MEMO REPORT CI-1052

Chemical and Electrical Insulation Sub-Section
MATERIALS AND PROCESSES LABORATORY

EXAMINATION OF A BOAT SAMPLE SUPPLIED BY GE I&SE NUCLEAR PLANT SERVICES

-by-

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ABSTRACT: This report describes the procedures, results and conclusions of the examination of a pressure vessel crack removed in a boat sample from a girth weld in a pressure vessel.

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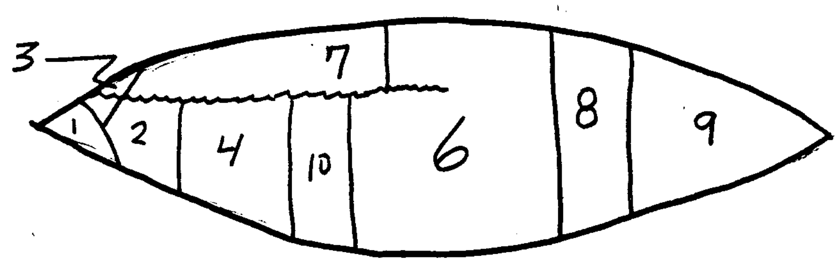
Examination of a Boat Sample Supplied by G.E. I&SE Nuclear Plant Services

INTRODUCTION

A boat sample was removed in the proximity of a weld on the steam generator at Indian Point. The boat sample had been cut up prior to being sent to the Turbine Technology Laboratory and the following sketch shows the original sample, the slices made, and identifies the pieces by number.



We received pieces #3, 6, 7, 9 and 10.

ASSUMPTIONS

Before discussing the procedures and results of this investigation a list of assumptions should be stated.

1. The boat sample (and the primary crack contained therein) are oriented horizontally on the pressure vessel, parallel to the weld.

2. The crack contained in the boat sample is a representative crack, i.e. most of the cracks are parallel to the horizontal weld joint.

3. The crack contained in the boat sample intersects the interior surface of the pressure vessel.

4. The base metal is 302B welded with 8018C-3 and this has been verified by other (Lucius Pitkin, Inc.) analysis.

PROCEDURE

Scanning Electron Microscopy -- SEM

Samples 6a and 6b were produced by cutting sample #6 from the original boat sample. The primary fracture surface was then examined by SEM. The original surface proved to be coated with oxide too thick to allow any resolution of the fracture surface. Ultrasonic bath cleaning was employed using alternate immersion in a 5% H_2SO_4 1% Catechol solution and a distilled water detergent solution. Figures 1-3 were taken on primary fracture surfaces after this cleaning procedure.

Optical Metallography

Pieces of 6a and 6b were mounted in epoxy resin and polished so that secondary cracks were intersected and Figures 4-7 were photographed from these secondary cracks.

Some of the secondary cracks were filled with oxide and an example of one of these is shown in Figure 9.

Specimen #7 was sliced, mounted, polished, and photographed. The photomicrograph is shown in Figure 8.

Microprobe Analysis

A microprobe analysis was conducted on the oxide filled crack shown in Figure 9. The material was scanned looking for any indication of contamination (corrodant).

Hardness Survey

The microstructure shown in Figure 8 showed weld metal, base metal, and two HAZ's and a Knoop hardness survey was run on each of these structures.

RESULTS

Scanning Electron Microscopy

The SEM photographs showed insufficient detail to determine whether the primary crack was intergranular or transgranular. The SEM photographs do reveal extensive secondary cracking, much of which seems nearly parallel the original crack surface, i.e. it branches at a small angle.

Optical Metallography

The optical metallography shown in Figures 4-7 shows secondary cracks, some with oxide and some with none. Resolution of the crack path is not simple in these micrographs but the secondary crack propagation is transgranular.

Electron Microprobe

An oxide filled crack, shown in Figure 9, was analyzed by the electron microprobe and the analyst's report is as follows: "The materials found in the cracks are iron oxides with varying small amounts of Mn and Si, and an organic material, probably the epoxy mounting material. No corrodants were detected by the X-ray energy spectrometer. Specifically sought using mechanical spectrometers, and not detected, were Na, Cl, and S."

