

Final Report for the Erosion-corrosion Analysis of Tank 241-AW-02E Feed Pump Pit Jumpers B-2 and 1-4 Removed from Service in 2013

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Executive Summary

Two pipe sections, referred to as jumpers, from the 241-AW-02E feed pump pit in the 241-AW tank farm were removed from service in 2013 and sent to the 222-S Laboratory for erosion-corrosion forensics analysis of the pipe walls and inner pipe surfaces to ascertain pipe integrity. Jumper B – 2, installed in 1980 as part of the 241-AW tank farm construction connecting nozzle B to nozzle 2 and consisting of a single pipe with two 90-degree short radius elbows, transferred approximately 161 million gallons of evaporator feed waste. Jumper 1 – 4, installed in 1997 connecting nozzle 1 (pump discharge nozzle) to nozzle 4 and consisting of two separate pipe sections, transferred at least 33 million gallons of waste. Both jumpers were constructed from 3-inch schedule 40 carbon steel pipe with welded stainless steel Purex connector blocks.

Ultrasonic transducer measurements were acquired across selected sections of both jumpers to gain data on the pipe wall thicknesses and to determine if wall thinning had occurred due to general corrosion from contact with tank waste and/or erosion-corrosion from the flow of tank waste. All ultrasonic transducer thickness measurement results ranged between 0.211 to 0.286 inches. The nominal wall thickness of schedule 40 pipe is 0.216 inches. No discernable areas of wall thinning were observed using the ultrasonic transducer. Some areas of the pipe could not be measured due to obstructions, rust, or paint on the outer pipe surfaces.

In total, seven pieces (coupons) of the jumpers, approximately 1.5 x 1.5 inches, were cut from the pipe and were further analyzed using optical microscopy and scanning electron microscopy. Three of the coupons were embedded in epoxy to both preserve any corrosion and residues on the surface of the pipe and allow cross-sectioning of the coupon to characterize features and pits. The other four coupons were subjected to an ammonium citrate treatment process which removed enough corrosion and tank waste product to allow examinations of the inner pipe surface for general corrosion and erosion-corrosion analysis. No definitive erosion-corrosion features were detected on the pipe, and no significant wall thinning was observed on any of the coupons. Varying levels of corrosion were detected on the coupons, but in general, the levels of corrosion were minor. Jumper B – 2 displayed the greatest amount of general corrosion for the two jumpers, and the largest pit was 10.2 mils wide and 4.6 mils deep. Although jumper 1 – 4 had less overall corrosion with some areas on the pipe wall displaying a very low level of general corrosion and pitting, the level of corrosion was observed to change dramatically across the coupon. This suggests a varying amount of exposure to the liquid in the pipe possibly from the pipe not completely draining between usages. Some small pitting was also detected in the areas of general corrosion. The largest pit on jumper 1 – 4 was 27.5 mils wide and 6.2 mils deep.

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List of Terms

Abbreviations

BEI	Backscattered Electron Imaging
EDS	Energy Dispersive Spectrometry
NDE	Non-Destructive Examination
NIST	National Institute of Standards and Technology
RWP	Radiological Work Permit
SAS	Special Analytical Studies
SEI	Secondary Electron Imaging
SEM	Scanning Electron Microscopy or Microscope
UT	Ultrasonic Transducer
XRD	X-ray Diffractometry

Units

ft	Foot/Feet
mil	Thousandth of an inch
mm	Millimeters
μm	Micrometers

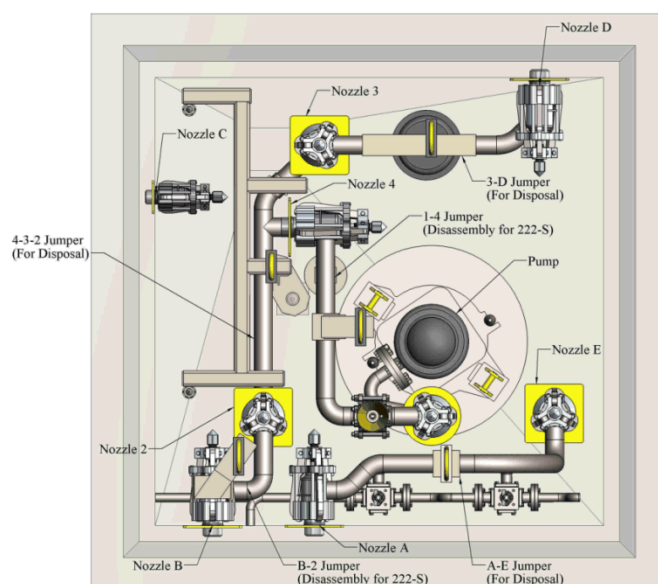
1 INTRODUCTION

This document is the final report summarizing the results in the examination of two pipe sections (jumpers) from the tank 241-AW-02E feed pump pit in the 241-AW tank farm. These pipe section samples consisted of jumper AW02E-WT-J-[B – 2] and jumper AW02E-WT-J-[1 – 4]. For the remainder of this report, these jumpers will be referred to as B – 2 and 1 – 4. The overall configuration of this pit prior to their removal in fiscal year 2013 is shown in Figure 1-1.

Jumper B – 2, shown as the complete assembly in Figure 1-2, was installed at the tank farm in 1980 as part of the Project B-120 AW Farm construction. The first waste transfers began in 1981. Approximately 161 million gallons of evaporator feed waste was transferred through this pipe section until it was replaced in 2013. This jumper was constructed using 3-inch schedule 40 carbon steel seamless pipe (ASTM¹ A53 Type S Grade B) and was coated on the outside with primer (Amercoat #86) and protective coating (Amercoat #33). Jumper 1 – 4, shown as the complete assembly in Figure 1-2, was installed in 1997 and began transferring waste in the same year. Approximately 33 million gallons of waste was transferred to the evaporator through this pipe section. This jumper was connected to the AW-02E pump discharge and also connected to the

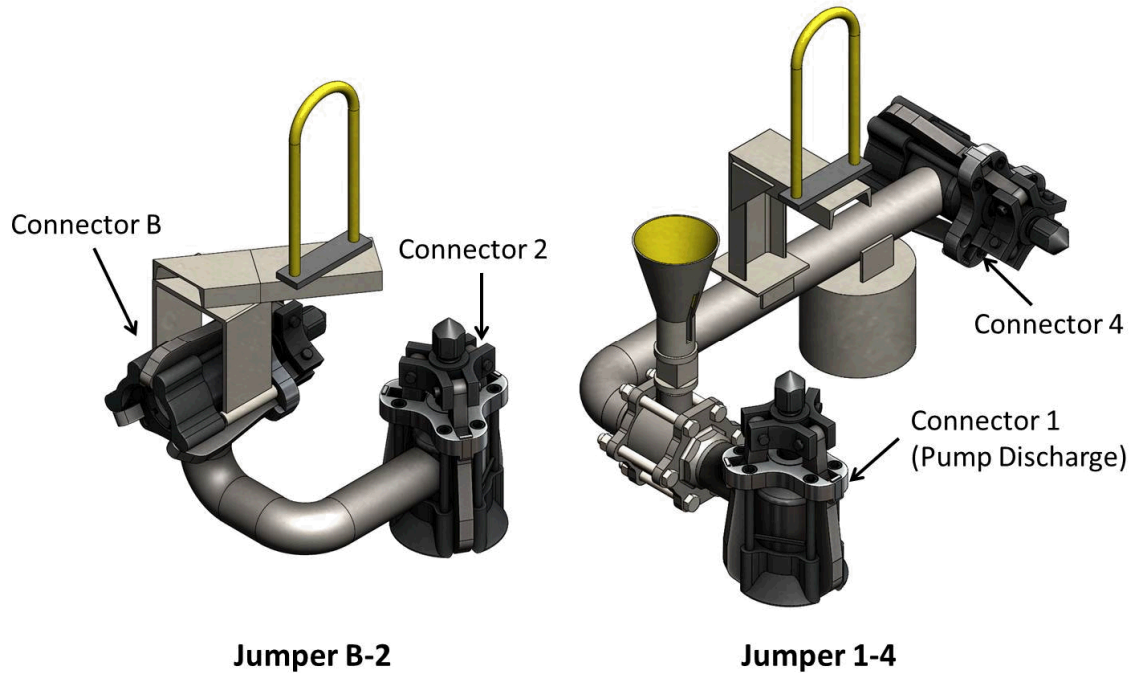
re-circulation loop, which increased the overall amount transferred through this pipe section as well as flow velocity (~ 135 gallons per minute). This pipe section was constructed using 3-inch schedule 40 carbon steel pipe (ASTM[®] A53 Type S Grade B or ASTM[®] A106 Grade B) coated with a primer (Amercoat #187) and protective coating (Amercoat #33).

Figure 1-1. Tank 241-AW-02E Feed Pit Installed Jumper Arrangement.



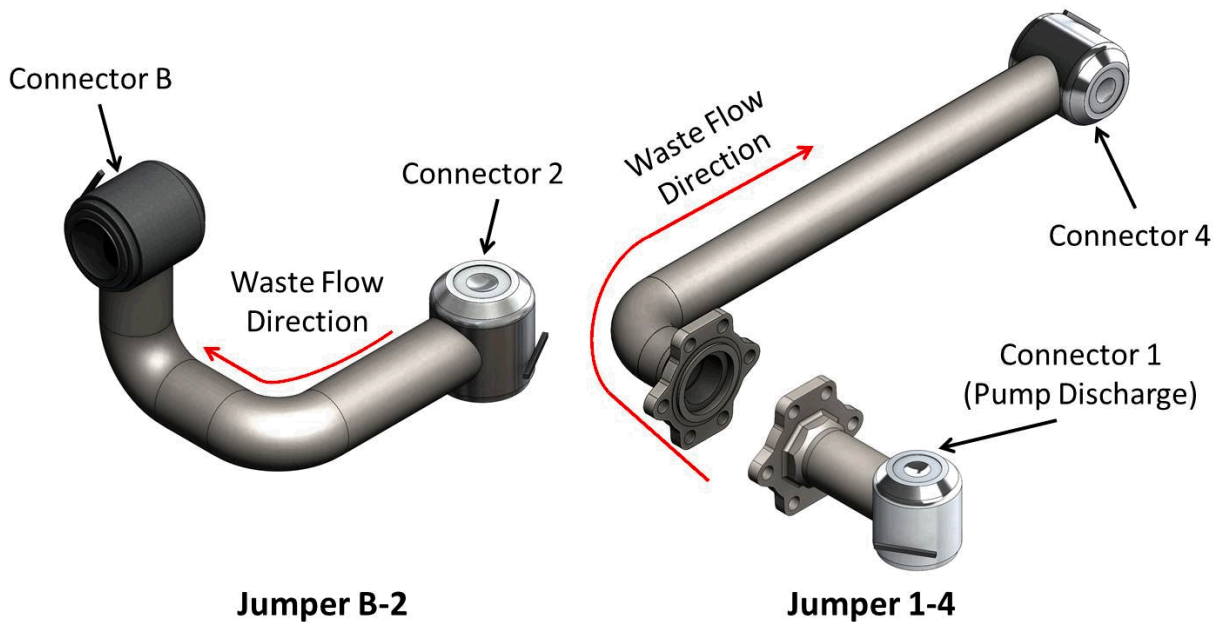
¹ ASTM is a registered trademark of the American Society for Testing and Materials, West Conshohocken, Pennsylvania.

Figure 1-2. Isomeric Sketches of Jumpers B – 2 and 1 – 4.



The jumpers were disassembled in the field via tank farms work package TFC-WO-5518, and the connectors, the valve, dunnage, and lifting bails were removed from the jumpers prior to packaging and shipment to the 222-S Laboratory. Figure 1-3 shows drawings of the pipe sections illustrating how they were received for analysis at the laboratory.

Figure 1-3. Drawings of Jumper B – 2 and Jumper 1 – 4 as Received by the 222-S Laboratory.



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The analysis of these jumper sections was carried out as described in the approved 222-S Laboratory test plan, LAB-PLN-13-00002, *Test Plan and Procedure for the Erosion and Corrosion Analysis of AW-02E Jumper Pipeline Sections*, and is similar to previous transfer pipeline analyses performed at the 222-S Laboratory by the Special Analytical Studies (SAS) group, LAB-RPT-12-00007, *Final Report for the Erosion and Corrosion Analysis of Waste Transfer Primary Pipeline Sections from 241-SY Tank Farm*.

This final report summarizes the results of this examination by providing photographs, photomicrographs, ultrasonic transducer (UT) thickness measurements, scanning electron microscopy (SEM) images, and energy dispersive spectroscopy (EDS) spectra acquired during the execution of the test plan by SAS. Photographs provide visual documentation of the progression of the analysis and an overall view of the tank waste residues and corrosion inside the transfer pipes and pipe sections (coupons) cut from the pipes. Photomicrographs provide magnified views of the coupons and areas of interest on the surface. The SEM analyses afford increased magnification of the tank waste residues, corrosion, pitting, and elemental identification of these phases. Data tables summarize the UT thickness measurements recorded across the jumper sections on the locations requested by the customer.

2 JUMPER B – 2

2.1 SAMPLE UNPACKING, DECONTAMINATION, AND ULTRASONIC TRANSDUCER MEASUREMENT PREPARATION

Jumper B – 2 was received at the 222-S Laboratory packed inside a 55-gallon drum, and it was removed from the drum and placed in hood 1 of room 1-E. Figure 2-1 shows this jumper in its original packaging (A) and after replacing the packaging with a new bag (B) which aided in the control of the removable contamination on the jumper. Several locations on this jumper contained patches and splatters of a white epoxy paint. It was determined that this paint was used to coat the walls and other components in the pump pit using long reach equipment, and it was inadvertently applied to the jumper. This paint interfered with some of the requested UT measurements because of the thickness and roughness of the coating. Several rust spots were also on the jumper, especially on the bottom of the pipe, possibly from repeated hanging droplets of moisture during its lifetime in the pump pit. These rust spots were a source of higher levels of removable contamination and made it more challenging to decontaminate. In addition, the rough surface made it difficult to obtain the UT thickness measurement at some of these locations. Notes were made on the UT data sheets (Attachment A) when the measurements were acquired in these areas of paint or rust.

Figure 2-1. Photos of Jumper B – 2 Before and After Packaging Removal.

Some areas of the jumper contained high levels of removable contamination ($>1,000,000$ dpm). The two Purex connector blocks on jumper B – 2 (stainless steel components welded to the pipes enabling attachment to the Purex nozzles located in the AW-02E) had the greatest levels of removable contamination. Since UT measurements would not be performed on the end of these connectors, they were covered with a layer of rubber matting and taped. The other areas of the jumper were decontaminated with a series of wipes with wet and dry paper towels until the levels dropped below the action level of the radiological work permit (RWP) S-806 used for this work.

The locations on the jumper for the individual UT measurements were marked using a white paint marker (Sharpie, Mean Streak®²) with guidance from the UT maps supplied by the customer. The paint marker dries to a thin coating which does not affect the quality of the UT measurement as tested on a pipe sample in a lab at AREVA³. The UT maps are in Attachment A as part of the data sheets in the UT results report from AREVA. To mark the correct locations, a template was wrapped around the pipe and taped in place. A dot of white paint was applied to the pipe through holes in the template. Figure 2-2 shows the first straight section of jumper B – 2 during and after the marking process. Templates were used to mark all the straight sections of the pipe, and a partitioned rubber band was used to mark the elbows.

Figure 2-2. Photos of a Section of Jumper B – 2 During and After the Marking Process.

² Mean Streak is a registered trademark of the Newell Rubbermaid Corporation, Selangor D.E., Malaysia.

³ AREVA Federal Services LLC, Richland, Washington.

2.2 ULTRASONIC TRANSDUCER THICKNESS MEASUREMENTS

In order to acquire pipe wall thicknesses across jumper B – 2, UT measurements were performed by a qualified nondestructive examination (NDE) engineer from AREVA. This process measured locations around the jumper at the pre-marked locations, as described in the previous section, to determine where, if any, thin spots were located on the jumper which may have occurred due to erosion-corrosion of the inner wall by the pumping of the tank waste. In order to acquire a measurement, a drop of UT couplant was applied over the pipe. The transducer was then placed on the pipe through the couplant and manipulated until a strong signal was received

on the UT instrument and the thickness measurement was recorded. A photo of a measurement being acquired is shown in Figure 2-3. This was repeated until the section containing all the UT measurement locations was completed. The results of the UT measurements are reported in Attachment A and in individual tables in the body of this report.

Central to the accuracy of the UT measurements was the use of certified calibration blocks. The calibration blocks used for these analyses were made from schedule 40 carbon steel pipe sections which were used as-is or milled to different pipe wall thicknesses. The calibration block thicknesses ranged from 0.179 to 0.283 inches. In addition, a stainless steel calibration block made from bar stock was used for the connector block thickness measurements. Figure 2-4 shows a photograph of one of the calibration blocks with couplant applied to the surface to ensure a proper contact of the transducer with the metal. The calibration blocks were used to verify the accuracy of the transducer before (pre), and after (post) each series of data collection sets on each section of the jumper.

UT thickness measurements were acquired on the schedule 40, carbon steel pipe and the stainless steel connector blocks. The carbon steel pipe contained both straight and 90-degree elbow sections. Measurements on the straight sections consisted of 16 equally spaced points

Figure 2-3. Photo of an Ultrasonic Transducer Measurement Acquired on Jumper B – 2.



Figure 2-4. Photograph of the Calibration Block.



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around the perimeter of the pipe forming a band. Figure 2-5 shows a drawing of the jumper section focused on the inlet side of jumper B – 2 with several of these bands drawn on the pipe. The elbow sections consisted of 12 equally spaced points around the pipe perimeter. The three points on the intrados of the bend were not requested by the customer (see Figure 2-5) due to the inability to properly lay the UT probe on the pipe surface in this area. The corresponding UT pipe wall thickness results for the labeled bands in Figure 2-5 are shown in Tables 2-1 through 2-3. The locations of the coupons cut from the jumper are marked with the dashed box around the UT measurement results. The locations were chosen based on the UT results and with consultation with the customer.

Figure 2-5. Locations of Ultrasonic Transducer Thickness Measurements on the Inlet Area of Jumper B – 2.

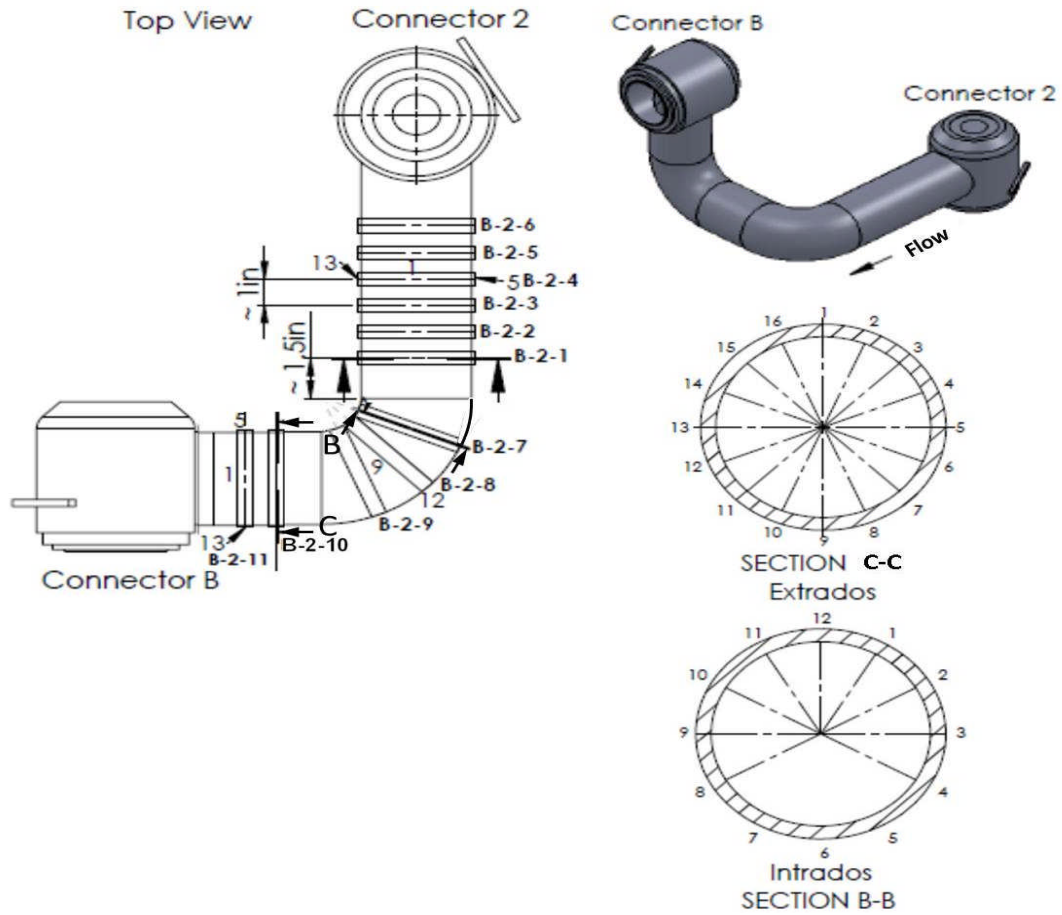


Table 2-1. Measured Ultrasonic Transducer Pipe Wall Thicknesses in Inches for the First Straight Section of Jumper B – 2.

Location on Band	UT Map Band Label					
	B-2-1	B-2-2	B-2-3	B-2-4	B-2-5	B-2-6
1	0.246	0.242	0.254	0.240	0.241	0.237
2	0.253	0.250	0.248	0.248	0.250	0.242
3	0.257	0.258	0.251	0.253	0.253	0.254
4	0.250*	0.249*	0.256	0.248	0.250	0.244
5	0.231*	—*	0.233	0.231	0.226	0.230
6	0.226*	0.233*	0.233	0.220	0.226	0.226
7	0.230	0.231	0.228	0.230	0.230	0.227
8	0.225	0.221	0.226	0.225	0.220	0.226
9	0.229	0.228	0.233	0.231	0.228	0.233
10	0.230	0.233	0.229	0.227	0.230	0.229
11	0.237	0.231	0.237	0.233	0.237	0.235
12	0.246	0.236	0.238	0.233	0.231	0.226
13	0.217	0.226	0.217	0.241	0.222	0.224
14	0.222	0.219	0.213	0.217	0.218	0.222
15	0.222	0.221	0.225	0.226	0.223	0.226
16	0.226	0.231	0.227	0.223	0.229	0.226

* - Epoxy paint on UT measurement location and/or rough surface.

---- - Area where coupon #1 was cut.

Table 2-2. Measured Ultrasonic Transducer Pipe Wall Thicknesses in Inches for the First Elbow Section of Jumper B – 2.

Location on Band	UT Map Band Label		
	B-2-7	B-2-8	B-2-9
1	0.258	—*	—*
2	0.266	0.269	—*
3	0.272	0.276	—*
4	—*	—*	0.271
5	N/A	N/A	N/A
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	0.273	0.270	0.268
9	0.278	0.278	0.272
10	0.254	0.263	0.265
11	0.255	0.240	0.270
12	0.231	0.231	0.237

* - Epoxy Paint on UT Measurement Location and/or Rough Surface.

**Table 2-3. Measured Ultrasonic Transducer
Pipe Wall Thicknesses in Inches for the Second
Straight Section of Jumper B – 2.**

Location on Band	UT Map Band Label	
	B-2-10	B-2-11
1	0.258	0.252
2	0.257	0.256
3	—*	0.225
4	—*	0.227
5	0.223	0.223
6	0.235	0.225
7	0.224	0.224
8	0.234	0.238
9	0.256	0.251
10	0.253	—*
11	0.235	0.244
12	0.237	0.225
13	0.234	0.226
14	0.240	0.241
15	0.231	0.228
16	0.225	0.227

* - Epoxy Paint on UT Measurement Location and/or Rough Surface.

---- - Area where coupon #2 was cut.

The results for this first area on jumper B – 2 did not indicate any significant wall thinning as the nominal wall thickness for a schedule 40 pipe is 0.216 inches. Most of the measurements were well above the nominal with the thickest wall readings of 0.258 inches on the straight sections. The thinnest reading was 0.217, which was located on the first straight section. The elbow ranged from 0.278 to 0.231 with the thinnest wall thicknesses on the extrados as expected for the manufacturing of this pipe section. Some locations contained paint, which did interfere with the measurement on some readings. Other areas with paint still allowed a reading to be acquired, but these readings should be suspect due to the coating.

Figure 2-6 shows the remaining areas of the carbon steel pipe on jumper B – 2 with corresponding UT map bands located and labeled. The UT thickness results for this area are shown in Tables 2-4 and 2-5.

Figure 2-6. Locations of Ultrasonic Transducer Thickness Measurements on the Outlet Area of Jumper B – 2.

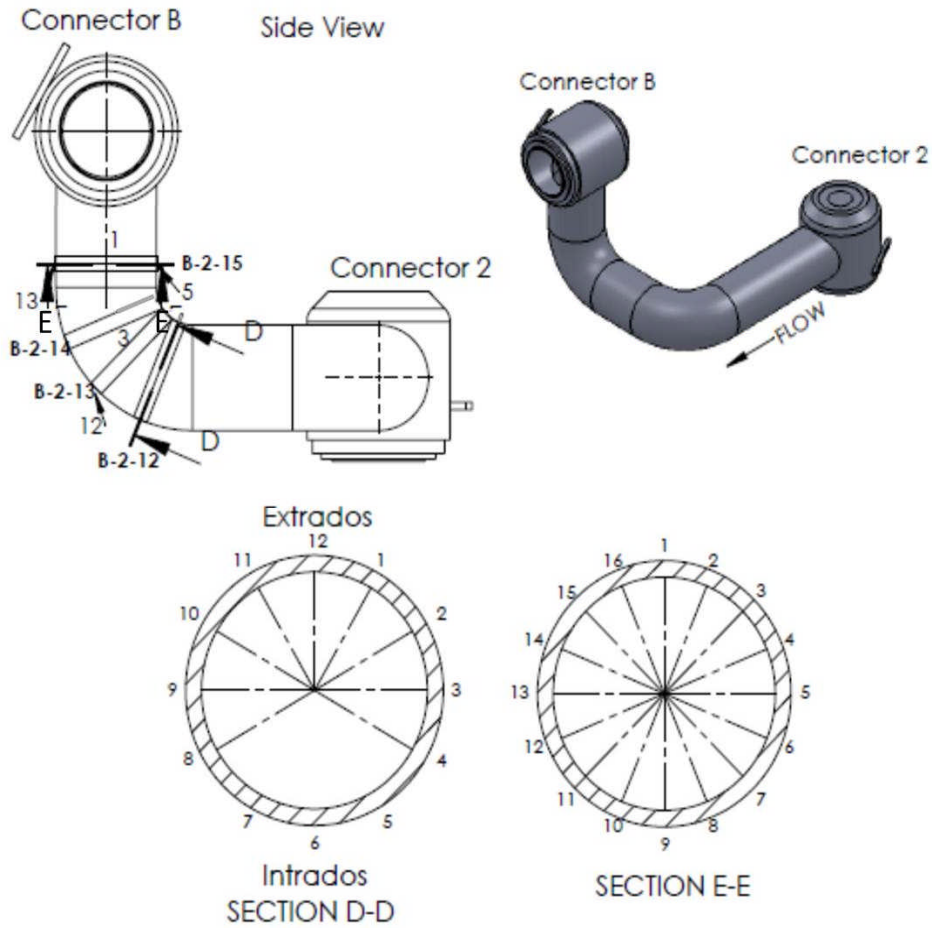


Table 2-4. Measured Ultrasonic Transducer Pipe Wall Thicknesses in Inches for the Second Elbow Section of Jumper B – 2.

Location on Band	UT Map Band Label		
	B-2-12	B-2-13	B-2-14
1	0.231	0.234	0.234
2	0.235	0.237	0.246
3	0.250	0.238	0.246
4	0.252	0.245	0.256
5	N/A	N/A	N/A
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	—*	0.268	0.265
9	0.257	0.257	0.258
10	0.262	0.262	0.256
11	0.253	0.241	0.235
12	0.221	0.218	0.226

* - Epoxy Paint on UT Measurement Location and/or Rough Surface.

Table 2-5. Measured Ultrasonic Transducer Pipe Wall Thicknesses in Inches for the Third Straight Section of Jumper B – 2.

Location on Band	UT Map Band Label	
	B-2-15	
1	0.231	
2	0.226	
3	0.228	
4	0.231	
5	0.229	
6	0.228	
7	0.238	
8	0.273	
9	0.267	
10	0.217	
11	0.220	
12	0.224	
13	0.219	
14	0.211	
15	0.222	
16	0.233	

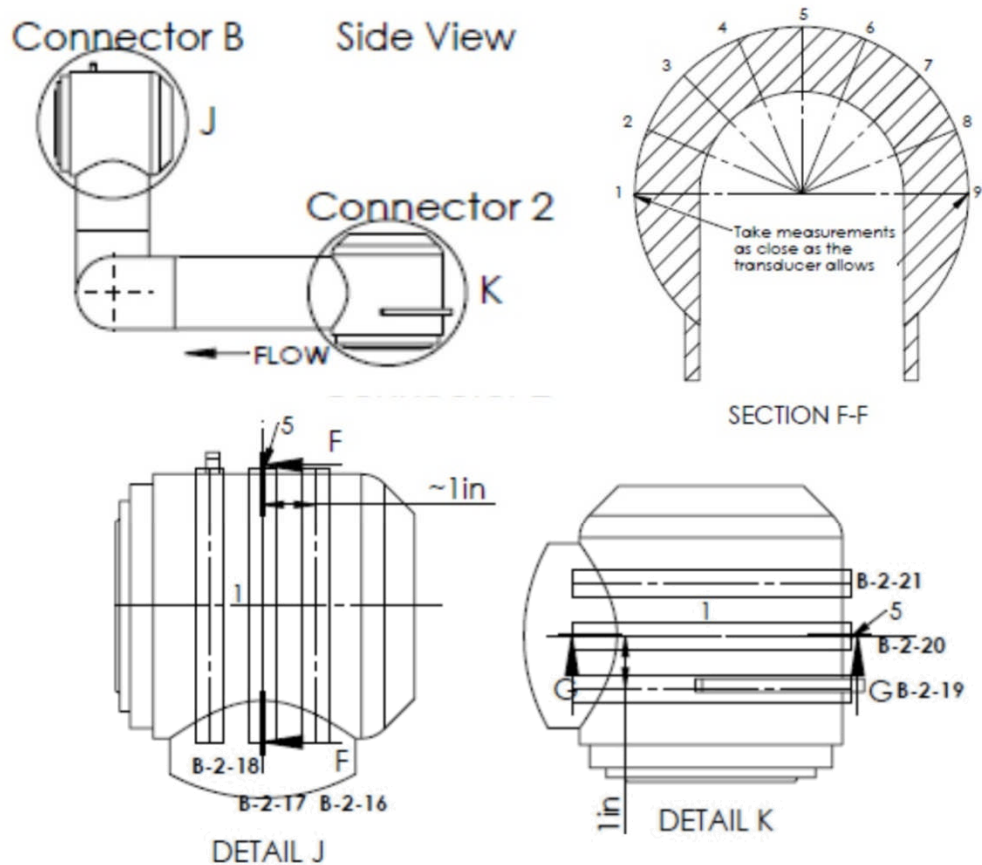
---- - Area where coupon #3 was cut.

The UT results indicated that there were no significant thin-wall locations on these areas of jumper B – 2. The thinnest reading was located in the third straight section at 0.211 inches, which is only 0.005 inches less than the nominal schedule 40 pipe thickness of 0.216 inches. The thickest wall was measured near the intrados of the elbow at 0.268 inches. Variations in the

pipe wall thickness resulting from the pipe manufacturing process are expected, and the intrados of a bend would likely have a slightly thicker pipe wall than the surrounding areas.

Stainless steel connector blocks were welded to both ends of jumper B – 2. For each connector block, 3 bands of 9 UT measurement locations were requested as shown in Figure 2-7. The resulting UT thickness readings are displayed in Tables 2-6 and 2-7 and show very consistent measurements revealing the precision of the fabrication and lack of any erosion-corrosion.

Figure 2-7. Locations of Ultrasonic Transducer Thickness Measurements on the Connector Blocks of Jumper B – 2.



**Table 2-6. Measured Ultrasonic Transducer
Pipe Wall Thicknesses in Inches for Connector B
of Jumper B – 2.**

Location on Band	UT Map Band Label		
	B-2-16	B-2-17	B-2-18
1	1.000	0.998	—*
2	0.985	0.985	—*
3	0.985	0.985	—*
4	0.985	0.985	—*
5	0.985	1.000	—*
6	0.985	0.985	—*
7	0.985	0.985	—*
8	0.998	0.985	—*
9	0.985	0.985	—*

* - Area covered with tape and welded bar.

**Table 2-7. Measured Ultrasonic Transducer
Pipe Wall Thicknesses in Inches for Connector 2
of Jumper B – 2.**

Location on Band	UT Map Band Label		
	B-2-19	B-2-20	B-2-21
1	—*	0.985	0.985
2	—*	0.985	0.985
3	—*	0.985	1.000
4	0.985	0.985	0.985
5	0.985	0.985	0.985
6	0.985	0.985	0.985
7	0.985	0.985	0.985
8	0.985	0.985	0.985
9	1.000	0.934	0.985

* - Area covered with welded bar.

2.3 CUTTING OF COUPONS IN A HOT CELL

Jumper B – 2 was loaded into the 1-E-1 hot cell. Through a succession of cuts using a portable band saw and a grinder with a cut-off wheel, small square sections (coupons; approximately 1.5 x 1.5 inches) of the pipe were cut from the jumper from the locations requested by the customer and indicated in Section 2.2. Figure 2-8 shows the initial cut of the jumper using the band saw.

Figure 2-8. Photo of the Initial Cut on Jumper B – 2 Using a Portable Band Saw in a Hot Cell.



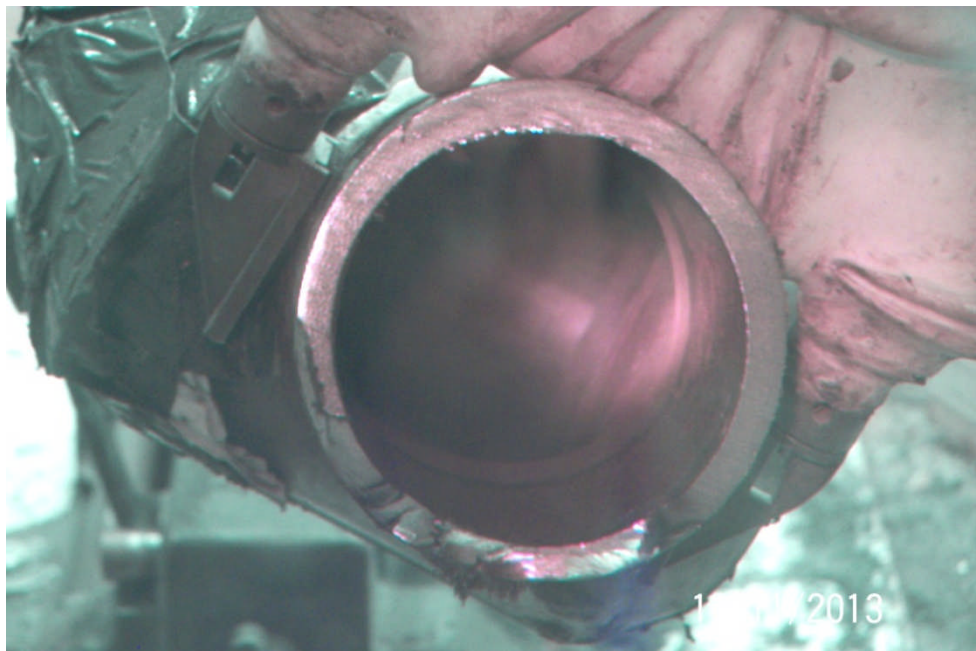
The cutting of coupons from the jumper also allowed some of the inner walls to be viewed through the hot cell window. Looking inside the jumper pipes revealed some residue and possible corrosion products. The following figures show many of the details observed through the hot cell window, and Appendix B contains additional pictures taken of the jumper pieces in the hot cell. Figure 2-9 shows the inside of the first elbow on jumper B – 2. A flashlight was shone through the hot cell window which better showed the interior but also gave a reddish hue to the surfaces. A thin, light, opaque layer was observed having some variation in the thickness. The SEM analysis of the coupon cut from the jumper in this area provided more details on the composition and thickness of this layer, Section 2.4.

Figure 2-9. Photo of the Inner Wall of the First Elbow of Jumper B – 2.



Connector B of jumper B – 2 was also held up to the hot cell window for visual inspection of the inside surface of the stainless steel connector. Figure 2-10 shows that the inner surface is considerably clean, shiny, and free of residue and corrosion. This corresponds well with the UT results which showed no thinning of the wall thickness on the connector.

Figure 2-10. Photo Showing the Inner Wall of Connector B.



A section of the straight pipe was also examined at the hot cell window before a coupon was cut from it. Figure 2-11 shows the pipe from two different angles displaying a majority of the inner surface. The surface has an area of a thin white residue on one side and a few patches of blistering, indicating spots of possible corrosion. The wall exposed from the cross-sectioning of the pipe appears to have a uniform thickness supporting the UT work which showed only small variations in the pipe wall thickness measurements.

Figure 2-11. Photos of the Inner Surface of a Straight Section of Pipe from Jumper B – 2.



A total of three coupons were cut from the B – 2 jumper. These coupons were loaded out of the hot cell and analyzed for residue and erosion-corrosion using optical microscopy and SEM analysis.

2.3.1 Clamshell Cutting of the First Elbow on Jumper B – 2

The first elbow in the flow direction of jumper B – 2 and nearest to connector 2 was isolated and clamshelled using a combination of the portable band saw and cut-off wheel in the hot cell. The clamshell cut allowed a visual inspection of the extrados and intrados pipe walls of the 90-degree elbow to look for any wall thinning from erosion-corrosion of the flowing liquid. Figure 2-12 shows photos of the resulting sections of the elbow as taken through the hot cell window. Several observations were gained by this clamshell cut. First, there was no appreciable thinning of the pipe wall on the elbow. If wall thinning associated with impingement and erosion-corrosion had taken place, it would most likely be located at the extrados wall at the exit of the elbow with respect to the flow (“Complexities in predicting erosion-corrosion” [Poulson 1999]). In other words, it would be on the outside wall near the second weld where the flow arrow is

pointing. Second, the clamshell section in the left image represents the bottom side of the pipe. There is considerably more corrosion and residue on this section, possibly caused by pooling of the liquid when the flow was stopped. Third, the welds are intact with no visual erosion-corrosion near or on the welds.

Figure 2-12. Photos of the Clamshelled Sections of the First Elbow of Jumper B-2.

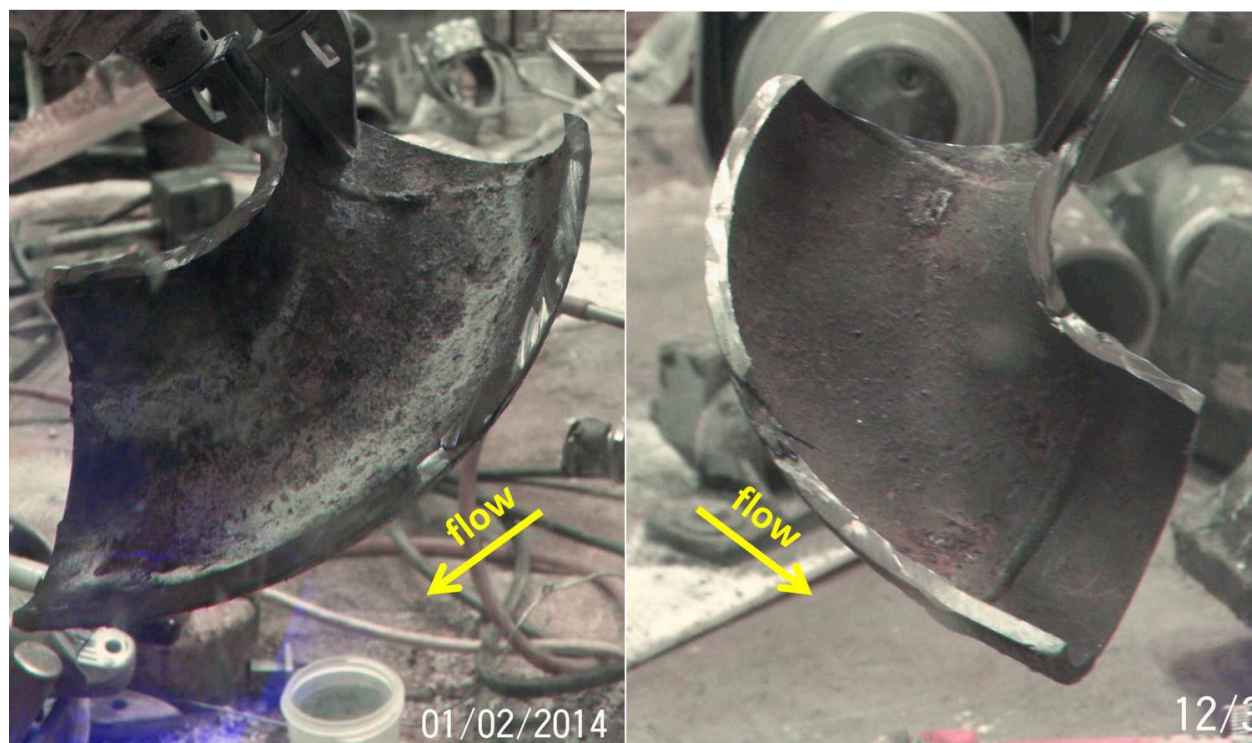
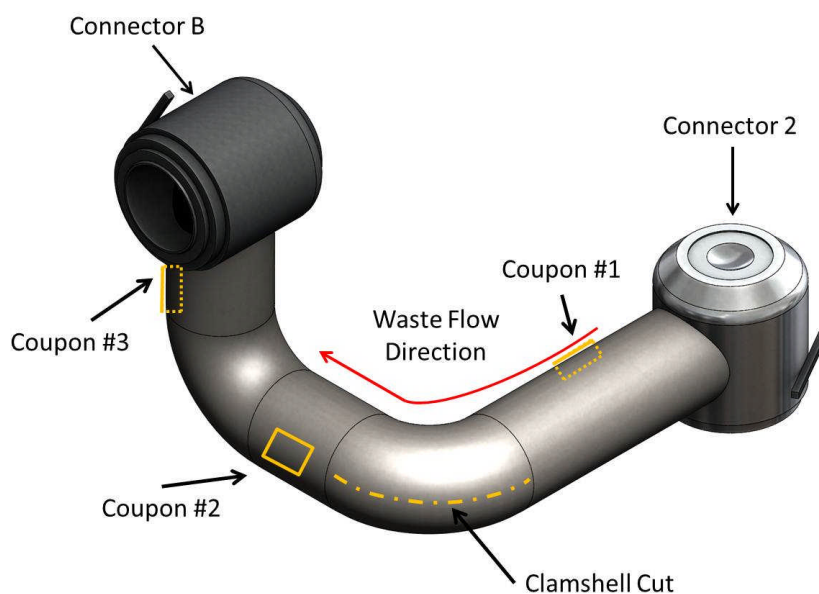


Figure 2-13. Location of the Coupons Cut from Jumper B-2.

