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Records

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MASTER

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Leak SWR Test and Analysis

"LLTR Relief System Materials Evaluation"

Dear Mr. Harbison:

Attached is a GE report on LLTR relief system materials evaluation. It describes the examination of LLTR relief system piping removed after the Series I Large Leak Program and the subsequent metallurgical examination of a stainless steel weld which had shown cracking indications. This report also summarizes the stress corrosion cracking (SCC) experience with a stainless steel weld at the outset of the Series II program. This report satisfies FY-79 Milestone Y4.8.

Mr. J. C. Whipple or Mr. P. J. Ring of our staff may be contacted regarding this transmittal.

Very truly yours,

W. V. Leeburn
W. V. Leeburn, Manager
Steam Generator Projects

WVL:JCW:aim

Attachment

cc: Attached Distribution List

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Attachment to Letter XL-796-79132

LLTR RELIEF SYSTEM
MATERIALS EVALUATION

September 1979

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AT03-765F-70030

LLTR RELIEF SYSTEM MATERIALS EVALUATION

1.0 INTRODUCTION

The scope of Subtask Y4, "Sodium/Water Reaction Recovery" of Work Package Task Number SG037, "Large Sodium/Water Reaction Test and Analysis," is to establish procedures for LMFBR plant cleanup and recovery following sodium/water reaction (SWR) events. Encompassed within the "recovery" aspects of this scope is the evaluation of steam generator and relief systems material behavior following SWR events. Of particular concern is the potential for stress corrosion cracking (SCC) that may occur in the steam generator and sodium/water reaction pressure relief system (SWRPRS) during or following SWR events. The large leak test programs carried out at Energy Technology Engineering Center provide the opportunities for conducting the necessary materials evaluation work.

During FY-79 the GE materials evaluation work under Subtask Y4 consisted of 1) planning a materials evaluation program to be carried out in conjunction with the LLTR Series II Large Leak Test Program followed by preparing some U-bend specimens with specimen racks for insertion in the LLTR relief system, and 2) the examination of LLTR relief piping removed after the Series I testing program in preparation for Series II. Full implementation of the LLTR Series II-related materials program (Item 1 above) in FY-80 is subject to available funding.

This report focuses on the latter examination work (Item 2) and satisfies Milestone Y4.8, "Evaluate LLTR Relief System Material Performance Report." It also summarizes the SCC experienced at the outset of Series II testing in a stainless steel line which had been used during the Series I testing.

2.0 SUMMARY

Extensive intergranular SCC was found in two Type 304 stainless steel LLTR SWRPRS welds and in their heat-affected zones. The geometry of the cracked Series I relief line stainless steel weld (joining two type 304 s/s sections of unequal thickness at a slight angle with offset) would indicate that high stresses were probably present during service, which increased

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the probability of SCC occurrence. The other stainless steel weld that failed was in a piping run that was subjected to repeated thermal cycling, thermal gradients and long exposures to sodium/water reaction products (SWRP).

SCC occurrence in two stainless steel welds of the LLTR SWRPRS confirms that a SCC environment exists for that material during large sodium/water reaction events.

3.0 EXAMINATION RESULTS

3.1 Inspection of Removed Series I Relief Piping

In replacing the Series I MSG with the Series II Large Leak Test Vessel (LLTV), ETEC was required to replace sections of the relief lines. Under GE direction, selected sections of the removed piping were inspected by liquid dye penetrant methods at ETEC. These sections included:

- o One 457.2 mm (18") tee, including flange and dissimilar metal weld, plus reducer weld from Line 121 (Spool B in Figure 1);
- o Three elbows from Line 121 (Spools D and E in Figures 2 and 3);
- o One straight length of stainless steel pipe from Line 121 (Spool C in Figure 4).
- o Two sections from Line 107, including elbows, dissimilar metal weld and reducer (Spools A and F in Figure 4).

All the above materials were type 304 stainless steel with the exception of dissimilar metal welds which were 304 stainless steel welded to 2-1/4 Cr-1 Mo.

All sections, with the exception of Spool A, showed either minor short linear indications or no indications at all. These indications were mainly in the weld metal itself and could be determined as laps in the weld or lack of penetration. Spool A, on the other hand, showed extensive cracking up to 38.1 mm (1.5 in.) from the stainless steel weld bead into the HAZ. Two sections were cut from Spool A and sent to GE for further metallographic

examination. The locations from which these sections were cut, in relation to the elbow's features, are shown in Figure 5. Figure 6 shows the location of Spool A (and others) in relation to the rest of the Series SWRPRS.

The weld in Spool A was located 57.2 mm to 82.6 mm (2-1/4-3/4") from a dissimilar metal weld joining 304 SS to the 2-1/4 CR-1 Mo MSG. The transition weld was removed prior to the ETEC dye penetrant examination, but was included with MSG parts sent to GE for further study. Figure 7 shows Section 1 of Spool A together with the sections of the transition weld sent to GE with the MSG parts.