Hardness Survey

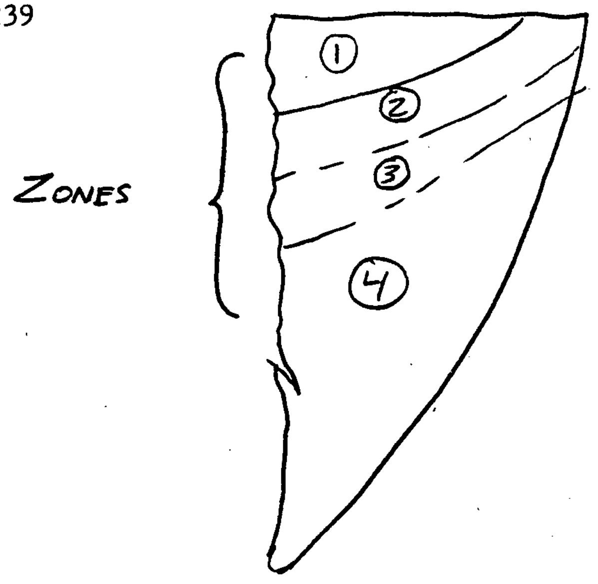
The sample shown in Figure 8 (Sample 7) was used in a hardness survey where the hardness of each of the four "zones" shown in Figure 8 was measured. The hardness results are shown in Table 1, along with a sketch showing the zones, contains the Knoop hardness values.

Table 1

Hardness Survey Results on Specimen #7 (Figure 8)

Knoop Hardness 500 gm Load

Location	Knoop Hardness
Zone 1 (Weld)	257 258
Zone 2 HAZ	405 408 376
Zone 3 HAZ	289 278 289
Zone 4 Base Metal	244 246 239



CONCLUSIONS

It is not possible to say why the cracking occurred on the basis of the examinations described in this report, however, some observations and deductions can be made.

The cracking examined, both the primary crack surface and the secondary cracks are brittle in nature, i.e. there is no evidence of strain or metal ductility (dimple rupture) associated with them. This would seem to rule out simple mechanical overload, unless the brittle-ductile transition temperature is unexpectedly high.

The multiplicity of cracks reported along with the frequent branching that is seen from the one crack examined make it very unlikely that a fatigue mechanism is the cause of the cracking.

The primary crack cuts across or through the weld metal, HAZ(s) as well as the base metal and this observation coupled with the general fracture appearance rules out hot tearing of the weld.

As much by a process of elimination as by deduction it appears most likely that the cracking is propagated by a stress-environment interaction most often called stress corrosion cracking. The stress could be generated by the pressure in the vessel during operation or by a substantial residual stress left in or around the weld. The corrodant or enviroinment need be no more than the water in the vessel during operation. No evidence of a more noxious corrodant was found. It would be interesting to know if there is a "water line" in this vessel and where it is with respect to this girth weld and the cracking.

It is quite possible that a two component mechanism is operative. One component generates the initial cracks that then propagate by an environmentally assisted cracking medium. It has been reported that there are cracks in the vessel that do not intersect any free surface. If this proves to be true, examination of these cracks may shed a great deal more light on the initiating mechanism. Without having seen them one can only speculate on a mechanism, but hydrogen flaking should be considered.

Recommended Further Work

An eight inch diameter "plug" is being removed from the wall containing more cracks, and there are a number of things that should be done with that material.

Crack Inspection

1) Determine the morphology of the cracks. Are they all the same? Branched?

2) Are there subsurface cracks? Hydrogen flaking?

3) Any evidence of corrodants? Boiler water chemicals or residues?

Material Evaluation

1) Determine, if possible, the state of residual stresses in the weld metal, HAZ, and base metal.

2) Measure Charpy V notch transition temperature of weld metal, base metal

and, if possible, HAZ.

3) Do a drop weight ductility test on each of the weld metal, HAZ, and base metal.

4) Use this data to determine the material toughness.

5) Depending on the results of steps 2-4 J integral toughness tests using 1T compact tension tests should be conducted.

