NUCLEAR ENERGY
BUSINESS OPERATIONS

GENERAL ELECTRIC

F&PMT TRANSMITTAL
NO. 87-178-037

FUEL & PLANT MATERIALS TECHNOLOGY
FINAL REPORT

LABORATORY EXAMINATION OF RECIRCULATION LINE DECONTAMINATION FLANGE FROM MONTICELLO NUCLEAR POWER STATION (WORK PERFORMED FOR NORTHERN STATES POWER)

January 15, 1988

Prepared By: [signature]
T.P. Diaz
Plant Materials Performance

Approved By: [signature]
G.M. Gordon, Manager
Fuel & Plant Materials Technology

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1.0 INTRODUCTION

This report summarizes the results of laboratory examination performed on a portion of 2 inch diameter Type 316L decontamination pipe received from Northern States Power Monticello plant. The specimen consisted of the upper portion of an 8 inch long, 2 inch diameter line connecting the decontamination flange to the recirculation piping. The socket weld between the 2 inch line and the recirculation pipe was found to be leaking during hydro tests conducted at 550°F, and 1,000 psi. The pipe had been in service less than 3 years when the leak was detected.

2.0 OBSERVATIONS AND CONCLUSIONS

- The crack length was about 2-1/4 inches on the OD and 3/4 inch on the ID.
- Optical metallography and SEM fractography revealed that the fracture mode was transgranular.
- There was no evidence of base material sensitization
- There was no evidence of damage to the base material due to weld repairs or cold work.
- The crack initiated at the weld fusion line on the OD surface.
- The cracking mechanism ha been attributed to high cycle fatigue.

3. VISUAL AND DYE PENETRANT EXAMINATION

The specimen received consisted of the socket weld and the top four inches of pipe. Figures 1 and 2 are photographs of the as received specimen. A crack about 1 inch on the OD and 5/8 inch on the ID was visible with the unaided eye. Some staining/streaking was visible on the OD of the pipe and weld

probably due to corrosion during the leak. A slight oxidation stain was also visible along the crack on the ID surface. Liquid penetrant examination of the OD and ID was performed as shown in Figures 3 and 4. The OD indication was about 2-1/4 inches long and followed the weld fusion line. The ID indication was about 3/4 inch long. The longer indication visible in Figure 4 is due to the gap between the pipe and socket fitting beyond the weld. After visual and liquid penetrant examination, the specimen was sectioned transversely about 1/2 inch from the fusion line and then axialy to remove specimens for optical metallography and Scanning Electron Microscopy. Figure 6 is a close-up photograph of the SEM specimen showing a dark brown oxidation layer on the fracture surface close to the OD and becoming lighter in color towards the ID.

4.0 METALLOGRAPHIC EVALUATION

The sectioning plan is illustrated in Figure 5. Specimens 1 and 3 represent the ends of the crack and specimen 2 is representative of the through-wall portion of the crack at a location equidistant from the crack ends. A fourth specimen for optical metallography was sectioned 180° from the crack center. The SEM specimen was pried slightly open before the photograph of Figure 5 was taken. Figures 7 through 13 show the optical metallography results. The crack originated at the OD closely following the fusion line and then propagating into the base metal. The crack mechanism is clearly transgranular and the base metal microstructure is typical of annealed 316L thin walled piping. There is no evidence of grain boundary sensitization and the grain structure was revealed only after heavy etching. A "banding" effect resulting from the extrusion process prior to annealing and repeated preferential etching was visible, but the annealed structure showed no evidence of grain deformation due to cold work, nor was there any visible damage to the base material (i.e. burn through) as a result of a reported weld repair. No cracking was detected in specimen #4, 180° from the through wall crack.

SEM evaluations of the fracture surface (Figures 14 and 15) provide additional evidence of the transgranular cracking mechanism. The above findings lead to the conclusion that the observed cracking was the result of high cycle fatigue. Crack initiation occurred at the weld fusion line which acted as a stress riser at the pipe OD.

5.0 HARDNESS MEASUREMENTS

Hardness measurements using a 200 gram load were conducted on specimen #2 near the through wall portion of the crack. The results shown in Figure 16 indicate that the base material meets current requirements for annealed Type 316L pipe (Rockwell B-92). The hardness measurements ranged from Rockwell B-87 to -89.

6.0 CHEMICAL ANALYSIS

A chemical check analysis was performed on a decontaminated sample by an outside laboratory. The results, which are compared to the ASME SA312 and GE "Nuclear Grade" requirements in Figure 17, indicate that the pipe material meets specification.