Section 1 of Spool A was sent to the GE-NDE Lab to verify the suitability of ultrasonic inspection (UT) for the detection of SCC. The method (though in need of refinement) in several instances was able to detect cracks penetrating approximately 0.5 mm (20 mils) in the 304 stainless steel pipe wall. The transition weld section and Section 2, Spool A (Figures 7 and 8) were reinspected using a color contrast liquid penetrant system and photographed. Cracking was again obvious in the Spool A section; however, no cracking was detected in the transition weld joint. A sample was cut from Section 2, Spool A, at the region of the most extensive cracking. Figure 9 shows the configuration of the weld at that point. The weld joins two 304 SS sections of unequal thickness at a slight angle. Also shown is a slight offset of approximately 2.45 mm (0.1 in.) which was most noticeable in the area of the most extensive cracking. All indications were in the thinner section. The geometry of the weld section suggests that stresses could have been magnified at the surface of the thinner section during service, thereby causing an increased probability of SCC occurring. The presence of the dissimilar metal weld would have caused high thermal stresses during service. The three most prominent cracks found in the sample were photographed in "as polished" and "as etched" conditions at 250x magnification (Figures 10, 11, and 12). The cracks ranged in observable depth from 0.31 to 0.64 mm (12 to 25 mils) and were located between 3.81 to 7.62 mm (150 to 300 mils) from the edge of the weld. By comparing the as-polished vs the as-etched photos, the intergranular nature of the cracks can be discerned. The geometry of the weld, the locations of the cracks, and the intergranular nature of the cracks indicate that the cracks were formed by SCC.

3.2 Examination of Failed Elbow (Outset of Series II Program)

During sodium fill and pressurization of the LLTR for Series II Test A-1a, a sodium leak was discovered in an elbow from Line L-111-4" (101.6 mm). The leak was in a weld of the 304 SS elbow as shown in Figure 13. The location of this leak in relation to the Series II piping is shown in Figure 14. Although this leak was discovered during the initial Series II operations, the initial cracking probably occurred during Series I tests.

The elbow is included in portions of the 101.6 mm (4 in.) line (running from the upper relief header/surge tank to the lower relief header) that was not replaced after Series I testing. Of interest is the fact that the weld was near the design boundary of the freeze zone below the upper header. From the upper header to that point, sodium and SWRP were allowed to solidify. The piping went through large thermal cycles during testing and contained a thermal gradient between tests. The portions of the line that were not replaced immediately after Series I testing were replaced by 304 SS piping and fittings after this leak occurred. Figure 15 shows the results of a ETEC dye penetrant and metallurgical examination of the failed weld. Cracking was extensive in both the weld and its heat-affected zone. A subsequent dye penetrant inspection of the rest of the replaced piping of Line L-111-4" (101.6 mm) did not show any more indications of SCC.

Figure 1. Spool B – Line 121 (No Indications Were Found)

79-465-6

Figure 2. Spool D – Line 121 (Long Indications Were Found in the Center of the Weld that Were Probably Due to Incomplete Penetration)

79-465-7

Figure 3. Spool E Line 121 (Short Linear Cracks were Found in the Weld and HAZ; Possibly Due to Weld Overlap or SCC. A Section Containing the HAZ Crack Was Not Sent to GE)

79-465-8

Figure 4. Spools A and F Line 107, Spool C Line 121. (Spools C and F Showed Minor Indications in Weld. Spool A Showed Many Linear Indications of SCC)

79-465-9

Figure 5. Locations of Sections Removed from Spool A

79-465-10

Figure 6. Series I LLTR

(a) SECTION 1 AND PARTS CONTAINING TRANSITION WELD (0.3X)

(b) SECTION 1 WITH FLUORESCENT LIQUID DYE PENETRANT INDICATIONS

Figure 7. Section 1 From Spool A Plus Transition Weld

0.7X

Figure 8. Section 2 From Spool A With SCC Indications

79-465-13

1X

Figure 9. Sample From Section 2, Showing Weld Configuration

79-465-14

250X

(a) As Polished

(b) As Etched

Figure 10. Crack Located 150 mils From Weld Edge. Depth = 12 mils

79-465-15

(a) As Polished

(b) As Etched

250X

Figure 11. Crack Located 200 mils From Weld Edge. Crack Depth = 24 mils

79-465-16

(a) As Polished

(b) As Etched

Figure 12. Crack Located 300 mils From Weld Edge. Depth = Over 25 mils

79-465-17

Figure 13. Stainless Steel Weld Showing Severe SCC. (From 4 in. Elbow on Line L-111-4 in.)

Figure 14. Series II LLTR Showing Location of Cracked Weld

0.25X

0.25X

(a) LIQUID DYE PENETRANT INDICATIONS

25X

25X

(b) CRACK APPEARANCE

Figure 15. Extent of SCC in Weld and HAZ of Elbow. (Line L-111-4 in.)