In total, three coupons were cut from jumper B – 2 and one elbow was clamshelled. Figure 2-13 shows the approximate locations of these cuts; for the exact locations see Figures 2-5 and 2-6 and Tables 2-1, 2-3, and 2-5.

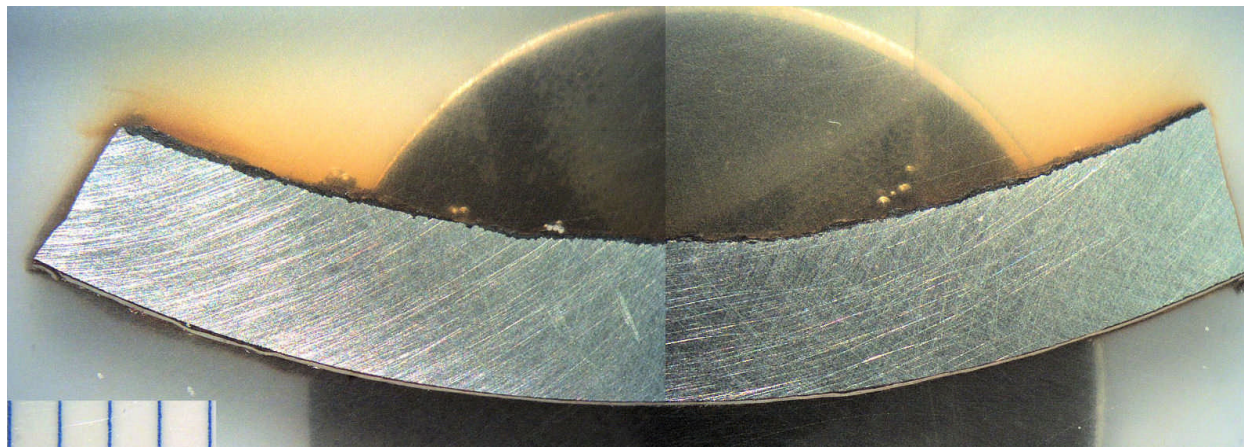


2.4 COUPON ANALYSIS

2.4.1 Jumper B – 2 Coupon #1

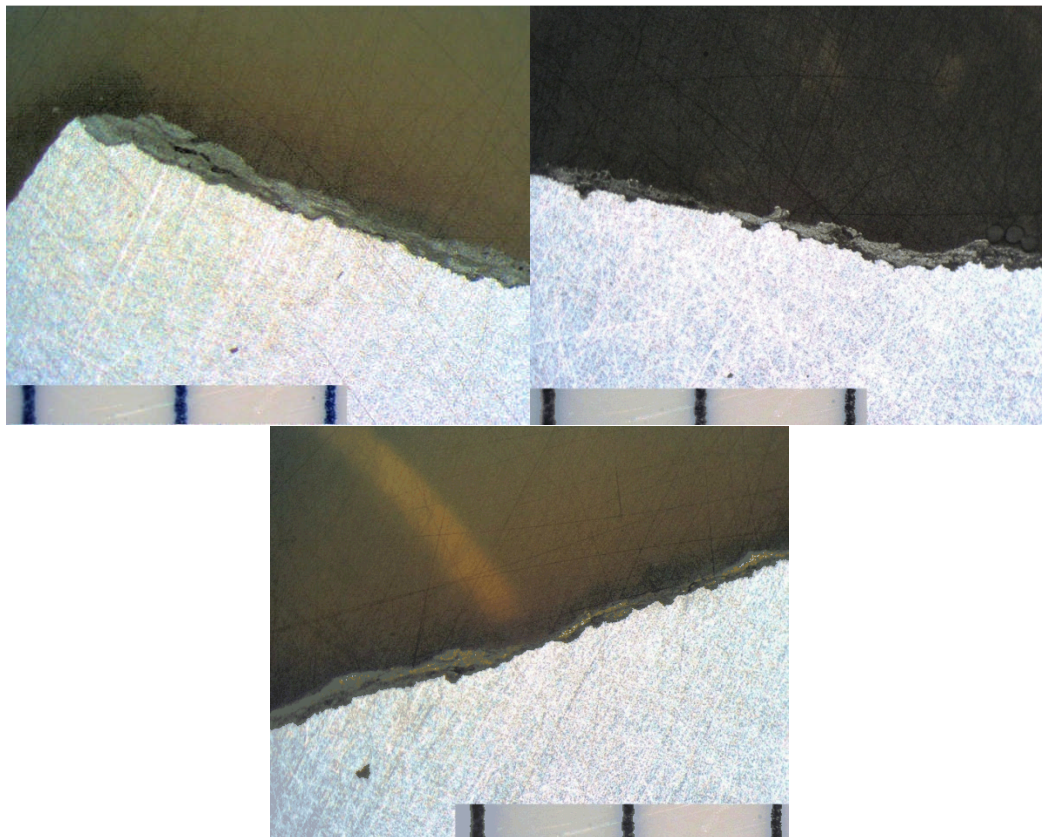
A coupon was cut from the first straight section of jumper B-2 in the location indicated in Table 2.1. This coupon, referred to as coupon #1 with the OmniLims sample #S13R000606, was immediately embedded in epoxy after being loaded out of the hot cell. The epoxy immobilized any corrosion and residues on the surface of the pipe, preserving the features for SEM analysis. After the epoxy cured overnight, the coupon was wafered using a low-speed diamond saw creating a cross-section of the pipe wall. This cross-section was then polished with sandpapers through consecutive grits ending in a 600-grit finish and mounted onto a SEM sample stub. The mounted cross-section was then photographed using an optical microscope, and the resulting image is shown in Figure 2-14. The size of the cross-section was larger than could be photographed by the microscope, so the image in Figure 2-14 is a mosaic of two separate images. A scale bar is shown in the lower left of the image with marks at increments of 1/16 of an inch. The black circle behind the pipe cross-section is the SEM stub. Epoxy completely surrounds the cross-section and is stained brown near the inner surface of the pipe due to particulate dissolving into the epoxy before it was completely cured.

Figure 2-14. Microphotograph of the Cross-Section Cut from Coupon #1 of Jumper B - 2.



Visual inspection of the cross-section in Figure 2-14 shows that the pipe wall is intact with no areas of excessive wall thinning due to erosion-corrosion. The presence of a corrosion layer and the rougher surface texture of the interior surface indicate that some slight wall thinning has occurred. The inner surface of the pipe contains small pits along the cross-section and a thin layer of corrosion and/or tank waste. The pits and corrosion/residue layer can also be seen in Figure 2-15, which is a series of microphotographs taken at a higher magnification across the coupon. The scale bars are in increments of 1/16 of an inch.

Figure 2-15. Microphotographs of Selected Areas Across the Inner Pipe Surface of Coupon #1 of Jumper B - 2.



The increased magnification in the images in Figure 2-15 shows that the pits are small and continuous with a continuous layer of corrosion/residue product on the surface of the pipe.

The cross-section was next analyzed by SEM providing further information on the integrity of this pipe section and the identification of these surface layers. Figure 2-16 contains SEM images at the lowest instrument magnification to show and measure the entire wall thickness at two different locations on the cross-section. Conversion of the SEM measured distances from micrometers to inches shows that the measurements in Figure 2-15 are from 0.200 to 0.206 inches. The UT measurements of this coupon ranged from 0.213 to 0.241, Table 2.1. The cross-section was cut in an area between the UT measurement locations, and although the SEM distances were less than the UT measurements, they are similar to what was measured by the UT. Another contribution to the thickness discrepancy is the presence of a coating on the outside of the pipe with a measured thickness of $\sim 150\text{ }\mu\text{m}$ by SEM. This coating can be seen in the lower left image of Figure 2-16. The slower sound velocity through this coating could bias the UT measurements to a thicker value than the actual pipe wall.

Figure 2-16. Scanning Electron Microscopy Images of the Pipe Wall of Coupon #1 of Jumper B-2.

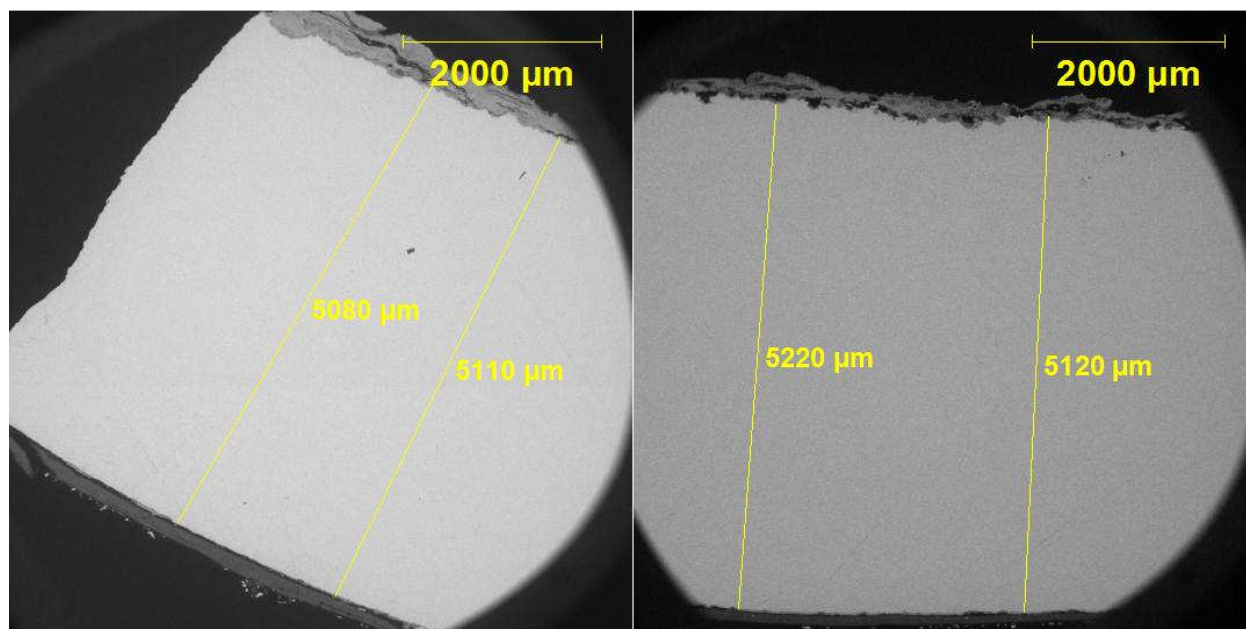
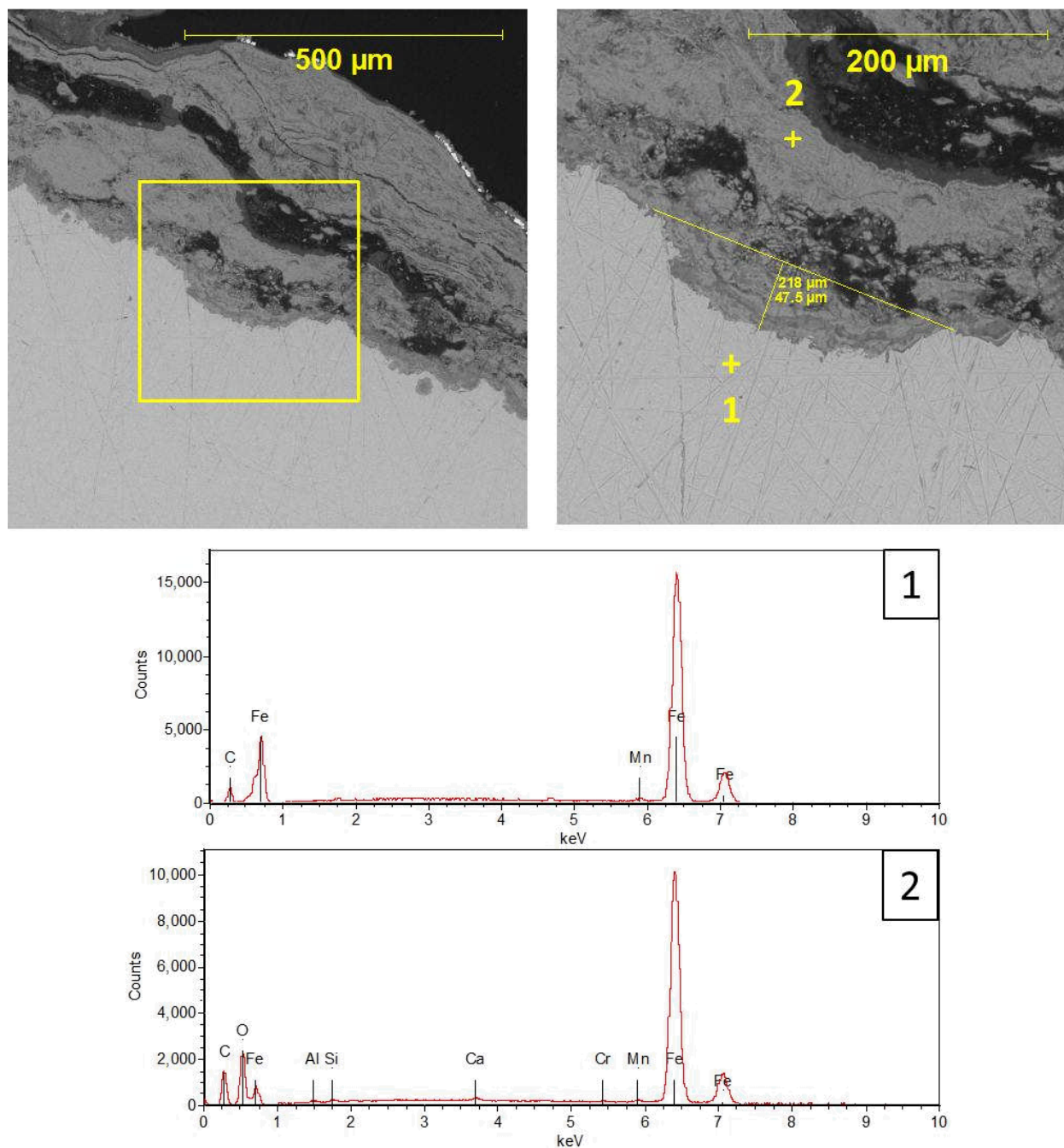


Figure 2-17 is an SEM image of a wide, shallow pit on the inner surface of coupon #1 cut from the B – 2 jumper. The brighter material in the lower left of the images is the pipe steel, the darker gray material on the steel is a layer of corrosion/residue, and the black areas of the image are the epoxy. The right image is a magnified view of the boxed area in the left image. The pit was measured at 8.5 mils (218 µm) wide by 1.9 mils (47.5 µm) deep and is in an area of general corrosion. The two EDS spectra, acquired at the locations labeled with the yellow cross, indicate the layer immediately on top of the pipe steel wall is the oxide of the steel (corrosion). This small pit is representative of the pits that were detected across the entire cross-section.

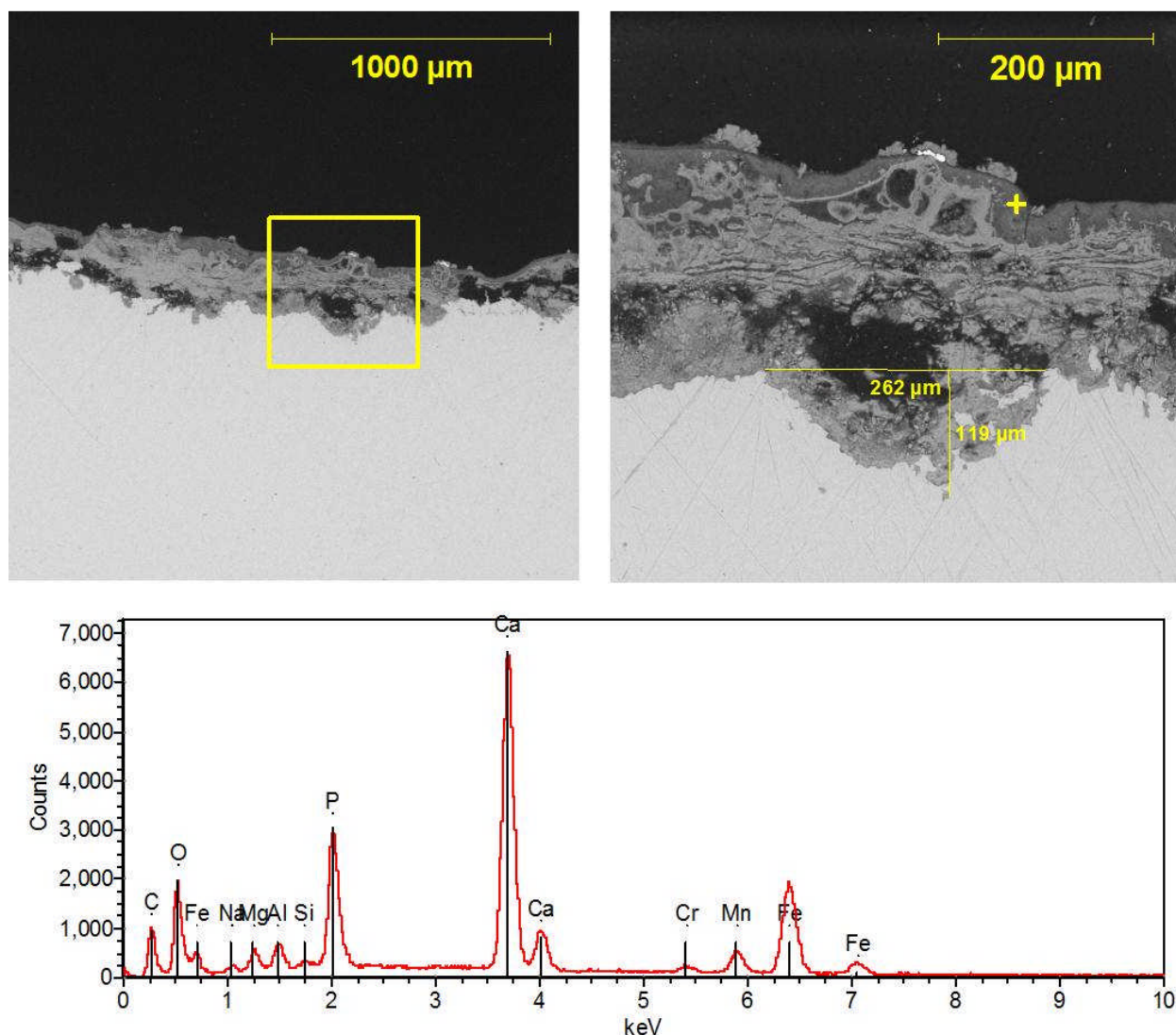
Figure 2-17. Scanning Electron Microscopy Images and Energy Dispersive Spectroscopy Spectra of a Wide, Shallow Pit on Coupon #1 from the B - 2 Jumper.



Another pit detected on the inner pipe surface of coupon #1 is shown in Figure 2-18. The pit is 10.2 mils wide and 4.6 mils deep with iron oxide/hydroxide in the pit and along the surface. Several smaller pits can also be seen near this pit in the left image with various morphologies ranging from undercutting to subsurface. A layer of tank waste residue was also detected on top of the corrosion layer. The EDS spectrum in Figure 2-18 was acquired at the yellow cross and shows the layer to be a calcium phosphate (similar to hydroxylapatite) with trace amounts of

sodium, magnesium, aluminum, and silicon. This tank waste layer was observed across the pipe cross-section, and it maintained a consistent elemental composition suggesting a single phase.

Figure 2-18. Scanning Electron Microscopy Images of a Pit on Coupon #1 of Jumper B - 2 and an Energy Dispersive Spectroscopy Spectrum of a Tank Waste Layer.



Small nodules and crystals were detected along the surface of the corrosion and tank waste layers. Figure 2-19 shows one set of these features. The images were acquired in backscatter electron image (BEI) mode which produces a brightness that corresponds to elemental mass. In other words, heavier mass elements reflect the impinging electrons better, producing a brighter spot in the image. The bright nodules in the right image are rich in silver as detected in the corresponding EDS. The darker particles attached to the nodules are a crystalline iron oxide/hydroxide. Silver has been detected in the past using SEM on corroded metals exposed to tank waste (RPP-RPT-56410, *Report on the Examination of Tank 241-AY-102 Removable*

Corrosion Probe Extracted in September 2013 from the Multi-Probe Corrosion Monitoring System). A possible mechanism is the electrochemical deposition of silver as silver ions are reduced at the metal surface due to the corrosion electrochemical circuit.

Figure 2-19. Scanning Electron Microscopy Images and Energy Dispersive Spectrometry Spectra of Particles on the Corrosion Layer.

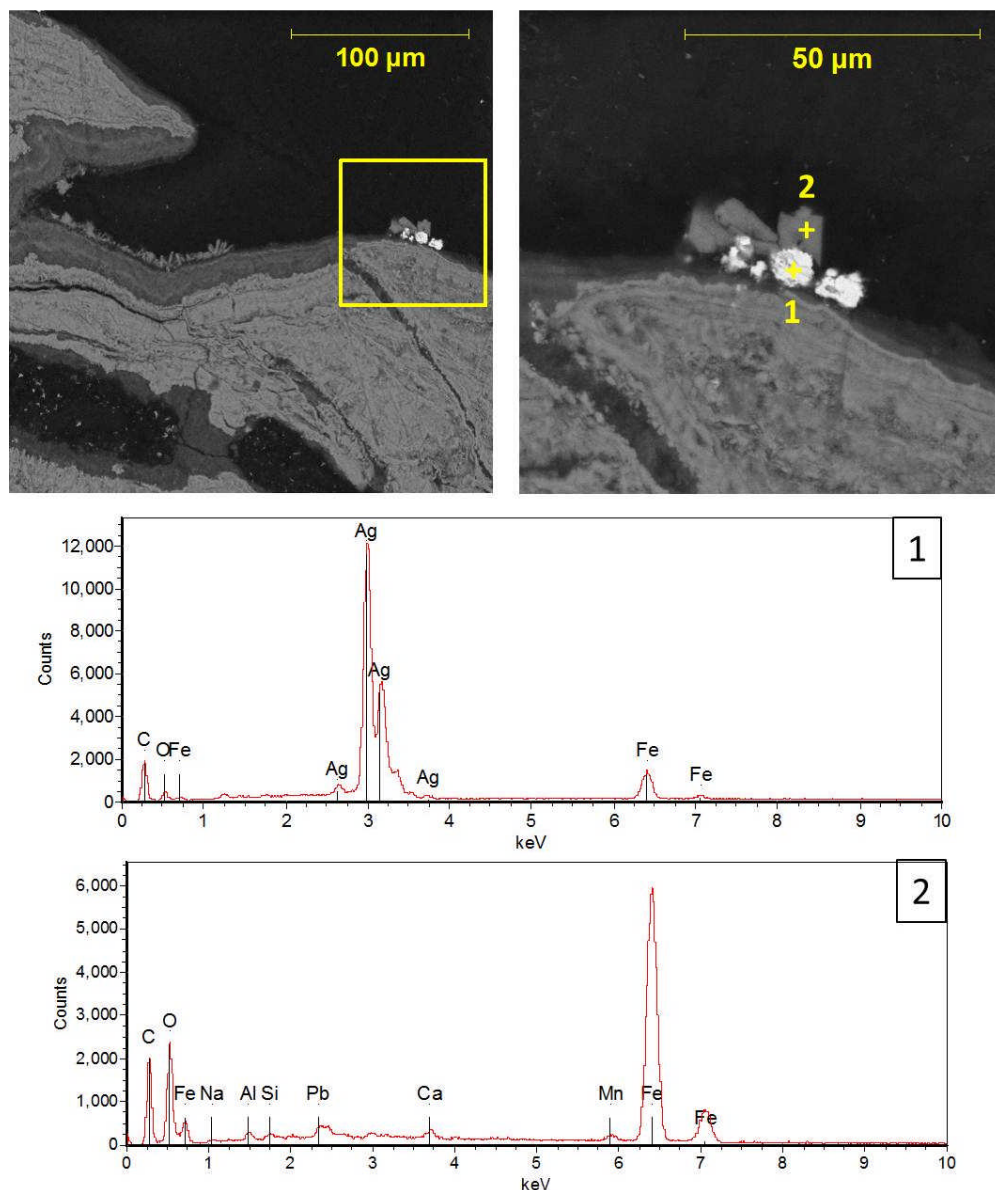
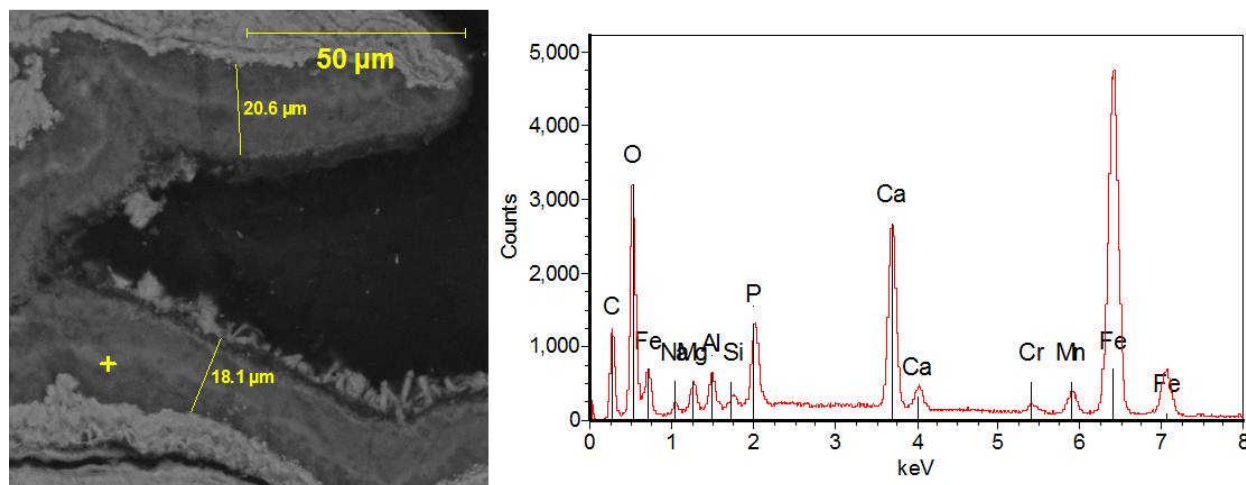


Figure 2-20 shows an SEM image of the tank waste layer on a section of corrosion which has partially lifted from the corrosion layer. The tank waste layer, ~0.8 mils (20 µm) thick, has penetrated this area and coated the corrosion indicating that the tank waste was deposited after the corrosion had formed and separated. The EDS spectrum from the marked location again shows the tank waste to be primarily calcium phosphate with trace sodium, magnesium, aluminum, and silicon.

Calcium phosphate is a relatively rare species in tank waste. However, it has been observed, typically in sludge due to the low solubility. It may have formed on the pipe surfaces when calcium-rich process water was used to flush residual supernatant, rich in phosphate.

Figure 2-20. Scanning Electron Microscopy Image and Energy Dispersive Spectrometry Spectrum of a Tank Waste Layer on the Corrosion Layer of Coupon #1 of Jumper B - 2.



2.4.2 Jumper B – 2 Coupon #2

Progressing down the flow of jumper B – 2 from the location of coupon #1, coupon #2 (OmniLims sample #S13R000607) was cut from the second straight section in the area shown in Table 2.3 and Figure 2-13. Unlike coupon #1, this coupon was not embedded in epoxy. Instead, coupon #2 was subject to a corrosion and residue removal treatment using ammonium citrate.

The exposure to hot ammonium citrate reacts with the iron oxide and loosens it from the surface along with any tank waste residue. Light brushing with a plastic bristle brush also helps remove these layers from the metal surface enabling photographic and SEM imaging of the inner wall of the jumper to detect signs of erosion and corrosion. Only one wash treatment was performed to remove a majority on the corrosion and tank waste from the inner surface.

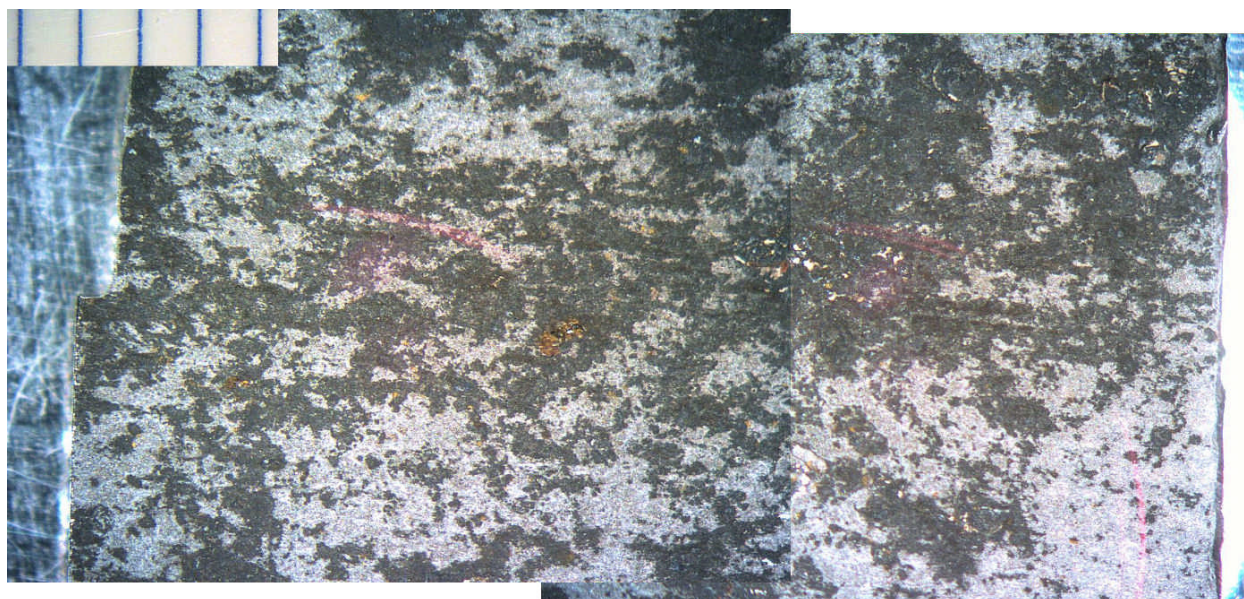
Photos of coupon #2 from jumper B – 2 were taken before and after the citrate treatment and are shown in Figure 2-21. The photo on the left was taken before the corrosion removal process, and a dark-brown, rough coating of corrosion and tank waste product is seen across the entire surface. The photo on the right was taken after the citrate treatment, and the surface is free of the brown layer. Much of the pipe surface is bare metal with black areas (possibly a thin oxide layer). Overall, the total mass loss due to removal of the corrosion and tank waste layers was only 0.4%, which indicates that there was only a minimal amount of corrosion and tank waste on the surface.

Figure 2-21. Photos of Coupon #2 from Jumper B – 2 Before (Left) and After (Right) the Ammonium Citrate Treatment Corrosion Removal Process.



The cleaned coupon was then imaged on the optical microscope to look for features which might indicate corrosion or erosion. Figure 2-22 is the resulting mosaic of two combined images since the size of the coupon did not allow for a complete view at the lowest magnification. The scale bar in the upper left is in increments of 1/16 of an inch.

Figure 2-22. Photomicrograph of Coupon #2 After the Corrosion Layer was Removed.

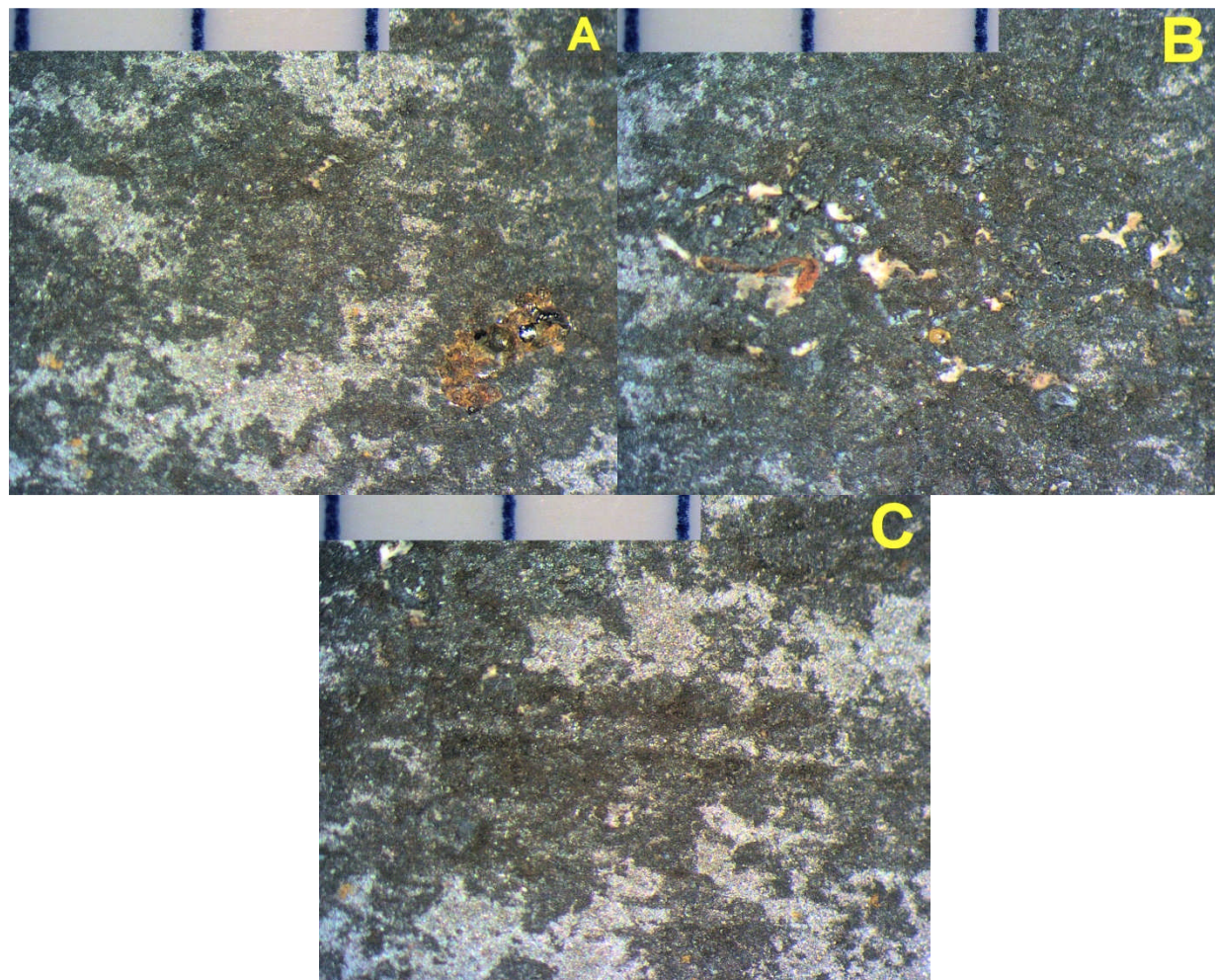


A National Institute of Standards and Technology (NIST) certified micrometer was used to measure the thickness of the cleaned coupon at the four corners. The resulting thicknesses were

0.219, 0.222, 0.208, and 0.202 inches, and the measured UT thicknesses near these locations were 0.237, 0.225, 0.234, and 0.226 inches. The inability to measure at the exact same locations (due to cutting near and on the UT spots, and the coating on the outside of the pipe) may have contributed to the discrepancy.

The following figure shows three photomicrographs which are magnified views of different areas on coupon #2. The scale bar in the figures is marked at 1/16-inch increments. Figure 2-23A shows that the surface of the pipe is a combination of bare metal (light-gray material) and pitted metal (dark-gray material). A spot of blistering orange-brown corrosion is seen in the lower right which was not fully removed during the citrate treatment. Figure 2-23B was taken on a location of the coupon which displayed flakes of a yellowed, shiny material adhered to the surface (possibly remnants of a tank waste layer). Figure 2-23C is an image that represents the majority of the pipe inner surface, containing a mix of bare metal and a thin layer of pitted metal.

Figure 2-23. Photomicrographs of Different Locations of the Cleaned Coupon #2 from the B - 2 Jumper.

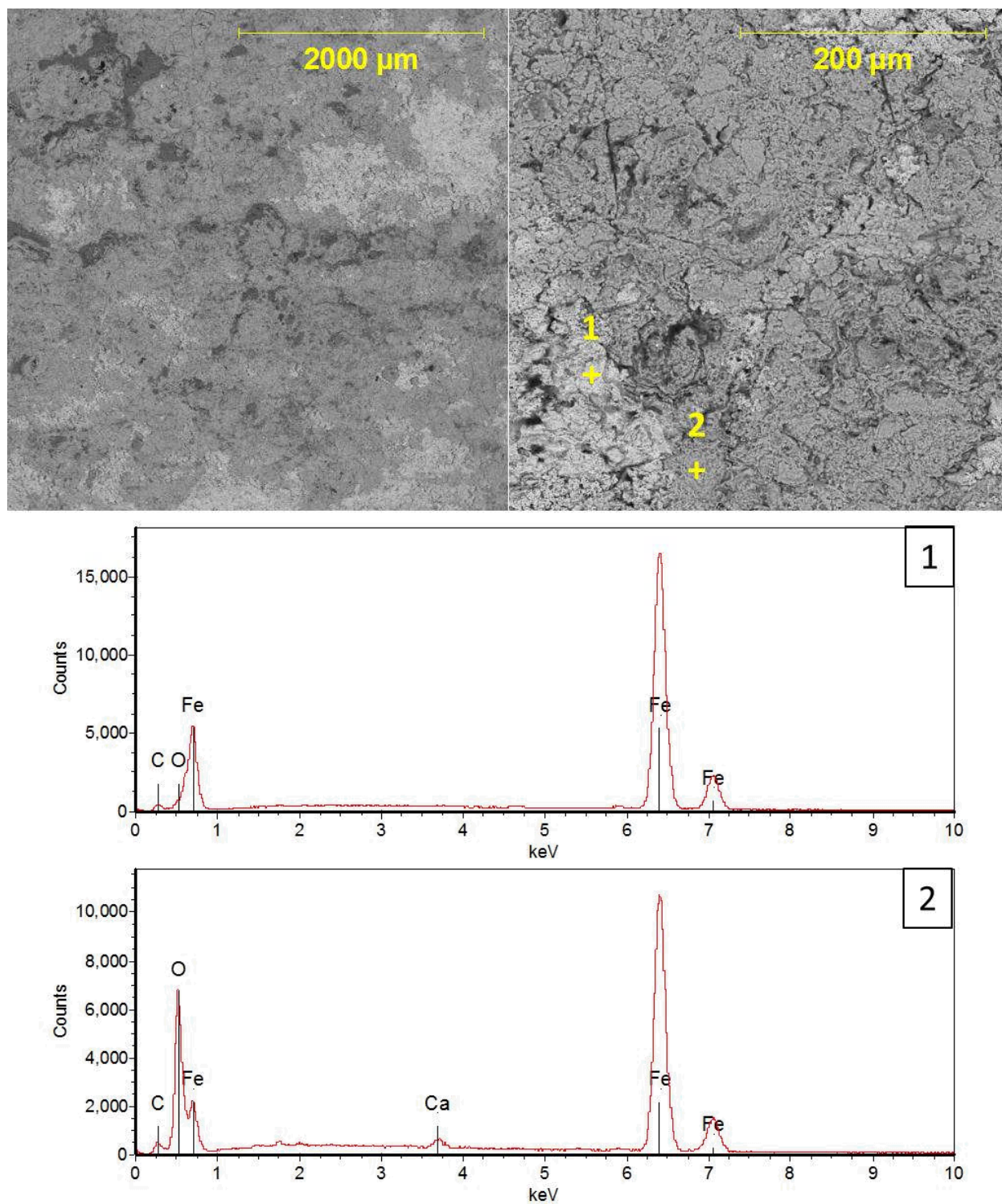


Viewing the inner surface of coupon #2 from jumper B – 2 revealed no features which would positively indicate that erosion-corrosion occurred in this area of the pipe. The effects of erosion-corrosion are reported in the literature as displaying a range of features which are dependent on the Reynolds number of the flowing medium. A turbulent flow tends to produce scalloped or scale-like features on the surface of the pipe with sizes relative to the amount of turbulent flow (more turbulence creates smaller scallops). (Poulson 1991, and “Flow Accelerated Corrosion and Cracking of Carbon Steel Piping in Primary Water – Operating Experience at the Point Lepreau Generating Station,” [Gendron and Slade 2005]).

Coupon #2 was then loaded into the SEM for higher magnification imaging and elemental identifications. The coupon was analyzed at high vacuum using both secondary electron image (SEI) and BEI modes. SEI mode affords improved surface morphology compared to BEI, but BEI provides information on elemental mass as heavier elements reflect electrons better, producing a brighter spot on the image.

Figure 2-24 shows two BEI images taken at different magnifications. The left image is a general view of the coupon surface showing three shades of gray on the surface. Since BEI mode produces a brighter image for heavier elements, the brightest areas of the coupon are locations of bare metal while the darker locations are layers on the surface comprised of elements lighter than iron. This is confirmed in the EDS spectra acquired at the marked locations on the magnified image on the right. Spot #1 is from the brighter area, and the elements iron and carbon from the pipe are detected. Spot #2 is from the darker area and shows the presence of oxygen with trace calcium in addition to the metal, indicating a thin layer of oxide on the pipe surface. These different locations were also seen in the photos of the coupon, Figure 2-23, as lighter and darker areas.

Figure 2-24. Scanning Electron Microscopy Images and Energy Dispersive Spectrometry Images of Bare Metal and an Oxide Layer on Coupon #2 of Jumper B – 2.