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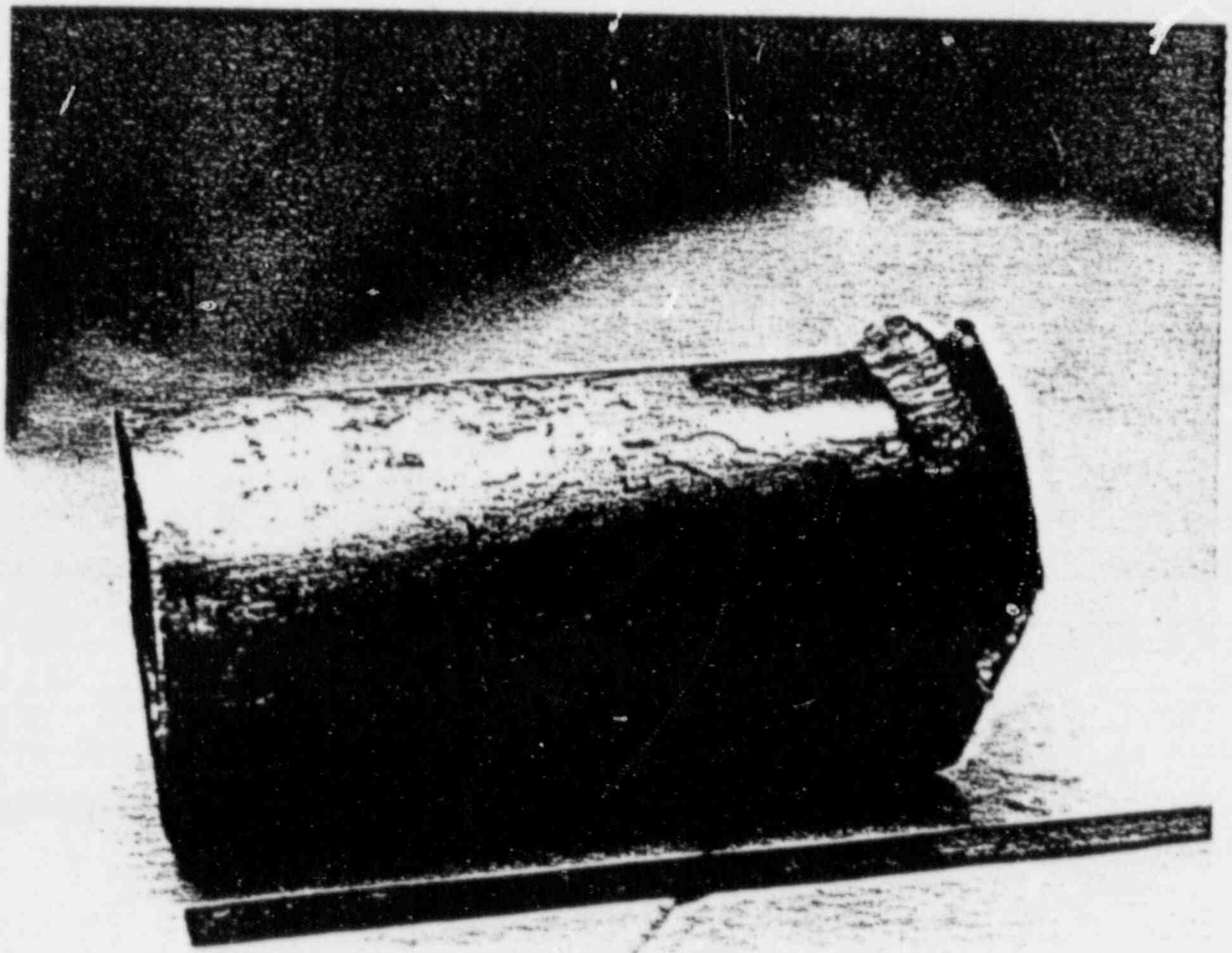


Figure 1. Side view of as received specimen showing visible crack at fusion line on OD surface and Serial Number 469167.

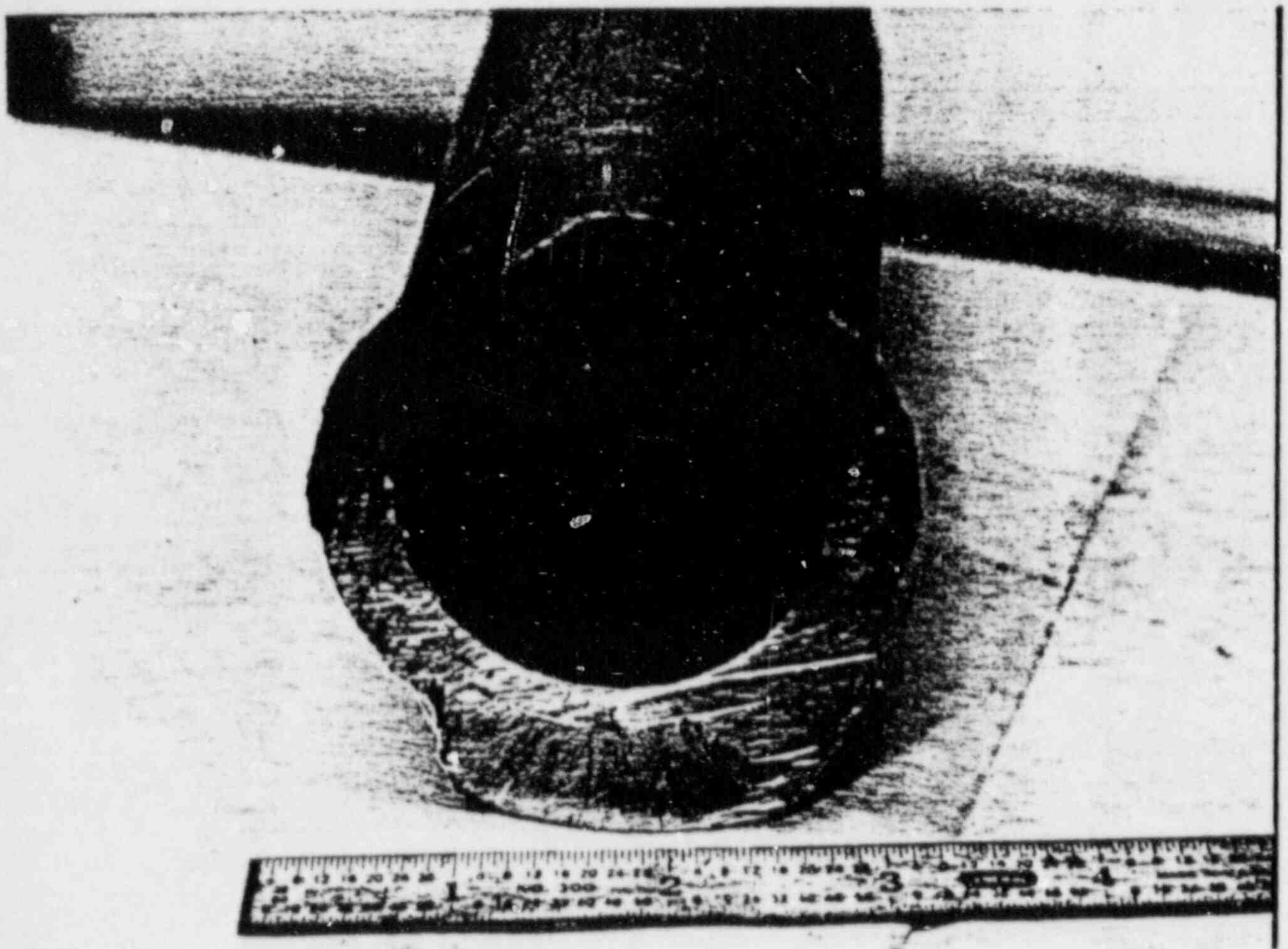


Figure 2. End view of as received specimen.

