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Metallurgical Evaluation of Failed Shroud Tie Rod Lower Spring Contact Wedge Latches

Nine Mile Point Unit 1, RF014

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Rev. 0	D. E. Delwiche	6/10/97	Resolution of Review Comments and Minor Editorial Changes

IMPORTANT NOTICE REGARDING

CONTENTS OF THIS REPORT

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EXECUTIVE SUMMARY

During the Spring 1997 refueling outage of Nine Mile Point Unit 1, the nuclear core shroud repair assemblies, installed during the 1995 outage, were found to be degraded. The degradation consisted of loose tie rods and failed lower spring contact wedge latches (retainer clips). This report describes the results of the metallurgical evaluation performed at GE's Vallecitos Nuclear Center laboratories to validate the root cause of the retainer clip failures.

The root cause of the contact wedge latch failure was determined to be high sustained loads applied to the underside of the latch nose (due to unacceptable movement of the shroud repair assemblies during plant operation) resulting in an intergranular stress corrosion (SCC) crack fracture of the contact wedge latch. Crack initiation and growth of the SCC fracture occurred within one cycle of plant operation. Such crack growth is consistent with laboratory predictions of SCC propagation rates of Alloy X-750 in the BWR environment under high sustained loads.

CONTENTS

1.0 INTRODUCTION

During the Spring 1997 refueling outage at Nine Mile Point Unit 1 (NMP1), anomalies were found with the shroud repair hardware. In particular, irregularities were found with the lower spring contact wedge latches (also referred to in this report and elsewhere as "retainer clips"). The shroud repair hardware was in service for approximately two years. The anomalies consisted of loose tie rods and failed lower spring contact wedge latches. This report describes the metallurgical evaluations of the failed contact wedge latches, and the results of those evaluations. In addition, a non-failed wedge latch was included in the evaluation.

The anomalies were found during planned visual inspections of the shroud repair hardware and during the planned replacement of a shroud repair assembly at 270 degrees.

2.0 SUMMARY

All four shroud repair assemblies were found to have lost vertical preload and three of the wedge latches that prevent relative motion between the lower spring and the wedge were damaged. One latch had failed in service(the 90 degree latch), another failed during the removal process(the 350 degree latch), and a third had visual evidence of damage(the 270 degree latch). The fourth(166 degree latch) had no evidence of damage. Similar wedge latches on the mid-supports and on the upper springs were found to be normal. The lower spring latches are similar in physical features to the upper spring and mid-support latches but have different applied loadings.

The root cause of the latch failure and the tie rod looseness is related to the design assumption of sliding on the vessel surface. Refer to report GENE B13-01739-40 (Reference 1) for a full discussion of shroud repair anomalies. This report describes the results of the metallurgical evaluation performed at GE's Vallecitos Nuclear Center laboratories to validate the root cause of the retainer clip failures.

3.0 BACKGROUND

The as found condition, design description, and field inspection results are discussed in this section. Also included is the initial assessment of the cause of latch failure.

3.1 Design Description

The shroud repair was designed to structurally replace the circumferential welds in the core shroud. Four assemblies are placed approximately uniformly around the shroud (azimuths 90, 166, 270, and 350 degree). Each assembly functions to vertically hold the shroud to the shroud support cone and to horizontally support the shroud at the top guide and core plate elevations. In addition, there are other horizontal supports that would prevent unacceptable horizontal movement of any shroud cylindrical segment that could be produced by failure of the horizontal shroud welds.

Figure 1 shows an elevation view of one set of shroud repair assemblies. There are four such sets at azimuths 90, 166, 270, and 350 degrees around the core shroud. The tie rod is the main component for reacting axial loads. The lower spring is the linear spring for supporting the shroud at the core plate elevation. The lower wedge is a component that was machined based on actual site measurement to fit between the RPV and the lower spring with a small compression of the lower spring at room temperature. The latch is a wishbone shaped piece, intended to prevent relative motion between the lower wedge and the lower spring. Figure 2 provides detail of the lower spring wedge latch within the shroud repair assembly. Similar latches are also used to prevent relative motion at the mid-support and at the upper spring. The lower support is an assembly that connects the shroud repair hardware to the shroud support cone. The tie rod nut is at the top of the tie rod and is used to tighten the assembly. During installation, the tie rod nut was torqued to preload the assemblies to assure minimal tightness of components. The mid-support is used to limit relative motion between the middle of the shroud and the RPV. The upper spring is a linear spring for supporting the shroud at the top guide elevation. For more extensive description, see Reference 1.

3.2 Field Inspections

The lower support wedge latch at 90 degrees was found broken and separated during the visual inspection. The "nose" piece of the latch was missing and later found on the lower support cone at approximately azimuth 330 degrees. Figure 3 is a photograph of the broken 90 degree latch. Based on an examination of photographs of the fracture surface taken at the NMP-1 site, and IVVI video tapes, the failure was judged to be not consistent with a fatigue mechanism. In addition, there was no visible evidence of plastic deformation, which would be necessary for a single event overload type of failure. The failure surface appeared to be consistent with a stress corrosion failure under high stress. Based solely on the visual information, a stress corrosion fracture was believed more likely than an overload fracture.

Video tape inspection of the other three lower wedge latches showed them all to be intact, but the 350 degree latch appeared to be "bent". In addition, the lower spring wedges had evidence of local hard contact with the wedge latch, due to vertical loads within the tie rod assembly. Since the latches are Alloy X-750 and the lower spring wedges are Type 316 low carbon stainless steel, the lower spring wedges will show surface imprint before the latches.

The similar latches used in each mid-support assembly and two similar latches are used in each upper spring assembly all had been visually examined and all appeared normal. Because of design differences, these other latches can not be loaded as severely as the lower wedge latches. The contact force between the RPV and the shroud repair is much smaller at these locations as compared to the contact force at the lower wedge. In addition, these latches are not loaded during plant heat-up.

3.3 Initial Assessment of Failure Cause

During normal plant operation there are only a few sources of loads on the shroud repair. These are installation, differential thermal and pressure expansion, fluid flow and dead weight. The dead weight, fluid flow, and installation stresses are low. The main forces on the shroud repair are due to differential thermal expansion between the shroud, RPV, and shroud repair, which both are in the vertical and horizontal directions.

Based on the initial IVVI observations of the loose tie rod at 270 degrees and the failure of the latch at 90 degrees, different potential causes were postulated. These causes were possible vibration leading to yielding of the tie rods, fatigue of the latch, or other unexpected displacements causing a single event failure. Evaluations solely by IVVI techniques and photo

macrographs of the fracture face of the latch, are of course insufficient evidence to establish the actual cause of latch fracture.

A review of the stress analyses showed that the tie rods could not have been overloaded to yield, and the failure surface did not show visible evidence of plastic deformation typical of a single event overload failure. The jagged, irregular failure surface of the broken 90 degree latch tends to rule out fatigue as a possible failure mechanism. However, the evidence obtained by macroscopic field observation strongly suggests that the latch fracture was due to a stress corrosion mechanism rather than a fatigue or mechanical overload failure. The surface has the irregular features with characteristics of secondary cracking, suggestive of stress corrosion under high stress.

The only known source of high stress is due to restraint of differential vertical motion between the RPV and the lower spring wedge. If the lower spring wedge did not slide vertically along the RPV, then the differential displacement must occur between the lower spring and the lower wedge. Such movement will cause high stress in the latch. Sources of such differential displacement are the vertical looseness of the tie rods and the differential displacements discussed in Reference 1. Therefore, the root cause of the latch failure and the tie rod looseness is related to the design assumption of the contact wedge sliding on vessel surface.

4.0 LABORATORY CHARACTERIZATION OF CRACKS

Details of the metallographic examination performed on the wedge latches are presented in this section. The focus of the evaluation was to perform a reasonable amount of work to provide a high confidence, technically supportable understanding of the cause of wedge latch failure. Three lower contact wedge latches were examined at the General Electric Vallecitos Nuclear facility in Pleasanton, California. Two failed latches and one undamaged latches were examinaed.

4.1 Receipt Inspection

Three lower wedge latches (90 degree, 166 degree, and 350 degree) were packaged in a 55 gal drum prepared as a Type A radioactive shipment container at the Nine Mile Point Unit 1 site, and transported to General Electric's Vallecitos Nuclear Center (GE-VNC) metallurgical laboratory for failure analysis. The shipping container was provided by GE-VNC.

4.1.1 Radiological Survey

Upon receipt at the metallurgical laboratory, the latches were unpackaged in the GE-VNC - RHO(Remote Handling Operation) controlled corrider area. A radiological survey was performed. Results indicated gamma + beta activity to be in the range (approx 2R/hr contact, and 300 mR at 18 inches) allowing hands-on evaluation procedures to be used. Following radiological survey, the latches were decontaminated by ultrasonic cleaning in a mild, diluted CORPEX cleaning solution, followed by deionized water rinsing and air dry.

4.1.2 Visual Examination

Visual examination and documentation of the surface condition was performed on each latch. Particular attention was applied to evidence of plastic deformation, and condition of the fracture surfaces. Direct low magnification photographs were prepared to document condition. The results are provided in Figures 3 through 6, and 8 through 11.

Figures 3 and 4 are photo-macrographs of 90 degree lower spring contact wedge latch, found in the broken and separated condition. The nose piece of the latch was found in the annulus region of the reactor. This is the latch fracture face photographed during site IVVI activities, used to make the preliminary assessment that the fracture was probably due to a stress

corrosion mechanism. The irregular surface condition was suggestive of a corrosion related mechanism. In Figure 4 it is noted that the fracture surface is uniformly colored with an oxidation characteristic of that produced by exposure to the BWR environment. There was no evidence of plastic deformation, suggesting mechanical overload was not a causitive factor. In addition, it was noted that the underside of the latch "nose" had an oxide pattern suggestive of sustained contact during service.

Figures 5 and 6 are close-up photographs of the 166 degree latch. This latch was found intact and without damage. Figure 6 is an enlarged view of the underside of the nose region of the latch. In contrast to that observed on the 90 degree latch documented in Figure 4, an absence of oxide patterning is found on this latch suggesting no sustained contact during service. Since the 166 degree latch was not obviously cracked, the nose portion of the latch was cut from the remainder of the latch and examined under the SEM at relatively low magnification. This technique is effective in locating small or tight cracks if they are present. The results are provided in Figure 7. Figure 7 has typical views of the 'inside' corner region. The examination revealed no cracking in the area of crack initiation as found on the other wedge latches.

Figures 8 through 11 are close-up photographs of the 350 degree latch. This latch was reported as "bent" in the IVVI report, the "bend" being located at the underside of the nose. During removal, the latch broke, separating into two pieces. Figure 8 is an enlarged view of the 350 degree latch, showing the location of separation. The separation is the same location as the fracture of the 90 degree latch, with the implication that the latch was nearly through-wall cracked during service and removal handling resulted in the final separation. Figure 9 shows a side view of the broken segments of the 350 latch, showing an absence of plastic deformation. The IVVI indicated a possible deformation - now known to be caused by a yawning open of a nearly through wall crack. Figure 10 is an enlarged view of the 350 degree latch fracture faces. Note the gradation of oxide coloration, ranging from darkest brown in the region of crack initiation (oldest crack surface) to a light brown in the region of the crack tip (recent crack growth in the BWR environment). The unoxidized band at the lower edge was caused by room temperature ductile fracture during latch removal. Figure 11 is an enlarged view of the fracture face and the underside of the latch nose of the 350 degree latch. Note the gray band at the upper edge of the underside surface. This band was caused by surface contact during service. Compare this condition with photos of the 166 degree latch in Figures 5 and 6, which show no pattern of contact on the oxide surface.

4.2 Scanning Electron Microscopic (SEM) Fractography

4.2.1 350 Degree Latch SEM Fractography

Scanning Electron Microscopic Fractography (SEM) was performed on the fracture face removed from the 350 degree and 90 degree latches. The 350 degree latch was selected for a more comprehensive evaluation because the BWR service crack was not through wall, and therefore contained a crack tip. In the region adjacent to the crack tip, the surface was nearly free of oxide, allowing clear imagery of fractographic features. Figures 12 through 19 provide the results. The 90 degree latch fracture face was studied to confirm the mechanism of fracture was the same.

Figure 12 is an SEM view at 12 X of the fracture face of the 350 degree latch. This low magnification macroscopic view showed secondary cracking associated with the primary fracture. This is characteristic of SCC growth. This figure also provides location information for the higher magnification views of Figures 13-16.

Figure 13 is a 300 X magnification view of the fracture face in the region of crack initiation. See arrow location 4 in Figure 12. Note the intergranular nature of the fracture, with minor plastic deformation and moderate oxide build-up. Figure 14 is the same fracture face at a magnification of 200 X in the mid-fracture region. Note the intergranular characteristic of the surface, with moderate oxide build-up. This is location 3 in Figure 12. Figures 15 a & b (Location 2 in Figure 12), are fracture face views taken at 200 and 300 X of the region near the crack tip. Note the slight build-up of oxide, indicating recent growth in the BWR environment. Figure 16 contains views of the fracture face (300 X and 1000 X) at location 5 in Figure 12. This is the region of ductile rupture which occurred at room temperature during latch removal.

The central region of the 350 degree latch fracture face is shown in Figure 17. The left hand edge of the fracture (arrow location 1 in the Figure) was the region of low temperature fracture during latch removal. This figure provides location information for the higher magnification views of figure 18. Figure 18 contains 200 X and 300 X views of the fracture surface shown in Figure 17 at location 1. Note the IGSCC character, and the only very slight oxide. This region is near the crack tip. Location 2 has appearance the same as Figure 14.

Figure 19 is a high magnification (2000X) view of the fracture face of the 350 degree contact wedge latch. The area selected is the central region of the view of Figure 15a, and was

selected because it was relatively clean of surface oxide. Features characteristic of a fatigue fracture were not observed. An intergranular failure mode was observed.

4.2.2 90 Degree Latch SEM Fractography

Scanning Electron Microscopic Fractography (SEM) was also performed on the fracture face removed from the 90 degree latch. While the 350 degree latch was selected for a more comprehensive evaluation latch because the BWR service crack was not through wall, the 90 degree latch fracture face was studied to confirm the mechanism of fracture was the same. Figures 20 through 23 provide the results.

Figure 20 is a SEM view (12X) of the fracture face of the 90 degree contact wedge latch. This low magnification macroscopic view shows secondary cracking associated with the primary fracture. As was found on the 350 degree wedge latch fracture face, this is characteristic of SCC growth. This figure also provides location information for the higher magnification views of the 90 degree wedge latch fracture, Figures 21-23. Figure 21 is a 200X view of the fracture face in the area of crack initiation. The cracking is intergranular with heavy oxide buildup characteristic of IGSCC. Figure 22 is a 200X view of the region near the site of final separation of the 90 degree wedge latch. The cracking is clearly intergranular, with less oxide buildup than seen in Figure 21. Figure 23 is a 800X view of the center of fracture face of Figure 22. Note the oxide buildup and obscuring of the fracture face detail.

4.3 Optical Microscopy

4.3.1 350 Degree Latch Microscopy

A single section was prepared for optical microscopic evaluation of the 350 degree latch fracture. The section was located as indicated in Figure 24. This location was selected as it captured secondary cracking as well as the primary surface feature of crack initiation, growth, crack tip, and room temperature ductile separation. The plane of polish is perpendicular to the plane of the service fracture. Figure 25 is an as-polished, and etched view of the fracture.

Figure 26 contains optical microscopic views of the latch failure. Photo a. is the region of the crack mouth (initiation). Photo b. is the mid-fracture region, and c. is the region of final separation characterized by transgranular ductile rupture. The upper left photograph in Figure 27 shows secondary cracking characteristic of IGSCC. Magnified views of the crack

are noted in the lower photo of Figure 27. This crack morphology is characteristic of IGSCC. Figure 28 is a high (250X) view of the fracture in the region of the crack initiation. Evidence of minor cold work was observed. Figure 29 is a high magnification (250X) view of the mid-fracture region of the 350 degree wedge latch, clearly showing the IGSCC nature. Figure 30 shows high magnification (250X) view of latch fracture face in region of final separation. The final separation occurred by ductile rupture, and has an associated plastic deformation. The observation is fully consistent with the results of SEM fractography, as seen in the views of Figure 16.

4.3.2 90 Degree Latch Microscopy

A single section was prepared for optical microscopic evaluation of the 90 degree latch fracture. The section was located and prepared in manner similar to that used for the 350 degree latch sample. This location was selected as it captured secondary cracking as well as the primary surface features of crack initiation, growth and final separation. The plane of polish is perpendicular to the plane of the service fracture. Figure 31 is an as-polished, and etched view of the fracture.

Figure 32 contains optical microscopic views of the latch failure. Photo a. is the region of the crack mouth (initiation). Photo b. is the mid-fracture region, and c. is the region of final separation. There was no transgranular ductile rupture associated with this latch fracture. Figure 33 shows secondary cracking characteristic of IGSCC. Figure 34 is a high (250X) view of the fracture in the region of the crack initiation. Note evidence of minor cold work, similar to that found on the 350 degree latch. Figure 35 is a high magnification (250X) view of the mid-fracture region of the 90 degree wedge latch, clearly showing the IGSCC nature. Figure 36 is a view of a portion of the secondary cracking near the mouth of the secondary crack, with significant oxide buildup. This buildup is characteristic of a crack surface exposed to the BWR environment for some time. By comparison, the 350 degree latch was a more "recent" failure.

4.3.3 166 Degree Latch Microscopy

Figure 37 has cross-sectional views of the uncracked 166 degree wedge latch. Note the lack of incipient cracking or plastic deformation in the area of crack initiation on the 90 and 350 degree latches.

4.4 Materials Properties Verification

The lower contact wedge latches were fabricated to GE Drawing 112D6560 of Alloy X750: ASTM Specification ASTM-B-637 Type 3, Heat HT#51072-2, as indicated in the Appendix A- "Alloy X-750 Certificate of Conformance/Compliance/CMTR." Heat Treatment Procedure was in accordance with GE-SAP-AH-1Revision 2, dated 10/25/1994, and GE-NE Specification P50YP107/ Attachment 1. These documents indicate an age hardening heat treatment at 1300 degrees F for 20 1/2 hours, followed by a fan air cool. The material of a failed wedge latch was tested by various means to assess the correctness of material composition and heat treatment. The results are documented in the following paragraphs.

4.4.1 Material Compositional Analysis

Initial compositional analysis screening was performed at the time of the SEM fracture surface study. Figure 38 is EDS (Energy Dispersive X-ray Spectroscopy) data used to qualitatively check composition of the latch material. The scan was prepared on a relatively clean (low oxidation) region of the fracture face. The data are consistent with Alloy X-750.

Further analysis was performed by using a direct coupled plasma spectrographic quantitative analysis technique. More accurate than the SEM/EDS method, the results of this analysis was used to compare the composition with the ASTM-B-637-89, Type 3 designated in the GE Purchase Specification, as well as the check analysis provided in the CMTR for the appropriate latch heat HT#51072-2. These comparisons are listed in Figure 39. The sample for the spectrographic analysis was prepared from a 1 gram portion of the metallographic specimen removed from the 350 degree wedge latch. To ensure the removal of surface contamination, the sample was alternately etched with concentrated hydrochloric and nitric acids until freshly exposed metal was observed on all surfaces. The sample was then rinsed in deionized water, then dried. The clean sample was then weighed, then disolved in approximately 20 mL concentrated nitric acid and 2 mL hydrochloric acid for each gram of metal. The dissolution was carried out by heating to near boiling in a 100 mL Teflon beaker covered with a Teflon watch glass. The solution was then analyzed with a Spectraspan III plasma emission spectrometer equiped with an ADaM data acquisition and control system. Standard steel materials used to calibrate the spectrometer response were obtained from the National Bureau of Standards (NBS), now known as the National Institute of Standards and Technology. The results obtained in this analysis, provided in Figure 39 demonstrate good agreement with the certified values. It is concluded the composition of the wedge latch material is consistent with Alloy X-750.

4.4.2 Microhardness Traverses

Microhardness measurements were performed on the polished and etched sample of the 350 degree wedge latch originally used for optical microscopic characterization of latch cracking. Figure 40 is a photo-macrograph of the microhardness imprints. Measurements were made in the Knoop scale, with a 500 gram load. Average Knoop readings were approximately 373 Knoop, corresponding to a reading of approximately 346 on the HB scale. For this material, Knoop readings ranging from 292 to 391 are specified (or 267 to 363 on the HB scale). No hardness gradients, or increases in readings near the fracture edge, were found. These observations demonstrate the fracture failure was not associated with plastic deformation, or ductile overload. These results are consistent with the results of optical microscopy and SEM fractography, and consistent with the heat treatment.

