METALLURGICAL INVESTIGATION OF A FRACTURED SECTION OF THE 20" O.D. PIPELINE AT MILEPOST 314.77 IN THE CONWAY TO CORSICANA SEGMENT OF THE PEGASUS CRUDE OIL PIPELINE

REPORT NO. 64961, REV. 1

Prepared for
ExxonMobil Pipeline Company and the
Pipeline and Hazardous Materials Safety Administration
pursuant to Corrective Action Order CPF 4-2013-5006H

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1.0 INTRODUCTION

1.1 Brief Narrative of the Incident

On March 29, 2013 at 2:37 pm CST, a drop in pressure was detected within the Pegasus Pipeline of the Conway to Corsicana line segment by ExxonMobil Pipeline Company (EMPCo) at their Operations Control Center in Houston, Texas. The cause of the pressure drop was the rupture of a section of the pipeline at Milepost 314.77 in Mayflower, Arkansas. The operating pressure at the time of failure was estimated to be between 702 psig and 708 psig.

1.2 Scope of the Investigation

Hurst Metallurgical Research Laboratory, Inc. (HurstLab) was retained by EMPCo, with approval by the U.S. Department of Transportation, Pipeline and Hazardous Materials Safety Administration (PHMSA), to provide technical support in the investigation of the failed section of the pipeline, as well as conduct and direct the required metallurgical tests to determine, if possible, the root cause of the failure, pursuant to Corrective Action Order CPF 4-2013-5006H.

The investigation of the cracked section of the pipeline conducted by HurstLab is a joint effort by various staff members of the Laboratory, which includes some of the report writing and analysis conducted by Susan Dalrymple-Ely, Materials Analyst and metallurgical tests conducted by Clint Myers, Staff Metallurgist of the Laboratory. The investigative effort made by this Laboratory also includes a review of the UT data and SEM fractographs provided by approved vendors.

The investigation conducted by this Laboratory is primarily based on the tests and analyses performed in accordance with the approved test protocol, review of the available information, and research conducted by this Laboratory. We reserve the right to change, amend, or omit our opinions, as warranted, based upon any additional information or further test results that may be obtained or made available to this Laboratory.

1.3 Development of Test Protocol

On April 13, 2013, a preliminary metallurgical test protocol was development by HurstLab following the general guideline entitled “Metallurgical Laboratory Examination Protocol” dated 05/08/2007 for metallurgical failure investigation of pipeline prepared by PHMSA. Following various revisions that were made to incorporate the changes requested by PHMSA, a protocol entitled “Pegasus Line - Conway to Corsicana M.P. 314.77, Mechanical and Metallurgical Testing and Failure Analysis Protocol”, referenced as Test Protocol Rev. 4, CPF No. 4-2013-5006H, Amended 4/18/13, was developed and was approved by PHMSA. A copy of the final approved protocol is presented in Appendix I.

2.0 BACKGROUND INFORMATION

2.1 Pipe Manufacturing and Coating

2.1.1 The subject section of the 20" Patoka to Corsicana #1-20" North Pipeline, the segment from Conway to Corsicana, consisted of approximately 50' long sections of 20" O.D. x 0.312" thick wall DC Electric Resistance Welded (ERW) pipe that was manufactured in 1947 and 1948 by Youngstown Sheet and Tube Company in Youngstown, Ohio. The welded pipe was manufactured from Open Hearth Steel meeting Grade B mechanical requirements.

2.1.2 The O.D. surface of the pipeline was coated with some type of a viscous bitumen or coal-tar coating, on top of which was a layer of somewhat harder but more brittle fibrous coating. No details concerning the coating type or process were available. The pipeline had reportedly been impressed current cathodically protected since installation, with possible anodes as well. The weight of the coated pipe was reported to be 65.71 lbf/ft.

2.2 Inspection and Service History

2.2.1 The subject section of pipeline was placed in service in 1948, and was buried approximately 3' below ground in native sandy clay soil. The pipeline carried crude oil from west Texas to Patoka, Illinois between 1948 and 1995. From 1995 to 2002 the line carried both west Texas crude oil and foreign crude oil (via the Gulf of Mexico) northward. In December 2002 the line was purged and idled with nitrogen. The pipeline containing the subject section of the pipe was successfully hydrostatic tested on January 24, 2006 at 1082 psig, which established a calculated MAOP of 866 psig at the failure location, based upon the Arkansas River ROV test site pressure at 1091 psig adjusted for elevation difference to the failure location. The line was then placed back in service transporting crude oil south towards the Gulf of Mexico, and remained in service up until the time of the failure.

2.2.2 Prior to failure, the pipeline was reported to typically operate between 47°F and 78° at pressures ranging between 240 psig and 820 psig. The pressure at the time of the failure was estimated to be between 702 psig and 708 psig. The fractured segment of the pipeline was located in a cleared right-of-way at the edge of a subdivision. No trees, roads, or buildings were located directly above the pipeline where the fracture occurred. As shown in Photograph No. 1, two (2) homes were built in close proximity to the pipeline, with driveways crossing over the pipeline at two (2) points downstream of the fractured segment. During construction of the homes, the pipeline may have experienced vehicle loadings caused by construction equipment and/or vehicles crossing the pipeline at multiple locations, including over the fractured segment. There was no indication of construction, digging, localized flooding, or other ground movements in the area of the fractured segment occurring during or immediately prior to the pipeline rupture.

2.3 Specifications

2.3.1 At the request of EMPCo, the subject pipe was compared to two (2) versions of the API 5L specification throughout this report, both the edition that was in effect at the time the pipe was manufactured, and the current edition of said specification, both of which are detailed below.

2.3.1.1 At the time the pipe was manufactured in 1947 and 1948, the specification in effect was API STD. 5-L, 10^{th} Edition, August 1945. Per this specification, the smelting type of steel was reportedly Open Hearth Steel, the pipe was classified as an Electric Welded Pipe, and the strength was specified to meet Grade B requirements. This edition will be referred to as API 5-L, 10^{th} Edition throughout the report and the accompanying tables.

2.3.1.2 The currently applicable edition of the specification is ANSI/API 5L, 44^{th} Edition, Effective October 1, 2007, with Errata dated January 2009, Addendum 1 dated February 2009, Addendum 2 dated April 2010, and Addendum 3 dated July 2011. The requirements for PSL 1 Welded Pipe, Grade X42 will be used for comparison, with the exception of the Charpy V-Notch (CVN) impact tests. For the CVN impact tests, there are no requirements for PSL 1 Welded Pipe, so the requirements for PSL 2 Welded Pipe will be referenced instead. This edition of the specification will be referred to as API 5L, 44^{th} Edition throughout the report and accompanying tables.

2.4 Items Received for Testing

2.4.1 On April 16, 2013 at approximately 1:50 pm CST, HurstLab received two (2) cut sections of pipe, and various other items from the failure location in Mayflower, Arkansas, which had been transported on a flatbed trailer. The two (2) sections of pipe were each wrapped in protective plastic with the open ends of the pipe sealed, and with the entire surface covered with plastic padding to protect from damage during loading/unloading and transportation. A 55 gallon steel drum, containing the coating that was removed in the field where the pipe was sectioned transversely, as well as a small bag containing possible calcareous deposits, were also received. The two (2) sections of pipe are described below in the same manner they are referenced throughout the report.

1) 33' 11-1/2" Long Fractured Section of a 20" O.D. x 0.312" wall Pipe; Removed from Milepost 314.77 in the Conway to Corsicana Pegasus Crude Oil Pipeline after it failed in service in Mayflower, Arkansas.

2) 19' 10" Long Intact Section of a 20" O.D. x 0.312" wall Pipe; Removed from Milepost 314.77 in the Conway to Corsicana Pegasus Crude Oil Pipeline after it failed in service in Mayflower, Arkansas.

The Chain of Custody documents for the sections of pipe, as well as the steel drum of coating material and the possible calcareous deposits as well as the photographs documenting the evidence in the as-received condition are presented in Appendix II of this report.

3.0 METALLURGICAL EXAMINATION, TESTING AND ANALYSIS

3.1 Visual and Macroscopic Observations

3.1.1 A 49' 9-1/2" long section of the Pegasus Pipeline, which fractured over a length of 22' along the ERW seam and 3" into the base metal at Milepost 314.77 in Mayflower, Arkansas, as shown in Photographs No. 1 through No. 3, was removed from the ground by sectioning through three (3) locations of the pipeline following removal of the coating at those areas on the O.D. surface. The pipeline was transversely sectioned 3' upstream from the north girth weld through the adjoining intact pipe, 33' 11-1/2" from the north cut end, and 1' downstream from the south girth weld through the adjoining intact pipe.

3.1.2 The sections of pipe were received at HurstLab on April 16, 2013. The protective plastic, wrapping, and end plugs from both 33' 11-1/2" and 19' 10" long sections of the pipeline were carefully removed following receipt for examination and documentation of the evidence in the as-received condition, and to allow examination of the general condition of the pipe sections, such as the fracture, ERW seam and girth weld conditions, coating condition, evidence of any corrosion, mechanical damage, etc. Photographs No. 4 through No. 7 display the pipe sections in the as-received condition, and following removal of the plastic and wrapping.

Examination of the 33' 11-1/2" long section of the pipe revealed a 22' long fracture along the ERW weld seam, which traversed diagonally, approximately 3" in length, into the base metal near the south end of the fracture. The fracture faces had been coated with a protective white grease in the field following the pipeline rupture to help preserve the fracture faces for subsequent analysis. All four (4) cut ends of the pipe sections were marked in the field denoting the location of the ERW seam, the relative position in ground, direction of the crude oil flow, station number and field cut match line in each section of the pipe. Photographs No. 8 and No. 9 display the as-received condition of the pipe and field markings on the pipe sections.

3.2 As-Received Condition of the Pipe and Coating

3.2.1 Following unloading of the pipe from the transport truck and unwrapping of the protective material, the pipe was closely inspected to ascertain and document the as-received condition of the pipe and the coating. The 33' 11-1/2" long section of pipe contained a circumferential girth weld at the north end, and an approximately 3' long section of the adjoining intact pipe. The fracture, which followed the ERW seam at the 12:00 o'clock position of the pipe, extended 22' 3" in length, with one fracture tip terminating in the north girth weld and the other in the base metal adjacent to the ERW seam. The maximum separation of the open crack was approximately 1-3/8" wide near the center of the crack, 12' from the north girth weld.

3.2.2 Examination of the coating showed a number of areas where the coating was damaged or split adjacent to the ERW seam. The maximum width and depth of the various splits in the coating on the O.D. surface of the pipe adjacent to the ERW seam, between the 10:30 and 1:30 o'clock positions, were measured and photographically documented. Photographs No. 10 through No. 23 show the condition of the coating from 3' north of the north girth weld, referenced to as -3' from the north girth weld, to the girth weld at 0', and all the way to 50' 9-1/2" south of the north girth weld. As previously mentioned, the coating had been removed in the field from the areas where the pipe had been transversely sectioned.

Distance from North Girth Weld		Coating Split Maximum Width	Coating Split Maximum Depth	Notes
-3'	0'	1"	*	Some coating had been removed during sectioning in the field
0'	4'	2"	0.10"	Longitudinal fracture or rupture of the pipe extended from the north girth weld at 0' to 22'
4'	8'	0.5"	0.14"	
8'	12'	0.5"	*	
12'	16'	*	0.07"	
16'	20'	0.25"	0.09"	
20'	24'	0.5"	0.10"	
24'	28'	1.5"	0.10"	
28'	30' 11-1/2"	1"	0.05"	Some coating had been removed during sectioning in the field
30' 11-1/2"	35'	1"	0.15"	
35'	39'	1"	0.10"	
39'	43'	0.75"	0.11"	
43'	47'	0.5"	0.11"	
47'	50' 9-1/2"	1"	*	Some coating had been removed during sectioning in the field

*Not measurable at location.

The total thickness of the coating was estimated to be approximately 0.15" based on relatively intact areas of the coating, so some of the splits in the coating noted in the table above had likely penetrated to the base metal of the pipe.

In addition to the splits noted above, the coating at the bottom, or 6 o'clock position of the pipe was wrinkled, with the coating appearing to have sagged downward during the years the pipe lay buried. Although the coating did not appear stretched over the top and sides of the pipe, excess coating was folded over at the bottom of the pipe. Several places had small areas of coating missing, although it is not known at what point the coating loss had occurred during service. Additional photographs of the pipe and coating in the as-received condition are displayed in Photographs No. 24 through No. 64.

3.3 Coating Removal Process

A procedure for a safe removal of the coating from the O.D. surface of the pipe was developed and approved by EMPCo and PHSMA, and is listed in Section A4 of the Test Protocol in Appendix I.

The coating on the O.D. surface of the pipe was carefully removed on April 22, 2013 by Watkins Construction Company, LLC. (Watkins), a vendor contracted directly with EMPCo. Prior to proceeding, the contracted workers were briefed by HurstLab personnel as to the importance of preserving the fracture surface and integrity of the pipe; HurstLab personnel supervised the removal of the coating to ensure the safe removal of the coating.

The coating on both pipe sections was first wet down with water, and each pipe section was then tightly wrapped in plastic wrap to securely collect all the coating. To remove the coating it was first cracked by tapping, and was then gently peeled off. First striking the coating with a resin hammer was tried; when the resin hammer did not crack the coating a steel mallet was used. The steel mallet was tapped against the coating, cracking the coating but not damaging the pipe underneath. The pipe sections were then cleaned using mineral spirits. Extreme care was taken to prevent any damage to the pipe or the fracture surface that could have affected the metallurgical investigation.

All of the coating removed from the pipe sections at HurstLab, as well as the steel drum containing the coating that was removed in the field by EMPCo personnel, was collected and retained at EMPCo's facility in Corsicana, Texas. Appendix III shows several representative photographs of the coating removal process and contains the document signed by the employees of Watkins who removed the coating following the briefing by HurstLab personnel.

3.4 Condition of the Pipe Following Coating Removal

3.4.1 Following removal of the O.D. coating in accordance with the specified guidelines, the pipe sections were re-examined to ascertain and photographically document the conditions of the pipe. The bottom of the pipe sections between approximately 4 and 8 o'clock, at the locations where the coating had wrinkled and sagged, was covered with a reddish-orange substance, likely a mixture of the surrounding native sandy soil that the pipe had been buried in and various corrosion products resulting from contact between the pipeline and moisture. Some corrosion pitting was visible within this area, as well as at various locations along the O.D. surface where the coating had previously split and allowed moisture to contact the surface of the pipe. No preferential or knife-like corrosion was present along the ERW seam at 12 o'clock.

3.4.2 The depth of the corrosion pitting at the various locations around the O.D. surface of the fractured pipe section was measured using a certified and calibrated caliper, and the results are summarized in the following table.

Distance from North Girth Weld	Circumferential Location (o'clock position)	Depth of Corrosion Pitting		
		Minimum	Average	Maximum
-3' to 0'	All	No Corrosion Pitting Visible		
0' to 4'	7:30 to 10:00	0.006"	0.017"	0.029"
4' to 8'	1:30 to 3:00	0.008"	0.013"	0.026"
	6:45 to 10:00	0.002"	0.013"	0.037"
8' to 12'	3:45 to 5:00	0.004"	0.011"	0.022"
	7:30 to 11:15	0.002"	0.011"	0.026"
12' to 16'	3:00 to 5:00	0.003"	0.013"	0.033"
	6:30 to 10:00	0.003"	0.017"	0.031"
16' to 20'	2:45 to 5:15	0.005"	0.015"	0.031"
	7:00 to 10:00	0.006"	0.012"	0.021
20' to 24'	2:45 to 5:00	0.004"	0.020"	0.033
	7:15 to 10:00	0.005"	0.010"	0.021
24' to 28'	All	No Corrosion Pitting Visible		
28' to 31'	All	No Corrosion Pitting Visible		

As shown, all of the corrosion pitting occurred between the 1:30 and 11:15 o'clock positions on the fractured section of pipeline; no pitting corrosion was observed at the 12 o'clock position where the ERW seam was positioned in the pipe. The average pitting depth over the entire section of the pipe was determined to be 0.014", and the maximum depth at any location was 0.037", which are approximately 4.5% and 12%, respectively, of the total wall thickness of the pipe. No corrosion pitting was present at either cut end of the fractured pipe section. Photographs showing the corrosion pitting on the east and west sides of the pipe following removal of the coating are displayed in Photographs No. 65 through No. 82.

3.4.3 The I.D. surface of both pipe sections was examined using oblique lighting and pivoting mirrors and magnifying glasses prior to sectioning. No corrosion pitting was visible on the I.D. surface of either the fractured or intact sections of pipe. However some shallow bottomed depressions were observed at random locations.

Following sectioning of the 33' 11-1/2" long and the 19' 10" long pipe lengths, the I.D. surfaces at several areas were more closely examined. Multiple shallow depressions, including those noted above, were visible around the entire circumference of the I.D. surface. The depressions were very smooth in appearance and contained no visible corrosion products, suggestive of mechanical deformation as opposed to corrosion pitting. No evidence of any significant corrosion pits was visible on the I.D. surface. Photographs No. 83 and No. 84 show representative areas of the I.D. surface.

3.5 Dimensional Measurements

3.5.1 The out-of-roundness at intact locations at either end of the fracture, as well as at the south cut end of the 33' 11-1/2" long fractured section of pipe, was determined as specified in Section 10.2.8.3 of API 5L, 44th Edition. At each of the three (3) locations, four (4) measurements of the I.D. were taken, spanning between 12:00 and 6:00 o'clock, 1:30 and 7:30 o'clock, 3:00 and 9:00 o'clock, and 4:30 and 10:30 o'clock using a certified and calibrated I.D. micrometer. In accordance with the method specified in the aforementioned section of API 5L, 44th Edition, the out-of-roundness at each location was then determined to be the difference between the largest and smallest I.D. measurement. The calculated out-of-roundness at each location is displayed in the following table, along with the API requirements.

Circumferential Location of Measurement (o'clock)		I.D. Measurement Distance from North Girth Weld		
Begins	Ends	-6"	271"	371"
12:00	6:00	19.3652"	19.363"	19.392"
1:30	7:30	19.463"	19.375"	19.457"
3:00	9:00	19.353"	19.390"	19.357"
4:30	10:30	19.350"	19.354"	19.437"
Calculated Out-of-Roundness		0.111"	0.036"	0.100"
API 5L, 44th Edition, Table 10, Pipe Except End Out-of-Roundness tolerance for D = 20"				0.400"

As shown, at each of the locations tested the calculated out-of-roundness was determined to be within the allowable tolerance specified in API 5L, 44th Edition, Table 10, for welded pipe with a nominal O.D. between 6.625" and 24". The results of the multiple I.D. measurements and the out-of-roundness calculations are recorded in Table 1.

3.5.2 Wall thickness measurements of the failed pipe were made at 2" intervals along the fracture adjacent to each mating fracture surface, using a certified and calibrated micrometer. The measurements were taken beginning at a location 40" south of the north girth weld and terminating at the crack tip, located 267", or 22' 3", from the north girth weld. Although the other crack tip was located at the north girth weld, the distance between the mating fracture surfaces was too small to allow for accurate wall thickness measurements at or directly adjacent to the north girth weld.

