DRAFT

CATAWBA SOCKET WELD EVALUATION *

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INTRODUCTION

Region II (Atlanta, Ga.) of the U. S. Nuclear Regulatory Commission had received various allegations regarding possible welding procedure violations on the off shifts at the Catawba nuclear site. These allegations intimated that certain stainless steel socket weld joints may have been assembled and welded with no regard for the interpass temperature restrictions imposed by the site's procedures and specifications. Since the non-judicious use of too much heat input could possibly cause significant sensitization of the Type 304 stainless steel being welded potentially causing susceptibility to intergranular stress corrosion cracking (IGSCC), Region II requested Brookhaven National Laboratory's (BNL) assistance in the development and implementation of field inspection techniques which could provide useful and reasonably accurate information regarding a given weld's degree of sensitization.

PROCEDURE DETERMINATION

In order to provide a gage of the developed procedure's effectiveness, Region II had eight samples of stainless steel socket weld coupons sent to BNL. Figure 1 is a photograph of the outside surface of the eight socket welds. In addition to the eight half-sectioned socket welds, a cross-sectional slice of each socket weld was also sent. A photograph (Figure 2) of the inside surface of these eight socket welds disclosed that there was significantly more heat tinting (wider band of oxidized metal) in coupons 1, 3, 5 and 7. This observation was in conformance with the information received from Duke Power Company regarding the welding procedures used for each socket weld coupon:

Coupon No. 1 - 2" Sch. 40 SS pipe welded into a 2" - 3000# SS full coupling

Weld position 2F
Voltage 10V
Amperage 150A
DCSP (Direct Current Straight Polarity)
GTAW Process (Gas Tungsten Arc Welding)
Filler Material ER308
Filler Material Diameter 3/32" - 1st Pass
1/8" - 2nd Pass
3/32" - 3rd Pass

The weld was made using no interpass temperature control. The only stops made in the weld were during filler metal and position changes. Duke Power reported that the base material was raised to a temperature of approximately 750°F after welding.

Coupon No. 2 - Identical to coupon No. 1 except that a maximum interpass temperature restriction of 350°F was imposed.

Coupon No. 3 - 1" Sch. 40 SS pipe welded into a 1" - 300# SS full coupling

Weld position 2F
Voltage 10V
Amperage 138A
DCSP (Direct Current Straight Polarity)
GTAW Process (Gas Tungsten Arc Welding)
Filler Material ER308
Filler Material Diameter 3/32" - 1st Pass
3/32" - 2nd Pass

This weld was made using no interpass temperature control. The only stops made in the weld were during filler metal and position changes. Duke Power reported that the base material was raised to a temperature of approximately 750°F after welding.

Coupon No. 4 - Identical to coupon No. 3 except that a maximum interpass temperature restriction of 350°F was imposed.

Coupon No. 5 - 1" Sch. 160 SS pipe welded into a 1" - 6000# SS full coupling

Weld position 2F
Voltage 12V
Amperage 180A
DCSP (Direct Current Straight Polarity)
GTAW Process (Gas Tungsten Arc Welding)
Filler Material ER308
Filler Material Diameter 1/8" - all 5 passes

This weld was made using no interpass temperature control. The only stops made in the weld were during filler metal and position changes. Duke Power reported that the base material was raised to a temperature of approximately 1000°F after welding.

Coupon No. 6 - Identical to coupon No. 5 except that a maximum interpass temperature of 350°F was imposed.

Coupon No. 7 - 2" Sch. 160 SS pipe welded into a 2" - 6000# SS full coupling

Weld position 2F
Voltage 12V
Amperage 180A
DCSP (Direct Current Straight Polarity)
GTAW Process (Gas Tungsten Arc Welding)
Filler Material ER308
Filler Material Diameter 1/8" - All 5 passes

This weld was made using no interpass temperature control. The only stops made in the weld were during filler metal and position changes. Duke Power reported that the base material was raised to a temperature of approximately 1000°F after welding.

Coupon No. 8 - Identical to coupon No. 7 except that a maximum interpass temperature of 350°F was imposed.

2.0 TECHNIQUE

Intergranular corrosion is generally defined as a local attack on the grain boundaries of a metal by a corrosive media.

In stainless steels, susceptibility to intergranular corrosion is greatly enhanced by the sensitization process. Sensitization can be described (in austenitic stainless steels) as the formation of chromium carbide precipitates in the grain boundaries and the resultant depletion of Cr, brought about by heating the steel in the temperature range 500-800°C (1,2).