4.4.3 Microstructural Assessment

Based on the Heat Treatment record for Ht#51072-2, as documented in the CMTR (Appendix A) the material was supplied in the Annealed (1975 +/- 25 F) condition, and age hardened at 1300 F +/- 15 F for 20 1/2 hours, followed by removal from the furnace and a fan air cool. Optical microscopy of a tensile test specimen of this heat, with this anneal condition, shows a grain size of 7.0. High magnification optical microscopic views of samples prepared from 90 and 166 degree wedge latches Figures 41 and 42 show a microstructure correct and appropriate for this material and heat treat condition.

5.0 ANALYSIS OF RESULTS

5.1 Fracture Mechanism

The preceeding sections of this report have documented the key evaluation evidence associated with the microstructural and fractographic features of the latch failure. They are summarized here (and summarized in Table 1):

1. The wedge latch material is of correct composition (Alloy X-750), and is as specified. The heat treatment was correct and resulted in appropriate hardness levels.

2. There is only minor evidence of plastic deformation (at the point of crack initiation), as shown by optical microscopy, indicating the failure was not due to a single event overload. This statement is further supported by the absence of microhardness gradients in the fracture region.

3. The fracture is intergranular, characteristic of IGSCC found in BWR internal components.

4. Crack initiation occurred under the latch nose at the transition from a 200 mil thick section to a much thicker "nose" section.

5. Those latches that failed had an oxide pattern on the underside of the nose, indicating contact during service. The uncracked latch (166 degree latch) did not have the oxide contact pattern. Confirmation of the absence of cracking was provided by both SEM surface imagery as well as by optical microscopy.

With this evidence, it is concluded that the lower spring contact wedge latches failed as a result of Intergranular Stress Corrosion Cracking of a material having a known susceptibility under high stress conditions. The root cause of the failure of the contact wedge latch failure was determined to be high sustained loads applied to the underside of the latch nose (due to unacceptable movement of the shroud repair assemblies during plant operation) resulting in an intergranular stress corrosion crack fracture of the contact wedge latch. Crack initiation and growth of the SCC fracture occurred within one cycle of plant operation.

5.2 Crack Growth Considerations

The results presented in Reference 2 (Intergranular Stress Corrosion Cracking Propagation Rates of Alloy X-750 in the BWR Environment, dated 25 March 1977) indicate that although Alloy X-750 is a suitable structural material for BWR applications, and the fact that the IGSCC failed wedge latches were manufactured from Alloy X-750 with appropriate composition, heat treatment and mechanical properties, demonstrate that Alloy X-750 is not immune to IGSCC in the BWR environment. The measured (fracture mechanics specimens) and calculated (CBB specimens) Alloy X-750 crack growth rates indicate that at moderate to high stress intensities, Alloy X-750, even heat treated to obtain its highest resistance to IGSCC in the BWR environment, can suffer rapid intergranular crack growth. These measured and calculated Alloy X-750 crack growth rates are readily high enough to result in failure of the 200 mil thick wedge latch within one fuel cycle, as supported by the data of Reference 2.

6.0 ROOT CAUSE OF FAILURE

The most probable root cause of the lower spring contact wedge latch (retainer clip) failure was determined to be high sustained loads applied to the underside of the latch nose (due to unacceptable movement of the shroud repair assemblies during plant operation) resulting in an intergranular stress corrosion crack fracture of the retainer clip. Crack initiation and growth of the SCC fracture occurred within one cycle of plant operation. Such crack growth is consistent with laboratory predictions of SCC propagation rates of Alloy X-750 in the BWR environment under high sustained loads.

7.0 REFERENCES

7.1 GENE B13-01739-40, "Nine Mile Point 1 - Shroud Repair Anomalies", April 1997

7.2 "Intergranular Stress Corrosion Cracking Propagation Rates of Alloy X-750 in the BWR Environment", 25 March 1997. B. M. Gordon, Corrosion Technology Report.

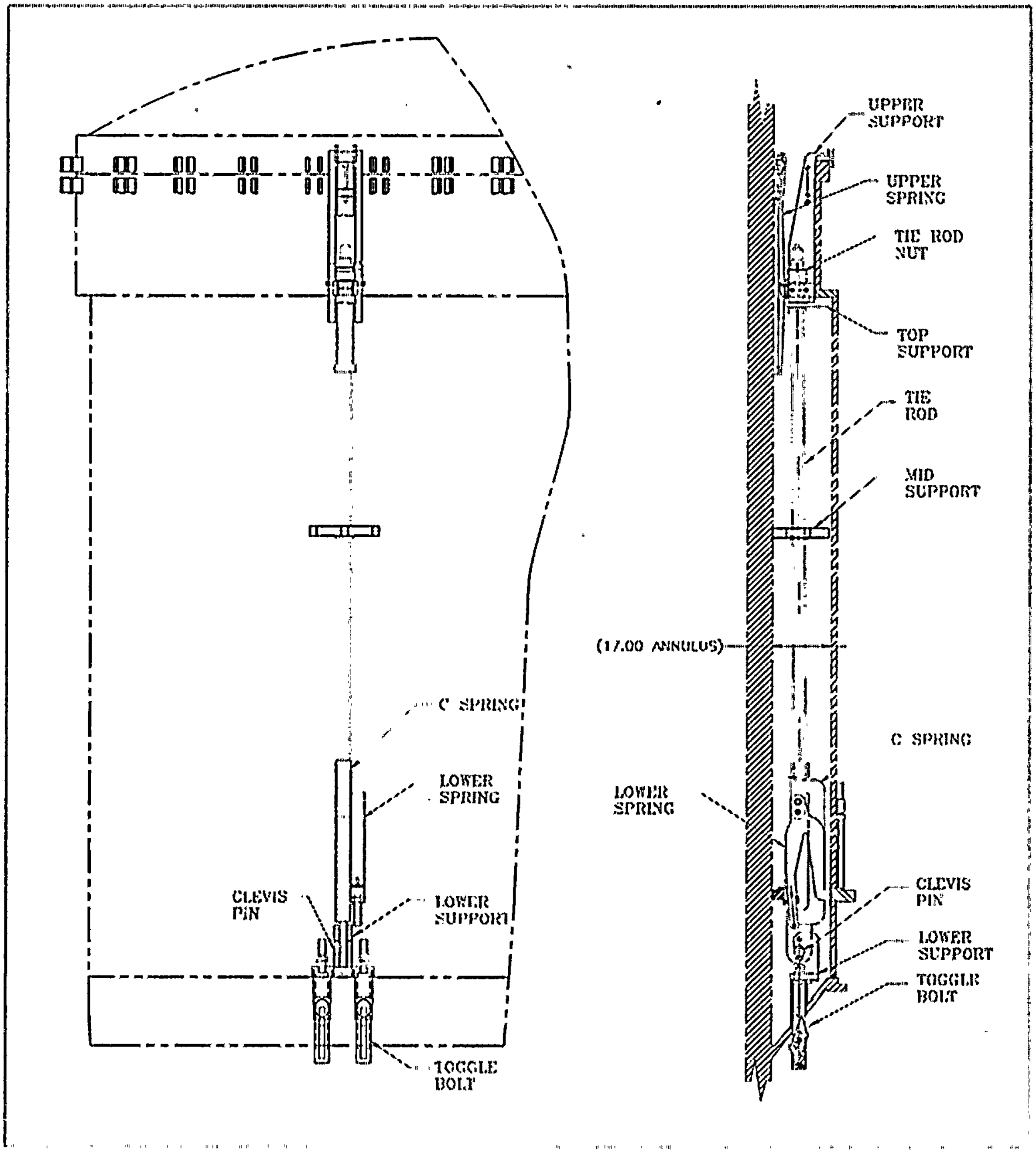


Figure 1. **Shroud Repair Assemblies**

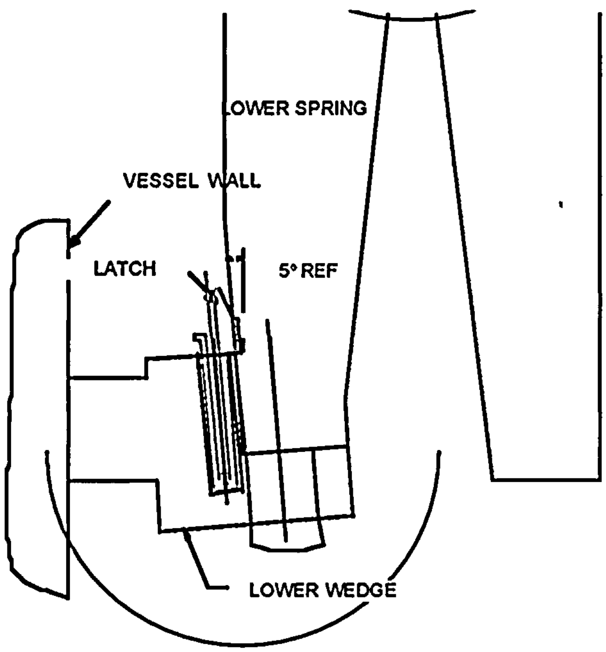


Figure 2. Shroud Repair Lower Support Configuration

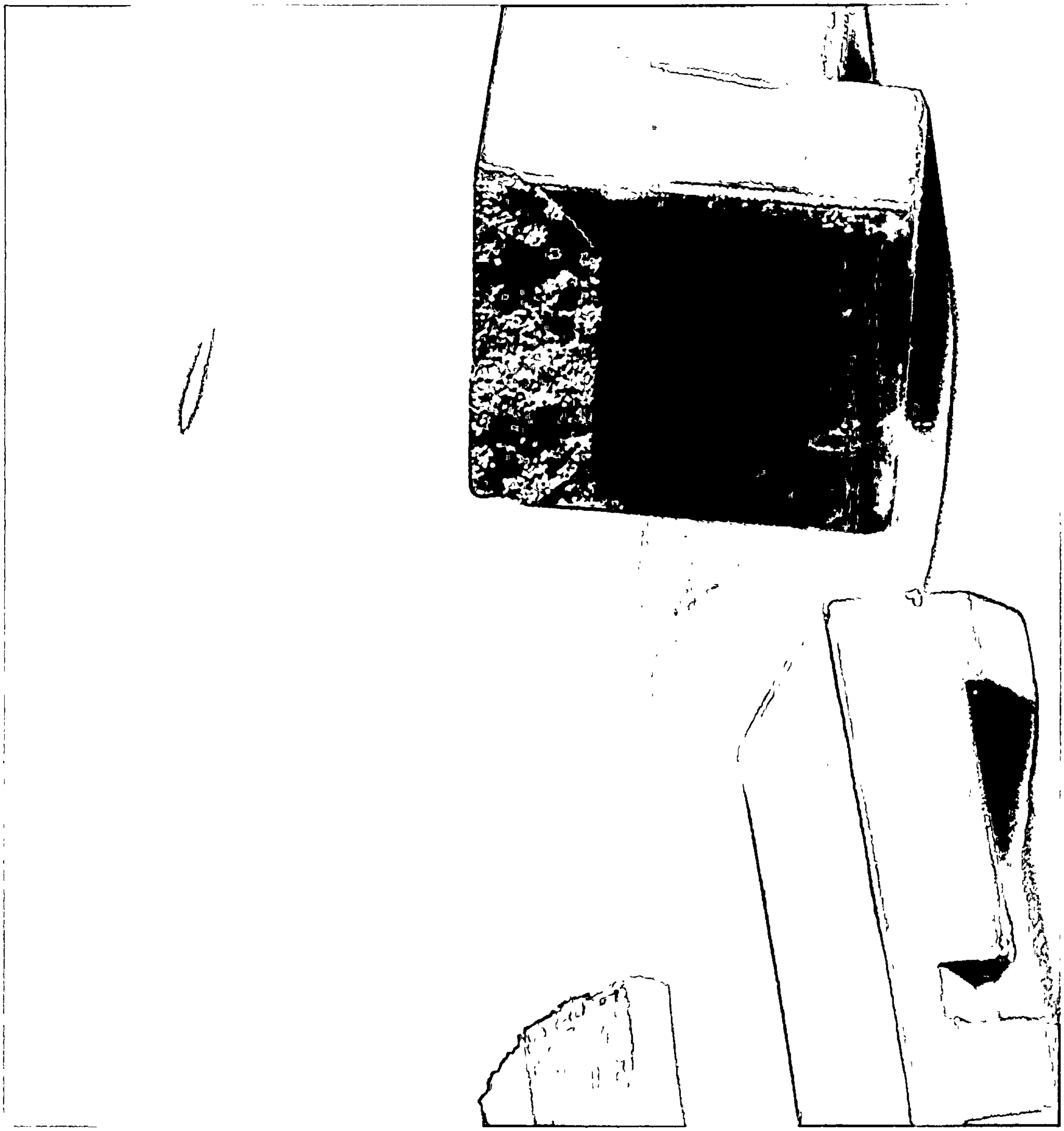


Figure 3. Photo-macrograph of 90 degree lower spring contact wedge latch, found in the broken and separated condition. The nose piece of the latch was found in the annulus region of the reactor.

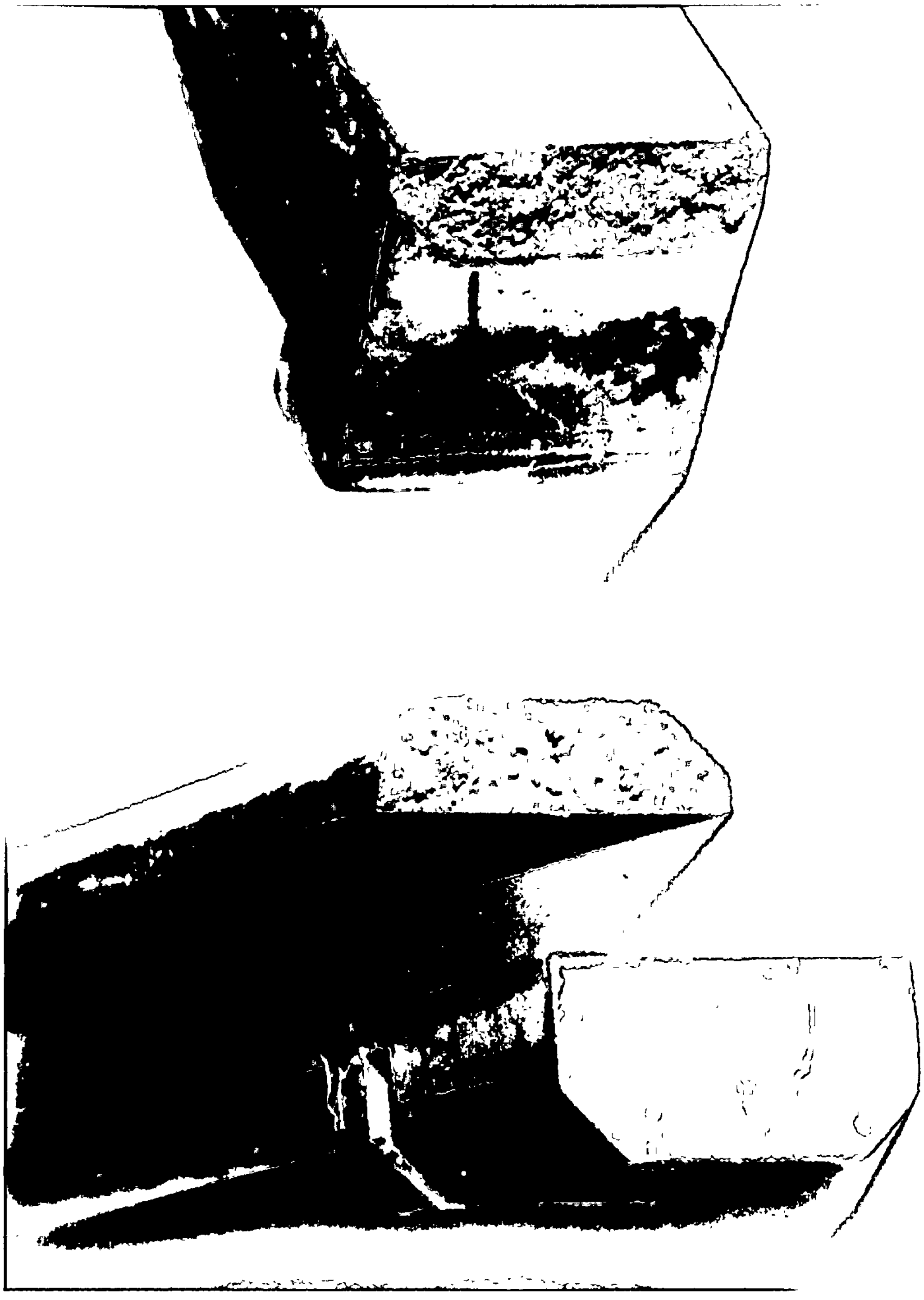


Figure 4. Enlarged view of the 90 degree contact wedge latch fracture surfaces. Note uniform oxide coloration of fracture surface and absence of plastic deformation. Oxide pattern on underside of latch "nose" indicates contact during service.

166° Clip

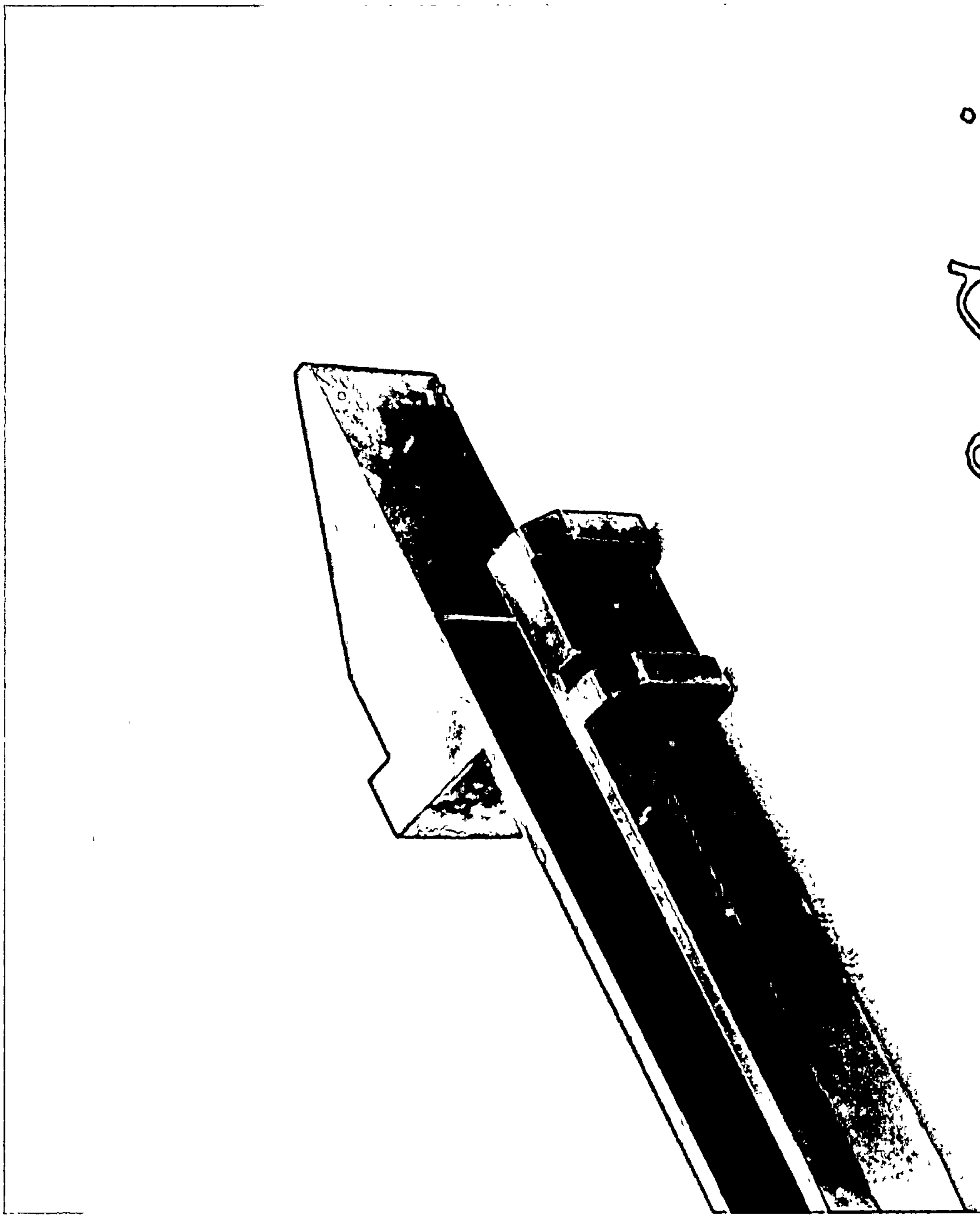


Figure 5. Contact wedge latch removed from the lower position of the 166 degree tie rod assembly. Clip was intact and without irregularity.