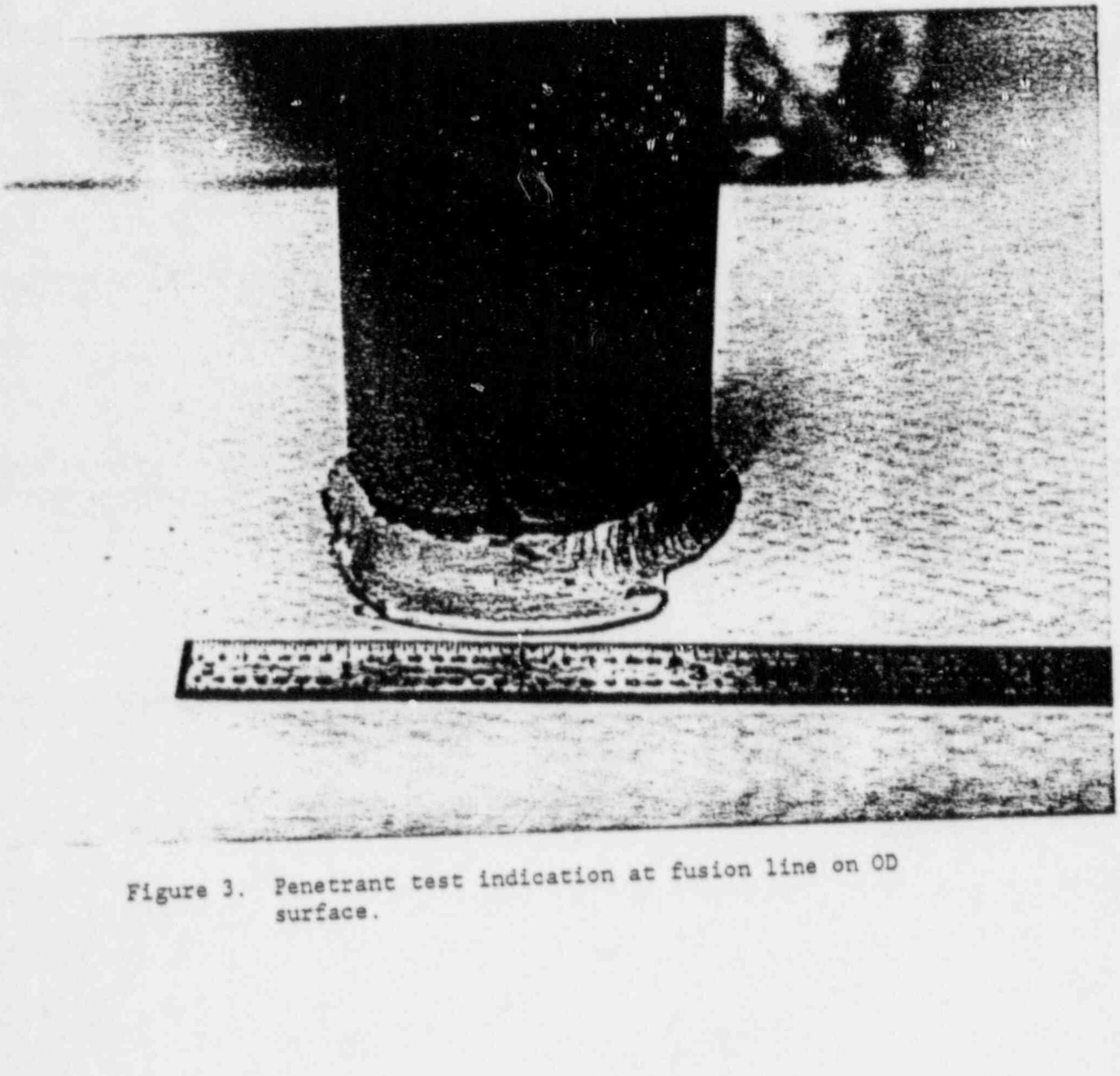


Figure 3. Penetrant test indication at fusion line on OD surface.