The darkest areas in the images of Figure 2-24 are locations where a layer of tank waste residue remained on the coupon after the citrate treatment. The locations where this layer was detected

tended to be areas of thicker corrosion which may have resulted in a thicker waste layer or prohibited effective removal by the coupon cleaning and scrubbing process. Figure 2-25 shows an SEM image and resulting EDS spectrum of a patch of this tank waste layer. The elemental makeup of the waste suggests a form of calcium phosphate (such as hydroxylapatite).

Figure 2-25. Scanning Electron Microscopy Analysis of a Tank Waste Layer on Coupon #2 of Jumper B – 2.

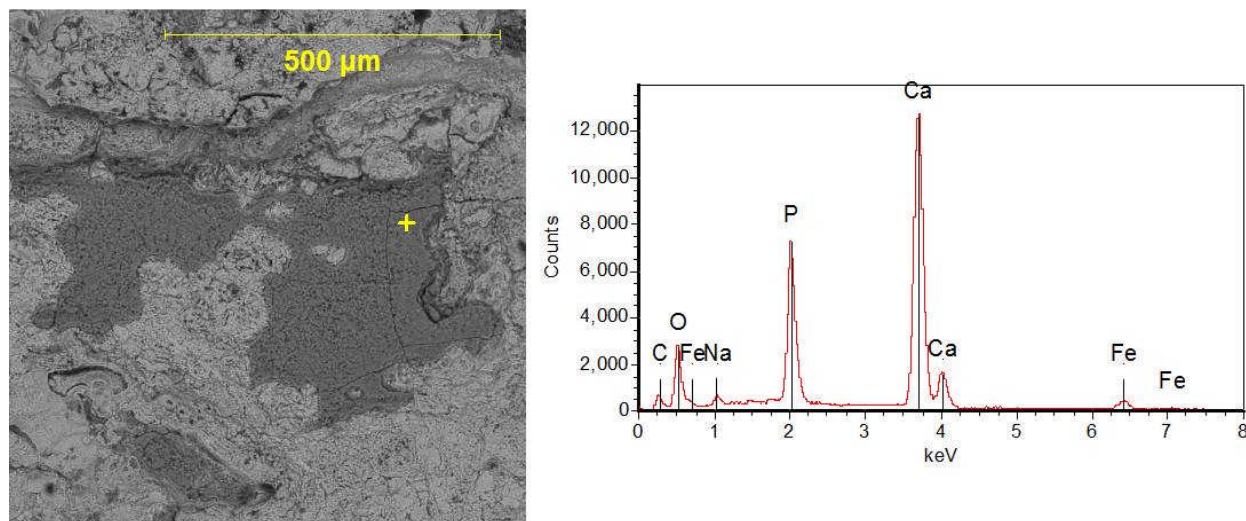
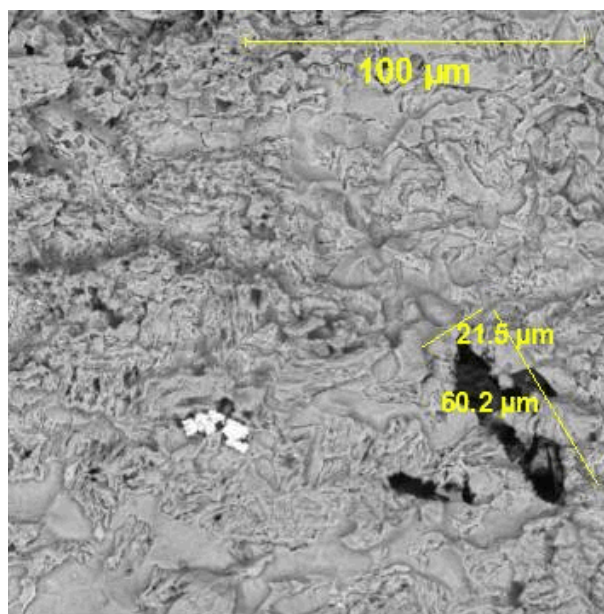


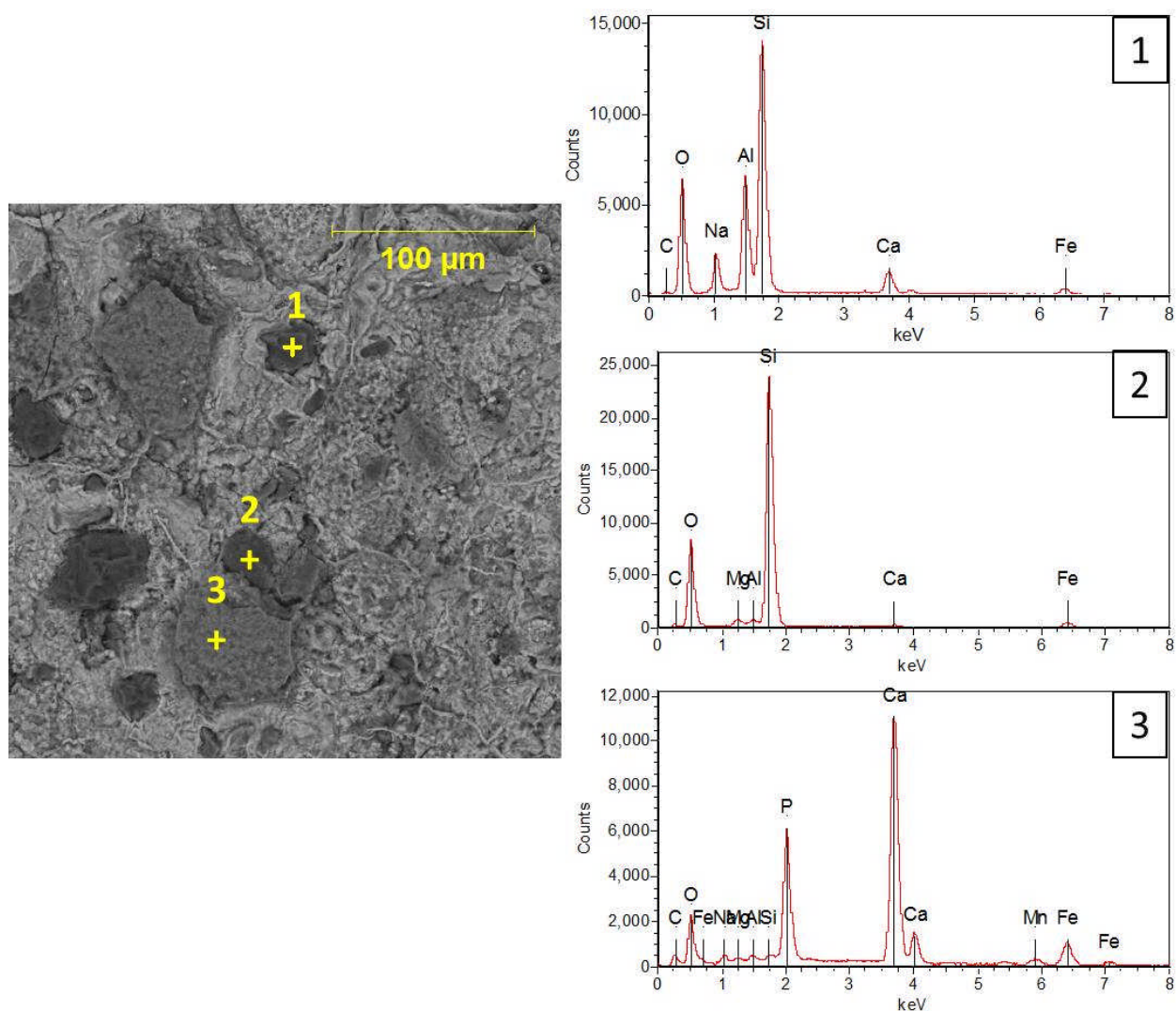
Figure 2-26. Scanning Electron Image of a Pit on Coupon #2 of Jumper B – 2.

Some pitting was also observed on coupon #2 from jumper B – 2. Figure 2-26 shows a small pit measuring 2.3 mils (60.2 μm) by 0.8 mils (21.5 μm). The bright particles to the left of the pit are silver particles, seen routinely near other pits and corrosion on both jumper sections and in previous corrosion analyses using passive corrosion coupons (RPP-RPT-56410); this is probably from the electrochemical corrosion circuit reducing ionic silver from the surrounding solution.



Occasionally, other particles were detected embedded in the corrosion layer that remained on the surface after the citrate treatment. Figure 2-27 shows a sodium aluminosilicate (possibly cancrinite) at spot #1, a silicate (quartz) at spot #2, and the calcium phosphate layer at spot #3. In addition, aluminum oxide particles were also detected (images not shown).

Figure 2-27. Scanning Electron Microscopy Image and Energy Dispersive Spectrometry Spectra of Different Particles Embedded In and On the Corrosion Layer.



In total, the citrate treatment removed enough of the corrosion and tank waste layers to allow imaging of the bare metal surface in several locations. Although some small pits and general corrosion was observed, no clear indications of erosion-corrosion were detected. Residual tank waste layers on the coupon were identified as calcium phosphate, and various tank waste-related and soil-related particles were seen embedded in the corrosion layer.

2.4.3 Jumper B – 2 Coupon #3

The final coupon cut from jumper B – 2, coupon #3 (OmniLims sample #S13R000608), was located on the third straight section of the jumper near connector B as indicated in Table 2.5 and Figure 2-13. Like coupon #2, this coupon was subjected to the corrosion and residue removal treatment using ammonium citrate to enable photographic and SEM imaging of the inner wall of the jumper to detect signs of erosion and corrosion.

Photos of coupon #3 from jumper B – 2 were taken before and after the citrate treatment and are shown in Figure 2-28. The upper photo is from before the corrosion removal process, and a dark-brown, rough coating of corrosion and tank waste product is seen across the entire surface. A small scratch in the middle of coupon is from handling with tweezers. The left side of the coupon contains a weld. On the weld is a drop of water from wet tweezers that were used to transfer the coupons to the citrate bath. The lower photo was taken after the citrate treatment, and the surface is free of a majority of the brown layer. A large portion of the pipe surface is bare metal with darker areas (possibly a thin oxide layer). Overall, the total mass loss due to removal of the corrosion and tank waste layers was only 0.4%, indicating that there was only a minimal amount of corrosion and tank waste on the surface.

The cleaned coupon was then imaged on the optical microscope to look for features which might indicate corrosion or erosion. Figure 2-29 is the combination of two images that show the majority of the span across the coupon since the size of coupon did not allow for a complete view at the lowest magnification. The scale bar in the lower left is in 1/16-inch increments.

Figure 2-28. Photos of Coupon #3 from Jumper B - 2 Before (Top) and After (Bottom) Corrosion Removal by the Ammonium Citrate Treatment.

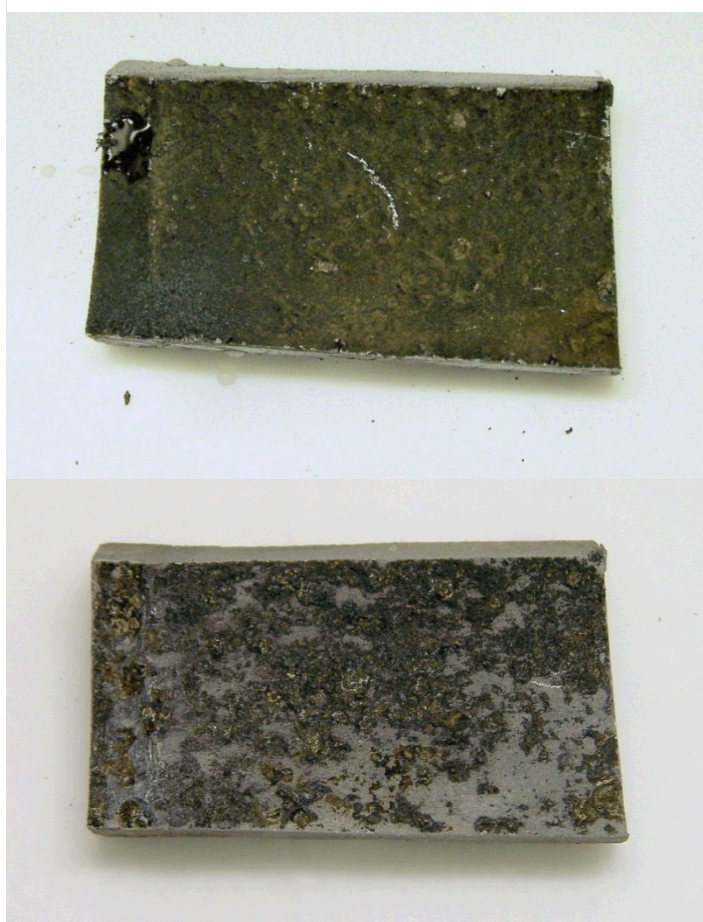
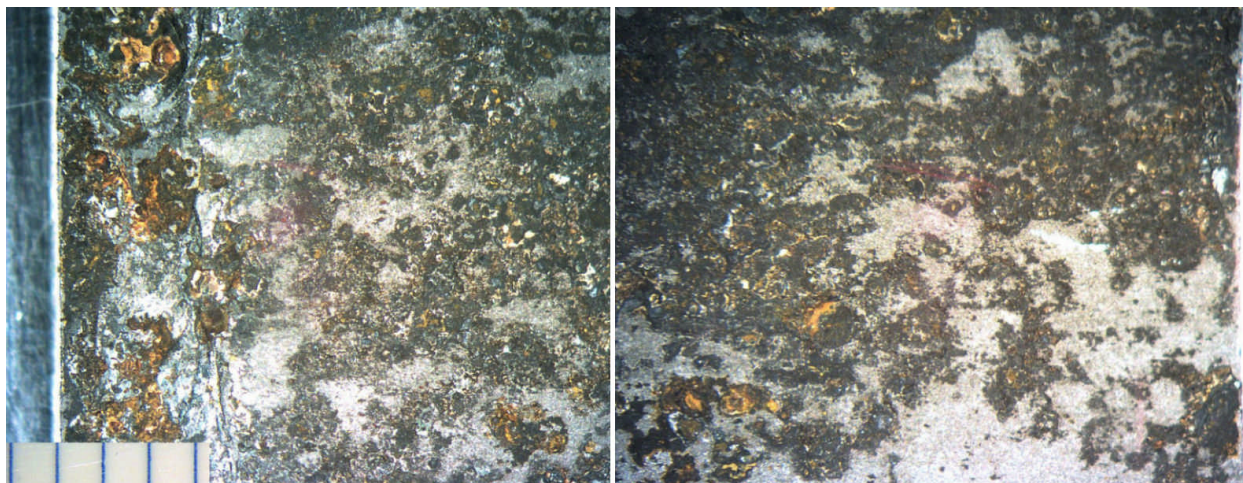
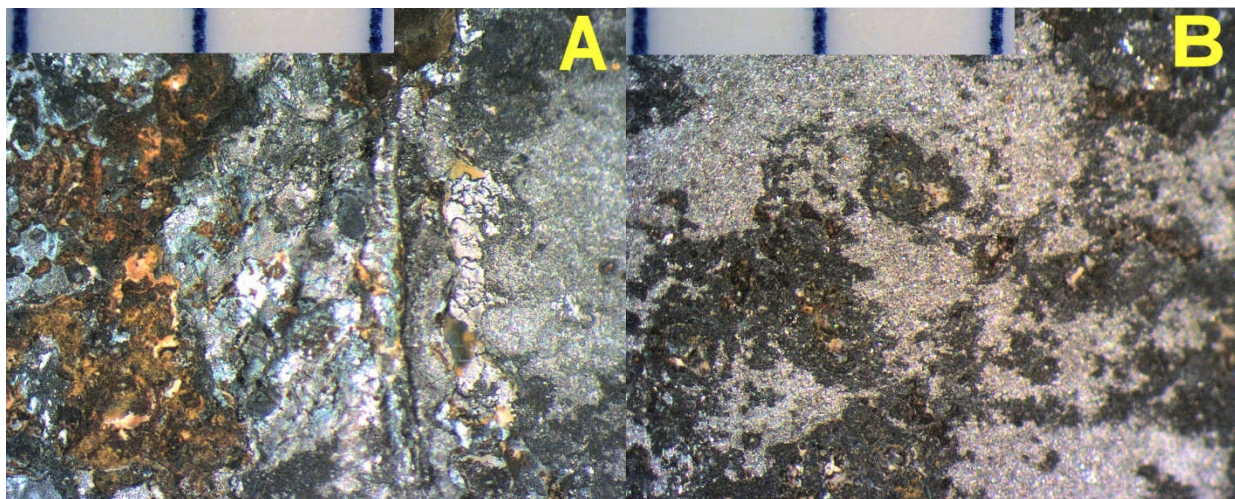


Figure 2-29. Photomicrographs of Coupon #3 After the Corrosion Layer was Removed.

A NIST-certified micrometer was used to measure the thickness of the cleaned coupon at the four corners. The resulting thicknesses were 0.232, 0.227, 0.227, and 0.224 inches, and the measured UT thicknesses near these locations were 0.222 and 0.211 inches. The inability to measure at the exact same locations (due to cutting near and on the UT spots and the coating on the outside of the pipe) and the presence of the weld may have contributed to any discrepancy.

The following figure shows two photomicrographs which are magnified views of different areas on coupon #3. The scale bar in the figures is marked at 1/16-inch increments. Figure 2-30A shows the area at the weld where it joins with the pipe (dark line right of center). Some orange-brown corrosion (probably an iron oxide/hydroxide) is adhered to the weld. Overall, there is no scalloping on the pipe surface right of the weld (downstream), indicating no noticeable erosion-corrosion. Figure 2-30B is an image that represents the majority of coupon #3. There are areas of bare metal with patches of a darker, thin layer of the metal oxide and possibly some tank waste residue. The surface appears rough from general corrosion but shows no indications of erosion-corrosion.

Figure 2-30. Photomicrographs of Different Locations of the Cleaned Coupon #3 from the B – 2 Jumper.



Coupon #3 was then loaded into the SEM for higher magnification imaging and elemental identifications. The coupon was analyzed at high vacuum using both SEI and BEI modes.

Figure 2-31 shows two BEI images taken at different magnifications of the weld on coupon #3 of jumper B – 2. The left image is a general view of the weld showing layers of varying shades of gray on the surface. The brightest areas of the coupon are locations of bare metal, while the darker locations are layers of corrosion product and tank waste comprised of elements lighter than iron. This is confirmed in the EDS spectra acquired at the marked locations on the magnified image on the right. Spot #1 is from the brighter area, and the elements of iron and trace copper from the weld are detected. Spot #2 shows the presence of oxygen with iron indicating a layer of oxide on the weld surface. Spot #3 is part of a layer of tank waste which survived the ammonium citrate treatment and is comprised of a calcium phosphate phase such as hydroxylapatite. In general, the weld appears intact with minimal general corrosion and no indication of erosion-corrosion.

A location away from the weld and representative of the inner pipe wall of the coupon was analyzed, and the resulting SEM images and EDS spectra are shown in Figure 2-32. Similarly to the section at the weld, the image also shows three main areas, bare metal exposed by the ammonium citrate treatment (spot #1), a thin layer of the corrosion product, iron oxide (spot #2), and parts of a tank waste layer made up of a calcium phosphate phase (spot #3) that survived the cleaning process. The bare metal surface reveals a rough surface caused by general corrosion across the inside surface of pipe, and there are no noticeable scalloped features that would indicate erosion-corrosion.

Figure 2-31. Scanning Electron Microscopy Images and Energy Dispersive Spectrometry Spectra of the Weld on Coupon #3 of Jumper B – 2.

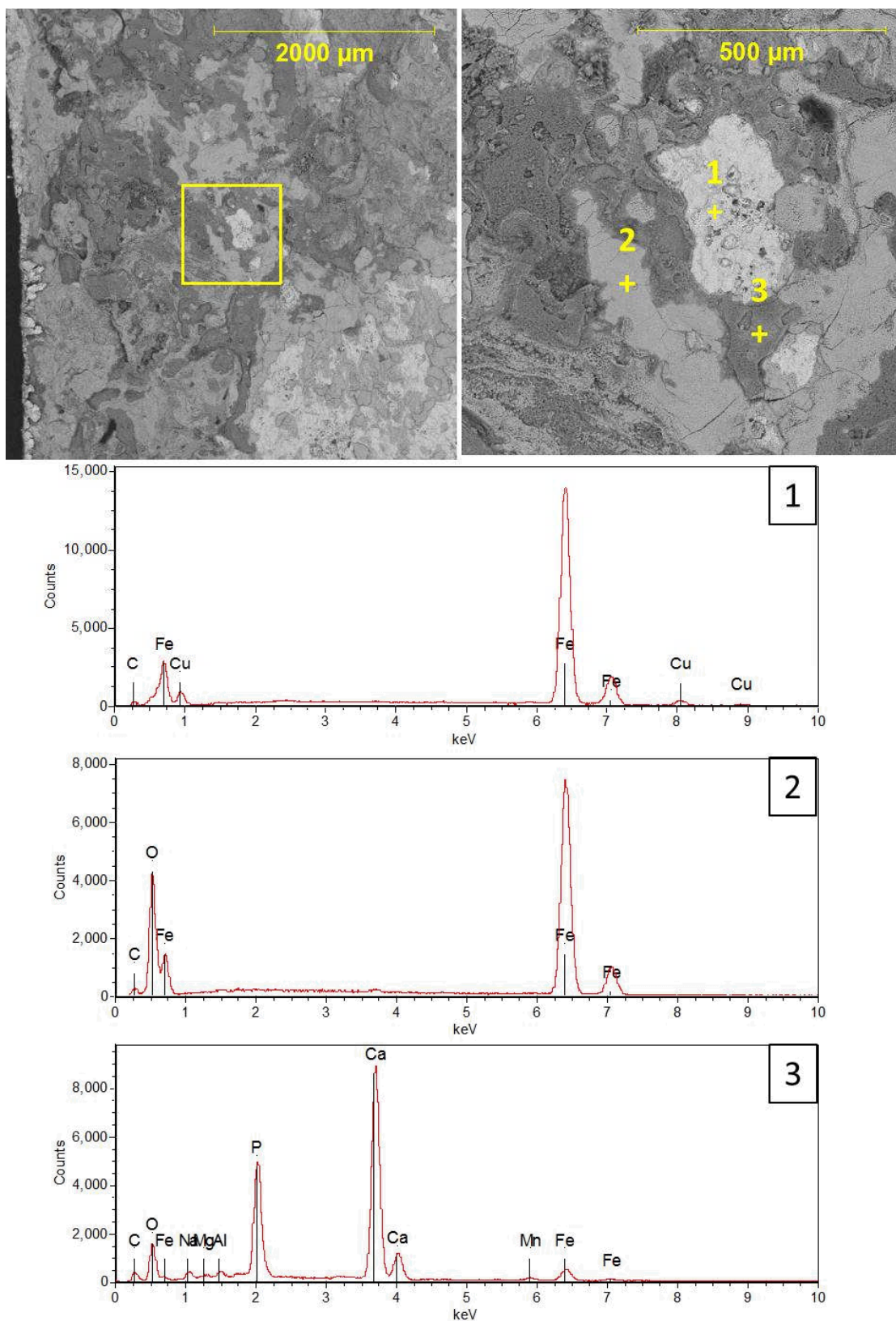


Figure 2-32. Scanning Electron Microscopy Images and Energy Dispersive Spectrometry Spectra of the Inside Surface on Coupon #3 of Jumper B – 2.

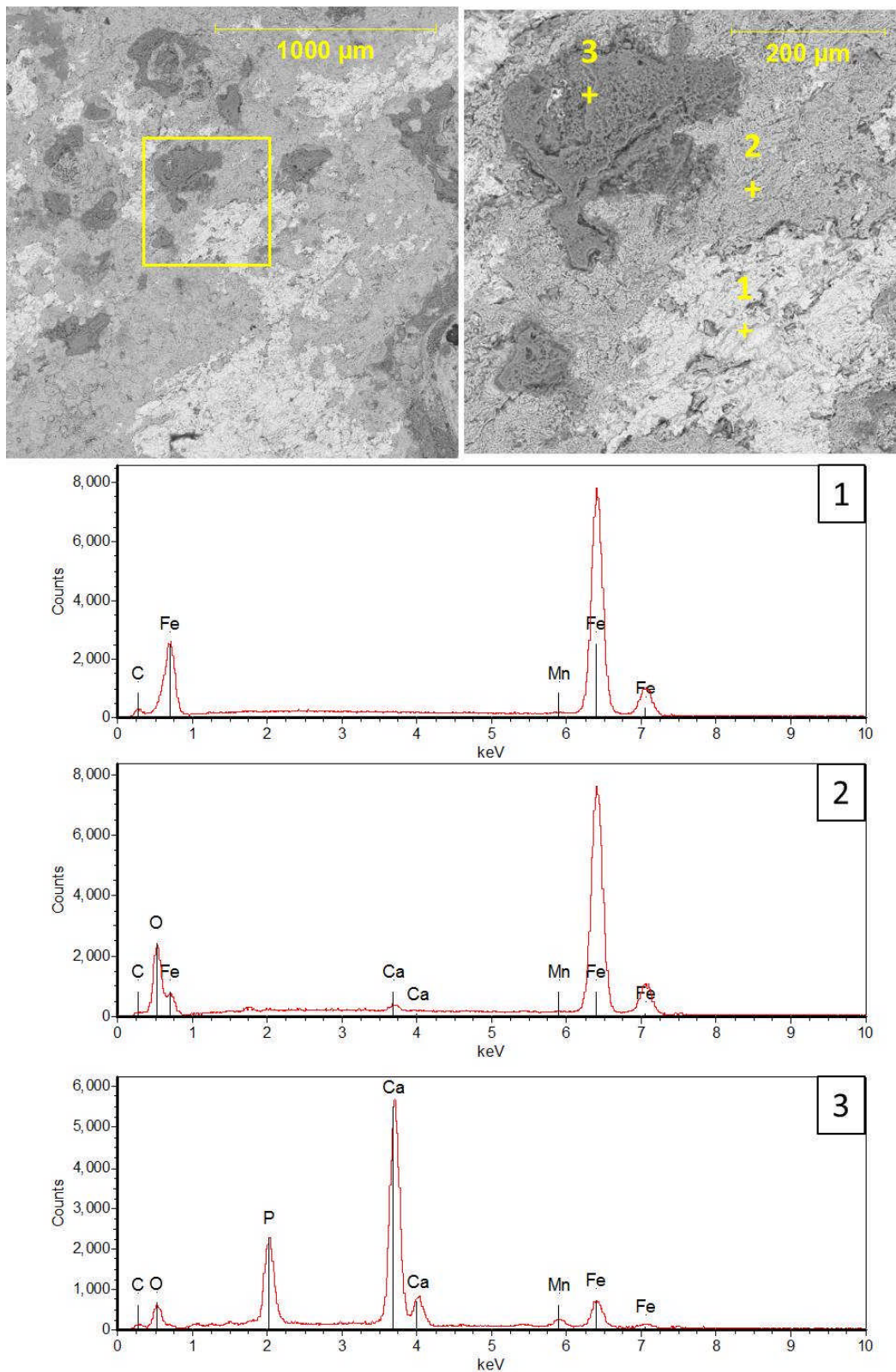
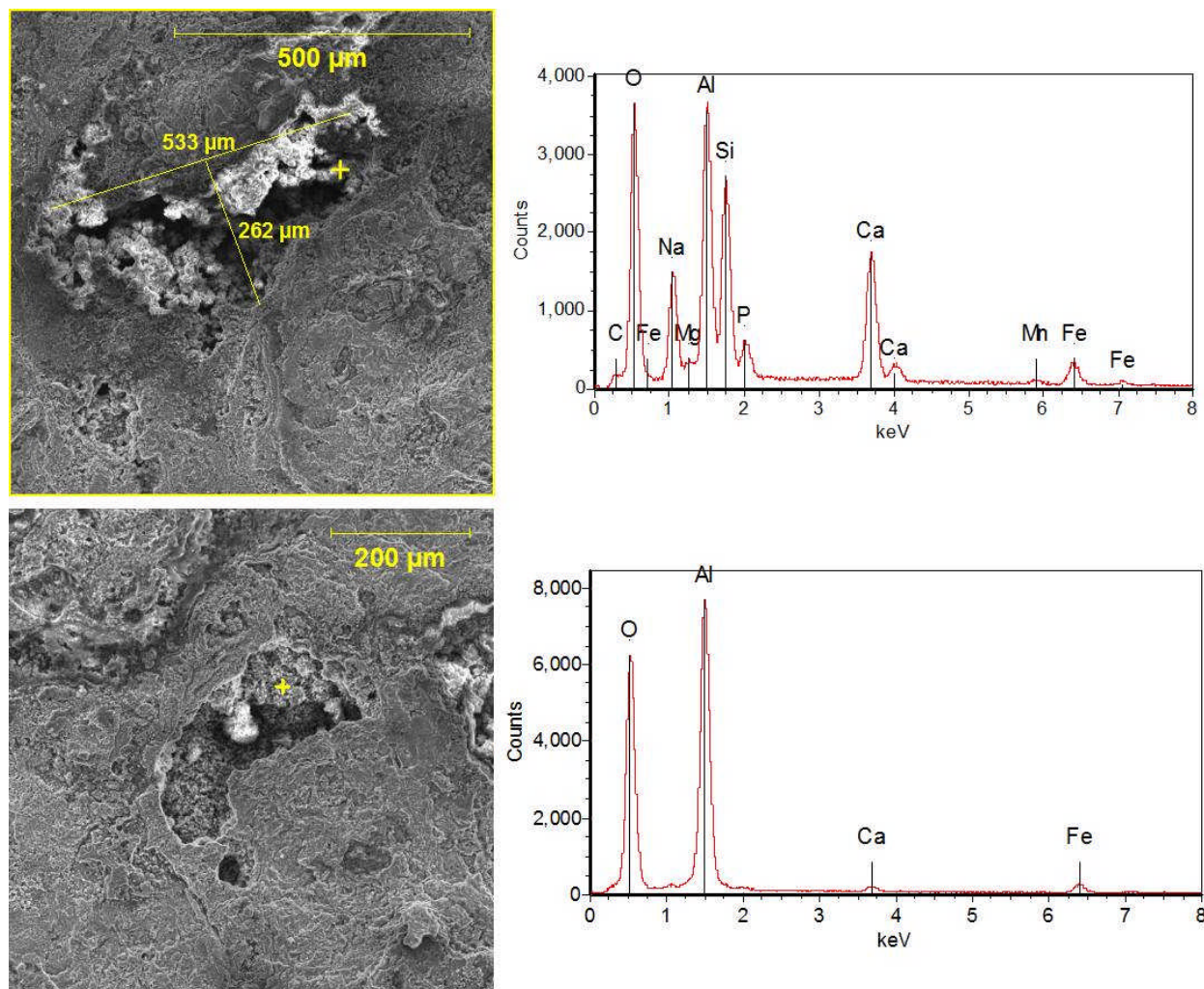


Figure 2-33 displays two pits that were characterized using SEI mode of the SEM providing morphology and the perspective of depth of these features. The pit in the upper image measured 20.8 mils (533 μm) by 10.2 mils (262 μm) and has a mixture of tank waste particles inside the pit comprised of both sodium aluminosilicate and calcium phosphate. The pit in the lower image measured at about 12 mils (300 μm) across contained aluminum oxide (possibly gibbsite) particles.

Figure 2-33. Scanning Electron Microscopy Images and Energy Dispersive Spectrometry Spectra of Pits on Coupon #3 of Jumper B – 2.



In total, the citrate treatment removed enough of the corrosion and tank waste layers to allow imaging of the bare metal surface on both the pipe wall and weld area. Although some small pits and general corrosion was observed, no clear indications of erosion-corrosion were detected on the pipe or the weld. A residual tank waste layer on the coupon was identified as calcium phosphate, and various tank waste-related and soil-related particles were seen embedded in the pits.

3 JUMPER 1 – 4

3.1 SAMPLE UNPACKING, DECONTAMINATION, AND ULTRASONIC TRANSDUCER MEASUREMENT PREPARATION

Jumper 1 – 4 was received at the 222-S Laboratory in two sections packed inside an 85-gallon drum. The jumper was size reduced as part of the packaging in the field by unbolting the side fittings of a ball valve. This allowed the pieces to meet the size and weight restrictions required for the lab to handle in the hot cell. The larger section was ~3.5 ft long with a single long radius elbow and one Purex connector block, and the smaller section was ~1.0 ft long with a single Purex connector block, see Figure 1-3. The longer section was removed from the drum and placed in hood 1 of room 1-E. Figure 3-1 shows this jumper in its original packaging (A) and after cutting off tape/package and replacing the packaging with a new bag (B), which aided in the control of the removable contamination on the jumper. Similar to jumper B – 2, several locations on jumper 1 – 4 contained patches and splatters of a white paint. In addition, a large, yellow label was attached to the pipe near the connector block end of the jumper. The paint and label interfered with some of the requested UT measurements due to the thickness and roughness of the coatings. Several rust spots were also present on the jumper, especially on the bottom of the pipe, possibly from repeated hanging droplets of moisture during its lifetime in the pump pit. These rust spots were a source of higher levels of removable contamination and made it more challenging to decontaminate. Some areas of rust, where no UT measurements were planned, were covered with tape. The ends were also covered with rubber matting and tape. Similar to jumper B – 2, templates were used to mark the locations of the UT measurements. Notes were made on the UT data sheets (Attachment A) when the measurements were acquired in the areas of paint, label, or rust.

Figure 3-1. Photographs of the Larger Jumper 1 – 4 Section Before and After Removal of the Packaging.



The smaller section of jumper 1 – 4 was removed from the shipping drum and placed in hood 1 of room 1 – E after the decontamination process was finished on the longer section. During the packaging removal, high levels of removable contamination were measured on the pipe surfaces. The pipe was decontaminated using a series of wet and dry wipes with paper towels, and the ends were covered with three layers of rubber matting and tape to bring the removable contamination and dose levels down to enable the UT measurements. Figure 3-2 shows a photograph of the smaller jumper 1 – 4 section after decontamination.

Figure 3-2. Photo of the Smaller Section of Jumper 1 – 4 After Decontamination.



Similar to jumper B – 2, the UT measurement locations were marked on this jumper section using the white paint marker with guidance from the customer supplied UT maps, Attachment A.

3.2 ULTRASONIC TRANSDUCER THICKNESS MEASUREMENTS

Pipe wall thicknesses were acquired across the two sections of jumper 1 – 4 using the same UT probe and method as was used for jumper B – 2. Wall thicknesses were measured at locations around the jumper section at the pre-marked locations to determine where, if any, thin spots were located on the jumper which may have occurred due to general corrosion and/or erosion-corrosion of the inner wall by the pumping of the tank waste. The UT couplant was applied in droplets over marked locations, and the transducer was placed on the pipe through the couplant and manipulated until a strong signal was received on the UT instrument. This was repeated until all the UT measurement locations were completed. The results of the UT measurements are reported in Attachment A.

Certified calibration blocks were used to check the accuracy of the UT probe and instrument throughout the pipe wall thickness measurement process. The same calibration blocks used for jumper B – 2 were also used for jumper 1 – 4. The calibration blocks were analyzed by the UT probe before (pre), and after (post) each series of data collection on each area of the jumper sections.

UT thickness measurements were acquired on the pipe and connector blocks. The 3-inch carbon steel pipe contained straight piping and one long radius 90-degree elbow. Measurements on the straight piping consisted of 16 equally-spaced points around the perimeter of the pipe forming a band. Figure 3-3 shows a drawing of the larger section of jumper 1 – 4 with several of these bands located on the inlet side of the pipe. The elbow sections consisted of 12 equally-spaced points around the pipe perimeter. The three points on the intrados of the bend were not requested (see Figure 3-3) due to the inability to properly lay the UT probe on the pipe surface in this area. The corresponding UT pipe wall thickness results for the labeled bands in Figure 3-3 are shown in Tables 3-1 and 3-2.

Figure 3-3. Locations of Ultrasonic Transducer Thickness Measurements on the Inlet Area of Jumper 1 – 4.

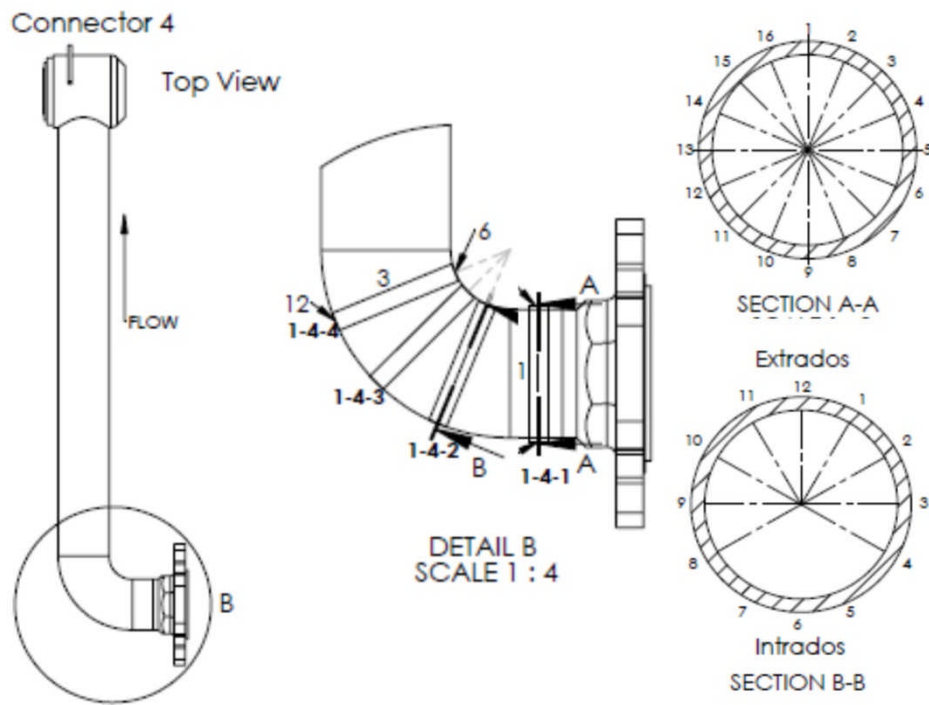


Table 3-1. Measured Ultrasonic Transducer Pipe Wall Thicknesses in Inches for the First Straight Section of Jumper 1 – 4.

Location on Band	UT Map Band Label
	1-4-1
1	0.252
2	0.249
3	0.241
4	0.256
5	0.260
6	0.265
7	0.242
8	0.237
9	0.226
10	0.252
11	0.259
12	0.256
13	0.241
14	0.242
15	0.248
16	0.269

Table 3-2. Measured Ultrasonic Transducer Pipe Wall Thicknesses in Inches for the First Elbow Section of Jumper 1 – 4.

Location on Band	UT Map Band Label		
	1-4-2	1-4-3	1-4-4
1	0.234	0.244	0.241
2	0.257	0.235	0.267*
3	0.256	0.261*	0.260*
4	0.257	0.254	0.243
5	N/A	N/A	N/A
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	0.235	0.232	0.234
9	0.245	0.224	0.224
10	0.254	0.239	0.235
11	0.243	0.241	0.235
12	0.247	0.249	0.239

* - Epoxy Paint on UT Measurement Location and/or Rough Surface.

Similar to jumper B – 2, there was no significant thinned section on this area of the pipe. The thinnest measurement of 0.224 inches was located on the bottom of the elbow (as arranged in the drawing in Figure 3-3).

Two more straight sections were analyzed by the UT, Figure 3-4. The section closest to the outlet contained a large yellow label painted onto the pipe. Pipe thickness measurements were acquired over the label, but the quality of the measurement is suspect due to the roughness and thickness of the paint. The UT measurement results are shown in Tables 3-3 and 3-4. The locations of the coupons cut from the jumper are marked with the dashed box around the UT measurement results. The locations were chosen based on the UT results and through consultation with the customer.

Figure 3-4. Locations of Ultrasonic Transducer Thickness Measurements on the Outlet Area of Jumper 1 - 4.

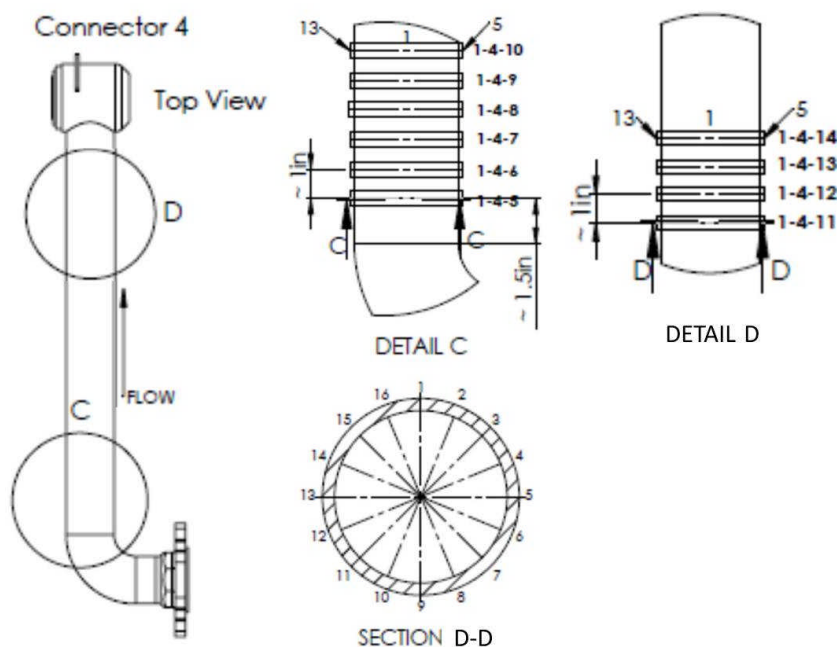


Table 3-3. Measured Ultrasonic Transducer Pipe Wall Thicknesses in Inches for the Second Straight Section of Jumper 1 – 4. (2 sheets)

Location on Band	UT Map Band Label					
	1-4-5	1-4-6	1-4-7	1-4-8	1-4-9	1-4-10
1	0.236	0.228	0.232	0.235	0.228	0.232
2	0.226	0.230	0.241*	0.236*	0.235*	0.218
3	0.212	0.219	0.228*	0.231	0.220*	0.211
4	0.230	0.232*	0.232	0.233	0.228	0.230
5	0.236	0.251*	0.245	0.244*	0.248*	0.245*
6	0.253	0.246	0.243	0.250*	0.242	0.244*
7	0.241	0.242	0.240	0.247	0.242	0.242
8	0.230	0.219	0.230	0.227	0.222	0.228
9	0.230	0.236	0.227	0.228	0.225	0.230
10	0.220	0.228	0.215	0.230*	0.225	0.222
11	0.230*	0.231	0.228	0.254*	0.243*	0.225
12	0.220*	0.226	0.220	0.220	0.224	0.245*
13	0.233*	0.226	0.217	0.227	0.224	0.230*

Table 3-3. Measured Ultrasonic Transducer Pipe Wall Thicknesses in Inches for the Second Straight Section of Jumper 1 – 4. (2 sheets)

Location on Band	UT Map Band Label					
	1-4-5	1-4-6	1-4-7	1-4-8	1-4-9	1-4-10
14	0.232*	0.232	0.232*	0.233	0.231	0.230
15	0.231	0.230	0.233	0.222	0.223	0.251*
16	0.228	0.232	0.222	0.218	0.218	0.217

* - Epoxy Paint on UT Measurement Location and/or Rough Surface.