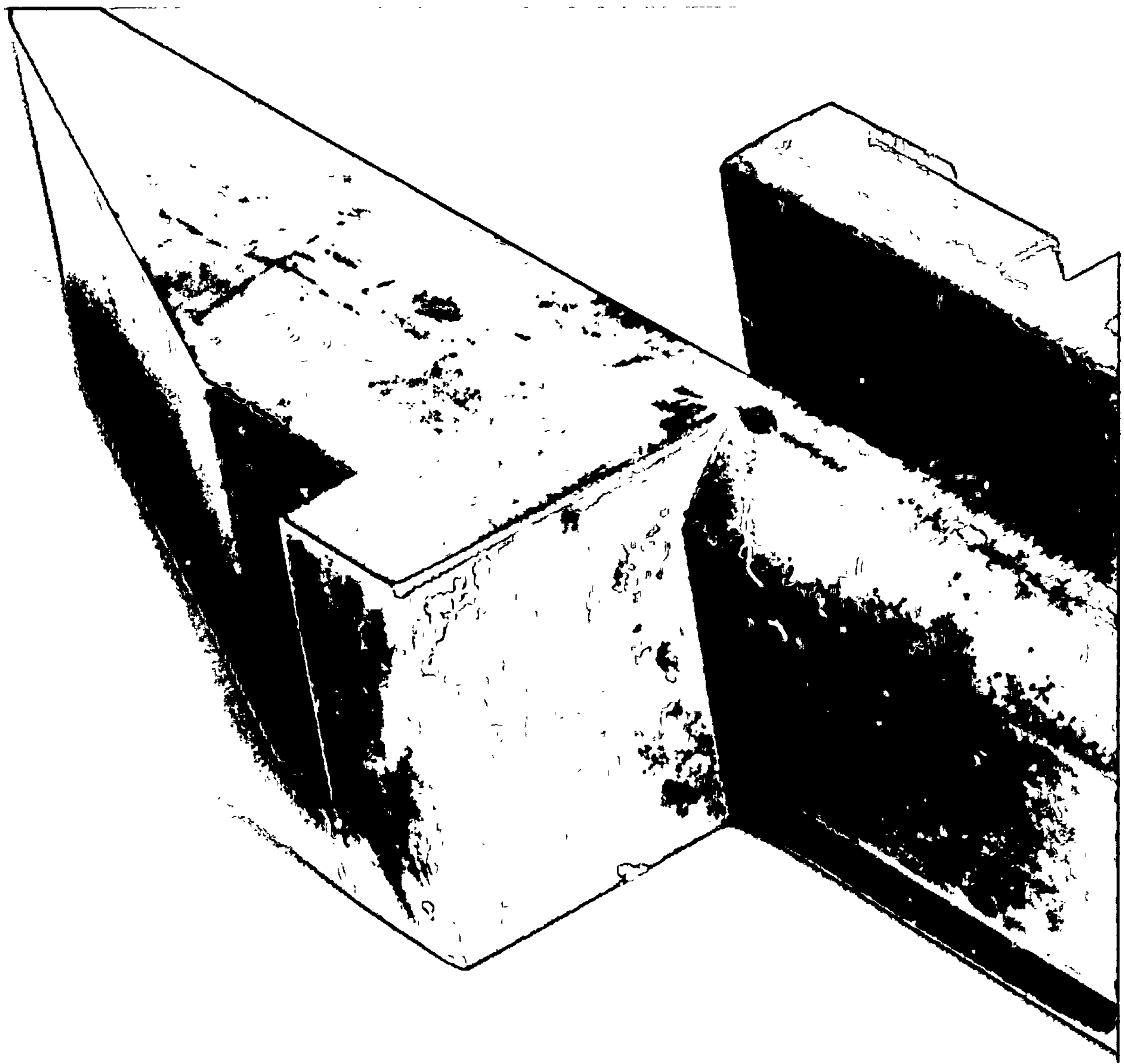
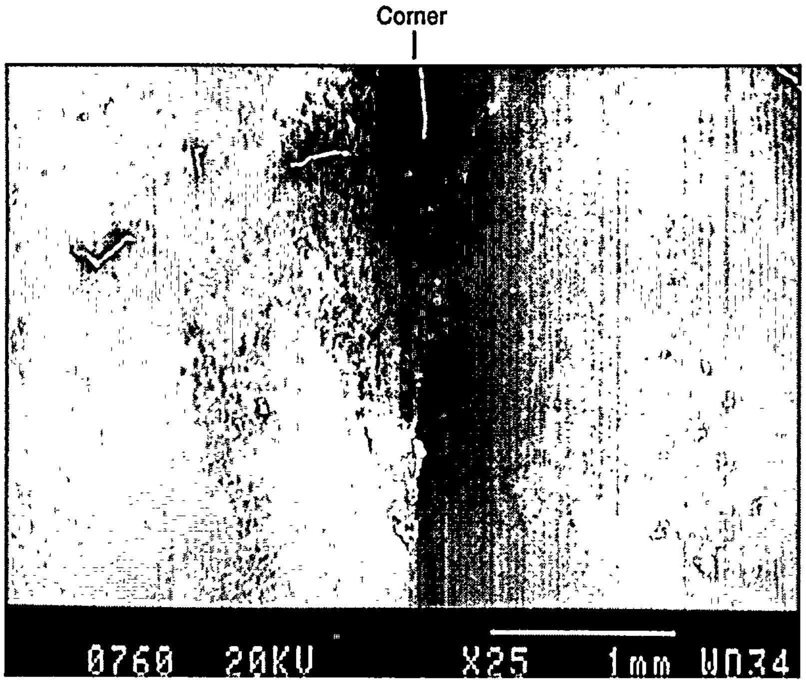
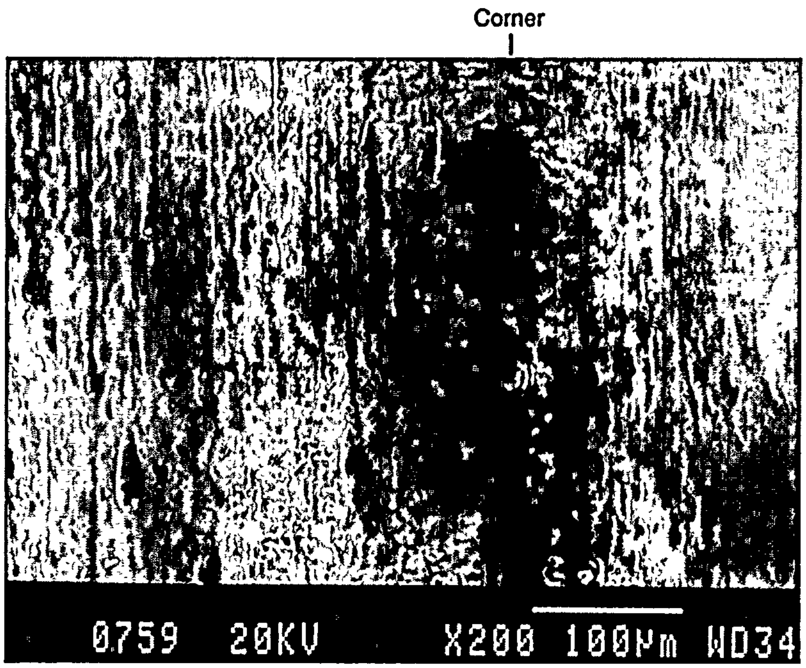


Figure 6. Enlarged view of underside of 166 degree contact wedge latch nose. Note the absence of oxide pattern indicating no contact during service. Compare with Figure 4.





<u>Figure 7.</u> Typical views of "inside corner" region of 166 degree contact wedge latch by SEM imagery, performed to identify possible cracking. The method, used in place of PT (penetrant testing), revealed no cracking in area of crack initiation as found on cracked wedge latches.

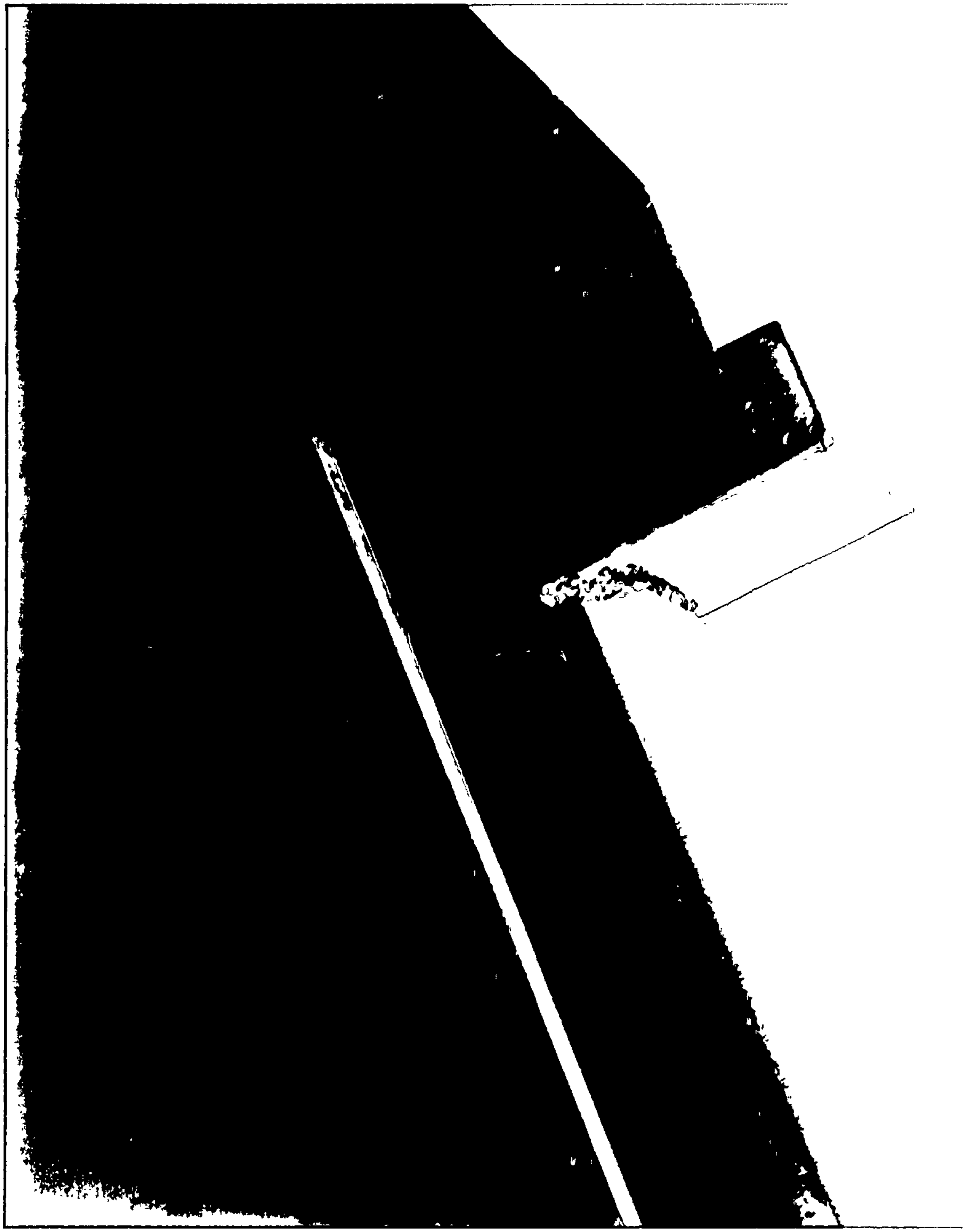


Figure 8. Enlarged view of 350 degree contact wedge latch, showing location of separation. The nose separated during latch removal.

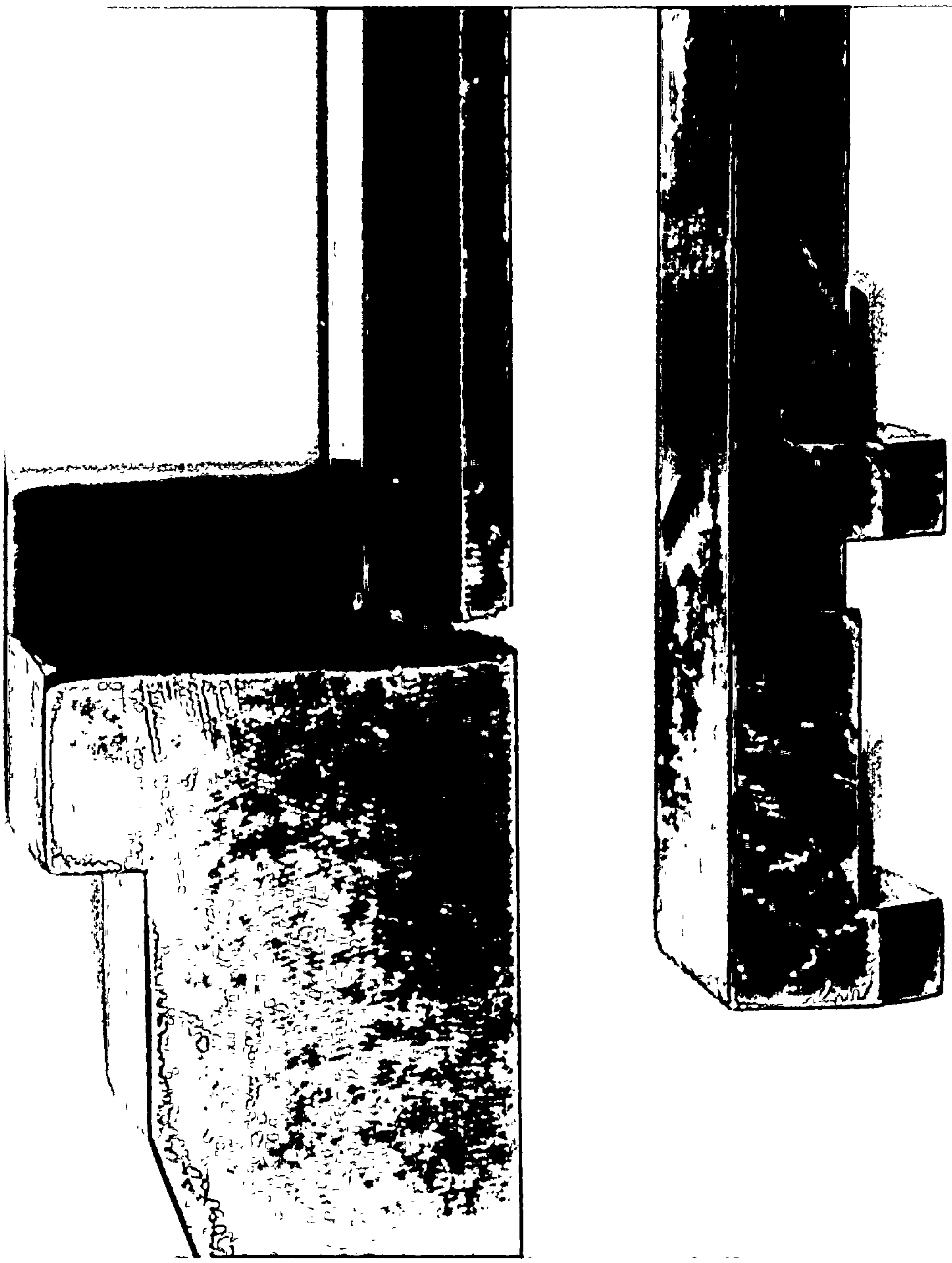


Figure 9. Side view of broken segments of 350 degree contact wedge latch, showing the absence of plastic deformation. The IVVI photo indicated a possible deformation - now known to be caused by a yawning open of a nearly through-section crack.

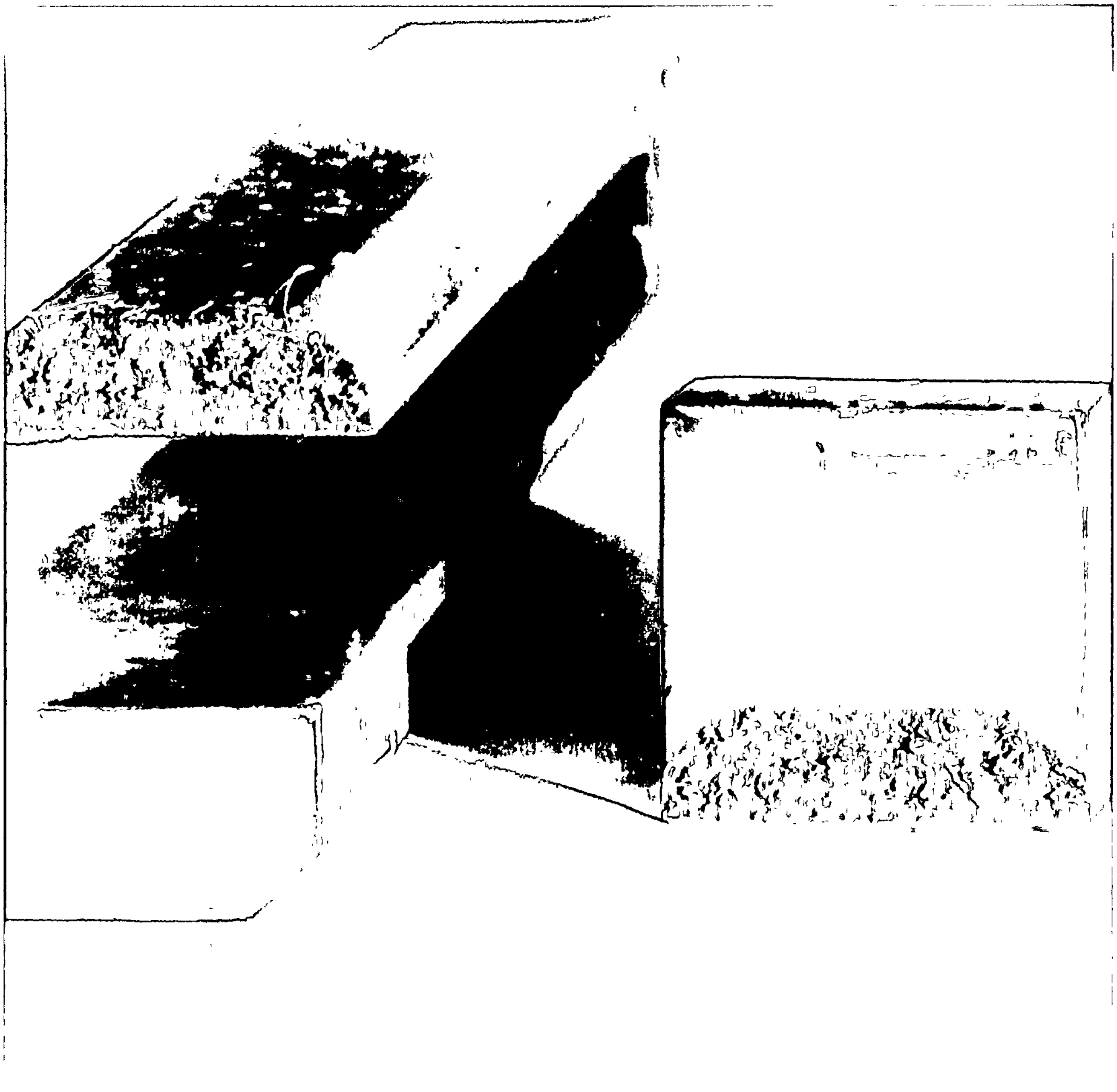


Figure 10. Enlarged view of 350 degree contact wedge latch fracture faces. Note the gradation of oxide coloration, ranging from darkest brown in the region of crack initiation (oldest crack surface) to a light brown in the region of the crack tip (recent crack) in BWR environment. The unoxidized band of the lower edge was caused by room temperature ductile fracture during latch removal.