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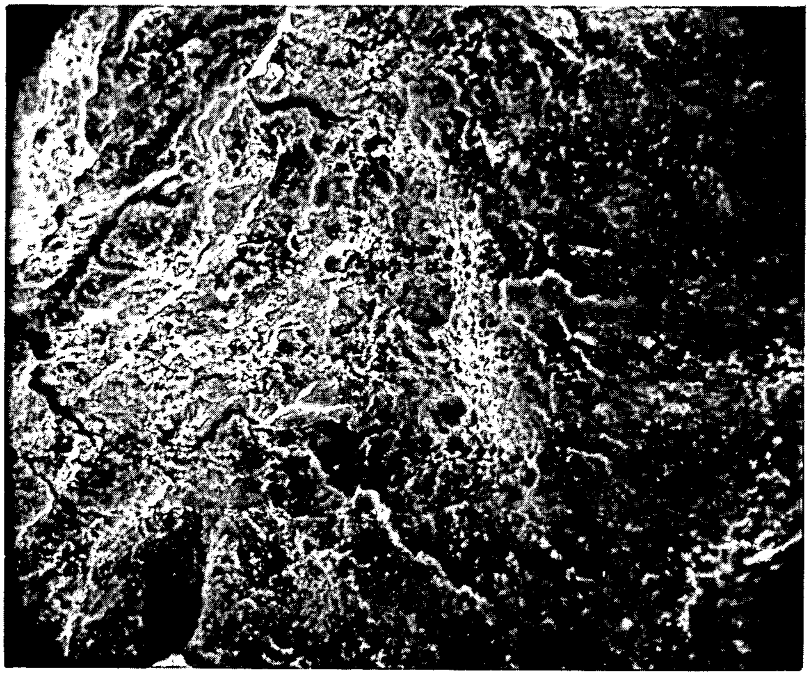

FIGURE 1. SEM of primary fracture surface after some ultrasonic cleaning. Note secondary cracks.

Mag 100X

FIGURE 2. SEM of primary fracture surface after some ultrasonic cleaning. Note the secondary cracks.

Mag 200X

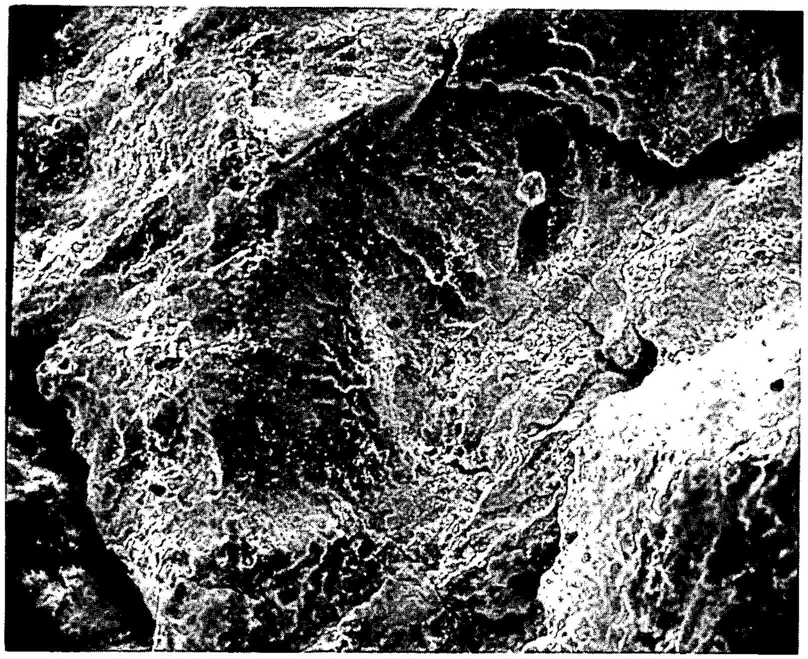

FIGURE 3. SEM of primary fracture surface after some ultrasonic cleaning. Note the secondary cracks.

Mag 500X

FIGURE 4. Secondary crack in Specimen 6A. Etchant 2% Nital.