---- - Area where coupon #1 was cut.

Table 3-4. Measured Ultrasonic Transducer Pipe Wall Thicknesses in Inches for the Third Straight Section of Jumper 1 – 4.

Location on Band	UT Map Band Label			
	1-4-11	1-4-12	1-4-13	1-4-14
1	0.247*	0.233*	0.253*	0.243*
2	0.244*	0.245*	0.250*	0.241*
3	0.241*	0.245*	0.235*	0.249*
4	0.223	N/A*	N/A*	0.226
5	0.230	0.225	0.231	0.243
6	0.230	0.232	0.236	0.237
7	0.236	0.238	0.241	0.248
8	0.228	0.220	0.231	0.238
9	0.220	0.217	0.223	0.228
10	0.228	0.228	0.221	0.231
11	0.223	0.228	0.228	0.231
12	0.224	0.227	0.224	0.223
13	0.228	0.228	0.230	0.226
14	0.226	0.227	0.225	0.232
15	0.246*	0.252*	N/A*	0.245*
16	0.247*	0.247*	0.244*	0.240*

* - Yellow Paint Label Between Transducer and Surface of Pipe.

---- - Area where coupon #2 was cut.

The thinnest wall reading was measured on the straight section immediately after the elbow and was 0.211 inches. There were several locations on this section that contained droplets of the white paint (see Figure 3-1), however, the UT measurements were still obtained. The following straight section had a yellow label painted or applied to the surface. The thickness measurements in this location did produce results about a hundredth of an inch thicker than the pipe without a label. The discrepancy may have resulted from the different sound velocity and thickness of the label. In all, the UT measurements were above or around the nominal wall thickness of 0.216 inches, and no definitive areas of wall thinning were observed.

The jumper section also contained a Purex connector block. A drawing of the connector block is in Figure 3-5 which shows the UT measurement locations around this pipe section. The results

for this pipe section are in Table 3-5. Many of the UT measurement locations on this connector contained either a bar welded to the surface or droplets/splatters of white paint, but the measurements that were acquired do show good consistency in the thicknesses, indicating the precision of the fabrication and lack of any erosion-corrosion.

Figure 3-5. Locations of Ultrasonic Transducer Thickness Measurements on Connector 4 of Jumper 1 - 4.

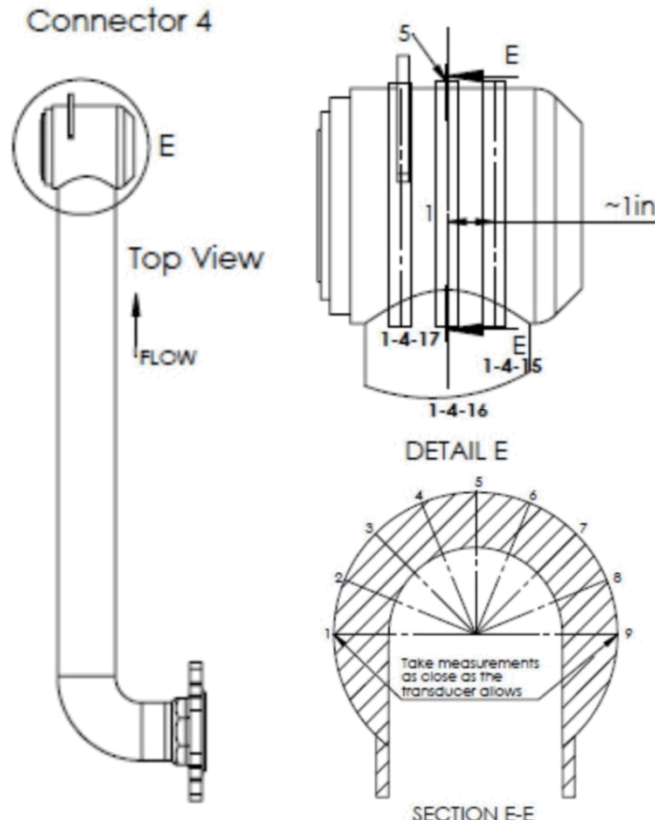


Table 3-5. Measured Ultrasonic Transducer Pipe Wall Thicknesses in Inches for Connector 4 of Jumper 1 – 4.

Location on Band	UT Map Band Label		
	1-4-15	1-4-16	1-4-17
1	—*	—**	—**
2	—*	—**	—**
3	—*	1.000	—**
4	—*	—**	1.000
5	0.985	1.000	0.999
6	0.985	0.999	1.000
7	1.000	0.985	0.999
8	0.999	1.000	1.000
9	0.998	1.000	1.000

* - Area covered with welded bar.

** - Area contained white paint.

The smaller pipe section of jumper 1 – 4 contained one straight section and one Purex connector block. Figure 3-6 shows two drawings of this pipe section. The first drawing shows the measurements for the straight section, and the second drawing shows the locations for the measurements for the connector. Tables 3-6 and 3-7 contain the results from the UT pipe wall thickness measurements.

Figure 3-6. Locations of Ultrasonic Transducer Thickness Measurements on the Straight Section and Connector 1 of the Smaller Pipe Section of Jumper 1 - 4.

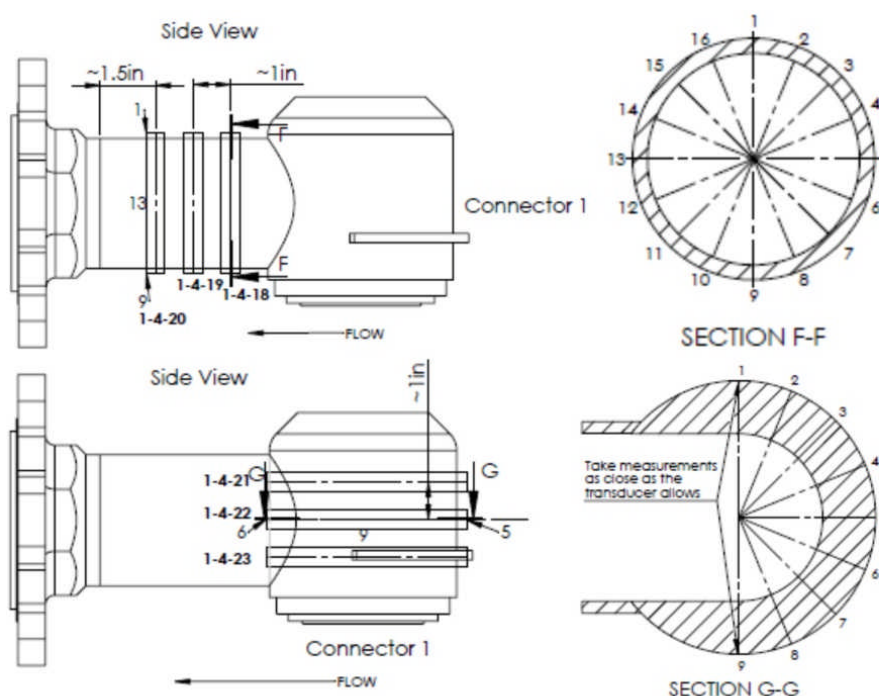


Table 3-6. Measured Ultrasonic Transducer Pipe Wall Thicknesses in Inches of the Straight Section of the Smaller Pipe Section of Jumper 1 – 4. (2 sheets)

Location on Band	UT Map Band Label		
	1-4-18	1-4-19	1-4-20
1	.223	.223	.222
2	.223	.226	.225
3	.231	.247	.231
4	.217	.226	.236
5	—*	.226	.228
6	.240	.230	.230
7	.234	.225	.231

**Table 3-6. Measured Ultrasonic Transducer
Pipe Wall Thicknesses in Inches of the Straight
Section of the Smaller Pipe Section of
Jumper 1 – 4. (2 sheets)**

Location on Band	UT Map Band Label		
	1-4-18	1-4-19	1-4-20
8	.222	.224	.222
9	—**	.242	.241
10	.244	.244	.242
11	.254	.251	.253
12	.243	.251	.247
13	.231	.231	.231
14	.231	.232	.231
15	.229	.225	.223
16	.217	.216	.214

* - Area contained white paint.

** - Area with grinder mar.

---- - Area where coupon #3 was cut.

**Table 3-7. Measured Ultrasonic Transducer
Pipe Wall Thicknesses in Inches for Connector 1
of Jumper 1 – 4.**

Location on Band	UT Map Band Label		
	1-4-21	1-4-22	1-4-23
1	1.003	0.999	—*
2	1.000	0.985	—*
3	1.000	0.999	—*
4	1.005	0.985	1.000
5	0.985	1.006	0.984
6	0.985	0.985	0.998
7	1.005	0.985	0.985
8	1.005	0.985	0.985
9	1.000	0.985	0.985

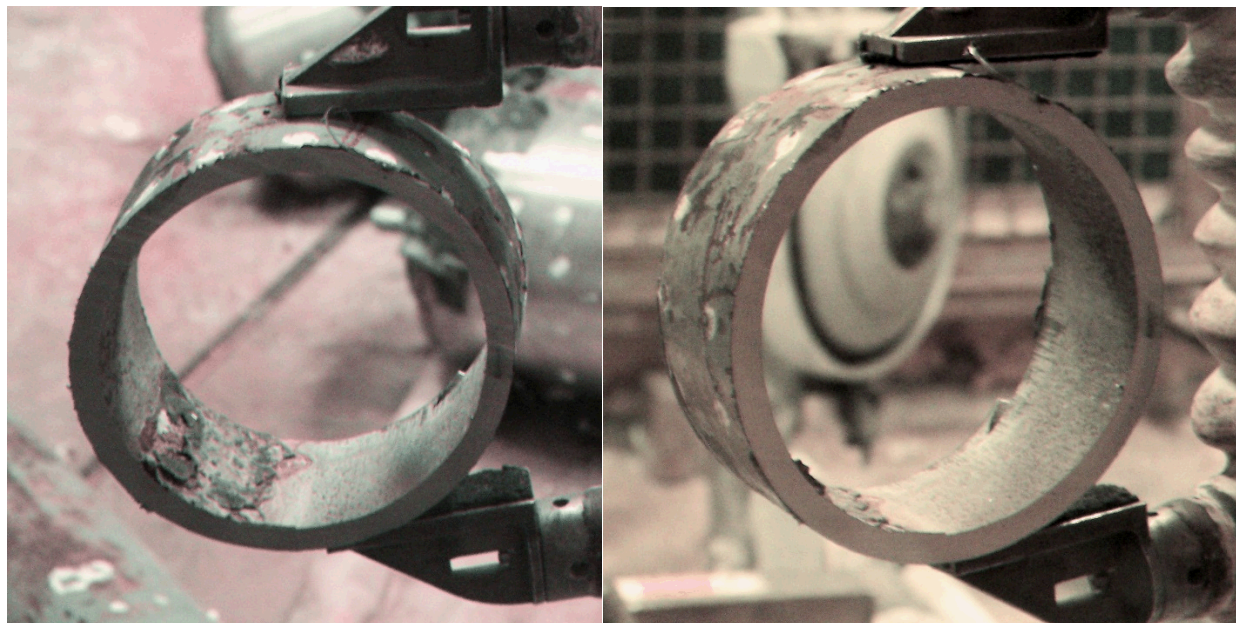
* - Area covered with welded bar.

3.3 CUTTING OF COUPONS IN A HOT CELL

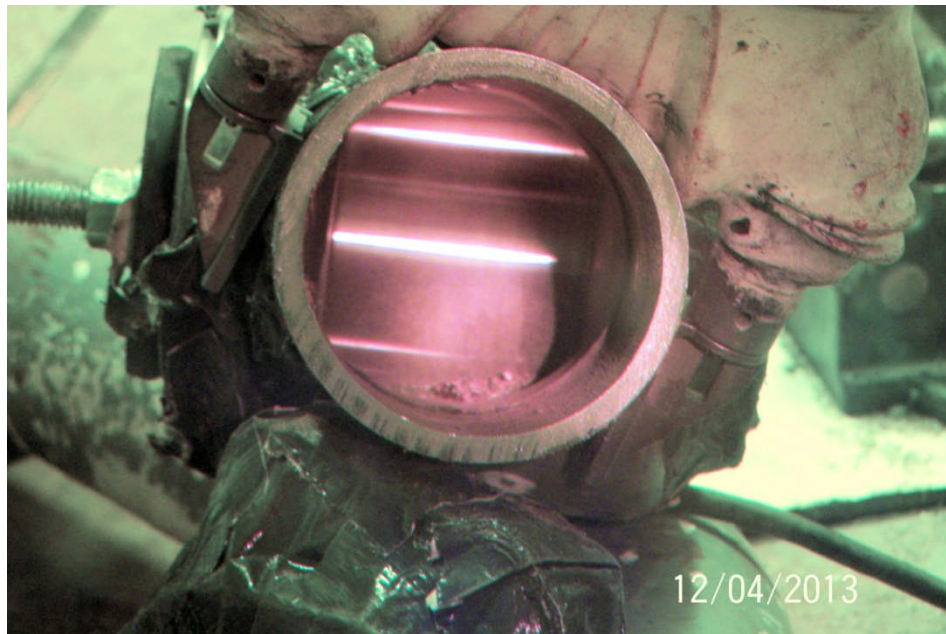
The two sections of jumper 1 – 4 were loaded into hot cell 1-E-1 in order to cut coupons from the pipe to enable optical microscopy and SEM analysis of the pipe walls and inner pipe surfaces. The coupons were cut from the areas indicated by a dashed box in the UT measurement results tables in Section 3.2. A series of cuts were made using a combination of a portable band saw and a grinder with a cut-off wheel in order to liberate the ~1.5-inch by 1.5-inch square coupons from the pipes. The following figures show many of the details observed through the hot cell window, and Appendix B contains additional pictures taken of the jumper pieces in the hot cell.

The smaller pipe section of jumper 1 – 4, containing connector 1, was cut first. Initial cuts removed the large flange (ball valve side fitting) and liberated an ~1.5-inch wide ring of straight pipe. Figure 3-7 shows this ring from two different angles. A majority of the inner surface of the ring appears free of residue and corrosion; however, an area of platy corrosion and/or tank waste residue can be seen in the left image which is located at the bottom of the pipe. In addition to the coupon selected by the UT measurements, a coupon which captured this platy material was also cut from this ring at that location.

Figure 3-7. Photos of a Ring Cut from the Short Pipe Section of Jumper 1 – 4.



Connector 1 (connected to the pump discharge nozzle) was also held up to the hot cell window to inspect the inner wall of the stainless steel connector, Figure 3-8. The surface of the inner wall of the connector appeared free of any corrosion and tank waste residue and reflected the light from a flashlight (bright line in the photo). A pile of material can be seen on the bottom surface of the connector and is likely a result of the cutting process.

Figure 3-8. Photo of Connector 1 After Coupon Cutting of Jumper 1 – 4.

Two coupons were cut from the longer pipe section of Jumper 1 – 4. The first cut of this pipe section allowed a visual inspection of the inside of the elbow. Figure 3-9 shows two photos of the elbow at different viewing angles. Larger particles adhered to the wall were located on the bottom inner surface, and a thin residue appears to coat the entire inner wall. These particles were also observed in the straight pipe section immediately downstream of the elbow, Figure 3-10. A spatula was used to scrape and collect some of the particulate for X-ray diffractometry (XRD) and SEM analysis.

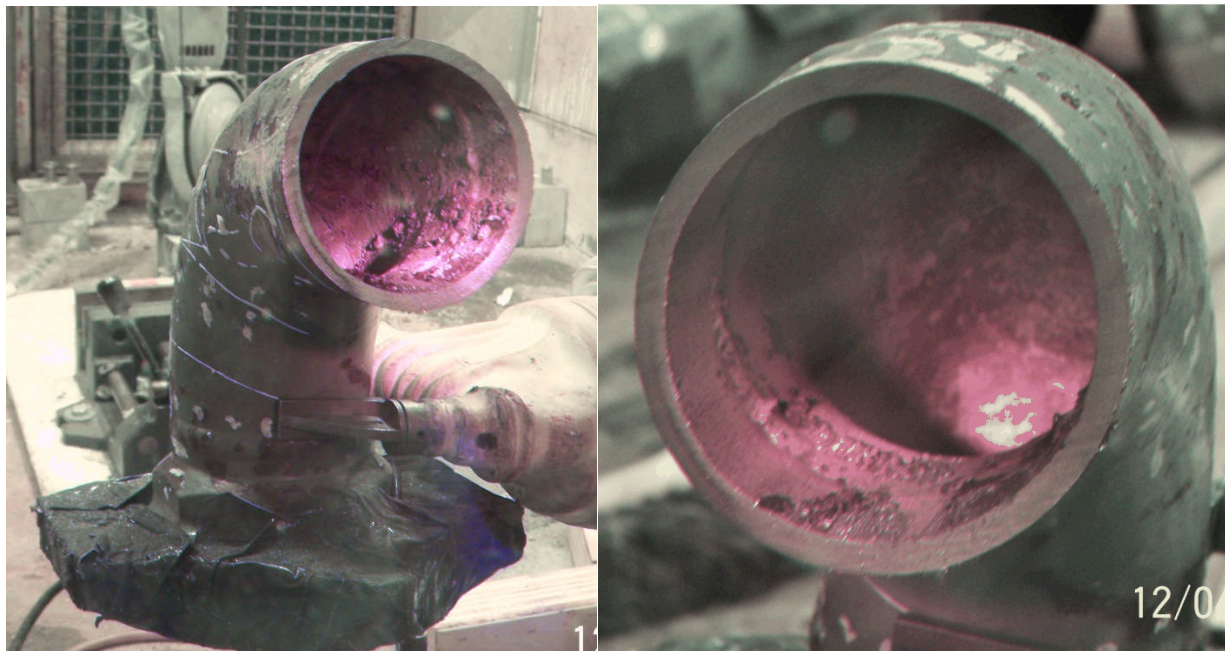
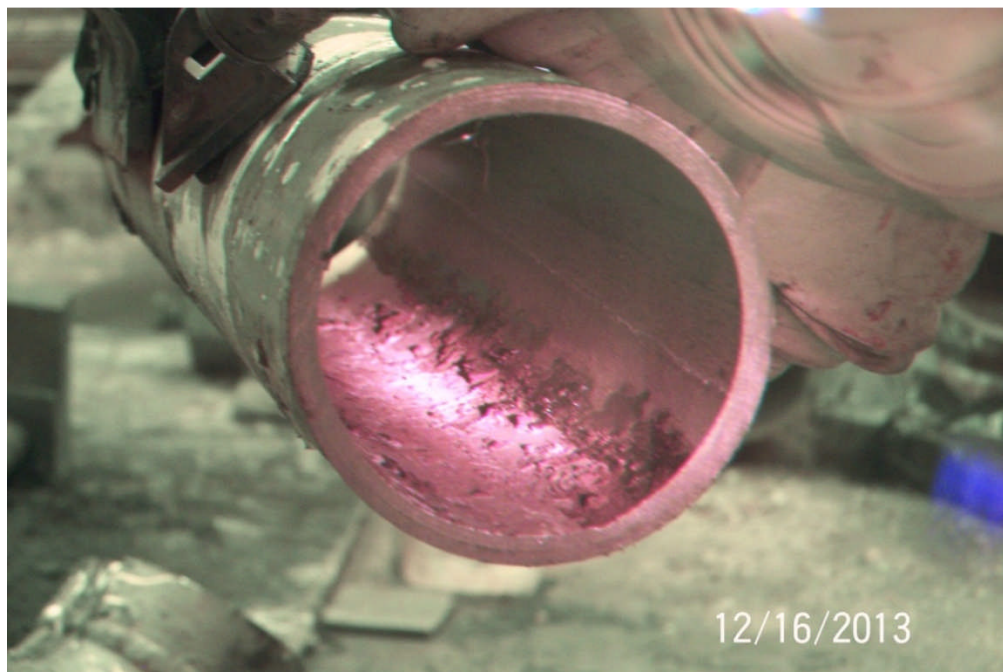
Figure 3-9. Photos of the Elbow Section on Jumper 1 – 4.

Figure 3-10. Photo of Particles Adhered to the Bottom Inner Wall of Jumper 1 – 4 which were Scraped and Collected for Further Analysis.

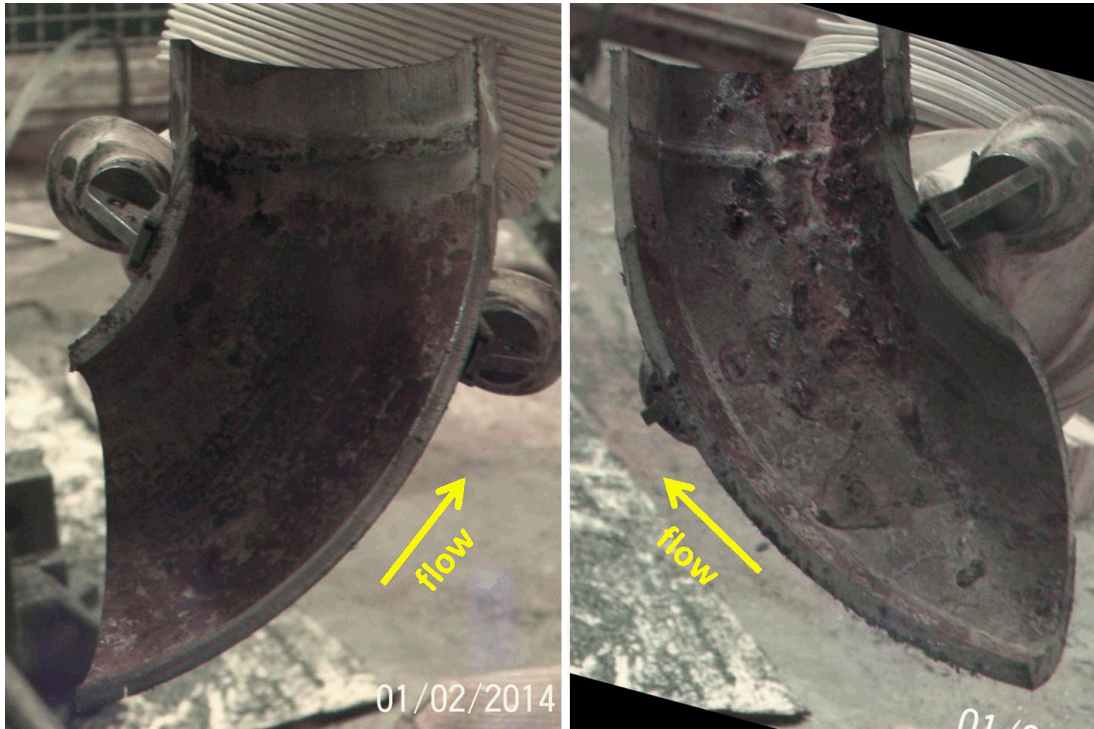


In total, four coupons were cut from jumper 1 – 4; two from the shorter pipe section and two from the longer pipe section. These coupons were loaded out of the hot cell and analyzed for erosion-corrosion and residues using optical microscopy and SEM.

3.3.1 Clamshell Cutting of the Elbow in Jumper 1 – 4

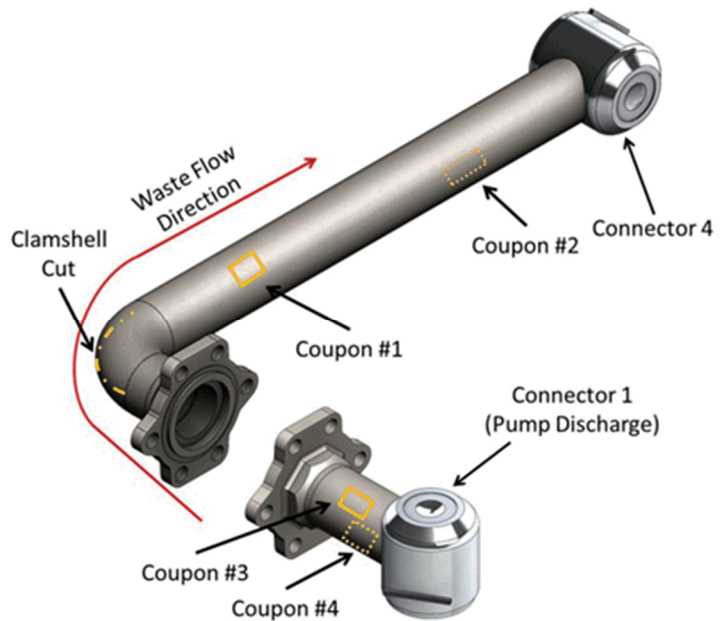
The elbow in jumper 1 – 4 was isolated by cutting with the band saw and then clamshelled. The clamshell cut was accomplished using a combination of a portable band saw and cut-off wheel in the hot cell. The clamshell cut allowed a visual inspection of the extrados and intrados pipe walls of the 90-degree elbow to look for any wall thinning from impingement or erosion-corrosion of the flowing liquid. Figure 3-11 shows photos of the resulting sections of the elbow, taken through the hot cell window. Three observations were gained by this clamshell cut. First, there was not an appreciable thinning of the pipe wall on the elbow. If erosion-corrosion-associated wall thinning had taken place, it would most likely be located at the extrados wall between the weld and the center of the elbow (Poulson 1999). Second, the clamshell section in the right image was located on the bottom side of the pipe. There is considerably more corrosion and residue on this section as the liquid flowed on this section and possibly pooled when the flow was stopped. Third, the weld is intact with no visual erosion-corrosion near or on the weld.

Figure 3-11. Photographs of the Elbow in Jumper 1 – 4 which was Clamshelled to Allow Visual Observation of the Wall and Interior.



In total, four coupons were cut from jumper 1 – 4, and the elbow was clamshelled. Figure 3-12 shows the approximate locations of these cuts; for the exact locations see Figures 3-4 and 3-6 and Tables 3-3, 3-4, and 3-6.

Figure 3-12. Jumper 1-4 Showing the Locations of the Coupons.



3.3.2 Analysis of Pipe Scrapings from Jumper 1 – 4

The XRD preparation and analysis of the scrapings (OmniLims sample #S13R000643) from the longer section of jumper 1 – 4, see Figure 3.10, was performed in accordance with ATS-LT-507-103, “222-S Laboratory X-Ray Diffractometry (XRD) Using The Rigaku®⁴ MiniFlex II.” A fraction of the sample was ground as required, placed in the well of a quartz zero-background slide, compressed with the plane of a glass slide, fixed with collodion binder, and allowed to dry. The sample was scanned using X-rays from a copper anode at the rate of 1 degree per minute with a 2-Theta angle from 3 to 65 degrees.

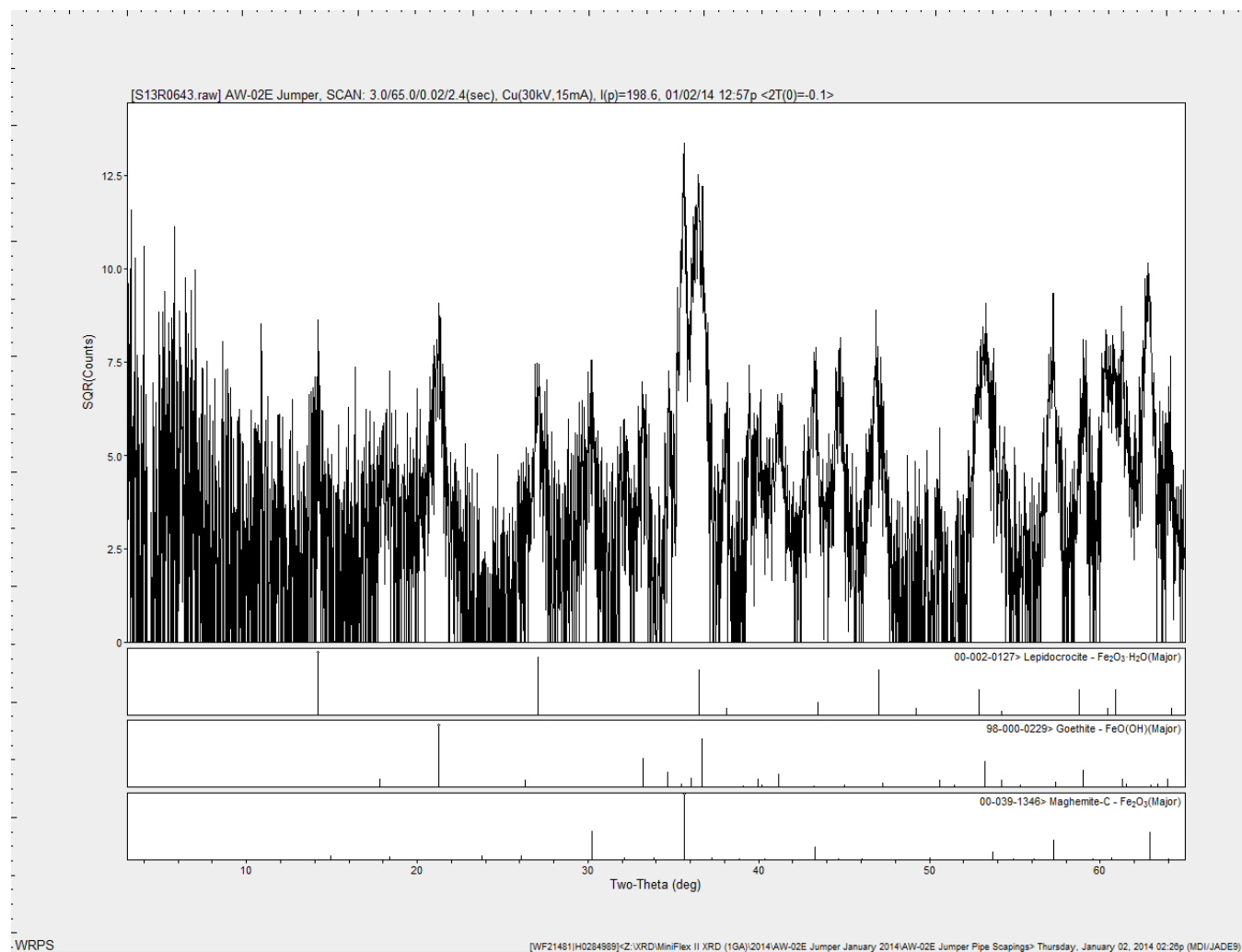
Three iron-bearing phases, consistent with particulate derived from steel, were observed in the pipe scrapings sample, Table 3-8. The three major phases were goethite [FeO(OH)], lepidocrocite [Fe₂O₃•H₂O], and maghemite [Fe₂O₃], which are consistent with rust-type material. The low peak intensity and an increased background were observed in the raw spectrum during the XRD analysis of the sample. This suggests the presence of mostly amorphous material and few crystalline phases, contributing to the difficulty of phase identification. Figure 3-13 is the XRD spectrum with the background subtracted and phase peak matches below. At least one minor/trace phase could potentially remain unidentified in the diffraction pattern.

Refer to laboratory notebook HNF-N-710-1, “Rigaku® MiniFlex II X-Ray Diffractometer (XRD) Maintenance and Operations (GD400212),” page 33, for test information and specifics. The composition reported below reflects relative amounts based upon all the crystalline species observed in the sample.

Table 3-8. Major X-ray Diffraction Phase Identification, Sample S13R000643.

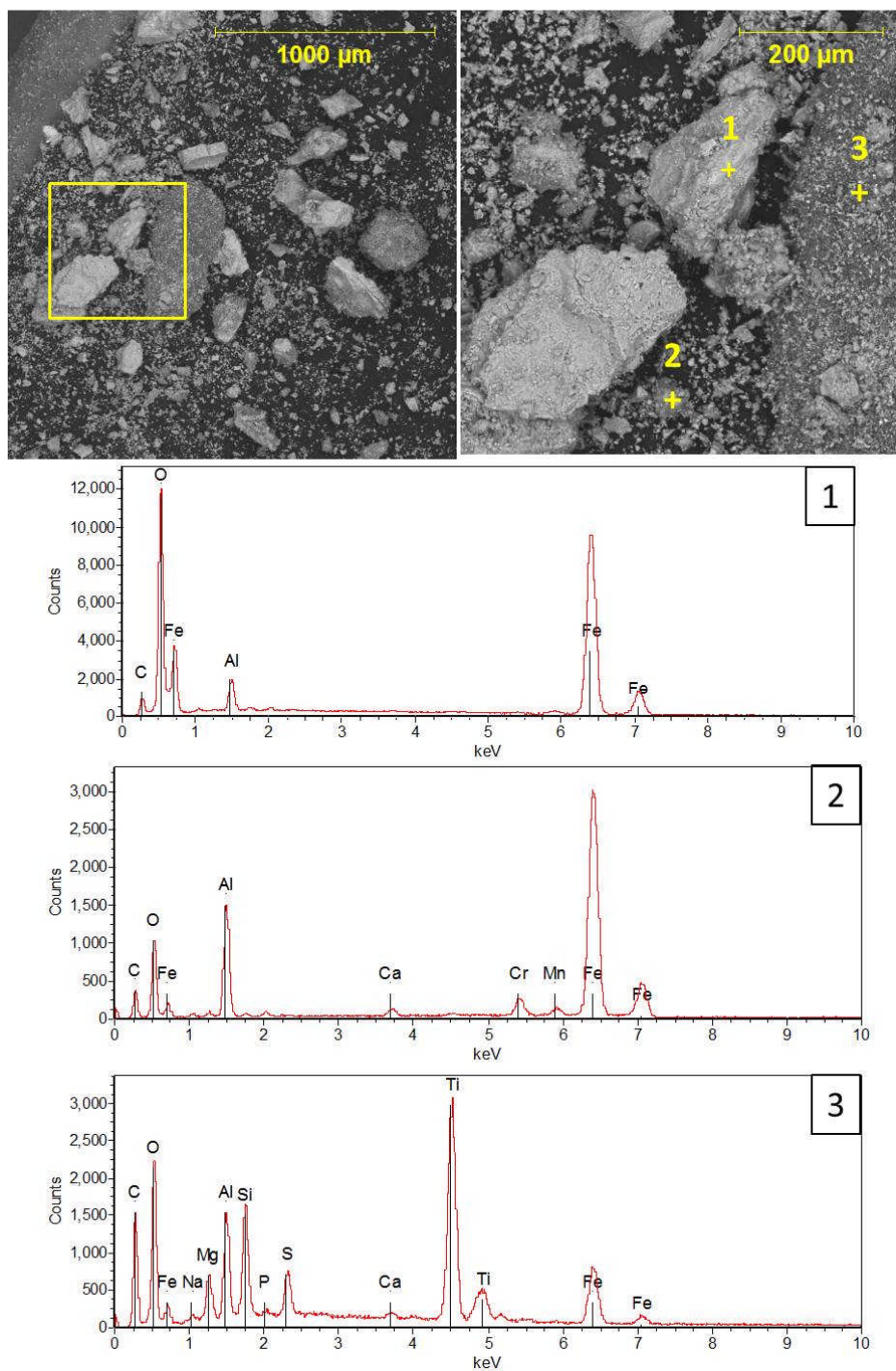
Chemical Name	Mineral Name	Formula	Relative Amount
Iron Oxide Hydrate	Lepidocrocite	Fe ₂ O ₃ •H ₂ O	Major
NA	Goethite	FeO(OH)	Major
Iron Oxide	Maghemite	Fe ₂ O ₃	Major

⁴ Rigaku is a registered trademark of Rigaku Americas Corporation/USA, The Woodlands, Texas.

Figure 3-13. X-ray Diffraction Pattern, Sample S13R000643.

Analysis of the scrapings by SEM confirmed the findings in the XRD analysis which determined the particulate to be mainly iron oxide/hydroxide. The SEM analysis also found various tank waste components and possible soil particles, Figure 3-14, embedded in the corrosion products.

Figure 3-14. Scanning Electron Microscopy and Energy Dispersive Spectrometry of the Pipe Scrapings from Jumper 1 – 4.



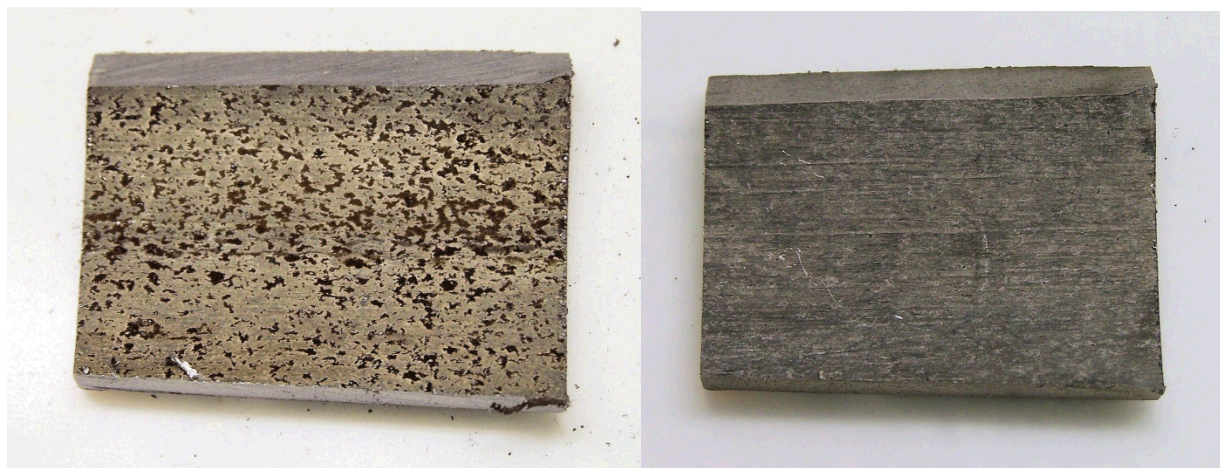
3.4 COUPON ANALYSIS

3.4.1 Jumper 1 – 4 Coupon #1

The first coupon cut from jumper 1 – 4 (coupon #1; OmniLims sample #S13R000609) was taken from the long, straight section of the pipe after the elbow in the location shown in Table 3-3 and Figure 3-12. This coupon was subjected to a corrosion and residue removal treatment using ammonium citrate. The exposure to hot ammonium citrate reacts with the iron oxide and loosens it from the surface along with any tank waste residue. Light brushing with a plastic bristle brush also helps remove these layers from the metal surface, enabling photographic and SEM imaging of the inner wall of the jumper to detect signs of erosion and corrosion.

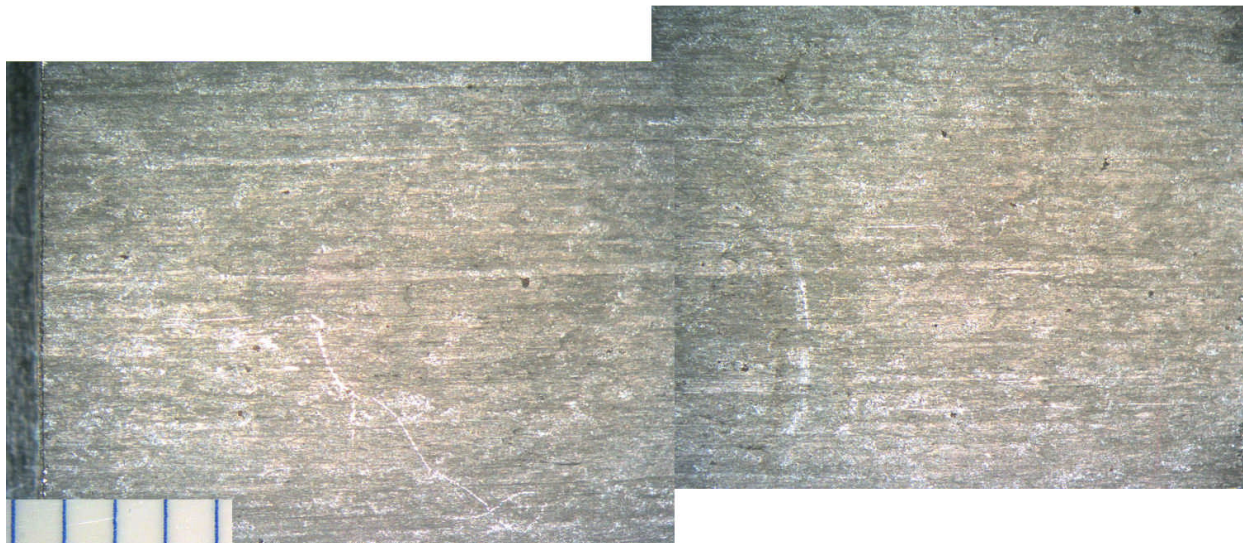
Photos of coupon #1 from jumper 1 – 4 were taken before and after the citrate treatment and are shown in Figure 3-15. The left photo was taken before the corrosion removal process, and a scattering of dark brown spots is seen across what appears to be a bare metal surface, although the sheen on the surface may be from a thin coating or residue. The right photo was taken after the citrate treatment, and the surface is free of the brown spots, leaving bare metal. Some horizontal striations can also be observed on the inner surface of the pipe. Overall, the total mass loss due to removal of the corrosion and tank waste layers was only 0.1%, indicating that there was only a minimal amount of corrosion and tank waste on the surface; this amount was even less than what was removed from the two B – 2 jumper coupons.

Figure 3-15. Photographs of Coupon #1 of Jumper 1 – 4 Before and After the Ammonium Citrate Corrosion Removal Process.



The cleaned coupon was then imaged on the optical microscope to look for features which might indicate corrosion or erosion. Figure 3-16 is the resulting mosaic of two combined images since the size of the coupon did not allow for a complete view at the lowest magnification. The scale bar in the lower left is in 1/16-inch increments.