The smallest wall thickness was measured to be 0.310" and the largest was 0.321". The average wall thickness was calculated to be 0.315", while the nominal specified wall thickness for the 20" O.D. pipe was 0.312". The complete results of the wall thickness measurements taken on either side of the crack using a certified and calibrated digital micrometer are recorded in Table 2.

3.5.3 The wall thickness of the fractured pipe was measured at numerous locations both at and away from the fracture by SGS-PfiNDE, Inc. (PfiNDE), an approved third party vendor using the non-destructive ultrasonic test method.

3.5.3.1 A grid or 'map' of ultrasonic wall thickness measurements, covering from 12" upstream to 12" downstream of the fracture and around the entire 360° circumference of the pipe, were taken at 2" intervals over a total pipe length of 24.67'. The wall thickness was determined to range between 0.288" and 0.316" along the evaluated length. No internal corrosion areas were noted, although a linear inclusion in the mid-wall area of the pipe was noted on the CMAPPs (AUT) inspection. The complete results of the ultrasonic wall thickness measurements of the fractured pipe are recorded in Appendix IV.

3.6 Residual Stresses

3.6.1 As the pipe containing the fracture was sectioned for fractographic examination, a significant amount of displacement of the sectioned portion of pipe was observed near the crack tip adjacent to the north girth weld, as shown in Photograph No. 85, indicating that the pipe had been under a considerable amount of constraint since it was manufactured, placing the ERW seam under sustained tension forces, which contributed to the increase in stresses at the ERW seam joint. The separation of the fracture faces confirms elastic spring back in the circumferential direction, indicating the presence of circumferential residue stresses likely associated with the original forming and ERW seam welding of the pipe. However, the extent to which these residual stresses may have contributed to the initiation of the hook cracks or the final fracture is unknown at this time.

3.7 Fractographic Examination

3.7.1 The mating fracture faces of the entire 22' 3" long fracture were visually examined using oblique lighting prior to removal of the coal-tar coating, but following removal of the protective grease with mineral spirits, acetone, and a nylon brush. A thorough, careful examination of both mating fracture faces revealed fine chevrons or radial lines emanating from the fracture zone at a distance between 19' 10" and 21' 6-1/4" from the north girth weld, indicating that the final fracture, which resulted in the leakage of the crude oil, originated from this zone. Visual examination of the mating fracture faces from the distance between 1/4" and 26" south of the north girth weld revealed evidence of upturned grain flow lines or bands, and/or inclusions near the outer wall. However, there was no evidence of any chevron marks pointing to this fracture zone, indicating that the fracture did not initiate from this zone, but rather propagated through the surface imperfections. Photograph No. 86 displays overall and close-up views of the fracture origin and the tip areas, as well as field markings on the pipe.

The fracture zones from a distance between 19' 10" and 20' from the north girth weld was further examined to characterize the fracture morphologies. Fractographic examination revealed flat, highly oxidized, fracture zones predominantly in the upper half (adjacent to the O.D. surface) of the fracture surface along the ERW seam, which are characteristic of hook cracks. Examination further revealed radial lines emanating from the tips of the hook cracks, indicating that the final fracture, which occurred during service and resulted in the leakage of the crude oil, originated from the tips of hook cracks that had reduced the effective cross-sectional area of the wall at the ERW seam location. A hook crack is defined in API Bulletin 5TL as “Metal separations resulting from imperfections at the edge of the plate of skelp, parallel to the surface, which turn toward the inside diameter or outside diameter pipe surface when edges are upset during welding.” Photograph No. 87 displays the final fracture initiation sites with insert photographs, revealing the hook cracks, final fracture zones, and the direction of the fracture propagation. The secondary fracture zone, found from a distance between 1/4" and 26" from the north girth weld, contained ERW seam manufacturing imperfections in the upset/HAZ area that had most likely cracked during the final rupture, and is displayed in Photographs No. 88 through No. 94.

3.7.2 A section of the pipe containing the hook cracks, which measured approximately 3-1/2" to 4" in width and approximately 40" in length, was cut and removed from the pipe for closer examination of the O.D. and I.D.

surfaces, and characterization of the fracture morphology. Photographs No. 95 and No. 96 display the cut sections. Close-up examination of the fracture face from a distance between 18' 10" and 19' 10-1/4" from the north girth weld revealed fine chevrons pointing to the hook cracks, indicating that the final fracture originated from the hook cracks and rapidly propagated upstream toward the north girth weld through the HAZ of the ERW seam. Photographs No. 97 through No. 100 display the evidence of chevrons pointing to the hook cracks. Further examination of the fracture face from a distance between 19' 10" and 20' 8" from the north girth weld revealed continuation of the hook cracks and transitioning of the radial lines into vertical lines, indicating the primary fracture origins to be between 20' 2-3/8" and 20' 7-3/8", as displayed in Photographs No. 101 through No. 103. Examination of the remaining fracture surface of the selected fracture face revealed continuation of the hook cracks with intermittent termination and continuation up to a location approximately 20' 11" from the north girth weld, and occasional hook cracks near the I.D. surface of the pipe with chevrons pointing in the opposite direction, indicating that the remaining final fracture propagated toward the south end and terminated in the base metal, as displayed in Photographs No. 104 through No. 110.

In addition to the total depth of the hook cracks, the length and depth below the O.D. surface of various fracture zones on the fracture surface were measured as per the client's request. The darker smooth areas on the fracture surface, all beginning at the O.D. surface, indicated areas of the hook cracks that contained a tightly adhered layer of oxide scale from exposure to moisture; the length and maximum depth of each of these areas was measured. Several axial ridges were also visible on the fracture surface within the hook cracks, formed most likely as a result of the microstructural conditions of the upturned banded grain structure within the ERW seam upset and primary HAZ and potential microcracks through which the fracture occurred. The following table records the measurements, along with the distance from the north girth weld and reference to the photographs showing the various fractographic features.

Fracture Zone Number	Photograph Number	Distance from North Girth Weld	Feature Appearance	Total Length	Depth Below O.D. Surface
1	101	20' 3/8" to 20' 7/8"	Darker Smooth Area	1/2"	0.125"
2	102	20' 2-1/8" to 20' 2-5/8"	Darker Smooth Area	1/2"	0.063"
3	102 - 103	20' 3" to 20' 4-3/8"	Darker Smooth Area	1-3/8"	0.085"
4	102	20' 3" to 20' 3-3/4"	Ridge	3/4"	0.061"
5	102 - 103	20' 3-7/8" to 20' 4-1/8"	Ridge	1/4"	0.058"
6	103	20' 4-5/8" to 20' 7-5/8"	Darker Smooth Area	3"	0.150"
7	103	20' 4-5/8" to 20' 6-3/8"	Ridge	1-3/4"	0.113"
8	104	20' 7-7/8" to 20' 8-1/8"	Darker Smooth Area	1/4"	0.046"
9	104	20' 8-5/8" to 20' 9"	Darker Smooth Area	3/8"	0.063"
10	104 - 105	20' 9-1/8" to 20' 11-1/4"	Darker Smooth Area	2-1/8"	0.048"
11	105 - 106	21' 1/8" to 21' 1-1/2"	Darker Rough Area	1-3/8"	0.062"
12	106 - 107	21' 3" to 21' 4-3/8"	Darker Rough Area	1-3/8"	0.031"
13	107	21' 5" to 21' 5-1/2"	Darker Rough Area	1/2"	0.042"
14	107	21' 5-1/2" to 21' 5-7/8"	Darker Smooth Area	3/8"	0.020"

3.7.3 An approximately 5-1/2" long section of the fracture surface containing the primary final fracture origins and some of the hook cracks between a distance of 20' 2-1/2" and 20' 8" from the north girth weld was removed, electrolytically descaled, cleaned using alkaline Endox® 214 solution, and examined at low magnifications to ascertain the general condition of the pipe surface at the O.D. and I.D. surfaces along the ERW seam near the fracture origins. The mating fractured surface was not cleaned to preserve the sample for the later evaluation of the condition of the scale or oxidation that was present on the fractured face.

Close-up examination of the cleaned fracture face containing hook cracks and the final fracture origins revealed that one of the final fracture origins was at a location where the outer coal-tar coating had split diagonally during service. Some of the coal-tar had melted onto the fracture surface. The examination also revealed localized melting of the pipe metal caused by the copper electrode contacts that were apparently originally used to weld the skelp to form the ERW pipe. Photographs No. 111 through No. 116 display the O.D. surface condition of the pipe near the fracture origins.

Close-up examination of the fracture face between a distance of 20' 2-1/2" and 20' 8" from the north girth weld revealed highly oxidized hook cracks and the final fracture originating from the hook cracks, which were present to a maximum depth of 0.150". Photographs No. 117 through No. 122 display the hook cracks and the origins from where the final fracture initiated and propagated north toward the north girth weld along the ERW seam and south into the base metal south of the fracture origins.

3.7.4 The hook cracks and the final fracture zones across the entire fracture face from the O.D. to the I.D. of the pipe at two (2) of the several fracture origins, located at 20' 5-5/16" and 20' 6-3/4" from the north girth weld, as shown in Photographs No. 117 through No. 122, were examined at higher magnifications using a Scanning Electron Microscope (SEM) to further characterize the fracture morphologies. The SEM examination of the hook cracks revealed fractures through the multiple planes across the weld upset, HAZ, and/or fusion line of the ERW seam, which were covered with tightly adhered scale or oxidation products obscuring the fracture morphology. However, the fractures through multiple planes in the weld upset, HAZ, and/or fusion line suggest that the cracks propagated through the path of least resistance. There was some evidence of what appeared to be intergranular fracture in an extremely small area of the hook crack, which can be attributed to the prior grain structure of the material. The final fracture zone revealed essentially cleavage to quasi-cleavage fracture, indicative of brittle instantaneous failure. The fracture through the weld flash near the I.D. surface revealed evidence of ductile fracture. Photographs No. 123 through No. 150 document the fracture morphologies at the fracture origin locations.

3.8 Crack Measurements

3.8.1 Fractographic examination of the fracture face between 19' 10" and 22' revealed the presence of the hook cracks along the multiple planes of the ERW seam between a distance of 19' 10-1/8" and 21' 9-1/2"; however, the hook cracks were predominantly located between 19' 10-1/8" and 20' 11-3/8", and 21' 2" and 21' 9-1/4", as measured from the north girth weld. The maximum depth of the hook cracks, from where the final fracture initiated during service and lead to the rupture of the pipeline, was 0.150"; however, the depth of the hook cracks varied between 0.016" and 0.150", as recorded in Table 3.

3.8.2 The mating fracture faces in the crack origins area from where the final fracture had initiated between a distance of 20' 2-1/2" and 20' 8" were reconstructed and sectioned transversely across the fractured ERW seam, more specifically at distances of 20' 3-3/4", 20' 4-7/8", and 20' 5-1/2" from the north of the girth weld, and were prepared for metallographic examination as well as the crack width measurements. Additional cross-sections were also removed through the fractured ERW seam from a distance of 20' 6-13/16" and intact seam from a distance of 35' 8-1/2" and prepared for metallographic examination.

3.8.3 The maximum width and depth of the hook cracks were measured at several locations and were found to be 0.0038" and 0.150", respectively. It should be noted here that the hook crack width measurements were made following reconstruction of the two (2) mating fracture faces and, therefore, the values shall be considered as approximates only. Table 4 records the hook cracks width measurements.

3.9 Metallographic Evaluation

3.9.1 Microstructural examination of the cross-sections removed transversely through the ERW seam at a distance of 20' 4-7/8" and 20' 6-13/16" from the north girth weld and prepared for metallographic examination was performed to characterize the microstructural conditions of the ERW seam at the fracture origin locations. Microstructural examination revealed hook cracks through the ERW upset/HAZ along the realigned inclusions and upturned bands of extremely brittle untempered martensite.

Both cross-sections removed through the final fracture origins and prepared for metallographic examination confirmed the presence of hook cracks through the excessive amount of manganese sulfide inclusions and bands which were essentially parallel to the ERW fusion line, an undesirable condition that was apparently created during the skelp forming and ERW processes. The microstructure of the upturned bands consisted of very brittle, hard untempered martensite, while the ERW upset/HAZ area consisted of a mixed-microstructure with grain boundary ferrite, unresolved bainite, and some untempered martensite, which is undesirable since this microstructure possesses extremely low ductility. The secondary HAZ and the base metal consisted of grain boundary ferrite and pearlite.

Microstructural examination also revealed evidence of localized melting and cracking to a shallow depth at the electrode contact areas at the O.D. locations parallel to the weld seam. Photographs No. 151 through No. 202 document the microstructural condition of the ERW seam at the locations of the hook cracks from where the final fracture had initiated and predominantly propagated upstream toward the north girth weld.

3.9.2 A cross-section was removed transversely through the intact portion of the ERW seam of the 49' 9-1/2" section of the pipeline at a distance of 35' 8-1/2" from the north girth weld and prepared for metallographic examination to characterize the microstructural condition of the ERW seam.

The microstructural examination revealed excessive amounts of predominantly manganese sulfide stringers and some oxide inclusions, several of them aligned parallel to the fusion line in the upset area of the ERW seam, which is a highly undesirable condition and can lead to the formation of hook cracks. The microstructural examination of the cross-section following etching in a 2% Nital solution revealed the presence of some upturned bands, however not as severe as those found in the fractured seam. The microstructure of the upturned bands consisted of brittle untempered martensite, while the upset/HAZ away from the bands consisted of mix-microstructure of grain boundary ferrite, bainite, and some untempered martensite. Photographs No. 203 through No. 220 document the microstructural condition of the intact ERW seam.

3.9.3 Longitudinal cross-sections were removed through the corrosion pitting at representative areas on the O.D. surface and through the shallow indentations on the I.D. surface, and were metallographically prepared and etched in a solution of 2% Nital. On the O.D. surface multiple pits filled with oxides and corrosion products were visible, extending to a maximum depth of 0.008" on the metallographically prepared cross-sections. Following etching, the non-uniform pits were confirmed to be the result of material loss due to corrosion, with no evidence of grain deformation or mechanical damage. As previously noted, all of the corrosion pitting was observed between the 1:30 and 11:15 o'clock positions on the fractured section of pipe, and no pitting corrosion was observed at the 12:00 o'clock position where the ERW seam was positioned in the pipe. The corrosion observed on the O.D. surface did not contribute to the pipeline failure.

Examination of the I.D. surfaces on the metallographically prepared cross-sections revealed that the shallow depressions were smooth indentations, between 0.137" and 0.189" wide and up to 0.007" deep. The I.D. surface and the surfaces of the indentations were smooth, with no visible oxide scale, and in the etched condition some grain deformation was visible at the edges of the indentations, indicating mechanical damage. However, the thickness of the microstructural band containing partial decarburization on the I.D. surface remained constant, indicating that the impressions occurred most likely during the hot-rolling of the steel or manufacturing of the pipe and not during service. The I.D. surface indentations did not contribute to the pipeline failure. Photographs No. 221 through No. 226 display representative areas of the O.D. and I.D. surfaces on the metallographically prepared longitudinal cross-sections in both the as-polished condition and following etching in a solution of 2% Nital.

3.10 Microhardness Surveys

3.10.1 Vickers microhardness surveys were performed on the metallographically prepared cross-sections at both the representative fractured and intact locations of the ERW seam on the pipe sections in accordance with the test method specified in ASTM E384-11$^{\epsilon1}$. The Vickers microhardness values were converted to equivalent Rockwell B or C scale values based on the conversions provided in ASTM E140-07, Tables 1 and 2. It should be emphasized that the hardness equivalents are approximates based on equations developed from empirical data, and are typically higher than the results obtained by testing using the larger Rockwell indenter and much higher load forces.

3.10.2 Vickers microhardness surveys were performed on the metallographically prepared cross-sections removed from representative fractured areas of the ERW seam at 20' 4-7/8" and 20' 6-13/16" from the north girth weld. Each cross-section was evaluated along the fracture surface, including along the hook crack(s), the hardened martensitic upturned grains, and the final fracture zone, as well as in the ERW seam at the fusion line, the HAZ and the base metal. The results of the Knoop microhardness surveys at fractured locations of the pipe are summarized in the following table.

Cross-section Location (from North Girth Weld)	Average Hardness, Rockwell Equivalent					
			At Fracture Surface			
	Base Metal	Heat-Affected Zone	Hook Crack	Hardened Upturned Grains	Final Fracture	ERW Fusion Line
20' 4-7/8"	96 HRB	100 HRB	29 HRC	52 HRC	28 HRC	42 HRC
20' 6-13/16"	100 HRB	21 HRC	29 HRC	49 HRC	29 HRC	32 HRC

As shown, the hardness varied extensively along the fracture surface of the hook crack(s) within the upturned grains. The hardened, martensitic microstructure was 20 to 23 Rockwell C hardness points higher than the adjacent microstructure within the upturned grains and along the fusion line in the ERW seam. The hardness decreased the farther away from the ERW seam, resulting in approximately a 30 Rockwell C hardness point difference between the ERW seam and the softer base metal. The large difference in hardness is undesirable and results in increased internal stresses, which can contribute to crack initiation and propagation. The complete results of the Vickers microhardness surveys, including micrographs showing the locations of each indentation on the metallographically prepared cross-sections removed through the crack are displayed in Table 5 and Table 6.

3.10.3 A Vickers microhardness survey was also performed on the metallographically prepared cross-section that was removed through the ERW seam at a representative intact area approximately 35' 8-1/2" from the north girth weld for comparison with the data from the fractured location. The results of the Vickers microhardness survey of the intact area are displayed in the following table.

Cross-section Location (from North Girth Weld	Hardness, Rockwell Equivalent			
	Base Metal	Heat-Affected Zone	Upturned Grain Flow Lines	ERW Fusion Line
35' 8-1/2"	100 HRB average	99 HRB average	Varied between 21 HRC and 54 HRC	Varied between 23 HRC and 54 HRC

As shown, the cross-section removed from an intact area of the pipe also contained a hardened martensitic microstructure within the upturned grain flow pattern of the ERW seam at the O.D. surface. The fusion line, HAZ, and base metal hardnesses of the intact cross-section were similar to those areas on the fractured cross-sections, including the large variation between the ERW seam and the base metal of the pipe. The complete results of the Vickers microhardness survey, including a micrograph of the metallographically prepared cross-section removed from the ERW seam in an intact area, are displayed in Table 7.

3.11 Tensile Tests

3.11.1 In order to determine the ultimate tensile stress, yield stress at a 0.5% offset, and percent elongation of the pipe, multiple tensile test specimen blanks were removed through the ERW seam, as well as in both the transverse and longitudinal directions away from the seam, on the intact 19' 10" long section of pipe as shown in Appendix V. All of the test specimens were machined to have a 2" long gauge length, a 1-1/2" wide reduced section, and represented essentially the entire wall thickness, with only slight sanding to remove minor surface imperfections or, as noted, the weld flash.