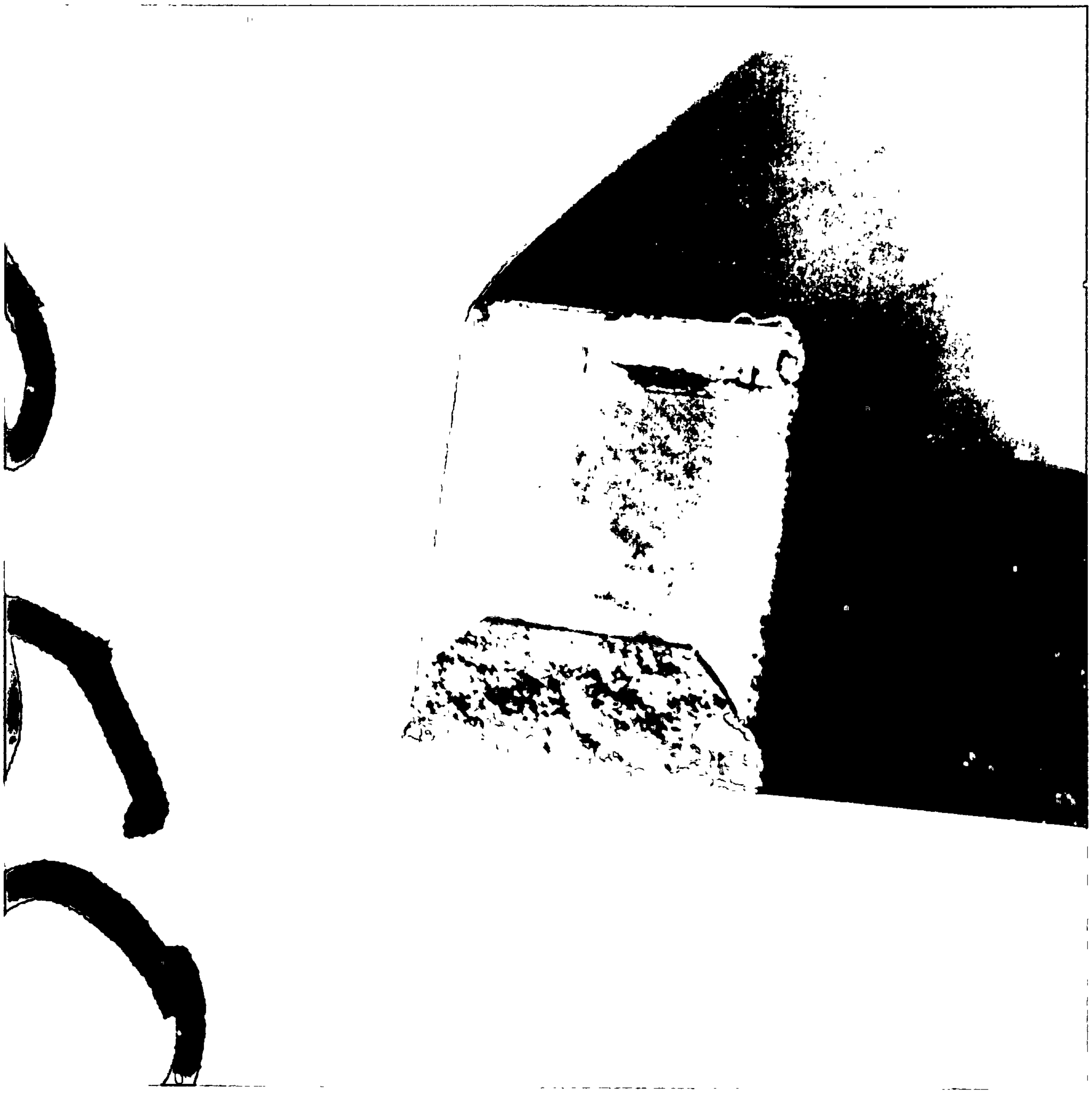
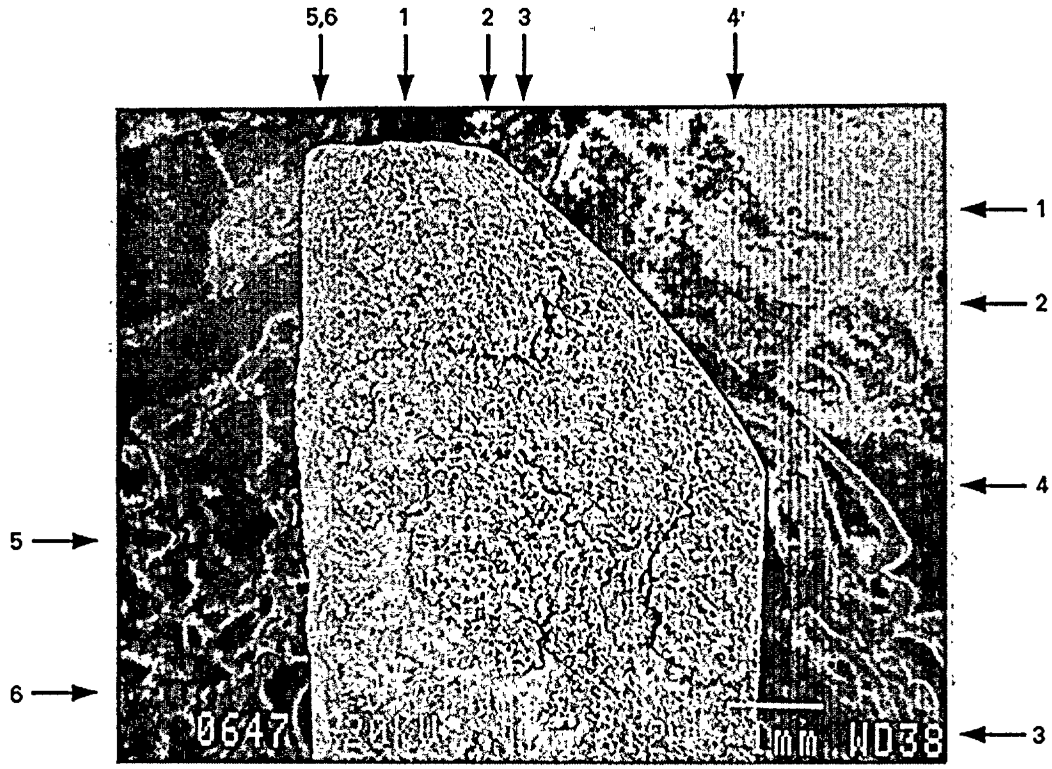


Figure 11. Enlarged view of fracture face and underside of latch "nose" of 350 degree contact wedge latch. Note the gray band at the upper edge of the underside surface. This band was caused by surface contact during plant operation. Compare with Figures 4 and 6.



FRACTURE FACE AT END "A"

Figure 12. SEM view (12X) fracture face of 350 degree wedge latch. This low magnification macroscopic view shows secondary cracking associated with the primary fracture. This is characteristic of SCC growth. This figure also provides location information for the higher magnification views of the following four figures. End "A" is at the left end of the left hand fracture seen in Figure 10.

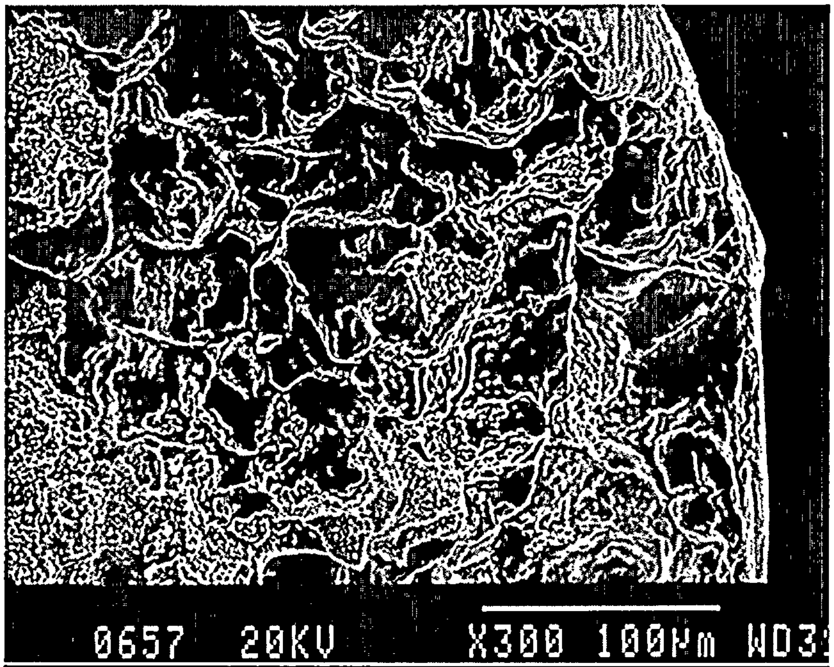


Figure 13. Fracture face (300x) in region of crack initiation - Arrow location (4) in Figure 12. Note intergranular nature of fracture, with minor plastic deformation, and moderate oxide buildup.

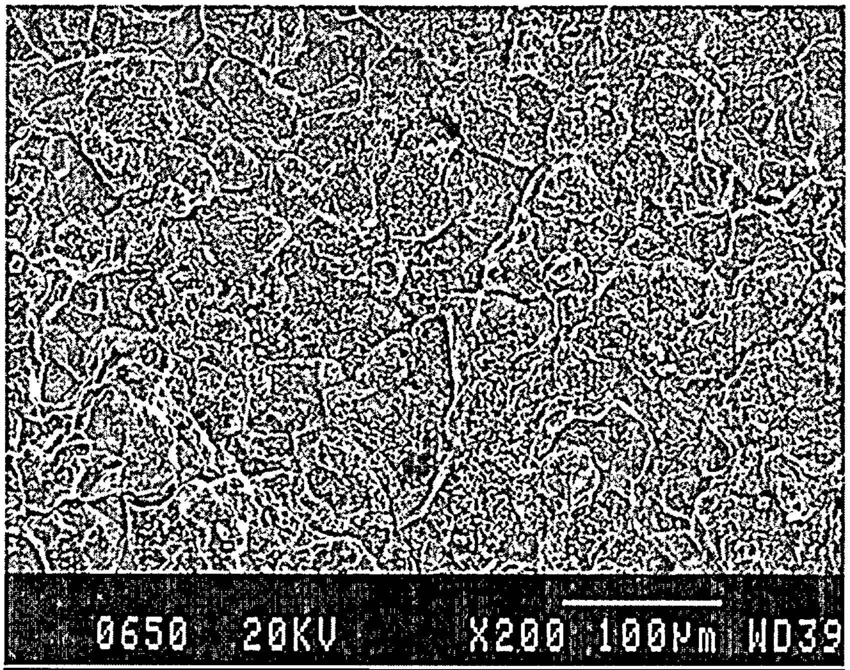
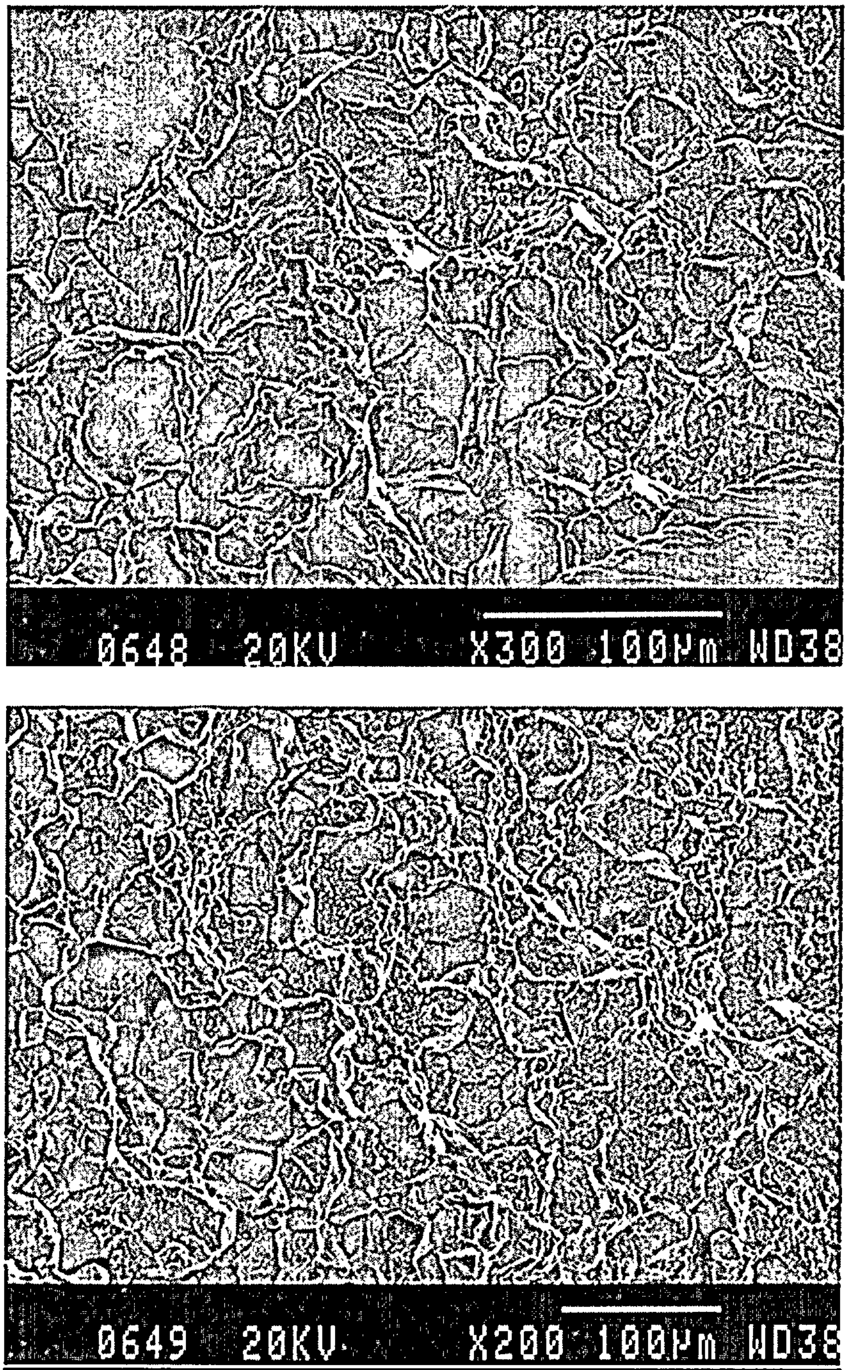
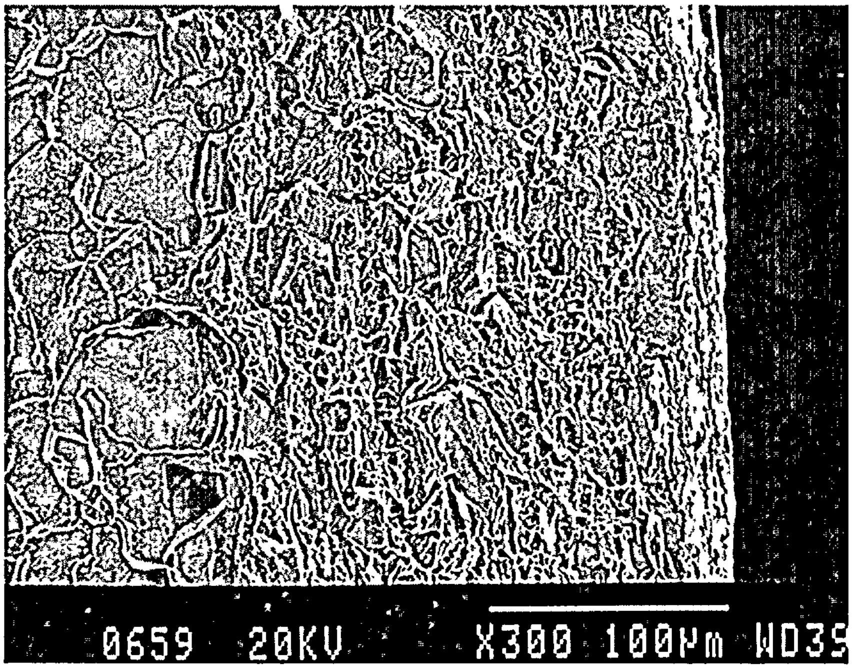


Figure 14. Fracture face (200X) in mid-fracture region of 350 degree wedge latch. Note intergranular characteristic of surface, with moderate oxide buildup. Location (3) in Figure 12.



<u>Figure 15 a & b.</u> Fracture face views (200 and 300X) of region near crack initiation in the 350 degree wedge latch. Note slight buildup of oxide, indicating recent growth in BWR environment. (Location (2) in Figure 12.)



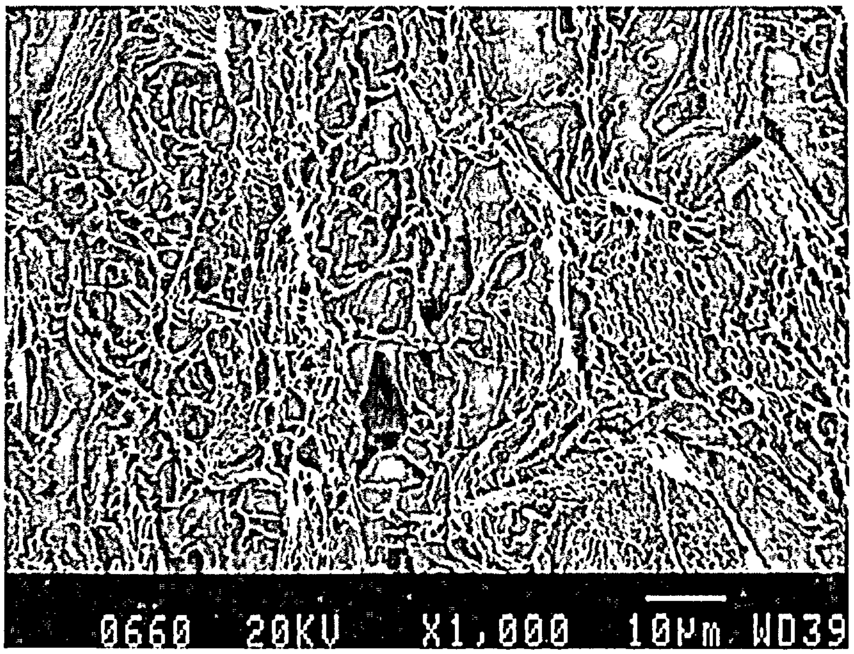


Figure 16. Views of fracture face (300 and 1000X) at location (5) in Figure 12. This is the region of ductile rupture which occurred at room temperature during the 350 degree wedge latch removal.

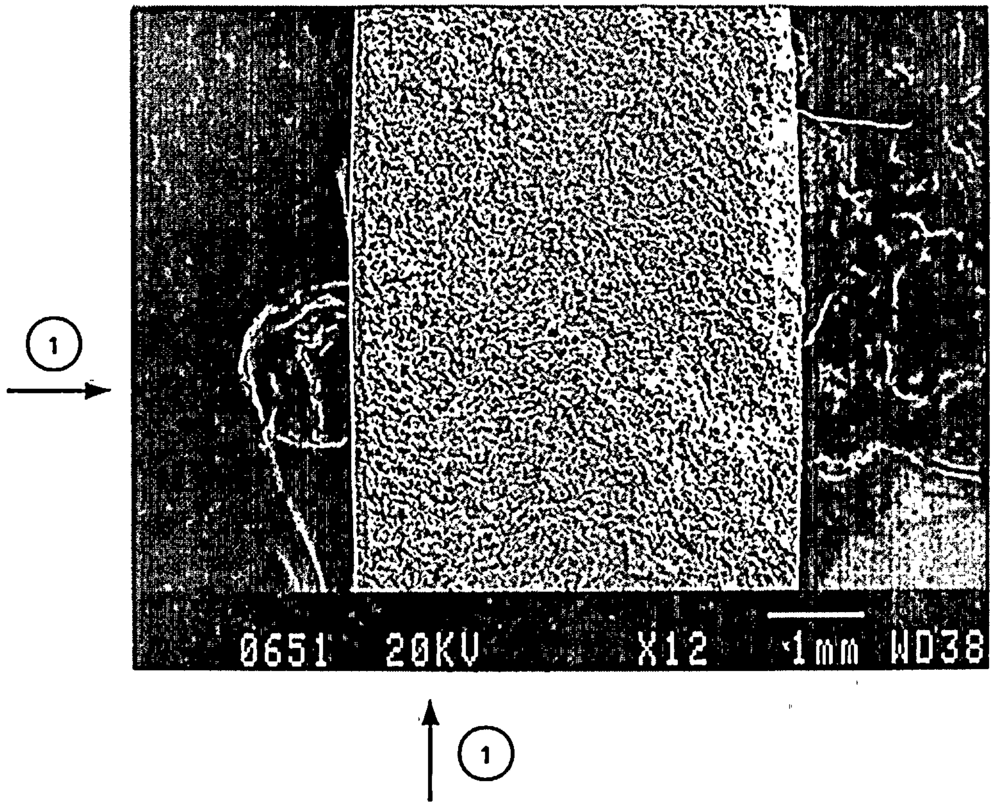


Figure 17. SEM view (12X) of central region of fracture face of 350 degree wedge latch. The left hand edge of the fracture (arrow 1) is region of low temperature fracture during latch removal. The figure provides location information for the higher magnification views of the following figures.

