ComEd

Quad Cities Generating Station
22710 206th Avenue North
Cordova, IL 61242-9740

www.exeloncorp.com

An Exelon Company

October 27, 2000

SVP-00-169

U. S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, D.C. 20555

Quad Cities Nuclear Power Station, Unit 1
Facility Operating License No. DPR-29
NRC Docket Nos. 50-254

Subject: Examination to Support Evaluation of a Recirculation System Pipe Weld

Reference: (1) Letter from J.P. Dimmette, Jr. (ComEd) to U.S. NRC, "Request for Approval of Weld Repair and Pipe Flaw Evaluation," dated October 25, 2000

The purpose of this letter is to provide the results of the ultrasonic (UT) examination of a previously identified flaw in weld 02BS-F4 in the reactor recirculation piping at the Quad Cities Nuclear Power Station (QCNPS), Unit 1 as discussed in Reference 1. A weld overlay repair was initiated for this flaw but was stopped after two layers of overlay and one finish layer due to radiation dose concerns. Additionally, an evaluation that accounts for the worst-case flaw size and its impact on pipe integrity was completed and is provided.

The automated UT examination with the General Electric (GE) Smart 2000 technique and the manual UT examinations of 02BS-F4 have been completed using the examination techniques described in Reference 1. Data analysis has determined that no indications associated with Inter Granular Stress Corrosion Cracking (IGSCC) were detected. Attachment 1 to this letter provides the details of these examinations. The station has also completed manual and automatic UT examination of two other recirculation system pipe welds, 02AS-S4 and 02AD-F12. These experienced the same operating conditions, i.e., chemistry, stresses, etc. as the 02BS-F4 weld. These results are provided in Attachment 2 and 3 to this letter. They show no growth in the flaws in these welds during the last operating cycle. Thus it is reasonable to conclude that the flaw in weld 02BS-F4 experienced little or no growth.

Although the flaw evaluation, using normal water chemistry and NUREG-0313 crack growth provided in Reference 1, showed significant margin to the American Society of Mechanical Engineers (ASME) Section XI acceptance criteria, the difficulty of conducting a UT examination for this configuration prevents confirmation of the evaluated flaw. Although the UT procedure used was demonstrated to be capable of interrogating the entire pipe wall through the partial weld overlay, the Performance Demonstration Initiative (PDI) qualified procedure has only been qualified to detect and size indications in the weld overlay and outer 25% of the base metal. Due to the lack of PDI qualification for interrogating the piping inside diameter, the station completed an additional evaluation of a postulated, worst case flaw.

A001

This evaluation postulated a flaw that would have grown from the 0.25-inch depth identified in 1998 to the 75% through wall pipe depth as of the most recent UT examination date (October 25, 2000). This evaluation was performed for the next operating cycle and it is provided in Attachment 4. It demonstrated that even for this very conservative case ASME Section XI flaw evaluation acceptance criteria are satisfied.

A combination of factors support continued operation for the next cycle:

- evaluation of the flaw growth rate based on the 1998 UT data showed margin to support continued operation,
- the additional bounding study for the postulated *worst case* crack could be 75% through wall showed margin to support continued operation,
- the UT examination that has been qualified to examine the weld overlay and the first 25% of the pipe wall found no flaws,
- the same UT examination procedure that has also been demonstrated to be capable of examining the weld overlay material and the pipe wall below the outer 25% of the pipe wall found only inside surface geometry,
- the UT examinations of the 02AS-S4 and 02AD-F12 recirculation system welds which experienced similar conditions as the 02BS-F4 weld, reveal no growth in the indications in these welds during the last operating cycle,
- the beneficial chemistry environment during the cycle just completed should have significantly reduced the crack growth rate for that cycle,
- the chemistry environment planned for the next operating cycle will continue to significantly reduce the crack growth rate for that cycle, and
- the application of the partial overlay (i.e., approximately 0.2-in. thick) provides significant benefits both from the viewpoint of structural reinforcement and stress improvement.

For these reasons, continued operation for the next cycle is justified.

Should you have any questions, please contact Mr. C. C. Peterson at (309) 654-2241, extension 3609.

Respectfully,

J.P. Dimmette, Jr.

J.P. Dimmette, Jr.
Site Vice President
Quad Cities Nuclear Power Station

Attachments:
1 Summary Report for the Automatic Examination of Weld 02BS-F4
2 Summary Report for the Automatic Examination of Weld 02AS-S4
3 Summary Report for the Automatic Examination of Weld 02AD-F12
4 Quad Cities Unit 1, Evaluation of the Indication in Weld 02BS-F4 in the 28 inch Recirculation Piping based on the UT inspection Results with the Partial Thickness Weld Overlay.

cc: Regional Administrator - NRC Region III
NRC Senior Resident Inspector - Quad Cities Nuclear Power Station

bcc: Project Manager – NRR
Office of Nuclear Facility Safety, - IDNS
Senior Reactor Analyst – IDNS
Manager of Energy Practice – Winston and Strawn
Office of Nuclear Facility Safety - Illinois Department of Nuclear Safety
Director, Licensing and Compliance – ComEd
Vice President, Regulatory Services– ComEd
ComEd Document Control Desk Licensing (Hard Copy)
ComEd Document Control Desk Licensing (Electronic Copy)
W. Leech – MidAmerican Energy Company
D. Tubbs – MidAmerican Energy Company
Regulatory Assurance Manager – Dresden Generating Station
Regulatory Assurance Manager – Quad Cities Generating Station
NRC Coordinator – Quad Cities Generating Station
NSRB Site Coordinator – Quad Cities Generating Station
Site Vice President - Quad Cities Generating Station
Station Manager - Quad Cities Generating Station
SVP Letter File

Attachment: 1

Summary Report for the Automatic Examination of Weld 02BS-F4

## Summary of Automatic Ultrasonic Examination of Weld – 02BS-F4 Overlay

During the automated ultrasonic examination of the above referenced weld overlay, no indications associated with IGSCC were recorded, however, two (2) lack of bond indications at the base metal-overlay interface were recorded by the "Smart 2000" System. This examination was performed utilizing 0°, 45°RL, 60°RL, & OD Creeping wave search units.

The previously recorded circumferential flaw was located from 30.0" to 56.5" and was not detected. The above-qualified procedure is for the overlay volume and upper 25% of the original base material. According to the procedure, geometric indications are expected from the overlay edge and indications in the weld overlay volume that are determined to be metallurgical which do not interfere with the detection of the original flaw, need not be recorded.

The 45° and 60°RL observed root geometry intermittent 360°, which was recorded in previous outages.

The 0° degree search unit exam recorded two (2) lack of bond areas at the weld metal-base material interface.

The 45RL which was performed to interrogate the original flaw recorded non-relevant indications, root geometry and acoustic interface.

The 60RL exam recorded non-relevant indications and root geometry.

The ODCR exam resulted in no recordable indication.

No automated exam was performed from "L" of 41.8" to 52.75" due to proximity of a drain line.

A manual exam was performed in the area of the automated limitation. This examination utilized 0°, 45°RL, 60°RL, and OD Creeping wave search units. In addition circ scans were performed 360 degrees with the 60RL search unit. These exams resulted in no recordable indications.

100% of the overlay exam volume was examined.

This is a new overlay, therefore, this examination was performed as a pre-service inspection.

# Table for "W" positions and apparent Through-wall dimensions

## Weld # 02AS-S4 Elbow to Pipe

| SCAN | TRANSDUCER | "W"-1 | "W"-MAX | "W"-2 | "L" MAX | TOTAL LENGTH |
|---|---|---|---|---|---|---|
| A10-upstream | 45° shear | 1.34" | 1.62" | 1.84" | 10.86" | 10.67" - 11.67" |
| A20-downstream | 45° shear | 0.76" | 1.08" | 1.40" | 10.97" | 10.62" - 11.27" |
| C10-upstream | 60° RL | 1.86" | 2.03" | 3.28" | 10.77" | 10.53" - 11.61" |
| C20-downstream | 60° RL | N\A | N/A | N/A | N/A | N/A |
| D10-upstream | 60° shear | 1.29" | 1.53" | 2.19" | 11.78" | 11.53" - 12.86" |
| D20-downstream | 60° shear | 1.56" | 1.81" | 2.33" | 11.88" | 11.53" - 12.61 |

Max T\W depth of .30" with 60° RL

## Weld # 02AD-F12 Pump to Pipe

INDICATION # 1

| SCAN | TRANSDUCER | "W"-1 | "W"-MAX | "W"-2 | "L" MAX | TOTAL LENGTH |
|---|---|---|---|---|---|---|
| A20-downstream | 45° shear(1.5 MHz.) | 0.90" | 1.15" | 1.42" | 14.67" | -15.95" to -13.79" |
| A21-downstream | 45° shear(2.25 MHz.) | 1.01" | 1.18" | 1.35" | 14.57" | -15.85" to -13.49" |
| C20-downstream | 60° RL | 2.01" | 2.50" | * | 14.23" | -15.41" to -13.63" |
| D20-downstream | 60° shear | 1.49" | 2.36" | * | 14.57" | -15.53" to -13.56" |

* - W-2 not obtained due to transducer limitation.
Max T\W depth of .35" with 60° shear

INDICATION # 2

| SCAN | TRANSDUCER | "W"-1 | "W"-MAX | "W"-2 | "L" MAX | TOTAL LENGTH |
|---|---|---|---|---|---|---|
| A20-downstream | 45° shear(1.5 MHz.) | 1.01" | 1.25" | 1.49" | -2.95" | -3.84" to -2.16" |
| A21-downstream | 45° shear(2.25 MHz.) | 1.11" | 1.32" | 1.60" | -3.05" | -3.64" to -1.97" |
| C20-downstream | 60° RL | 2.22" | 2.47" | * | -2.7" | -2.80" to -1.72" |
| D20-downstream | 60° shear | 1.84" | 2.22" | * | -2.61" | -2.84" to -1.97" |