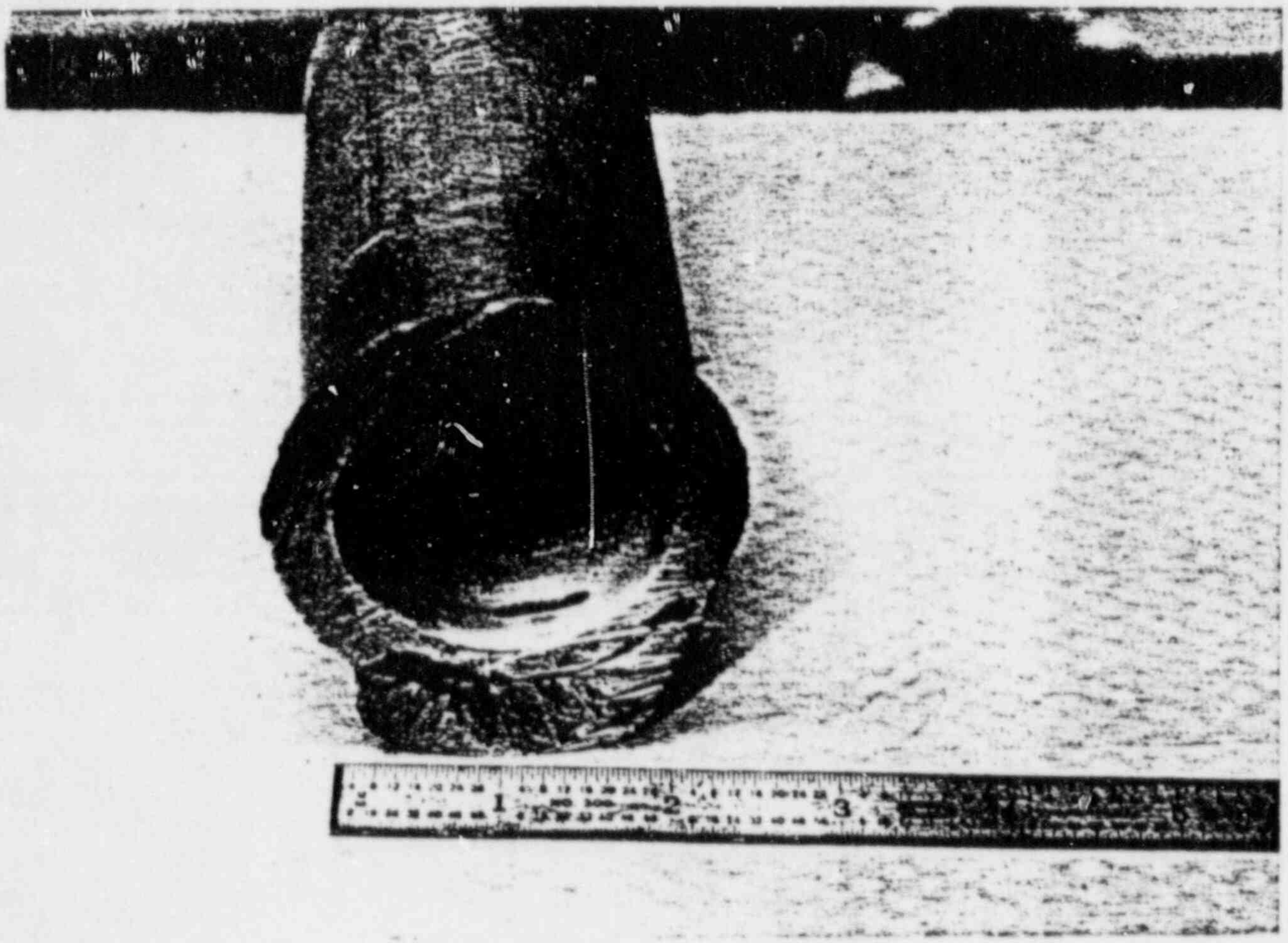


Figure 4. Liquid penetrant indication at ID surface. The longer indication is due to the gap between the pipe and the socket beyond the weld and is not connected to the crack.

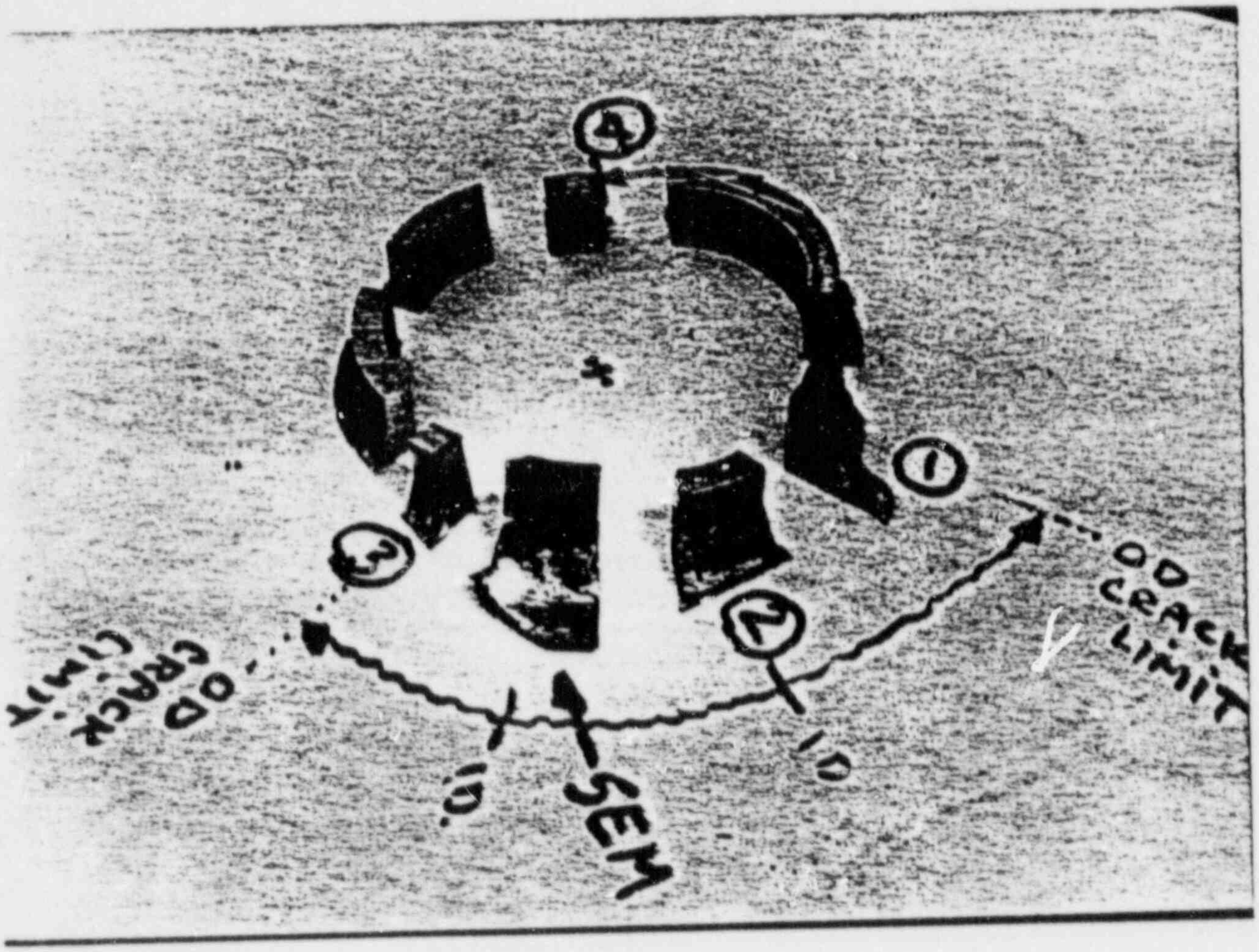


Figure 5. Sectioning plan for o :ical and SEM metallographic evaluation.