This temperature range is easily achieved during the welding process where the normal temperature of welding exceeds 1600°C during fusion welding. Therefore, the welded base material could receive a sensitizing heat treatment in the critical range (500 - 800°C) at some point outward from the weld fusion line which would be maintained long enough to precipitate Cr carbide at the grain boundaries. This is not to say that the welding process alone will induce a sensitizing effect on the base material, as the degree of material sensitization is a cumulation of the material's prior thermal and mechanical treatments, weld cycle history, (# passes, heat input, etc.) material chemistry, thickness and thermal conductivity, and time at temperature in the sensitization range.

In order to measure a materials' degree of sensitization, the American Society for Testing and Materials (ASTM) has published Standard A-262, "Standard Recommended Practices for Detecting Susceptibility to Intergranular Attack in Stainless Steels." This standard includes a rapid screening test as part of its content; Practice A - Oxalic Acid Etch Test for classification of etch structures of stainless steels. This practice is described in A-262 as: "1.3 The oxalic acid etch test is a rapid method of identifying, by simple etching, those specimens of certain stainless steel grades which are essentially free of susceptibility to intergranular attack associated with Cr carbide precipitates. These specimens will have low corrosion rates in certain corrosion tests and therefore can be eliminated (screened) from testing as "acceptable.""

For purposes of this investigation, each of the socket welds were hand ground (similar to field conditions) and then polished down to a 1 micron finish. The polished specimens were then etched with a current density of $1A/cm^2$ for 1.5 min. in a 10% oxalic acid + demineralized water solution. The cathode used for the etching was a piece of 304 stainless steel while the socket weld specimen was used as the anode. For comparison study, the welded cross sections were also polished and etched in a similar manner. The welded cross sections were examined on a metallograph while the socket weld specimens were examined on a microscope simulating field examinations. The results of the examinations are shown in the photomicrographs (Figures 3-10). It should be noted that these photomicrographs were taken at approximately 250X and were the areas of <u>most</u> pronounced sensitization. In no instance was any structure considered rejectable (ditched structure in accordance with ASTM 262 - Practice A). There were no rejectable structures found on either the socket welds or the socket weld cross sections. The worst case structure was found on coupon #5 which showed a definite dual structure but no one grain was completely encircled by carbide ditching.

One area of cracking was found on socket weld specimen #7 (Figure 11). This area appeared to be associated with an arc strike which appeared to have cracked on cooling. The cracking was found on the pipe portion of the weldment; outside the socket weld's heat affected zone.

3.0 CONCLUSIONS

The examination of the eight socket weld coupons and their associated cross sections have led to the following conclusions:

a) None of the welds examined were considered rejectable if compared to ASTM A-262 - Practice A. Even the specimens with no heat input control would be considered acceptable.

b) The ASTM A-262 - Practice A technique is a viable method of field metallography for determination of sensitization of stainless steels.

c) Care should be taken to prevent arc strike on these stainless steels.