3.11.2 Six (6) transverse tensile test specimen blanks were removed through the ERW seam and were then flattened as specified in both the 10th Edition and the 44th Edition of API 5L. The tensile test specimens were then machined and tested in accordance with ASTM A370-12a and the applicable sections of each edition of the API 5L specification. The results of the transverse tensile tests through the ERW seam, along with the tensile requirements from both the 10th Edition of API 5-L that was in effect at the time the pipe was manufactured and the current API 5L, 44th Edition are shown in the following table.

Sample Identification	Ultimate Stress (psi)	Yield Stress (psi)	Elongation (%)	Fracture Location
Transverse, Through ERW Seam, Weld Flash Included, Sample 1	101,000	77,000	4	HAZ
Transverse, Through ERW Seam, Weld Flash Included, Sample 2	93,500	79,000	5	HAZ
Transverse, Through ERW Seam, Weld Flash Included, Sample 3	102,000	84,000	23	Base Metal
Transverse, Through ERW Seam, Weld Flash Removed, Sample 1	85,500	73,000	3	HAZ
Transverse, Through ERW Seam, Weld Flash Removed, Sample 2	85,500	75,000	3	HAZ
Transverse, Through ERW Seam, Weld Flash Removed, Sample 3	92,500	77,000	5	HAZ
API 5-L, 10th Edition, Electric Welded Pipe, Open Hearth Steel, Grade B	60,000 minimum	None Specified	None Specified	Not Applicable
API 5L, 44th Edition, PSL 1, Welded Pipe, Grade X42	60,200 minimum	None Specified	None Specified	Not Applicable

As shown, all of the tensile test specimens, regardless of whether the specimens contained the weld flash, met the minimum ultimate stress requirements specified in both API 5-L, 10th Edition and API 5L, 44th Edition. The complete results of the transverse tensile tests through the ERW seam are recorded in Table 8.

3.11.3 Multiple base metal transverse tensile test specimen blanks were removed from the pipe, at locations 90° from the ERW seam and 180° from the ERW seam, and were flattened prior to machining. Longitudinal base metal tensile test specimen blanks were also removed from the pipe at a location 90° from the ERW seam. All of the tensile test blanks were machined and tested in accordance with ASTM A370-12a and the applicable sections of sections of each edition of API 5L. The results of both the transverse and longitudinal base metal tensile tests, along with the tensile requirements from both the 10th Edition of API 5-L that was in effect at the time the pipe was manufactured and the current API 5L, 44th Edition are shown in the following table.

Sample Identification	Ultimate Stress (psi)	Yield Stress (psi)	Elongation (%)
Transverse, 90° from ERW Seam, Sample 1	87,000	59,000	30
Transverse, 90° from ERW Seam, Sample 2	86,500	59,000	31
Transverse, 90° from ERW Seam, Sample 3	89,000	62,000	28
Transverse, 180° from ERW Seam, Sample 1	87,000	63,000	28
Transverse, 180° from ERW Seam, Sample 2	85,500	60,000	28
Transverse, 180° from ERW Seam, Sample 3	87,500	64,000	28
Longitudinal, 90° from ERW Seam, Sample 1	89,000	64,500	31
Longitudinal, 90° from ERW Seam, Sample 2	90,000	66,500	31
Longitudinal, 90° from ERW Seam, Sample 3	90,500	68,500	31
API 5-L, 10th Edition, Electric Welded Pipe, Open Hearth Steel, Grade B	60,000 minimum	35,000 minimum	Unknown[1]
API 5L, 44th Edition, PSL1, Welded Pipe, Grade X42	60,200 minimum	42,100 minimum	27% minimum

[1]The required minimum elongation specified on the tensile requirements table in the provided paper copy of API 5-L, 10th Edition is illegible.

As shown, all of the base metal tensile test specimens, in both the transverse and longitudinal directions, met the requirements specified in both API 5-L, 10th Edition and API 5L, 44th Edition. Although the measured yield stress typically exceeded the minimum ultimate stress requirement, it should be noted that there were not any maximum strength requirements. The complete results of the base metal transverse and longitudinal tensile tests are recorded in Tables 9 and 10.

3.11.4 Sub-sized round, non-flattened transverse tensile test specimen blanks were removed through the ERW seam, 90° from the ERW seam, and 180° from the ERW seam on the intact section of pipe, and were machined and tested in accordance with the applicable sections of API 5L and ASTM A370-12a. The results of the non-flattened transverse tensile tests are summarized in the following tables.

Sample Identification	Ultimate Stress (psi)	Yield Stress (psi)	Elongation (%)
Transverse, Through ERW Seam, Weld Flash Removed, Non-flattened	99,600	65,100	21
API 5-L, 10th Edition, Electric Welded Pipe, Open Hearth Steel, Grade B	60,000 minimum	None Specified	None Specified
API 5L, 44th Edition, PSL1, Welded Pipe, Grade X42	60,200 minimum	None Specified	None Specified

Sample Identification	Ultimate Stress (psi)	Yield Stress (psi)	Elongation (%)
Transverse, 90° from ERW Seam, None-flattened	86,100	56,700	27
Transverse, 180° from ERW Seam, None-flattened	83,600	57,900	22
API 5-L, 10th Edition, Electric Welded Pipe, Open Hearth Steel, Grade B	60,000 minimum	35,000 minimum	Unknown[1]
API 5L, 44th Edition, PSL1, Welded Pipe, Grade X42	60,200 minimum	42,100 minimum	27% minimum

[1]The required minimum elongation specified on the tensile requirements table in the provided paper copy of API 5-L, 10th Edition is illegible.

As shown, the sub-sized, non-flattened transverse tensile test specimens met the requirements specified in both API 5-L, 10th Edition and API 5L, 44th Edition. The complete results of the sub-sized, non-flattened transverse tensile tests are recorded in Table 11.

3.12 Charpy V-Notch Impact Tests

3.12.1 Test blanks for multiple sets of transverse Charpy V-Notch (CVN) impact test specimens were removed from the intact 19' 10" long section of pipe as shown in Appendix V. Sets of half-sized 10 mm x 5 mm test specimens were machined per Section 9.8 of API 5L, 44th Edition and

ASTM A370-12a and were notched in the fusion line of the ERW seam, the primary HAZ of the ERW approximately 1 mm from the fusion line, and the base metal. Then for each notch location, one (1) set of three (3) specimens was tested per ASTM A370-12a at the selected test temperatures of plus 32°F, plus 65°F, plus 80°F, and plus 95°F. Base metal specimens were also tested at additional temperatures.

3.12.2 The results of the CVN impact tests for each location and each test temperature are recorded in the following tables.

V-Notch Location: ERW Fusion Line				
Specimen Number	Test Temperature	Impact Value (ft-lbf)	Lateral Expansion (mils)	Percent Shear (%)
1		3	0	0
2	Plus 95°F	2	1	0
3		3	0	0
1		3	0	0
2	Plus 80°F	2	0	0
3		3	1	0
1		3	1	0
2	Plus 65°F	2	0	0
3		3	1	0
1		3	0	0
2	Plus 32°F	3	0	0
3		2	0	0

V-Notch Location: ERW Primary Heat-Affected Zone				
Specimen Number	Test Temperature	Impact Value (ft-lbf)	Lateral Expansion (mils)	Percent Shear (%)
1		3	3	0
2	Plus 95°F	3	4	0
3		4	6	0
1		5	7	0
2	Plus 80°F	4	5	0
3		8	5	0
1		3	2	0
2	Plus 65°F	3	1	0
3		5	2	0
1		4	0	0
2	Plus 32°F	3	0	0
3		4	0	0

V-Notch Location: Base Metal				
Specimen Number	Test Temperature	Impact Value (ft-lbf)	Lateral Expansion (mils)	Percent Shear (%)
1	Plus 95°F	10	16	15
2		10	12	10
3		10	14	10
1	Plus 80°F	9	9	5
2		9	10	5
3		9	13	5
1	Plus 65°F	10	13	5
2		10	14	5
3		10	13	5
1	Plus 32°F	8	8	5
2		9	12	5
3		9	10	5
1	Zero°F	5	1	0
2		4	2	0
1	Minus 32°F	2	0	0

As shown, the impact values at each notch location were essentially the same between plus 32°F and plus 95°F, while the base metal impact values at 0°F were half the values at 32°F and above, and continued to drop with lower temperatures. The fusion line of the ERW seam had the lowest impact values and the base metal, as expected, had the highest values. The lateral expansion and percent shear was essentially zero at the fusion line of the ERW seam, and the lateral expansion was only slightly higher in the HAZ. The base metal had the largest lateral expansion and percent shear values. The results of the CVN impact tests are recorded in Tables 12, 13, and 14.

At the time the pipe was manufactured, no CVN impact tests or requirements were specified in APL 5-L, 10th Edition. Likewise, there are no impact requirements for Type PSL 1 welded pipe in the current 44th Edition of API 5L. The only impact requirements for comparison are that in the 44th Edition of API 5L, for all notch locations on Type PSL 2 welded pipe, Grade ≤X60, half-size transverse test specimens are required to have a 10 ft-lbf minimum average for a set of three test specimens and 8 ft-lbf minimum for a single individual test specimen, when tested at a test temperature of plus 32°F.

3.12.3 The CVN impact test results were then intended to be used to determine the lower shelf energy, upper shelf energy, the ductile-to-brittle transition temperature for the base metal, and if possible, the ERW seam, by plotting the results and developing an S-curve graph. The ductile-to-brittle transition temperature for the ERW fusion line and HAZ can not be determined, because the results of the impact tests at these areas were essentially the same regardless of test temperature. All of the CVN impact test specimens notched in the ERW seam, whether at the fusion line or in the HAZ, failed in an essentially brittle manner, therefore the ductile-to-brittle transition temperature is above 95°F and is outside the scope of this investigation.

However, additional tests at a temperatures below plus 32°F were performed on transverse CVN impact test specimens machined from the base metal because the base metal test specimens did fracture in a more ductile manner. The lower shelf would be considered to be around 2 ft-lbf for the size tested, or 4 ft-lbf for a full-size test specimen.

3.13 Chemical Analyses

3.13.1 An approximately 2" by 2" section was removed away from the ERW seam on the intact 19' 10" long section of pipe, as shown in Appendix V, and the surface was sanded smooth in preparation for determining the chemical composition of the pipe using the Optical Emission Spectroscopic (OES) test method in accordance with ASTM E415-08, with the percent carbon determined by an approved vendor using the combustion method specified in ASTM E1019-11. The results of the chemical composition analysis, as well as the compositional requirements for both the 10th Edition of API 5-L that was in affect at the time the pipe was manufactured and the current API 5L, 44th Edition are shown in the following table.

Element (wt%)	Sample Tested	API 5-L, 10th Edition, Electric Welded Pipe, Open Hearth Steel, Grade B Spec.	API 5L, 44th Edition, PSL 1, Welded Pipe, Grade X42 Specification
Carbon	0.30	0.30 max	0.26 max
Manganese	1.47	0.35 to 1.50	1.30 max
Phosphorus	0.017	0.045 max	0.030 max
Sulfur	0.031	0.06 max	0.030 max
Silicon	<0.01	[1]	[1]
Chromium	<0.01	[1]	0.50 max
Nickel	0.04	[1]	0.50 max
Molybdenum	<0.01	[1]	0.15 max
Copper	0.02	[1]	0.50 max
Aluminum	<0.01	[1]	[1]
Niobium	<0.01	[1]	[2]
Vanadium	<0.01	[1]	[2]
Titanium	<0.01	[1]	[2]
	Base	Base	Base

[1]Analytical range not specified for element.
[2]Sum of Niobium + Vanadium + Tantalum = 0.15% maximum

As shown, the pipe met the chemical composition that was specified in API 5-L, 10th Edition at the time of the pipe manufacture, but does not meet the compositional requirements specified in the current API 5L, 44th Edition for welded pipe. The complete results of the OES chemical analysis of the pipe are recorded in Table 15.

3.13.2 The foreign materials on the fracture surfaces, the O.D. surface, and the tightly adhered, very viscous black coating of the pipe was analyzed using the Energy Dispersive X-ray Spectroscopic (EDS) test method in accordance with ASTM E1508-12a in order to determine the elements present and the relative amounts of each. It should be noted that the fracture surface was protected with white grease prior to shipment to the laboratory, which was removed with the mineral spirit and acetone, and therefore the results of the EDS analysis may not be taken at the face value. Furthermore, it should also be noted that EDS is a semi-quantitative test method, and that the results should be used as comparative or relative values only. It should also be noted that the EDS used was not capable of detecting light elements, those elements with atomic weights less than fluorine.

The following table shows the results of the EDS analysis at three (3) different locations of the fracture surface.

Element (wt%)	Fracture Surface EDS-1	Fracture Surface EDS-2	Fracture Surface EDS-3
Magnesium	3.980	1.925	2.084
Aluminum	3.484	4.776	3.118
Silicon	12.974	12.032	8.578
Sulfur	4.081	2.144	3.006
Chlorine	2.794	2.377	1.864
Potassium	0.975	0.883	0.698
Calcium	1.162	0.874	1.198
Titanium	0.810	0.836	[1]
Manganese	1.603	1.056	1.541
Iron	68.137	73.097	77.912

[1]Element not detected.

As shown, in addition to iron and manganese from the base metal of the pipe, high levels of silicon, aluminum, and magnesium, were detected, most likely due to soil adhering to the fracture surface; similarly the calcium, potassium, and titanium were also likely from the surrounding soil. High levels of the corrosive elements chlorine and sulfur were also detected, although no pitting corrosion had yet occurred on the fracture surfaces. The complete results of the EDS analyses of the material on the fracture surfaces, including line spectra and SEM images of each location, are recorded in Tables 16, 17, and 18.

3.13.3 The chemical composition of the reddish-brown products on the O.D. surface of the pipe was also evaluated using the EDS test method. The results of the EDS analysis are displayed in the following table.

Element (wt%)	Reddish-Brown Product on O.D.
Magnesium	0.417
Aluminum	6.783
Silicon	33.882
Sulfur	0.391
Potassium	1.679
Titanium	0.949
Manganese	0.306
Iron	55.594

As shown, the products on the O.D. surface of the pipe were composed of primarily silicon with aluminum and potassium, in addition to the iron from the base metal of the pipe. The reddish-brown product on the O.D. surface of the pipe was likely soil that had migrated through the splits in the coating of the pipe. Some of the products may also have been from corrosion of the pipe, although it should be stressed that there was no evidence of significant localized or pitting corrosion on the received sections of pipe. The results of the EDS analysis of the products on the O.D. surface of the pipe are recorded in Table 19.

3.13.4 The viscous black bitumen, or coal-tar, coating that was on the O.D. surface of the pipe underneath the layer of fibrous coating was also analyzed using the EDS test method. The results of the test are displayed in the following table.

Element (wt%)	Black Bitumen Coating
Magnesium	4.522
Aluminum	6.942
Silicon	42.773
Sulfur	65.763
Silver	0.000

No specific chemical composition of the coating was available for comparison. Bitumen is a highly viscous mixture composed primarily of highly condensed polycyclic aromatic hydrocarbons that is used as a waterproof coating for buried pipe, among other uses such as paving roads. The results of the EDS analysis of the viscous black coating on the O.D. surface of the pipe are recorded in Table 20.

4.0 CONCLUSION

4.1 Technical Causes of Failure

Based on the inspection, testing, and evaluation performed in accordance with the approved metallurgical test protocol, review of the background information, and technical research, the following is HurstLab's opinion.

The failure of the pipeline at Milepost 314.77 in the Conway to Corsicana section of the Pegasus crude oil pipeline located in Mayflower, Arkansas, which occurred at 2:37 pm CST on March 29, 2013, resulted because of the reduction of the wall thickness in the upset zone of the Electric Resistance Weld (ERW) seam caused by the presence of manufacturing defects, namely the upturned bands of brittle martensite, combined with localized stress concentrations at the tips of the hook cracks, low fracture toughness of the material in the upset/HAZ, excessive residual stresses in the pipe from the initial forming and seam and girth welding processes, and the internal pressure creating hoop stresses.

The hook cracks, with maximum dimensions of 0.0038" in width, 0.150" in depth, and 13-1/4" in length, as measured on the examined section of the fracture surface, were present in the ERW seam prior to the incident for an unknown period of time. The weak upturned fibers or bands of untempered brittle martensite were created during the manufacturing of the pipe. The presence of the tightly adhered scale or oxidation products on the fracture faces of the hook cracks suggests that the hook cracks had been present for an unknown period of time. It is unclear, however, whether the hook cracks occurred immediately after manufacturing or during service. The hook cracks initiated and followed the brittle upturned grain flow lines or bands that were created during the manufacturing of the pipe due to effects of the stresses induced by hydrostatic testing, thermal stresses, residual stresses, and/or pressure cycles.

The hook cracks may not have all occurred simultaneously, as suggested by variation in coloration of the scale or oxides on the fracture surface and the macroscopic features of the fracture. The hook cracks and potential microcracks in the upset/heat-affected zones may have then merged due to stresses during service.

4.2 Failure Scenario

Based on the preceding conclusion, the evidence of the hook cracks through multiple ductile and brittle zones, significant variance in hardness between the various zones of the ERW seam, the tightness and depth of the hook cracks along multiple planes through the upset heat-affected zones, and the extremely low impact toughness and elongation properties across the ERW seam, it is highly probable that some micro-cracking within the upset/heat-affected zones might have occurred immediately following the pipe manufacturing. The micro-cracks then likely would have merged by further cracking through the adjacent areas in the localized upset/HAZ zones during service, forming a continuous hook crack in each of the localized areas to the critical depths, at which point the remaining wall thickness, combined with the localized stress concentration and the residual stresses, could no longer support the internal hoop stresses and resulted in the final failure.

Submitted by,

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Revised on July 9, 2013 to clarify the findings and to make editorial changes.

MP314.77

Photograph No. 1

The photographs provided by EMPCo of the 20" O.D. x 0.312" wall pipe at Milepost 314.77 of the Conway to Corsicana Pegasus crude oil pipeline, which failed on Friday, March 29, 2013 at 2:47 pm CST in Mayflower, Arkansas, display a straight, linear crack at approximately the 12:00 o'clock position.

Photograph No. 2

Photograph No. 3

The photographs display close-up views of the crack tips near the north girth weld in the ERW seam of the pipe and the south end in the base metal, respectively.

Photograph No. 4

Photograph No. 5

The photographs display the fractured section of the pipe in the as-received condition and following removal of the outer protective wrapping material.

Photograph No. 6

The photograph displays the intact section of the pipe in the as-received condition with the outer protective wrapping material.

Photograph No. 7

The photograph displays the intact section of the pipe following removal of the 2nd protective wrapping material.

Photograph No. 8

The photograph displays the fractured pipe section following removal of the 2nd wrapping material, revealing the fracture faces coated with grease to protect from post-incident corrosion.

Photograph No. 9

The photograph displays the intact section of the pipe following removal of the 1st protective wrapping material.