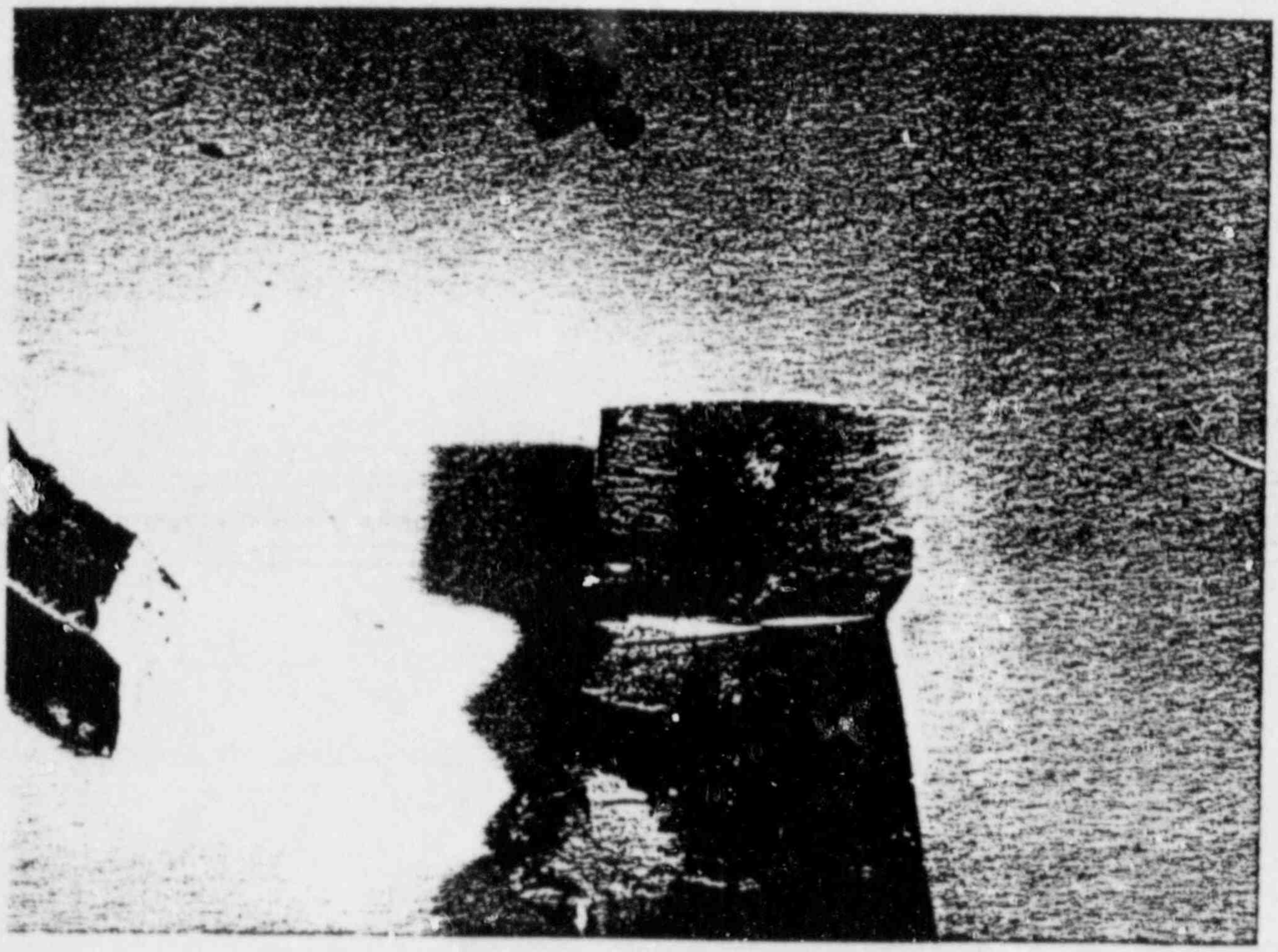
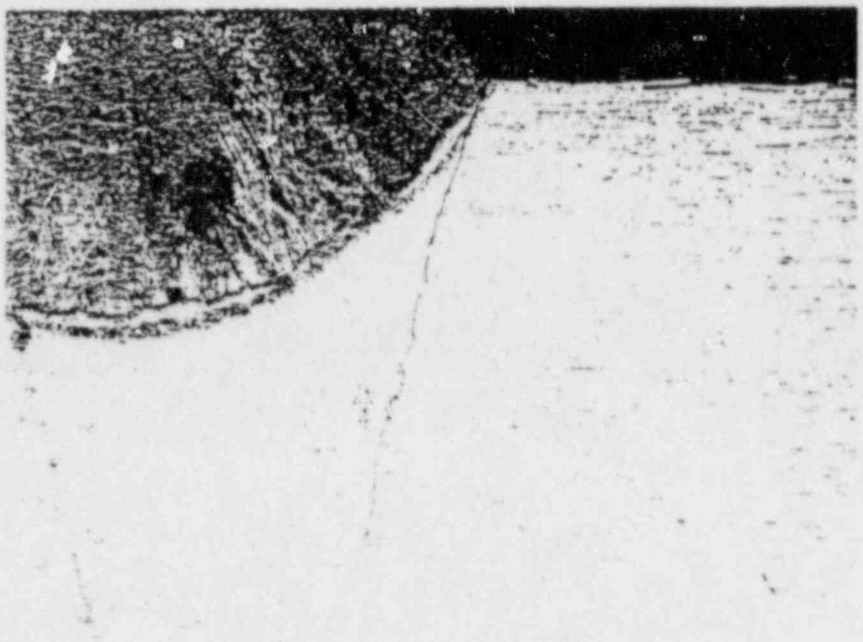
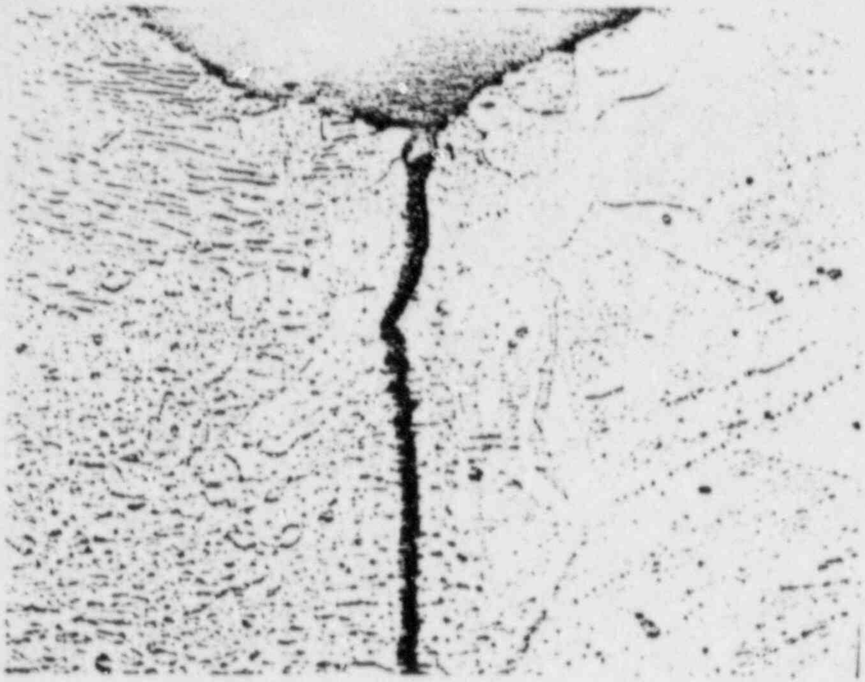