4.0 REFERENCES

1. Pande, C. S., Suenaga, M., Vyas, B., Isaacs, H. S., and Hailing, D. F., Scripta Metallurgica, Vol. 11, 1977, pg. 681.

2. Cowan R. L. and Tedmon, C. S., Jr., Advances in Corrosion Science and Technology, Vol. 3, 1973, pg. 293.

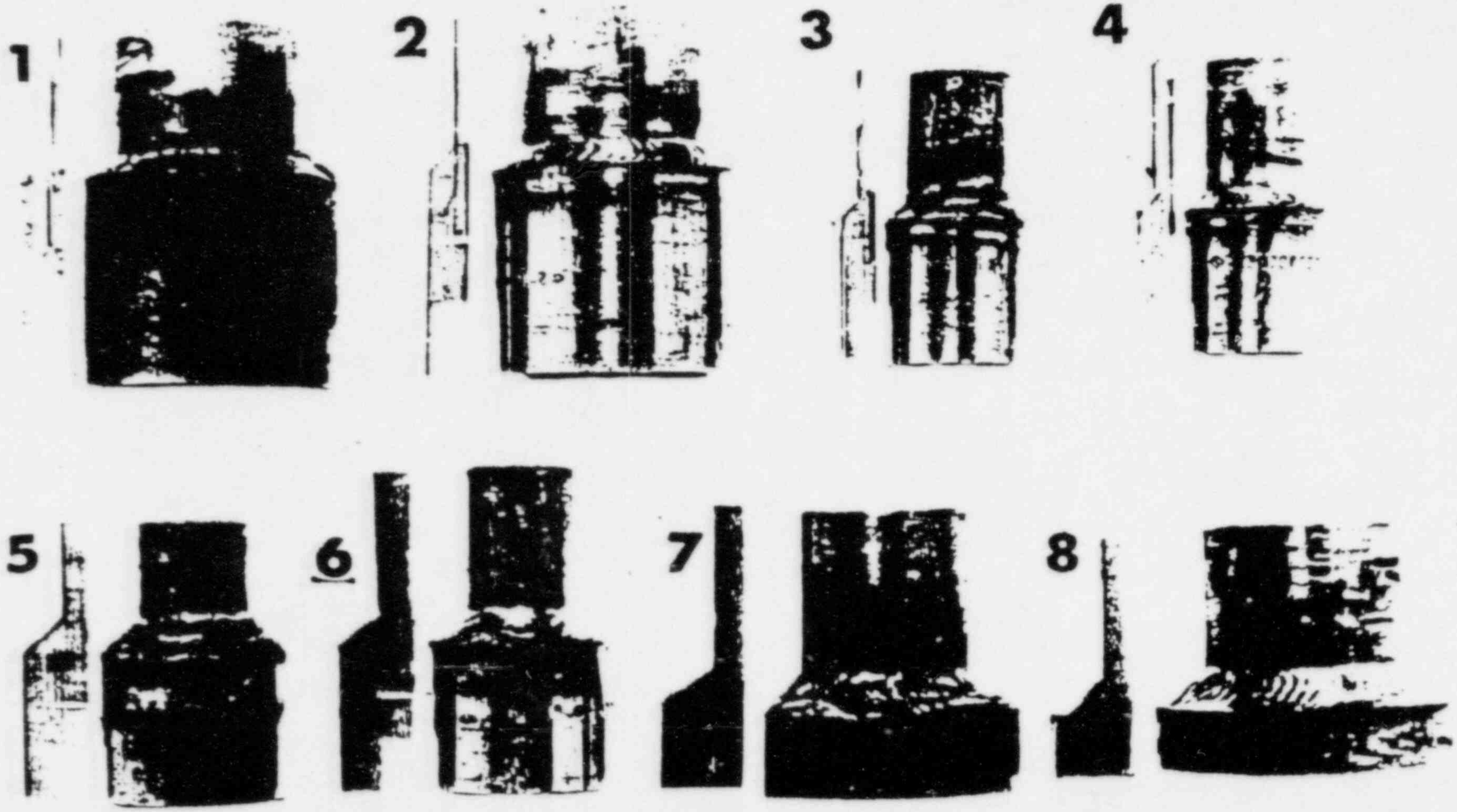

FIGURE 1 PHOTOGRAPH OF OUTSIDE SURFACES OF THE EIGHT SOCKET WELDS SENT TO BNL FROM DUKE POWER.