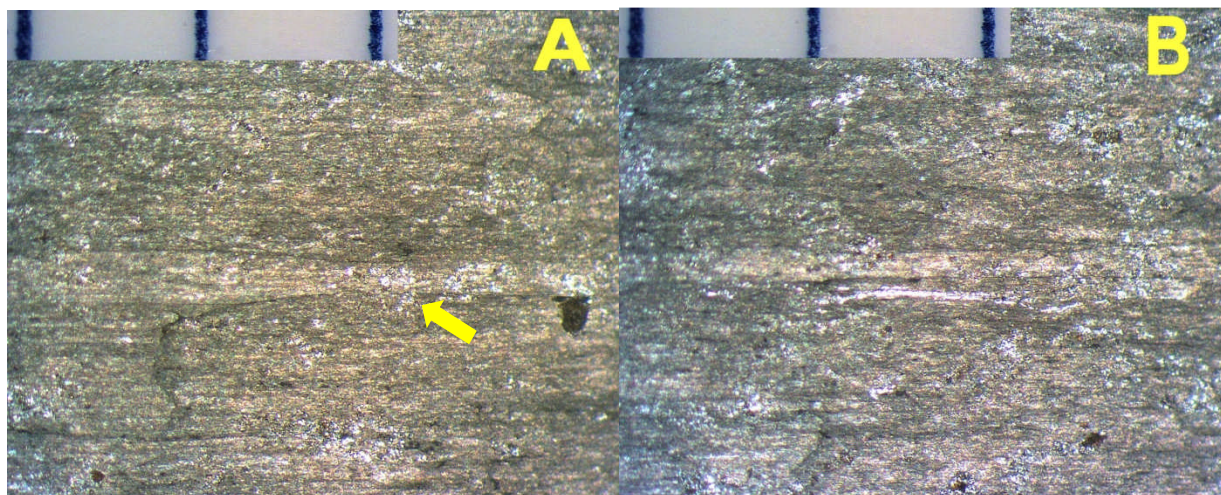
Figure 3-16. Photomicrographs of Coupon #1 of Jumper 1 – 4 After the Corrosion Layer was Removed.



A NIST-certified micrometer was used to measure the thickness of the cleaned coupon at the four corners. The resulting thicknesses were 0.217, 0.217, 0.205, and 0.204 inches, and the measured UT thicknesses near these locations were 0.226, 0.230, 0.212, and 0.219 inches. The inability to measure at the exact same locations (due to cutting near and on the UT spots and coatings on the outside of the pipe) may have contributed to any discrepancy. In general, the readings from the UT tend to be slightly thicker than what was measured directly by the micrometer.

The following figure shows two photomicrographs which are magnified views of different areas on coupon #1. The scale bar in the figures is marked at 1/16-inch increments. Figure 3-17A shows that most of the inner pipe surface is rough, bare metal. One spot of dark-brown material at the right of the image, possibly corrosion, is still on the coupon. The area in the image also shows part of a striation. This striation appears to be from pipe manufacturing, as an area of small pits on the striation overlaps with the bare surface (see the arrow on the photo), suggesting the striation was present during general corrosion on the pipe wall. Overall, there is no scalloping on the pipe surface or other features that would positively indicate erosion-corrosion. Figure 3-17B is an image from another location on coupon #1. The surface appears rough from general corrosion but there are no indications of erosion-corrosion. The lack of a control sample limits the ability to more fully interpret the small differences between the UT and actual measured thicknesses that were observed.

Figure 3-17. Photomicrographs of Different Locations of the Cleaned Coupon #1 from the 1 – 4 Jumper.



Coupon #1 was then loaded into the SEM for higher magnification imaging and elemental identifications. The coupon was analyzed at high vacuum using both SEI and BEI modes.

Figure 3-18 shows two SEI images of a general area on coupon #1 of jumper 1 – 4 taken at different magnifications. The lower magnification left image shows a clean surface with some clusters of small pits. The EDS spot #1 was taken at the termination of one of the striations seen in Figure 3-16 and confirms that the surface is a bare metal free of an oxide. The magnified image on the right is from the area marked by the yellow box on the left. This image displays one of the clusters of small pits showing one pit which measured 2.9 mils (73.9 μm) across. The EDS spectrum acquired at spot #2 shows that an iron oxide is inside the pit.

Figure 3-18. Scanning Electron Microscopy Images and Energy Dispersive Spectrometry Spectra of the Surface of Coupon #1 of Jumper 1 – 4.

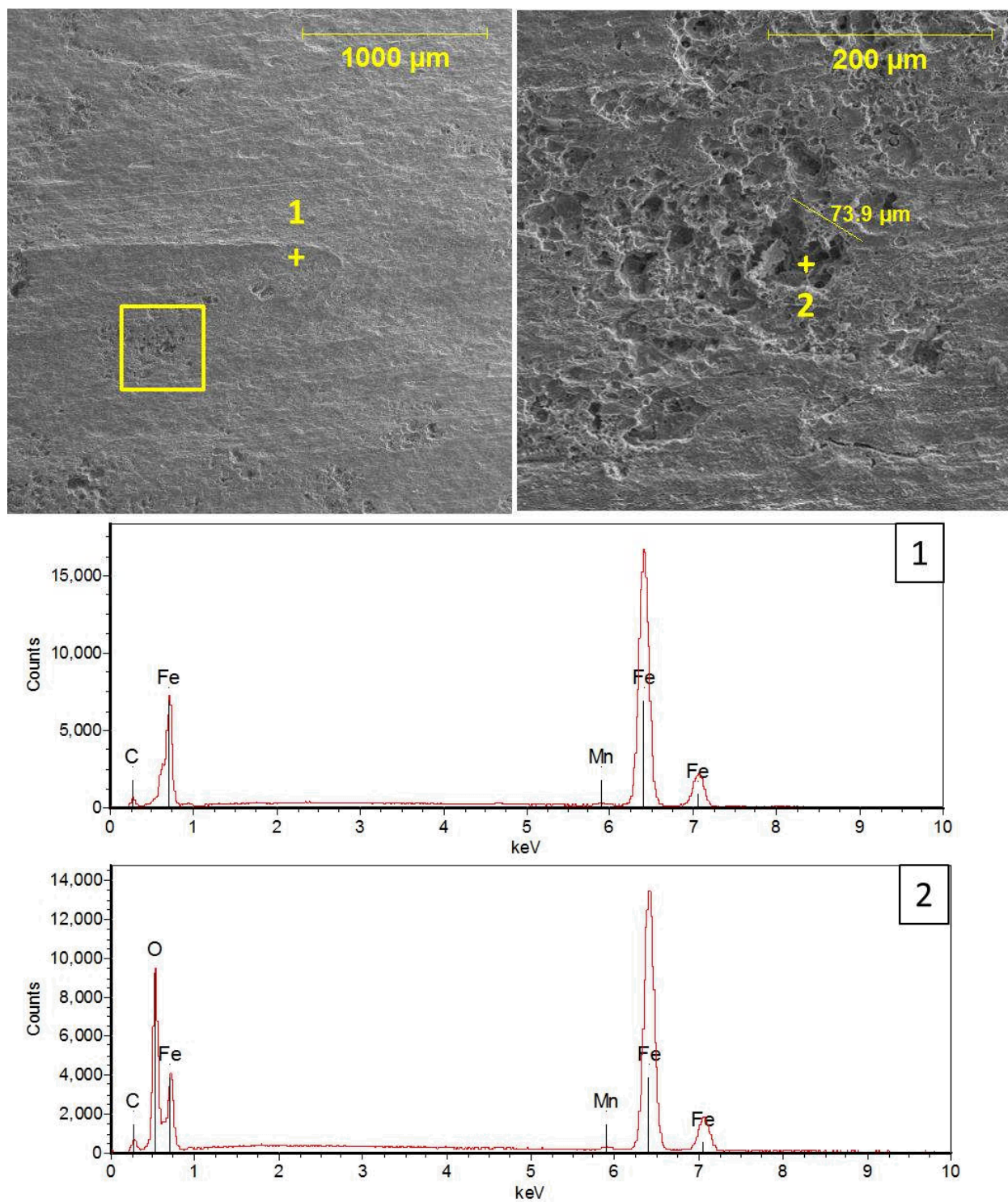
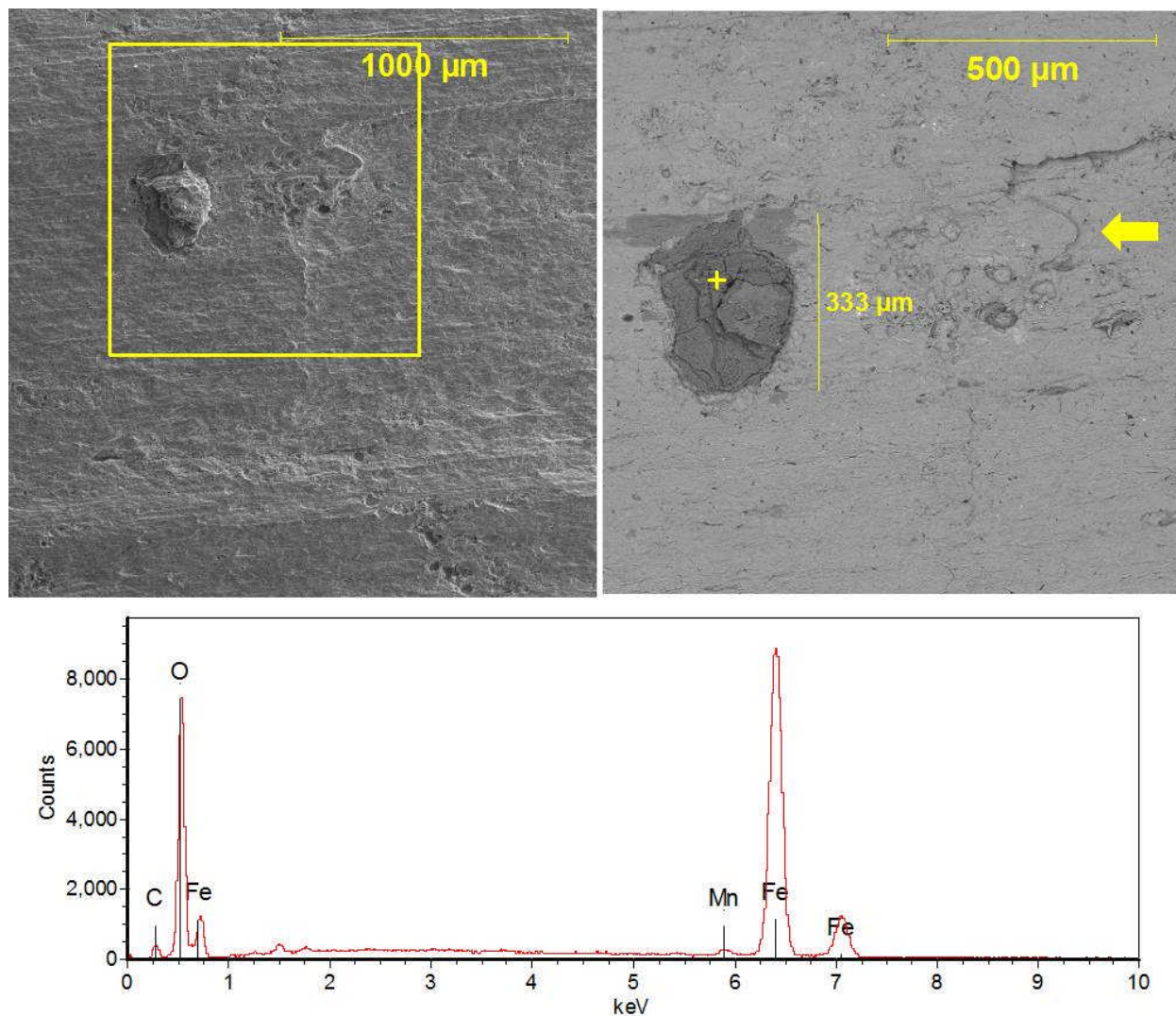


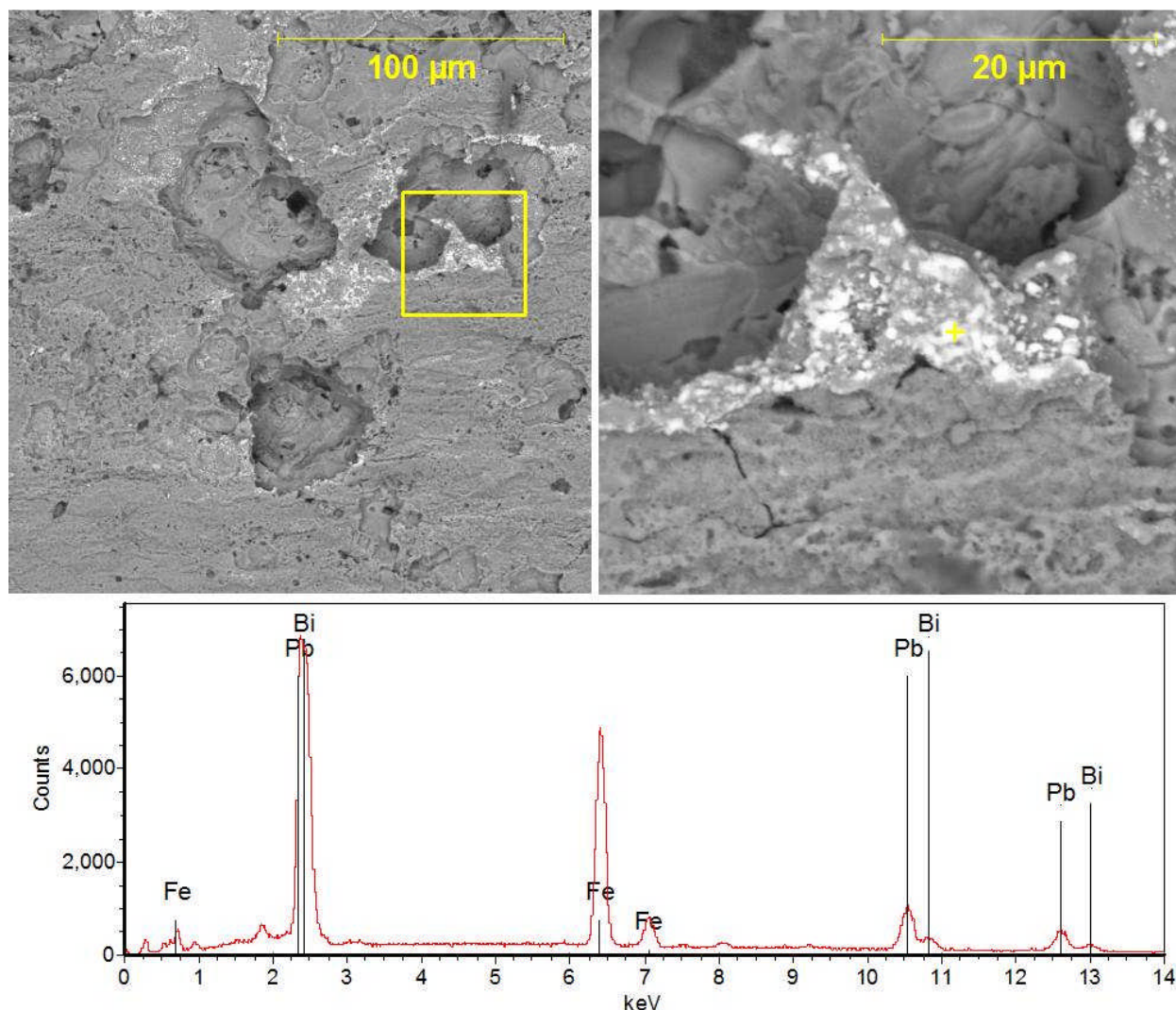
Figure 3-19 contains SEM images from another location on the coupon and shows two main features. The first feature is a spot of corrosion product which rests on a pit approximately 13.0 mils (333 μm) in diameter, and the second feature is a structure on the surface which corresponds to the striations seen in the optical images of this coupon (yellow arrow). This structure, along with the striations, appears to be an artifact from the pipe manufacturing process.

Figure 3-19. Scanning Electron Microscopy Images and Energy Dispersive Spectrometry Spectrum of the Surface Features on Coupon #1 of Jumper 1 – 4.



Similar to the silver deposits on the coupons from jumper B – 2, coupon #1 from jumper 1 – 4 also showed the deposition of heavy metals near pits on the pipe surface. Figure 3-20 shows particles of a lead-bismuth phase which were deposited near some pits and were likely from the reduction of the ion from the liquid flowing in the pipe.

Figure 3-20. Scanning Electron Microscopy Images and Energy Dispersive Spectrometry Spectrum of a Lead-Bismuth Deposit on Coupon #1 of Jumper 1 – 4.



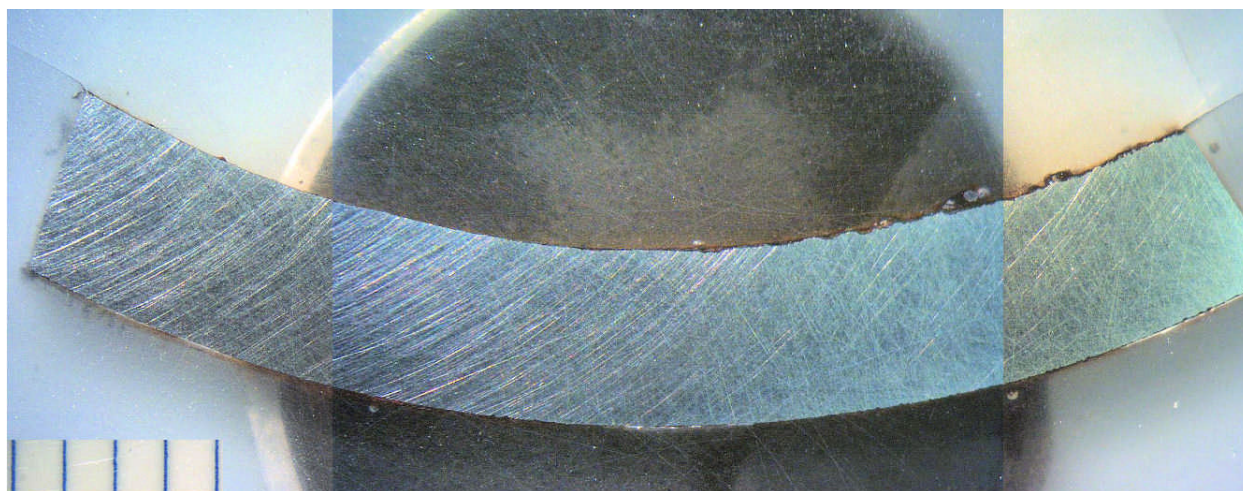
In all, the coupon surface appears to have very little corrosion, and the ammonium citrate treatment removed a majority of any corrosion and tank waste layers which may have been present on the inner surface of the pipe. Small pits and clusters of small pits were detected on the inner surface of the pipe, although the pipe in general appears intact with only a few signs of corrosion and no signs of erosion-corrosion. The striations seen in the optical photography and other features similar to the striations appear to have resulted from the pipe manufacturing process and not from usage in the tank farm.

3.4.2 Jumper 1 – 4 Coupon #2

A second coupon was cut from the long, straight section of jumper 1 – 4 further downstream of the first coupon in the location indicated in Table 3-4 and Figure 3-12. This coupon, referred to as coupon #2 with the OmniLims sample #S13R000610, was immediately embedded in epoxy

after being loaded out of the hot cell. The epoxy immobilized any corrosion and residues on the surface of the pipe, preserving the features for SEM analysis. After the epoxy cured overnight, the coupon was wafered using a low-speed diamond saw creating a cross-section of the pipe wall. This cross-section was then polished with sandpapers through consecutive grits ending in a 600-grit finish and mounted onto a SEM sample stub. The mounted cross-section was then photographed using an optical microscope, and the resulting image is shown in Figure 3-21. The size of the cross-section was larger than could be photographed by the microscope, so the image in Figure 3-21 is a mosaic of three separate images. A scale bar is shown in the lower left of the image with marks at 1/16 inch. The black circle behind the pipe cross-section is the SEM stub. Epoxy completely surrounds the cross-section and is lightly stained brown in some areas near the inner surface of the pipe due to particulate dissolving into the epoxy before it was completely cured.

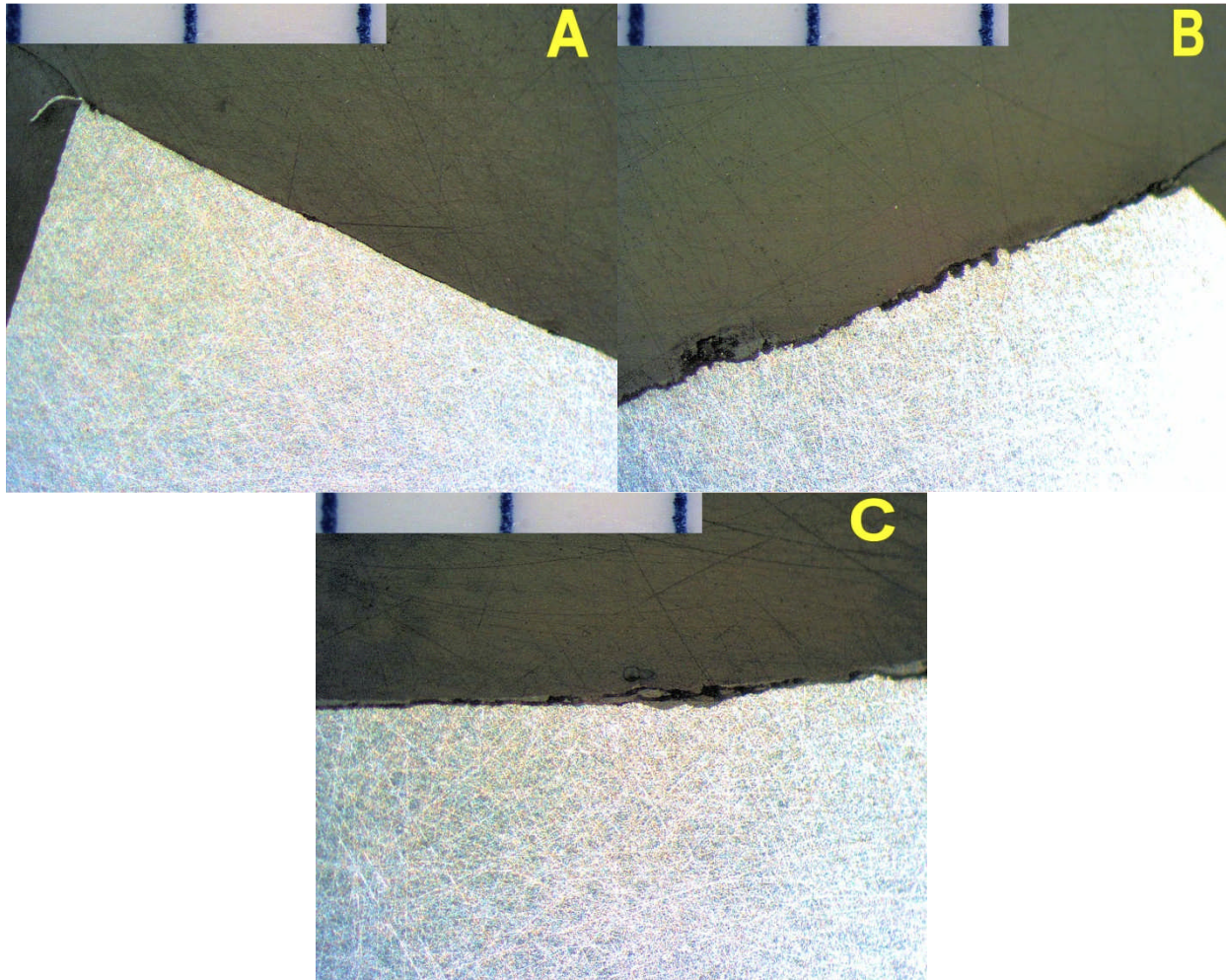
Figure 3-21. Microphotograph of the Cross-Section Cut from Coupon #2 of Jumper 1 – 4.



Visual inspection of the cross-section in Figure 3-21 shows that the pipe wall is intact with no areas of wall thinning due to erosion-corrosion. The right side of the image shows that the inner surface of the pipe here contains small pits along the cross-section and a thin layer of corrosion and/or tank waste. In contrast, the left side of the image appears less corroded at this magnification, indicating a non-uniform corrosion of the pipe.

Figure 3-22 shows three microphotographs taken at an increased magnification compared to Figure 3-21. The scale bar is in 1/16-inch increments. The images show locations across the cross-section from the left (A), right (B), and center (C) of the coupon. At this magnification, the varying level of corrosion becomes more apparent. The right side of the coupon contains continuous small pits which transition to minimal pitting on the left side. A thin layer resides above the pipe surface with a thickness that corresponds to the amount of pitting (corrosion), suggesting that this layer is a corrosion product.

Figure 3-22. Photomicrographs of the Cross-Section of Coupon #2 of Jumper 1 – 4 Showing Variations in the Level of Corrosion Along the Pipe Wall.



The cross-section was next analyzed by SEM, which provided further information on the integrity of this pipe section and the identification of the surface layer. Figure 3-23 contains two SEM images at the lowest instrument magnification to show and measure the entire wall thickness at two different locations on the cross-section (far left and far right sides). Conversion of the SEM-measured distances from micrometers to inches shows that the measurements in Figure 3-23 are 0.235 inches on the left and 0.223 inches on the right side of the cross-section. The UT measurements of this coupon ranged from 0.228 to 0.217, Table 3-4. The cross-section was cut in an area between the UT measurement locations, and although the SEM distances were slightly greater than the UT measurements, they are similar to what was measured by the UT.

Figure 3-23. Scanning Electron Microscopy Images at the Lowest Magnification with Measurements of the Pipe Wall Thicknesses.

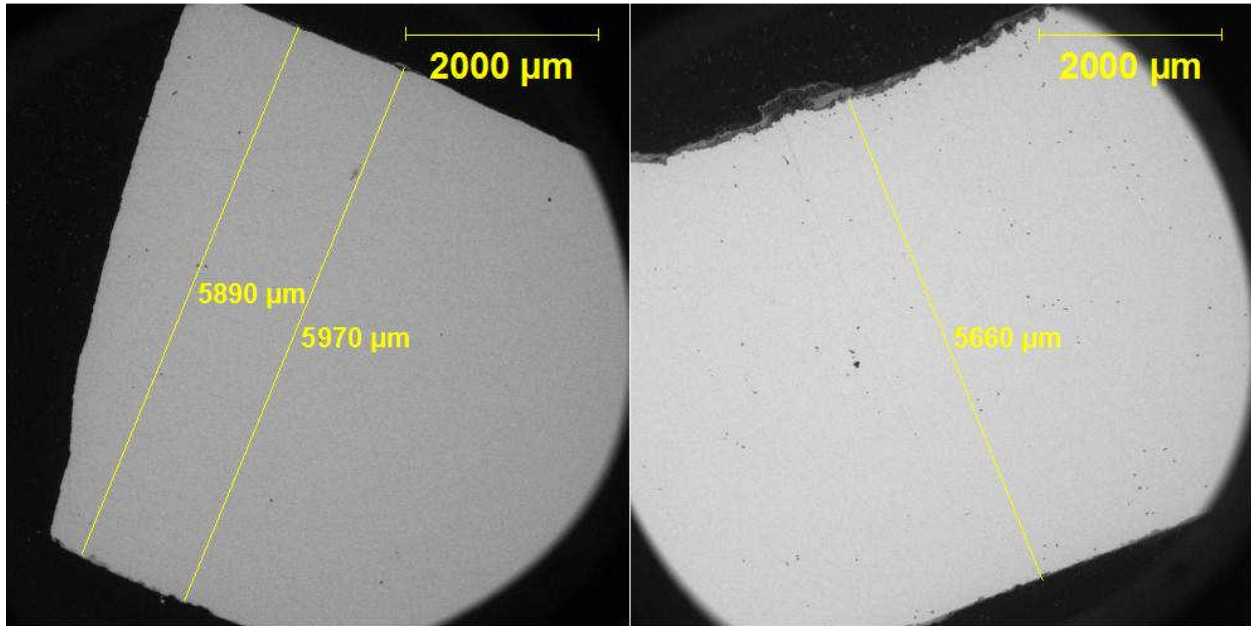
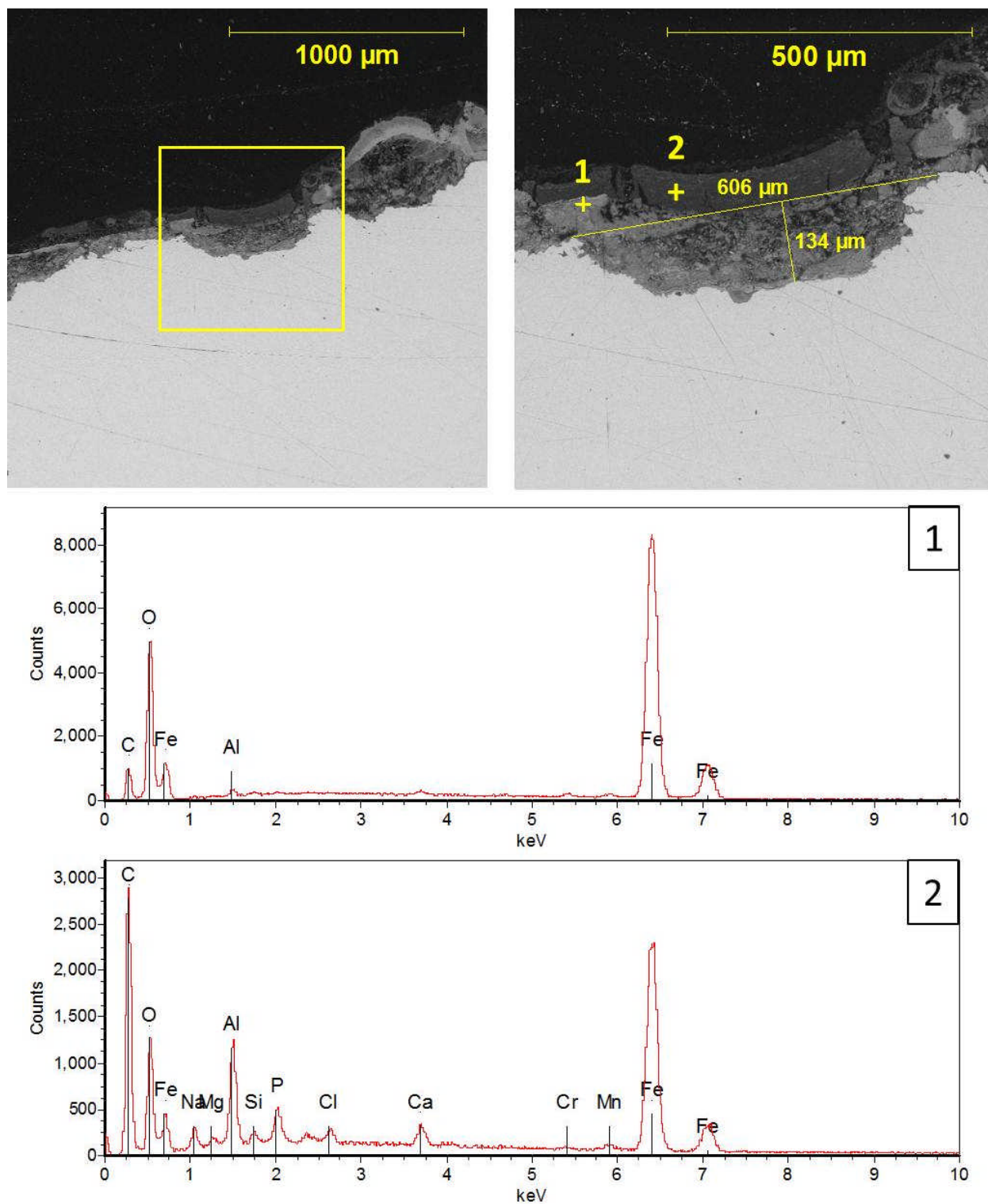


Figure 3-24 contains SEM images from a pit on the right side of the coupon cross-section that measured 23.6 mils (606 μm) across and 5.2 mils (134 μm) deep. The pit, along with the entire surface in this area, is coated with a layer of iron oxide as indicated in EDS spectrum 1. There is an additional layer on top of this corrosion layer, and it is comprised mainly of iron, aluminum, oxygen, and carbon (EDS spot #2). This tank waste layer appears to be an iron oxide, aluminum oxide, and either an oxalate or carbonate mix.

Figure 3-24. Scanning Electron Microscopy Images and Energy Dispersive Spectrometry Spectra of a Wide, Shallow Pit on Coupon #2 of Jumper 1 – 4.



In contrast to Figure 3-24, Figure 3-25 is an SEM image from the left side of the cross-section acquired at the same magnification as the left image in Figure 3-24. The absence of the general corrosion and pitting is apparent on the left side of this coupon. This suggests a varying environment of corrosion on the inside of this pipe. One section was probably exposed to the liquid for an extended period of time and supports the observations of the cross-sectioned elbow in Section 3.3.1.

Figure 3-25. Scanning Electron Microscopy Image of the Inner Pipe Surface on the Left Side of Coupon #2 of Jumper 1 – 4.

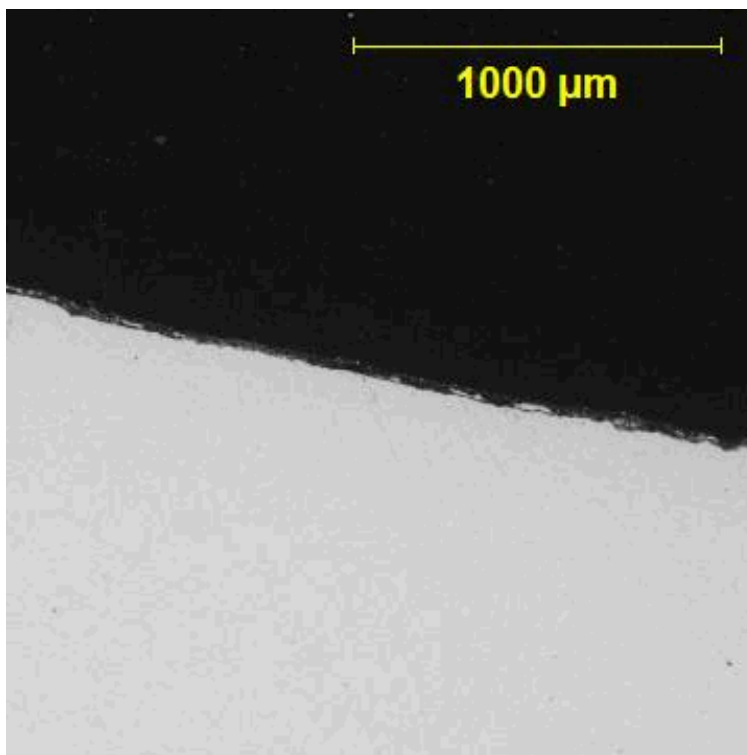
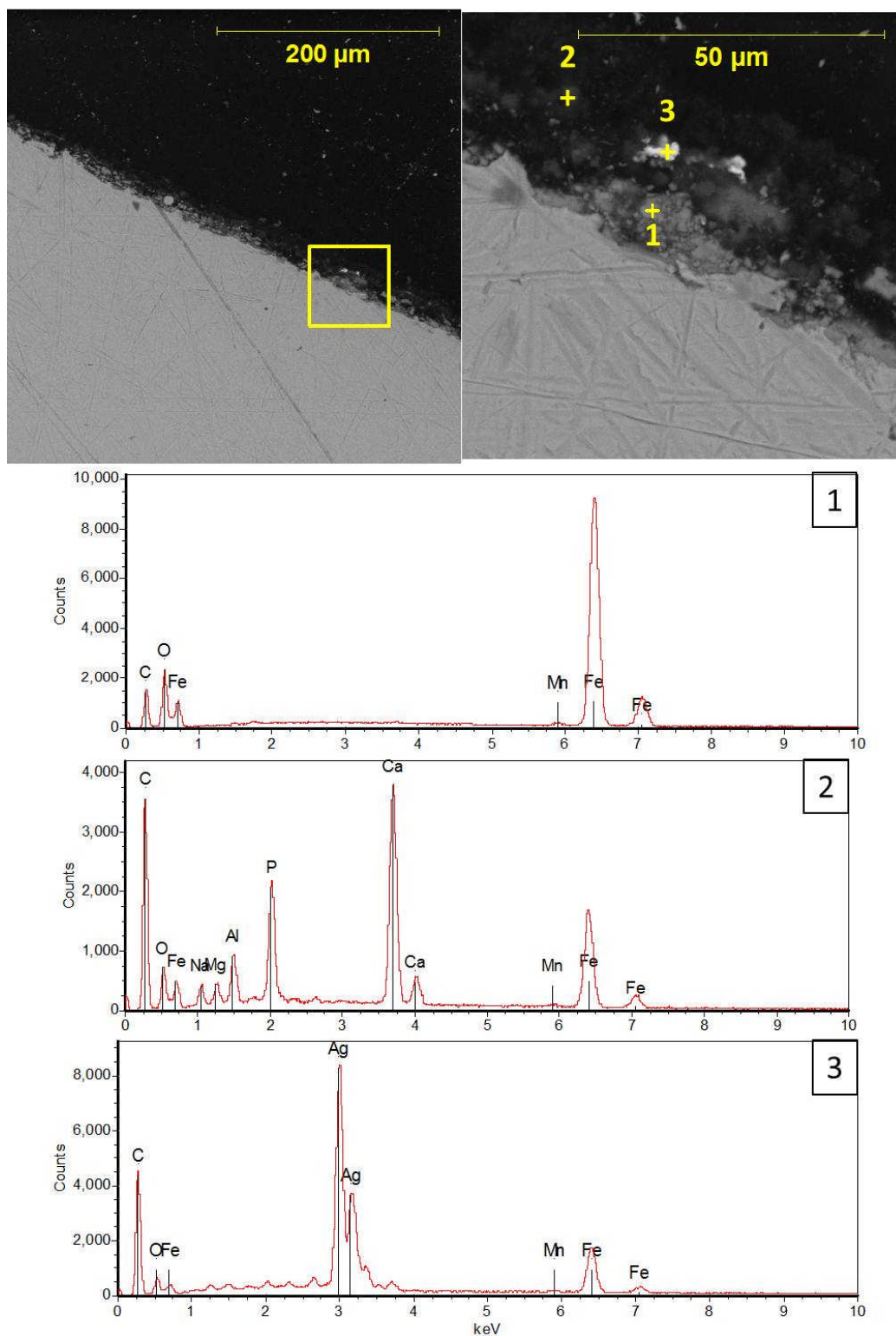


Figure 3-26 shows another location on the left side of the cross-sectioned coupon #2 of jumper 1 – 4. The right image is a magnified view of the location of the area in the yellow box in the left image. Three different locations were analyzed by EDS as indicated by the numbered yellow crosses and corresponding spectra. EDS spot #1 confirms that the thin layer immediately on the pipe wall is iron oxide/hydroxide (corrosion product). EDS spot #2 shows that a tank waste product consisting mainly of a calcium phosphate is also present at this location. Small particles of silver metal (EDS spot #3) are also dispersed on this section of the coupon.

Figure 3-26. Scanning Electron Microscopy Images and Energy Dispersive Spectrometry Spectra of Corrosion and Tank Waste Products on Coupon #2 of Jumper 1 – 4.

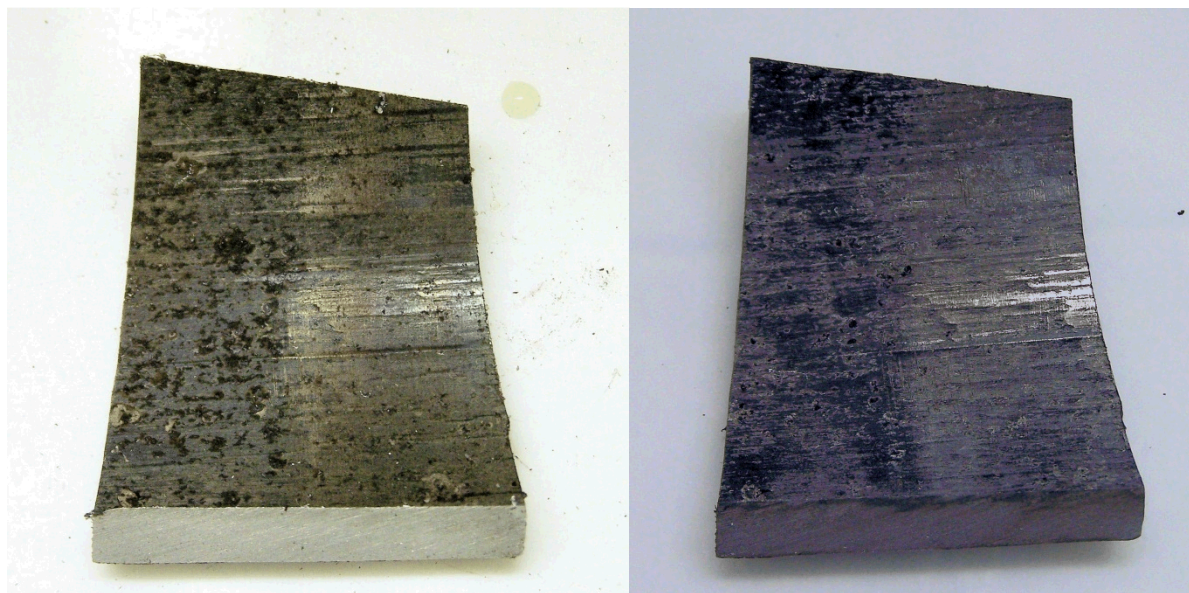


3.4.3 Jumper 1 – 4 Coupon #3

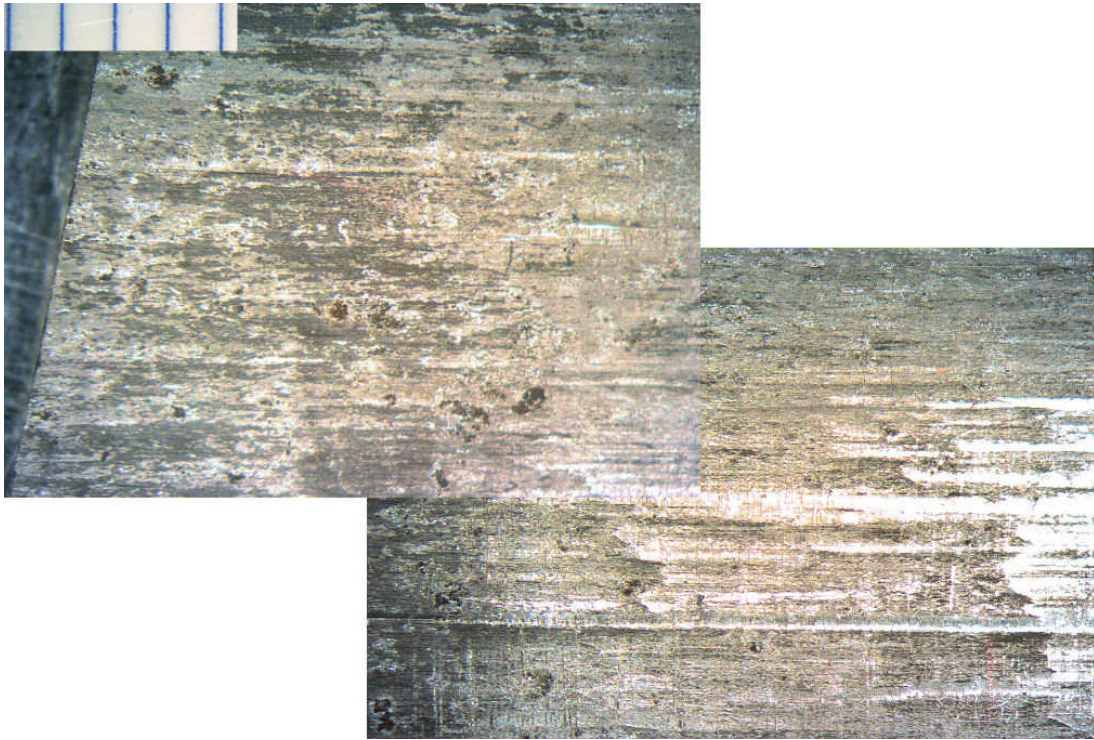
The next coupon was cut from the shorter section of jumper 1 – 4 (coupon #3; OmniLims sample #S13R000612A) in the location shown in Table 3-6 and Figure 3-12. This coupon was subjected to the same corrosion and residue removal treatment using ammonium citrate as coupon #1 of jumper 1 – 4. This treatment with hot ammonium citrate helps remove any corrosion or tank waste layers from the metal surface, enabling photographic and SEM imaging of the inner wall of the jumper to detect signs of erosion and corrosion.