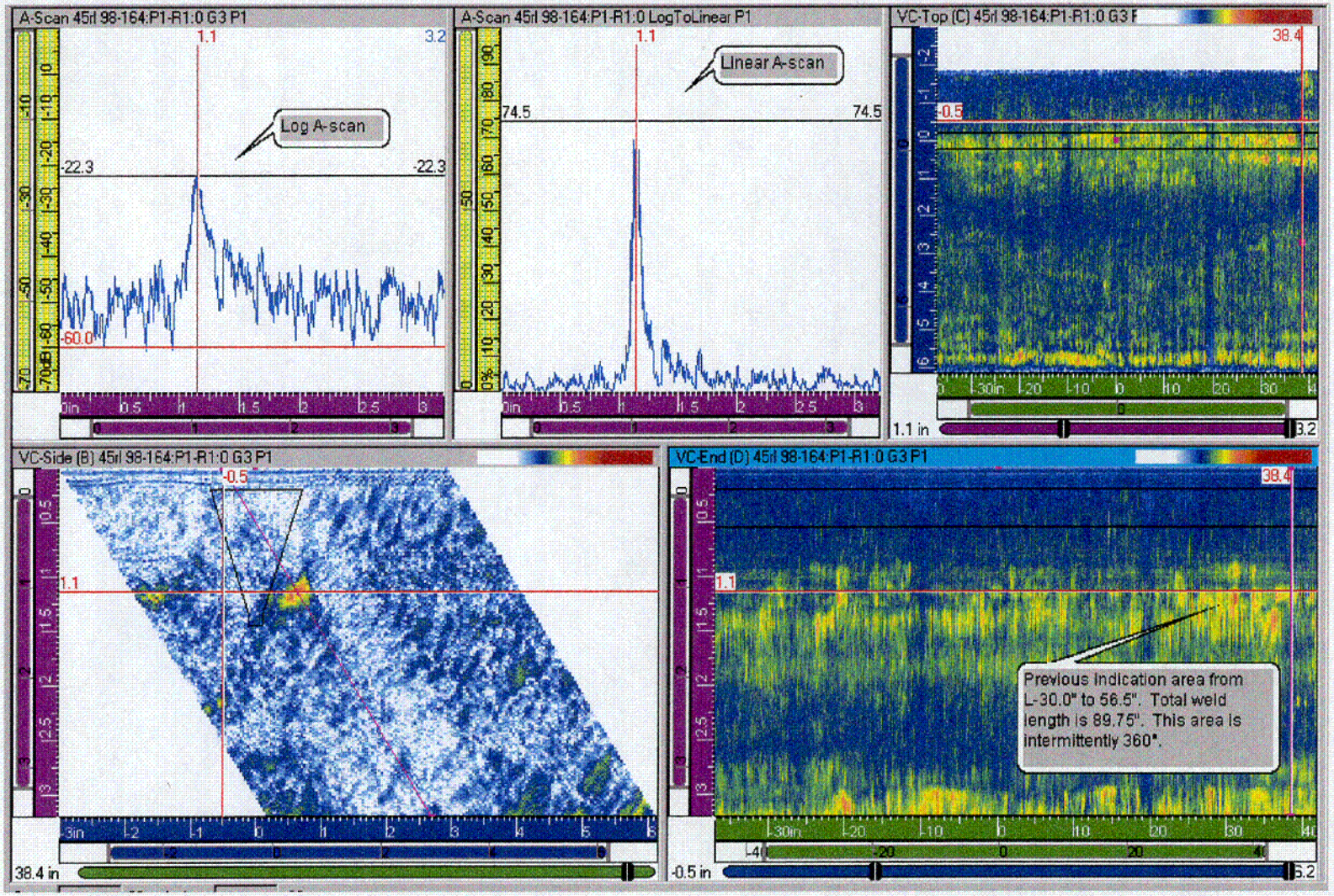
* - W-2 not obtained due to transducer limitation.
Max T\W depth of .25" with 60° shear

## Weld # 02BS-F4 Overlay Pipe to Pipe

| SCAN | TRANSDUCER | "W"-1 | "W"-MAX | "W"-2 | "L" MAX | TOTAL LENGTH |
|---|---|---|---|---|---|---|
| B10-upstream | 45° RL | -.56" | -.64" | -.92" | 38.10" | * |

* - This indication viewed 360° intermittently.
Max T\W depth of .26" with 45° RL

# WELD # 02BS-F4 45° RL 2.0 MHz Geometrical Reflector, LKDN Exam






C01

Attachment 2

Summary Report for the Automatic Examination of Weld 02AS-S4

# Summary of Automatic Ultrasonic Examination of Weld – 02AS-S4

During the automated ultrasonic examination of the above referenced weld, no indications associated with IGSCC were recorded by the "Smart 2000" System utilizing a 45° (1.5 MHz) shear waves, 60° (1.5 MHz) shear wave, and 60° (2.0 MHz) refracted longitudinal (RL) wave search units.

This examination was performed to interrogate one previously recorded IGSCC indications located from 12.0" to 13.25" upstream of the Elbow to Pipe weld configuration. The reference points of this examination are from 5.0" to 20.0" in the clockwise direction. This examination was performed in the axial direction (sound beam perpendicular to the weld) with no skew and no circumferential scans.

The examination scanning increments utilized were in accordance with the PDI Flaw Depth Sizing procedure, GE-UT-231 Version 3. The scan increment as stated in List 5 is an index size of 0.100" for axial scans and the resolution size as stated in List 3 is ≤0.036".

The 45° shear wave search unit recorded amplitude signal response from the inside surface geometry in the area of the previously recorded indication. The response dimension is from 10.5" to 11.7". This length reveals no apparent change from the previous indication.

The 60° shear wave search unit recorded a amplitude signal response from the inside surface geometry in the area of the previously recorded indication. The response dimension is from 11.5" to 12.6". This length reveals no apparent change from the previous indication in 1998.

The 60°RL search unit recorded an amplitude signal response from the inside surface geometry in the area of the previously recorded indication. The response dimension is from 10.5" to 11.7". This length reveals no apparent change from the previous indication.

Weld profile and thickness readings were taken to verify previous data readings resulting in no changes.

A manual examination was performed prior to the automated examination, which resulted in no recordable indications. The automated examination was performed to support the manual examination.

The radiographic films were reviewed which showed an excavation area in the approximate location of the previously recorded IGSCC indication. No previous weld fabrication or repair documents were available for review at the time of this summary.

# Table for "W" positions and apparent Through-wall dimensions

## Weld # 02AS-S4 Elbow to Pipe

| SCAN | TRANSDUCER | "W"-1 | "W"-MAX | "W"-2 | "L" MAX | TOTAL LENGTH |
|---|---|---|---|---|---|---|
| A10-upstream | 45° shear | 1.34" | 1.62" | 1.84" | 10.86" | 10.67" - 11.67" |
| A20-downstream | 45° shear | 0.76" | 1.08" | 1.40" | 10.97" | 10.62" - 11.27" |
| C10-upstream | 60° RL | 1.86" | 2.03" | 3.28" | 10.77" | 10.53" - 11.61" |
| C20-downstream | 60° RL | N\A | N/A | N/A | N/A | N/A |
| D10-upstream | 60° shear | 1.29" | 1.53" | 2.19" | 11.78" | 11.53" - 12.86" |
| D20-downstream | 60° shear | 1.56" | 1.81" | 2.33" | 11.88" | 11.53" - 12.61 |

Max T\W depth of .30" with 60° RL

## Weld # 02AD-F12 Pump to Pipe

INDICATION # 1

| SCAN | TRANSDUCER | "W"-1 | "W"-MAX | "W"-2 | "L" MAX | TOTAL LENGTH |
|---|---|---|---|---|---|---|
| A20-downstream | 45° shear(1.5 MHz.) | 0.90" | 1.15" | 1.42" | 14.67" | -15.95" to -13.79" |
| A21-downstream | 45° shear(2.25 MHz.) | 1.01" | 1.18" | 1.35" | 14.57" | -15.85" to -13.49" |
| C20-downstream | 60° RL | 2.01" | 2.50" | * | 14.23" | -15.41" to -13.63" |
| D20-downstream | 60° shear | 1.49" | 2.36" | * | 14.57" | -15.53" to -13.56" |

* - W-2 not obtained due to transducer limitation.
Max T\W depth of .35" with 60° shear

INDICATION # 2

| SCAN | TRANSDUCER | "W"-1 | "W"-MAX | "W"-2 | "L" MAX | TOTAL LENGTH |
|---|---|---|---|---|---|---|
| A20-downstream | 45° shear(1.5 MHz.) | 1.01" | 1.25" | 1.49" | -2.95" | -3.84" to -2.16" |
| A21-downstream | 45° shear(2.25 MHz.) | 1.11" | 1.32" | 1.60" | -3.05" | -3.64" to -1.97" |
| C20-downstream | 60° RL | 2.22" | 2.47" | * | -2.7" | -2.80" to -1.72" |
| D20-downstream | 60° shear | 1.84" | 2.22" | * | -2.61" | -2.84" to -1.97" |

* - W-2 not obtained due to transducer limitation.
Max T\W depth of .25" with 60° shear

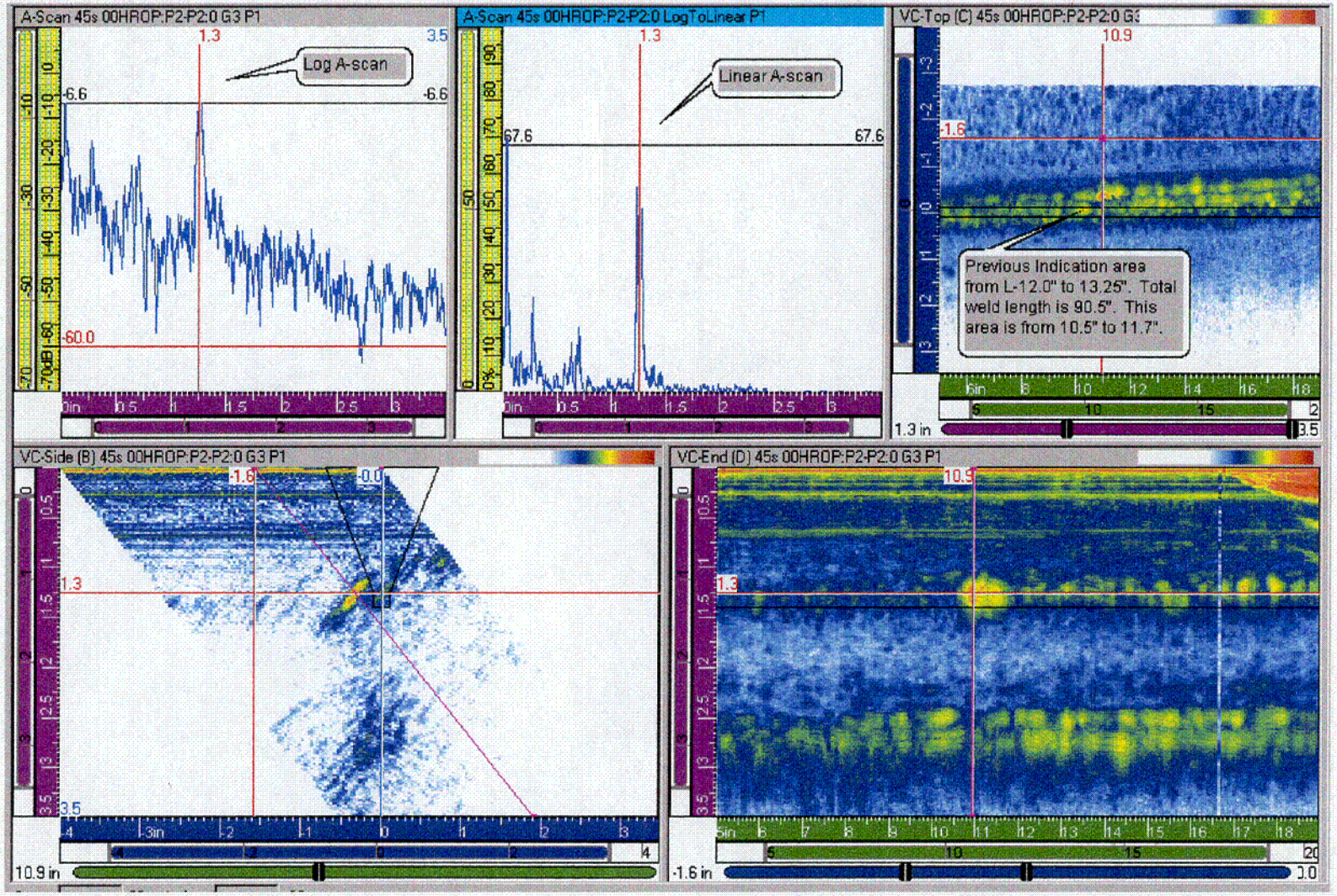
## Weld # 02BS-F4 Overlay Pipe to Pipe

| SCAN | TRANSDUCER | "W"-1 | "W"-MAX | "W"-2 | "L" MAX | TOTAL LENGTH |
|---|---|---|---|---|---|---|
| B10-upstream | 45° RL | -.56" | -.64" | -.92" | 38.10" | * |

* - This indication viewed 360° intermittently.
Max T\W depth of .26" with 45° RL

GE evaluation classified these indications as geometry. The forward movement to a maximum amplitude point performed through-wall dimensioning. These through-wall dimensions were taken with the assumption that the indications are flaws.