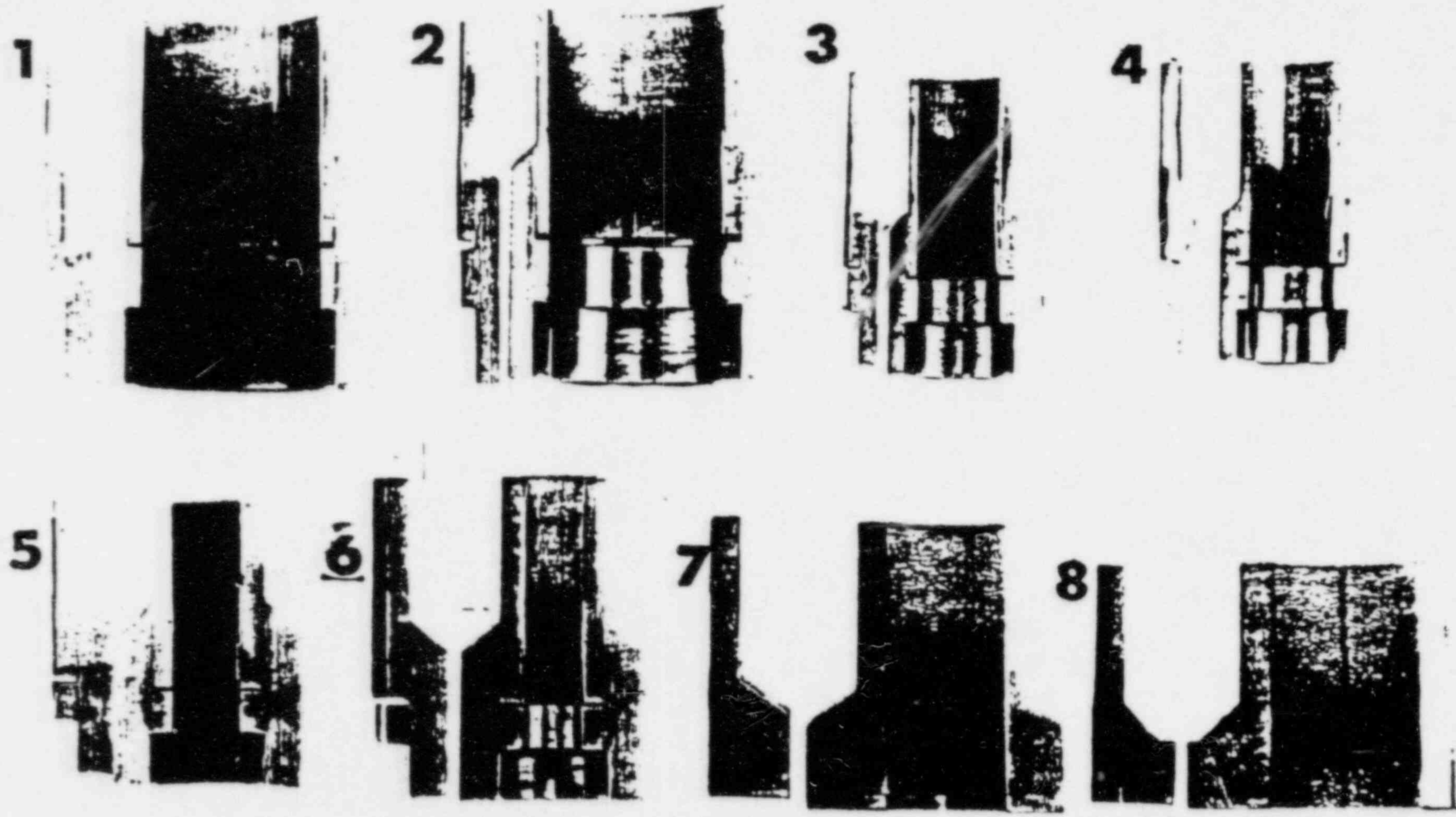

FIGURE 2 PHOTOGRAPHS OF THE INSIDE SURFACES OF THE EIGHT SOCKET WELDS SENT TO BNL FROM DUKE POWER. NOTE THE DIFFERENT EXTENTS OF HEAT TINTING FOR THE SPECIMENS.

FIGURE 3 PHOTOMICROGRAPH OF SOCKET WELD #1 AFTER ETCHING. STEP STRUCTURE.

FIGURE 3A PHOTOMICROGRAPH OF CROSS SECTION OF WELD #1 AFTER ETCHING. STEP STRUCTURE.

FIGURE 4 PHOTOMICROGRAPH OF

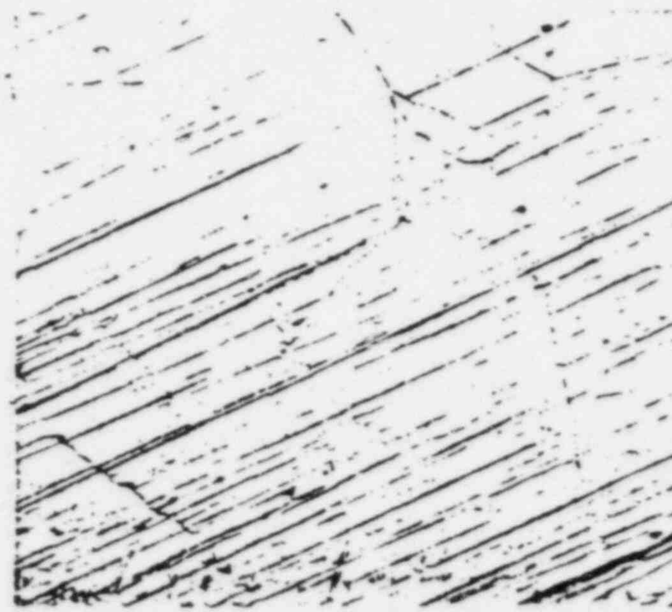

FIGURE 4A PHOTOMICROGRAPH OF

FIGURE 5 PHOTOMICROGRAPH OF SOCKET WELD #3 AFTER ETCHING. DUAL STRUCTURE.

