if failure of the cover (or significant opening) occurs, it will be readily detected by the change in the core bypass flow and the plant can be brought to normal shutdown.

7. A safety evaluation of the circumferential cracking showed that, even if potential separation of the AHC from the SSP were postulated, such a failure could be readily detected based on the observed changes in the core bypass flow. The safety consequences of circumferential cracking have been fully reviewed with the NRC and the staff concurs that the circumferential cracking does not represent a safety issue. No radial cracking has been observed at Hatch Unit 2 Thus there are no pressure boundary integrity concerns. Therefore, it was concluded that the circumferential cracking did not represent a safety concern.

8. The 0 degree cover is free from indications. Southern Nuclear Company is evaluating further all UT data to assess crack validity in the 180 degree cover. The weld represents a complicated configuration which could contain fabrication flaws and/or dissimilar metal reflectors.

9. GE provided reactor operating guidelines for detecting core bypass flow in SIL No. 462, Supplement 2, Revision 1, dated December 19, 1990. GE also recommended that the creviced Alloy 600 AHC plates in the affected plants should be inspected ultrasonically during the next outage and that the examination should be repeated at intervals of no longer than 3 years. Southern Nuclear Company will evaluate repair and inspection options to address the cracking concerns during the next Unit 2 outage.

In view of the above reasons, GE believes that continued operation for one more cycle is justified.

REFERENCES

1. S. Ranganath, "Hatch Access Hole Cover Assesment", Rev. 0, GE-NE-523-113-0892, August 1992.

2. "In-Core Response to Hydrogen Water Chemistry at J.A. FitzPatrick Plant", Prepared by GENE for Empire State Electric Energy Research Corporation, EP89-32, January 1992.

3. GE Doc. 383HA428, Rev 4, "Reactor Internal Pressure Difference Databook."

ATTACHMENT A

UNITED STATES
NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REACTOR REGULATION
WASHINGTON, D.C. 20555

February 2, 1988

NRC INFORMATION NOTICE NO. 88-03: CRACKS IN SHROUD SUPPORT ACCESS HOLE COVER WELDS

Addressees:

All holders of operating licenses or construction permits for boiling water reactors (BWRs).

Purpose:

This notice alerts addressees to the potential for cracks in the welds of the covers of the shroud support access holes within the reactor vessel. The cracks could result in weld failure with resulting formation of loose parts and core by-pass flow. The event described highlights the importance of inspecting the access cover welds. It is expected that recipients will review the information for applicability to their facilities and consider actions, as appropriate, to preclude similar problems from occurring at their facilities. However, suggestions contained in this information notice do not constitute NRC requirements; therefore, no specific action or written response is required.

Description of Circumstances:

Jet pump BWRs are designed with access holes in the shroud support plate which is located at the bottom of the annulus between the core shroud and the reactor vessel wall. Each reactor vessel has two such holes which are located 180 degrees apart. These holes are used for access during construction and are subsequently closed by welding a plate over the hole. The covers and shroud support ledge are Inconel Alloy 600 material. The connecting weld material is also Inconel 600 (Alloy 182 or 82).

The high residual stresses resulting from welding, along with a possible crevice geometry of the weld, when combined with less than ideal water quality, present a condition conducive to intergranular stress corrosion cracking (ISGCC). This has been recognized by General Electric and, as a result, they have developed a remotely operated ultrasonic testing capability for detecting cracks in the cover plate welds. The first use of this custom ultrasonic testing fixture was at Peach Bottom Unit 3.

On January 21, 1988, intermittent short cracks were found in the weld heat-affected zone around the entire circumference of the covers at Peach Bottom Unit 3. It is estimated that cracking exists over 50% to 60% of the circumference with cusps as deep as 70% through the wall. It is believed that cover plate welds have not been inspected previously on any other BWR. It is possible that the cracking is generic and may, therefore, affect all BWRs with jet pumps.