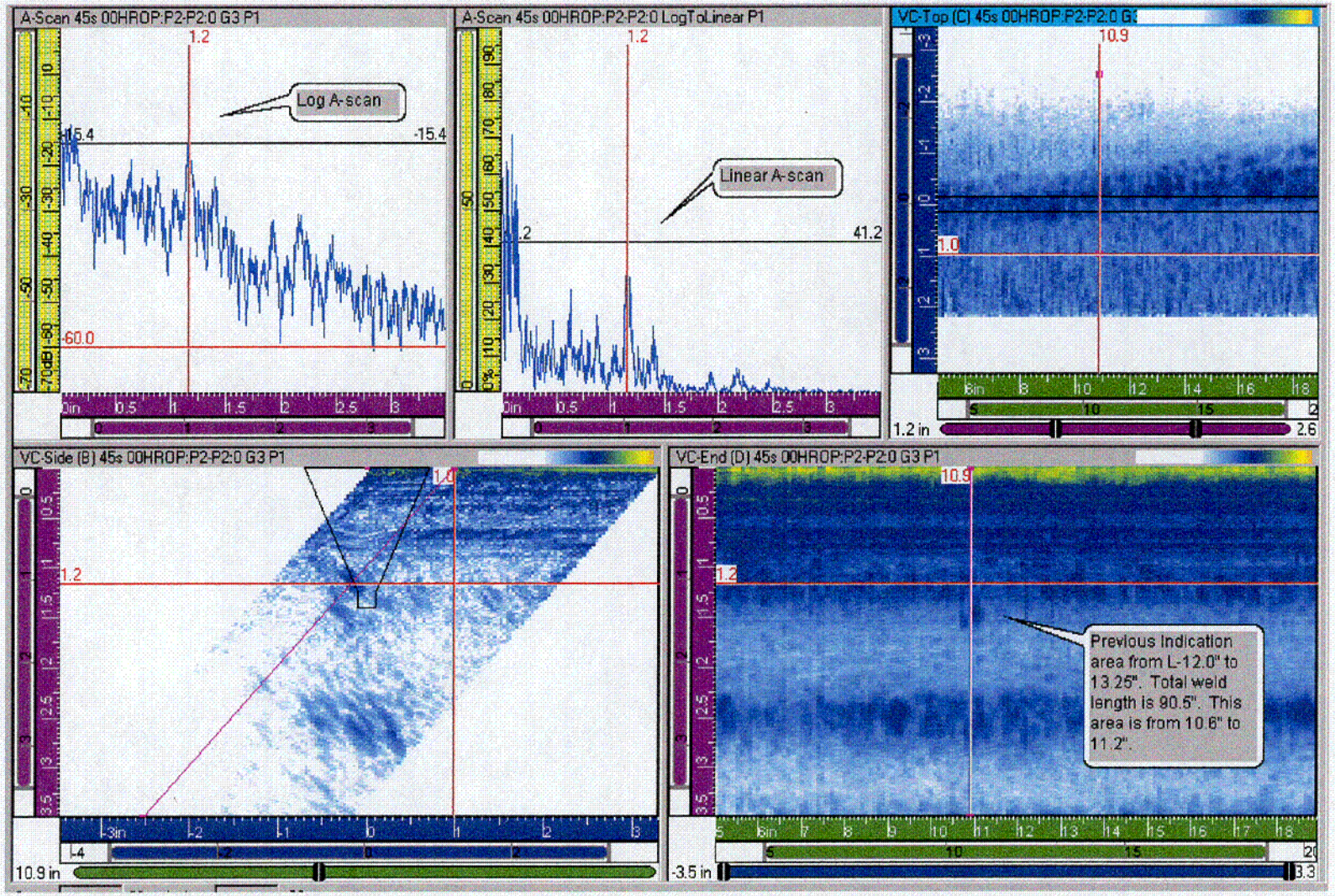
# WELD # 02AS-S4 45° SHEAR 1.5 MHz Inside Surface Geometry, UPST Side Exam





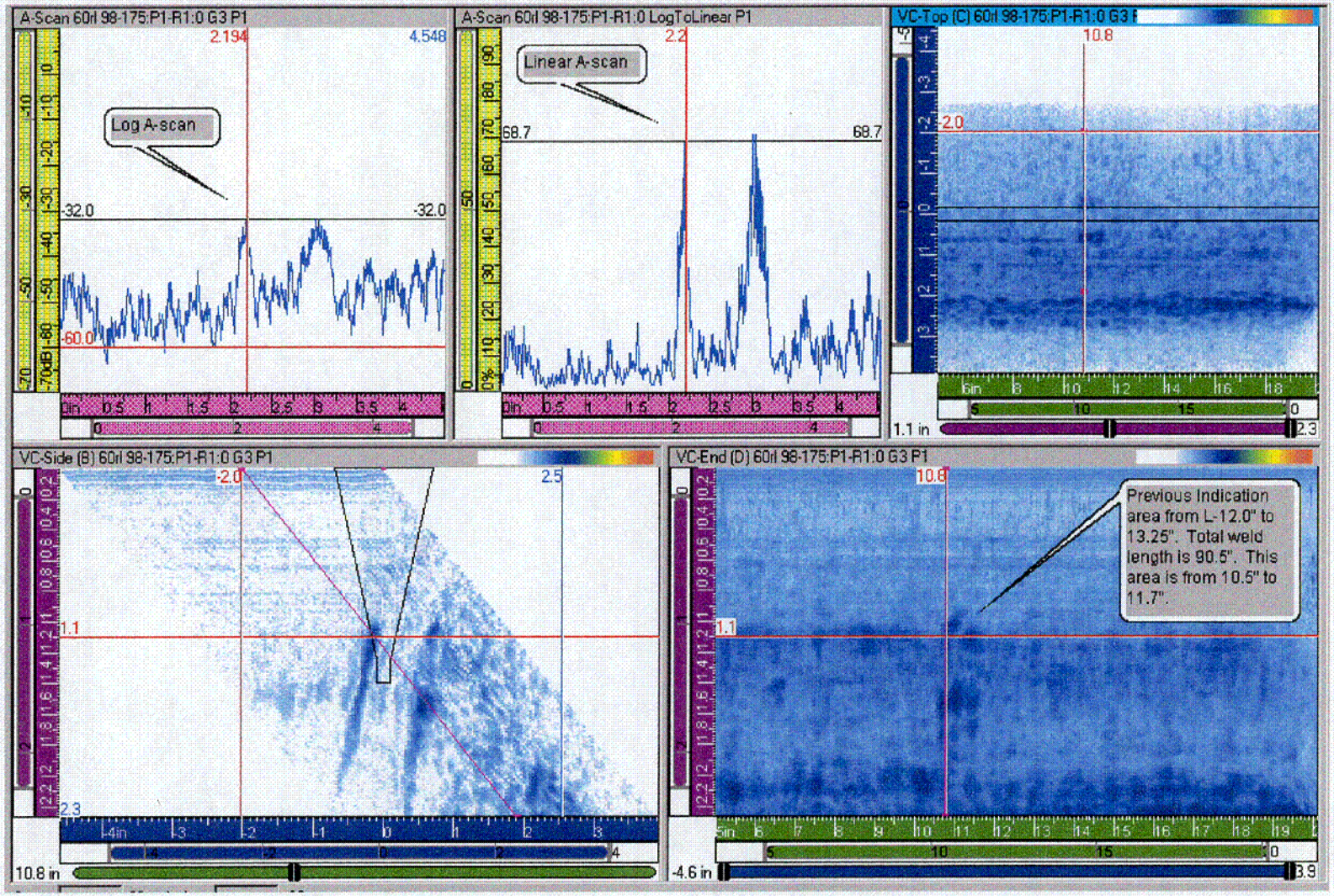

C02

# WELD # 02AS-S4 45° SHEAR 1.5 MHz Inside Surface Geometry, DNST Side Exam




C03

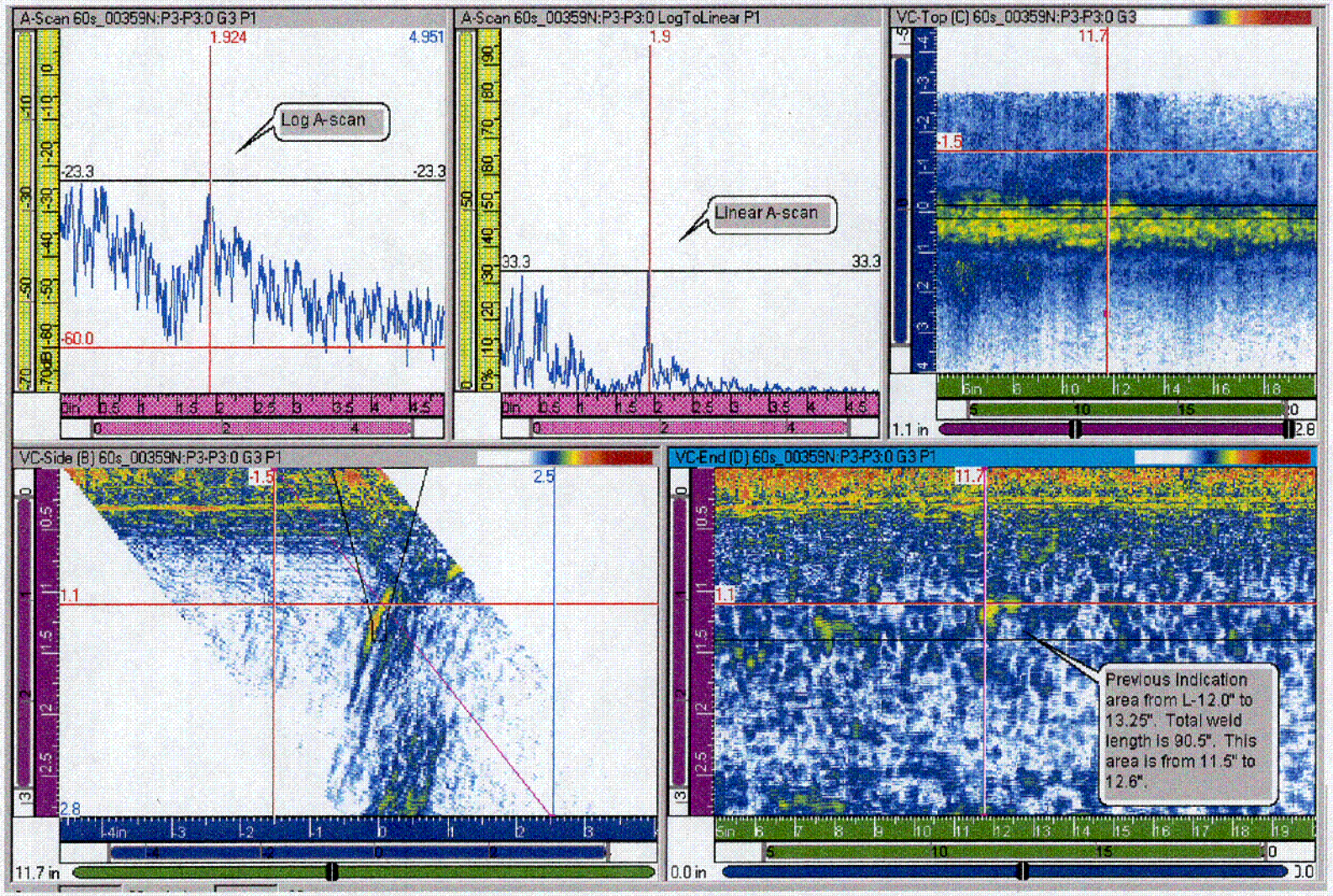
# WELD # 02AS-S4 60° RL 2.0 MHz Inside Surface Geometry, UPST Side Exam