Photograph No. 10

Photograph No. 11

As-received Condition of the Coating			
Circumferential Location	Distance from North Girth Weld	Split Width Maximum	Split Depth Maximum
10:30 o'clock to 1:30 o'clock	-3' to 0'	1"	-
	0' to 4'	2"	0.10"

The photographs display overall top views of the pipe adjacent to the fractured pipe from approximately 3' north of the north girth weld (-3') to the center of the north girth weld (0'), and the fractured pipe from the center of the girth weld to 4' south of the north girth weld, respectively, in the as-received condition prior to removing the coating. The fracture in the pipe along the ERW seam terminated at the north girth weld. The fracture was extremely tight at the girth weld but was measured to be approximately 13/16" in width approximately 4' south of the north girth weld. Relatively narrow longitudinal and transverse splits were present in the coating. The coating had been removed from the adjacent intact pipe prior to sectioning approximately 3' north of the north girth weld.

Photograph No. 12

Photograph No. 13

As-received Condition of the Coating			
Circumferential Location	Distance from North Girth Weld	Split Width Maximum	Split Depth Maximum
10:30 o'clock to 1:30 o'clock	4' to 8'	0.5"	0.14"
	8' to 12'	0.5"	-

The photographs display overall top views of the fractured pipe from 4' south to 8' south of the north girth weld, and from 8' south to 12' south of the north girth weld, respectively, in the as-received condition prior to removing the coating. Longitudinal and transverse splitting is present in the coating, and some of the coating is missing on either side of the fracture.

Photograph No. 14

Photograph No. 15

As-received Condition of the Coating			
Circumferential Location	Distance from North Girth Weld	Split Width Maximum	Split Depth Maximum
10:30 o'clock to 1:30 o'clock	12' to 16'	-	0.07"
	16' to 20'	0.25"	0.09"

The photographs display overall top views of the fractured pipe from 12' south to 16' south of the north girth weld, and from 16' south to 20' south of the north girth weld, respectively, in the as-received condition prior to removing the coating. Longitudinal and transverse splitting is present in the coating, and some of the coating is missing on either side of the fracture.

Photograph No. 16

Photograph No. 17

As-received Condition of the Coating			
Circumferential Location	Distance from North Girth Weld	Split Width Maximum	Split Depth Maximum
10:30 o'clock to 1:30 o'clock	20' to 24'	0.5"	0.10"
	24' to 28'	1.5"	0.10"

The photographs display overall top views of the fractured pipe from 20' south to 24' south of the north girth weld, and from 24' south to 28' south of the north girth weld, respectively, in the as-received condition prior to removing the coating. At approximately 22' south of the girth weld, the fracture in the ERW seam turned into the pipe material, progressing several inches prior to terminating. The damaged area of coating near the pipe fracture extended longitudinally past the fracture tip several feet.

Photograph No. 18

Photograph No. 19

As-received Condition of the Coating			
Circumferential Location	Distance from North Girth Weld	Split Width Maximum	Split Depth Maximum
10:30 o'clock to 1:30 o'clock	28' to 31'	1"	0.05"
	31' to 35'	1"	0.15"

The photographs display overall top views of the fractured pipe from 28' south to 31' south of the north girth weld, and from 31' south to 35' south of the north girth weld, respectively, in the as-received condition prior to removing the coating. The approximately 49' 9-1/2" long pipe was sectioned in the field transversely approximately 31' south of the north girth weld. The coating was removed in the field approximately 13" in either direction from the transverse cut prior to sectioning.

Photograph No. 20

Photograph No. 21

As-received Condition of the Coating			
Circumferential Location	Distance from North Girth Weld	Split Width Maximum	Split Depth Maximum
10:30 o'clock to 1:30 o'clock	35' to 39'	1"	0.10"
	39' to 43'	0.75"	0.11"

The photographs display overall top views of the fractured pipe from 35' south to 39' south of the north girth weld, and from 39' south to 43' south of the north girth weld, respectively, in the as-received condition prior to removing the coating. Longitudinal splitting is visible on the surface of the coating.

Photograph No. 22

Photograph No. 23

As-received Condition of the Coating			
Circumferential Location	Distance from North Girth Weld	Split Width Maximum	Split Depth Maximum
10:30 o'clock to 1:30 o'clock	43' to 47'	0.5"	0.11"
	47' to 51'	1"	-

The photographs display overall top views of the fractured pipe from 43' south to 47' south of the north girth weld, and from 47' south to 51' south of the north girth weld, respectively, in the as-received condition prior to removing the coating. Longitudinal splitting is visible on the surface of the coating. Some of the coating had been removed from the adjacent area pipe prior to sectioning.

Photograph No. 24

Photograph No. 25

The photographs display overall views of the west side of the pipe from 7:30 to 10:30 o'clock, adjacent to the fractured pipe from approximately 3' north of the girth weld (-3') to the center of the north girth weld (0'), and the fractured pipe from the center of the girth weld to 4' south of the north girth weld (+4'), respectively, in the as-received condition prior to removing the coating. The lower half of the pipe contains disbonded and wrinkled coating.

Photograph No. 26

The photograph displays an overall view of the west side from 7:30 to 10:30 of the fractured pipe from 4' south to 8' south of the north girth weld in the as-received condition prior to removing the coating. The lower half of the pipe contains disbonded and wrinkled coating, and some openings in the coating are present where the coating had begun to sag.

Photograph No. 27

Photograph No. 28

The photographs display overall views of the west side between 7:30 and 10:30 of the fractured pipe from 12' south to 16' south of the north girth weld, and from 16' south to 20' south of the north girth weld, respectively, in the as-received condition prior to removing the coating. The lower half of the pipe contains disbonded and wrinkled coating, along with some openings in the coating.

Photograph No. 29

Photograph No. 30

The photographs display overall views of the west side from 7:30 to 10:30 of the fractured pipe from 20' south to 24' south of the north girth weld, and from 24' south to 28' south of the north girth weld, respectively, in the as-received condition prior to removing the coating. The lower half of the pipe contains disbonded and wrinkled coating.

Photograph No. 31

Photograph No. 32

The photographs display overall views of the west side from 7:30 to 10:30 of the fractured pipe from 28' south to 31' south of the north girth weld, and from 31' south to 35' south of the north girth weld, respectively, in the as-received condition prior to removing the coating. The pipe had been sectioned transversely approximately 31' south of the north girth weld. The lower half of the pipe contains disbonded and wrinkled coating.

Photograph No. 33

Photograph No. 34

The photographs display overall views of the west side between 7:30 and 10:30 of the fractured pipe from 35' south to 39' south of the north girth weld, and from 39' south to 43' south of the north girth weld, respectively, in the as-received condition prior to removing the coating. The lower half of the pipe contains disbonded and wrinkled coating.

Photograph No. 35

Photograph No. 36

The photographs display overall views of the west side from 7:30 to 10:30 of the fractured pipe and adjacent intact pipe from 43' south to 47' south of the north girth weld, and from 47' south to 51' south of the north girth weld, respectively, in the as-received condition prior to removing the coating. The coating had been removed from the adjacent intact pipe prior to allow for sectioning. The lower half of the pipe contains disbonded and wrinkled coating.

Photograph No. 37

Photograph No. 38

The photographs display overall bottom views of the pipe from 4:30 to 7:30 o'clock adjacent to the fractured pipe from approximately 3' north of the north girth weld (-3') to the center of the north girth weld (0'), and the fractured pipe from the center of the north girth weld to 4' south of the north girth weld (+4'), respectively, in the as-received condition prior to removing the coating. The coating had been removed from the adjacent intact pipe prior to sectioning in the field. The coating on the lower half of the pipe is sagging and contains wrinkles.

Photograph No. 39

Photograph No. 40

The photographs display overall bottom views of the fractured pipe from 4:30 to 7:30 from 4' south to 8' south of the north girth weld, and from 8' south to 12' south of the north girth weld, respectively, in the as-received condition prior to removing the coating. The coating on the lower half of the pipe is sagging and contains wrinkles.

Photograph No. 41

Photograph No. 42

The photographs display overall bottom views of the fractured pipe from 4:30 to 7:30 from 12' south to 16' south of the north girth weld, and from 16' south to 20' south of the north girth weld, respectively, in the as-received condition prior to removing the coating. The coating on the lower half of the pipe contains wrinkles and has sagged.

Photograph No. 43

Photograph No. 44

The photographs display overall bottom views of the fractured pipe from 4:30 to 7:30 from 20' south to 24' south of the north girth weld, and from 24' to 28' south of the north girth weld, respectively, in the as-received condition prior to removing the coating. The coating on the lower half of the pipe contains a significant amount of wrinkles and has sagged quite a bit.

Photograph No. 45

Photograph No. 46

The photographs display overall bottom views of the fractured pipe from 4:30 to 7:30 from 28' south to 31' south of the north girth weld, and from 31' south to 35' south of the north girth weld, respectively, in the as-received condition prior to removing the coating. The fractured pipe was sectioned transversely approximately 31' south of the north girth weld into two sections.

Photograph No. 47

Photograph No. 48

The photographs display overall bottom views of the fractured pipe from 4:30 to 7:30 from 35' south to 39' south of the north girth weld, and from 39' south to 43' south of the north girth weld, respectively, in the as-received condition prior to removing the coating. The coating on the lower half of the pipe had sagged quite a bit and contains a significant amount of wrinkles.

Photograph No. 49

Photograph No. 50

The photographs display overall bottom views of the fractured pipe from 4:30 to 7:30 and the adjacent intact pipe from 43' south to 47' south of the north girth weld, and from 47' south to 51' south of the north girth weld, respectively, in the as-received condition prior to removing the coating. The coating on the lower half of the pipe contains a significant amount of wrinkles. The coating on the lower half of the pipe contains wrinkles.

Photograph No. 51

Photograph No. 52

The photographs display overall views of the east side of a pipe from 1:30 to 4:30 adjacent to the fractured pipe from approximately 3' north of the north girth weld (-3') to the center of the north girth weld (0'), and the fractured pipe from the center of the north girth weld to 4' south of the north girth weld (+4'), respectively, in the as-received condition prior to removing the coating. The lower half of the pipe contains wrinkled coating.

Photograph No. 53

Photograph No. 54

The photographs display overall views of the east side of the fractured pipe from 1:30 to 4:30 from 4' south to 8' south of the north girth weld, and from 8' south to 12' south of the north girth weld, respectively, in the as-received condition prior to removing the coating. The lower half of the pipe contains sagging and wrinkled coating.

Photograph No. 55

Photograph No. 56

The photographs display overall views of the east side of the fractured pipe from 1:30 to 4:30 from 12' south to 16' south of the north girth weld, and from 16' south to 20' south of the north girth weld, respectively, in the as-received condition prior to removing the coating. The lower half of the pipe contains sagging and wrinkled coating.

Photograph No. 57

Photograph No. 58

The photographs display overall views of the east side of the fractured pipe from 1:30 to 4:30 from 20' south to 24' south of the north girth weld, and from 24' south to 28' south of the north girth weld, respectively, in the as-received condition prior to removing the coating. The coating on the lower half of the pipe contains sagging and wrinkles.

Photograph No. 59

Photograph No. 60

The photographs display overall views of the east side of the fractured pipe from 1:30 to 4:30 from 28' south to 31' south of the north girth weld, and from 31' south to 35' south of the north girth weld, respectively, in the as-received condition prior to removing the coating. The lower half of the pipe contains sagging and wrinkled coating.

Photograph No. 61

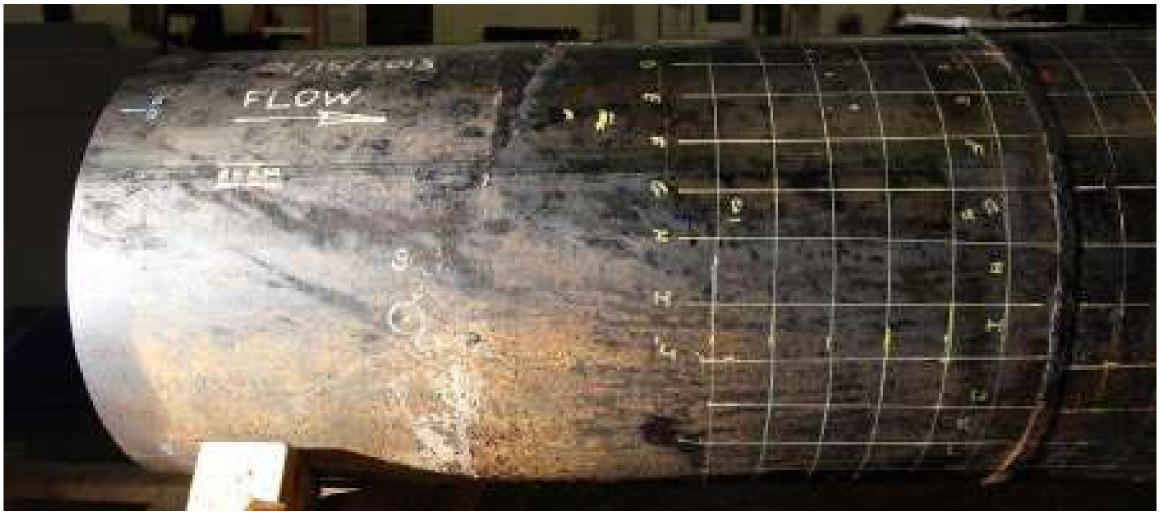
Photograph No. 62

The photographs display overall views of the east side of the fractured pipe from 1:30 to 4:30 from 35' south to 39' south of the north girth weld, and from 39' south to 43' south of the north girth weld, respectively, in the as-received condition prior to removing the coating. The coating on the lower half is wrinkled and sagging.

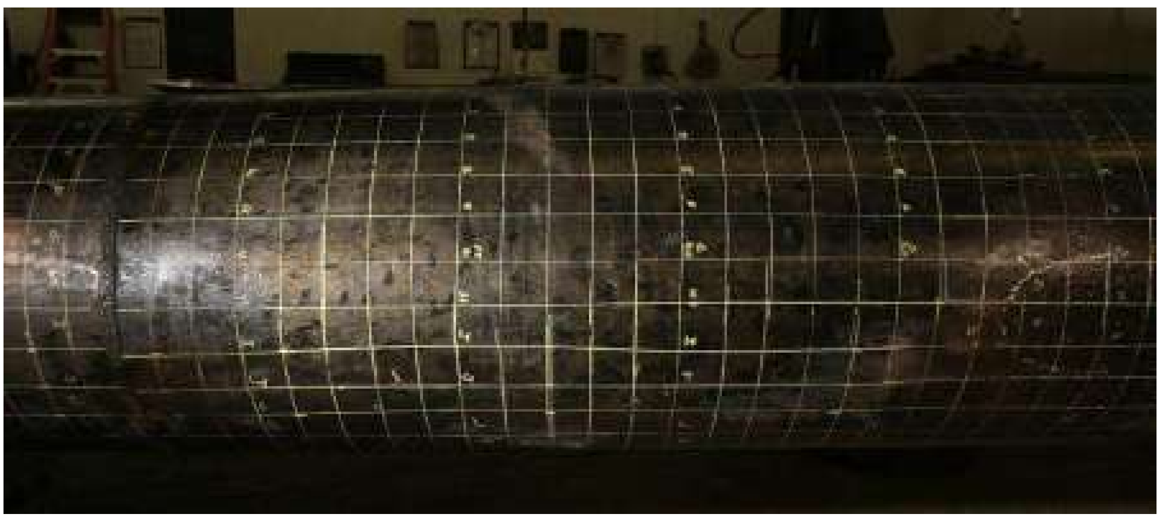
Photograph No. 63

Photograph No. 64

The photographs display overall views of the east side of the fractured pipe from 1:30 to 4:30 and adjacent intact pipe from 43' south to 47' south of the north girth weld, and from 47' south to 51' south of the north girth weld, respectively, in the as-received condition prior to removing the coating. The coating had been removed from the adjacent intact pipe prior to sectioning. The coating on the lower half of the pipe is wrinkled and sagging.



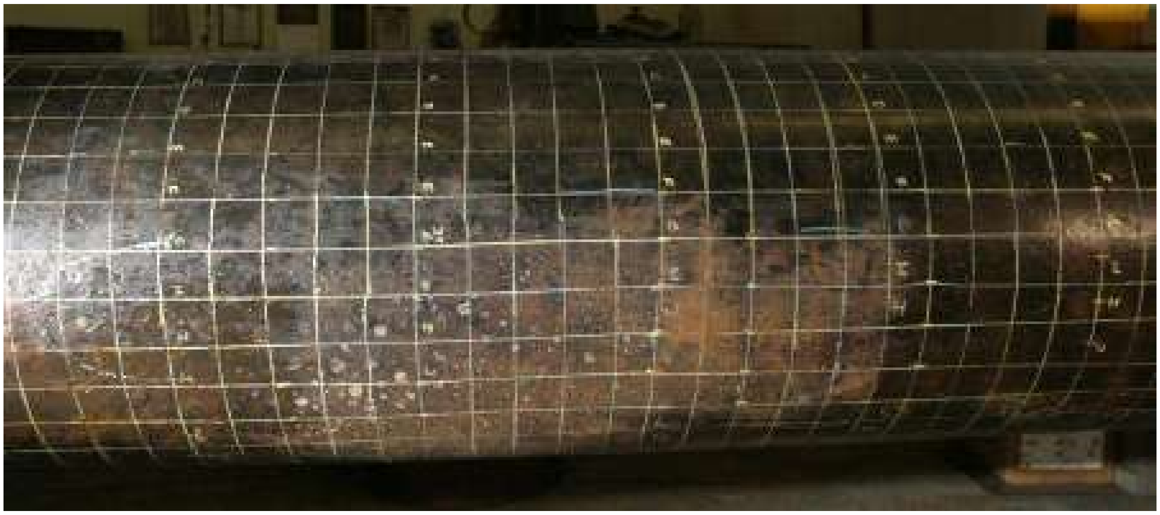
Photograph No. 65



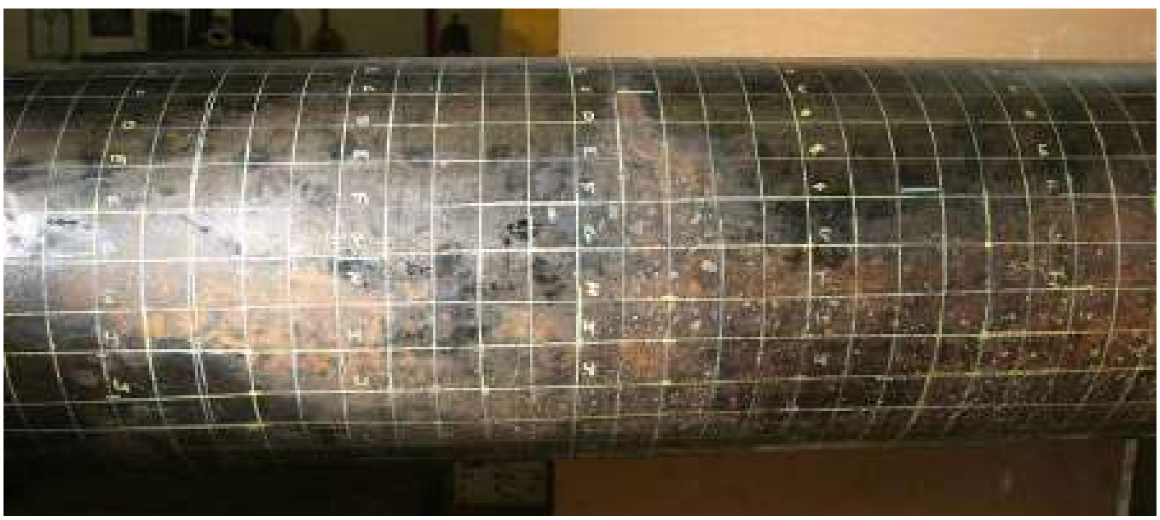
Photograph No. 66

Circumferential Location	Distance from North Girth Weld	Depth of Corrosion Pitting		
		Minimum	Average	Maximum
All	-3' to 0'	No Corrosion Pitting Visible		
7:26 o'clock to 10:07 o'clock	0' to 4'	0.006"	0.017"	0.029"

The photographs display overall views of the west side of the pipe adjacent to the fractured area of the pipe, from approximately 3' north of the north girth weld (-3') to the center of the girth weld (0'), and the fractured pipe from the center of the girth weld to 4' south of the girth weld (+4'), respectively, after the removal of the coating. The lower half of the pipe shows corrosion pitting on the O.D. surface where the coating had wrinkled and sagged.