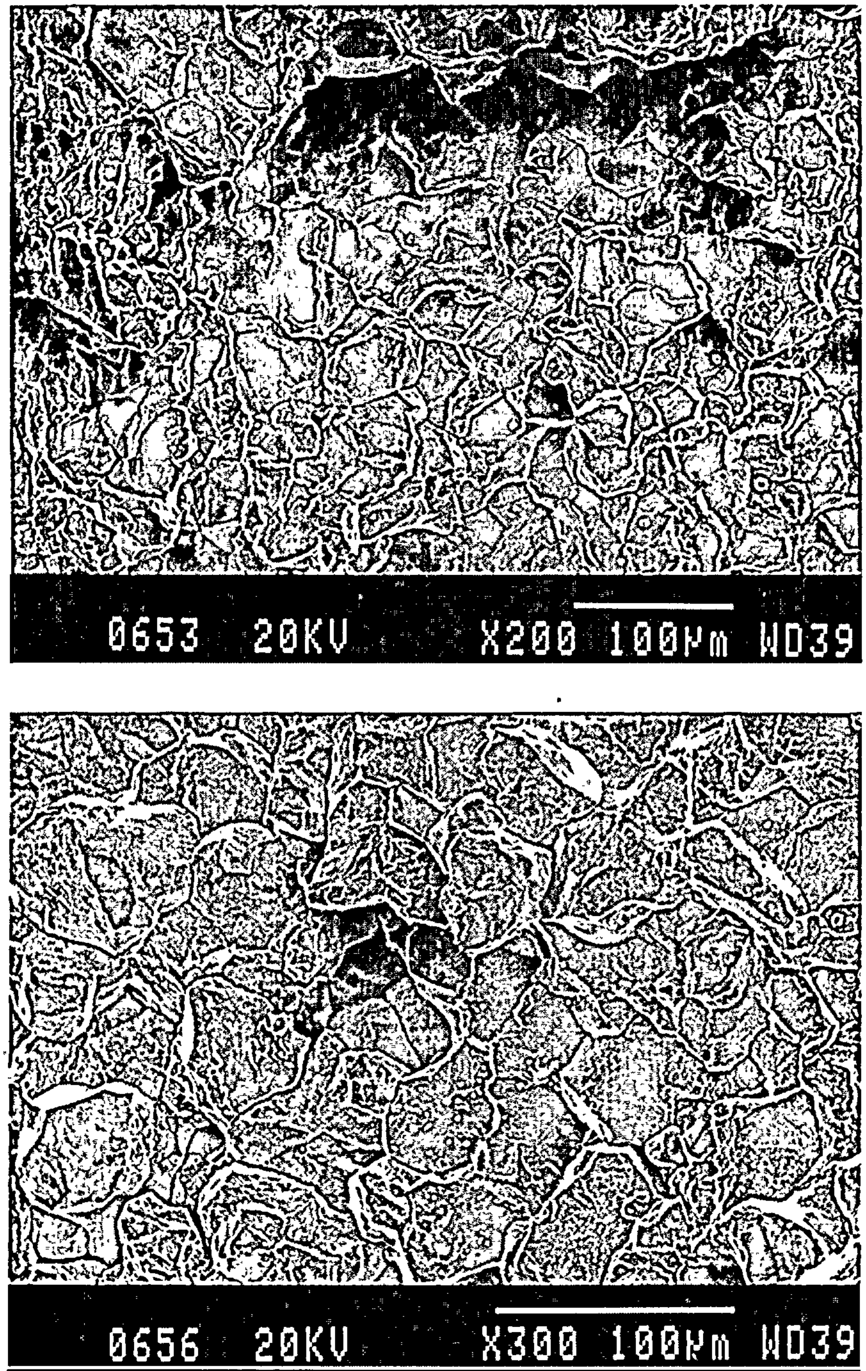


Figure 18. **SEM views (200 and 300X) of fracture surface shown in Figure 17 at location (1). Note IGSCC character, and only very slight oxide, since this location is near crack tip.**

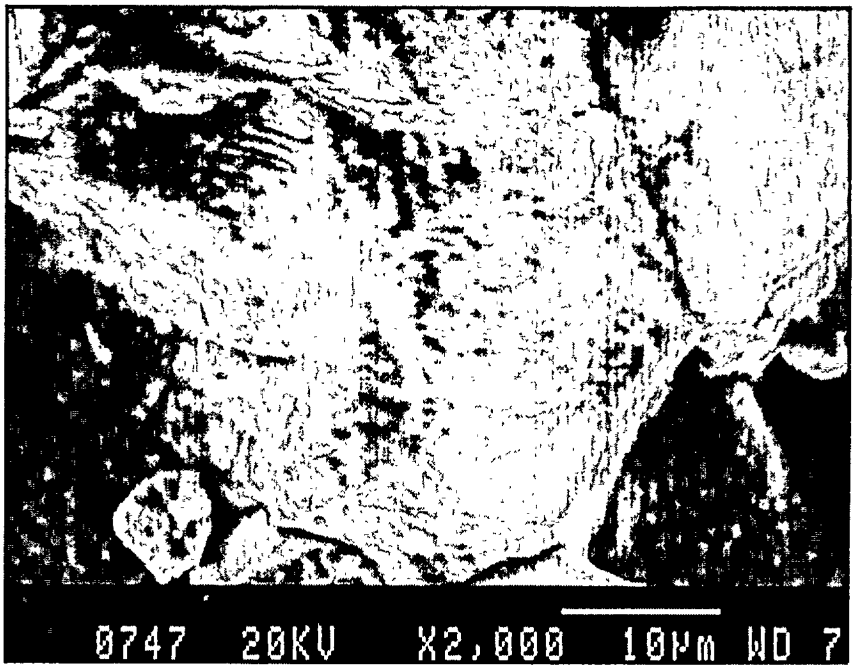


Figure 19. High magnification (2000X) view of fracture face of 350 degree contact wedge latch (Figure 15a). Features characteristic of a fatigue fracture are not observed. An intergranular failure mode is indicated.

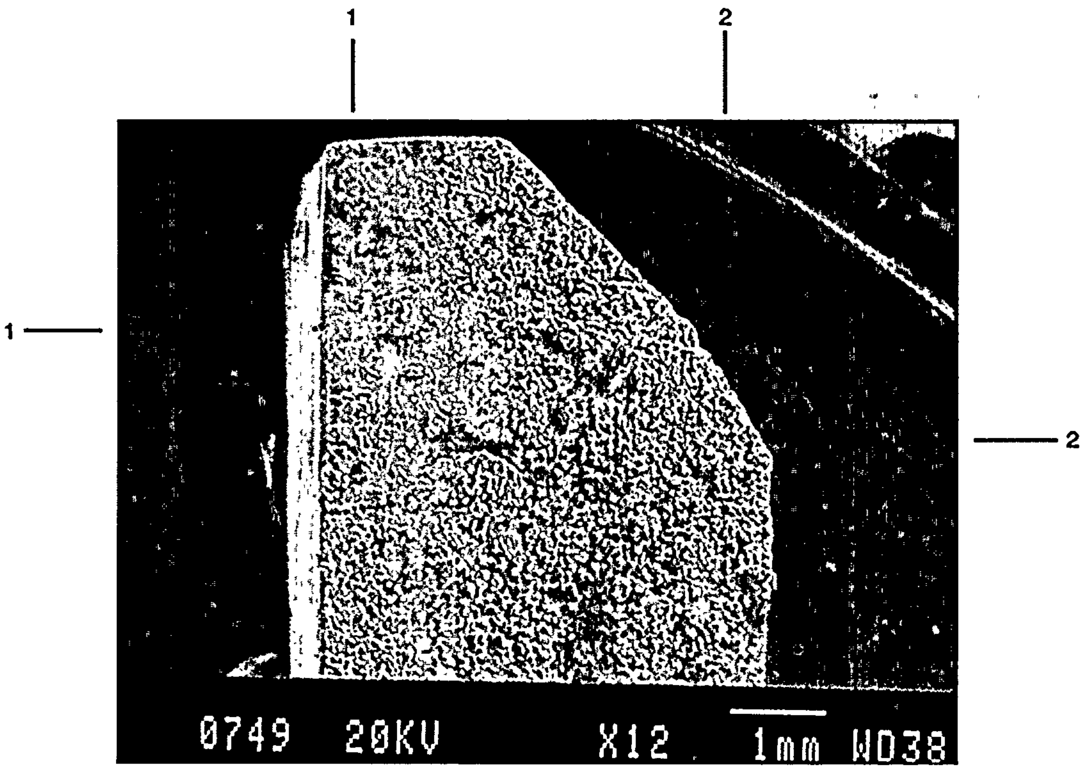


Figure 20. SEM view (12X) of the fracture face of 90 degree contact wedge latch. This low magnification macroscopic view shows secondary cracking associated with the primary fracture. As was found on the 350 degree wedge latch fracture face, this is characteristic of SCC growth. This figure also provides location information for the higher magnification views of the following 90 degree wedge latch fracture figures.

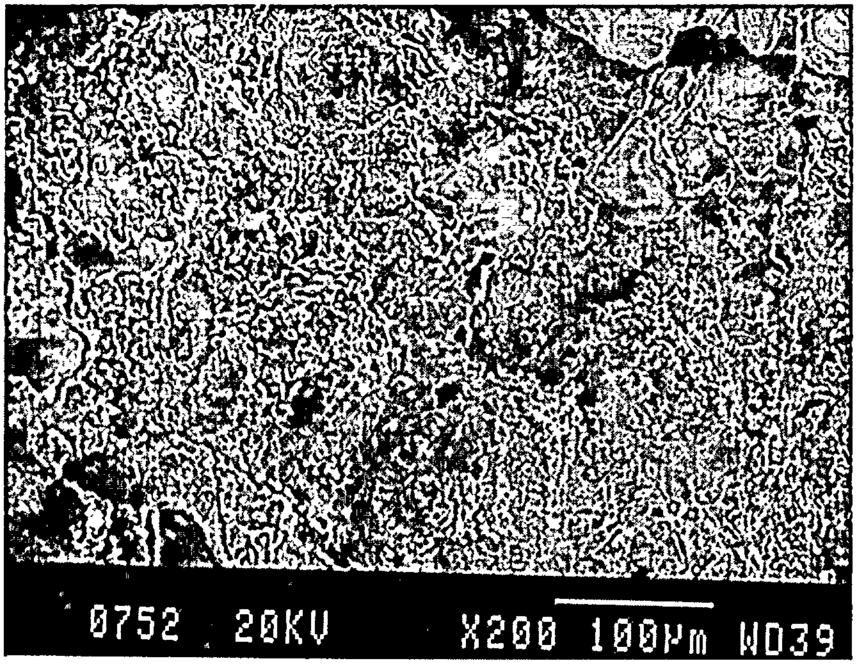


Figure 21. **Fracture face (200X) in region of crack initiation of the 90 degree wedge latch. Arrow ② location on Figure 20. Cracking is intergranular, with heavy oxide buildup – compare with Figure 13, the comparable view for the 350 degree wedge latch.**

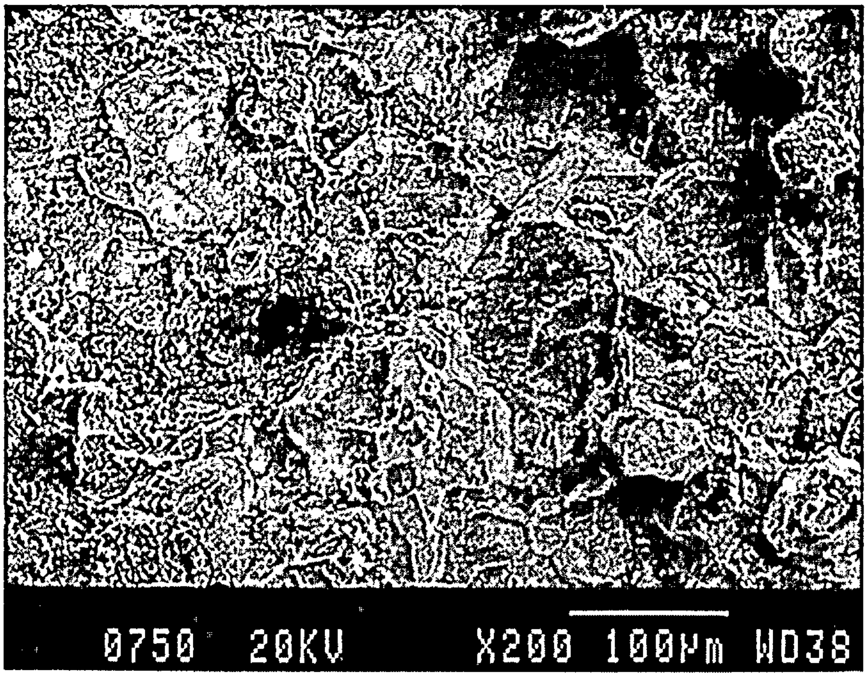


Figure 22. Fracture face view (200X) of region near site of final separation of the 90 degree wedge latch. (Arrow ① location on Figure 20) Cracking is clearly Intergranular, with less oxide buildup than seen in Figure 21.

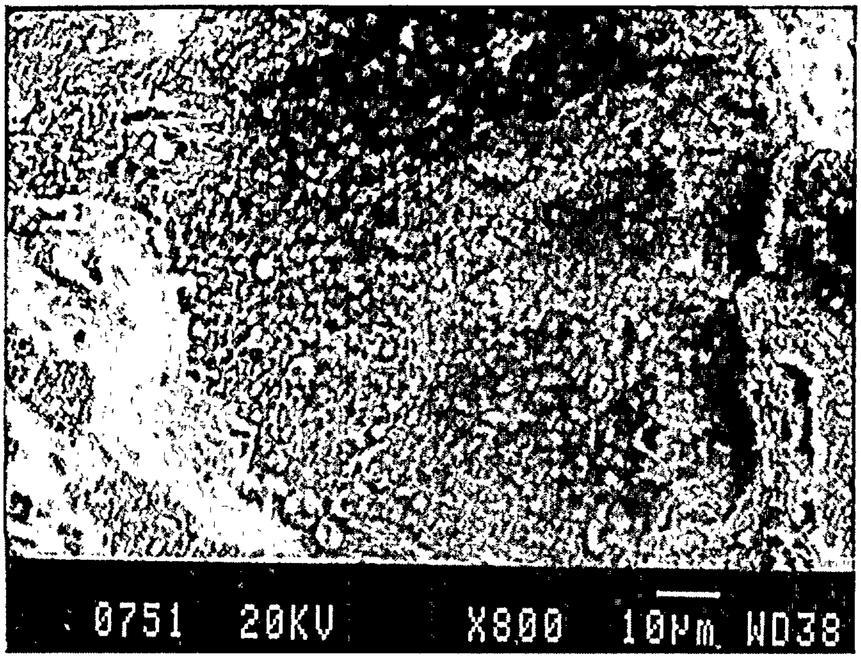
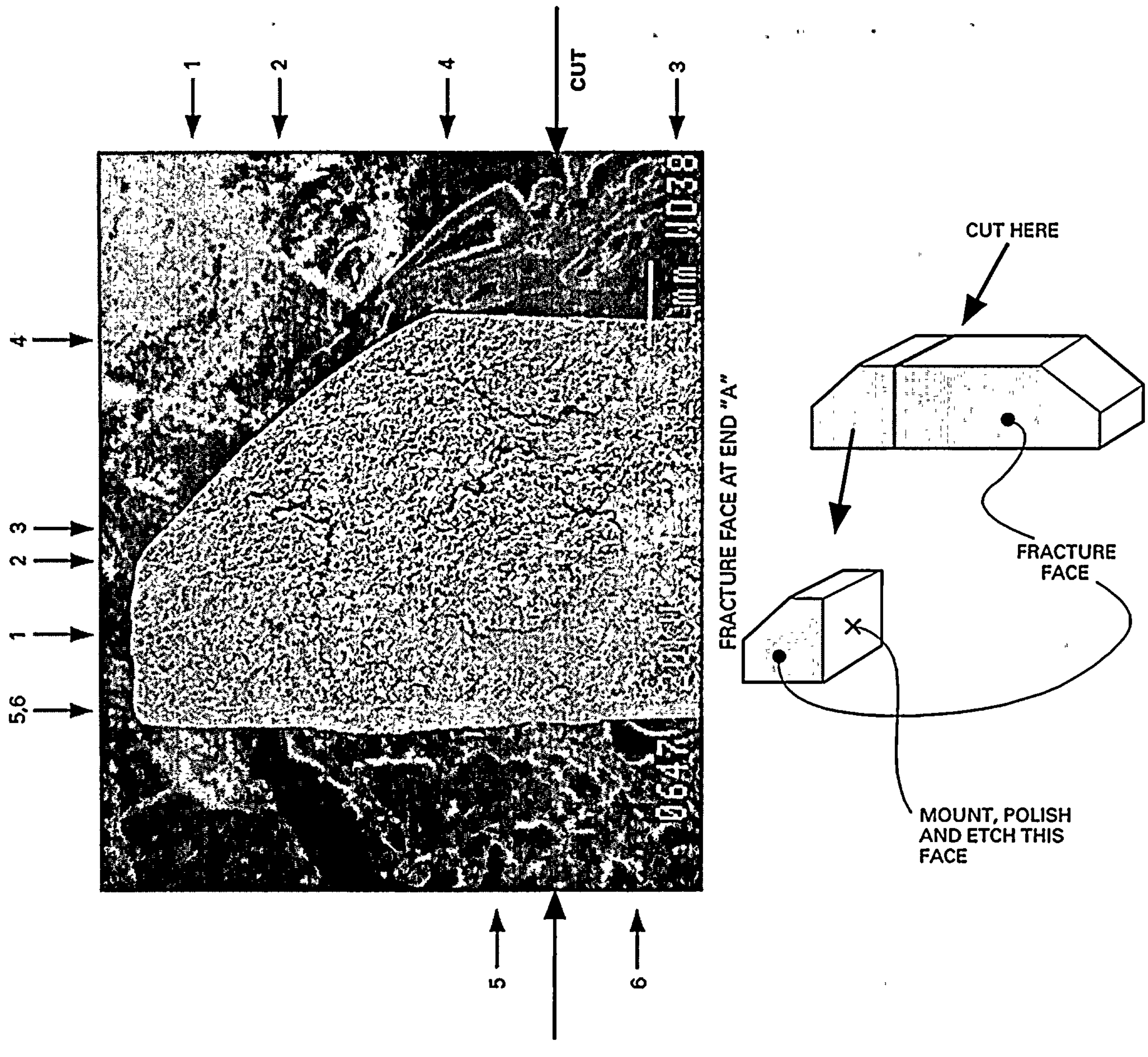


Figure 23. 800X view of center of fracture face of Figure 22. Note oxide buildup and obliteration of fracture face detail.