C04

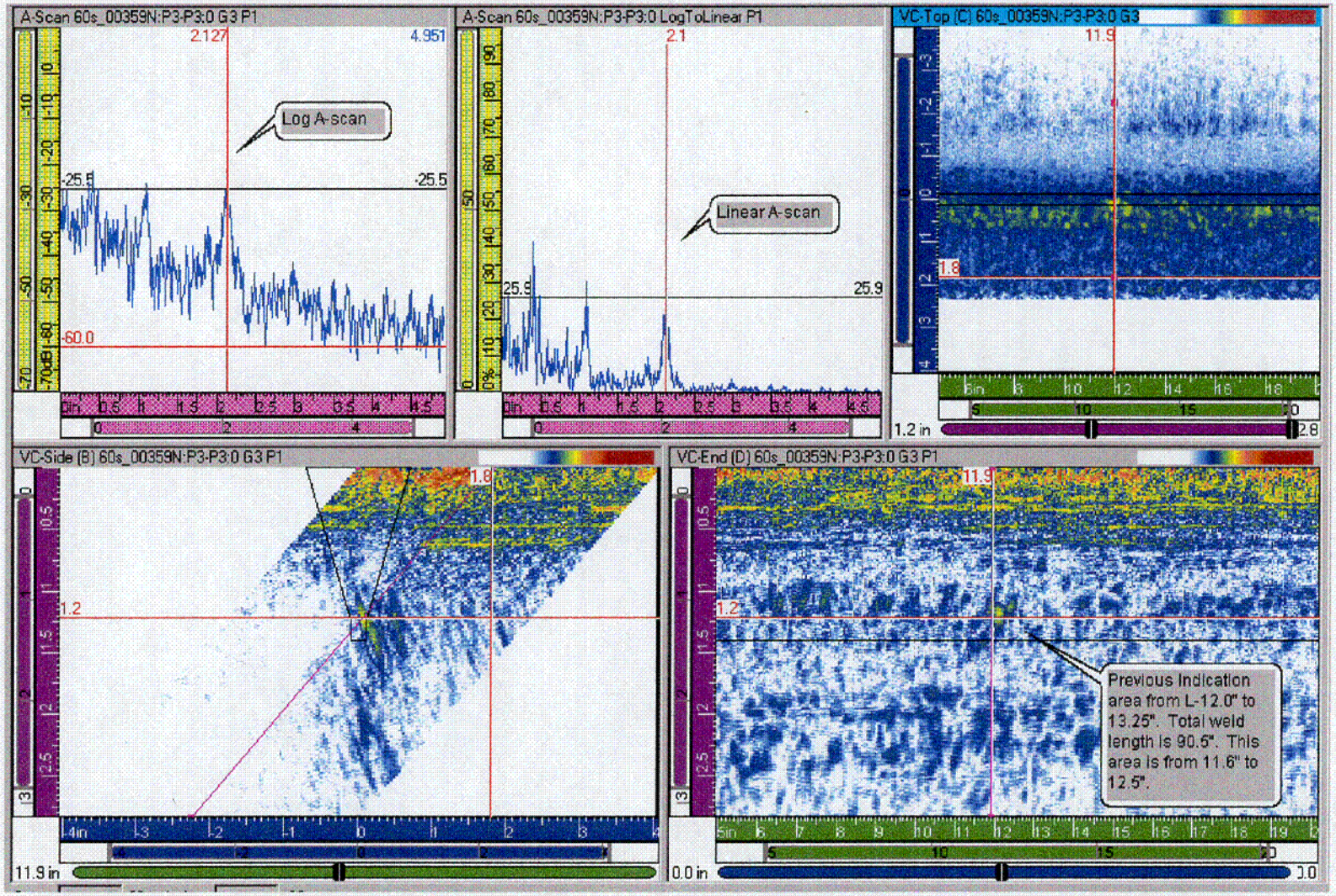
# WELD # 02AS-S4 60° SHEAR 1.5 MHz Inside Surface Geometry, UPST Side Exam






C05

# WELD # 02AS-S4 60° SHEAR 1.5 MHz Inside Surface Geometry, DNST Side Exam






C06

Attachment 3

Summary Report for the Automatic Examination of Weld 02AD-F12

# Summary of Automatic Ultrasonic Examination of Weld – 02AD-F12

During the automated ultrasonic examination of the above referenced weld, no indications associated with IGSCC were recorded by the "Smart 2000" System utilizing two 45° (1.5 & 2.25 MHz) shear waves, 60° (1.5 MHz) shear wave, and 60 refracted longitudinal (RL) wave search units.

This examination was performed to interrogate two previously recorded IGSCC indications located from 74.5" to 77.0" and 86.7" to 88.75" downstream of the Pump to Pipe weld configuration. This weld configuration precludes examination from the Pump side. The reference points of this examination are from 38.0" to 1.6" in the clockwise direction. This examination was performed in the axial direction (sound beam perpendicular to the weld) with no skew and no circumferential scans.

The examination scanning increments utilized were in accordance with the PDI Flaw Depth Sizing procedure, GE-UT-231 Version 3. The scan increment as stated in List 5 is an index size of 0.100" for axial scans and the resolution size as stated in List 3 is ≤0.036".

The two 45° shear wave search units recorded very high amplitude signal response from the root geometry in the area of the previously recorded indications as compared to the rest of the root geometry. Those response dimensions are from 74.5" to 77.0" and 86.7" to 88.7". This length reveals no apparent change from the previous indication in 1998.

The 60° shear wave search unit recorded a slightly higher amplitude signal response from the root geometry in the area of the previously recorded indications. Those response dimensions are from 74.8" to 77.5" and 87.5" to 88.7". This length reveals no apparent change from the previous indication.

The 60°RL search unit recorded an amplitude signal response from the root geometry in the area of the previously recorded indications. Those response dimensions are from 74.9" to 77.4" and 87.1" to 88.7". This length reveals no apparent change from the previous indication.

Weld profile and thickness readings were taken to verify previous data readings resulting in no changes.

A manual examination was performed prior to the automated examination, which resulted in no recordable indications. The automated examination was performed to support the manual examination.

The radiographic films were reviewed which showed slag or lack of fusion indications in the approximate locations of the previously recorded IGSCC indications. No previous weld fabrication or repair documents were available for review at the time of this summary.

# Table for "W" positions and apparent Through-wall dimensions

## Weld # 02AS-S4 Elbow to Pipe

| SCAN | TRANSDUCER | "W"-1 | "W"-MAX | "W"-2 | "L" MAX | TOTAL LENGTH |
|---|---|---|---|---|---|---|
| A10-upstream | 45° shear | 1.34" | 1.62" | 1.84" | 10.86" | 10.67" - 11.67" |
| A20-downstream | 45° shear | 0.76" | 1.08" | 1.40" | 10.97" | 10.62" - 11.27" |
| C10-upstream | 60° RL | 1.86" | 2.03" | 3.28" | 10.77" | 10.53" - 11.61" |
| C20-downstream | 60° RL | N\A | N/A | N/A | N/A | N/A |
| D10-upstream | 60° shear | 1.29" | 1.53" | 2.19" | 11.78" | 11.53" - 12.86" |
| D20-downstream | 60° shear | 1.56" | 1.81" | 2.33" | 11.88" | 11.53" - 12.61 |

Max T\W depth of .30" with 60° RL

## Weld # 02AD-F12 Pump to Pipe

INDICATION # 1

| SCAN | TRANSDUCER | "W"-1 | "W"-MAX | "W"-2 | "L" MAX | TOTAL LENGTH |
|---|---|---|---|---|---|---|
| A20-downstream | 45° shear(1.5 MHz.) | 0.90" | 1.15" | 1.42" | 14.67" | -15.95" to -13.79" |
| A21-downstream | 45° shear(2.25 MHz.) | 1.01" | 1.18" | 1.35" | 14.57" | -15.85" to -13.49" |
| C20-downstream | 60° RL | 2.01" | 2.50" | * | 14.23" | -15.41" to -13.63" |
| D20-downstream | 60° shear | 1.49" | 2.36" | * | 14.57" | -15.53" to -13.56" |

* - W-2 not obtained due to transducer limitation.
Max T\W depth of .35" with 60° shear

INDICATION # 2

| SCAN | TRANSDUCER | "W"-1 | "W"-MAX | "W"-2 | "L" MAX | TOTAL LENGTH |
|---|---|---|---|---|---|---|
| A20-downstream | 45° shear(1.5 MHz.) | 1.01" | 1.25" | 1.49" | -2.95" | -3.84" to -2.16" |
| A21-downstream | 45° shear(2.25 MHz.) | 1.11" | 1.32" | 1.60" | -3.05" | -3.64" to -1.97" |
| C20-downstream | 60° RL | 2.22" | 2.47" | * | -2.7" | -2.80" to -1.72" |
| D20-downstream | 60° shear | 1.84" | 2.22" | * | -2.61" | -2.84" to -1.97" |

* - W-2 not obtained due to transducer limitation.
Max T\W depth of .25" with 60° shear