Photograph No. 67



Photograph No. 68

Circumferential Location	Distance from North Girth Weld	Depth of Corrosion Pitting		
		Minimum	Average	Maximum
6:41 o'clock to 10:07 o'clock	4' to 8'	0.002"	0.013"	0.037"
7:03 o'clock to 11:16 o'clock	8' to 12'	0.002"	0.011"	0.026"

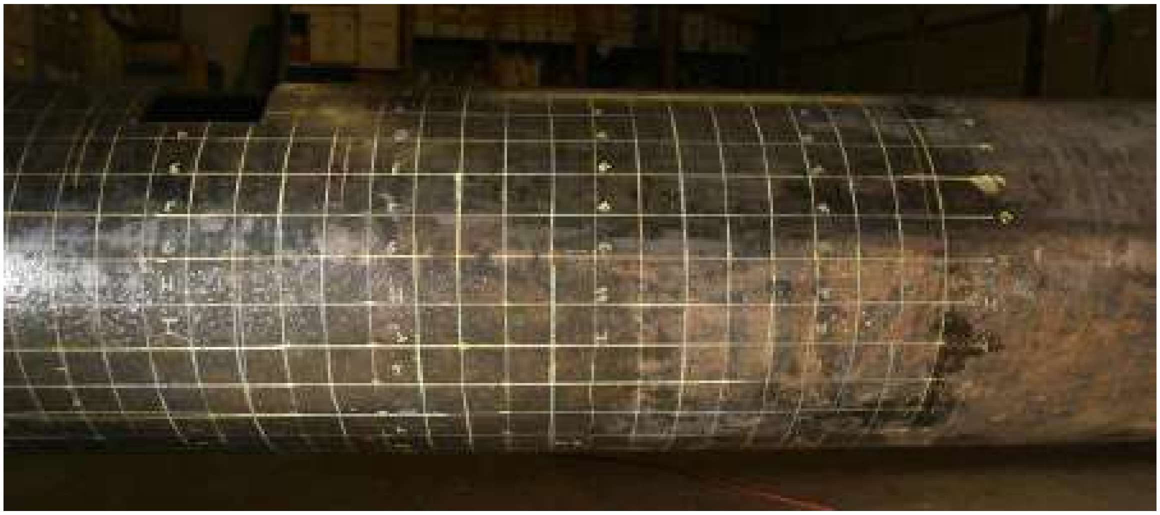
The photographs display overall views of the west side of the fractured pipe from 4' south to 8' south of the north girth weld, and 8' south to 12' south of the north girth weld, respectively, after the removal of the coating. The lower half of the pipe shows corrosion pitting on the O.D. surface where the coating had wrinkled and sagged.

Photograph No. 69

Photograph No. 70

Circumferential Location	Distance from North Girth Weld	Depth of Corrosion Pitting		
		Minimum	Average	Maximum
6:29 o'clock to 9:55 o'clock	12' to 16'	0.003"	0.017"	0.031"
6:52 o'clock to 10:07 o'clock	16' to 20'	0.006"	0.012"	0.021"

The photographs display overall views of the west side of the fractured pipe from 12' south to 16' south of the north girth weld, and 16' south to 20' south of the north girth weld, respectively, after the removal of the coating. The lower half of the pipe shows corrosion pitting on the O.D. surface where the coating had wrinkled and sagged.



Photograph No. 71

Photograph No. 72

Circumferential Location	Distance from North Girth Weld	Depth of Corrosion Pitting		
		Minimum	Average	Maximum
7:15 o'clock to 9:55 o'clock	20' to 24'	0.005"	0.010"	0.021"
All	24' to 28'	No Corrosion Pitting Visible		

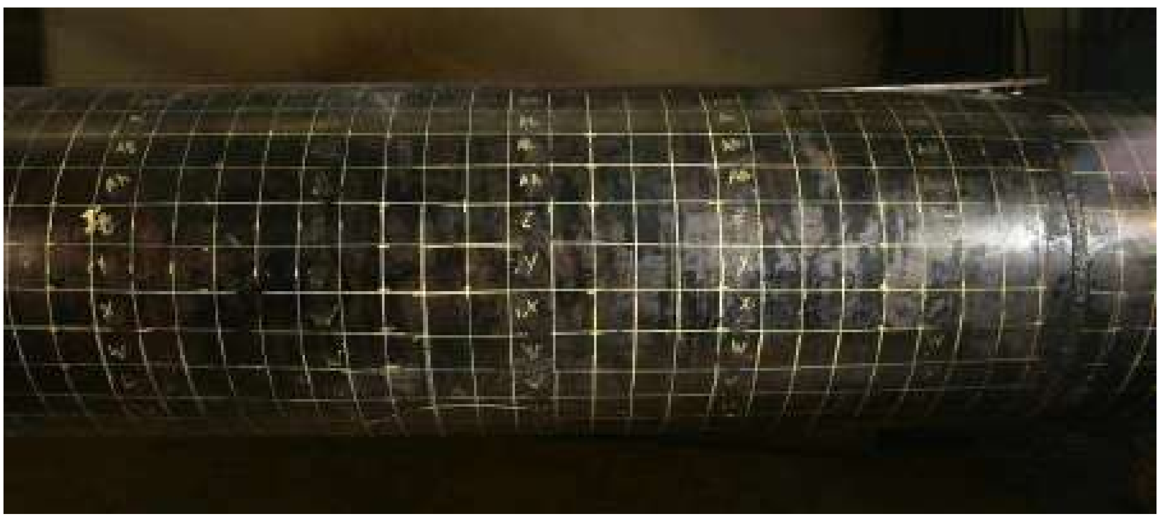
The photographs display overall views of the west side of the fractured pipe from 20' south to 24' south of the north girth weld, and 24' south to 28' south of the north girth weld, respectively, after the removal of the coating. The lower half of the pipe shows corrosion pitting on the O.D. surface where the coating had wrinkled and sagged.

Photograph No. 73

Circumferential Location	Distance from North Girth Weld	Depth of Corrosion Pitting		
		Minimum	Average	Maximum
All	28' to 31'	No Corrosion Pitting Visible		

The photograph displays an overall view of the west side of the fractured pipe from 28' south to 31' south of the north girth weld, respectively, after the removal of the coating. The fractured pipe was sectioned in the field transversely approximately 31' south of the north girth weld to allow for removal of the fractured section of pipe. No corrosion pitting is visible on the O.D. surface near the transverse cut at the south end of the fractured section of the pipe.

Photograph No. 74

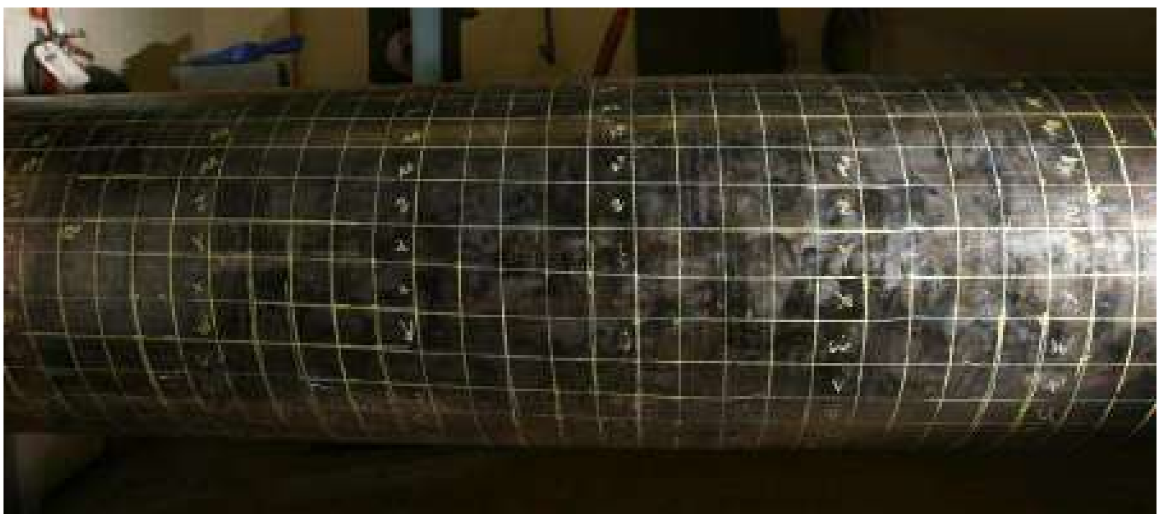


Photograph No. 75

Circumferential Location	Distance from North Girth Weld	Depth of Corrosion Pitting		
		Minimum	Average	Maximum
All	-3' to 0'	No Corrosion Pitting Visible		
All	0' to 4'	No Corrosion Pitting Visible		

The photographs display overall views of the east side of the pipe adjacent to the fractured pipe from approximately 3' north of the girth weld (-3') to the center of the north girth weld (0'), and the fractured pipe from the center of the girth weld to 4' south of the north girth weld (+4'), respectively, after the removal of the coating. No corrosion pitting is visible on the O.D. surfaces on the fractured or intact pipe around the north girth weld.

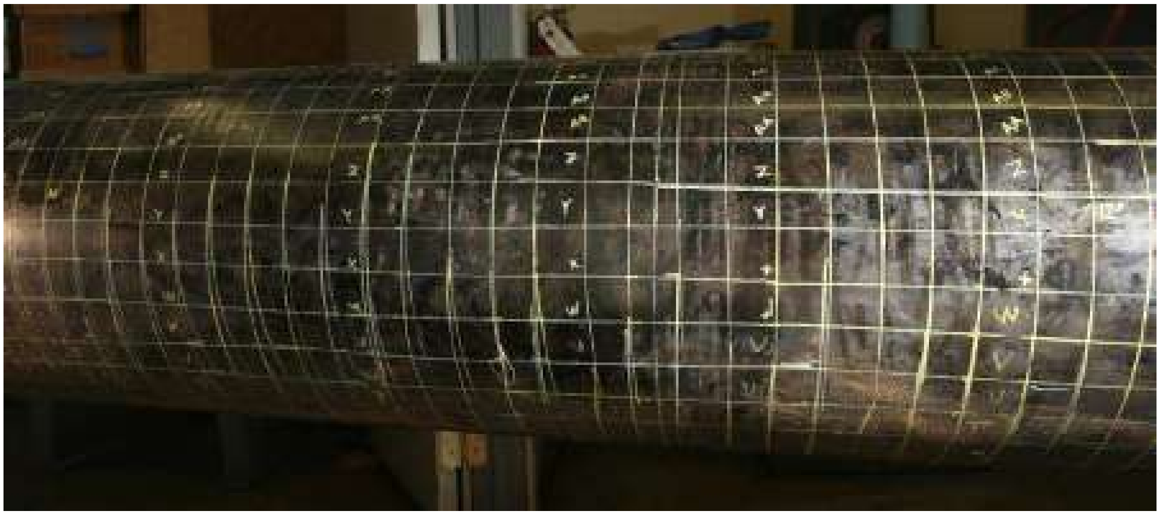
Photograph No. 76



Photograph No. 77

Circumferential Location	Distance from North Girth Weld	Depth of Corrosion Pitting		
		Minimum	Average	Maximum
1:31 o'clock to 3:03 o'clock	4' to 8'	0.008"	0.013"	0.026"
3:49 o'clock to 4:57 o'clock	8' to 12'	0.004"	0.011"	0.022"

The photographs display overall views of the east side of the fractured pipe from 4' south to 8' south of the north girth weld, and 8' south to 12' south of the north girth weld, respectively, after the removal of the coating. The lower half of the pipe shows corrosion pitting on the O.D. surface where the coating had wrinkled and sagged.



Photograph No. 78

Photograph No. 79

Circumferential Location	Distance from North Girth Weld	Depth of Corrosion Pitting		
		Minimum	Average	Maximum
3:03 o'clock to 4:57 o'clock	12' to 16'	0.003"	0.013"	0.033"
2:40 o'clock to 5:20 o'clock	16' to 20'	0.005"	0.015"	0.031"

The photographs display overall views of the east side of the fractured pipe from 12' south to 16' south of the north girth weld, and 16' south to 20' south of the north girth weld, respectively, after the removal of the coating. The lower half of the pipe shows corrosion pitting on the O.D. surface where the coating had wrinkled and sagged.

Photograph No. 80

Photograph No. 81

Circumferential Location	Distance from North Girth Weld	Depth of Corrosion Pitting		
		Minimum	Average	Maximum
2:40 o'clock to 4:57 o'clock	20' to 24'	0.004"	0.020"	0.033"
All	24' to 28'	No Corrosion Pitting Visible		

The photographs display overall views of the east side of the fractured pipe from 20' south to 24' south of the north girth weld, and 24' south to 28' south of the north girth weld, respectively, after the removal of the coating. The lower half of the pipe shows corrosion pitting on the O.D. surface where the coating had wrinkled and sagged.

Photograph No. 82

Circumferential Location	Distance from North Girth Weld	Depth of Corrosion Pitting		
		Minimum	Average	Maximum
All	28' to 31'	No Corrosion Pitting Visible		

The photograph displays an overall view of the east side of the fractured pipe from 28' south of the north girth weld to 31' south of the north girth weld, respectively, after the removal of the coating. No corrosion pitting was visible on the O.D. surface near the transverse cut at the south end of the fractured section of the pipe.

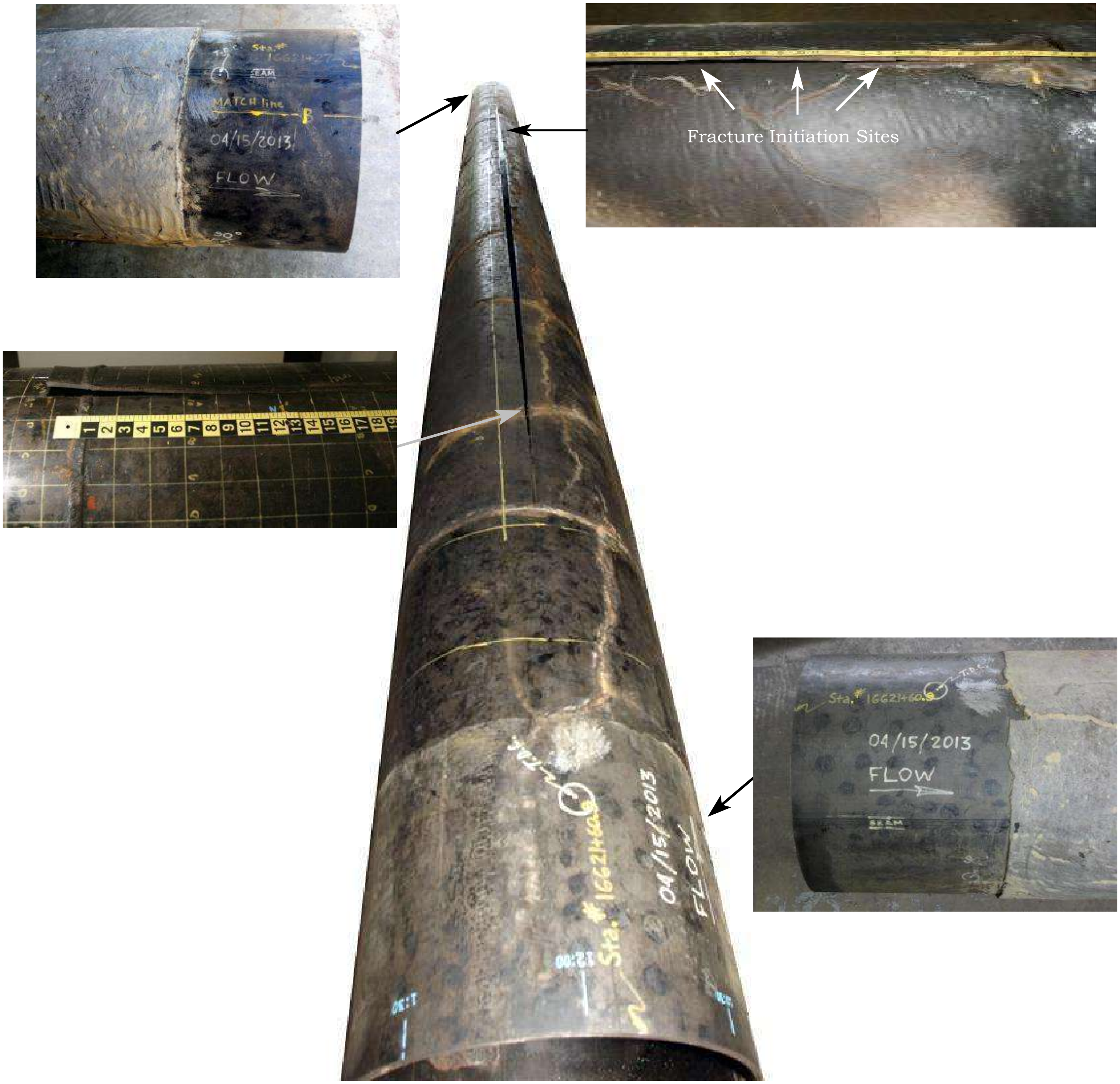
Photograph No. 83

Photograph No. 84

The photographs display representative areas of the I.D. surface at an intact area of the pipe, showing the smooth, shallow impressions that resulted from mechanical damage, most likely during the hot-rolling of the steel or manufacturing of the pipe. No evidence of corrosion pitting was observed on the I.D. surface.