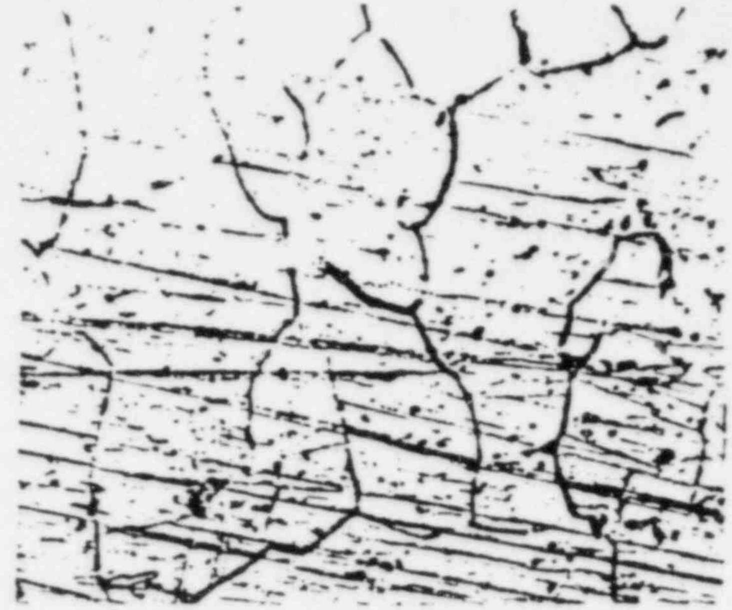

FIGURE 5A PHOTOMICROGRAPH OF CROSS SECTION OF WELD #3 AFTER ETCHING. DUAL STRUCTURE.

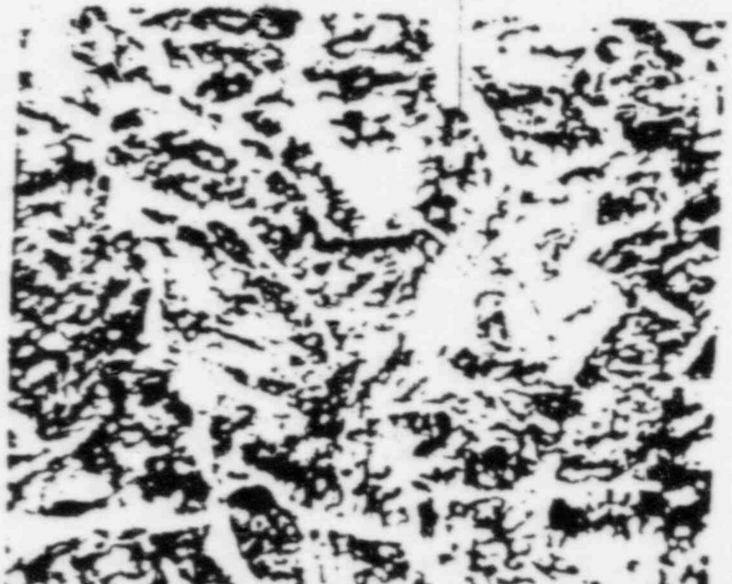

FIGURE 6 PHOTOMICROGRAPH OF SOCKET WELD #4 AFTER ETCHING.