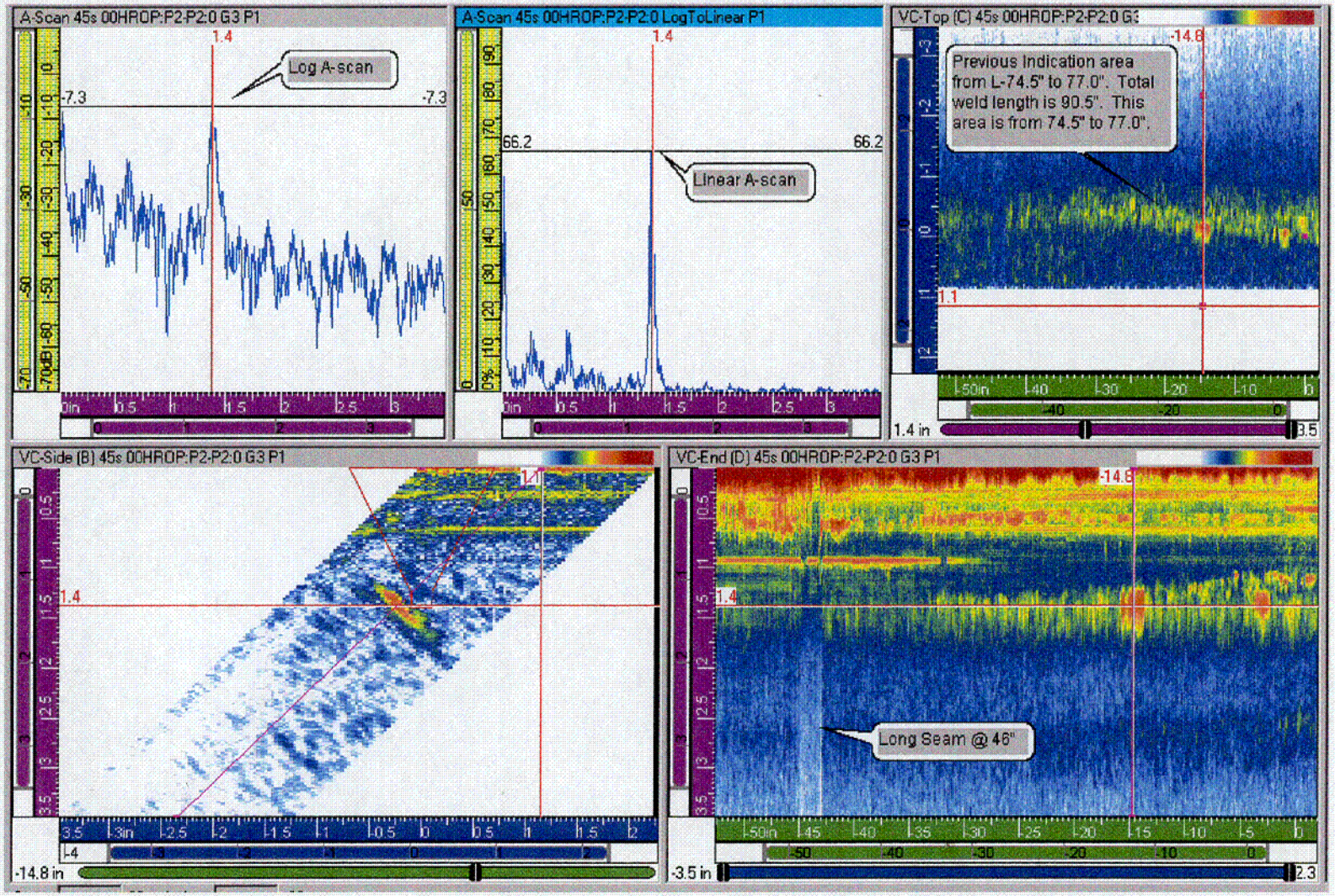
## Weld # 02BS-F4 Overlay Pipe to Pipe

| SCAN | TRANSDUCER | "W"-1 | "W"-MAX | "W"-2 | "L" MAX | TOTAL LENGTH |
|---|---|---|---|---|---|---|
| B10-upstream | 45° RL | -.56" | -.64" | -.92" | 38.10" | * |

* - This indication viewed 360° intermittently.
Max T\W depth of .26" with 45° RL

GE evaluation classified these indications as geometry. The forward movement to a maximum amplitude point performed through-wall dimensioning. These through-wall dimensions were taken with the assumption that the indications are flaws.

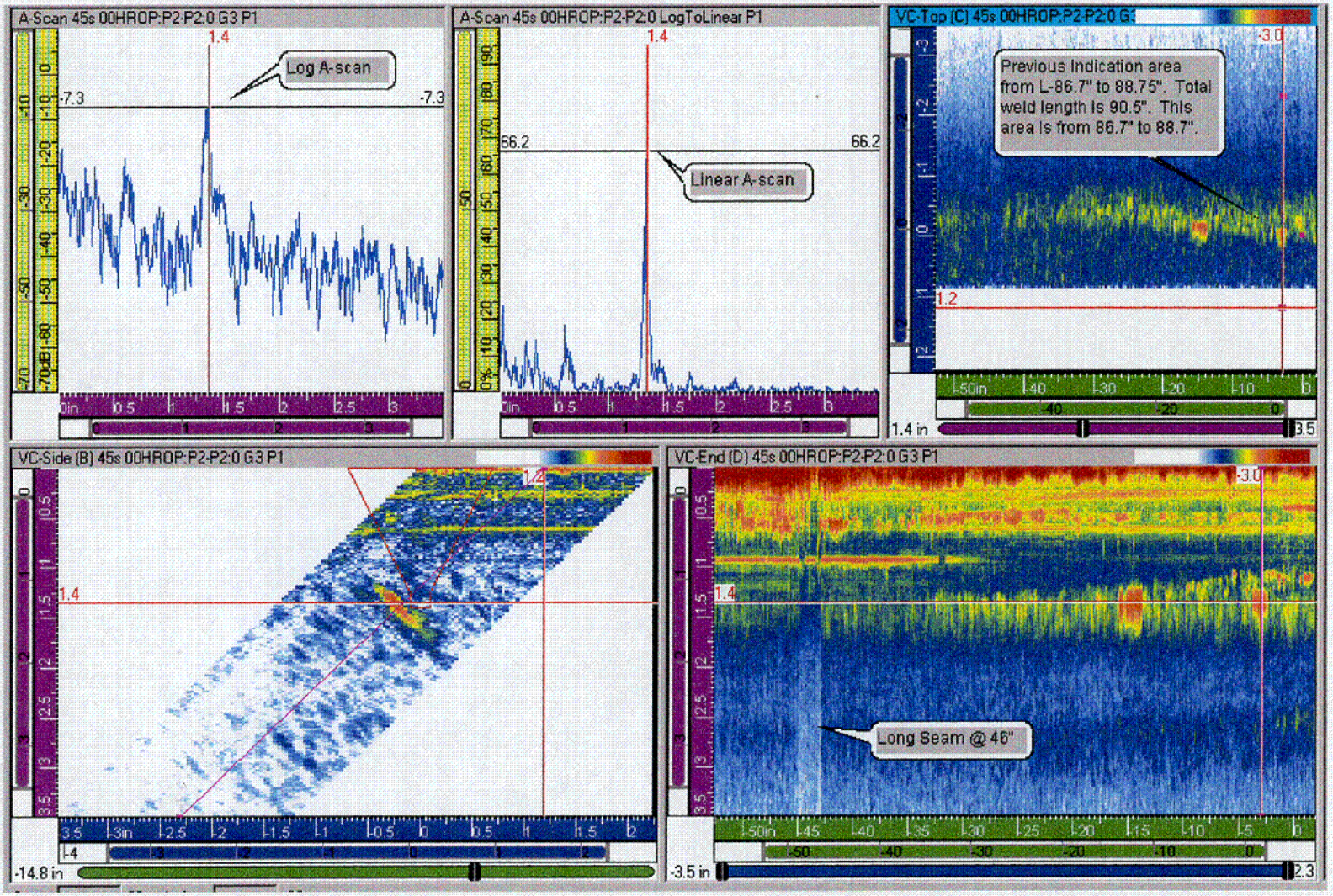
# WELD # 02AD-F12 45° SHEAR 1.5 MHz ROOT GEOMETRY






C07

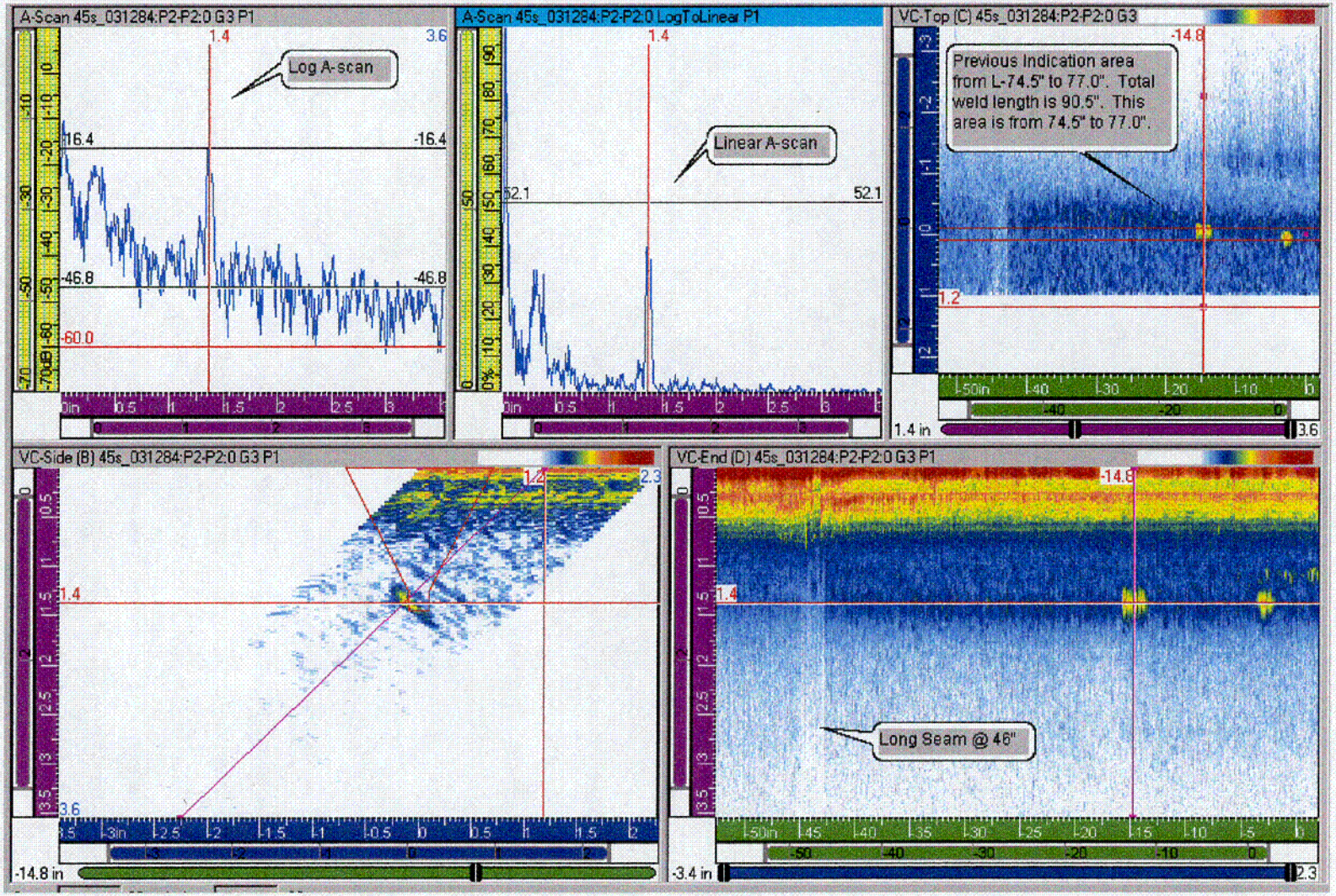
# WELD # 02AD-F12 45° SHEAR 1.5 MHz ROOT GEOMETRY