Photos of coupon #3 from jumper 1 – 4 were taken before and after the citrate treatment and are shown in Figure 3-27. The left photo is from before the corrosion removal process, and, like coupon #1 of jumper 1 – 4, a scattering of a dark-brown spots is seen across what appears to be a bare metal surface, although the sheen on the surface may be from a thin coating or residue. The right photo was taken after the citrate treatment, and the surface is free of the brown spots but black spots are scattered on the left side of the coupon. Some horizontal striations can also be observed on the inner surface of the pipe. Overall, the total mass loss due to removal of the corrosion and tank waste layers was only 0.1%, which indicates that there was only a minimal amount of corrosion and tank waste on the surface.

Figure 3-27. Photographs of Coupon #1 of Jumper 1 – 4 Before and After the Ammonium Citrate Corrosion Removal Process.



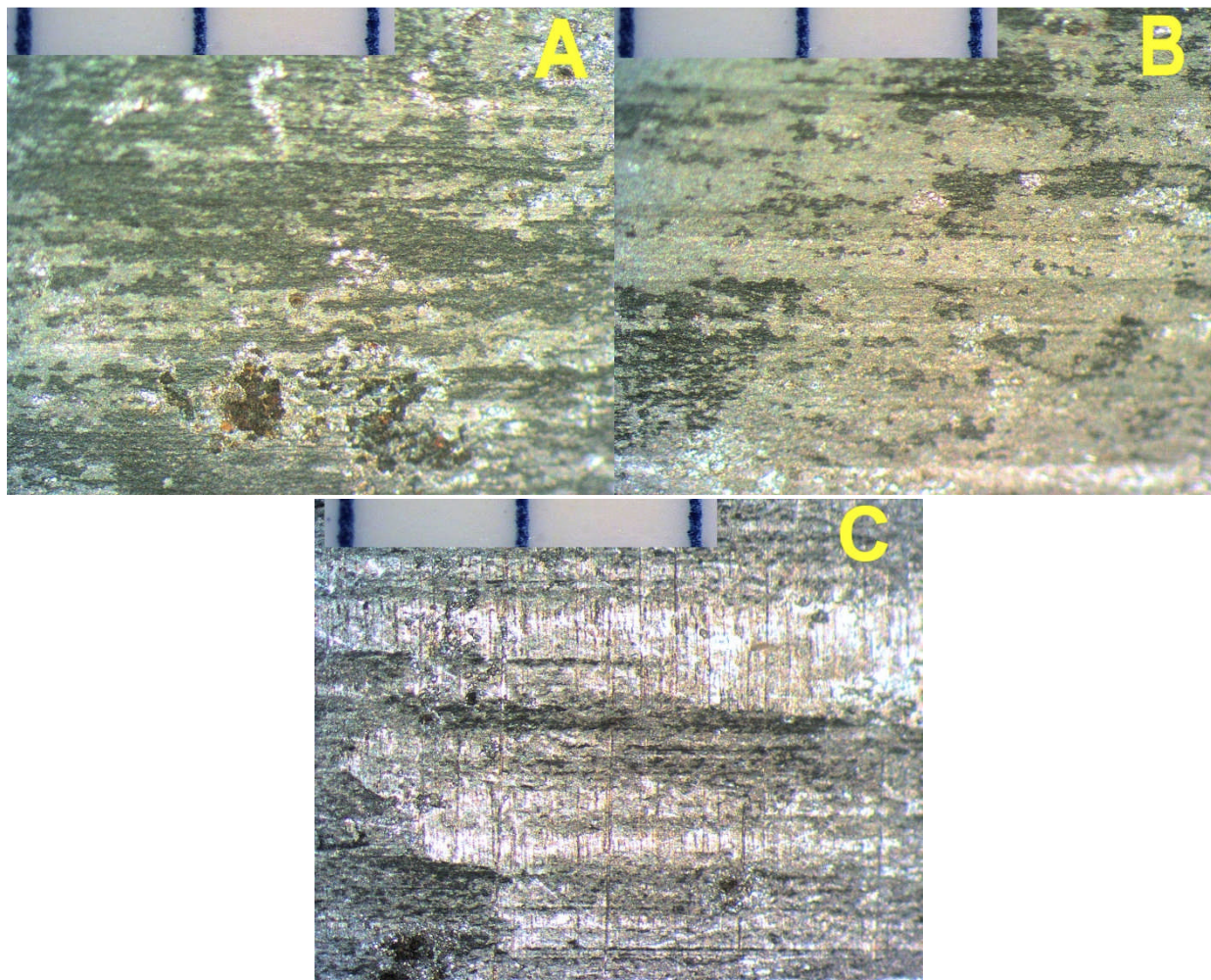
The cleaned coupon was then imaged on the optical microscope to look for features which might indicate corrosion or erosion. Figure 3-28 is the resulting mosaic of two combined images since the size of the coupon did not allow for a complete view at the lowest magnification. The scale bar in the upper left is in 1/16-inch increments.

Figure 3-28. Photomicrograph of the Cleaned Coupon #3 from Jumper 1 – 4.

A NIST-certified micrometer was used to measure the thickness of the cleaned coupon at the four corners. The resulting thicknesses were 0.213, 0.214, 0.209, and 0.205 inches, and the measured UT thicknesses near these locations were 0.225, 0.223, 0.216, and 0.214 inches. The inability to measure at the exact same locations (due to cutting near and on the UT spots and coatings on the outside of the pipe) may have contributed to any discrepancy. In general, the readings from the UT tend to be slightly thicker than what was measured directly by the micrometer.

The following figure shows three photomicrographs which are magnified views of different areas on coupon #3. The scale bar in the figures is marked at 1/16-inch increments. Figure 3-29A shows that most of the inner pipe surface is rough bare metal with areas of a darker gray which is possibly a thin oxide layer. A spot of dark-brown material at the bottom of the image and surrounded by a pitted surface is an area of corrosion still on the coupon. Figure 3-28B is another area on the coupon which also shows the bare metal surface with darker patches of a thin possibly oxide layer. One of the horizontal striations is in the middle of the image and is seen as a slightly brighter band running left to right. Figure 3-29C is from the far right of the image where both horizontal and vertical striations are observed.

Figure 3-29. Photomicrographs of Different Areas on Coupon #3 of Jumper 1 – 4 After Cleaning.



Coupon #3 was then loaded into the SEM for higher magnification imaging and elemental identifications. The coupon was analyzed at high vacuum using both SEI and BEI modes.

Figure 3-30 shows two BEI images of a general area on coupon #3 of jumper 1 – 4 taken at different magnifications. Since BEI mode correlates the brightness of the image with elemental mass of the species present at that location, it can be seen that there are three main areas on the coupon with three different elemental compositions on the surface of the pipe. The medium gray areas, as analyzed by EDS spot #1, are the bare carbon steel surfaces of the pipe. The darker gray areas, as analyzed by EDS spot #2, are the locations where the metal oxide is still present even after the ammonium citrate treatment. Finally, the bright gray areas, as analyzed by EDS spot #3, are locations on the pipe where silver has plated out from the solution. Silver deposits were also seen on the coupons from the B – 2 jumper, but they were not of as high a density as seen here.

Figure 3-30. Scanning Electron Microscopy Images and Energy Dispersive Spectrometry Spectra of the Surface of Coupon #3 of Jumper 1 – 4.

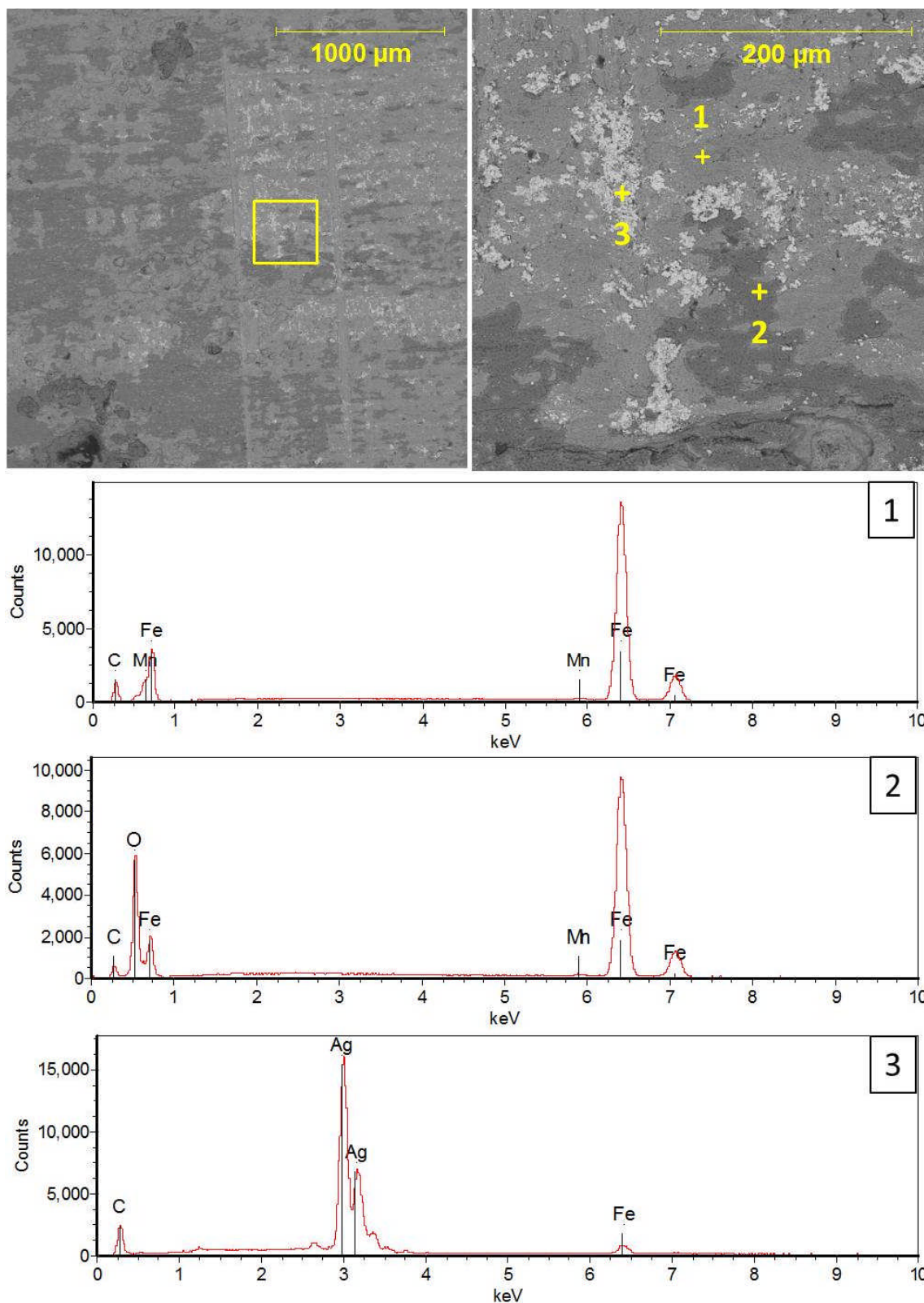
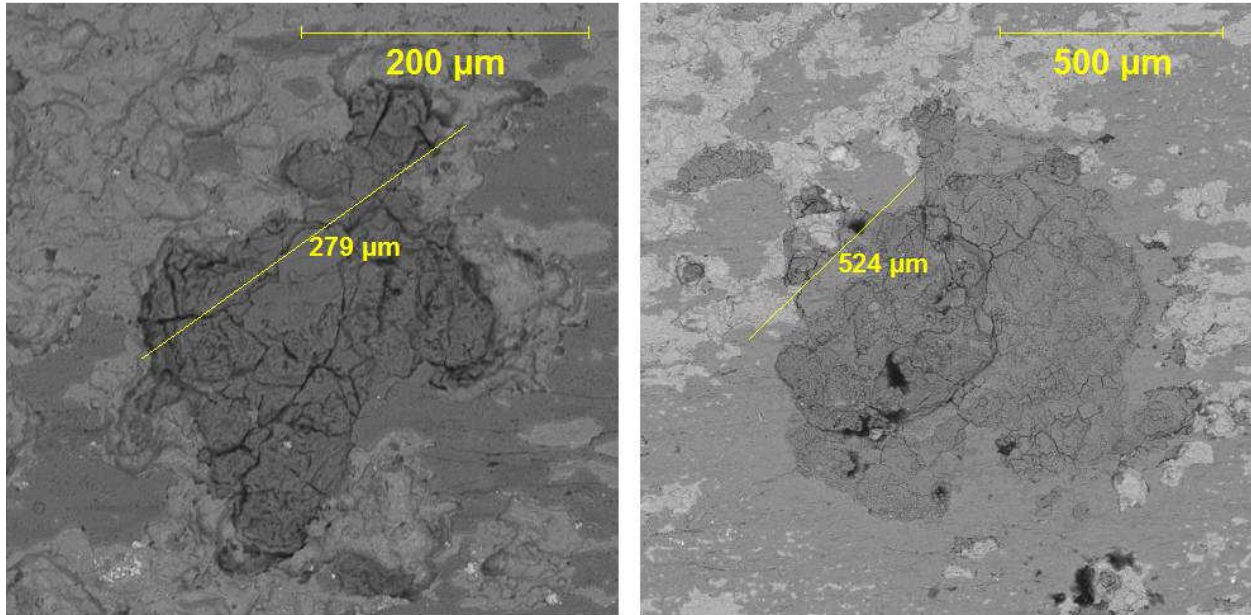


Figure 3-31 shows SEM images of two separate pits detected on the surface of coupon #3 of jumper of 1 – 4. Both pits are filled with corrosion product. The pit on the left was measured at 10.9 mils (279 μm) across, and the pit on the right was measured at 20.4 mils (524 μm) across.

Figure 3-31. Scanning Electron Microscopy Images of Pits on Coupon #3 of Jumper 1 – 4.



Tank waste material, which remained after the ammonium citrate treatment, was detected in a few locations lodged on areas of corrosion. The material varied from high carbon content which is probably organic material (Figure 3-32) to a calcium aluminum silicate (Figure 3-33).

Figure 3-32. Scanning Electron Microscopy Image and Energy Dispersive Spectrometry Spectrum of a Carbon-Rich Tank Waste Material on Coupon #3 of Jumper 1 – 4.

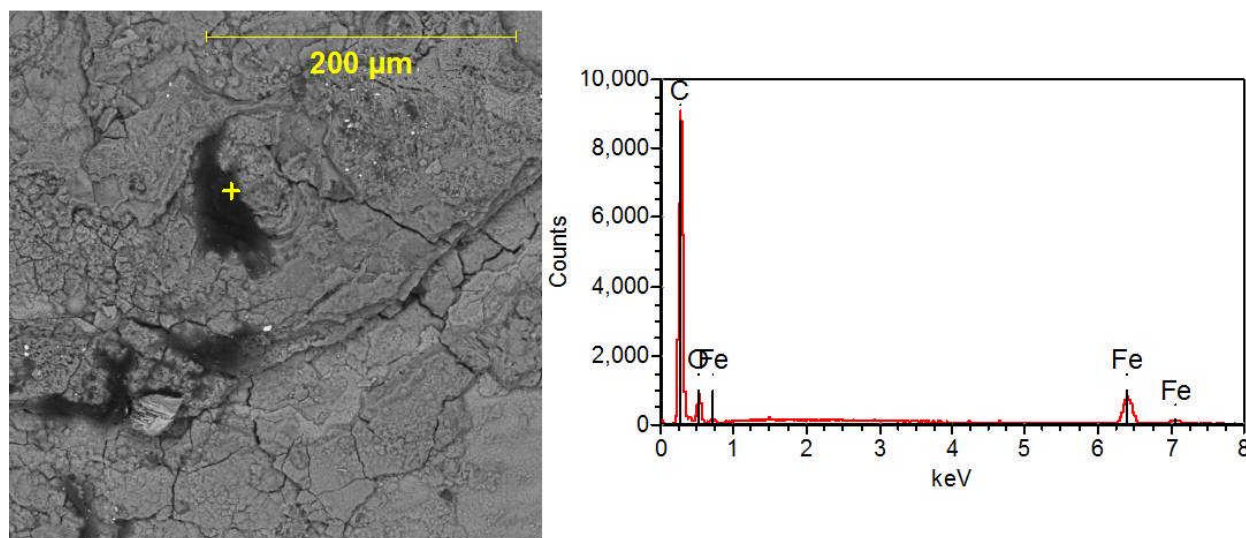
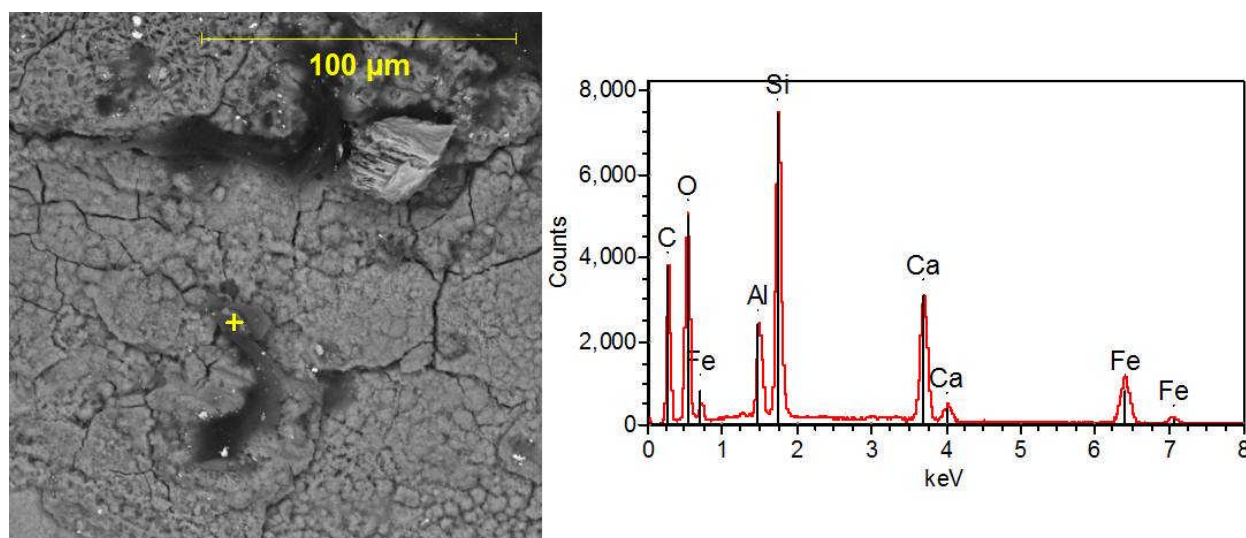


Figure 3-33. Scanning Electron Microscopy Image and Energy Dispersive Spectrometry Spectrum of a Calcium Aluminum Silicate Tank Waste Material on Coupon #3 of Jumper 1 – 4.



Similar to coupon #1 of jumper 1 – 4, several striations were seen on coupon #3 both with optical microscopy and SEM. Locations of these features were examined in closer detail using the high magnification of SEM to try to determine if these features were present on the pipe before deployment in the tank farm or had formed due to erosion-corrosion from the liquid transfers. Figure 3-34 shows SEM images acquired in SEI mode of one of a larger axial striation where there is a clear demarcation of two surfaces: one smoother and one rougher. The right SEM image is a magnified view of the area in the yellow box. This image shows that the

smoother area resides higher on the inner pipe surface than the rougher area. If the smooth area had been caused by abrasion or erosion, then the surface would be lower than the surrounding areas. Figure 3-35 shows BEI-mode SEM images of a radial striation at two different magnifications. The upper part of the right image shows some brighter silver deposits on the pipe surface. The silver transcends the striation boundary and suggests that the striation was there while the silver was deposited in the pipe from the solution being pumped through it. Again, this seems to indicate that the striation was present in the pipe before the pipe usage or earlier in the pipe usage.

Figure 3-34. Scanning Electron Microscopy Images of an Axial Striation on Coupon #3 of Jumper 1 – 4.

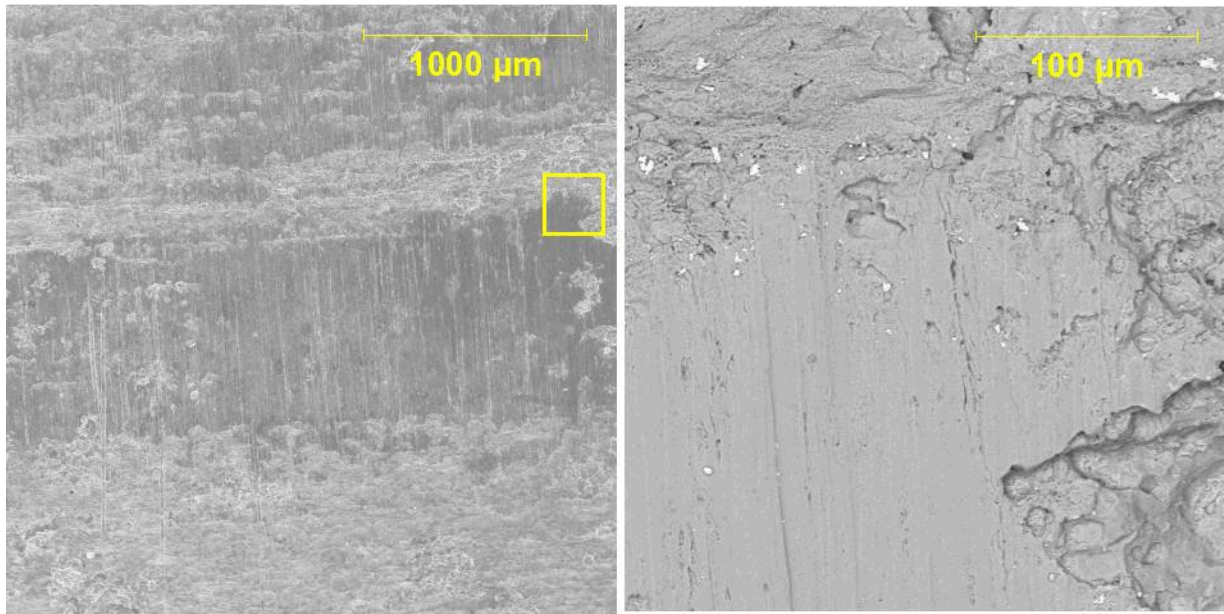
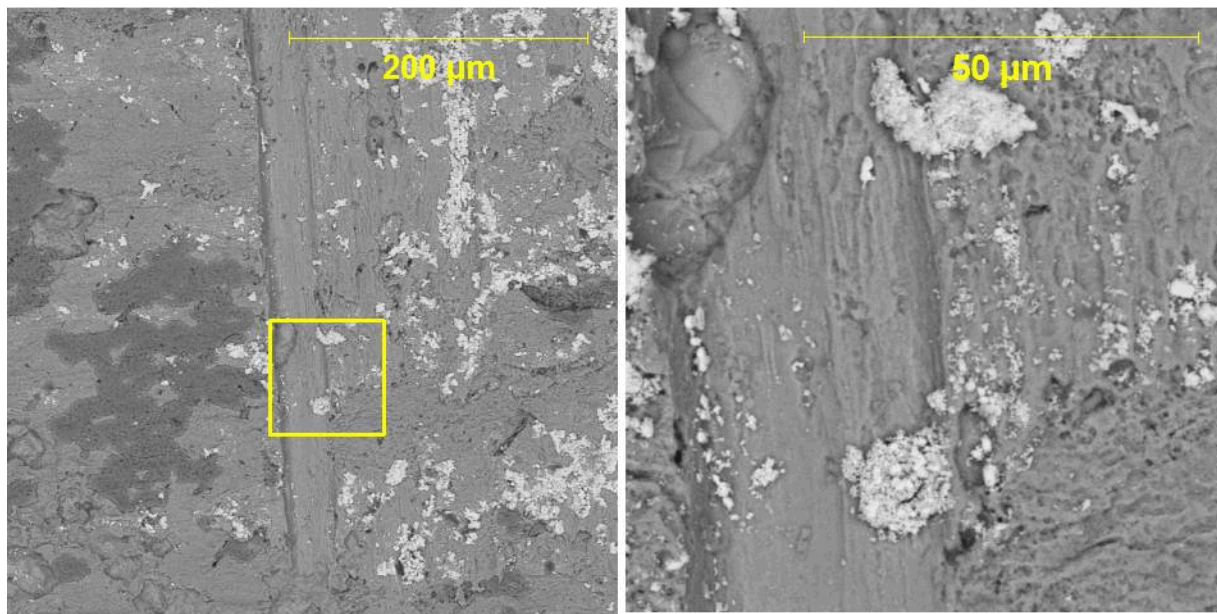


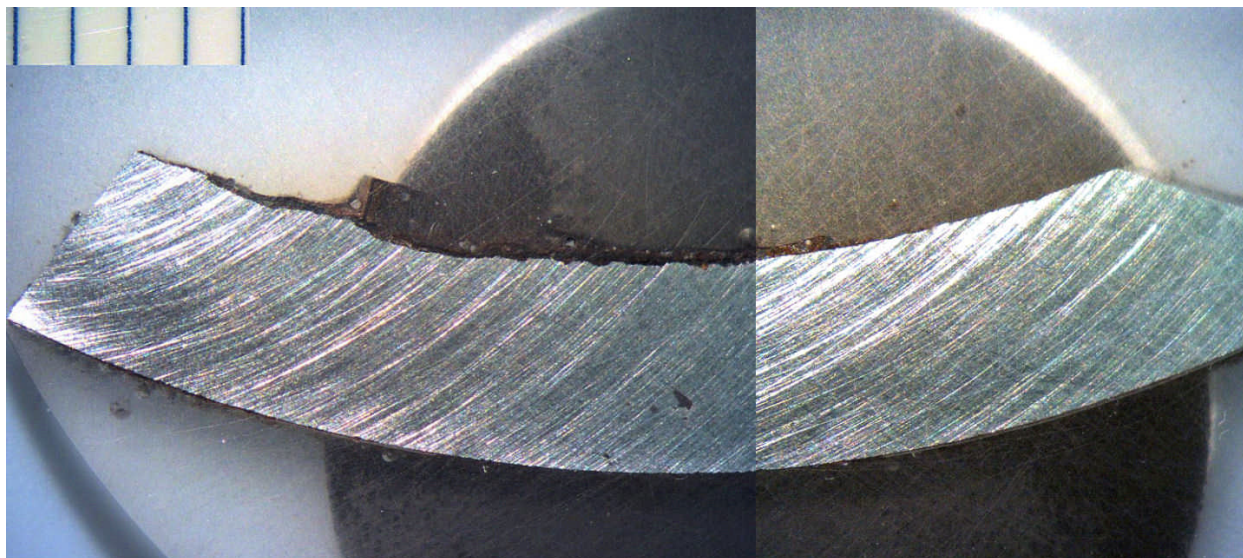
Figure 3-35. Scanning Electron Microscopy Images of a Radial Striation on Coupon #3 of Jumper 1 – 4.



In total, coupon #3 of jumper 1 – 4 appears to have very little corrosion, and the ammonium citrate treatment removed a majority of any corrosion and tank waste layers which may have been present on the inner surface of the pipe. A few pits around 10 to 20 mils in diameter were detected on the inner surface of the pipe, although the pipe, in general, appears intact with only a few signs of corrosion and no signs of erosion-corrosion. The striations seen in the optical photography appear to have been on the pipe either before deployment or were present in the pipe earlier in its lifetime.

3.4.4 Jumper 1 – 4 Coupon #4

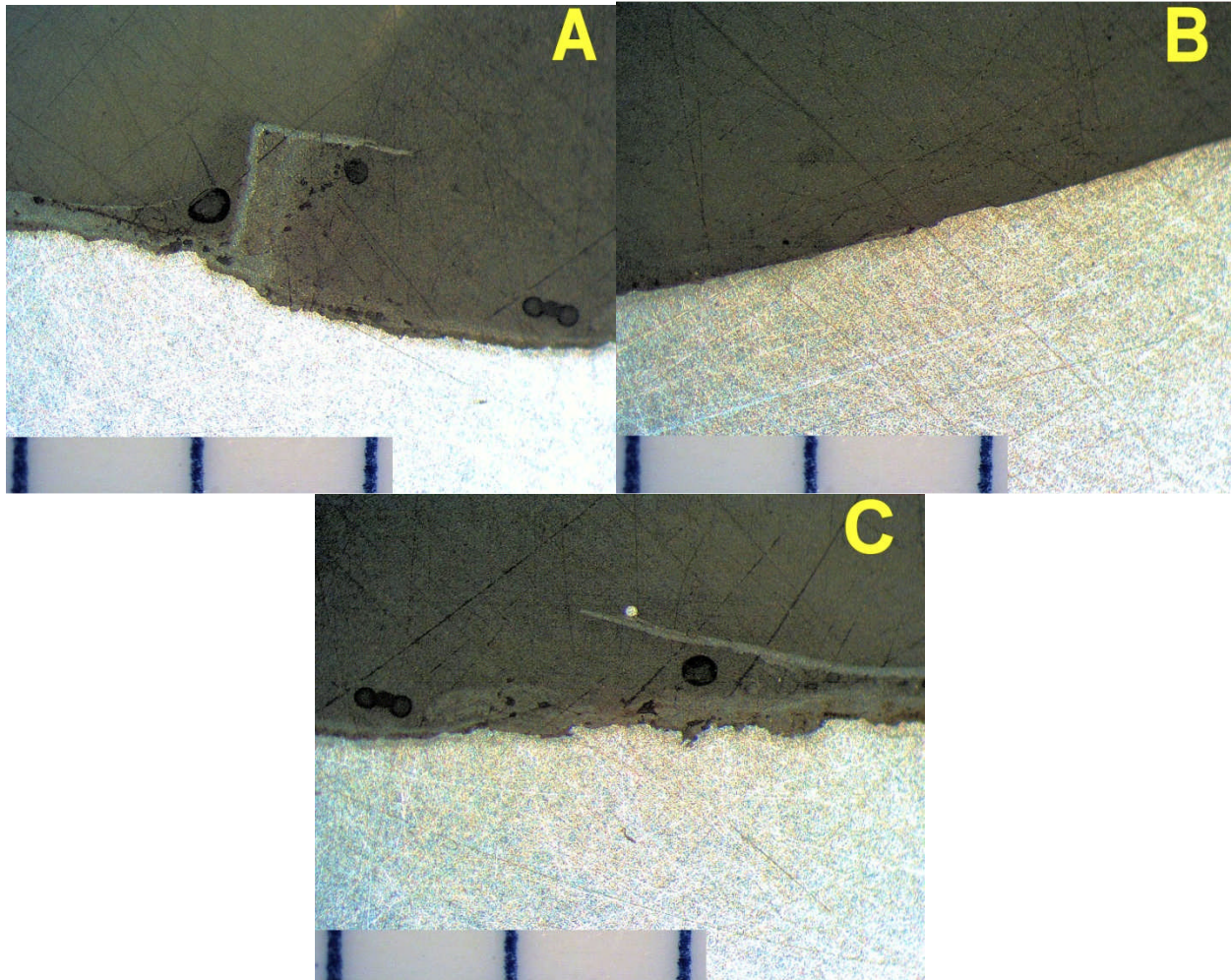
A second coupon was cut from the same area as coupon #3 at a location of the platy corrosion observed on the inside surface of the pipe. This coupon, referred to as coupon #4 with the OmniLims sample #S13R000612B, was cut to isolate a portion of this platy material seen in the left side of Figure 3-36 and in the photo in Figure 3-7. After load out from the hot cell, the coupon was immediately embedded in epoxy, immobilizing the surface material and preserving the features for SEM analysis. After the epoxy cured overnight, the coupon was wafered using a low-speed diamond saw, creating a cross-section of the pipe wall. This cross-section was then polished with sandpapers through consecutive grits ending in a 600-grit finish and mounted onto a SEM sample stub. The mounted cross-section was then photographed using an optical microscope, and the resulting image is shown in Figure 3-36. The size of the cross-section was larger than could be photographed by the microscope, so the image in Figure 3-36 is a mosaic of two separate images. The variation in sanding pattern between the two images is an artifact of the light source which highlights certain score directions. A scale bar is shown in the upper left of the image with marks at 1/16-inch increments. The black circle behind the pipe cross-section is the SEM stub. Epoxy completely surrounds the cross-section.

Figure 3-36. Microphotograph of the Cross-Section Cut from Coupon #4 of Jumper 1 – 4.

Visual inspection of the cross-section in Figure 3-36 shows that the pipe wall is intact with no areas of excessive wall thinning due to erosion-corrosion. The left side of the image shows a section of the platy material observed on the pipe and general corrosion, which reduced some of the pipe wall. In contrast, the right side of the image appears less corroded at this magnification, indicating a non-uniform corrosion of the pipe.

Figure 3-37 shows three microphotographs taken at an increased magnification compared to Figure 3-36. The scale bar is in 1/16-inch increments. The images show locations across the cross-section from the left (A), right (B), and center (C) of the coupon. At this magnification, the varying level of corrosion becomes even more apparent. The left side of the coupon displays general corrosion, which removed some of the inner surface of the pipe causing a wide depression. A part of the platy material can also be seen on top of the surface. In contrast to the left side of the coupon, the pipe surface on the right side is straight with minimal features. The image from the center of the coupon (Figure 3-37C) shows a transition between these two states with a few small pits and corrosion features across the pipe surface. This non-uniform corrosion on the pipe suggests the liquid was in contact with different areas of the pipe at various lengths of time. In other words, the liquid may have pooled on the bottom of pipe after use, causing more corrosion in this area.

Figure 3-37. Photomicrographs of Different Areas on the Cross-Section of Coupon #4 of Jumper 1 – 4 Showing Varying Levels of Corrosion.



The cross-section was next analyzed by SEM, providing further information on the integrity of this pipe section and the identification of the surface layer. Figure 3-38 contains two SEM images at the lowest instrument magnification to show and measure the entire wall thickness at two different locations on the cross-section (far left and far right sides). Conversion of the SEM measured distances from micrometers to inches shows that the measurements in Figure 3-38 are 0.226 inches on the left and 0.238 inches on the right side of the cross-section. The UT measurements of this coupon ranged from 0.222 to 0.231, Table 3-6.

Figure 3-38. Scanning Electron Microscopy Images and Measurements of the Pipe Wall Thickness of Coupon #4 of Jumper 1 – 4.

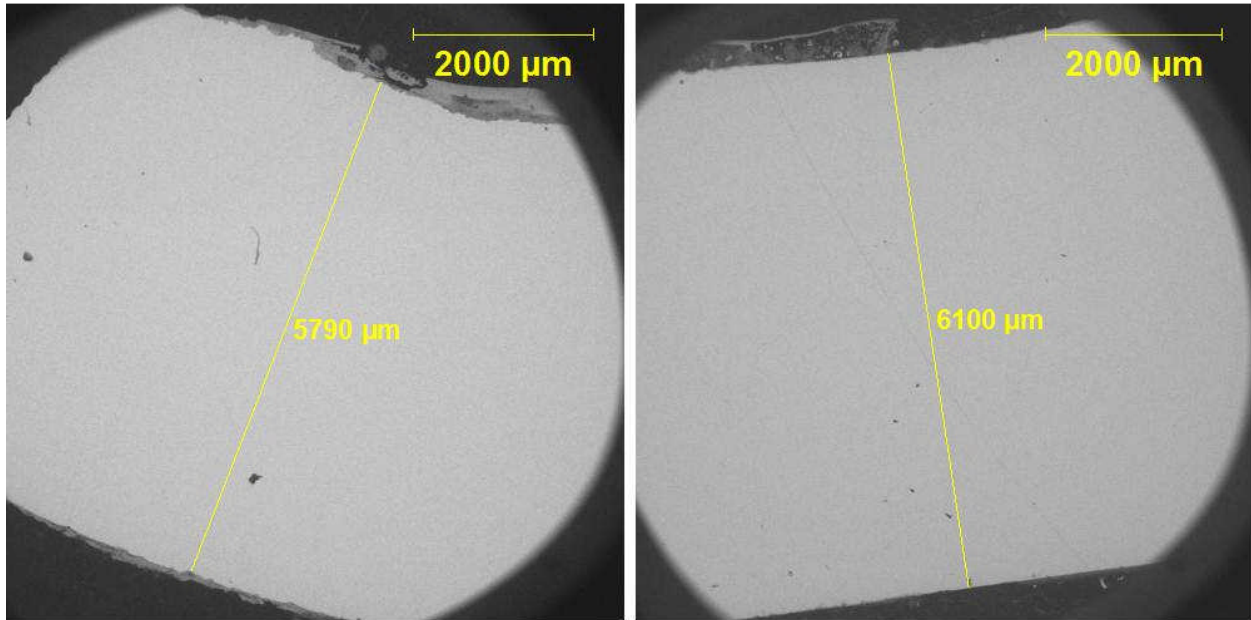


Figure 3-39 shows SEM images taken of the left side of the cross-section at two different magnifications and EDS spectra at two locations of the layer on the pipe surface. The surface displays a continuous general corrosion with some small pitting. The pit in the lower right portion of the right image was measured at 4.1 mils (105 μm) across and 1.8 mils (46.8 μm) deep. Although the layer has dramatic changes in thickness and morphology, the EDS spectra are similar at the two locations and indicate the presence of iron oxide/hydroxide (corrosion product) with trace tank waste elements of sodium, aluminum, and chromium.

Figure 3-39. Scanning Electron Microscopy Images and Energy Dispersive Spectrometry Spectra of the Left-Side Surface of Coupon #4 of Jumper 1 – 4.