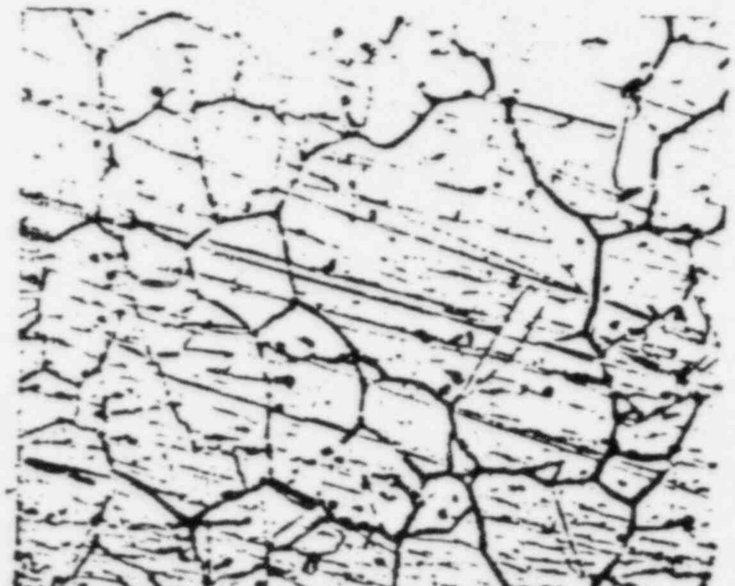

FIGURE 6A PHOTOMICROGRAPH OF CROSS SECTION OF WELD

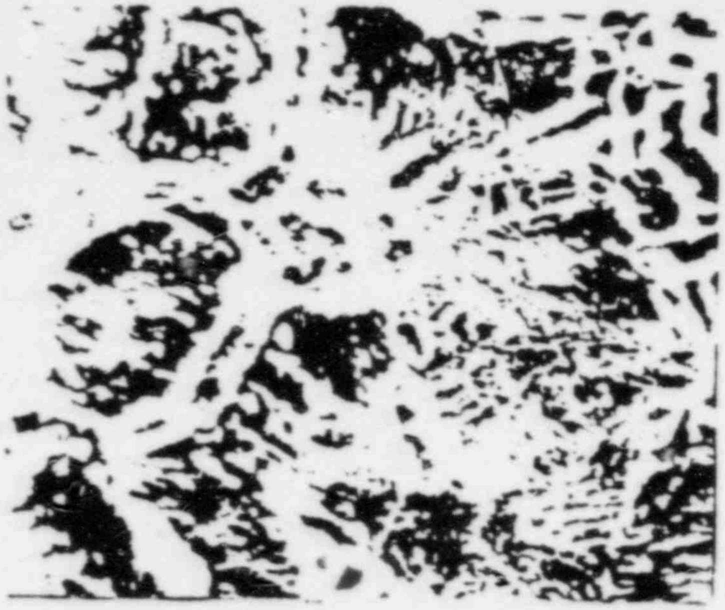

FIGURE 7 PHOTOMICROGRAPH OF SOCKET WELD #5 AFTER ETCHING. DUAL STRUCTURE.

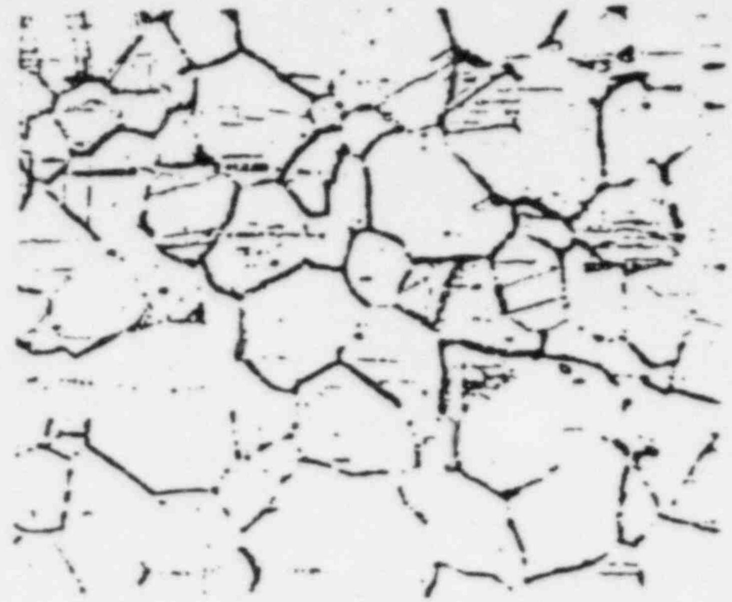

FIGURE 7A PHOTOMICROGRAPH OF CROSS SECTION OF WELD #5 AFTER ETCHING. DUAL STRUCTURE.