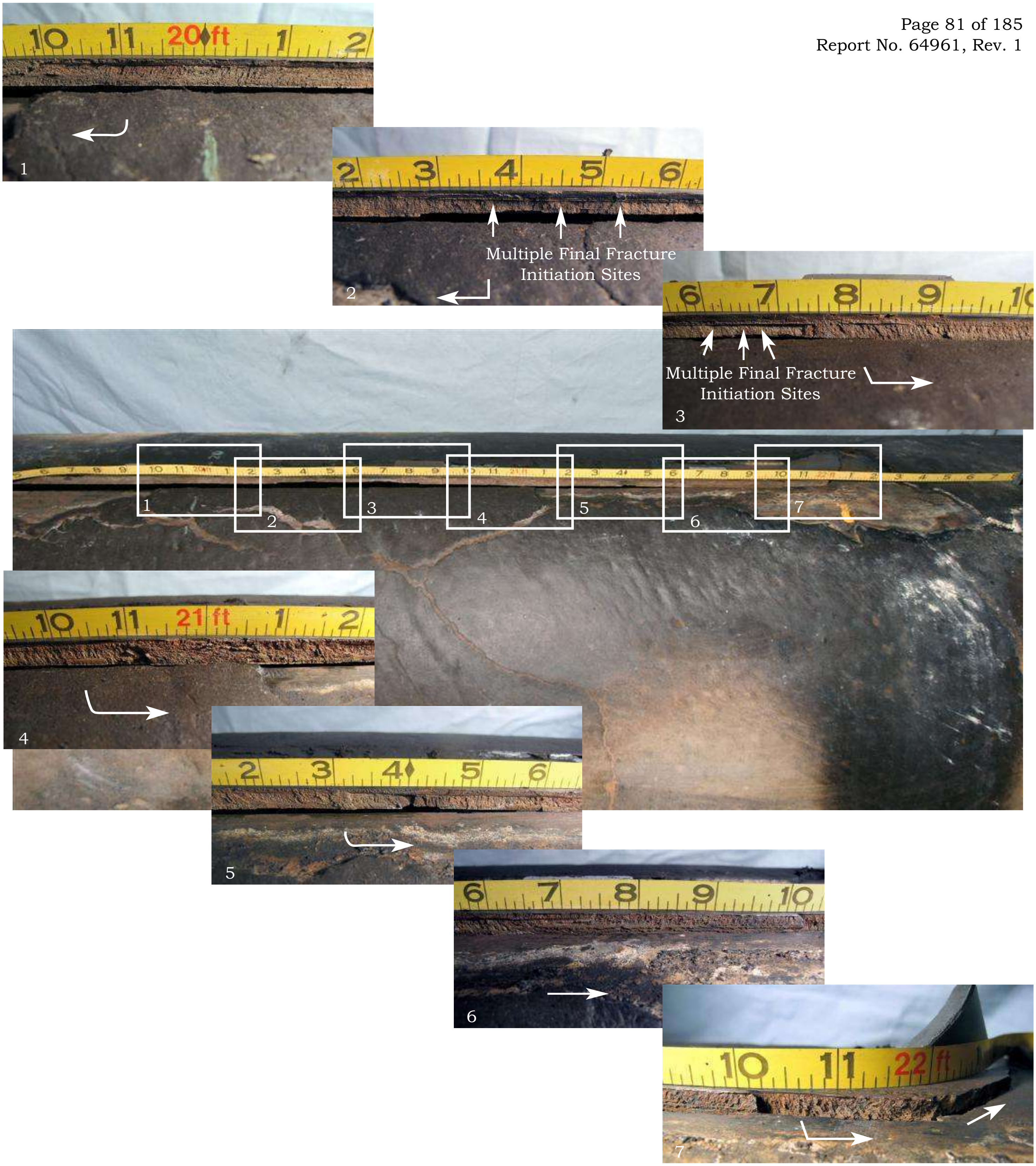
Photograph No. 85

The photograph shows the displacement of the pipe by approximately 2-31/32" following sectioning through the intact portion of the adjoining pipe, indicative of the presence of significant residual stress.



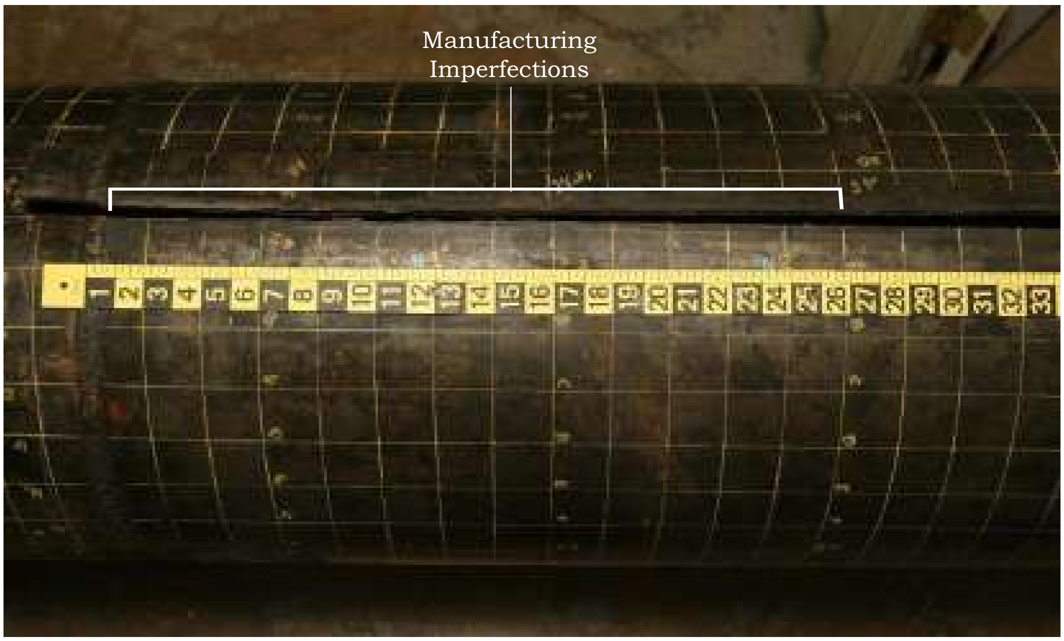
Photograph No. 86

The photographs display overall and close-up views of the 33' 11-1/2" long section of a fractured 20" O.D. x 0.312" wall pipe, which was removed from the Conway to Corsicana section of the Pegasus Crude Oil Pipeline at Milepost 314.77 in Mayflower, Arkansas.



Photograph No. 87

The photographs display overall and close-up views of one of the mating fracture faces from where the final rupture had occurred, resulting in the leakage of crude oil on March 29, 2013. The fractographs show the presence of hook cracks adjacent to the fusion line near the O.D. surface along the ERW seam, between a distance of 19' 10" and 21' 6-1/4" from the north girth weld, and radial lines emanating from the ends of the hook cracks as well as chevron marks revealing the crack propagation direction, which is denoted by the arrows.



Photograph No. 88

The photograph displays the presence of manufacturing imperfections that were found between a distance of 1/4" and 2' 2" from the north girth weld in the path of the final fracture.

Photograph No. 89

Photograph No. 90

The photographs display evidence of manufacturing imperfection, i.e. the upturned bands near the O.D. in the fracture path of the final fracture.

Photograph No. 91

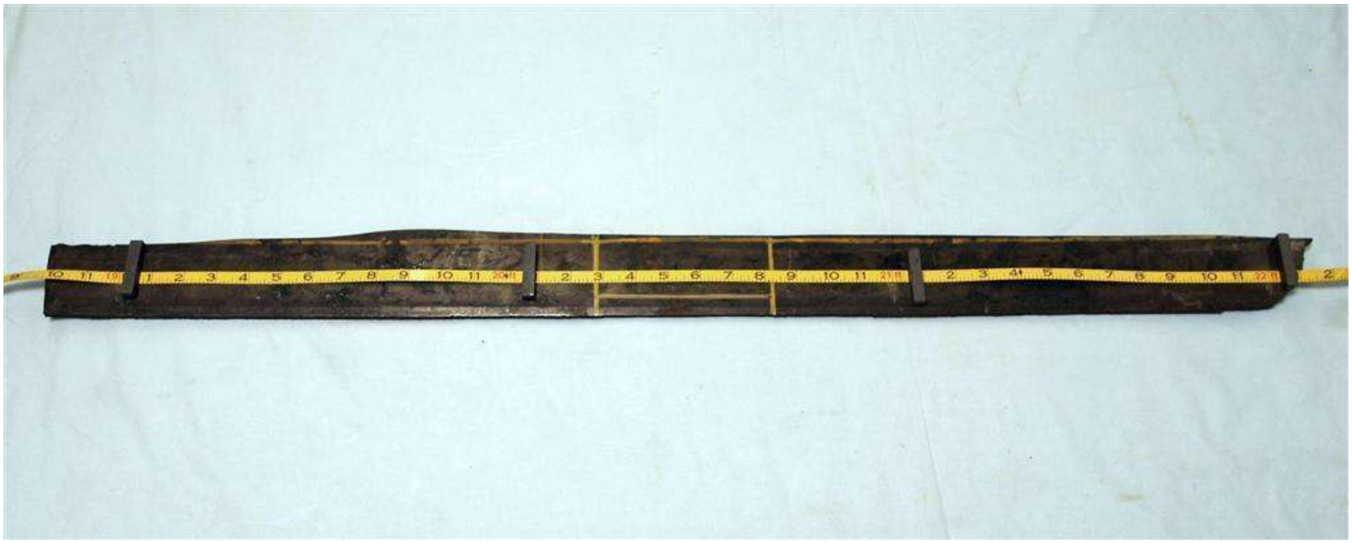
Photograph No. 92

The photographs display the continuation of the manufacturing imperfections in the path of the final fracture.

Photograph No. 93

Photograph No. 94

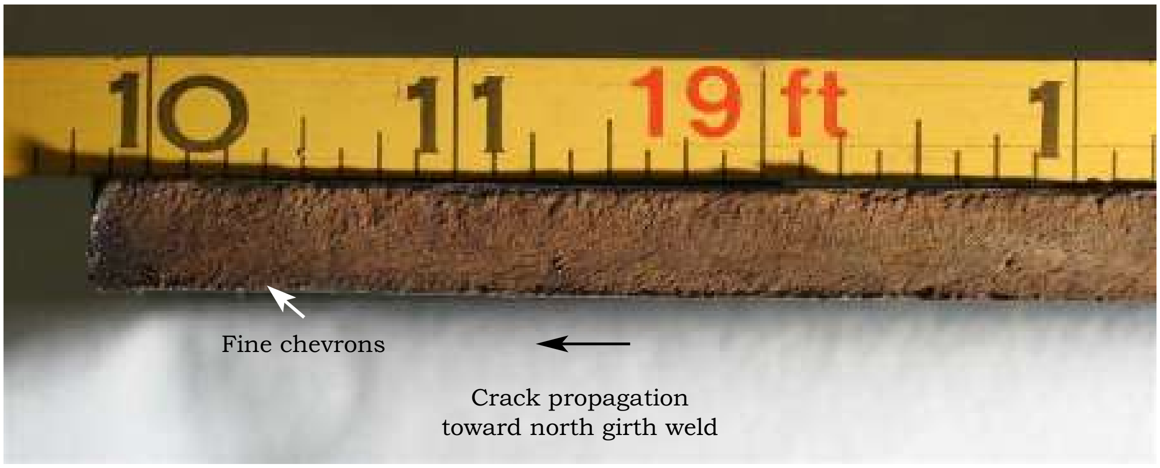
The photographs display evidence of chevron marks pointing downstream toward the fracture origins. The arrows point to some of the fine chevrons.



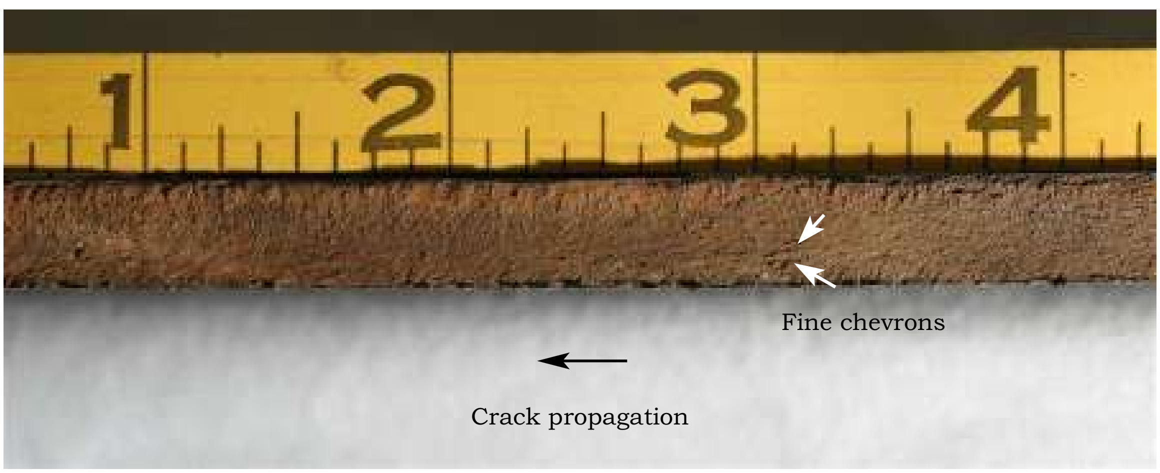
Photograph No. 95

Photograph No. 96

The photographs display the O.D. and I.D. surfaces of a section of the pipe that was removed between a distance of 18' 10" and 22' as measured from the north girth weld and which contained hook cracks along the ERW seam, from where the final failure initiated on March 29, 2013.

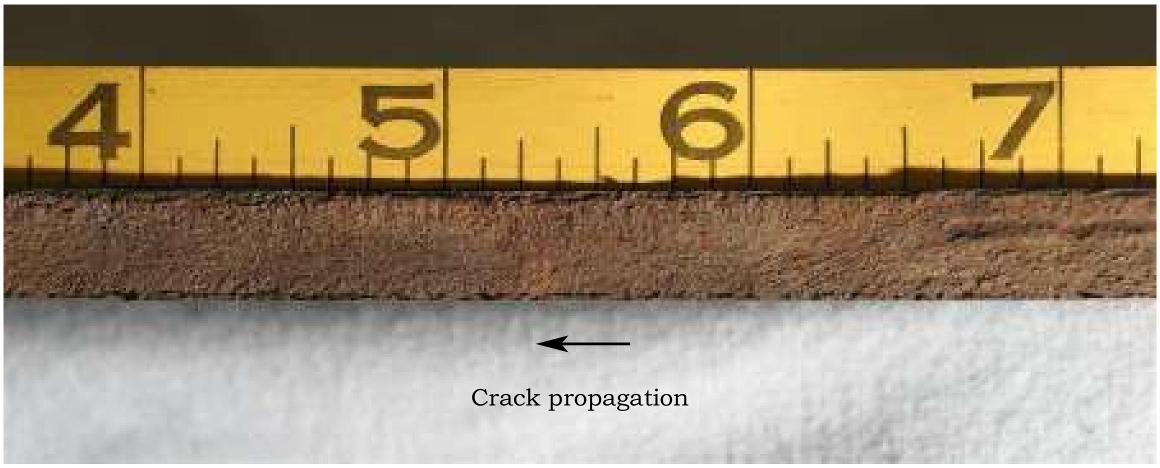


Photograph No. 97

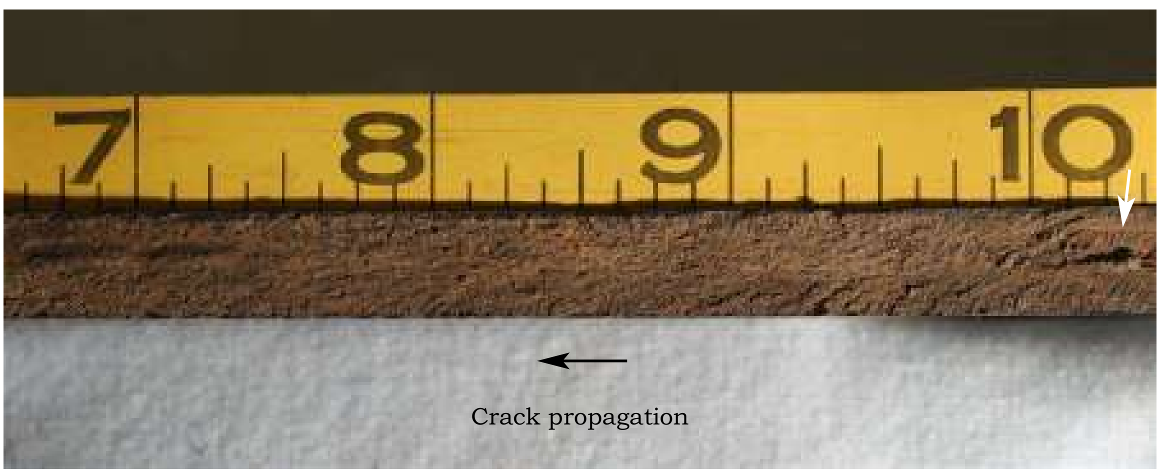


Photograph No. 98

The photographs display close-up views of the fracture face between a distance of 18' 10" and 19' 4" from the north girth weld of the pipe section, showing faint evidence of chevrons pointing toward the right (south end) near the fracture origins.

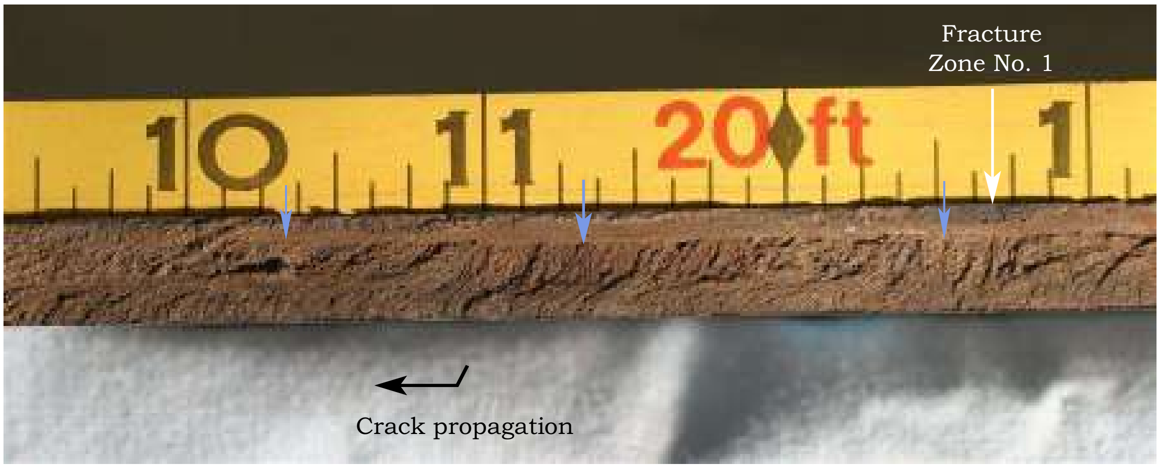


Photograph No. 99

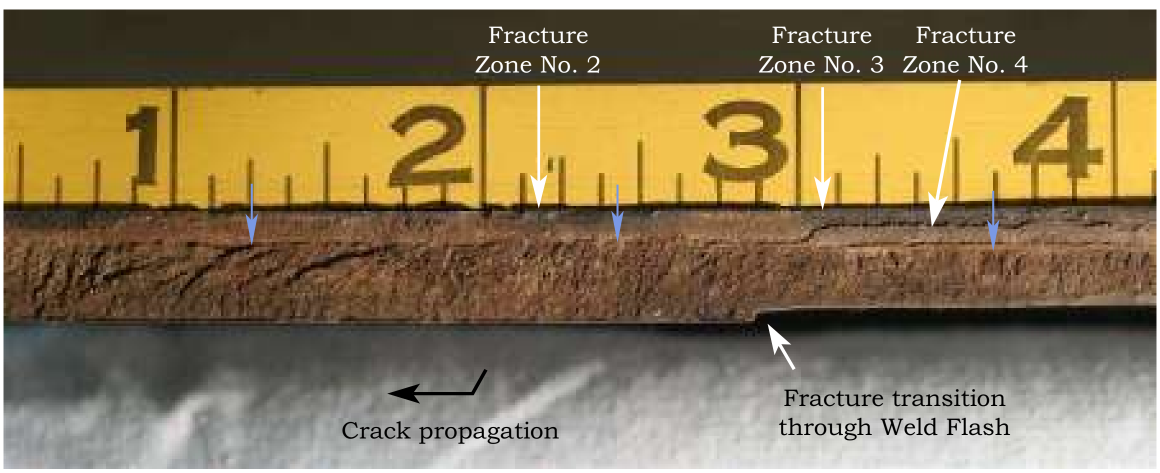


Photograph No. 100

The photographs display close-up views of the fracture face between a distance of 19' 4" and 19' 10" from the north girth weld of the pipe section, showing chevrons pointing toward the right (south end) near the fracture origins. The arrow in Photograph No. 100 points to the beginning of the hook cracks.