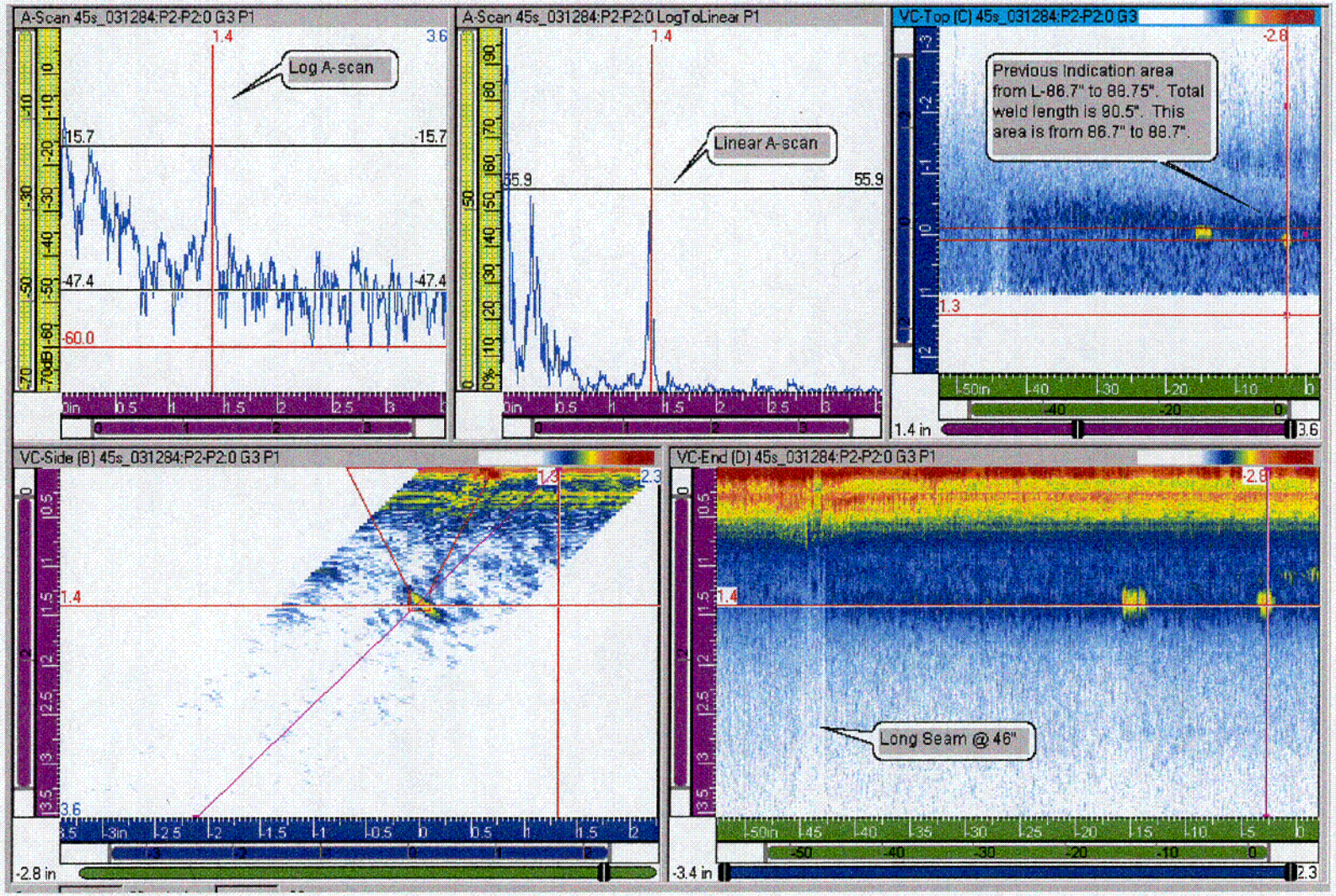

C08

# WELD # 02AD-F12 45° SHEAR 2.25 MHz ROOT GEOMETRY




C09

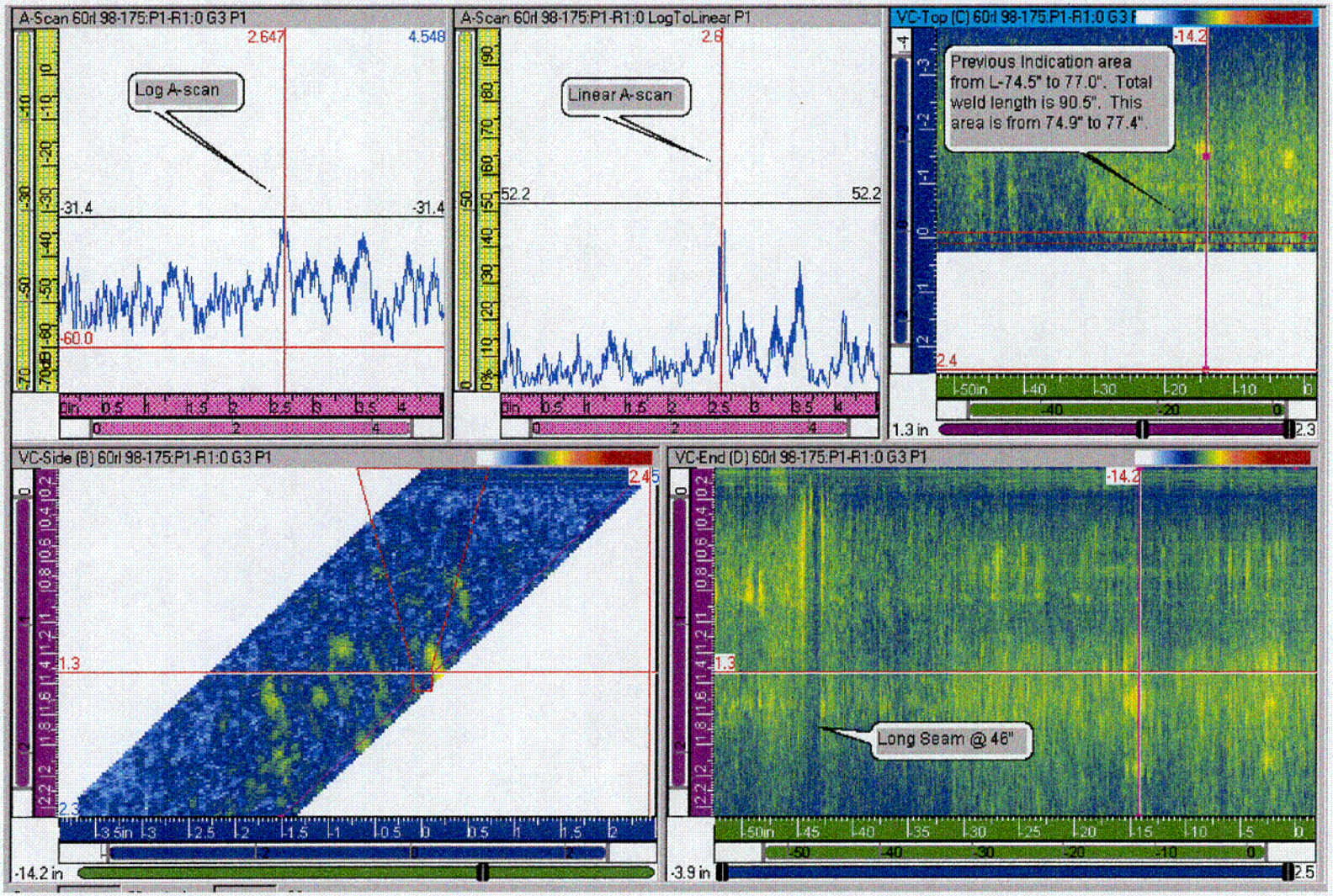
# WELD # 02AD-F12 45° SHEAR 2.25 MHz ROOT GEOMETRY