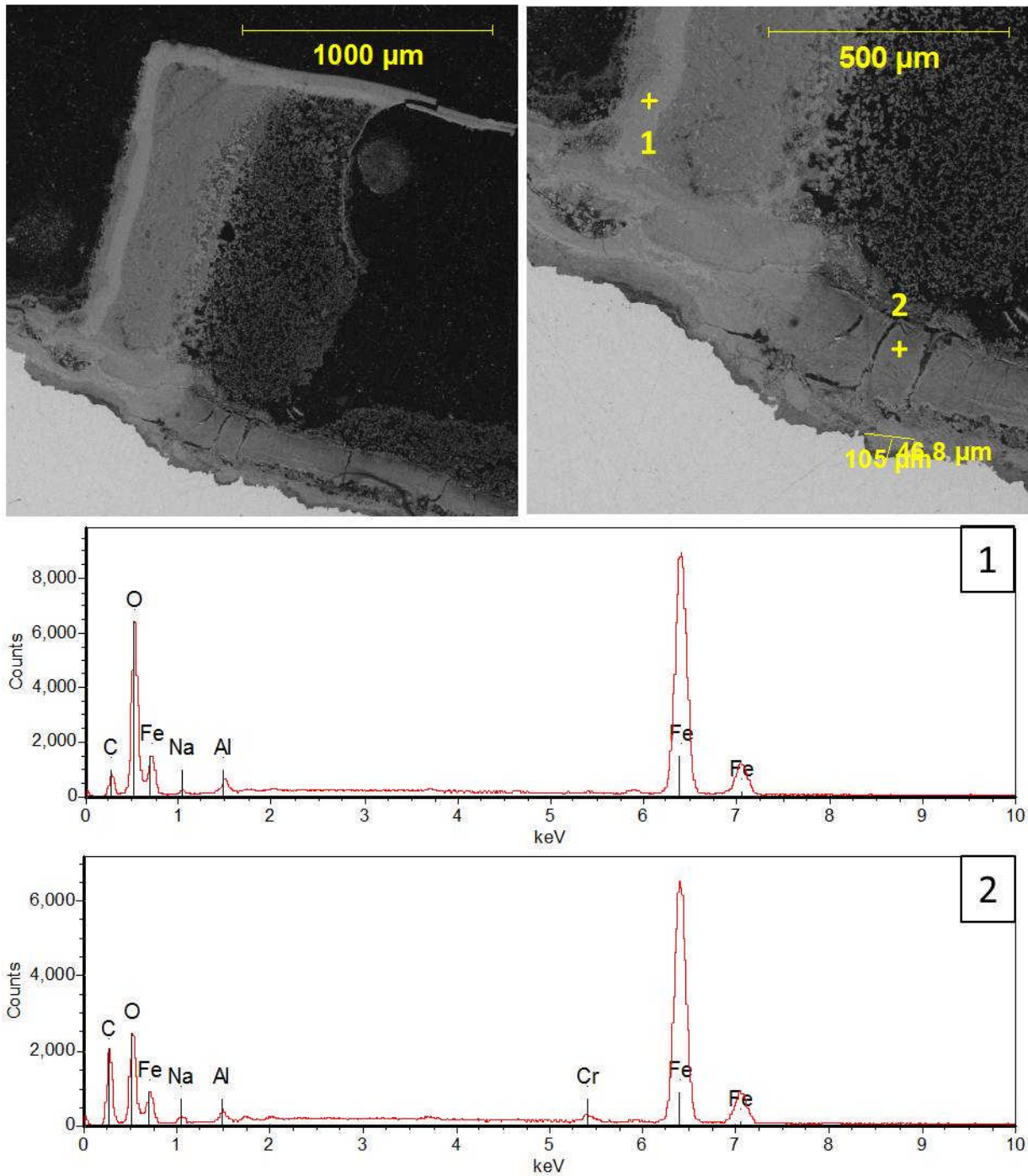
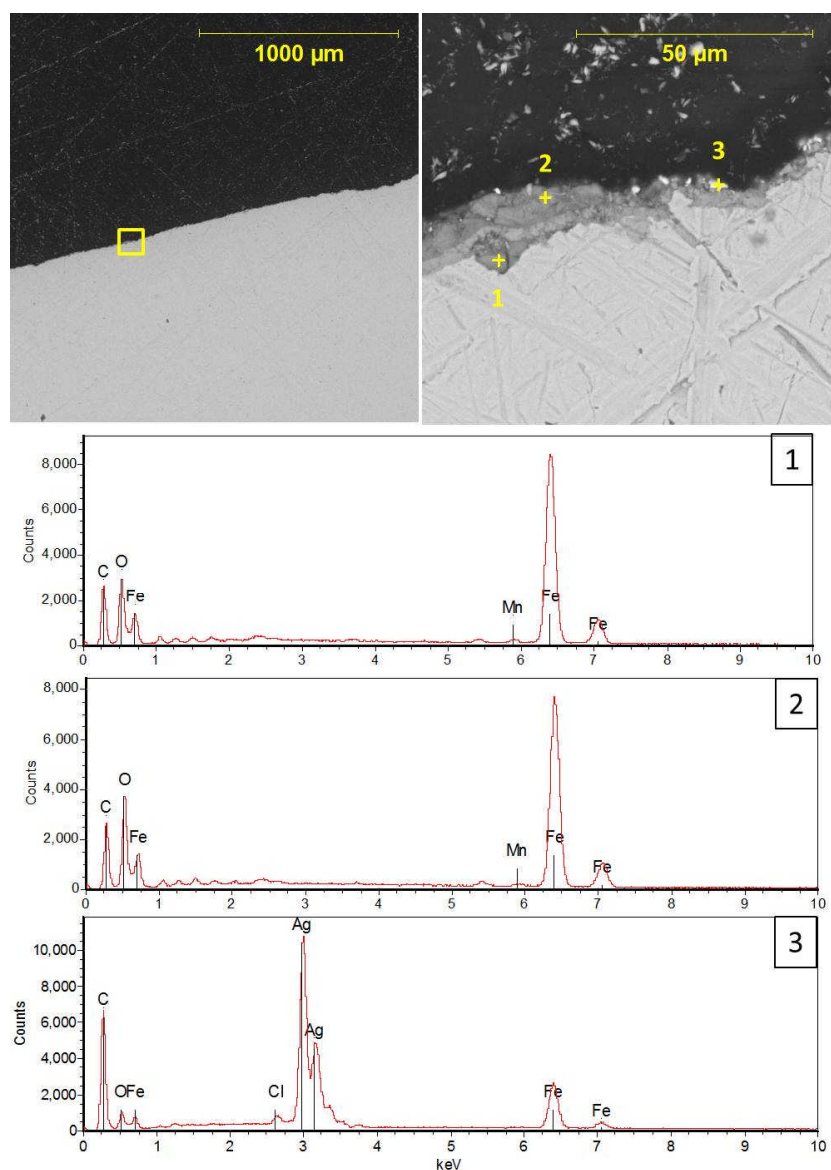


Figure 3-40 contains SEM images at different magnifications of the right side of the cross-section of coupon #4 from jumper 1 – 4. In contrast to the left-side of the coupon shown in Figure 3-39, the right-side displays considerably less corrosion of the pipe metal and less of a

layer on the surface. The magnified image on the right side shows more of the surface features in greater detail. There appears to be some corrosion on the surface, as indicated by the EDS spot #1 and #2, but the features are too small to be considered pits (“Pitting Growth Rate in Carbon Steel Exposed to Simulated Radioactive Waste,” Zapp 1996). The EDS spot #3 shows that brighter particles at the top of the thin corrosion layer are silver-rich, as discussed previously in this report. Since the right side of the coupon shows minimal corrosion and the left side of the coupon shows general corrosion, it is possible to obtain some information on a corrosion rate in this localized area of the pipe (assuming the manufactured pipe wall thickness in this segment of pipe was uniform). The difference in the wall thickness between these two areas is ~12 mils (see Figure 3-38). Knowing that the lifetime of this pipe was 16 years, the average corrosion rate at this location was ~0.8 mils per year.

Figure 3-40. Scanning Electron Microscopy Images and Energy Dispersive Spectrometry Spectra of the Right-Side Surface of Coupon #4 of Jumper 1 – 4.



A couple of examples of the pits detected by SEM on the left side of the cross-section are shown in Figures 3-41 and 3-42. The wide, shallow pit in Figure 3-41 measured 27.5 mils (705 μm) wide and 6.2 mils (159 μm) deep. The corresponding EDS spectrum shows iron oxide/hydroxide as the material in and above the pit. The vertical pit shown in Figure 3-42 is deeper at 9.1 mils (233 μm) and 18.6 mils (477 μm) wide. Both corrosion product (iron oxide/hydroxide) and tank waste residue (calcium phosphate) were detected around the pit. The structure of the corrosion/tank waste layer is complex, indicating a complex history of corrosion, spalling, and deposition.

Figure 3-41. Scanning Electron Microscopy Image and Energy Dispersive Spectrometry Spectrum of a Wide, Shallow Pit on Coupon #4 of Jumper 1 – 4.

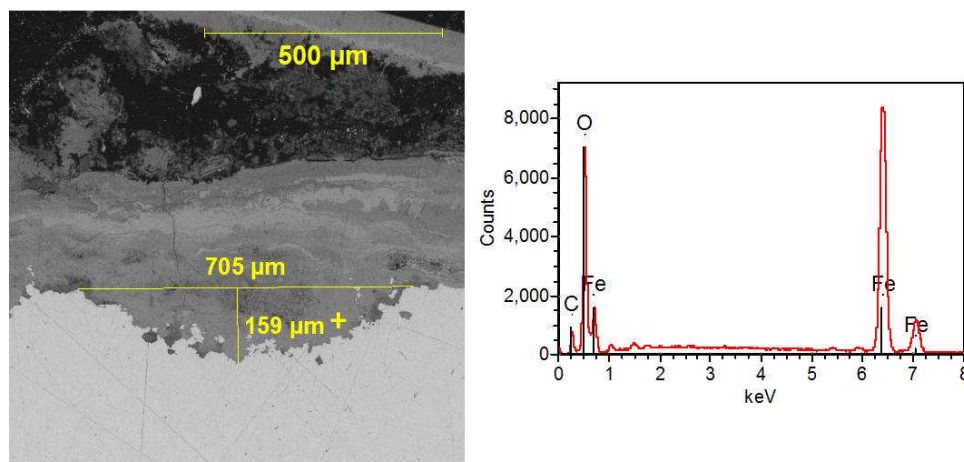
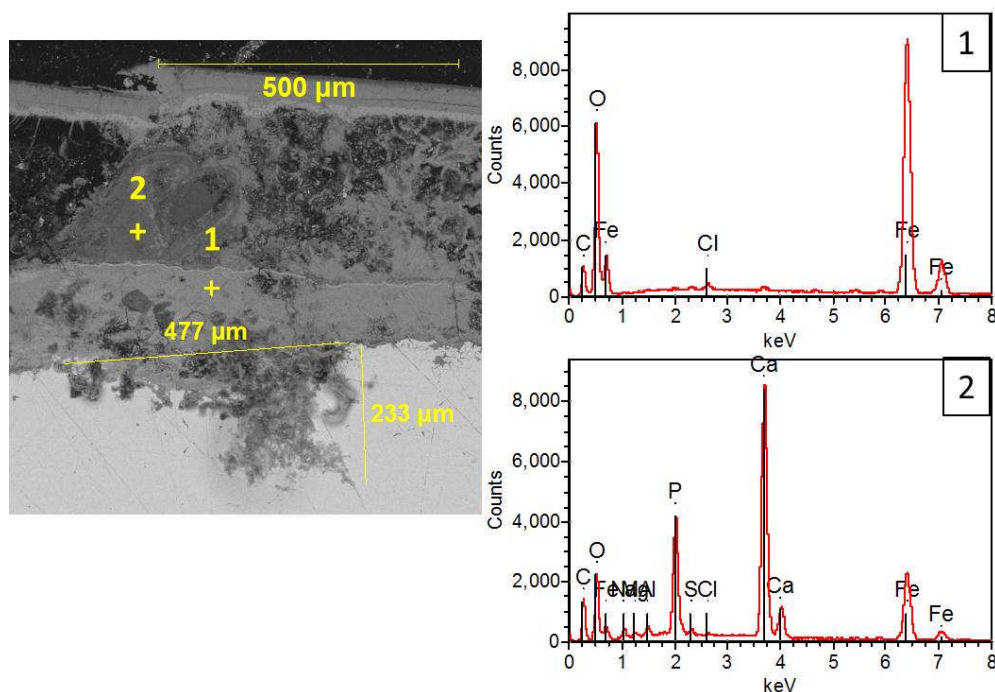
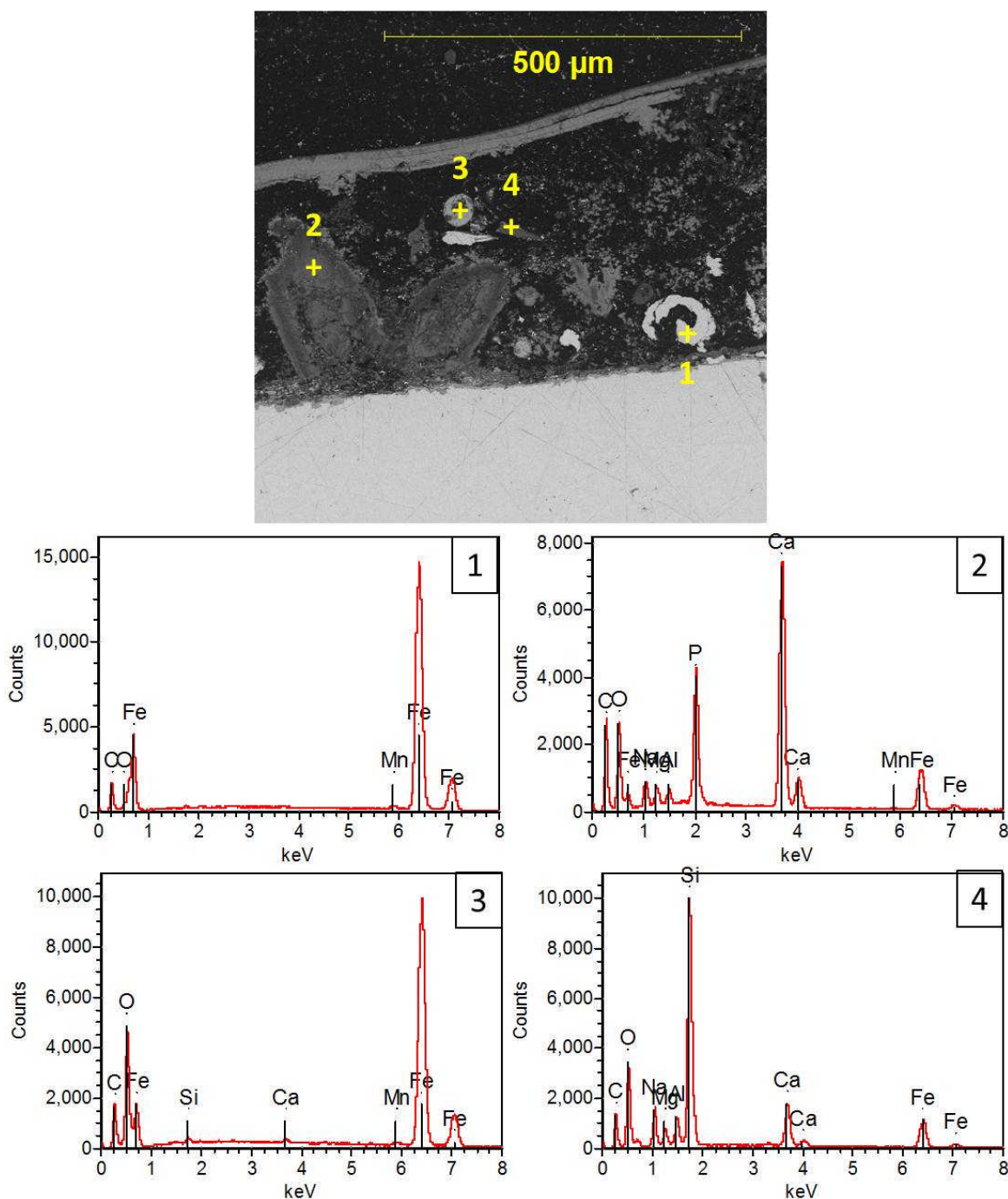


Figure 3-42. Scanning Electron Microscopy Image and Energy Dispersive Spectrometry Spectra of a Vertical Pit on Coupon #4 of Jumper 1 – 4.



Other particles besides iron oxide/hydroxide and calcium phosphate were detected inside the layer on the inner pipe surface of coupon #4. Figure 3-43 shows that along with these phases, metal particles or shavings were also seen (EDS spot #1). These metal particles are embedded in the corrosion layer and are, therefore, not a result of the coupon cutting process. In addition, a silicate particle was seen at EDS spot #4 and is possibly from Hanford soils.

Figure 3-43. Scanning Electron Microscopy Image and Energy Dispersive Spectrometry Spectra of Various Particles Embedded in the Layer on Coupon #4 of Jumper 1 – 4.



In general, coupon #4 of jumper 1 – 4 appears to have a varying level of corrosion across the cross-section with the left side of the coupon displaying a slightly thinner pipe wall, a greater amount of general corrosion and pitting, and more of a corrosion product and tank waste layer on the pipe wall. This could have been caused by a varying amount of exposure to the liquid in the pipe. For example, tank waste liquid or water may have pooled (not fully drained) in the bottom of the pipe after pumping, increasing the amount of corrosion in that area.

4 CONCLUSION

Ultrasonic transducer measurement maps for both jumpers were supplied by the customer that covered a majority of the pipe sections and Purex connector blocks while also focusing on areas with a higher susceptibility to erosion-corrosion, such as elbows and connector blocks. Even though the outside surface of the jumpers had paint, rust, and labels across the pipes, most of the requested UT measurements were successfully acquired, although measurements on some locations should be considered suspect due to possible interferences with the measurements. The measurement results ranged between 0.211 to 0.286 inches (nominal wall thickness of 3-inch schedule 40 pipe is 0.216 inches), and no discernable areas of wall thinning were observed, indicating that significant erosion-corrosion did not occur in the jumpers. In addition, clamshelling of an elbow from each jumper exposed the extrados and intrados pipe walls, and revealed no noticeable wall thinning.

Seven coupons from the jumpers were cut from the pipe and were further analyzed using optical microscopy and SEM. Three of the coupons were embedded in epoxy to preserve any corrosion and residues on the surface of the pipe as well as to allow cross-sectioning of the coupon to characterize features and pits. The other four coupons were subjected to an ammonium citrate treatment process which removed enough corrosion and tank waste product to allow examinations of the inner pipe surface for erosion-corrosion analysis. No definitive erosion-corrosion features were detected on the pipe, and no significant wall thinning was observed on any of the coupons. Varying levels of corrosion were detected on the coupons, but in general, the levels of corrosion were minor. Jumper B – 2 displayed the greatest amount of general corrosion for the two jumpers, and the largest pit was 10.2 mils wide and 4.6 mils deep. Although jumper 1 – 4 had less overall corrosion with some areas on the pipe wall displaying a very low level of general corrosion and pitting, the level of corrosion was observed to change more dramatically across the coupon. This suggests a varying amount of exposure to the liquid in the pipe, such as pooling of the liquid after pumping. The largest pit on jumper 1 – 4 was 27.5 mils wide and 6.2 mils deep.

5 REFERENCES

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- Poulson, B., 1999, “Complexities in predicting erosion-corrosion,” *Wear*, Vols. 233-235, pp. 497-504.
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LAB-RPT-14-00005 R 0

Appendix A

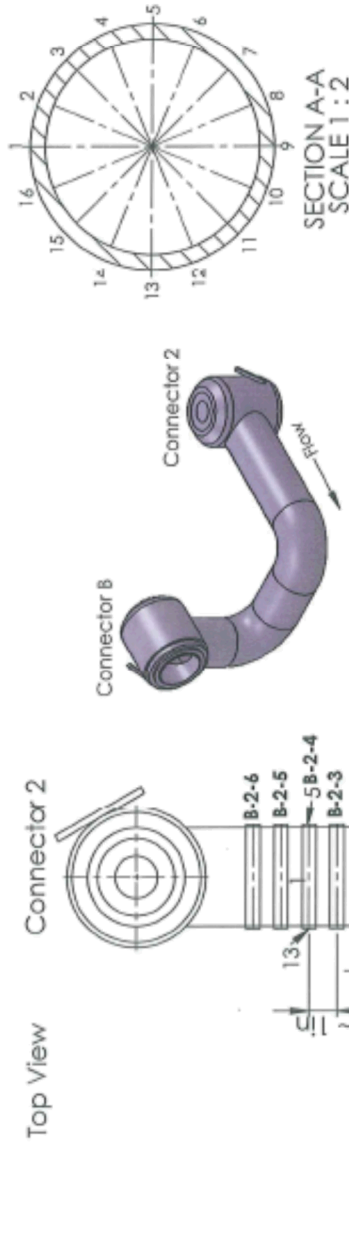
		AREVA Federal Services LLC																																								
		NDE ULTRASONIC THICKNESS MEASUREMENT PROCEDURE AND TEST REPORT																																								
Requester (Client)	Company	MSIN	Bldg	Area	Page 1 of 21																																					
Jason S. Page	WRPS	T6-05	2713-S	200-W	Job No. 13-33																																					
Project/System/Work Package/Traveler No. Ultrasonic wall thickness measurements taken on AW02-E Pipe Jumper #B-2 (3" Sch. 40 carbon steel pipe sections and elbows) Per Step #5.3 of Work Package WO-13-0871 (Areva Charge Code: 01950.03.T001.B1.T00B1)					PART INFORMATION Material Carbon Steel; ASTM A-53 ☐ NA Wall Thickness 0.216" (Nominal) ☐ NA Diameter 3" ☐ NA Schedule 40 ☐ NA Size ☐ NA																																					
Acceptance Std.	Section	Paragraph	Date	☐ NA	Dwg #	☒ NA																																				
For Information Only; Provide "As-Found" Thickness Measurements. Acceptance by Client.					NCR	☒ NA																																				
PROCEDURE NO. RCD-NE-PRC-UT1 Rev. 00		RESULTS: 1.) All thickness measurements are in "inches". 2.) Tolerance on reported thickness readings = +/- 0.005" of the stated value. 3.) All thickness readings were taken through Amercoat #86 primer and Amercoat #33 protective coating as applied during jumper fabrication. 4.) Measurement locations were established at either 12 or 16 evenly-spaced positions around the circumference of the pipe; see the attached data pages. 5.) Some thickness readings (particularly on the elbows) were outside of the upper-end range of the calibration standards. These thicknesses are well beyond what would reasonably be expected for such components and are higher than the industry standard wall thickness for 3" Schedule 40 pipe (0.216" nominal). 6.) Locations identified with an asterisk (*) indicate either that the thickness reading was taken through randomly-applied epoxy paint on the part's surface, or that no thickness measurement is available due to the epoxy paint and/or rough surface finish on the part in that localized area. 7.) "Repeat" means that a second thickness measurement was taken as a verification thickness at the same location to quick-check for reliable performance of the ultrasonic test system. 8.) See the attached data sheets for isometric and plan views of pipe Jumper #B-2 as well as the actual thickness measurements and locations. Periodic Calibration Checks: [Nom. Thkn. Value] Time=10:55am Time=11:36am Time=11:58am Time=1:42pm Time=2:31pm <table border="1"> <tr> <td>0.179"</td> <td>0.180"</td> <td>0.179"</td> <td>0.180"</td> <td>0.180"</td> <td>0.180"</td> </tr> <tr> <td>0.196"</td> <td>0.196"</td> <td>0.197"</td> <td>0.196"</td> <td>0.196"</td> <td>0.197"</td> </tr> <tr> <td>0.221"</td> <td>0.221"</td> <td>0.221"</td> <td>0.221"</td> <td>0.221"</td> <td>0.221"</td> </tr> <tr> <td colspan="6">*****</td> </tr> <tr> <td>0.225"</td> <td>0.226"</td> <td>0.226"</td> <td>0.226"</td> <td>0.227"</td> <td>0.226"</td> </tr> <tr> <td>0.239"</td> <td>0.240"</td> <td>0.240"</td> <td>0.241"</td> <td>0.240"</td> <td>0.239"</td> </tr> </table>					0.179"	0.180"	0.179"	0.180"	0.180"	0.180"	0.196"	0.196"	0.197"	0.196"	0.196"	0.197"	0.221"	0.221"	0.221"	0.221"	0.221"	0.221"	*****						0.225"	0.226"	0.226"	0.226"	0.227"	0.226"	0.239"	0.240"	0.240"	0.241"	0.240"	0.239"
0.179"	0.180"						0.179"	0.180"	0.180"	0.180"																																
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0.239"	0.240"						0.240"	0.241"	0.240"	0.239"																																
Appendix: A	Rev # 00																																									
Special Technique # N/A																																										
COVERAGE ☒ 100% of Area Requested ☐ Other																																										
INSTRUMENTATION Mfg. Krautkramer Model USN-52L S/N or Standards Lab No. OOR294 (WC76595)																																										
CALIBRATION STANDRD(S) Identification No. 584-99-30-155 (3-step pipe) Identification No. 3" CST elbow (0.225"/0.239")																																										
TRANSDUCER Diameter 0.250" Frequency 10 MHz. Mfg Nortec "Green-Top" Serial No. K-M-1/4-10 Stand Off (n/a)																																										
Couplant "Ultragel-II"																																										
Batch No. 10225-H																																										
Technician B.J.Sewart	UT Level II	Technician B.J.Sewart	UT Level II	Reviewed by W.D. Nelson																																						
Date of Examination July 30, 2013		Date of Examination July 30, 2013		Date 9/18/13																																						

RCD-NE-FRM-005 Rev. 00 (Issued April 17, 2009)
Refer to RCD-NE-PRC-UT1, Ultrasonic Examination

AREVA NDE JOB #13-33
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Jumper B-2: ST-1
(3 inch Schedule 40)



SECTION A-A
SCALE 1:2

	B-2-1	B-2-2	B-2-3	B-2-4	B-2-5	B-2-6
1	0.246	0.242	0.254	0.240	0.241	0.237
2	0.253	0.250	0.248	0.248	0.250	0.242
3	0.257	0.258	0.251	0.253	0.253	0.254
4	* 0.250	* 0.249	0.256	0.248	0.250	0.244
5	* 0.231	*	0.233	0.231	0.226	0.230
6	* 0.226	* 0.233	0.233	0.220	0.226	0.226
7	0.230	0.231	0.228	0.230	0.230	0.227
8	0.225	0.221	0.226	0.225	0.220	0.226
9	0.229	0.228	0.233	0.231	0.228	0.233
10	0.230	0.233	0.229	0.227	0.230	0.229
11	0.237	0.231	0.237	0.233	0.237	0.235
12	0.246	0.236	0.238	0.233	0.231	0.226
13	0.217	0.226	0.217	0.241	0.222	0.224
14	0.222	0.219	0.213	0.217	0.218	0.222
15	0.222	0.221	0.225	0.226	0.223	0.226
16	0.226	0.231	0.227	0.223	0.229	0.226

NOTE: B-2-1 through B-2-6 are the approximate locations for the UT measurements to be taken.

NOTE: Section A-A shows the approximate locations for UT measurements to be taken circumferentially.

"REPEAT" = 0.227" @ B-2-6
0.247" @ B-2-3 (3)

Inspector (print): B. J. SEWART / AREVA NDE

Inspector (sign): *Bj Sewart*

Date: 7/30/13

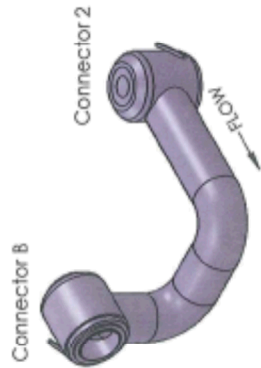
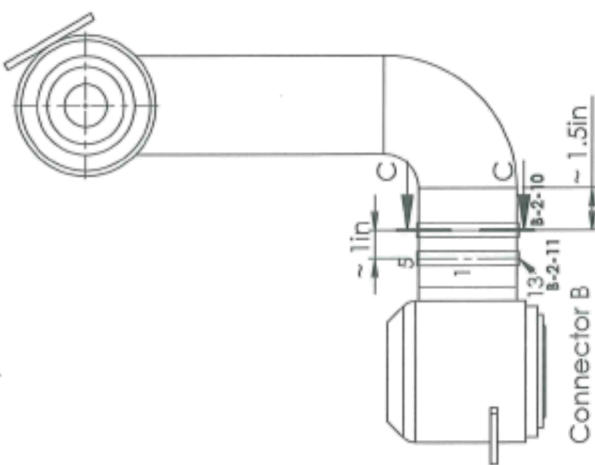
* HEAVY COATING OF EPOXY PAINT
AND/OR ROUGH SURFACE FINISH

T.J. Barnes
4/11/2013

ARENA NDE JOB # 13-33
PAGE 3 OF 21

Top View

Connector 2



SECTION C-C
SCALE 1:2

	B-2-10	B-2-11
1	0.258	0.252
2	0.257	0.256
3	*	0.225
4	*	0.227
5	0.223	0.223
6	0.235	0.225
7	0.224	0.224
8	0.234	0.238
9	0.256	0.251
10	0.253	* (No Signal)
11	0.235	0.244
12	0.237	0.225
13	0.234	0.226
14	0.240	0.241
15	0.231	0.228
16	0.225	0.227

NOTE: B-2-10 and B-2-11 are the approximate locations for the UT measurements to be taken.

NOTE: Section C-C shows the approximate locations for UT measurements to be taken circumferentially.

$${}^w\text{REPEAT}^u = \underline{\underline{0.256}}^u \in \underline{\underline{B21(2)}}$$
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Inspector (sign): Bye

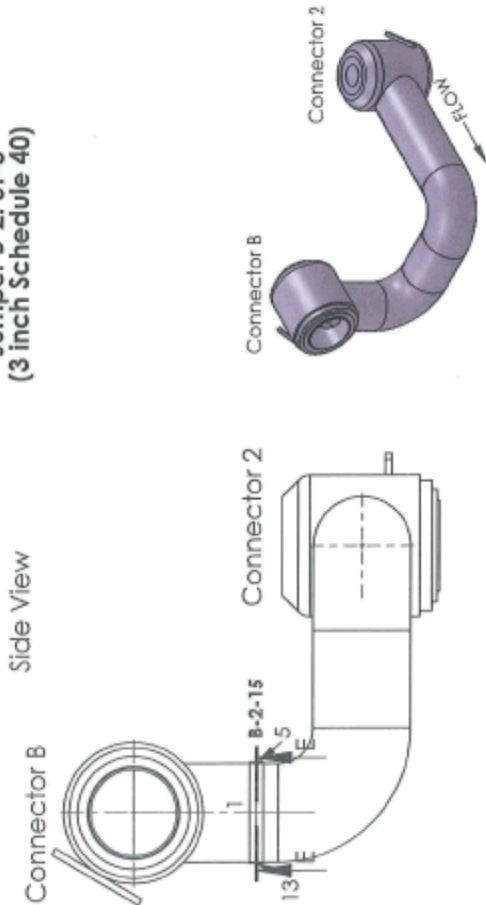
Date: 7/30/13T.J. Barnes
4/11/2013

* HEAVY EPOXY PAINT
ON PART SURFACE

LAB-RPT-14-00005 R 0
Appendix A

AREVA NDE JIG #13-33
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Jumper B-2: ST-3
(3 inch Schedule 40)



SECTION E-E
SCALE 1:2

B-2-15	
1	0.231
2	0.226
3	0.228
4	0.231
5	0.229
6	0.228
7	0.238
8	0.273
9	0.267
10	0.217
11	0.220
12	0.224
13	0.219
14	0.211
15	0.222
16	0.233

NOTE: B-2-15 is the approximate location for the UT measurements to be taken.

NOTE: Section E-E shows the approximate locations for UT measurements to be taken circumferentially.

$$\text{"REPEAT" } = 0.273'' @ \#8$$

Inspector (print): B. J. SEWART / AREVA NDE

Inspector (sign): Bj Sewart

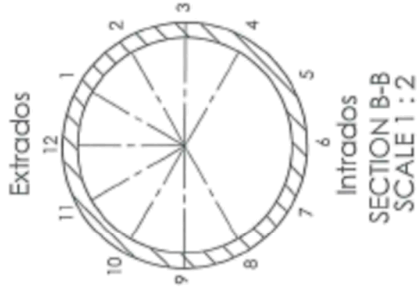
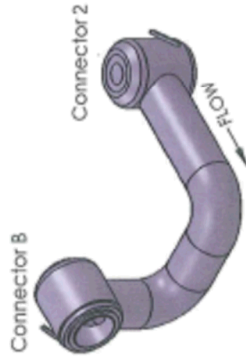
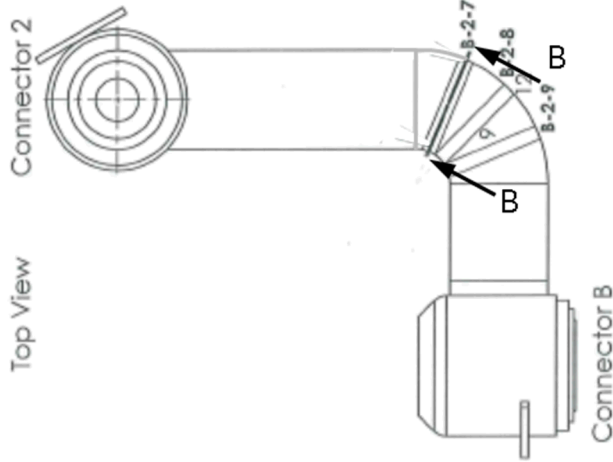
Date: 7/30/13

T.J. Barnes
3/25/2013

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Appendix A

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Jumper B-2: Elbow-1
(3 inch Schedule 40)



"REPEAT" = 0.23" @ B.2.8 (2)

	B-2-7	B-2-8	B-2-9
1	0.258	*	*
2	0.266	0.269	*
3	0.272	0.276	
4	—	—	0.271
5	N/A	N/A	N/A
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	0.273	0.270	0.268
9	0.278	0.278	0.272
10	0.254	0.263	0.265
11	0.255	0.240	0.270
12	0.231	0.231	0.237

NOTE: B-2-7 through B-2-9 are the approximate locations for the UT measurements to be taken along the outer radius of the elbow.

NOTE: Section B-B shows the approximate locations for UT measurements to be taken circumferentially.

Inspector (print): B. J. SEWART / AREVA NDE

Inspector (sign): B. J. Sewart

Date: 7/30/13

* HEAVY COATING OF EPOXY
PAINT AND/OR ROUGH SURFACE
FINISH

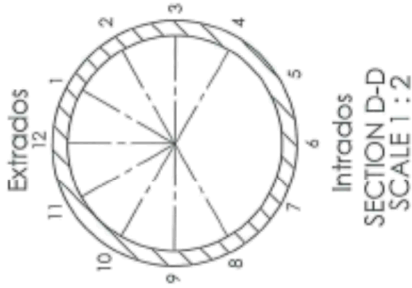
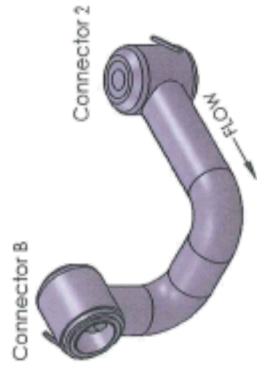
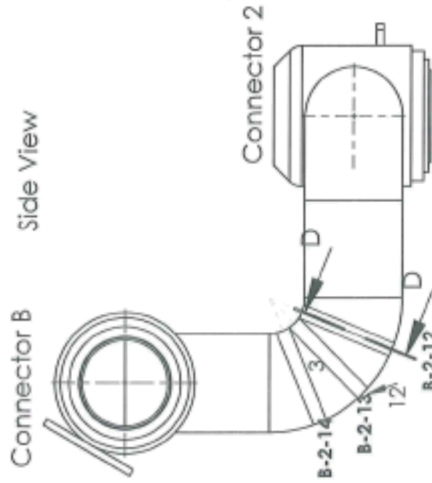
T.J. Barnes
3/25/2013

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Appendix A

AREVA NDE JCS #13-33
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Jumper B-2: Elbow-2
(3 inch Schedule 40)

Side View



"REPEAT" = $0.234'' @ B-2-14(1)$
 $0.239'' @ B-2-13(11)$

Inspector (print): B.J. SEWART/AREVA NDE

Inspector (sign): B.J. Sewart

Date: 7/30/13

* HEAVY EPOXY PAINT
ON PART SURFACE

	B-2-12	B-2-13	B-2-14
1	0.231	0.234	0.234
2	0.235	0.237	0.246
3	0.250	0.236	0.246
4	0.252	0.245	0.256
5	N/A	N/A	N/A
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	0.257	0.257	0.265
9	0.262	0.262	0.258
10	0.253	0.241	0.256
11	0.221	0.218	0.235
12	0.221	0.218	0.226

NOTE: B-2-12 through B-2-14 are the approximate locations for the UT measurements to be taken along the outer radius of the elbow.

NOTE: Section D-D shows the approximate locations for UT measurement to be taken circumferentially.

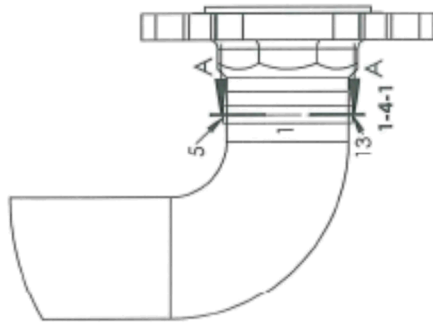
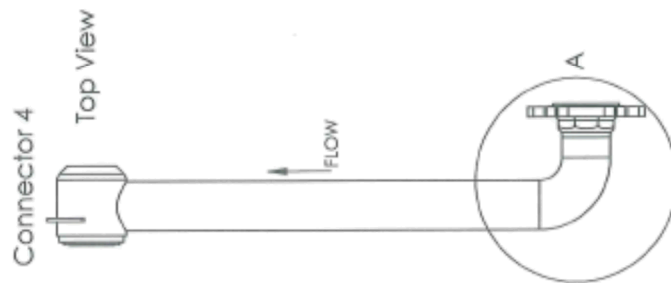
LAB-RPT-14-00005 R 0
Appendix A

		AREVA Federal Services LLC																													
		NDE ULTRASONIC THICKNESS MEASUREMENT PROCEDURE AND TEST REPORT																													
Requester (Client)	Company	MSIN	Bldg	Area	Page 7 of 21																										
Jason S. Page	WRPS	T6-05	2713-S	200-W	Job No. 13-33																										
Project/System/Work Package/Traveler No. Ultrasonic wall thickness measurements taken on AW02-E Pipe Jumper #1-4 Per Step #5.3 of Work Package WO-13-0871 (Areva Charge Code: 01950.03.T001.B1.T00B1)					PART INFORMATION Material Carbon Steel; ASTM A-53 ☐ NA Wall Thickness 0.216" (Nominal) ☐ NA Diameter 3" ☐ NA Schedule 40 ☐ NA Size ☐ NA																										
Acceptance Std.	Section	Paragraph	Date	☐ NA	Dwg #	☒ NA																									
For Information Only; Provide "As-Found" Thickness Measurements. Acceptance by Client.					NCR	☒ NA																									
PROCEDURE NO. RCD-NE-PRC-UT1 Rev. 00		RESULTS: 1.) All thickness measurements are in "inches". 2.) Tolerance on reported thickness readings = +/- 0.005" of the stated value. 3.) All thickness readings were taken through Amercoat #86 primer and Amercoat #33 protective coating as applied during jumper fabrication. 4.) Measurement locations were established at either 12 or 16 evenly-spaced positions around the circumference of the pipe; see attached data pages. 5.) Some thickness readings (particularly on elbows) were higher than what would normally be expected for 3" Schedule 40 pipe (0.216" nominal wall). For this reason, an additional calibrated thickness standard (Serial No. 5748) made from a 3" Sch. 80 pipe (0.300" nom. wall) was also used. 6.) Locations identified with an asterisk (*) indicate either that the thickness reading was taken through randomly-applied epoxy paint on the part's surface, or that no thickness measurement is available due to the epoxy paint and/or rough surface finish on the part in that localized area. 7.) "Repeat" reading means that a second thickness measurement was taken as a verification thickness at the same location to quick-check for reliable performance of the ultrasonic test system. 8.) See the attached data sheets for isometric and plan views of pipe Jumper #1-4 as well as the actual thickness measurements.																													
Appendix: A		Rev # 00																													
Special Technique # N/A		COVERAGE ☒ 100% of Area Requested ☐ Other																													
INSTRUMENTATION Mfg. Krautkramer Model USN-52L S/N or Standards Lab No. OOR294 (WC76595)		CALIBRATION STANDRD(S) Identification No. 584-99-30-155 (3-Step Std.) Identification No. 3" CST elbow (0.225"/0.239") S/N-5748, 3" Sch. 80 pipe section (0.283")																													
TRANSDUCER Diameter 0.250" Frequency 10 MHz. Mfg Nortec "Green-Top" Serial No. K-M-1/4-10 Stand Off (n/a)		Periodic Calibration Checks (August 20, 2013): [Nom. Thkn. Value] Time=10:26am Time=10:52am Time=11:32am Time=Noon <table border="1"> <tr> <td>0.179"</td> <td>0.180"</td> <td>0.180"</td> <td>0.177"</td> <td>0.178"</td> </tr> <tr> <td>0.196"</td> <td>0.198"</td> <td>0.198"</td> <td>0.196"</td> <td>0.197"</td> </tr> <tr> <td>0.221"</td> <td>0.224"</td> <td>0.224"</td> <td>0.222"</td> <td>0.222"</td> </tr> <tr> <td>0.239"</td> <td>0.244"</td> <td>0.244"</td> <td>0.241"</td> <td>0.242"</td> </tr> <tr> <td>0.283"</td> <td>0.283"</td> <td>0.283"</td> <td>0.281"</td> <td>0.283"</td> </tr> </table>					0.179"	0.180"	0.180"	0.177"	0.178"	0.196"	0.198"	0.198"	0.196"	0.197"	0.221"	0.224"	0.224"	0.222"	0.222"	0.239"	0.244"	0.244"	0.241"	0.242"	0.283"	0.283"	0.283"	0.281"	0.283"
0.179"	0.180"	0.180"	0.177"	0.178"																											
0.196"	0.198"	0.198"	0.196"	0.197"																											
0.221"	0.224"	0.224"	0.222"	0.222"																											
0.239"	0.244"	0.244"	0.241"	0.242"																											
0.283"	0.283"	0.283"	0.281"	0.283"																											
Couplant "Ultragel-II"		Periodic Calibration Checks (September 9, 2013): [Nom. Thkn. Value] Time=10:06 am Time=10:34 am <table border="1"> <tr> <td>0.179"</td> <td>0.179"</td> <td>0.179"</td> </tr> <tr> <td>0.196"</td> <td>0.196"</td> <td>0.197"</td> </tr> <tr> <td>0.221"</td> <td>0.222"</td> <td>0.223"</td> </tr> <tr> <td>0.283"</td> <td>0.283"</td> <td>0.284"</td> </tr> </table>					0.179"	0.179"	0.179"	0.196"	0.196"	0.197"	0.221"	0.222"	0.223"	0.283"	0.283"	0.284"													
0.179"	0.179"	0.179"																													
0.196"	0.196"	0.197"																													
0.221"	0.222"	0.223"																													
0.283"	0.283"	0.284"																													
Batch No. 10225-H		Technician B.J.Sewart <i>B.J.Sewart</i> UT Level II																													
Date of Examination August 20 and September 9, 2013		Date of Examination August 20 and September 9, 2013																													
		Reviewed by <i>W.D. [Signature]</i> Date 9/18/13																													

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Appendix A

AREVA NSE JCB #13-33
PAGE 8 OF 21

Jumper 1-4: ST-1
(3 inch Schedule 40)



"REPEAT" = 0.247
READING @ 1-4-1 (2)



	1-4-1
1	.252
2	.249
3	.241
4	.256
5	.260
6	.265
7	.242
8	.237
9	.226
10	.252
11	.259
12	.256
13	.241
14	.242
15	.248
16	.269

NOTE: 1-4-1 is the approximate location for the UT measurements to be taken.
NOTE: Section A-A shows the approximate locations for UT measurements to be taken circumferentially.