8802010084

Discussion:

General Electric has identified three concerns if failure of the access hole cover plates is postulated due to weld cracking:

1. Loose parts - In the event of complete failure of the access cover weld during normal reactor operation, the slightly higher bottom head area pressure would lift the cover out of its recess. It would most likely fall to one side, but there is a potential for it to be swept into the recirculation pump suction line causing severe pump damage.

2. Core flow bypass (normal operation) - Loss of one or both cover plates would allow some recirculation system flow to bypass the core, from the jet pump discharge through the open access hole to the recirculation pump suction. This flow transient would be readily detectable and would require reactor shutdown.

3. Core flow bypass (Loss of Coolant Accident) - If the access hole cover plate welds were to fail as a direct consequence of a recirculation suction line break, the bypass path would prevent the emergency core cooling system from reflooding the core to the 2/3 level. The core spray system would be capable of maintaining adequate core cooling provided there has been no degradation in the core spray piping.

No specific action or written response is required by this information notice. If you have any questions about this matter, please contact the technical contact listed below or the Regional Administrator of the appropriate regional office.

Charles E. Rossi

Charles E. Rossi, Director
Division of Operational Events Assessment
Office of Nuclear Reactor Regulation

Technical Contact: Warren Hazelton, NRR
(301) 492-0911

Attachment: List of Recently Issued NRC Information Notices

ATTACHMENT B

ATTACHMENT B

Preliminary Assessment of a 20.44 Inch Loose Access Hole Cover Approaching a Hatch 2 Reactor Recirculation Pump.

This is an assessment of what would happen if a manhole cover is carried by flow toward a Hatch 2 Reactor Recirculation Pump, and answer the question if the pressure boundary parts of the pump would be unacceptably degraded.

The postulate is that a 20.44 In. OD x 0.66 In. thick plate (manhole cover) has entered the pump suction proper in one piece. Minimum (eye) diameter of the pump suction (per telecon with BJ, the manufacturer of the pump) is also 20.5 In. Several scenarios are possible:

1. The plate approaches the impeller nut (see sketch) at right angle to the centerline of the pump shaft, such that the plate becomes like a butterfly valve that is closing the suction of the pump. The core flow would become uneven similar to single loop operation. The operator would notice drop in core power. In this case the plate would be pushed against the impeller nut, which in turn would wear out a hole in the plate. However, this event would not go unnoticed, because the pump would be operating in supercavitiation mode with large vibration. The pump motor vibration switches would also alert the operator of the anomaly. If unnoticed for extended time the pump internal parts (impeller, wear rings, journal, hydrostatic bearings, seals, and throttle bushings) would sustain damage. In the extreme the pump would seize, and cause overload of the motor. The overload would cause motor to trip. This would terminate the event. The pump casing pressure boundary parts (volute, cover, and main studs) would survive this event, however, a visual inspection would be warranted.

2. The plate approaches the impeller nut diagonally, with the edge of the plate impacting and rebounding against the impeller nut. This mode of interaction between the plate and the impeller is more difficult to detect, because it would be intermittent, with the plate bouncing against the rotating shaft. On the other hand, this mode would not be as stable as the first case. The plate would eventually be rotated to choke the eye of the impeller. This ensuing events and consequences described above would follow.

3. The plate approaches the pump impeller and fractures to several pieces. There has been two occasions where large metallic loose parts were ingested by the pumps of the same size and design without damaging the walls of the pump casing or impeller. The loose parts (hammer, and 5" manhole cover) were ejected by the pump.

   In a documented GE analysis it has been shown that in a hypothetical case that the pump impeller fractured in four equal pieces and struck the pump walls as a missile the pump wall was not perforated.

In summary: 1) various plant monitors would alert the operator to take action, 2) if unnoticed, the motor overload would trip automatically, and stop further damage, 3) the pump casing wall thickness can withstand large missiles without breach of pressure boundary as experienced in two actual cases. It should be noted when the access hole cover is dislodged, it will be readily detected by the operator and plant shutdown initiated. Thus it is very unlikely that the plate would reach the pump since the pumps trip on scram.