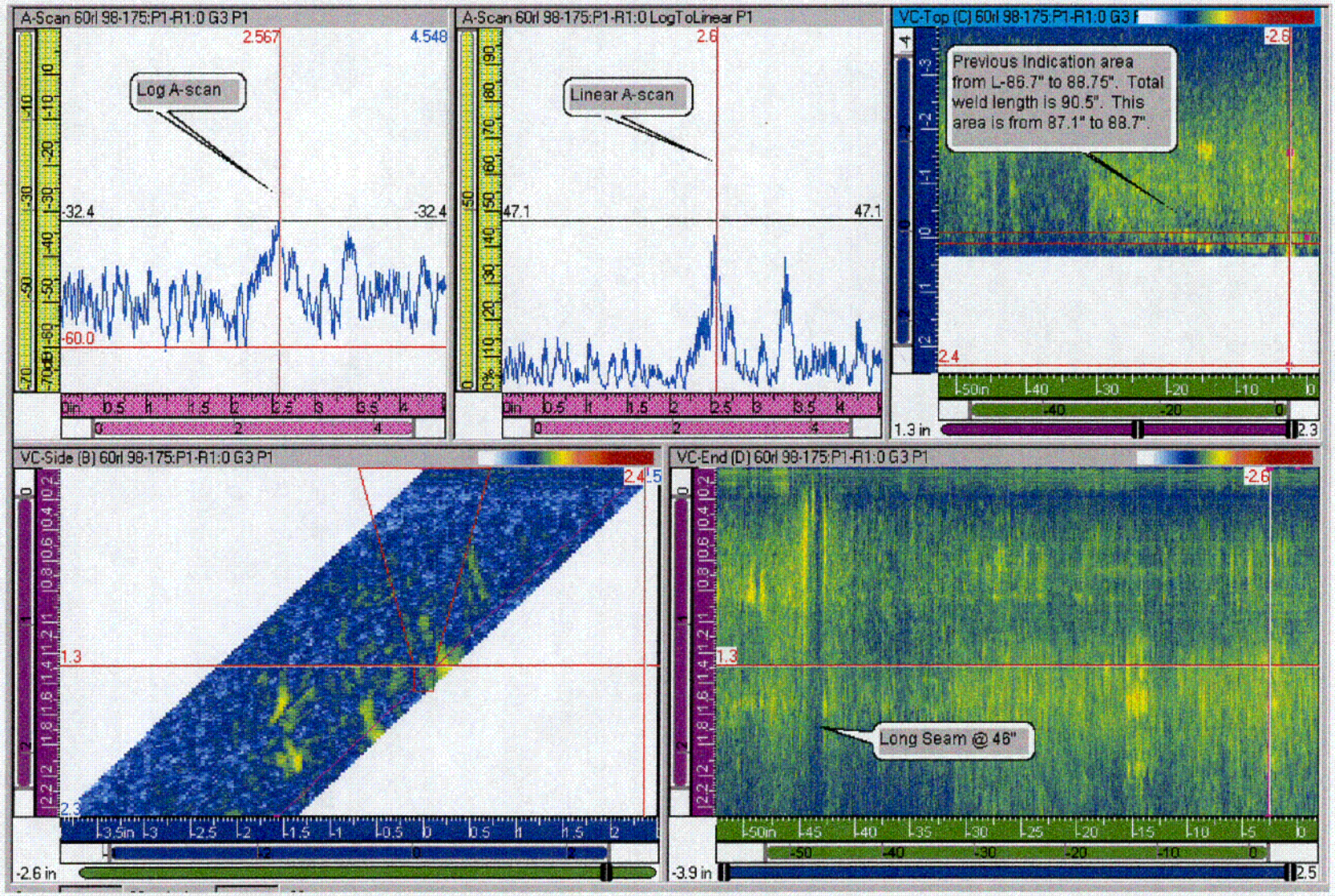

C10

# WELD # 02AD-F12 60° RL 2.0 MHz ROOT GEOMETRY



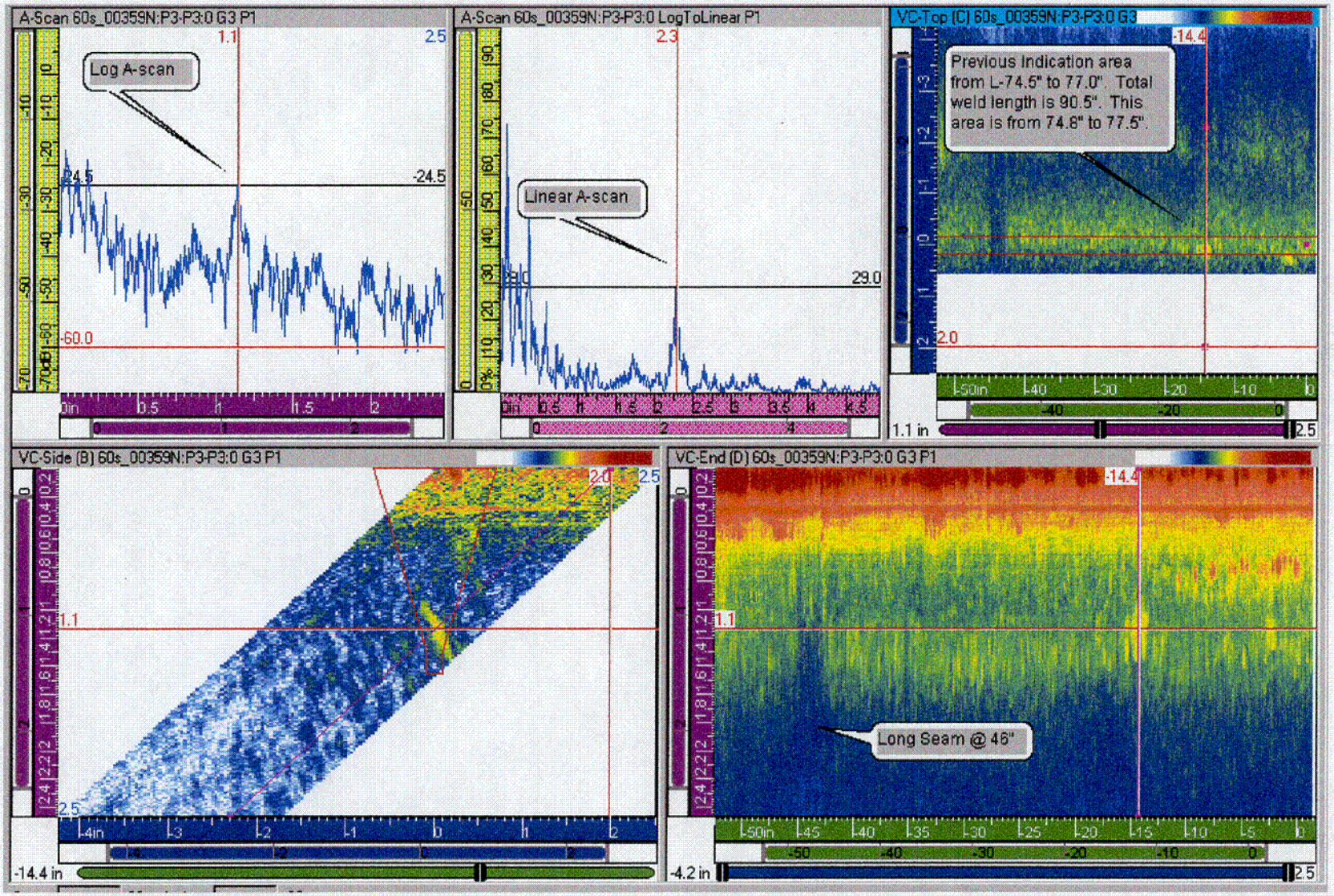

C11

# WELD # 02AD-F12 60° RL 2.0 MHz ROOT GEOMETRY



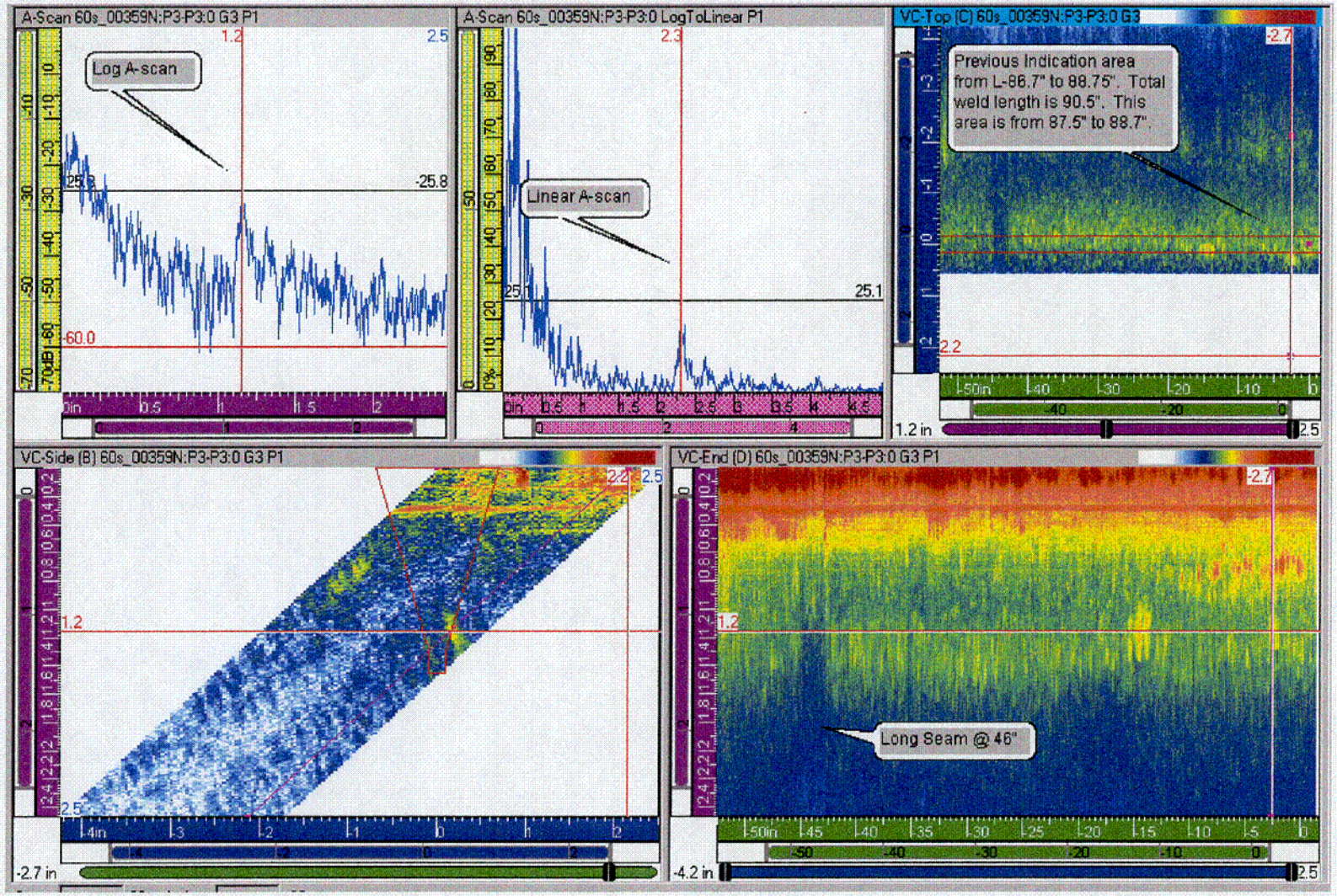

C12

# WELD # 02AD-F12 60° SHEAR 1.5 MHz ROOT GEOMETRY




C13

# WELD # 02AD-F12 60° SHEAR 1.5 MHz ROOT GEOMETRY






C14

Attachment 4

Quad Cities Unit 1, Evaluation of the Indication in Weld 02BS-F4 in the 28 inch Recirculation Piping based on the UT inspection Results with the Partial Thickness Weld Overlay.

REACTOR SERVICES
GE Nuclear Energy
175 Curtner Avenue, San Jose, CA 95125

*GE-NE-B13-02064-00-19*
*DRF #B13-02064-00*
*Class I*
*October 2000*

# Quad Cities Unit 1

# Evaluation of the Indication in Weld 02BS-F4 in the 28 inch Recirculation Piping based on the UT inspection Results with the Partial Thickness Weld Overlay.

**October 2000**

**Prepared for**

**Commonwealth Edison Co.**

**Prepared by**

**GE Nuclear Energy**

# Quad Cities Unit 1

# Evaluation of the Indication in Weld 02BS-F4 in the 28 inch Recirculation Piping based on the UT inspection Results with the Partial Thickness Weld Overlay.

**October 2000**

**Prepared by:** Randy Stark
**R.R. Stark, Engineer**
**Reactor Services**

**Approved by:** S Ranganath
**Sam Ranganath, Manager**
**Hardware Design, Reactor Services**

IMPORTANT NOTICE REGARDING

CONTENTS OF THIS REPORT

Please Read Carefully

The only undertakings of the General Electric Company (GE) respecting information in this document are contained in the Purchase Order between ComEd and GE-Nuclear Energy, and nothing contained in this document shall be construed as changing the contract. The use of this information by anyone other than ComEd, or for any purpose other than that for which it is intended is not authorized: and with respect to any unauthorized use, GE makes no representation or warranty, express or implied, and assumes no liability as to the completeness, accuracy or usefulness of the information contained in this document, or that its use may not infringe privately owned rights.