<u>Figure 24.</u> **Sketch of sectioning location for optical microscopy – 350 degree wedge latch.**

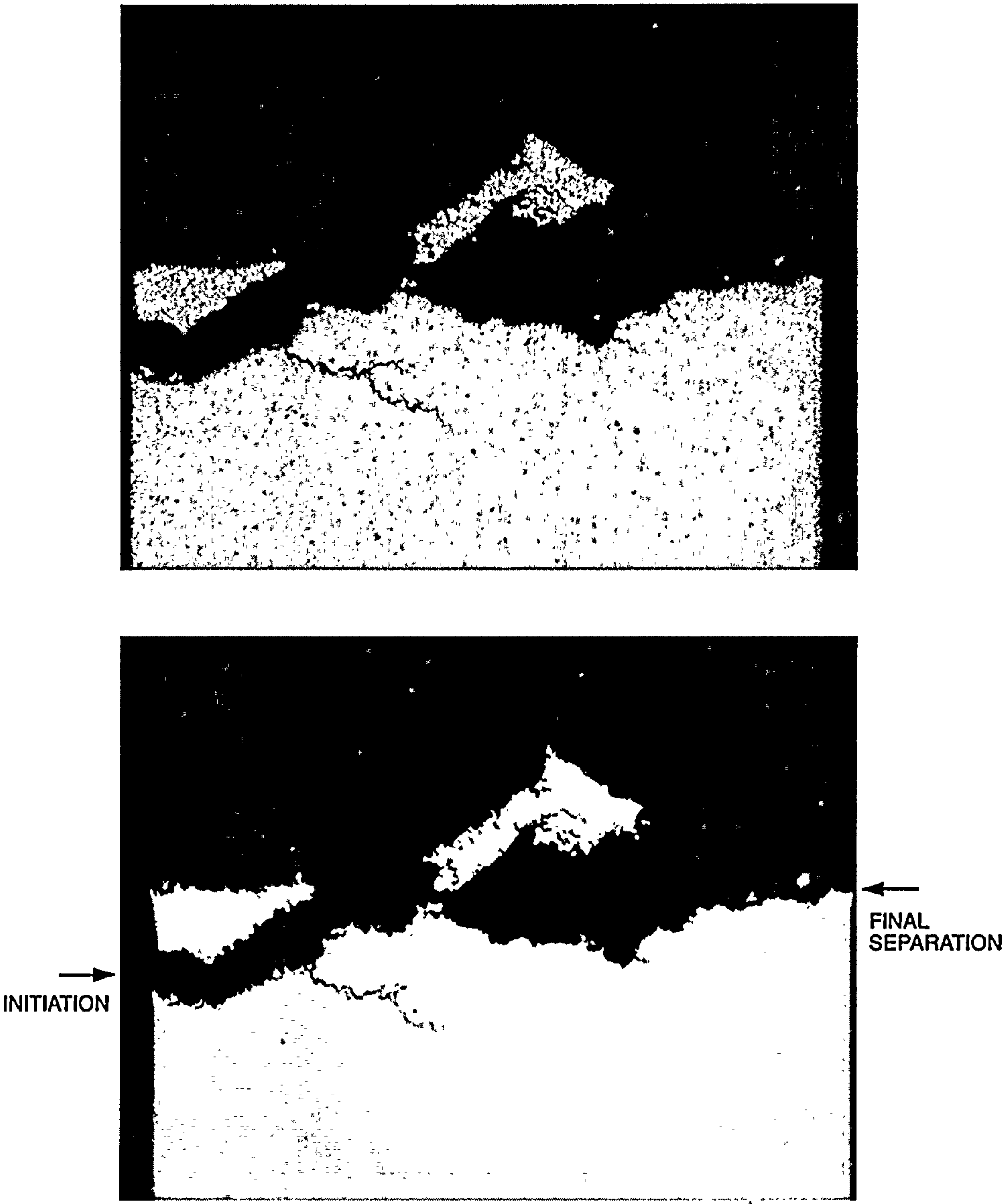
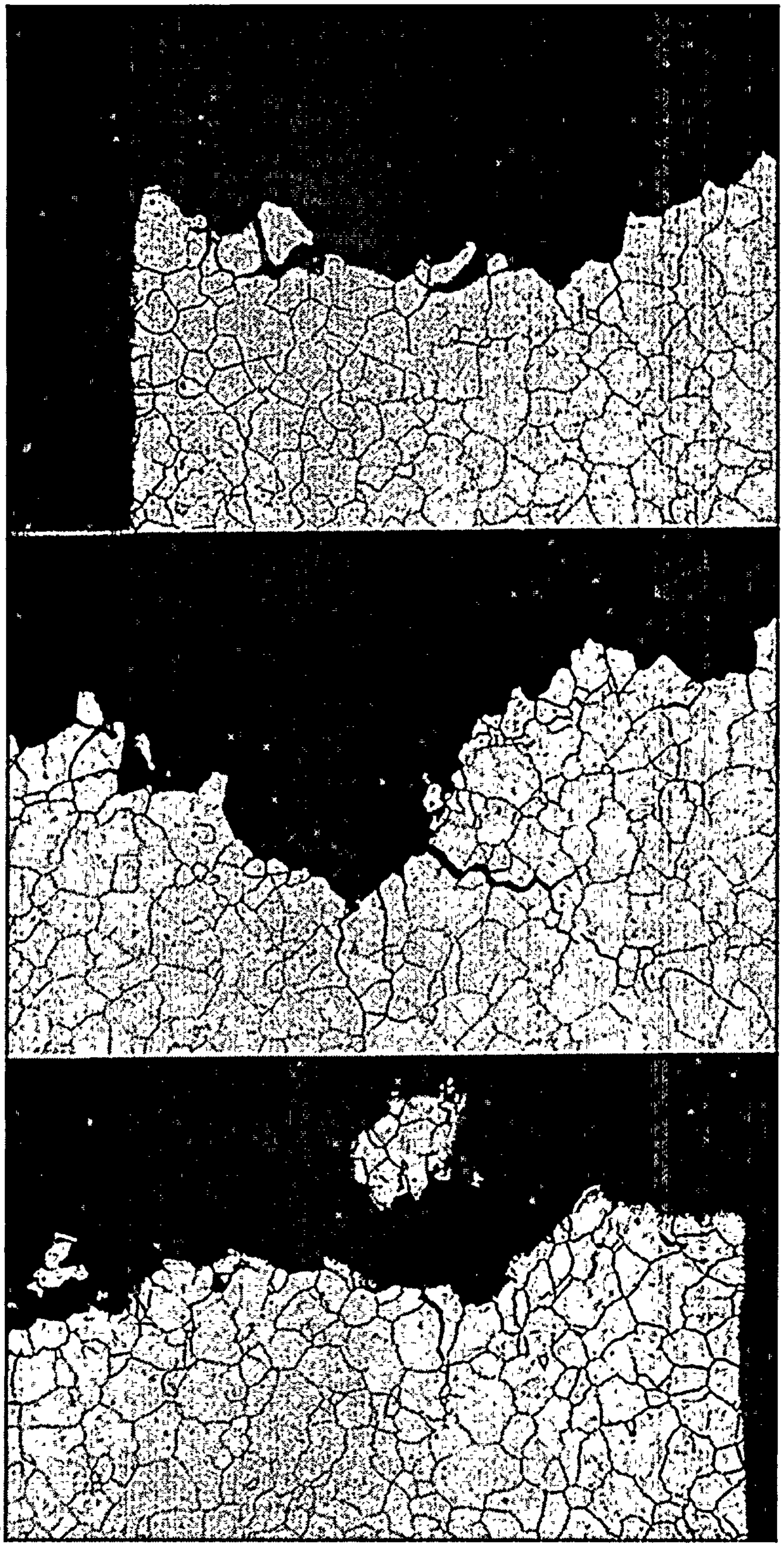


Figure 25. As-polished and etched views (20X) of 350 degree latch section. Plane of polish is perpendicular to fracture face at location indicated in Figure 24.



a. REGION OF CRACK MOUTH (INITIATION) 128X

b. MID FRACTURE REGION – NOTE SECONDARY IGSCC CRACKS. 128X

c. REGION OF FINAL SEPARATION TRANSGRANULAR DUCTILE RUPTURE. 128X

Figure 26. Views of fracture by optical microscopy – 350 degree wedge latch.

selected because it was relatively clean of surface oxide. Features characteristic of a fatigue fracture were not observed. An intergranular failure mode was observed.

4.2.2 90 Degree Latch SEM Fractography

Scanning Electron Microscopic Fractography (SEM) was also performed on the fracture face removed from the 90 degree latch. While the 350 degree latch was selected for a more comprehensive evaluation latch because the BWR service crack was not through wall, the 90 degree latch fracture face was studied to confirm the mechanism of fracture was the same. Figures 20 through 23 provide the results.

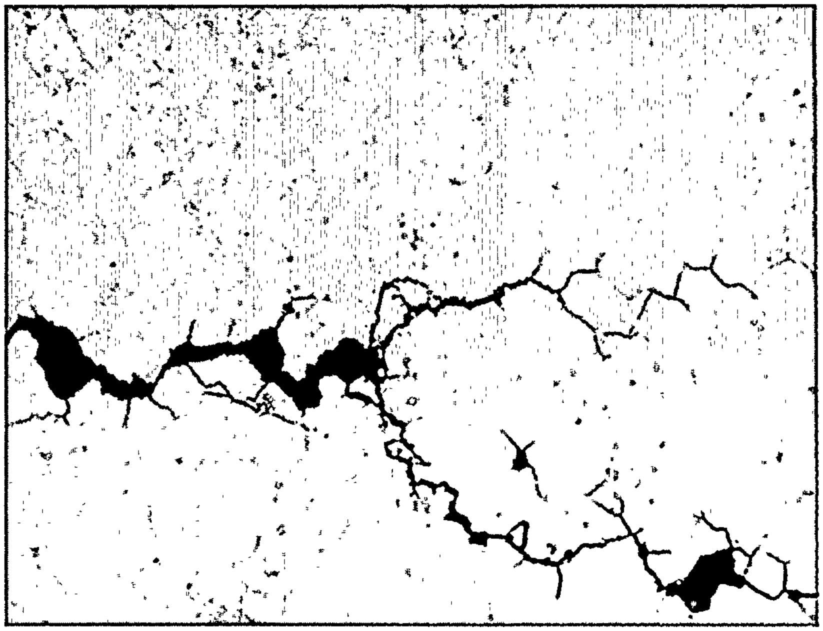
Figure 20 is a SEM view (12X) of the fracture face of the 90 degree contact wedge latch. This low magnification macroscopic view shows secondary cracking associated with the primary fracture. As was found on the 350 degree wedge latch fracture face, this is characteristic of SCC growth. This figure also provides location information for the higher magnification views of the 90 degree wedge latch fracture, Figures 21-23. Figure 21 is a 200X view of the fracture face in the area of crack initiation. The cracking is intergranular with heavy oxide buildup characteristic of IGSCC. Figure 22 is a 200X view of the region near the site of final separation of the 90 degree wedge latch. The cracking is clearly intergranular, with less oxide buildup than seen in Figure 21. Figure 23 is a 800X view of the center of fracture face of Figure 22. Note the oxide buildup and obscuring of the fracture face detail.

4.3 Optical Microscopy

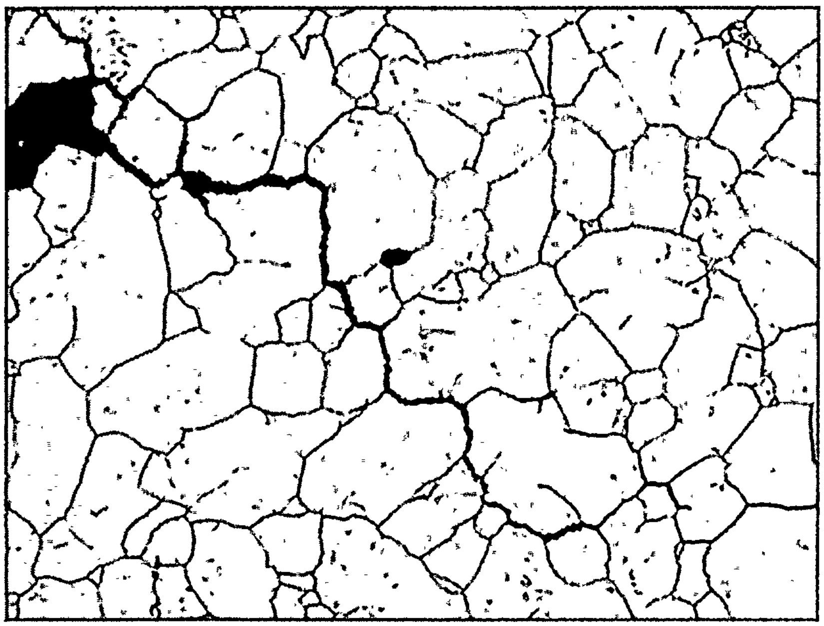
4.3.1 350 Degree Latch Microscopy

A single section was prepared for optical microscopic evaluation of the 350 degree latch fracture. The section was located as indicated in Figure 24. This location was selected as it captured secondary cracking as well as the primary surface feature of crack initiation, growth, crack tip, and room temperature ductile separation. The plane of polish is perpendicular to the plane of the service fracture. Figure 25 is an as-polished, and etched view of the fracture.

Figure 26 contains optical microscopic views of the latch failure. Photo a. is the region of the crack mouth (initiation). Photo b. is the mid-fracture region, and c. is the region of final separation characterized by transgranular ductile rupture. The upper left photograph in Figure 27 shows secondary cracking characteristic of IGSCC. Magnified views of the crack



128X



250X

Figure 27. Secondary cracking - IGSCC. Magnified views of crack noted in Figure 25 (upper photo). This crack morphology is characteristic of IGSCC.

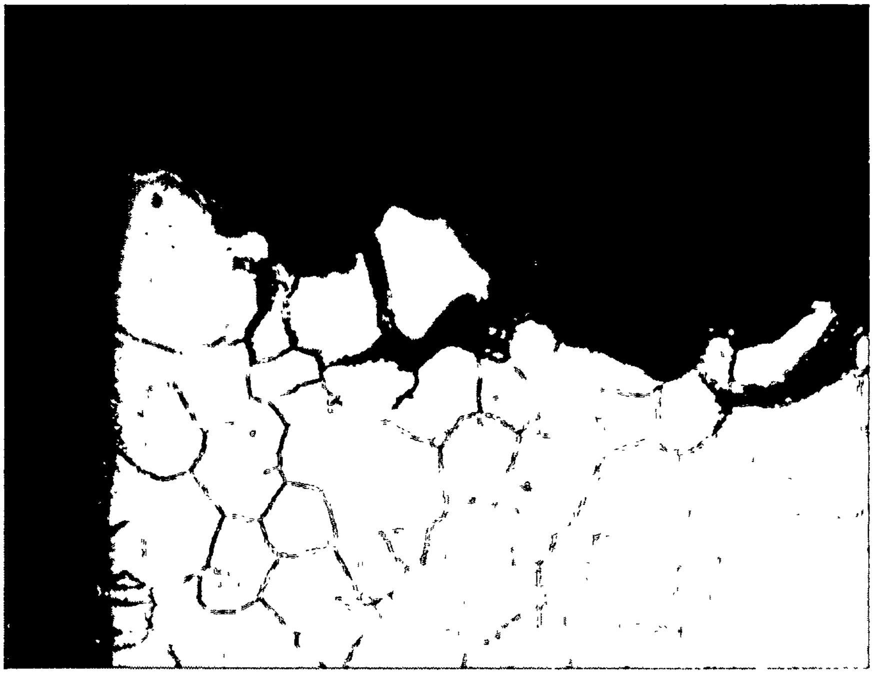


Figure 28. High magnification (250X) view of fracture in region of crack initiation – 350 degree wedge latch. Note evidence of minor cold work.

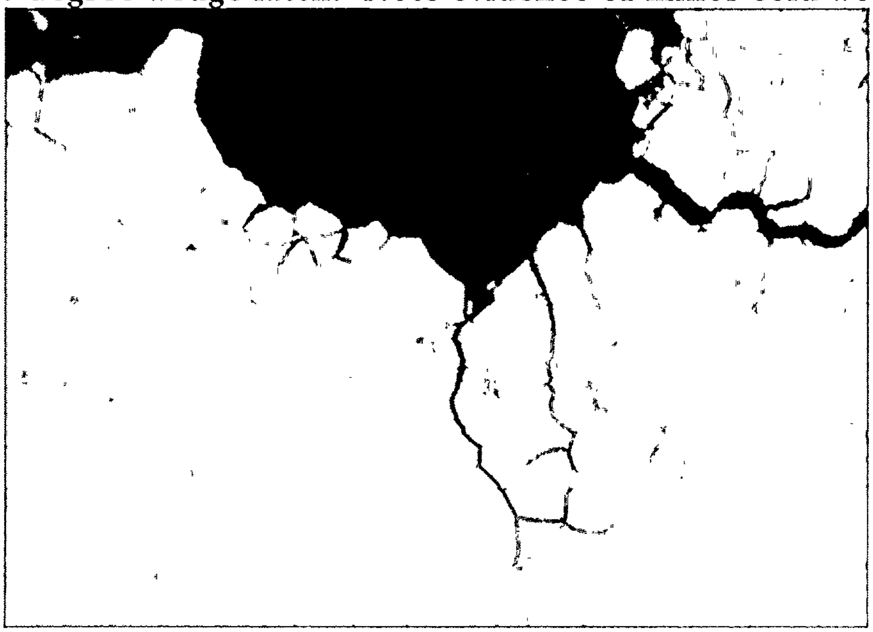


Figure 29. High magnification (250X) views of mid fracture region of 350 degree wedge latch, clearly shows IGSCC nature.

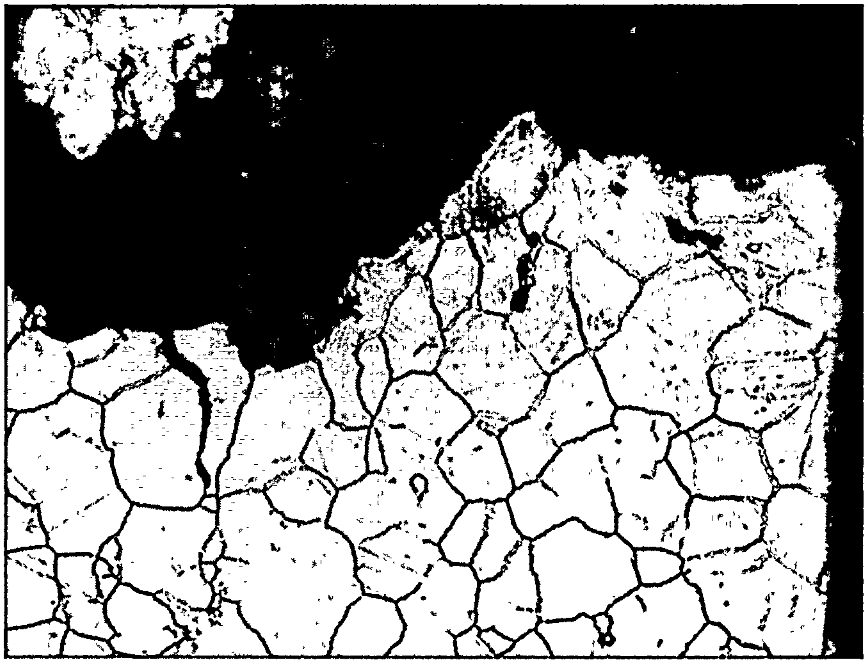


Figure 30. High magnification (250X) view of 350 degree latch fracture edge in region of final separation. The final separation occurred by ductile rupture, and has an associated plastic deformation. The observation is fully consistent with the results of SEM fractography, as especially seen in the views of Figure 16.