Inspector (print): B. J. SEWART (AREVA NSE)

Inspector (sign): *Bj Sewart*

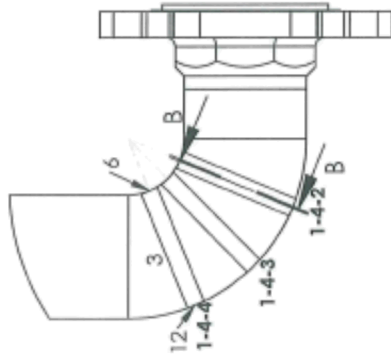
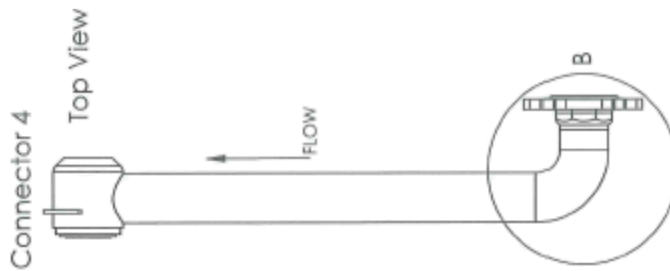
Date: 8/20/13

T.J. Barnes
4/11/2013

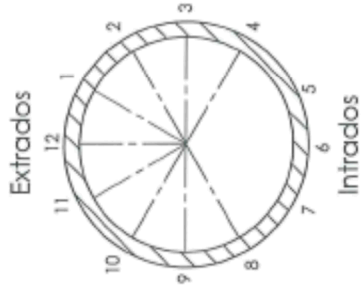
LAB-RPT-14-00005 R 0
Appendix A

AREVA NDE JCS #13-33
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**Jumper 1 to 4: Elbow-1
 (3 inch Schedule 40)**



**DETAIL B
 SCALE 1 : 4**



**SECTION B-B
 SCALE 1 : 2**

"REPEAT" READING:
 0.234" @ 1-4-3 (2)

	1-4-2	1-4-3	1-4-4
1	.234	.244	.241
2	.257	.235	.267 *
3	.256	.261	.260 *
4	.257	.254 *	.243
5	N/A	N/A	N/A
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	.235	.232	.234
9	.245	.224	.224
10	.254	.239	.235
11	.243	.241	.235
12	.247	.249	.239

NOTE: 1-4-2 through 1-4-4 are the approximate locations for the UT measurements to be taken along the outer radius of the elbow

NOTE: Section B-B shows the approximate locations for UT measurements to be taken circumferentially

Inspector (print): B. J. Sewart (AREVA NDE)

Inspector (sign): B. J. Sewart

Date: 5/20/13

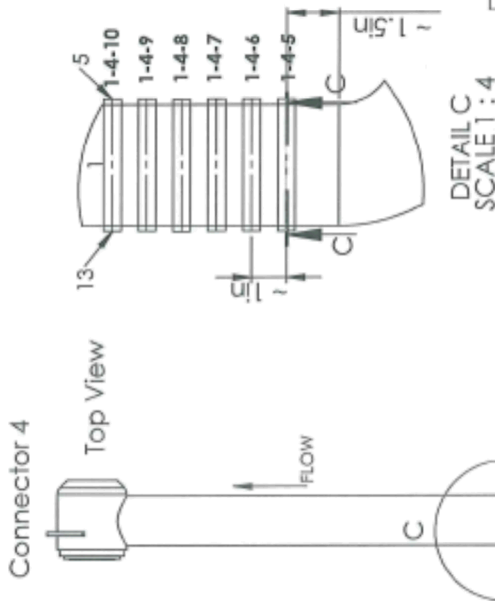
T.J. Barnes
 3/27/2013

* EPOXY PAINT ON
 SURFACE OF PIPE

LAB-RPT-14-00005 R 0
Appendix A



Jumper 1 to 4: ST-2
(3 inch Schedule 40)



	1-4-5	1-4-6	1-4-7	1-4-8	1-4-9	1-4-10
1	.236	.228	.232	.235	.228	.232
2	.226	.230	.241*	.236*	.235*	.218
3	.212	.219	.228*	.231*	.220*	.211
4	.230	.232*	.232	.233	.228*	.230
5	.236	.251*	.245	.244*	.248*	.245*
6	.253	.246	.243	.250*	.242	.244*
7	.241	.242	.240	.247	.242	.242
8	.230	.219	.230	.227	.222	.228
9	.230	.236	.227	.228	.225	.230
10	.220	.228	.215	.230*	.225	.222
11	.230*	.231	.228	.254*	.243*	.225
12	.220*	.226	.220	.220	.224	.245*
13	.233*	.226	.217	.227	.224	.230*
14	.232*	.232	.232*	.233	.231	.230
15	.231	.230	.233	.222	.223	.251*
16	.228	.232	.222	.218	.218	.217

NOTE: 1-4-5 through 1-4-10 are the approximate locations for the UT measurements to be taken.
NOTE: Section C-C shows the approximate locations for UT measurements to be taken circumferentially.

Inspector (print): B. J. SEWART (AREVA NDE)

Inspector (sign): *Bj Sewart*

Date: 8/20/13

T.J. Barnes
4/11/2013

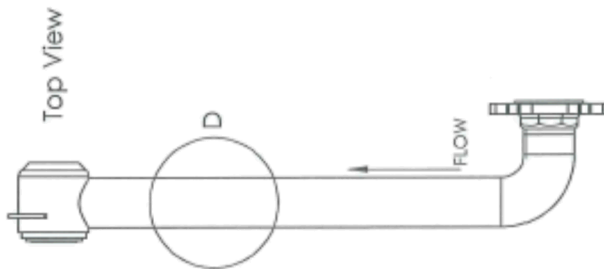
* HEAVY COATING OF EPOXY
PAINT ON SURFACE OF PIPE

LAB-RPT-14-00005 R 0
Appendix A

AREVA NDE JWB #13-33
PAGE 11 OF 21

Jumper 1 to 4: ST-3
(3 inch Schedule 40)

Connector 4



SECTION D-D
SCALE 1:2

Inspector (print): B. J. SEWART (AREVA NDE)
Inspector (sign): BJSewart
Date: 8/20/13

"REPEAT" READINGS = 0.228" @ 1-4-11(10)
0.243" @ 1-4-14(7)

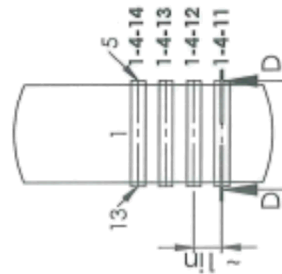
	1-4-11	1-4-12	1-4-13	1-4-14
1	.247 *	.233 *	.253 *	.243 *
2	.244 *	.245 *	.250 *	.241 *
3	.241 *	.243 *	.235 *	.249 *
4	.223	(PEELER LABEL)	(PEELER LABEL)	.226
5	.230	.225	.231	.243
6	.230	.232	.236	.237
7	.236	.238	.241	.248
8	.228	.220	.231	.238
9	.220	.217	.223	.228
10	.228	.228	.221	.231
11	.223	.228	.228	.231
12	.224	.227	.224	.223
13	.228	.228	.230	.226
14	.226	.227	.225	.232
15	.246 *	.252 *	(NO READING)	.245 *
16	.247 *	.247 *	.244 *	.240 *

NOTE: 1-4-8 through 1-4-11 are the approximate locations for the UT measurements to be taken.

NOTE: Section D-D shows the approximate locations for UT measurements to be taken circumferentially.

*

YELLOW ID LABEL/STRIPE
BETWEEN THE FACE OF THE TRANSDUCER
AND THE SURFACE OF THE PIPE



DETAIL D
SCALE 1:5

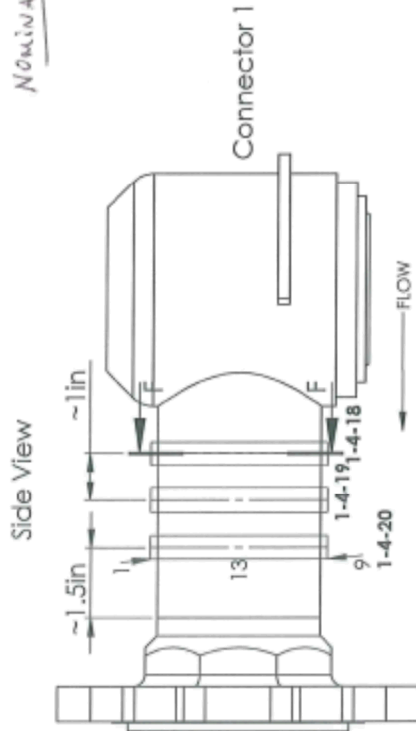
T.J. Barnes
4/11/2013

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Appendix A

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Jumper 1 to 4: ST-4
(3 inch Schedule 40)

NOMINAL = 0.216"



SECTION F-F
SCALE 1:2

	1-4-18	1-4-19	1-4-20
1	.223	.223	.222
2	.223	.226	.225
3	.231	.247	.231
4	.217	.226	.236
5	(ENOKY PAINT)	.226	.228
6	.240	.230	.230
7	.234	.225	.231
8	.222	.224	.222
9	(GRINDING MARK)	.242	.241
10	.244 ROUGH	.244 OFF OF SPOT	.242 FULL SCALE
11	.254	.251	.253
12	.243	.251	.247
13	.231	.231	.231 ROUGH SCALE
14	.231	.232	.231
15	.229	.225	.223 RUSTY
16	.217	.216	.214

NOTE: 1-4-18 through 1-4-20 are the approximate locations for the UT measurements to be taken.

NOTE: Section F-F shows the approximate locations for UT measurements to be taken circumferentially.

REPEAT:
1-4-19 (5) = .226
1-4-20 (6) = .214

Inspector (print): B. J. SEWANT / AREVA NDE

Inspector (sign): *Bj Sewant*

Date: 9/9/13

T.J. Barnes
4/11/2013

LAB-RPT-14-00005 R 0
Appendix A

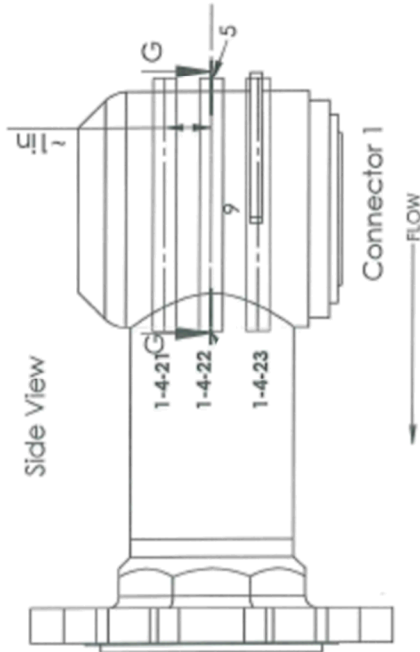
		AREVA Federal Services LLC				
		NDE ULTRASONIC THICKNESS MEASUREMENT PROCEDURE AND TEST REPORT				
Requester (Client)	Company	MSIN	Bldg	Area	Page 13 of 21	
Jason S. Page	WRPS	T6-05	2713-S	200-W	Job No. 13-33	
Project/System/Work Package/Traveler No. Ultrasonic Wall Thickness Measurements: Stainless Steel "Connector Blocks" from AW02-E Jumpers #B-2 and #1-4 Per Step #5.3 of Work Package WO-13-0871 (Areva Charge Code: 01950.03.T001.B1.T00B1)					PART INFORMATION	
					Material Stainless Steel ☐ NA	
					Wall Thickness 0.970" (per drawing) ☐ NA	
					Diameter ☒ NA	
					Schedule ☒ NA	
					Size ☒ NA	
Acceptance Std.	Section	Paragraph	Date	☐ NA	Dwg #	☒ NA
For Information Only; Provide "As-Found" Thickness Measurements. Acceptance by Client.					NCR	☒ NA
PROCEDURE NO.		RESULTS: 1.) All thickness measurements are in "inches". 2.) Tolerance on reported thickness readings = +/- 0.005" of the stated value. 3.) Measurement locations were established at evenly-spaced positions around the circumference of the connector block; see attached data pages. 4.) In some locations ultrasonic thickness measurements were unobtainable due to the obstruction caused by a welded-on tab, or by randomly-applied epoxy paint on the part's surface. 5.) "Repeat" reading means that a second thickness measurement was taken as a quick-check verification at the same location to assure reliable performance of the ultrasonic test system. 6.) See the attached data sheets for isometric and plan views of the Connector Blocks from Jumpers #B-2 and #1-4 as well as the actual thickness measurements. --> Periodic Calibration Checks for Connector Block #4 (August 20, 2013) (Nom. Thkn. Value) Time=12:10 pm Time=12:24 pm 0.750"0.750"0.750" 1.000"1.000"1.000" ----- --> Periodic Calibration Checks for Connector Block #1, 2, and B (September 9, 2013) (Nom. Thkn. Value) Time=10:38 am Time=10:51 am Time=1:45 pm Time=1:54 pm 0.750"0.750"0.750"0.750"0.750" 1.000"1.000"1.000"1.000"1.000"				
RCD-NE-PRC-UT1 Rev. 00						
Appendix: A Rev # 00						
Special Technique # N/A						
COVERAGE						
☒ 100% of Area Requested						
☐ Other						
INSTRUMENTATION						
Mfg. Krautkramer						
Model USN-52L						
S/N or Standards Lab No. OOR294 (WC76595)						
CALIBRATION STANDRD(S)						
Identification No. 584-99-30-093, s/n-797631						
Identification No. 0.750" and 1.000" steps (SST)						
TRANSDUCER						
Diameter 0.250"						
Frequency 10 MHz						
Mfg Nortec "Green-Top"						
Serial No. K-M-1/4-10						
Stand Off (n/a)						
Couplant "Ultragel-II"						
Batch No. 10225-H						
Technician	UT Level	Technician	UT Level	Reviewed by		
B.J.Sewart <i>B.J.Sewart</i>	II	B.J.Sewart <i>B.J.Sewart</i>	II	<i>W.D. Sub</i>		
Date of Examination		Date of Examination		Date		
August 20 and September 9, 2013		August 20 and September 9, 2013		9/18/13		

RCD-NE-FRM-005 Rev. 00 (Issued April 17, 2009)
Refer to RCD-NE-PRC-UT1, Ultrasonic Examination

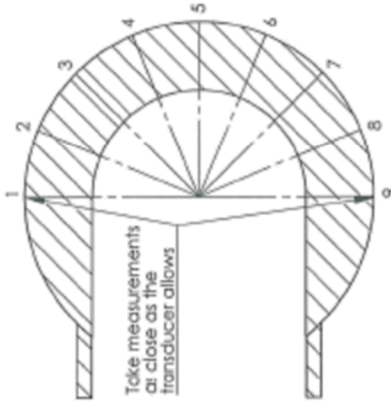
LAB-RPT-14-00005 R 0
Appendix A

AREVA NDE DES #13-33
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Jumper 1 to 4: Connector 1
(3 inch Schedule 40)



SECTION G-G
SCALE 1:2



REPEAT:
 $1-4-22(6) = 0.985$
 $1-4-21(9) = 1.000$

Inspector (print): B. J. SEWART / AREVA NDE

Inspector (sign): BJSewart

Date: 9/9/13

T.J. Barnes
3/27/2013

	1-4-21	1-4-22	1-4-23
1	1.003	0.999	N/A
2	1.000	0.985	N/A
3	1.000	0.999	N/A
4	1.005	0.985	1.000
5	0.985	1.000	0.984
6	0.985	0.985	0.998
7	1.005	0.985	0.985
8	1.005	0.985	0.985
9	1.000	0.985	0.985

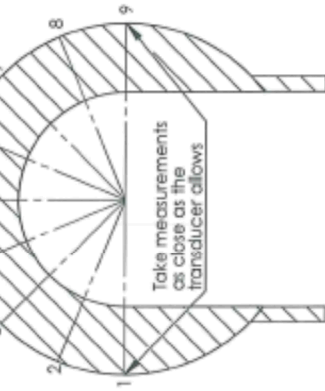
NOTE: 1-4-21 through 1-4-23 are the approximate locations for the UT measurements to be taken.

NOTE: Section G-G shows the approximate locations for UT measurements to be taken circumferentially.

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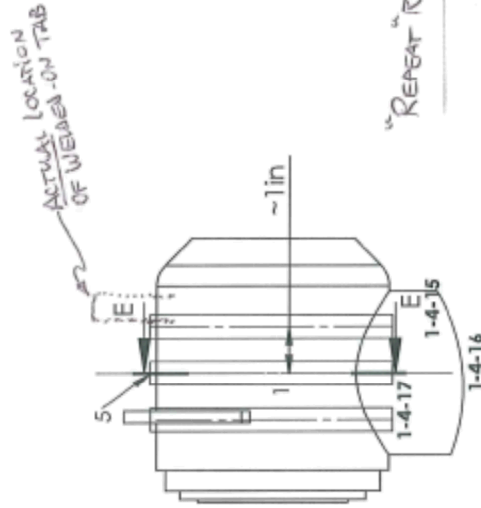
AREVA NDE JIG # 13-33
PAGE 15 OF 21

Jumpers 1 to 4: Connector 4
(3 inch Schedule 40)



SECTION E-E
SCALE 1:2

"REPEAT READING = 1.00" @ 1-4-16 (8)

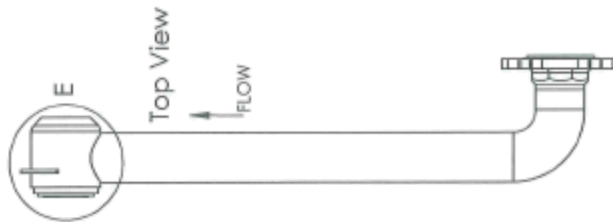


DETAIL E
SCALE 1:3

	1-4-15	1-4-16	1-4-17
1	(WELDED-ON TAB)	(THICK PAINT)	(THICK PAINT)
2	"	"	"
3	"	1.000	"
4	"	(THICK PAINT)	1.000
5	0.985	1.000	0.999
6	0.985	0.999	1.000
7	1.000	0.985	0.999
8	0.999	1.000	1.000
9	0.999	1.000	1.000

NOTE: 1-4-14 through 1-4-16 are the approximate locations for the UT measurements to be taken.
NOTE: Section E-E shows the approximate locations for UT measurements to be taken circumferentially

Connector 4



Inspector (print): B. J. SEWART (AREVA NDE)

Inspector (sign): B. J. Sewart

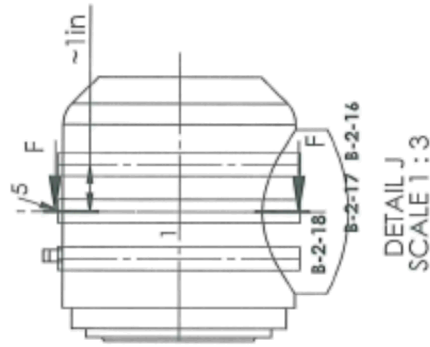
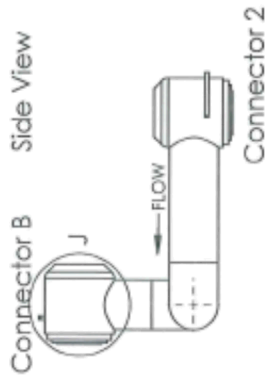
Date: 8/20/13

T.J. Barnes
3/27/2013

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Appendix A

AREA NINE JIG #13-33
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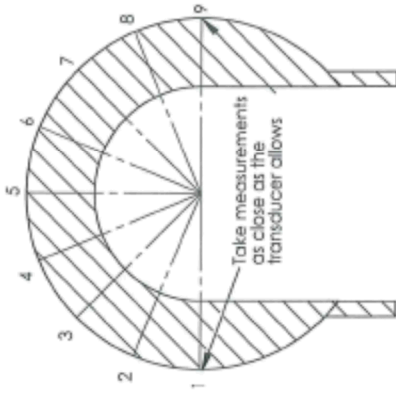
Jumper B-2: Connector B



REMARK:

B-2-16 (6) = 0.985
B-2-16 (9) = 0.985

SECTION F-F
SCALE 1:2



AREA COVERED OVER WITH PROTECTIVE TAPE

	B-2-16	B-2-17	B-2-18
1	1.000	0.998	N/A
2	0.985	0.985	N/A
3	0.985	0.985	N/A
4	0.985	0.985	N/A
5	0.985	1.000	N/A
6	0.985	0.985	N/A
7	0.985	0.985	N/A
8	0.998	0.985	N/A
9	0.985	0.985	N/A

Inspector (print): B. J. Stewart / AREA NINE

Inspector (sign): B. J. Stewart

Date: 9/2/13

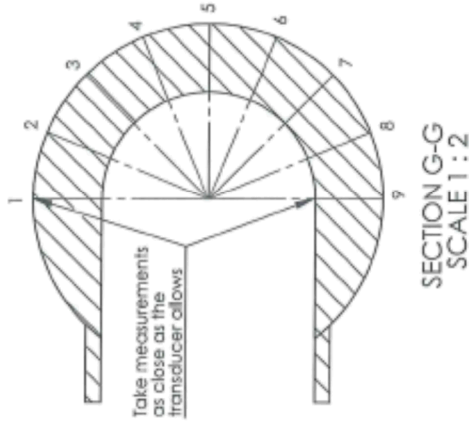
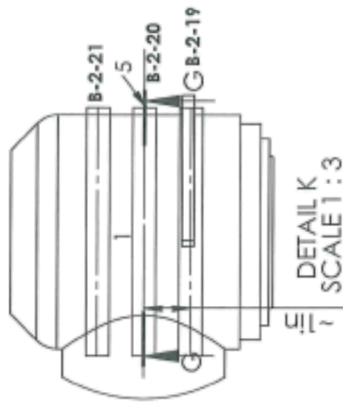
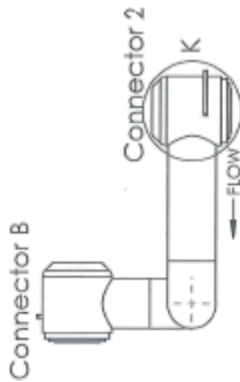
NOTE: B-2-16 through B-2-18 are the approximate locations for the UT measurements to be taken.
NOTE: Section F-F shows the approximate locations for UT measurements to be taken circumferentially.

T.J. Barnes
3/25/2013

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Appendix A

AREVA NDE JOB #13-33
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Jumper B-2: Connector 2



REPEAT:
B-2-20(5) = 0.985
B-2-20(7) = 0.985

	B-2-19	B-2-20	B-2-21
1 (WELDED TAG)	0.985	0.985	0.985
2 (WELDED TAG)	0.985	0.985	0.985
3 (WELDED TAG)	0.985	0.985	1.000
4 0.985	0.985	0.985	0.985
5 0.985	0.985	0.985	0.985
6 0.985	0.985	0.985	0.985
7 0.985	0.985	0.985	0.985
8 0.985	0.985	0.985	0.985
9 1.000	0.934	0.985	0.985

Inspector (print): B.J. SEWAT (AREVA NDE)
Inspector (sign): B.J. Sewat
Date: 9/9/13

NOTE: B-2-19 through B-2-21 are the approximate locations for the UT Measurements to be taken.
NOTE: Section G-G shows the approximate locations for UT measurements to be taken circumferentially.

T.J. Barnes
3/25/2013

LAB-RPT-14-00005 R 0
Appendix A

		AREVA Federal Services LLC																			
NDE ULTRASONIC THICKNESS MEASUREMENT PROCEDURE AND TEST REPORT																					
Requester (Client)	Company	MSIN	Bldg	Area	Page 18 of 21																
Jason S. Page	WRPS	TB-05	2713-S	200-W	Job No. 13-33																
Project/System/Work Package/Traveler No.					PART INFORMATION																
Ultrasonic wall thickness measurements taken on AW02-E Pipe Jumper #B-2 --> NOTE: Customer-requested retest areas for confirmation thicknesses <-- Per Step #5.3 of Work Package WO-13-0871 (Areva Charge Code: 01950.03.T001.B1.T00B1)					Material Carbon Steel, ASTM A-53	☐ NA															
					Wall Thickness 0.216" (Nominal)	☐ NA															
					Diameter 3"	☐ NA															
					Schedule 40	☐ NA															
					Size	☐ NA															
Acceptance Std.	Section	Paragraph	Date	☐ NA	Dwg #	☒ NA															
For Information Only; Provide "As-Found" Thickness Measurements. Acceptance by Client.					NCR	☒ NA															
PROCEDURE NO.		RESULTS: 1.) All thickness measurements are in "inches". 2.) Tolerance on reported thickness readings = +/- 0.005" of the stated value. 3.) All thickness readings were taken through Amercoat #86 primer and Amercoat #33 protective coating as applied during jumper fabrication. 4.) Measurement locations were established at either 12 or 16 evenly-spaced holes around the circumference of the pipe; see the attached data pages. 5.) Some thickness readings (particularly on elbows) were higher than what would normally be expected for 3" Sch. 40 pipe (0.216" nom. wall). For this reason an additional calibrated thickness standard (Serial No. 5748) fabricated from a 3" Sch. 80 pipe (0.300" nom. wall) was also used. 6.) These customer-requested confirmation thickness measurements were taken in areas which were originally inspected on July 30, 2013. Periodic Calibration Checks: [Nom. Thkn. Value] Time = 2:17 pm Time = 2:39 pm <table border="0"> <tr> <td>0.179"</td> <td>0.180"</td> <td>0.178"</td> </tr> <tr> <td>0.196"</td> <td>0.197"</td> <td>0.198"</td> </tr> <tr> <td>0.221"</td> <td>0.222"</td> <td>0.223"</td> </tr> <tr> <td colspan="3">*****</td> </tr> <tr> <td>0.283"</td> <td>0.283"</td> <td>0.284"</td> </tr> </table>					0.179"	0.180"	0.178"	0.196"	0.197"	0.198"	0.221"	0.222"	0.223"	*****			0.283"	0.283"	0.284"
0.179"	0.180"						0.178"														
0.196"	0.197"						0.198"														
0.221"	0.222"						0.223"														

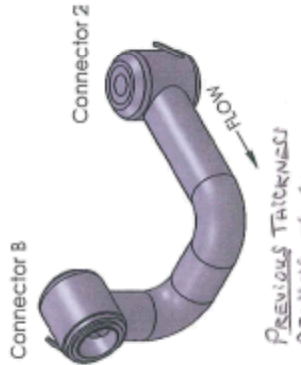
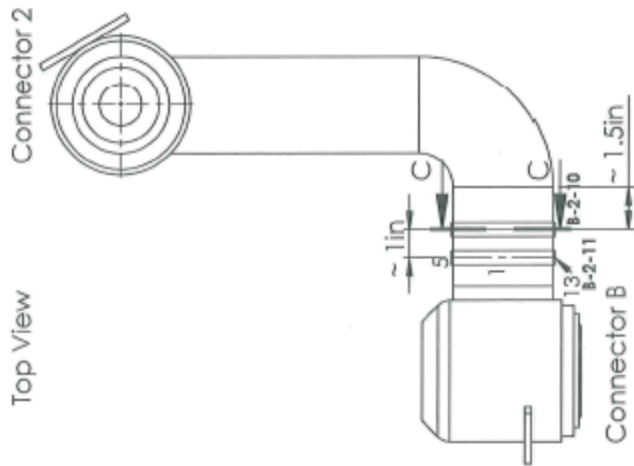
0.283"	0.283"	0.284"																			
RCD-NE-PRC-UT1 Rev. 00																					
Appendix A	Rev # 00																				
Special Technique # N/A																					
COVERAGE																					
☒ 100% of Area Requested ☐ Other																					
INSTRUMENTATION																					
Mfg. Krautkramer Model USN-52L S/N or Standards Lab No. OOR294 (WC76595)																					
CALIBRATION STANDRD(S)																					
Identification No. 584-99-30-155 (3-step pipe) Identification No. s/n-5748, 3" sch.80, 0.283" thk																					
TRANSDUCER																					
Diameter 0.250" Frequency 10 MHz. Mfg. Nortec "Green-Top" Serial No. K-M-1/4-10 Stand Off (n/a)																					
Couplant "Ultrageel-II"																					
Batch No. 10225-H																					
Technician B.J. Sewart	UT Level II	Technician B.J. Sewart	UT Level II	Reviewed by																	
Date of Examination September 9, 2013		Date of Examination September 9, 2013		Date																	

RCD-NE-FRM-005 Rev. 00 (Issued April 17, 2009)
Refer to RCD-NE-PRC-UT1, Ultrasonic Examination

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Appendix A

AREVA NDE JOB # 13-33
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Jumper B-2: ST-2
(3 inch Schedule 40)



SECTION C-C SCALE 1:2		
	B-2-10	B-2-11
1	.257 EROXY	
2	.262 EROXY	
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		

NOTE: B-2-10 and B-2-11 are the approximate locations for the UT measurements to be taken.
NOTE: Section C-C shows the approximate locations for UT measurements to be taken circumferentially.

Inspector (print): B. J. SEWART / AREVA NDE

Inspector (sign): B. J. Sewart

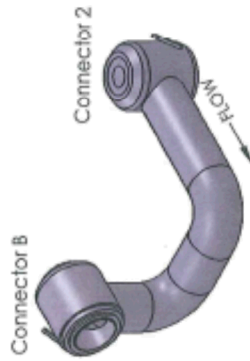
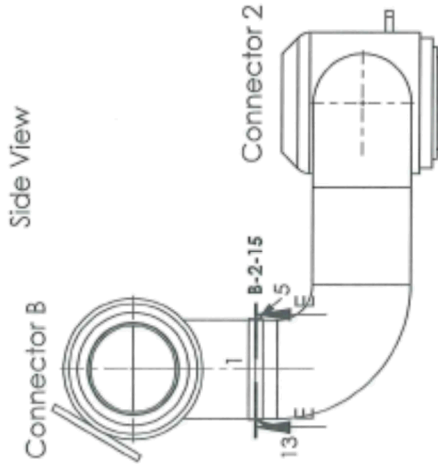
Date: 9/9/13

T.J. Barnes
4/11/2013

LAB-RPT-14-00005 R 0
Appendix A

AREVA NDE JOB #13-33
PAGE 20 OF 21

Jumper B-2: ST-3
(3 inch Schedule 40)



SECTION E-E
SCALE 1:2

B-2-15	
1	
2	
3	
4	
5	
6	
7	
8	.261
9	.276
10	
11	
12	
13	
14	
15	
16	

PREVIOUS TACKLES
READING 7/5/13

.273
→
.267
→

NOTE: B-2-15 is the approximate location for the UT measurements to be taken.
NOTE: Section E-E shows the approximate locations for UT measurements to be taken circumferentially.

Inspector (print): B. J. SEWART / AREVA NDE

Inspector (sign): Bj Sewart

Date: 9/9/13

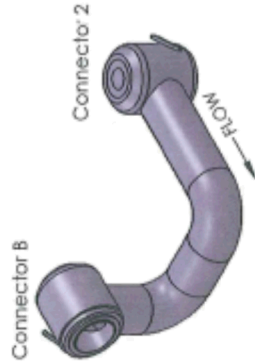
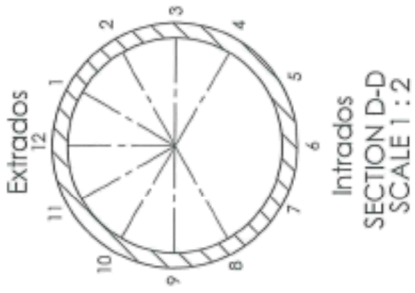
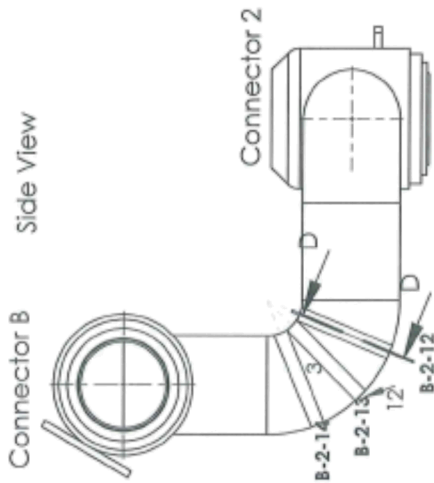
T.J. Barnes
3/25/2013

LAB-RPT-14-00005 R 0
Appendix A

AREVA NDE IIGB #13-33
 PAGE 21 OF 21

**Jumper B-2: Elbow-2
 (3 inch Schedule 40)**

Side View



Inspector (print): B. J. SEWART / AREVA NDE

Inspector (sign): B. J. Sewart

Date: 9/9/13

PREVIOUS THICKNESS REMAINING
 TAKEN ON 7/30/13:

1	B-2-12	B-2-13	B-2-14
2	0.250	0.237	0.235
3			
4	N/A	N/A	N/A
5	N/A	N/A	N/A
6	N/A	N/A	N/A
7			
8			
9			
10			
11			
12			

0.250 0.234 0.234

NOTE: B-2-12 through B-2-14 are the approximate locations for the UT measurements to be taken along the outer radius of the elbow.

NOTE: Section D-D shows the approximate locations for UT measurement to be taken circumferentially.

T.J. Barnes
 3/25/2013

Appendix B

Jumper and Jumper Pieces Photographed Through the Hot Cell Window

Jumper B-2 Elbow near Connector 2

Before Clamshell



Bottom of Clamshell



Bottom of Clamshell (Intrados)



Bottom of Clamshell Elbow Exit



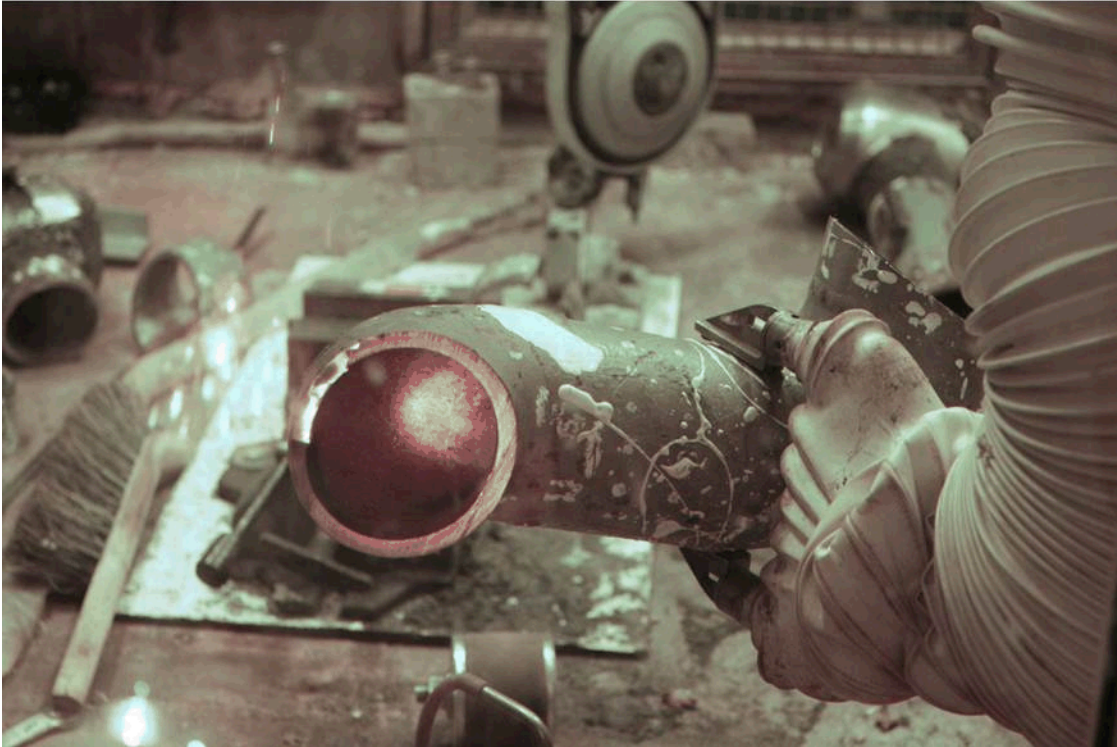
Bottom of Clamshell (Extrados)



Top of Clamshell



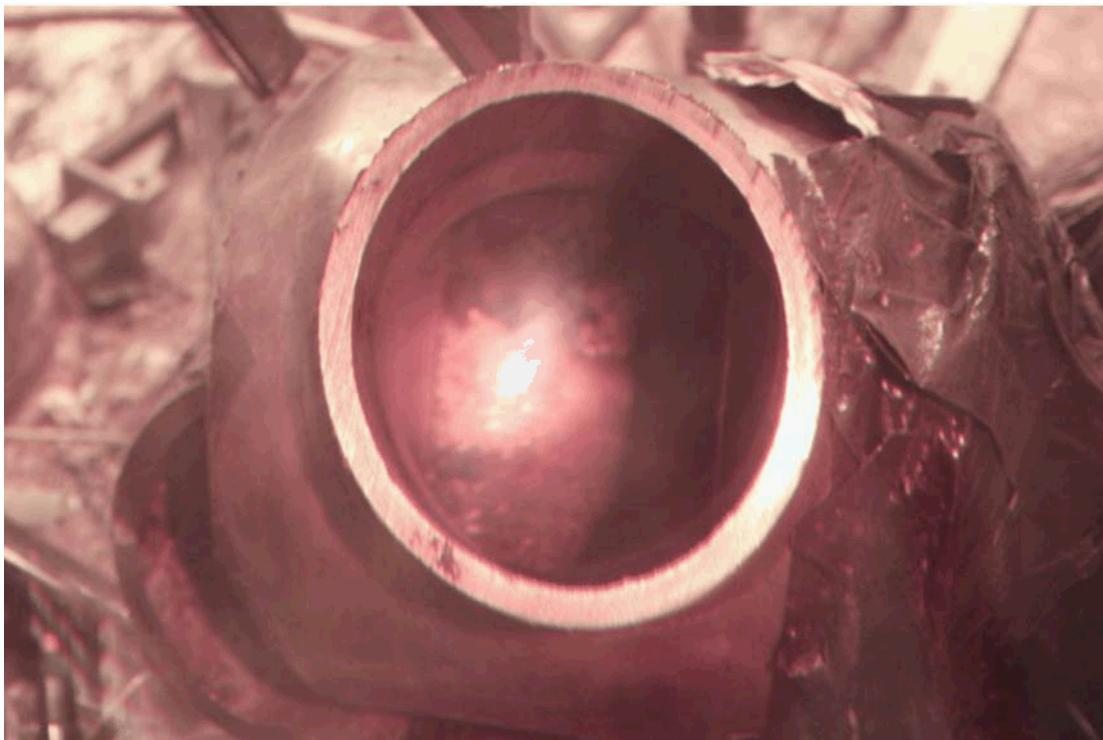
Jumper B-2 Elbow near Connector B



Jumper B-2 Slice of a Straight Section



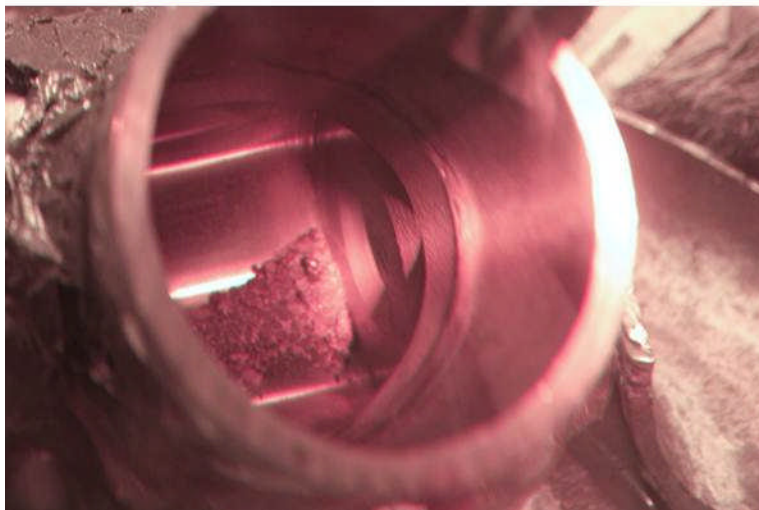
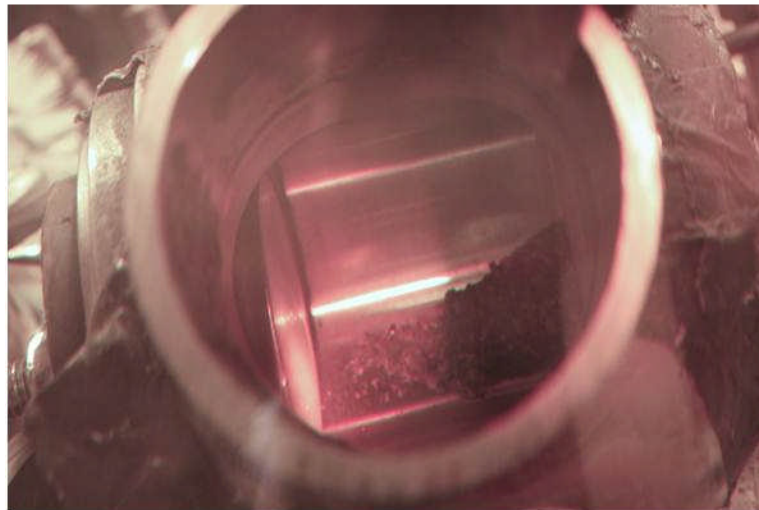
Jumper B-2 Connector B



Jumper 1-4 Slice of a Straight Section



Jumper 1-4 Connector 1



Jumper 1-4 Long Section Cutting



Jumper 1-4 Long Section Slice Cutting



Jumper 1-4 Long Section Elbow Clamshell



Electronically Approved by:

UserName: Page, Jason (h2841343)

Title:

Date: Monday, 24 March 2014, 04:05 PM Pacific Time

Meaning: Approved by the author or delegate

=====



UserName: Wyrwas, Richard (h3390899)

Title: APD Chemist

Date: Wednesday, 26 March 2014, 12:02 PM Pacific Time

Meaning: Additional approval obtained

=====

UserName: Castleberry, Jim (h0051558)

Title:

Date: Monday, 31 March 2014, 03:01 PM Pacific Time

Meaning: Approved by the customer or delegate

=====

UserName: Greenough, Keith (h0068375)

Title: Laboratory Facilities

Date: Tuesday, 01 April 2014, 01:49 PM Pacific Time

Meaning: Approved by the Facility Manager or delegate

=====

UserName: Cooke, Gary (h0410221)

Title: APD Chemist

Date: Tuesday, 01 April 2014, 04:37 PM Pacific Time

Meaning: Approved by the Group Manager or delegate

=====

Distribution List for LAB-RPT-14-00005

Organization	Recipient	Test Plan	Final Report
WRPS	—	—	—
Tank Farm Projects	—	—	—
Tank Farm Project Management	J. L. Castleberry (Manager)	✓	✓
	R. Gregory (Manager)		✓
Engineering	—	—	—
Tank & Pipeline Integrity	J. K. Engeman (Engineer)	✓	✓
	K. D. Boomer (Engineer)	✓	✓
	C. C. Joslyn (Engineer)	✓	✓
222-S Laboratory	D. L. Renberger (Manager)	✓	✓
Facility	K. J. Greenough (Acting Manager)	✓	
Integration and Control	J. R. Prilucik (Manager)	✓	✓
Process Chemistry	G. A. Cooke (Manager)	✓	✓
	J. S. Page (Chemist)	✓	✓
	R. B. Wyrwas (Chemist)	✓	✓
Analytical Project Management	J. M. Johnson (Manager)	✓	
	R. W. Sosa (Project Coordinator)	✓	✓