## Table of Contents


| Subject | Page No. |
|---|---|
| 1. BACKGROUND | 4 |
| 2. UT RESULTS ON THE PIPE WITH THE PARTIAL WELD OVERLAY | 5 |
| 3. JUSTIFICATION FOR CONTINUED OPERATION | 6 |
| 4. CONCLUSIONS | 7 |
| 5. REFERENCES | 7 |

# 1. Background

During the fall 1998 outage at Quad Cities Unit 1 a flaw indication was identified in weld 02BS-F4 in the 28-inch recirculation piping. The 1998 inspection determined that there was an Intergrannular Stress Corrosion Cracking (IGSCC) indication 0.25 in. deep and 27 inches long in the weld region. The indication was evaluated using Section XI, ASME Code, IWB-3640 and Appendix C [1] procedures using crack growth rates for normal water chemistry based on NUREG-0313, Rev. 2 [2] and shown to be acceptable for continued operation for two, 24 month, operating cycles (until October 2002).

Nevertheless, it was decided that a weld overlay should be performed on weld 02BS-F4 during the October 2000 outage so that a permanent repair would be in place. The weld overlay was designed to be a full structural overlay that meets Code Case N504-1 requirements. However, during the welding process the personnel exposure dose rate was found to be extremely high. If the overlay were to be completed as planned, the resulting personnel exposure would have been unacceptable. The weld overlay application was stopped after two full layers (approximately 0.2 in.). The measured ferrite content for all layers was in excess of 7.5. The high ferrite content as well as the fact that the plant is operating with hydrogen water chemistry (HWC) suggests that all deposited layers are effective in arresting the IGSCC.

Under the weld classification of Generic letter 88-01 the 02BS-F4 weld would be designated as Category F (cracked weld with inadequate or no repair) and would require inspection this outage. The weld has been prepared for inspection (removal of surface irregularities to assure a smooth surface for UT) and has been inspected. Verification of the actual depth of the original crack in the current overlay condition is difficult. Since the overlay was applied with water backed welding, there is a substantial heat sink benefit and the ID surface of the pipe is expected to be under compressive stress. While this offers a substantial benefit from the crack growth viewpoint, it also tends to close the crack so tightly that crack detection by UT from the outside is difficult. Studies performed by GE as part of an EPRI program for last pass heat sink welding (LPHSW) confirm that compressive residual stresses are developed even when only the last weld pass is melted by the LPHSW. For pipes in the vertical orientation, compressive stresses were developed even when there is no flow. Natural convection heat transfer is sufficient to produce the necessary heat sink and assure

compression. With the additional weld layers, it is expected that the resulting inside surface residual stress will be even more compressive than in the case of last pass heat sink welding.

Weld shrinkage measurements for the 02BS-F4 weld were taken in the *axial direction* after the application of the three weld layers. The actual average measured weld shrinkage was 0.074 inch over the width of the weld (10.97 inch). This indicates the presence of a compressive strain that confirms the compressive stress.

Recognizing this, the UT requirement for weld overlays does not call for detection or sizing of the original crack. PDI qualification requires weld overlay UT examinations to demonstrate flaw detection and sizing capability in the outer 25% of the original pipe. The PDI qualified examination will show that there are no cracks with depth greater than 75% of the original pipe thickness. Since it is difficult to find the original crack tip in the inner 75% of the original pipe thickness by UT in the pipe with partial overlay, a more conservative, but more reliable approach is to base the evaluation of the crack on the PDI qualified UT technique. Because of the UT qualification, it is known with high confidence that there are no cracks in the outer 25% of the *original pipe wall thickness.* This report demonstrates that continued operation is justified assuming a postulated worst case crack depth of 75% of the pipe wall, but taking credit for the 0.2 inch thick weld layer.

## 2. UT results on the pipe with the partial weld overlay

During the automated ultrasonic examination of 02BS-F4 with the Smart 2000, no indications associated with IGSCC were detected. As discussed earlier, the difficulty of detecting tight cracks resulting from the ID compressive stresses may explain the fact that no IGSCC indications were detected. Root Geometry was seen in the UT results. Specifically, in the area where the indication was previously recorded, root geometry and metallurgical interface at a much higher amplitude.

It is most likely that the original crack remained unchanged over the last two years. The welding process in itself would not cause crack extension or crack 'pop-in' since the crack is in the sensitized base material which has high ductility. The application of secondary stresses (weld residual) will not cause crack extension in ductile materials like stainless steel. This is supported by the widespread use of limit load techniques for stainless steel welds in the ASME Code and the exclusion of weld residual stresses in fracture assessment even for

flux welds. Furthermore, because of the HWC and NobleChem™ operation and the low conductivity and ECP values during the past cycle, crack growth due to IGSCC is expected to be negligible. Thus, it is reasonable to conclude that there has been very little change in the crack size during the last cycle. Nevertheless a bounding approach for the flaw evaluation is to base it on the PDI qualified procedures. With the PDI qualified overlay examination, it known with confidence that the outer 25% of the pipe wall has no cracks, or said another way, the maximum possible crack depth is 75% of the pipe wall thickness. This is the basis for the flaw evaluation described in the next section.

## 3. Justification for Continued Operation

The evaluation assumes a postulated worst case crack depth of 75% of the pipe wall, but takes credit for the 0.2-inch thick weld layer. With the 75% flaw, assuming a pipe thickness of 1.24 in. the crack depth is 0.75 x 1.24 = 0.93 in. This crack would be expected to grow under HWC operation for the next cycle (17,500 hours). The NRC Safety Evaluation Report on BWRVIP-14 allows a crack growth rate of $2.2 \times 10^{-05}$ in/hour for NWC in the absence of irradiation conditions. Assuming a factor of improvement of 5 on crack growth rate for HWC, the HWC crack growth rate is $(2.2 \times 10^{-05})/5 = 4.4 \times 10^{-06}$ in/hour. With this crack growth rate, the incremental crack growth is $4.4 \times 10^{-06} \times 17500 = 0.077$ in. Therefore, the final depth is 0.93 + 0.077 = 1.007 in. The crack length was also grown, using the NRC accepted $5 \times 10^{-05}$ in/hour crack growth Rate. With an initial flaw of 27 inches, the crack length at the end of the next cycle was calculated to be 30.5 inches.

Figure 1 shows the allowable flaw based on Section XI, IWB-3640 and Appendix C. In addition to the limit load requirements, IWB-3640 limits the flaw depth to 75% of the wall thickness. Taking credit for the additional 0.2 in. of weld overlay, the allowable depth is calculated to be 0.75 x (1.24 + 0.20) = 1.08 in. This is compared to the projected depth of 1.007 inch and even with the overly conservative postulated crack depth equal to 75% of the wall, the indication is acceptable. Thus, the predicted crack depth is less than the allowable value and the weld is acceptable for continued operation for one additional cycle.

## 4. Conclusions

The UT procedure is qualified to assure that there are no cracks in the outer 25% of the *original pipe wall thickness.* Thus, a postulated *worst case crack depth of 75% of the pipe wall was assumed.* With the 75% deep flaw, the crack depth is 0.75 x 1.24 = 0.93 inch. The analysis assumed crack growth rates based on HWC using a factor 5 improvement over NWC crack growth rates consistent with the NRC position on IGSCC growth rates. The resulting predicted depth is 1.007 inch at the end of the next 24-month operating cycle. This is less than the ASME Section XI, IWB-3640 allowable depth of 1.08 inches based on the wall thickness of 1.44 inches (including the partial overlay).

This report demonstrates that continued operation is justified assuming a postulated worst case crack depth of 75% of the pipe wall, but taking credit for the 0.2 inch thick weld layer. The evaluation results show that the subject indications meet the criteria of IWB-3640, Section XI of the ASME Code. Therefore, continued operation for at least one additional fuel cycle after the current outage (i.e. until October 2002) is justified for the 02BS-F4 weld.

## 5. References

[1] ASME Boiler & Pressure Vessel Code, Section XI, 1995 Edition, 1996 Addenda.

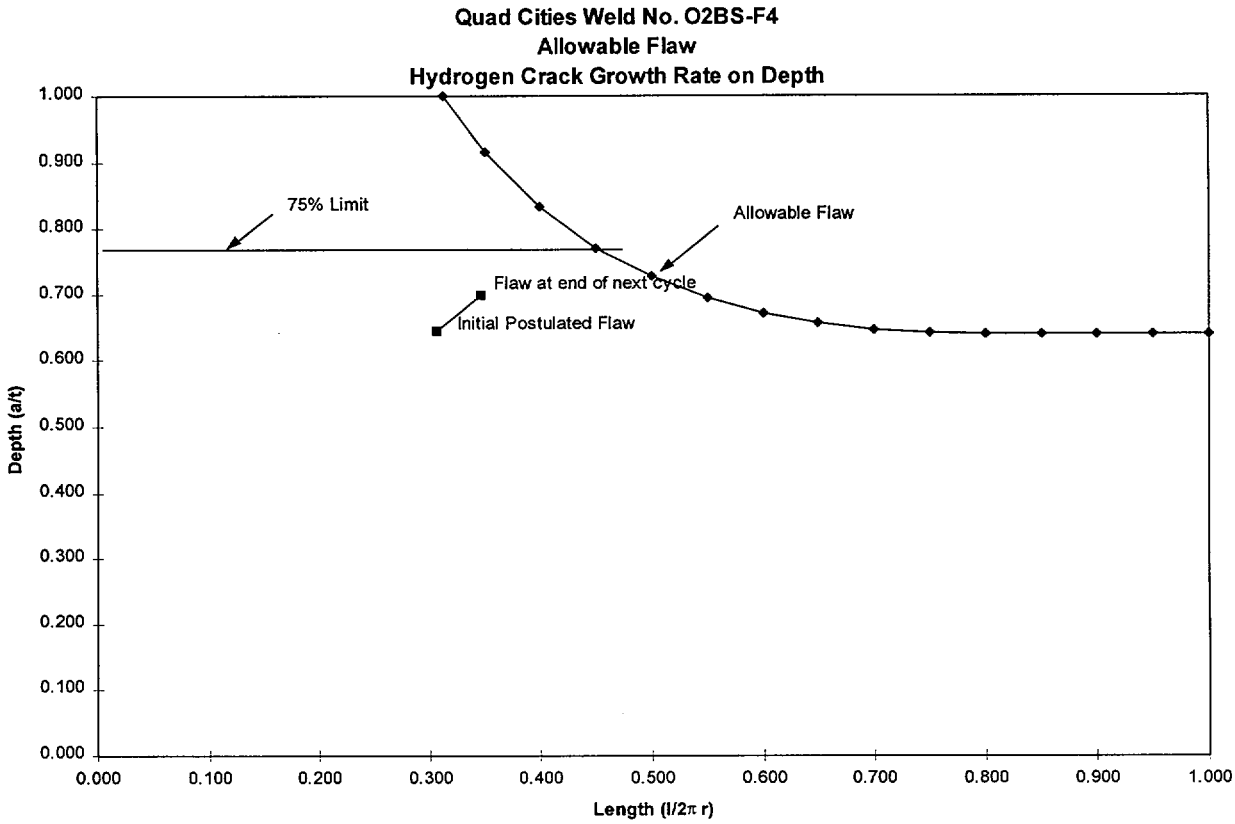



**Figure 1. Comparison with Allowable Flaw Size for Weld 02BS-F4**