Mag 200X
Neg. #2-2175F-1

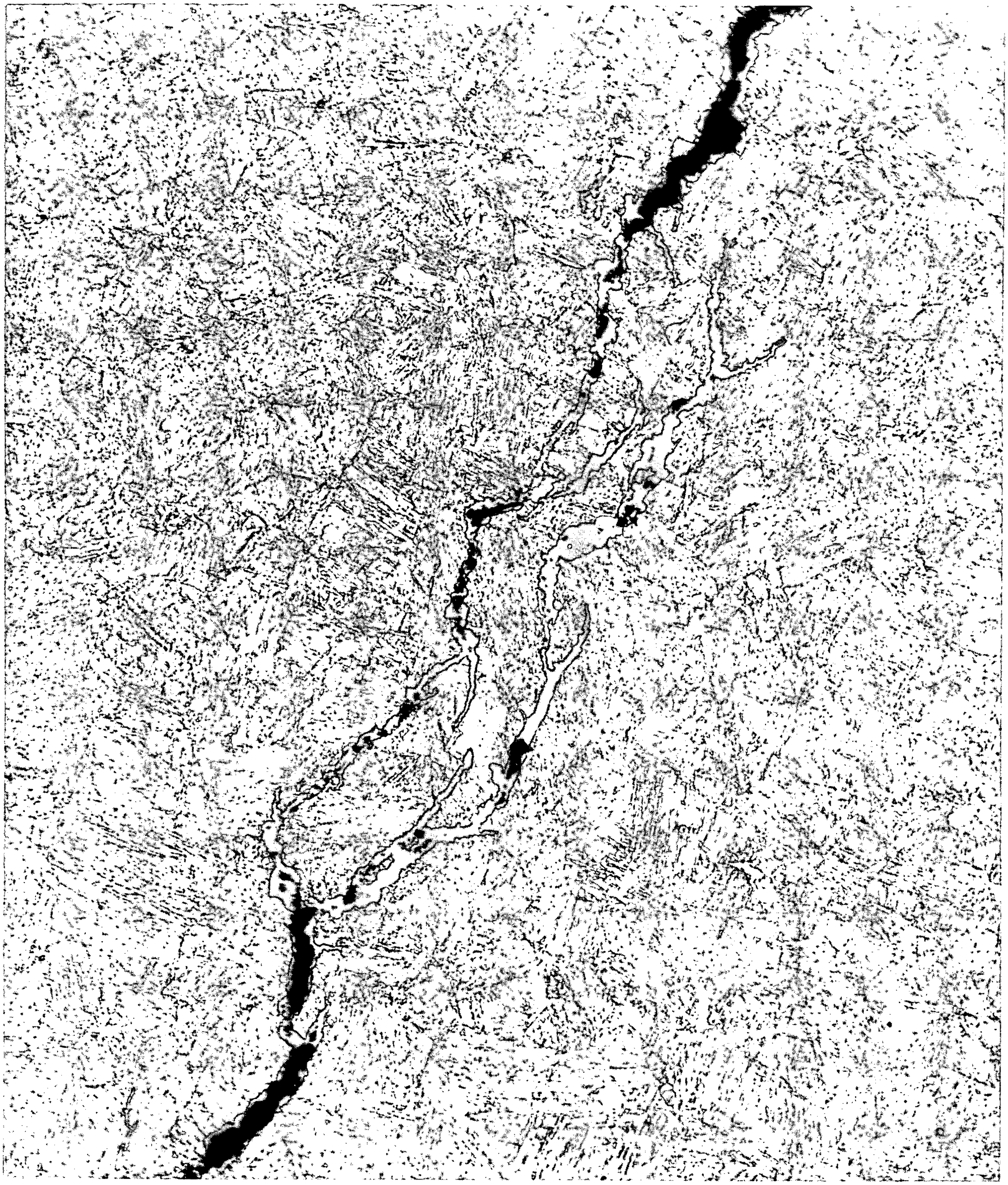

FIGURE 5. Secondary crack in Specimen 6A. Oxide Filled. Etchant 2% Nital.