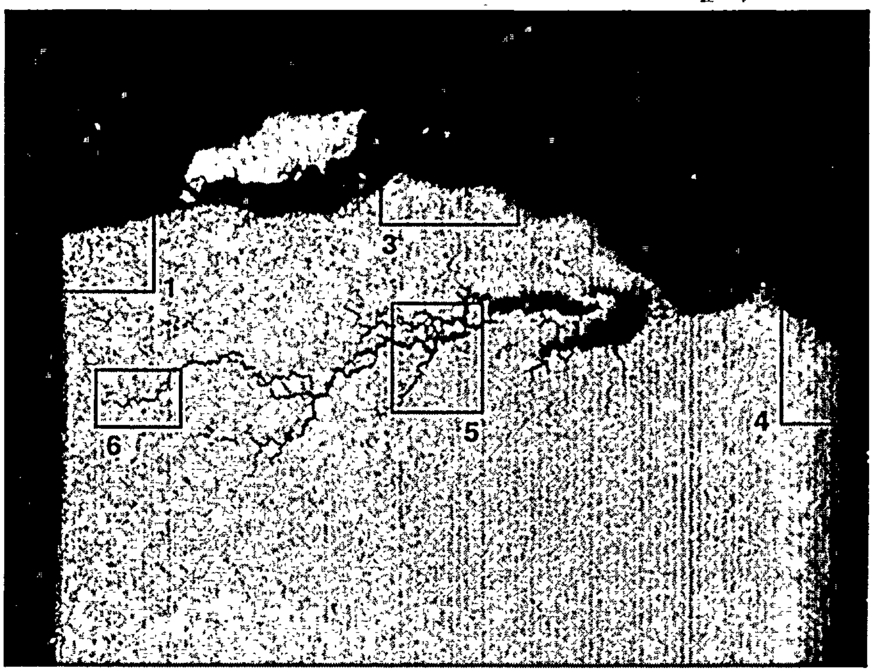
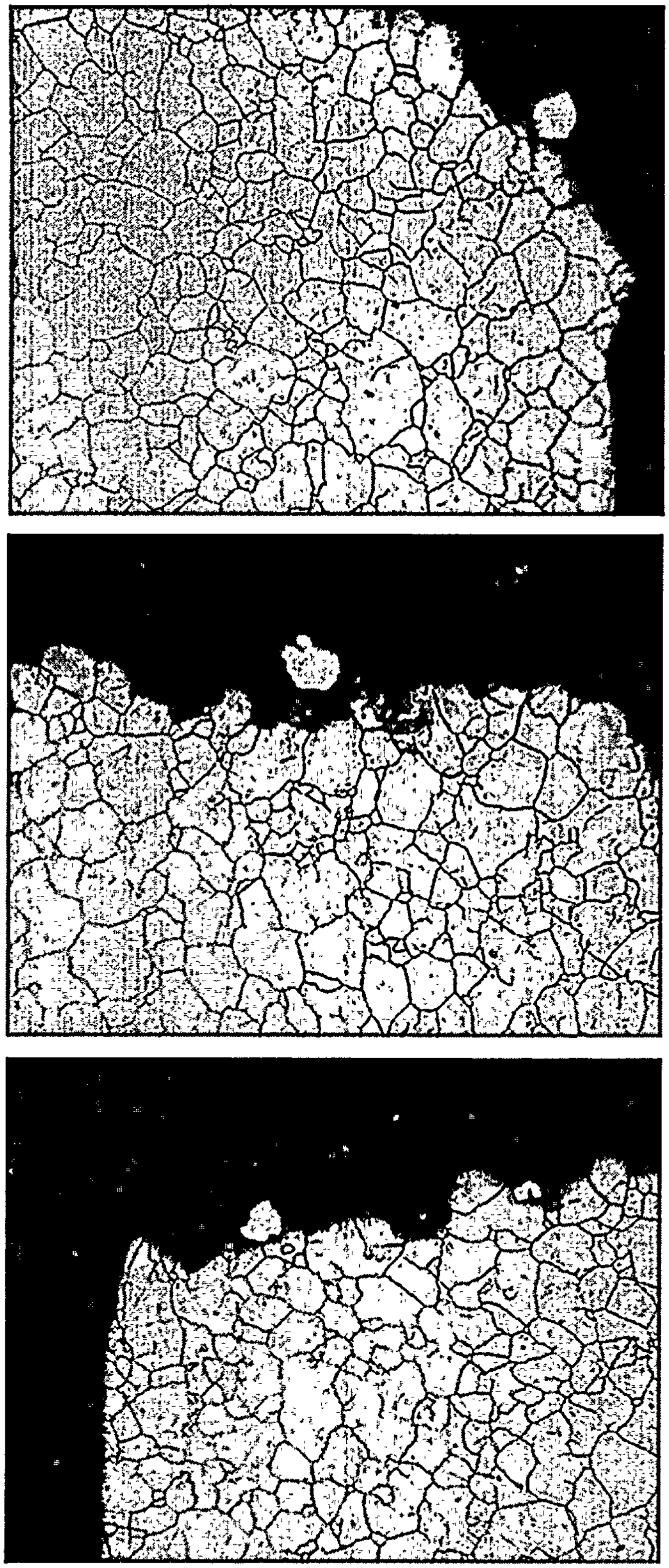


Figure 31. Etched view (20X) of 90 degree contact wedge latch section. Plane of polish is perpendicular to fracture face indicated in Figure 20. Note secondary branch cracking, and compare with view of 350 degree latch section of Figure 25.

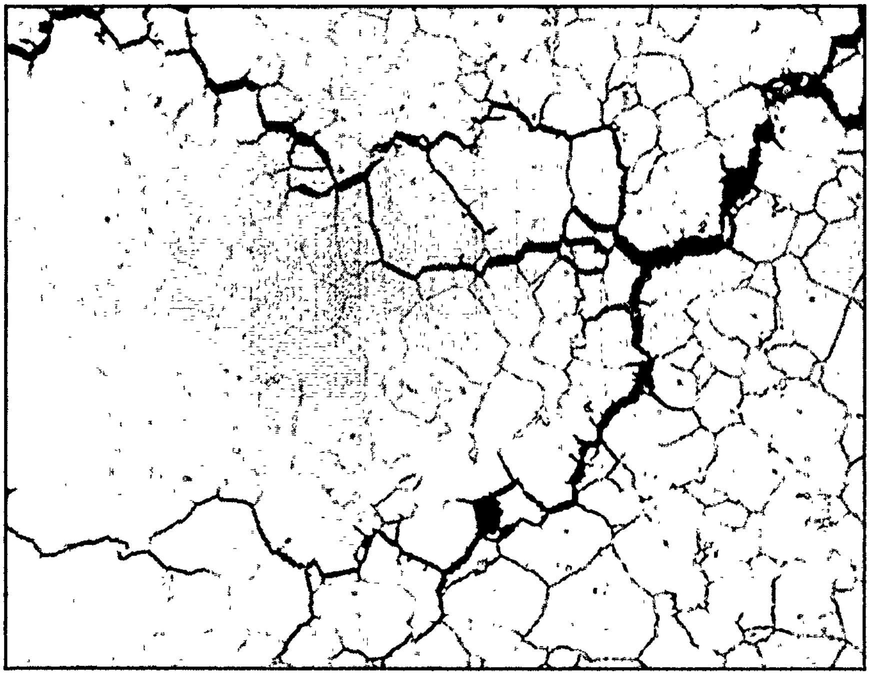


a. REGION OF CRACK MOUTH (INITIATION) 128 X

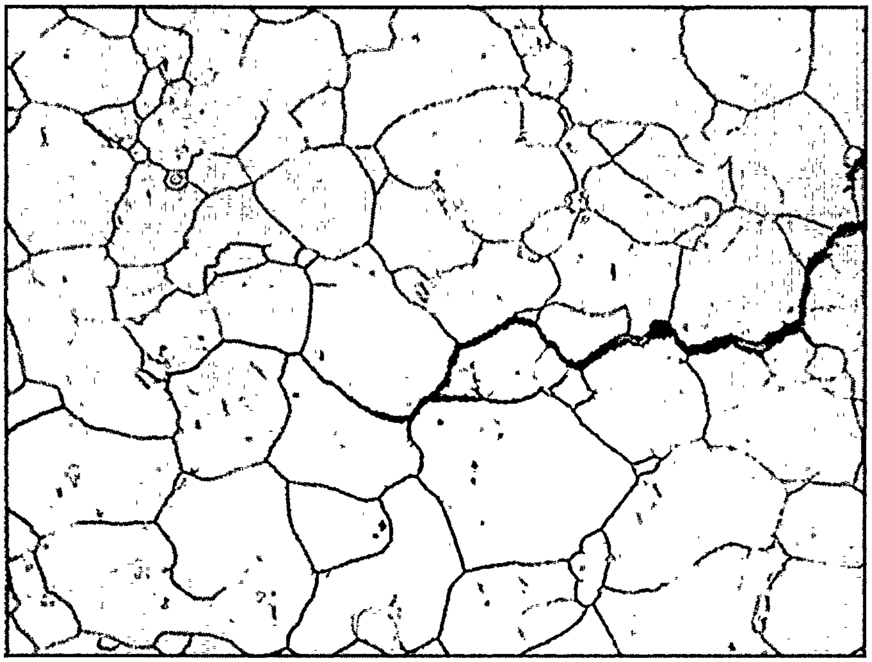
b. MID-FRACTURE REGION-NOTE SECONDARY IGSCC CRACKS. 128 X

c. REGION OF FINAL SEPARATION-IGSCC, WITHOUT DUCTILE RUPTURE. 128 X

Figure 32. View of fracture by optical microscopy – 90 degree wedge latch. 128X



128 X



250 X

Figure 33. **Secondary cracking in fracture of 90 degree contact wedge latch – IGSCC nature is same as that observed in 350 degree latch. Compare with Figure 27.**

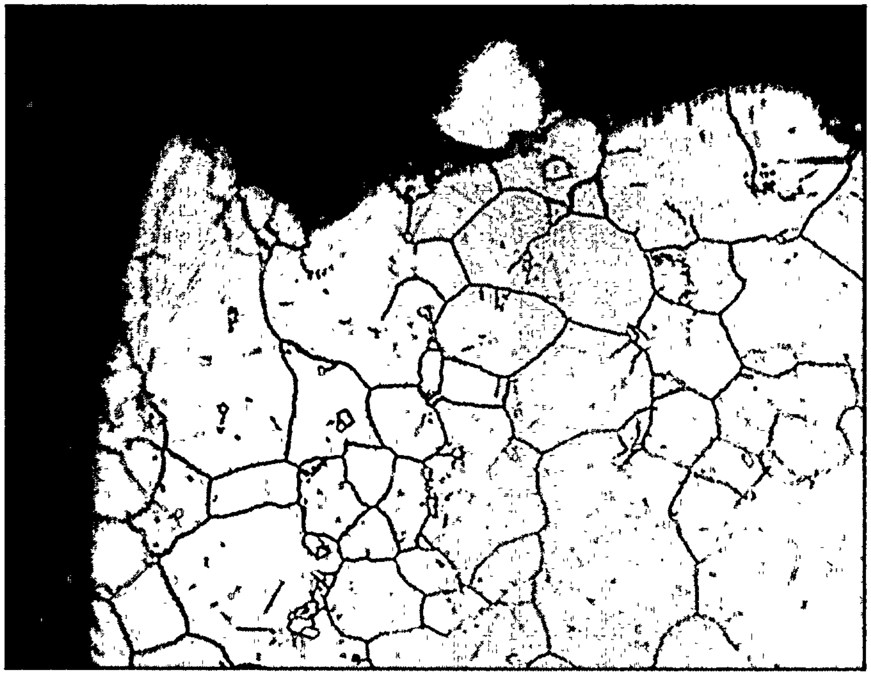


Figure 34. High magnification view (250X) of fracture in region of crack initiation of 90 degree wedge latch. Note evidence of minor cold work.

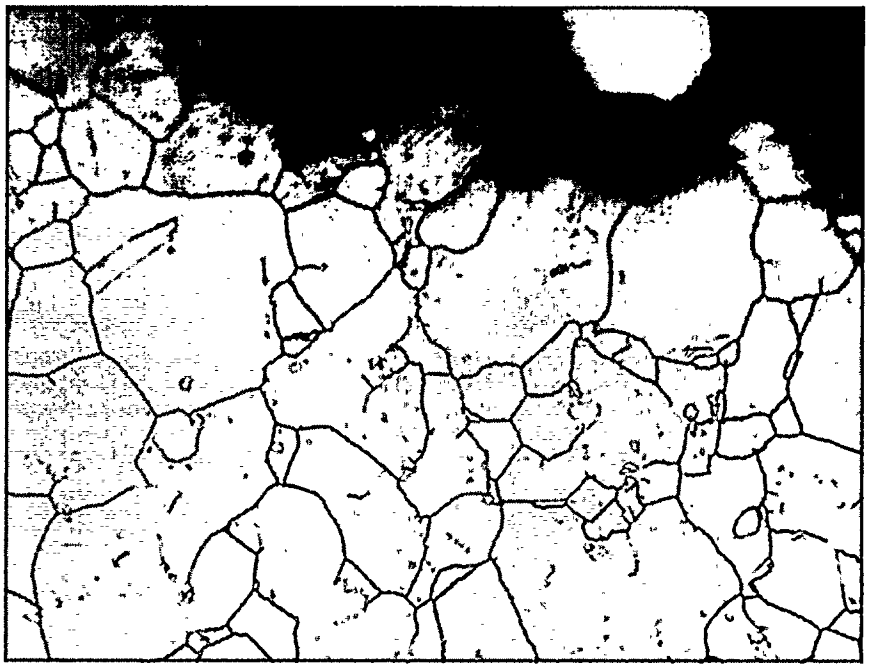


Figure 35. High magnification (250X) view of mid-fracture region, clearly showing IGSCC nature.

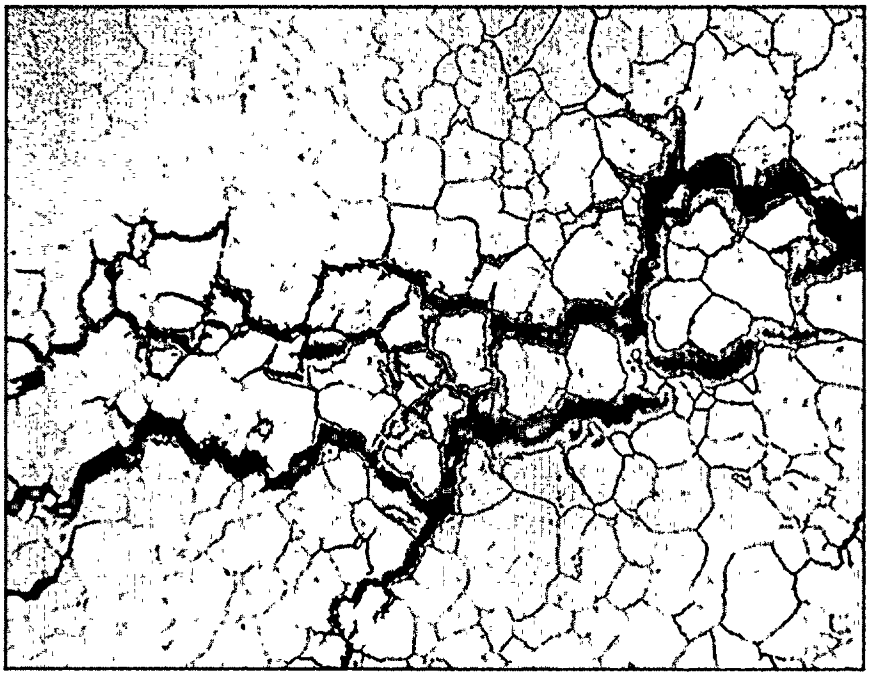


Figure 36. Secondary cracking in region 5 of Figure 31, with oxide buildup, characteristic of exposure to the BWR environment.

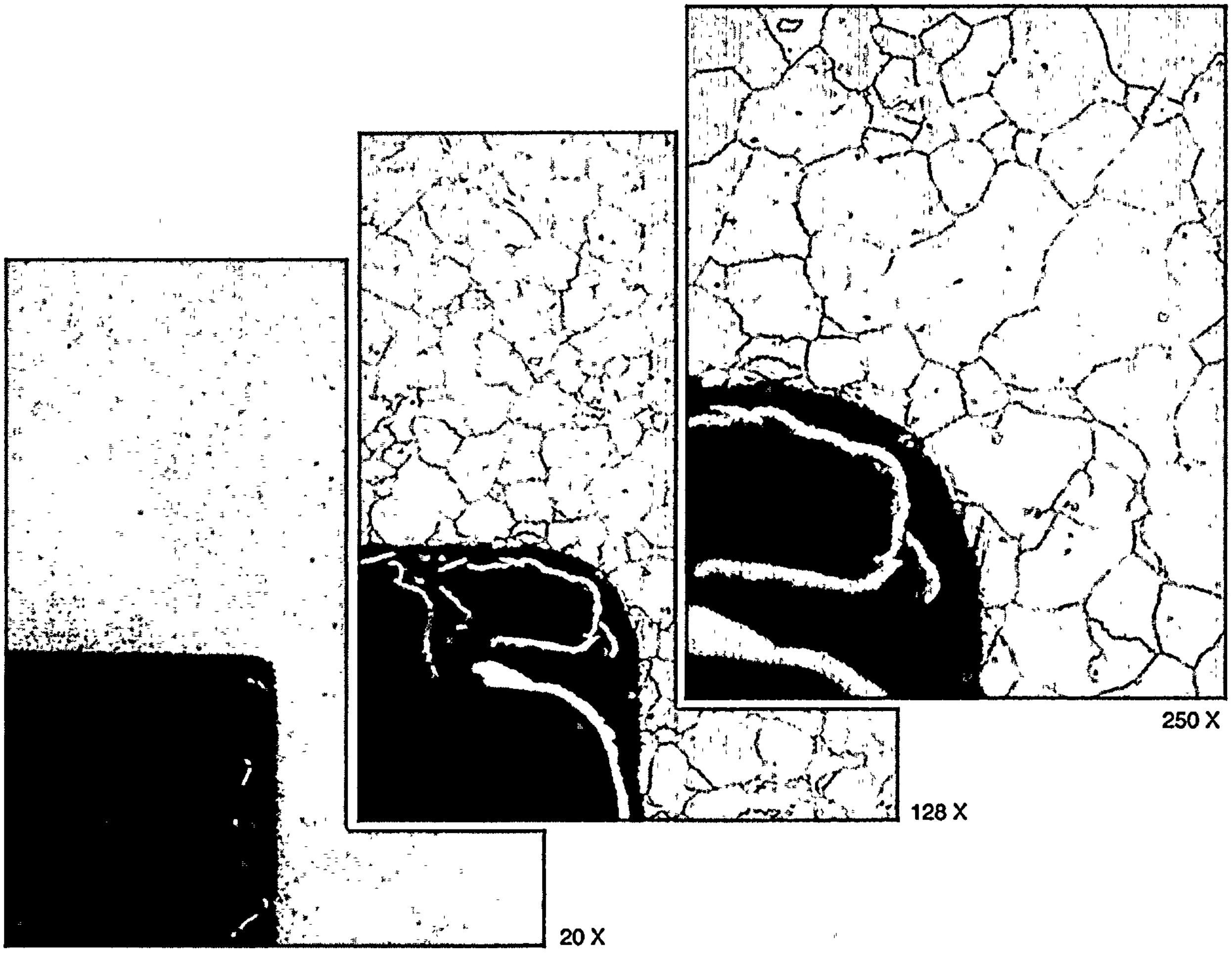
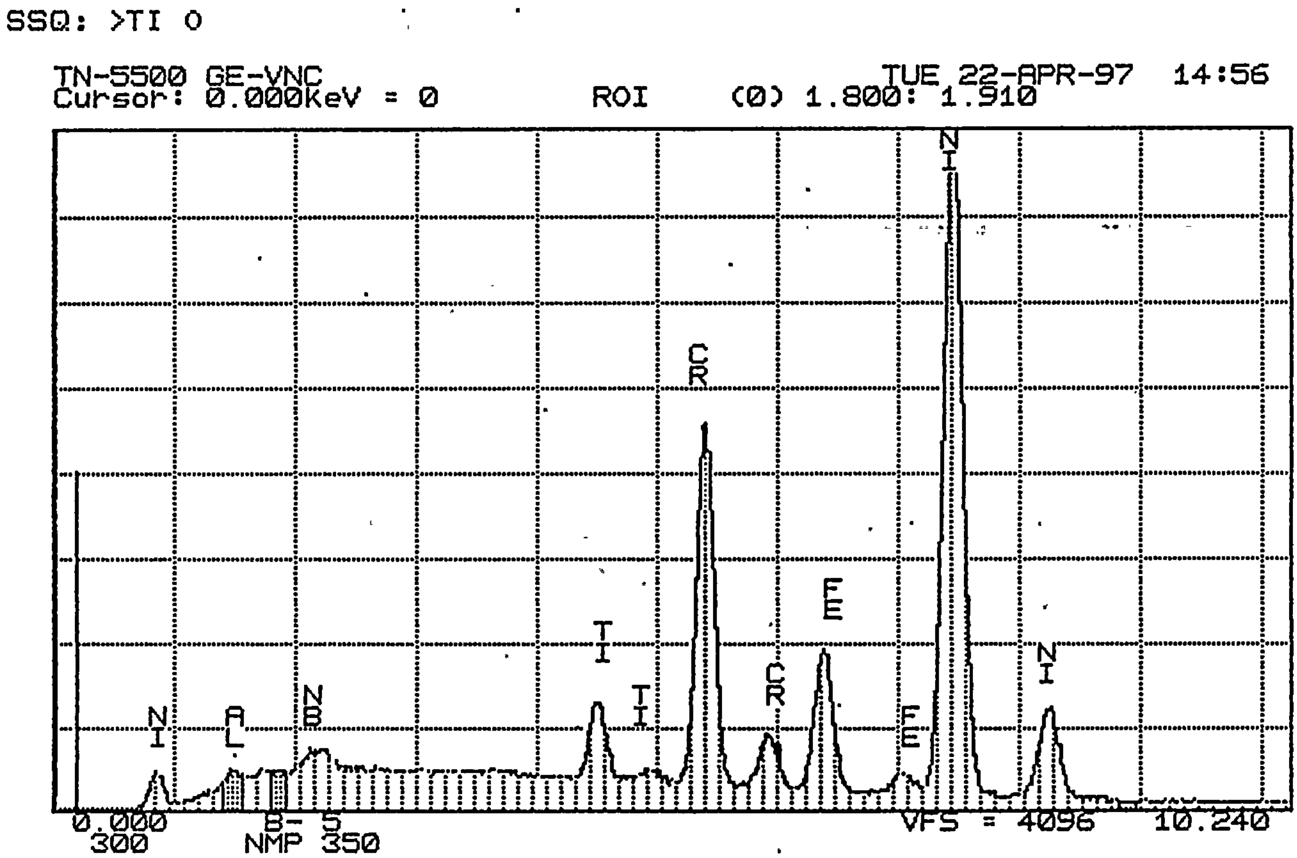


Figure 37. Cross-sectional views of uncracked 166 degree wedge latch. Note lack of incipient cracking or plastic deformation in area of crack initiation on the 90 degree and 350 degree latches.