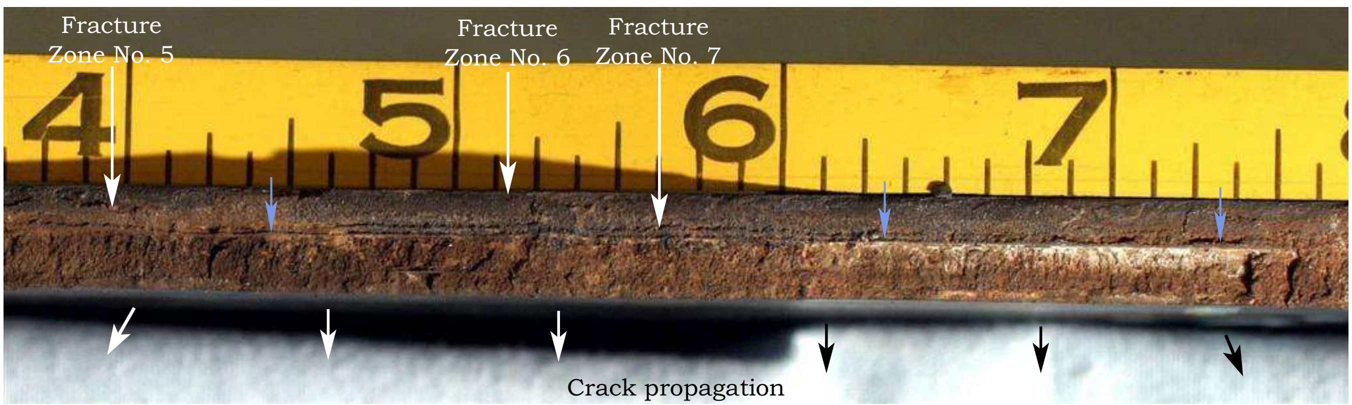


Photograph No. 101



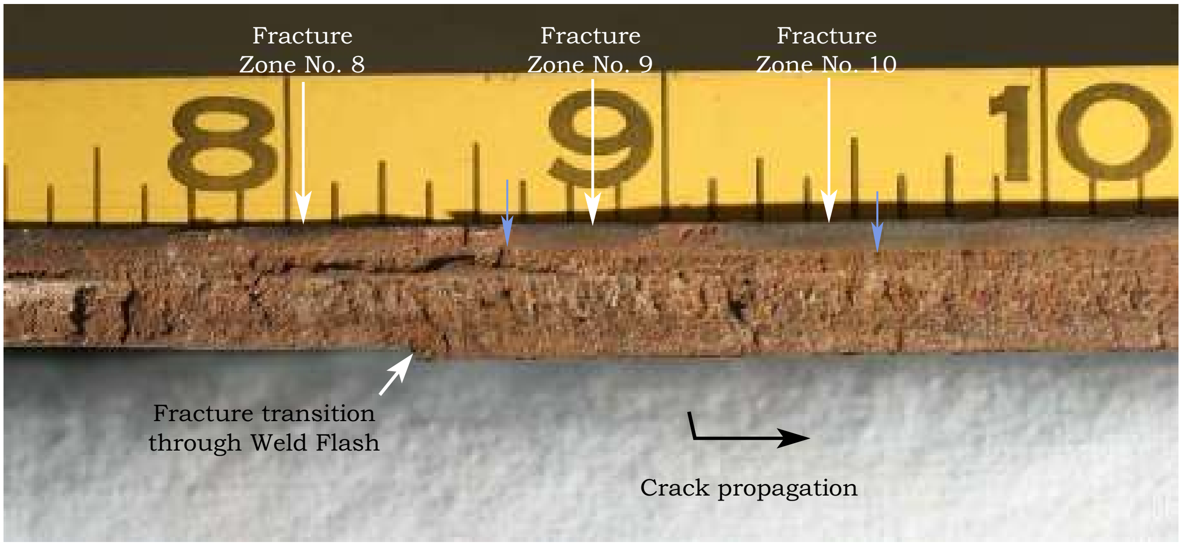
Photograph No. 102

The photographs display close-up views of the fracture face between a distance of 19' 10" and 20' 4" from the north girth weld, showing radial lines, marked by the blue arrows, which originated from hook cracks through the grain flow or banding formed during manufacturing the ERW seam.

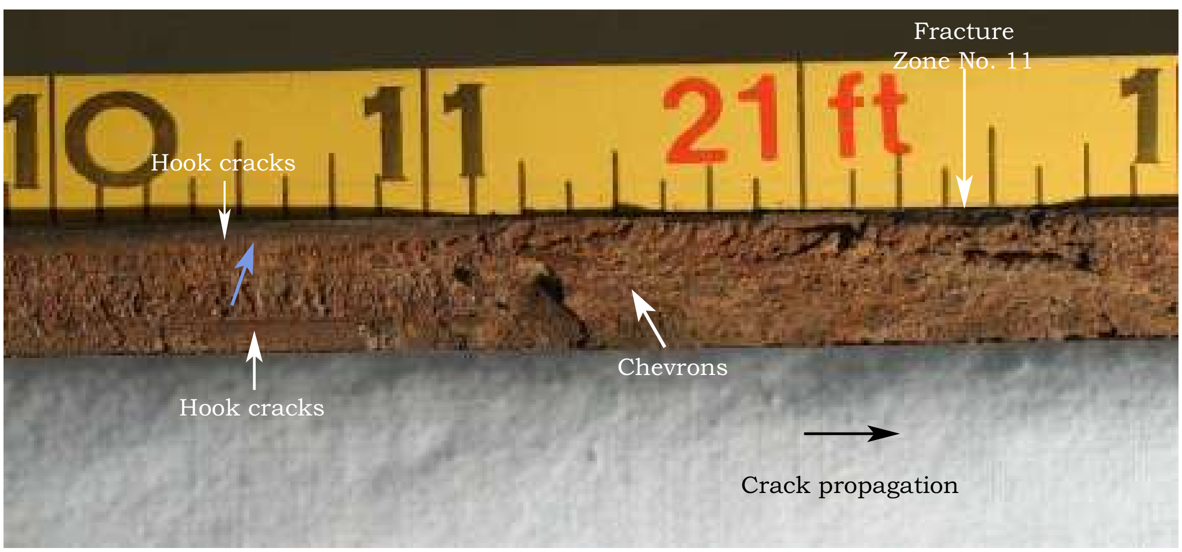


Photograph No. 103

The photograph displays a close-up view of the fracture face between a distance of 20' 4" and 20' 8" from the north girth weld, showing vertical radial lines emanating from the hook cracks, which are marked by the blue arrows, indicating the primary fracture initiation sites which resulted in the 22' 3" long fracture along the ERW seam of the 49' 9-1/2" long pipe.

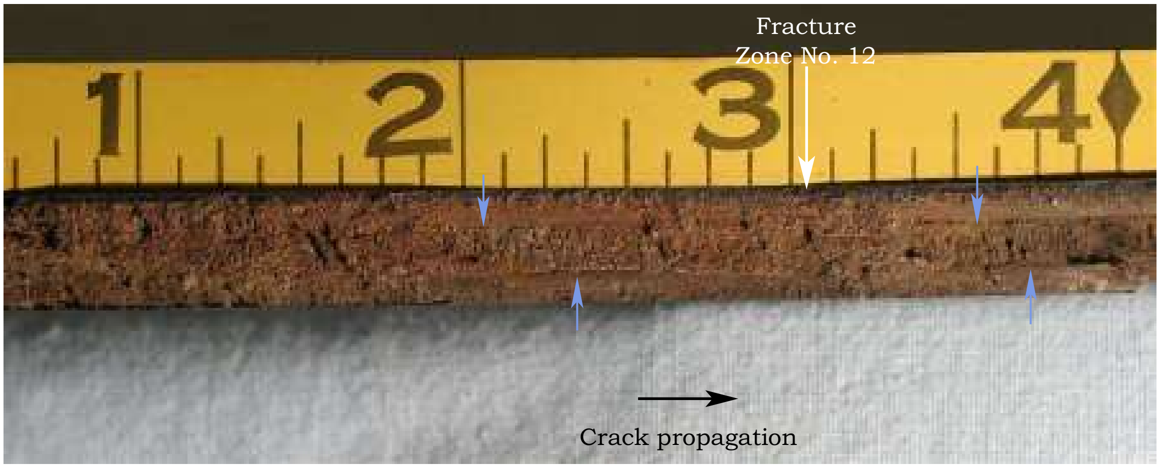


Photograph No. 104

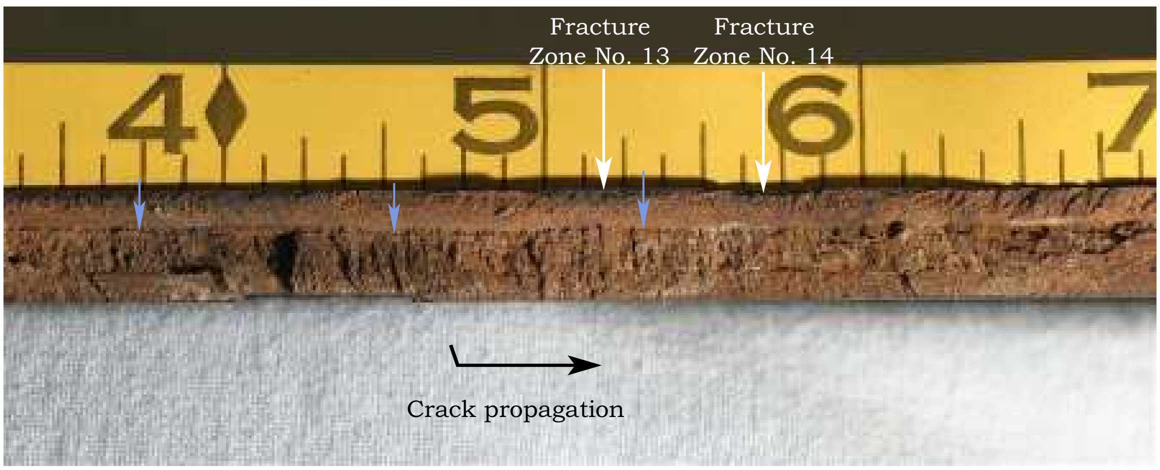


Photograph No. 105

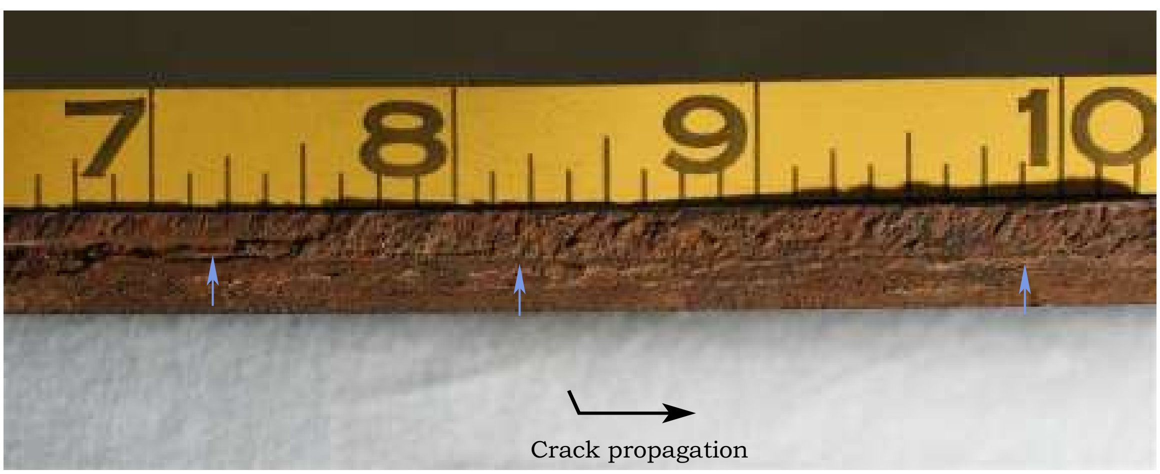
The photographs display close-up views of the fracture face between a distance of 20' 8" and 21' 1" from the north girth weld, showing radial lines emanating from the hook cracks, marked by the blue arrow, and chevrons pointing to the cracks, revealing some of the final fracture origins.



Photograph No. 106

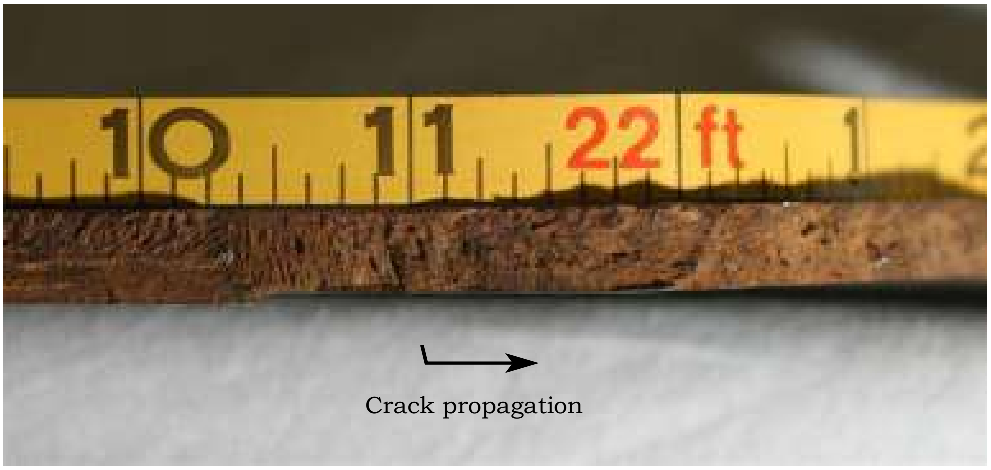


Photograph No. 107



Photograph No. 108

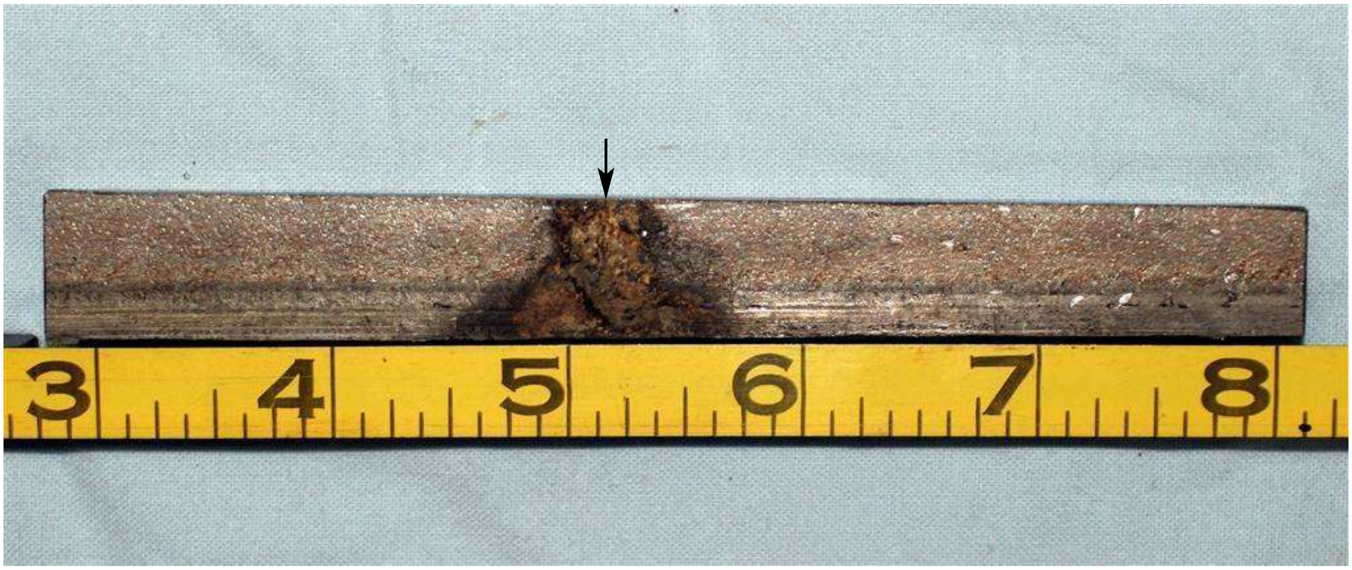
The photographs display close-up views of the fracture face between a distance of 21' 1" and 21' 10" from the north girth weld showing radial lines emanating from the hook cracks. The blue arrows point to the radial lines, indicative of some of the final fracture initiation sites.