Mag 500X
Neg. #2-2175F-2

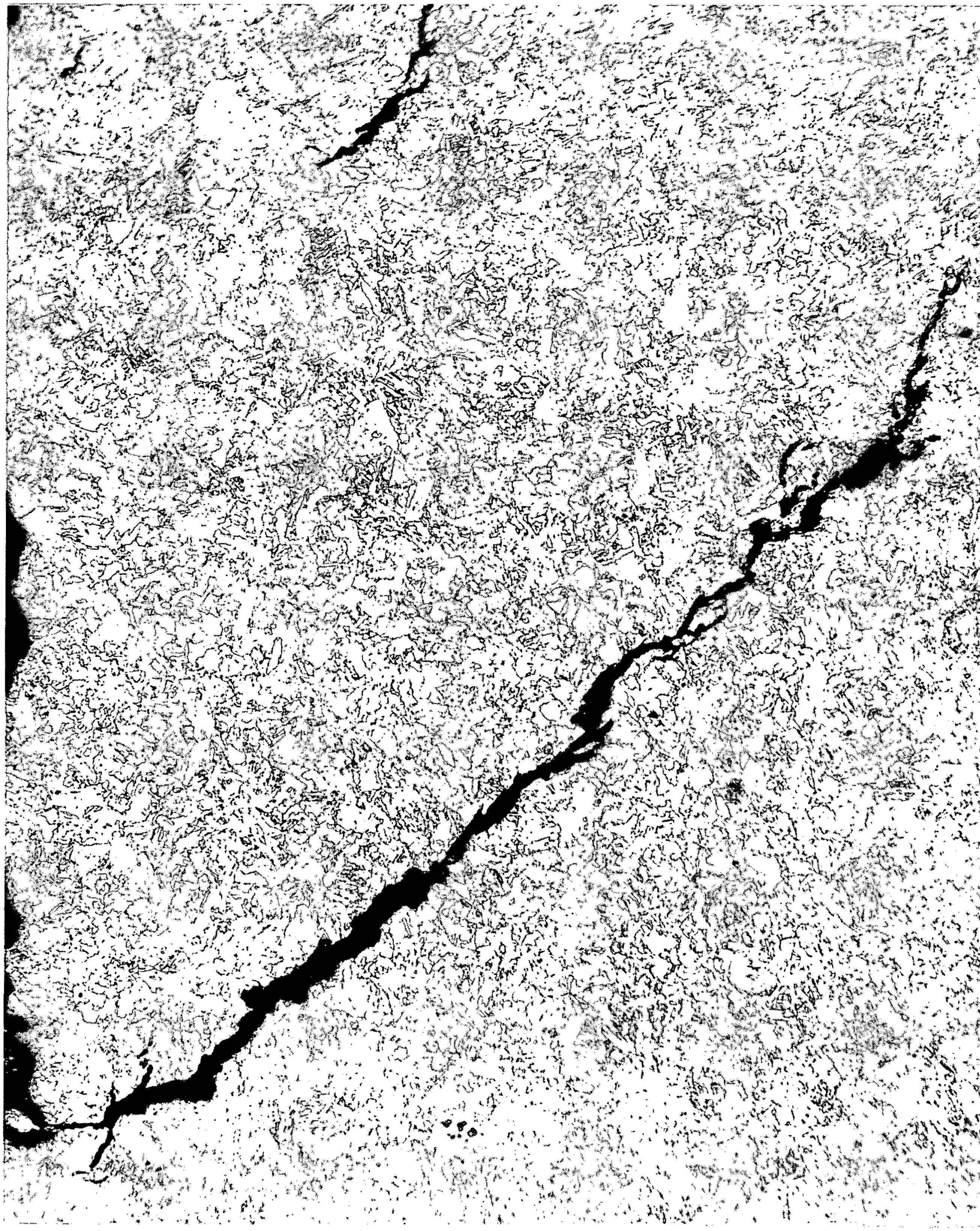

FIGURE 6. Secondary crack from Specimen 6B. Etchant 2% Nital.