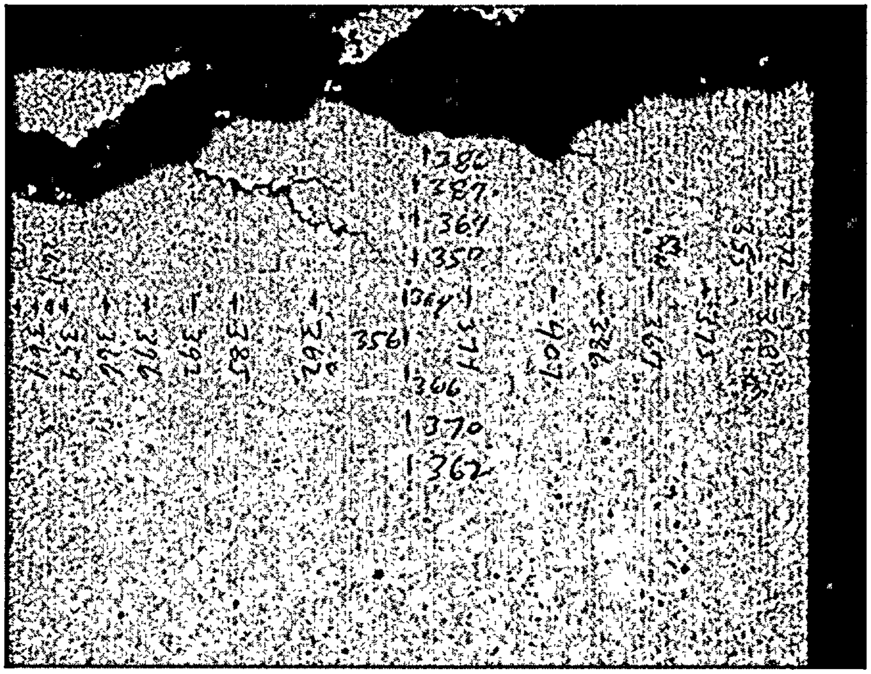


	Al	Nb	Ti	Cr	Fe	Ni
Normalized Elemental Wt%	0.40	1.55	3.05	18.09	9.35	67.56
ASM Specifications Inconel X-750	0.7	1.0	2.5	15.5	7.0	73.0

Figure 38. EDS (Energy Dispersive X-ray Spectrum) data use to qualitatively check composition of latch material. Scan was prepared on a relatively clean (low oxidization) region of the fracture face. The data are consistent with Alloy X-750.

	X.750 Nominal Composition	GE-Purchase Specification ASTM-B-637-89 Type 3	CMTR HT #51072-2	EDS (SEM) Composition Analysis	Direct Coupled Plasma Quantitative Analysis
Cr	15.5	14.0-17.0	15.40	18.09	15.1
Ni	73.0	70.00 min	71.63	67.56	71.5
Co	–	0.07	–	–	–
Mo	–	–	–	–	–
Nb	1.0	0.7-1.20	0.94	1.55	1.0
Ti	2.5	2.25-2.75	2.40	3.05	2.4
Al	0.7	0.4-1.00	0.73	0.4	1.1 *within spec on check analysis
Fe	7.0	5.00-9.00	8.14	9.35	8.9
C	0.04	0.08 max	0.053	N/A	N/A
Cu	0.25 max	0.50 max	0.02	–	–

Figure 39. X750 Contact Wedge Latch – Material Compositional Analysis Wt %



20 X

Figure 40. Etched view of 350 degree latch section (same view as Figure 20) showing microhardness imprints. Measurements in Knoop hardness scale, with 500g load.

Avg.	373 Knoop	(292 - 391 Knoop specified)
	346 HB	(267 - 363 HB specified)

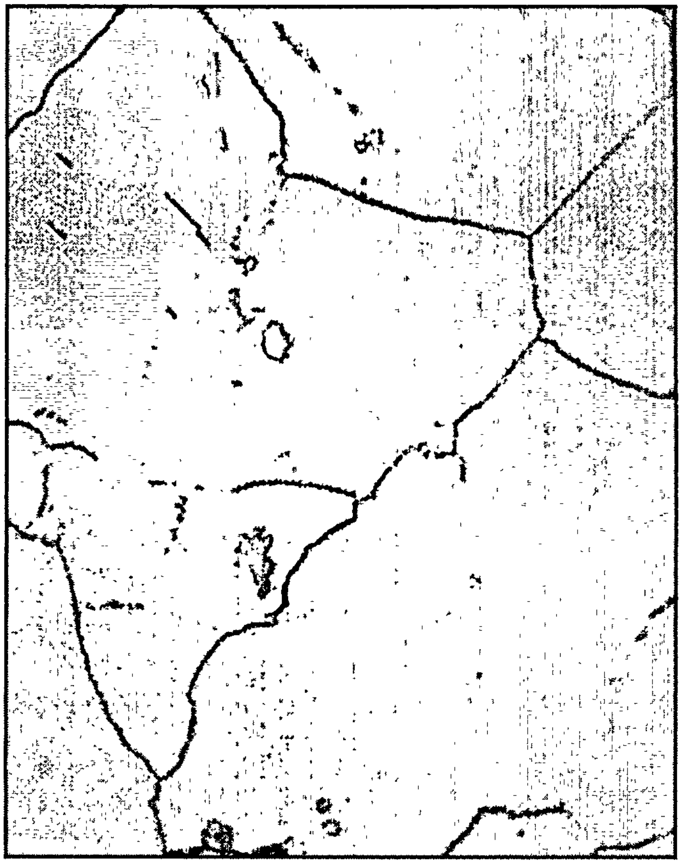


Figure 41. High magnification (1000X) view of 90° (broken) wedge latch microstructure. The structure is typical of a correctly heat treated X750 wedge latch material.

Figure 42. High magnification optical microscopic view of uncracked 166 degree wedge latch.

Test/Wedge Latch	90 Degree	160 Degree	350 Degree
Field visual inspection	Nose piece "missing"	Un-damaged	Nose piece "bent"
Lab-visual examination	Nose separated Load contact pattern on underside of nose	No "load " contact pattern Uncracked – by SEM	Nose separated (during removal) "Load" contact pattern on underside of nose
Optical microscopy	IGSCC nature No cold work	Not performed (no cracking found)	IGSCC nature Minor cold work at final separation
SEM fractography	Intergranular – heavy oxide	Not performed (no cracking found)	Intergranular – light-to-moderate oxide
Material properties	Heat # HT #51072-2	Heat # HT #51072-2	Heat # HT #51072-2
μ Hdnα transverse	–	–	Consistent with heat treatment Nominal properties No gradients
Micro-structure	As expected for specified heat treatment	–	–
Failure mode	IGSCC – initiation to final separation	Un-cracked	IGSCC with ductile final separation

<u>Table 1.</u> Summary of Analytical Test Results - NMP - Tie rod contact wedge latch failures (270 degree wedge latch - not examined)

Appendix A

Alloy X-750 Certificate of Conformance/Compliance/CMTR

SPECIALTY ALLOY PROCESSING COMPANY, INC.
PO Box 14006 • Pittsburgh, PA 15239 • (412) 327-3938 • FAX (412) 327-4716
INDUSTRIAL HEAT TREATING

METAL PROCESSING CERTIFICATION

Date: December 10, 1994

Customer: Tooling Specialists, Inc.
PO Box 828
Latrobe, PA 15650

Attn: Kim Farabaugh

Customer Order Number: TS 31739-7-51-6839
(GE PO# 529-94T749AT)

Quantity & Part:	5 spring retainer	dwg.112D6555 HT#51071-3
	24 spring retainer	dwg.112D6551 HT#51074-1
	24 screw top supt	dwg.112D6558 It 4 HT#32286
	10 washer jack bolt	dwg.112D6553 HT#32794
	5 screw	dwg.112D6558 IT 1 HT#32794
	5 bolt jack	dwg.112D6552 IT 1HT#32286
	5 latch	dwg.112D6560 IT 1 HT#51072-2
	15 latch	dwg.112D6560 IT 2 HT#51072-2
	50 screw	dwg.112D6558 It 6 HT#32794

Material: X750: ASTM-B-637 Type 3
Our Order Number: 4950-3 Lot # 3

Treatment: Heat Treat Procedure(GE-SAP-AH-1REV2),dated10/25/94
& GE-NE. SPEC. P50YP107/Attachment 1:
Age hardened 1300°F(+/-15°F) 20 1/2 hrs.
Remove and fan air cool.
10CFR21 applies

Date of Treatment: 12/9/94/ to 12/10/94

Specialty Alloy Processing Company, Inc.

E J Meses
E. J. Meses
Project Engineer

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DUBOSE NATIONAL ENERGY SERVICES, INC.
900 INDUSTRIAL DRIVE // CLINTON, NC 28328
Certificate of Conformance/Compliance/CMTR

Customer:

GE NUCLEAR ENERGY
G.E.TECH CENTER
302 HANSEN ACCESS ROAD
KING OF PRUSSIA PA 19406

Date 9/13/94 Serial No. 33844 D
Our DC No. 101316
This material meets the requirements of your PO number 528-94T398T

Item	Pieces	Description Specification	Grade		Heat # / Heat Code
10	1	2 1/4" X 15" X 64" ROLLED BAR			33231
		ASTM B637-89	N07750 TYPE 3*		
			PRECISION	JW REX	LTI
10	1	2 1/4" X 15" X 76" ROLLED BAR			33231
		ASTM B637-89	N07750 TYPE 3*		
			PRECISION	JW REX	LTI
10	1	2 1/4" X 15" X 128" ROLLED BAR			51072-2
		ASTM B637-89	N07750 TYPE 3*		
			PRECISION	JW REX	LTI
10	2	2 1/4" X 15" X 64" ROLLED BAR			51072-2
		ASTM B637-89	N07750 TYPE 3*		
			PRECISION	JW REX	LTI

This material has been supplied in accordance with DuBose National Energy Services, Inc. Quality System Program Rev. 3, dated 06-21-94 in compliance with 10CFR50 APP. B. The contents of the report are correct and accurate and the results are in compliance with the material specification, the code, and the customer purchase order.

10CFR21
QCP 6-1
*MATERIAL WAS ANNEALED AT 1975 +/- 25 DEG F WITH LONGITUDINAL AND TRANSVERSE TENSILE SPECIMENS AGE HARDENED AT 1300 DEG F PER GE ATTACHMENT T YK3399.

Laurie A Dickson 10/11/94

James N Dailey, QA Manager Date
Ruth Barber-Rich, Assistant QA Manager
Laurie Dickson, Certification Engineer
Tammy Williams, QA Technician

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DUBOSE NATIONAL ENERGY SERVICES, INC.
900 INDUSTRIAL DRIVE // CLINTON, NC 28328
Certificate of Conformance/Compliance/CMTR

Customer:

GE NUCLEAR ENERGY
G.E. TECH CENTER
302 HANSEN ACCESS ROAD
KING OF PRUSSIA PA 19406

Date 9/27/94 Serial No. 38974 D
Our DC No. 101663
This material meets the requirements of your PO number 528-94T398T

Item	Pieces	Description Specification	Grade	Heat # / Heat Code
10	2	2 1/4" X 15" X 128" ROLLED BAR ASTM B637-89	N07750 TYPE 3* PRECISION JW REX	33231 LTI
10	1	2 1/4" X 15" X 128" ROLLED BAR ASTM B637-89	N07750 TYPE 3* PRECISION JW REX	51072-2 LTI

This material has been supplied in accordance with DuBose National Energy Services, Inc. Quality System Program Rev. 3, dated 06-21-94 in compliance with 10CFR50 APP. B. The contents of the report are correct and accurate and the results are in compliance with the material specification, the code, and the customer purchase order.

10CFR21
QCP 6-1
*MATERIAL WAS ANNEALED AT 1975 +/- 25 DEG F WITH LONGITUDINAL AND TRANSVERSE TENSILE SPECIMENS AGE HARDENED AT 1300 DEG F PER GE ATTACHMENT T YK3399.

10/11/94

James N Dailey, QA Manager Date
Ruth Barber-Rich, Assistant QA Manager
Laurie Dickson, Certification Engineer
Tammy Williams, QA Technician

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DUBOSE
QA REVIEW
SATISFACTORY
9/16/94
INITIAL / DATE

Precision Rolled Products, Inc.
Specialty Alloy Melt Division
206 Columbia Road
Florham Park, New Jersey 07932
(201) 822-8100

GE NUCLEAR ENERGY
PO# 528-94T398T

Customer: DuBose Nat'l Energy Services
900 Industrial Drive
Clinton, NC 28328

Page 1 of 1
R87B

REVISED 9/15/94

Customer Order No.	Order Date	Ship Date	Shop Order	Alloy
5469-69 #9	08/08/94	09/02/94	N56657-1B	X-750

Specification(s): ASME-SB-637 GR 688 TYPE 3, ASTM-B-637-89 TYPE 3.
CHEMISTRY ONLY. MECHANICAL TESTING FOR INFORMATION ONLY.

Quantity (Pcs./Wt.)	Size or Dwg. Number
1 pc./660#	2.250" X 15.000" X 64.000"
1 pc./1307#	2.250" X 15.000" X 128.000"
1 pc./1355#	2.250" X 15.000" X 128.000"
1 pc./661#	2.250" X 15.000" X 64.000"

Heat Number: 51072-2. Melt Method: VIM/ESR
Chemical Analysis: Remelt Ingot Raw Material Source: PRP / Specialty Alloy Melt Division

C	Mn	Si	P	S	Cr	Ni	Co	Ni+Co	Nb+Ta
0.053	0.24	0.15	<.010	<.001	15.40	71.68	0.07	71.75	0.94

Fe	Cu	Al	Ti
8.14	0.02	0.730	2.40

Chemistry Source: PRP SAMD (VC T398S).
Mechanical and Metallurgical Tests:

Cnd.	Temp. (F)	/Dir.	UTS (ksi)	YS (.2%) (ksi)	%El.	%R.A.
A	RT	LONG.	167.5	105.7	30.0	36.1
A	RT	TRANS.	176.1	117.6	25.0	35.5
A	550	LONG.	163.5	109.2	25.0	42.8
A	550	TRANS.	158.4	104.8	25.0	36.1

Tensile test specimen was machined and tested by Accurate Metallurgical Services.
SHIPPED CONDITION:
Solution Treated 1975F, 1 hour, fan cool
Hardness: HB 285
Grain Size: 7.0

CAPABILITY THERMAL TREATMENT:
A.) 1300F, 20 hours, air cool
Hardness: 321 HB

Material is free of mercury contamination.
Solution Treatment performed by Rex Heat Treating.
Capability thermal treatment, grain size, and hardness tests performed by PRP/Reno.

Heat acceptance test results for these properties are on file and conform to requirements.
Material shipped as forged.

9/15/94
Don Allan/ Manager QC/QA

The test results shown above are certified to be true and in accordance with specification requirements and records maintained in our files.

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J. W. REX COMPANY

Specialists in the Modern Heat Treatments of Metals

5TH ST. & VALLEY FORGE ROAD • P.O. BOX 270 • LANSDALE, PA 19446-0270
TELEPHONE (215) 855-1131 • FAX (215) 855-2023

CERTIFICATION

DUBOSE STEEL INC
P O BOX 1098

ROSEBORO, NC 28382

DATE RECEIVED: 02 SEP 94
PO NUMBER: 5660-63

SHOP ORDER: 241796

DUBOSE
QA REVIEW
SATISFACTORY
RW 9/30/94
INITIAL DATE

2	HT#51072-2	FLAT BARS 2.25"X 15"X 128"
1	HT#33231	FLAT BARS 2.25"X 15"X 54"
1	HT#33231	FLAT BAR 2.25"X 15"X 76"
2	HT#51072-2	FLAT BARS 2.25"X 15"X 64"
2	HT#33231	FLAT BARS 2.25"X 15"X 128"

8 (=== TOTAL PIECES TOTAL WEIGHT ===) 8364.00

MATERIAL: X750

THIS IS TO CERTIFY THE MATERIAL LISTED ABOVE HAS BEEN PROCESSED AS FOLLOWS: SOLUTION TREATED AT 1975F FOR 1 HOUR PER J.W. REX PROCEDURE 380-8-15-94 REV.2 & J.W. REX QUALITY CONTROL MANUAL DATED 11/24/93 REV.7.

BY: Peter Kropff
QUALITY CONTROL DIRECTOR
PETER D. KROPFF

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NIAGARA MOHAWK

NRC CORRESPONDENCE APPROVAL FORM

Document: METALLURGICAL EVAL. of FAILED CORE SHROUD TIE ROD LATCH

Applicability: ☑ Unit 1 ☐ Unit 2 ☐ Site Due Date: 6-15-97

References: DER ______ NCTS 503897-42 Other ______

Prepared: THOMAS R. EGAN (Print) Thomas R. Egan (Signature) 6-11-97 (Date)

Developmental Review

	Name	Signature
☑ Licensing	S. LEONARD	[signature] 6.13-97
☑ Engineering	R. CORIERI	R Cor 6/11/97
☐ Generation		
☐ Other		

Technical/Safety Reviews

Technical Review: ☑ N/R ☐ Tech Spec 6.5.2 ☐ Verification ☐ Other ______

Designees:

SORC: ☑ N/R Meeting No.: ______

SRAB: ☑ N/R Meeting No.: ______

Final Review

	Name	Signature
☑ Engineering Manager	W. YAEGER	
☐ Generation: Operations Manager		
Tech Support Manager		
Maintenance Manager		
☑ System Attorney	G. WILSON	Gary Wilson per telecon 6/11/97
☑ Licensing Manager	D. WOLNIAK	D Wolniak 6/13/97
☑ Plant Manager	N. RADEMACHER	NOT AVAILABLE TRE
☐ Other		

Disposition

FSAR Change: ☐ N/R LDCR # ______

NCTS Commitments: ☐ N/R ☐ Attached

NIAGARA MOHAWK

NRC CORRESPONDENCE APPROVAL FORM

Document: METALLURGICAL EVAL. of FAILED CORE SHROUD TIE ROD LATCH

Applicability: ☑ Unit 1 ☐ Unit 2 ☐ Site Due Date: 6-15-97

References: DER ______ NCTS ______ Other ______

Prepared: THOMAS R. EGAN (Print) Thomas R. Egan (Signature) 6-11-97 (Date)

Developmental Review

	Name	Signature
☑ Licensing	S. LEONARD	
☑ Engineering	R. CARIERI	
☐ Generation		
☐ Other		

Technical/Safety Reviews

Technical Review: ☑ N/R ☐ Tech Spec 6.5.2 ☐ Verification ☐ Other ______

Designees:

SORC: ☑ N/R Meeting No.: ______

SRAB: ☑ N/R Meeting No.: ______

Final Review

	Name	Signature
☑ Engineering Manager	W. YAEGER	D. E. Sandwick for W. R. YAEGER
☐ Generation:		
Operations Manager		
Tech Support Manager		
Maintenance Manager		
☑ System Attorney	G. WILSON	
☑ Licensing Manager	D. WOLNIAK	
☑ Plant Manager	N. RADEMACHER	
☐ Other		

Disposition

FSAR Change: ☐ N/R LDCR # ______

NCTS Commitments: ☐ N/R ☐ Attached