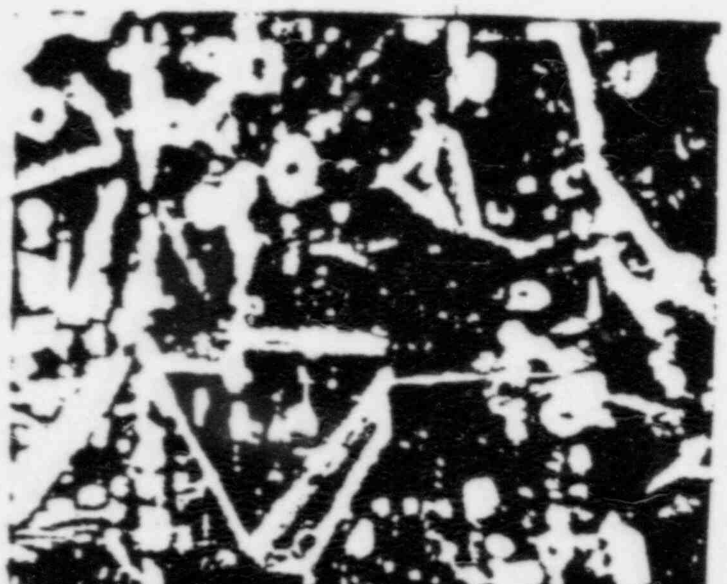

FIGURE 8 PHOTOMICROGRAPH OF SOCKET WELD #6 AFTER

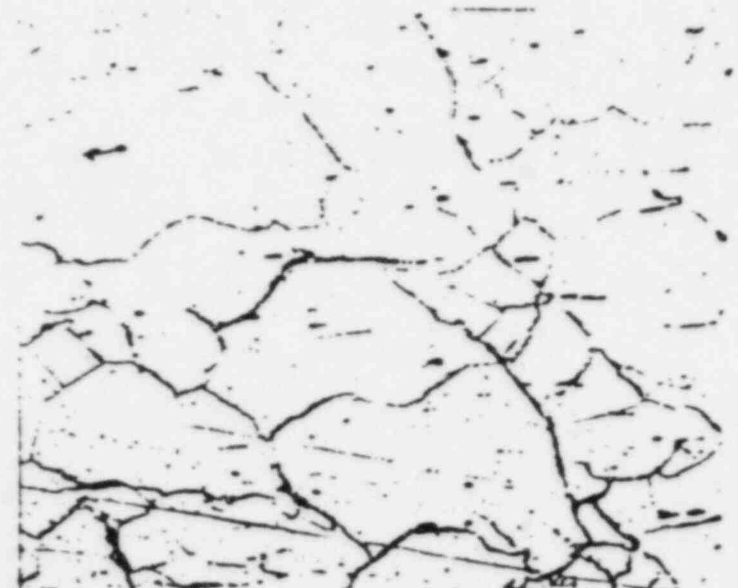

FIGURE 8A PHOTOMICROGRAPH OF CROSS SECTION OF WELD

FIGURE 9 PHOTOMICROGRAPH OF SOCKET WELD #7 AFTER ETCHING. DUAL STRUCTURE.

FIGURE 9A PHOTOMICROGRAPH OF CROSS SECTION OF WELD #7 AFTER ETCHING. DUAL STRUCTURE.

FIGURE 10 PHOTOMICROGRAPH OF SOCKET WELD #8 AFTER ETCHING. STEP

FIGURE 10A PHOTOMICROGRAPH OF CROSS SECTION OF WELD #8 AFTER ETCHING.

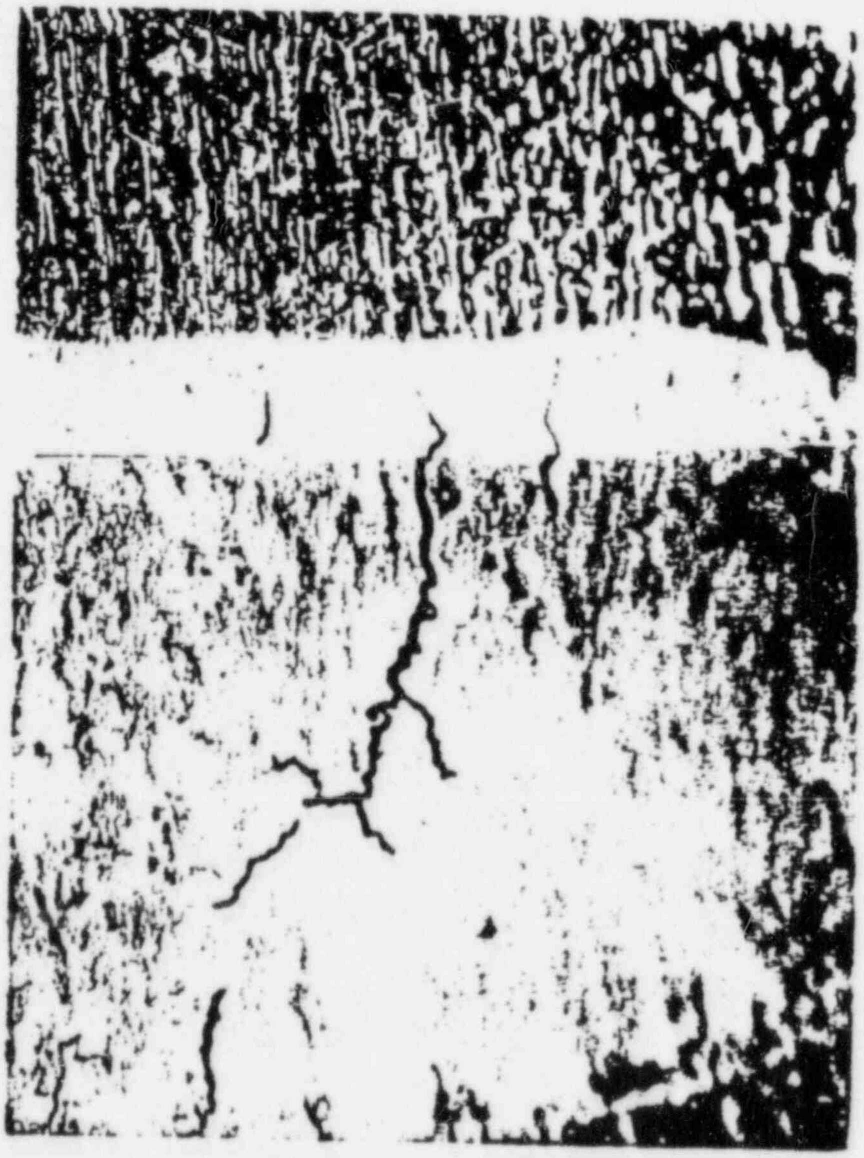

FIGURE 11 CRACK ASSOCIATED WITH AN ARC STRIKE FOUND ON SOCKET WELD #7.