Mag 200X
Neg. #2-2175F-4

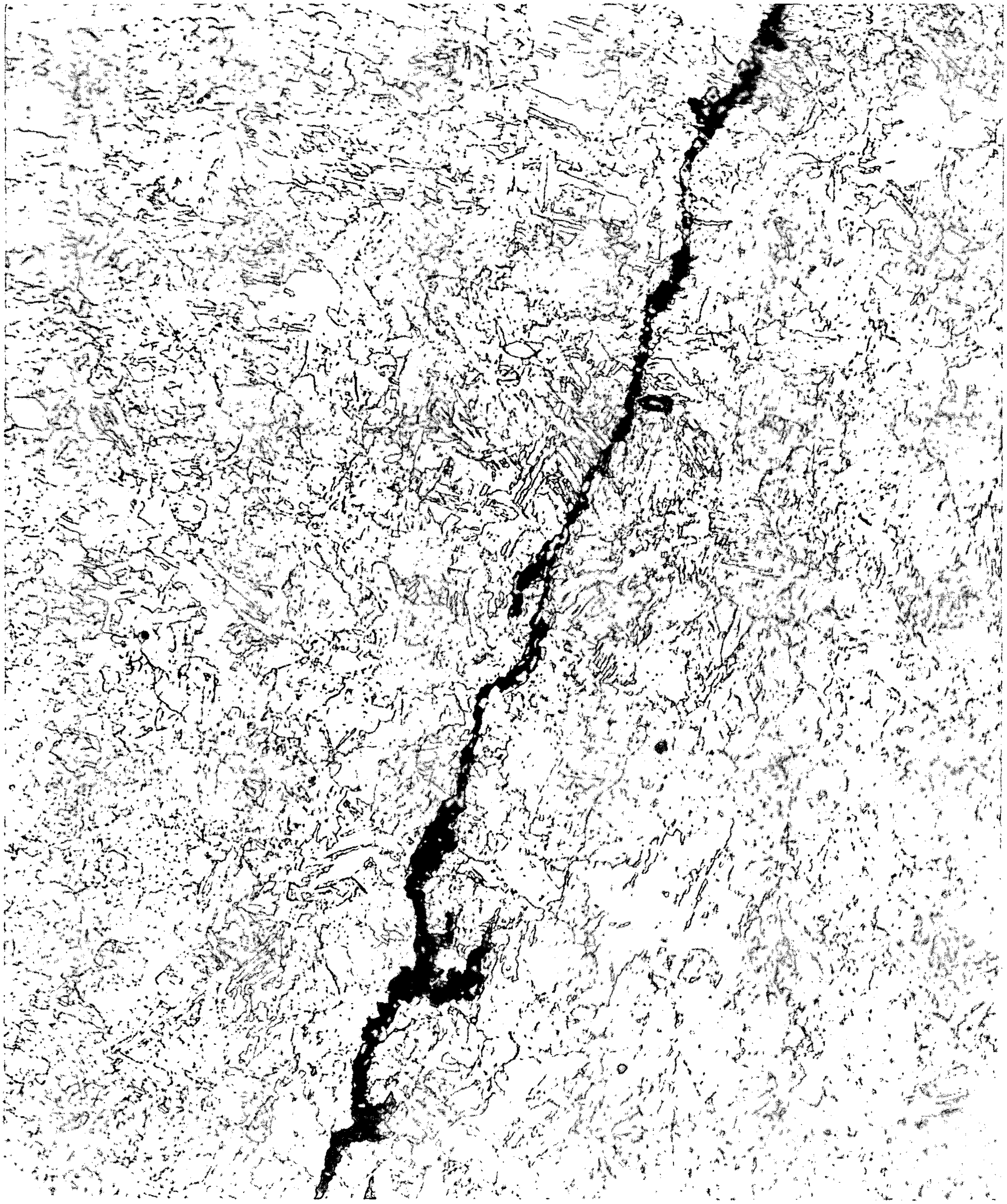

FIGURE 7. Secondary crack in Specimen 6B. Etchant 2% Nital.