Figure 6. Close-up photograph of specimen used for SEM. Oxidation of fracture surface is heavier (darker) near OD at crack center and becomes lighter closer to the ID and crack front.



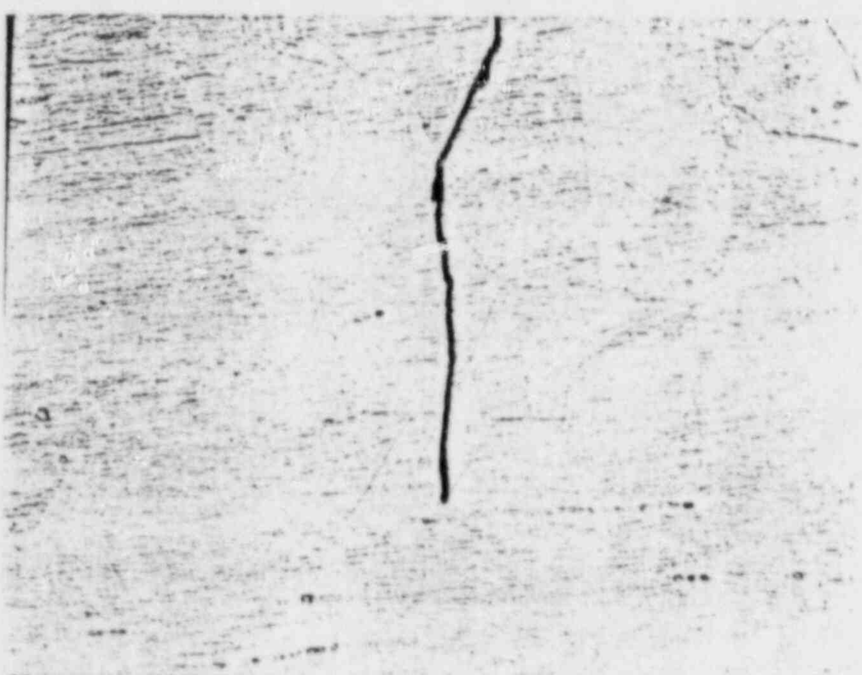
Oxalic Acid 33X

Figure 7. Specimen #1, near OD limit of crack.



Oxalic Acid 525X

Figure 8. Specimen #1, fusion line region of crack.



Oxalic Acid 525X

Figure 9. Crack tip, specimen #1.