APPENDIX A

FIELD TRIP TO CATAWBA SITE

On June 20, 1984, I visited the Catawba site with Mr. N. Economos from Region II - U. S. Nuclear Regulatory Commission. The purpose of the visit was to review the methods used by Duke Power in determining acceptability of stainless steel field installed socket welds.

An entrance meeting was convened on the morning of June 20, 1984 with the following people in attendance:

Attendee	Title	Company
A. R. Hollins	Construction	Duke
S. E. Ferdon	Engineer Assistant	Duke
C. J. Czajkowski	Research Engineer	BNL
N. Economos	Region II	U.S. NRC
D. H. Llewelyn	Assoc. Field Engineer	Duke
B. Kruse	Field Engineer	Duke

The agenda for the meeting is included (Attachment #1) of this report.

During discussions with the utility personnel at this meeting, it was decided that Mr. Economos and myself would witness the utility's method of field etching and replica production on three field welds.

The field welds reviewed were:

1-BB-130-18
1-BB-130-19
1-BB-97-18

The welds were ground and polished by high-speed motor-tool to 1/4 micron finish. After polishing, the suspect areas were electrochemically etched using oxalic acid and a portable power source. The voltage density was adjusted to $1A/cm^2$ and was maintained for 1.5 minutes. After cleaning with distilled water, a replica was made of the area using a silicone based (two-part) polymer. After thermal setting of the replica, it was removed and then examined in the weld test booth area using a metallograph.

Although the quality of the replicas varied somewhat in sensitivity even the least sensitive was capable of replicating the material's structure sufficiently to ascertain the degree of sensitization present in the weldment. In all three cases, the material condition would have been acceptable to ASTM A-262 - Practice A.

In order to verify the sensitivity of the replicating process; the welds themselves were inspected using a portable microscope. The structures observed were consistent with those obtained by this replicating process.

A review of the following field procedures/forms showed these to be consistent with good construction practices:

Patch/Wipe Test Documentation	Form CP-57A, Rev. 1
Alteration/Repair Process Control	Form F-10A, Rev. 1
Construction Procedure	CP-857, Rev. 9

Additional documentation reviewed included four mill test reports for stainless steel tube/pipe and fittings. Although one lot of material had a carbon content of .017%; all of the other lots of material ran between 0.05% - 0.07% carbon. (The lower the carbon content the less the susceptibility to sensitization.)

During discussions with utility personnel at an exit critique (Attachment #2) the following points were made by the BNL employee.

1) The replicating process and field etching technique appear to be satisfactory methods of determining the materials' conditions with regards to sensitization.

2) The carbon content of the materials used for construction would dictate the need for at least a sampling of suscept welds for a sensitized condition.

3) The welds which were performed by the welder who stated he did not use interpass control should be considered a separate population from the other welds and should be inspected accordingly.

4) The re-use of oxalic acid for etching by the utility was discouraged. It was suggested that any used oxalic acid be discarded in a waste bottle for proper disposal.

Although not discussed at the exit critique, the cleaning of the stainless steel after etching should be performed in accordance with ASTM A-262 - Practice A - Section 4.7 as practicable.

CATAWBA NUCLEAR STATION

MEETING TO REVIEW WELDING INDUCED SENSITIZATION
OF STAINLESS STEEL PIPING

JUNE 20, 1984

AGENDA

INTRODUCTION - OFFICE OF D. N. LLEWELLYN

REVIEW OF DUKE IDENTIFICATION OF CRITICAL WELDS

REVIEW OF FIELD PORTABLE METALLOGRAPHIC TECHNIQUE
USED BY DUKE - CATAWBA MET. LAB.

FIELD TOUR TO UNIT 1 REACTOR BLDG. TO EXAMINE
APPLICATION OF PROGRAM - #1 R. B.

EXAMINATION OF METALLOGRAPHIC RESULTS FROM
FIELD TOUR - CATAWBA MET. LAB.

CRITIQUE - CONF. ROOM

ATTACHMENT 1