Mag 500X
Neg. #2-2175-3

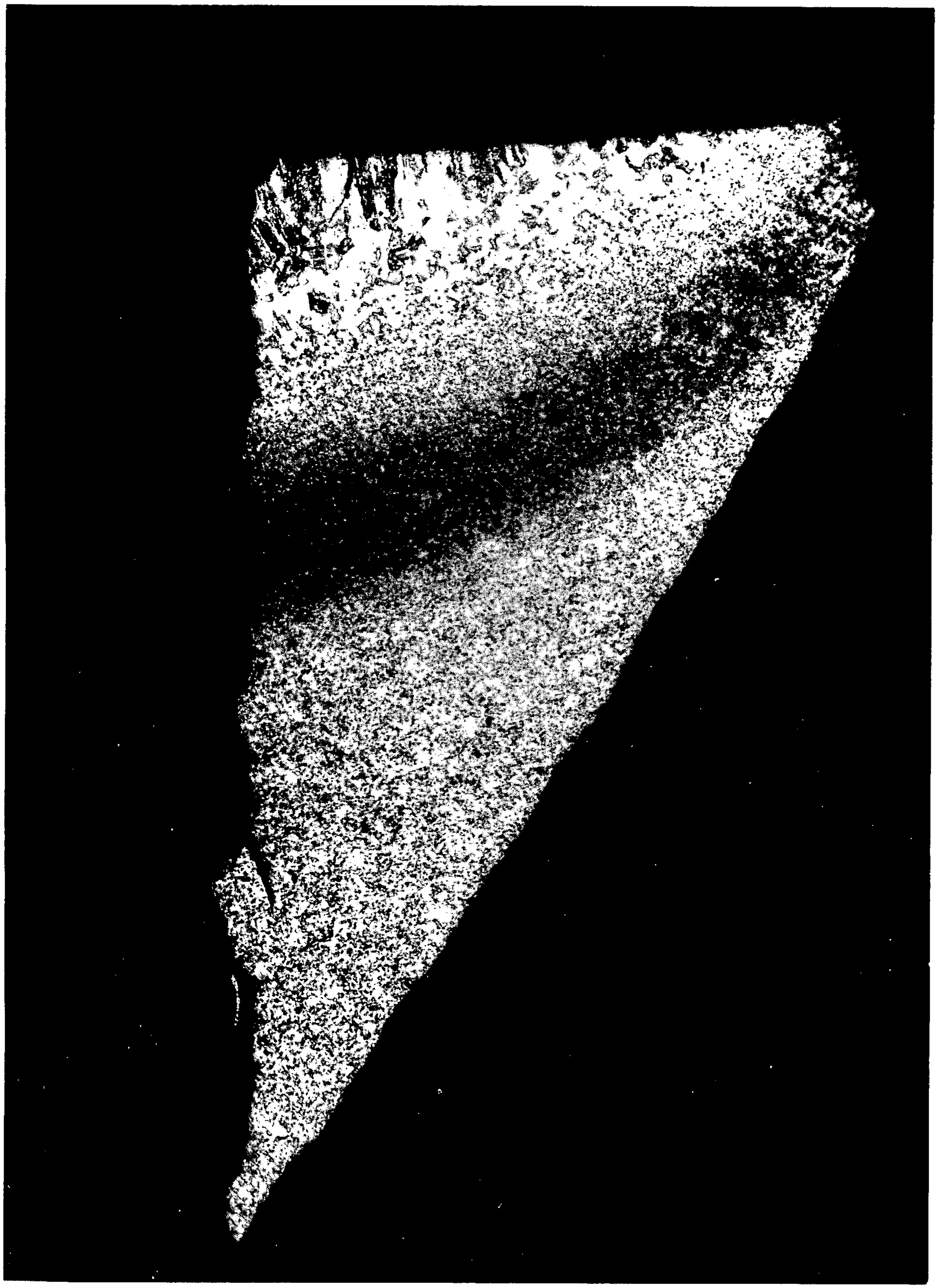

FIGURE 8. Boat sample 7 showing primary crack, secondary crack and weld, HA2 and base metal. Etchant 2% Nital.