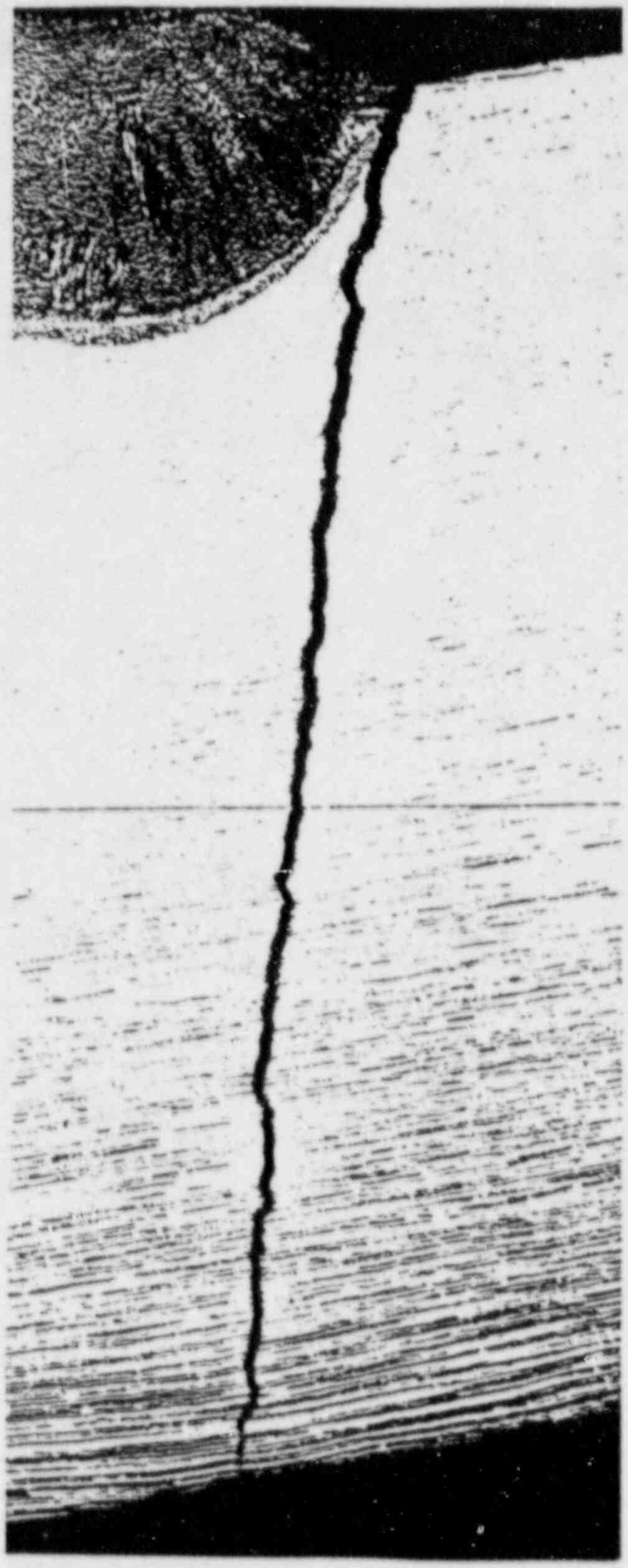
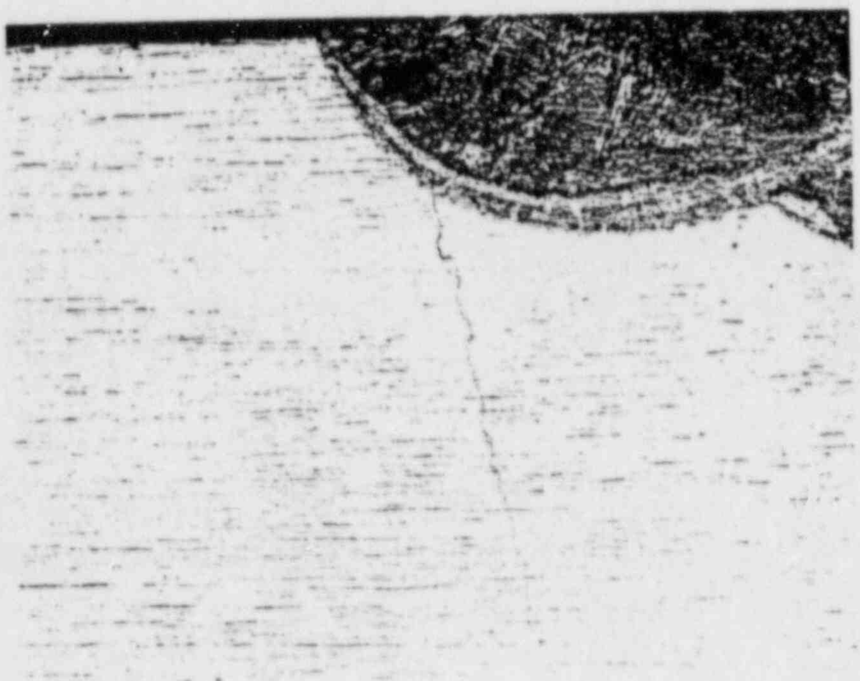


Figure 10. Specimen #2, center of through wall portion of crack.

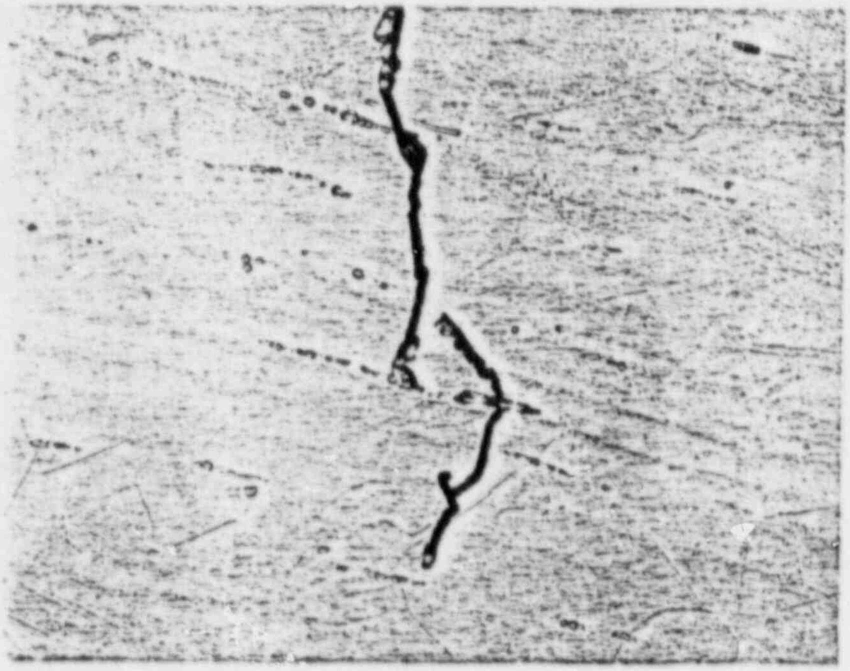


Oxalic Acid 33X

Figure 11. Specim :n #3, near OD limit of crack.

Oxalic Acid 525X

Figure 12. Specimen #3 fusion line region of crack.



Oxalic Acid 525X

Figure 13. Crack tip, specimen #3.

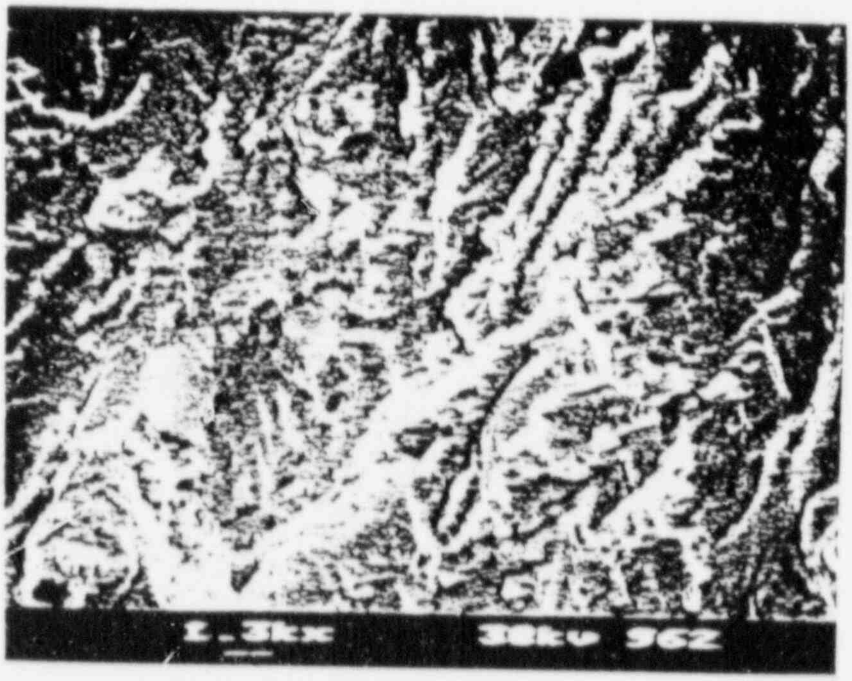


Figure 14. SEM fractograph near OD and crack center.

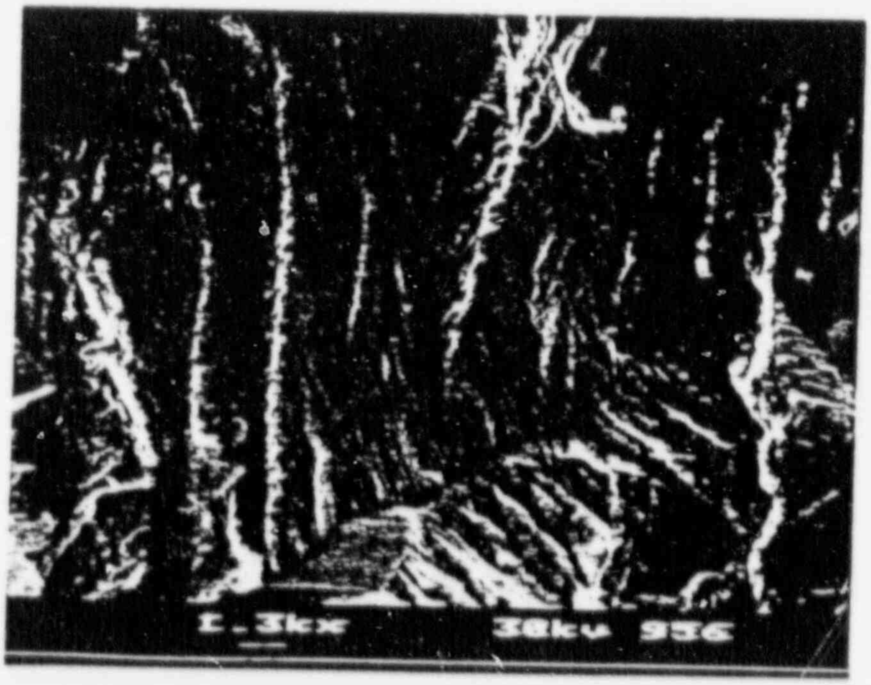


Figure 15. SEM fractograph near ID and crack tip.

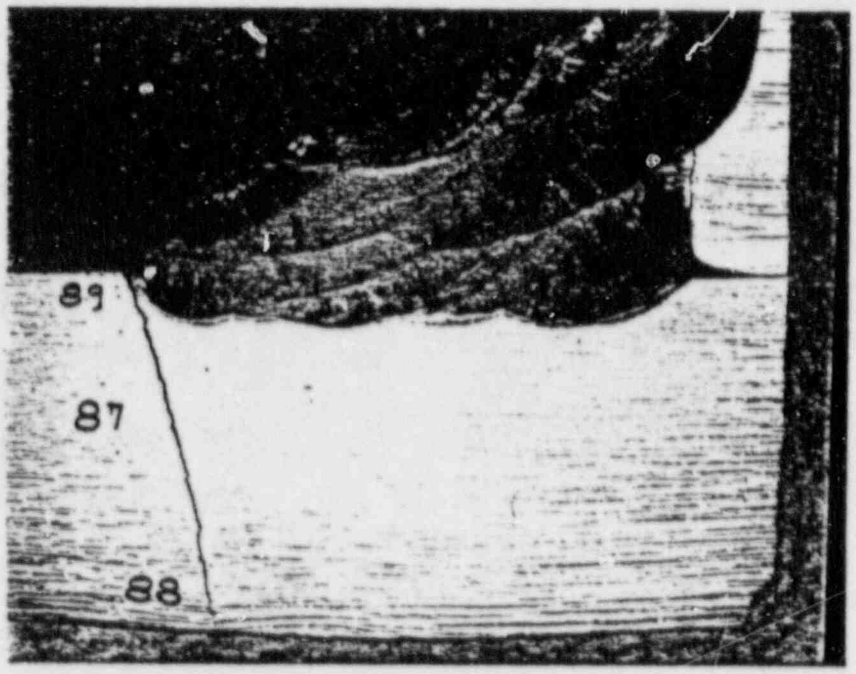


Figure 16. Hardness measurement location and results 200 gram load, specimen #2. Rockwell B equivalent.

Element	Check Analysis	ASME SA312 Type 316L	316 Nuclear Grade
C	0.014	0.035 Max.	0.020 Max.
Cr	16.90	16 - 18	-
Mo	2.52	2.0 - 3.0	-
Ni	13.40	10 - 15	-
P	0.023	0.04 Max.	0.035 Max.
Si	0.56	0.75 Max.	-
S	<0.005	0.030 Max.	0.005 Max.
Mn	1.77	2.00 Max.	-
N	0.065	-	0.060 - 0.120

Figure 17. Comparison of Check Analysis, ASME 312 Type 316L chemical composition and additional requirements of GE 316 Nuclear Grade material