Mag 15X
Neg. #2-2175F-1

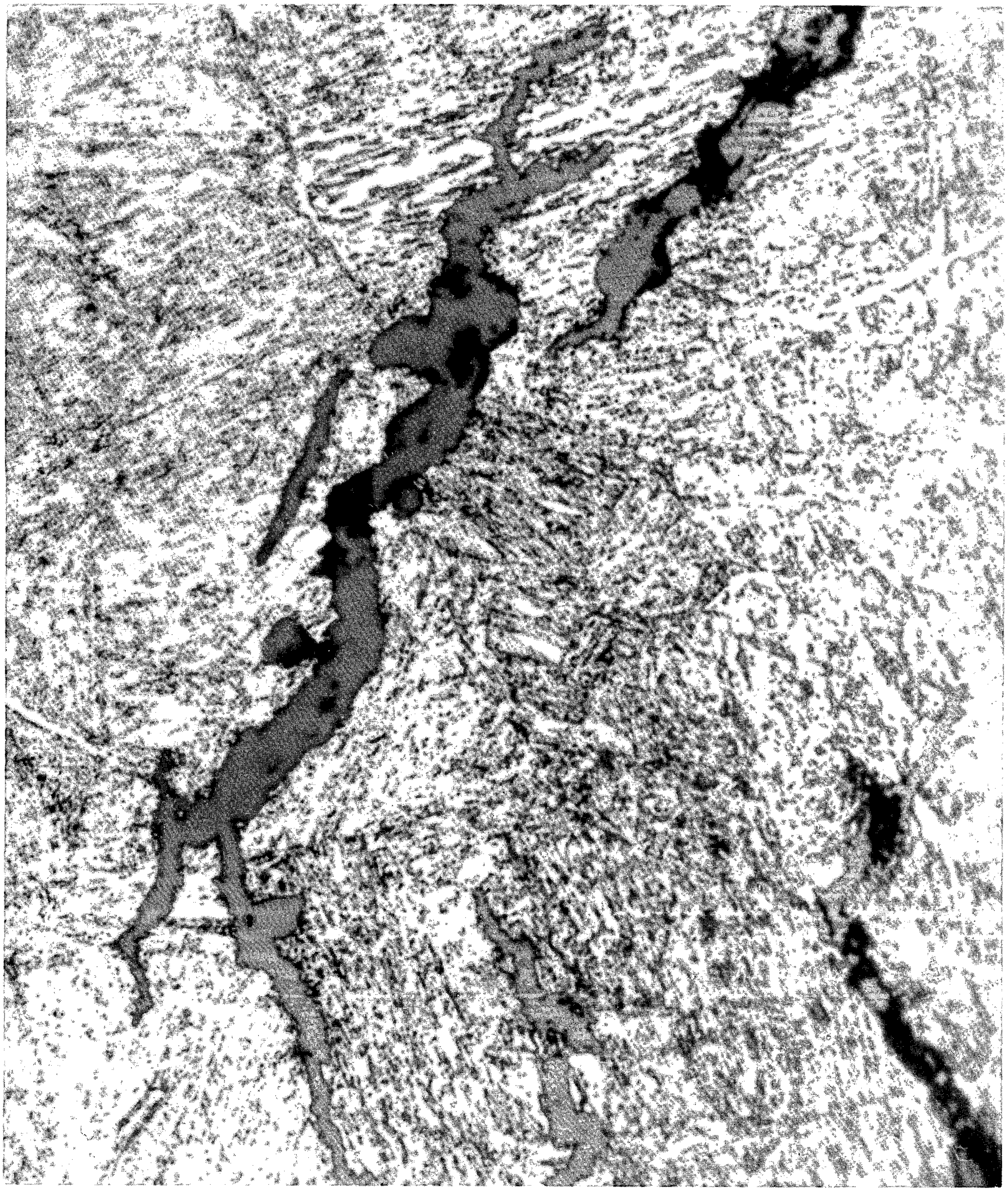

FIGURE 9. Secondary Crack filled with oxide in Sample 6A. Microprobe chemical analysis was done on this oxide. Etchant 2% Nital.

Mag 2000X
Neg. #2-2175F-2

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