Photograph No. 109

Photograph No. 110

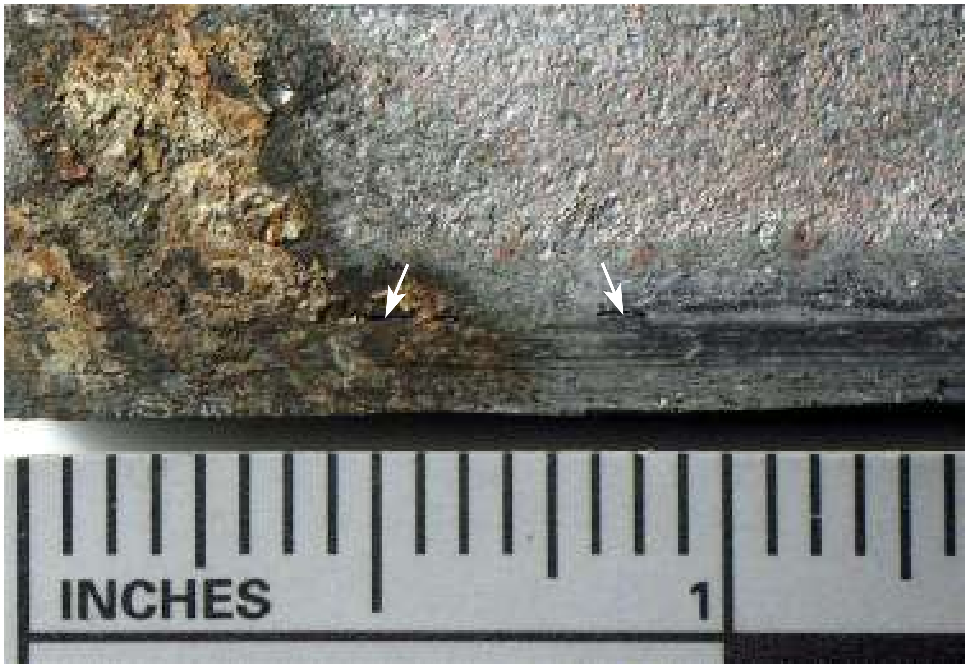
The photographs display close-up views of the fracture face between a distance of 21' 10" and 22' from the north girth weld, showing the final fracture which terminated in the base metal of the pipe, diagonally to a distance of approximately 3".



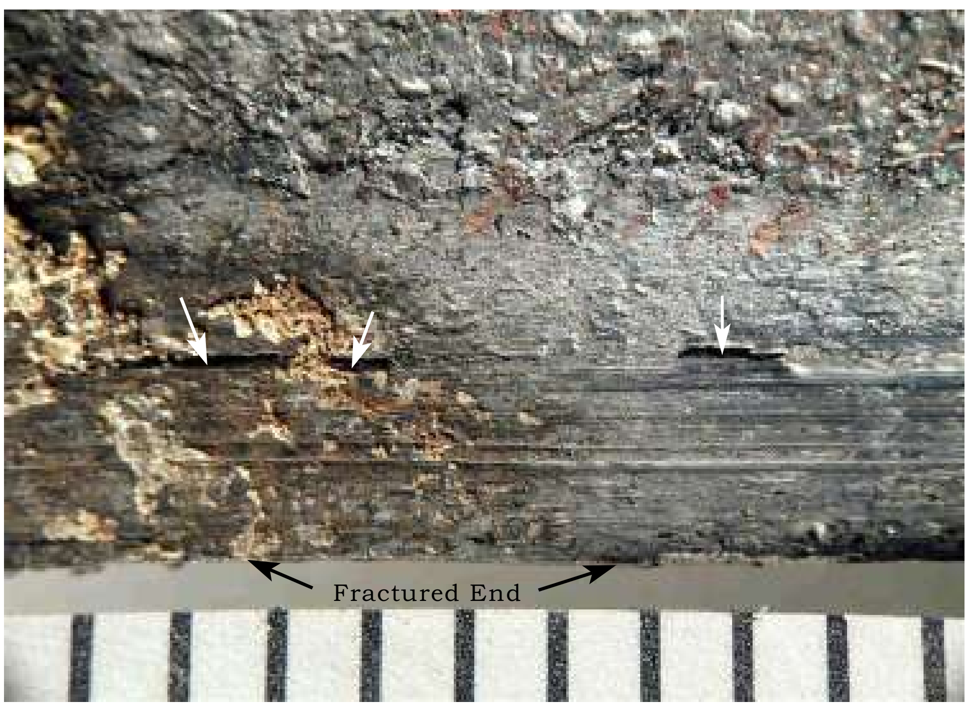
Photograph No. 111

Photograph No. 112

The photographs display the O.D. and I.D. surfaces adjacent to one of the mating fracture faces which contained multiple hook cracks. The arrow points to an area where the coating was apparently damaged prior to the incident.



Photograph No. 113



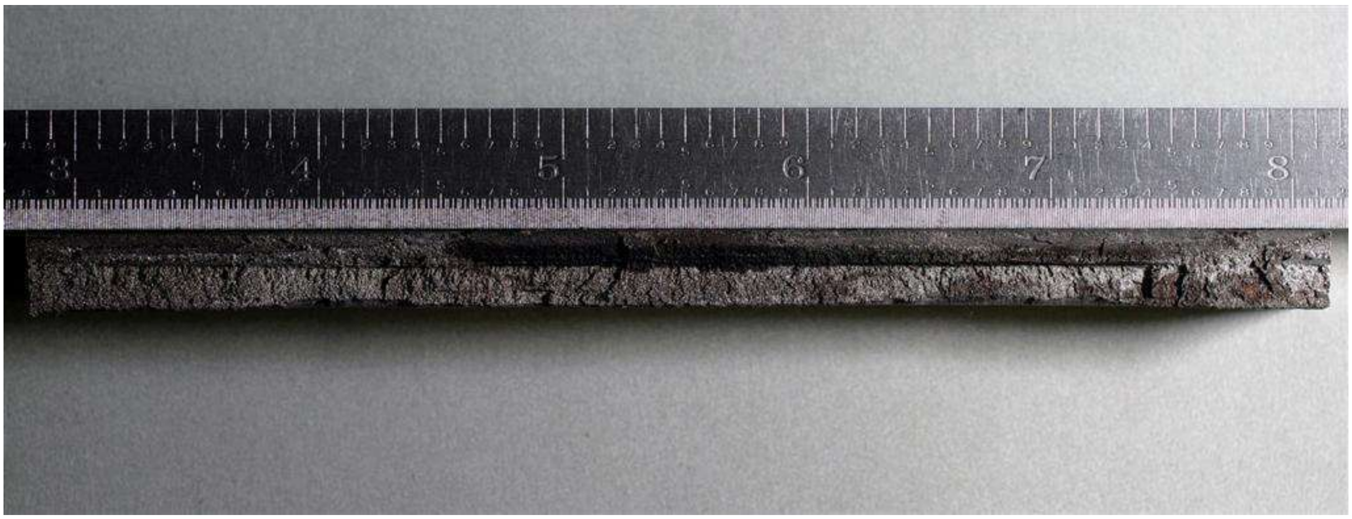
Photograph No. 114

The photographs of the outside surface of the fractured ERW seam at a distance between 20' 4-1/2" and 20' 6" from the north girth weld show evidence of what appears to be crack or melting caused by copper electrode contacts during the ERW seam fabrication. The arrows point to these imperfections.

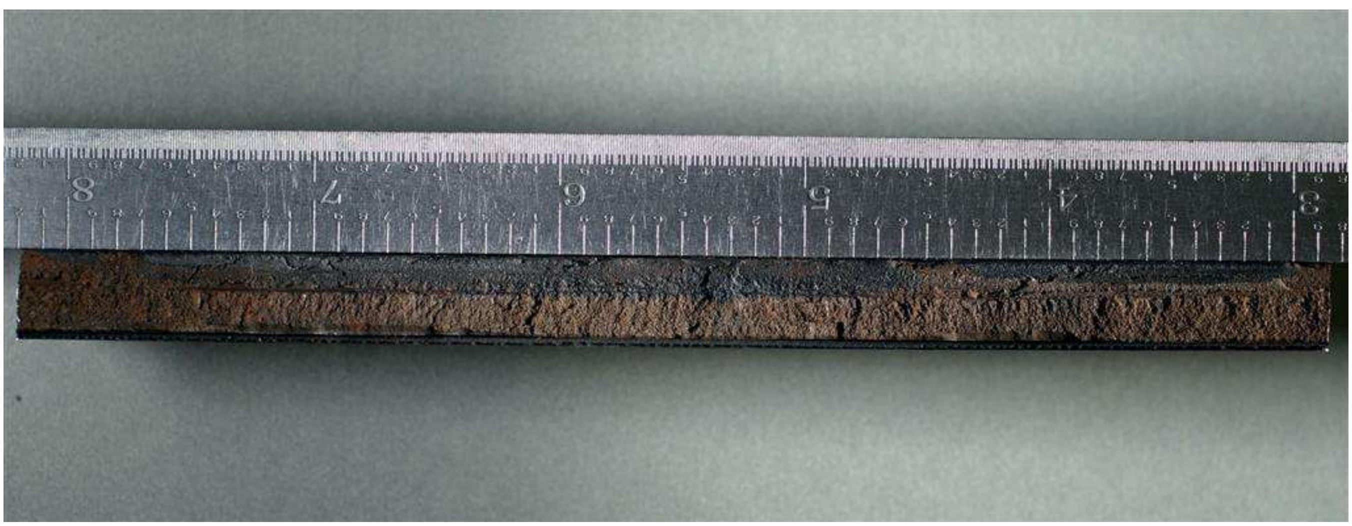
Photograph No. 115

Photograph No. 116

The photographs display close-up views of the copper electrode contact marks in the heat-affected zone of the ERW seam, at the arrow, on the O.D. surface and the presence of copper.

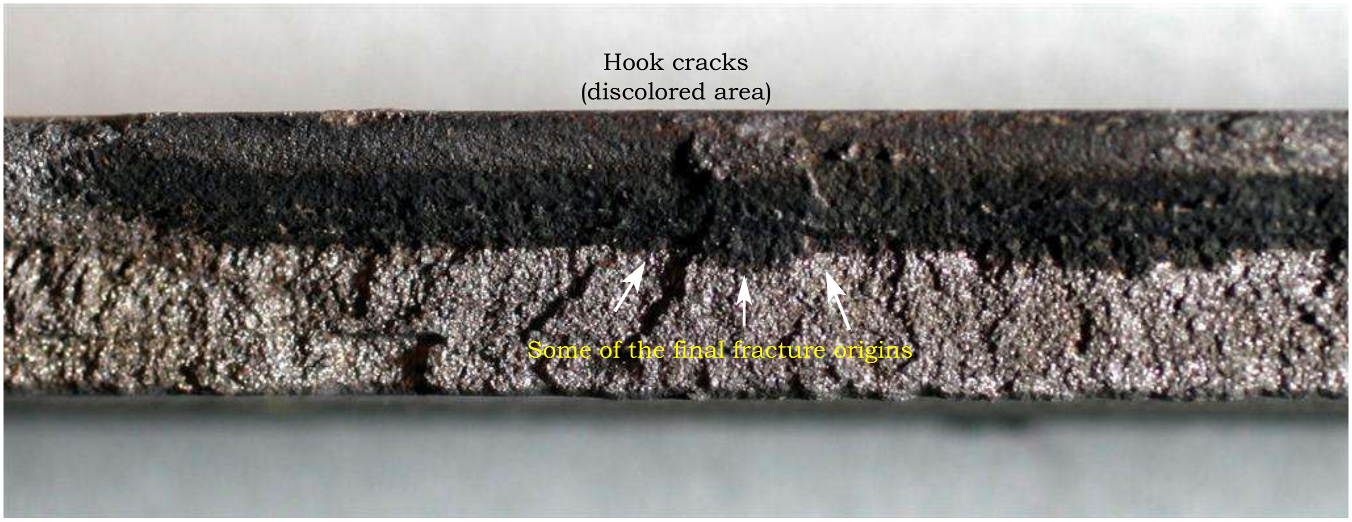


Photograph No. 117

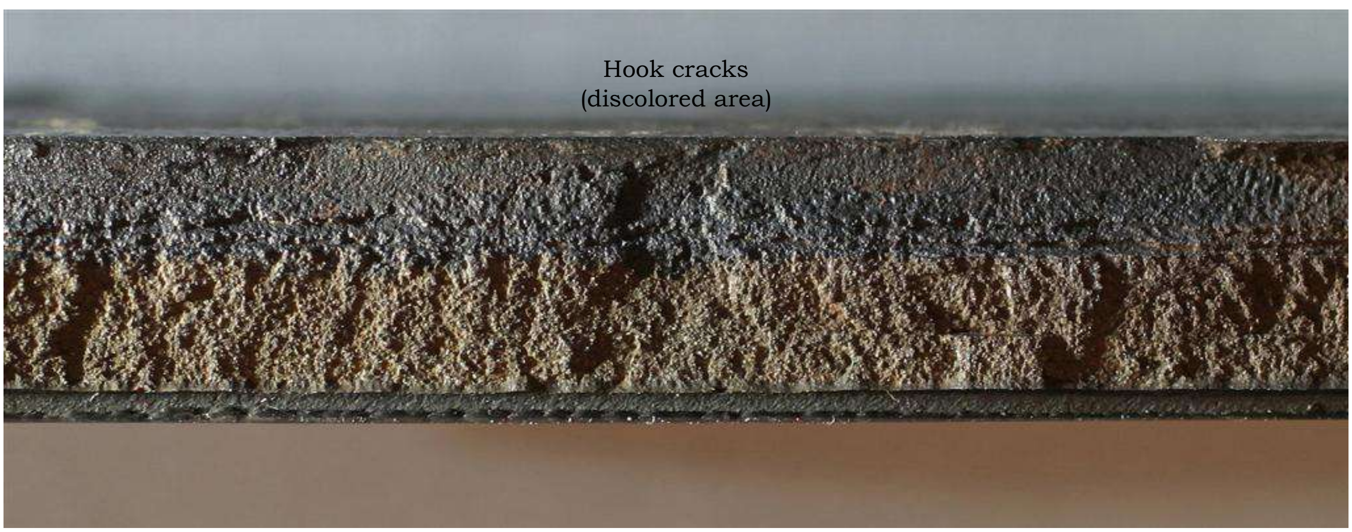


Photograph No. 118

The photographs display the mating fracture faces between a distance of approximately 20' 2-1/2" and 20' 8" from the north girth weld, revealing hook cracks in the heat-affected zone of the ERW seam to a maximum depth of 0.150" as measured from the O.D. surface, and vertical lines emanating from the tips of the hook cracks, indicative of the final fracture origin sites.

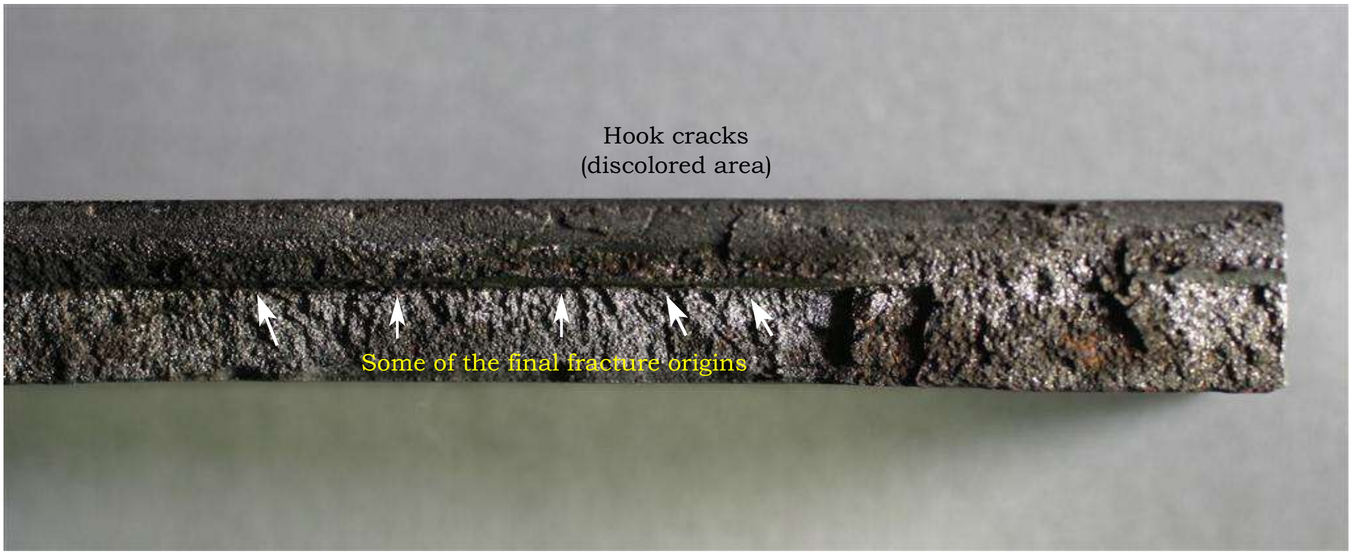


Photograph No. 119

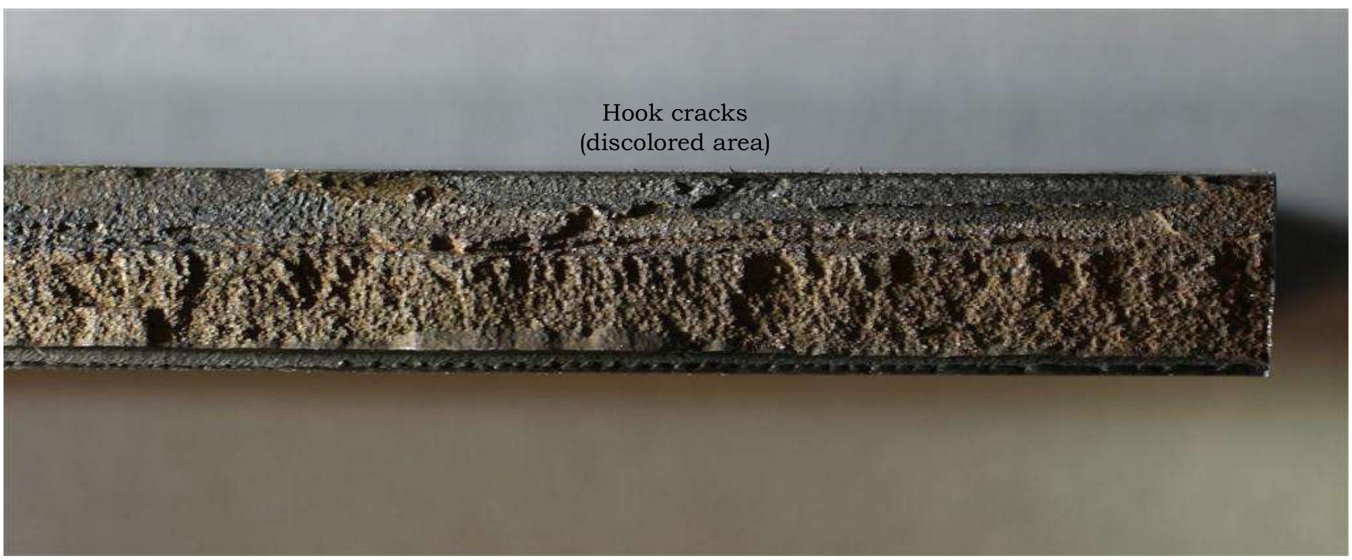


Photograph No. 120

The photographs display the mating fracture faces revealing some of the fracture origin site(s) at a distance of approximately 20' 5-5/16" from the north girth weld, which were later examined at higher magnifications using a Scanning Electron Microscope (SEM) to characterize the fracture morphologies.

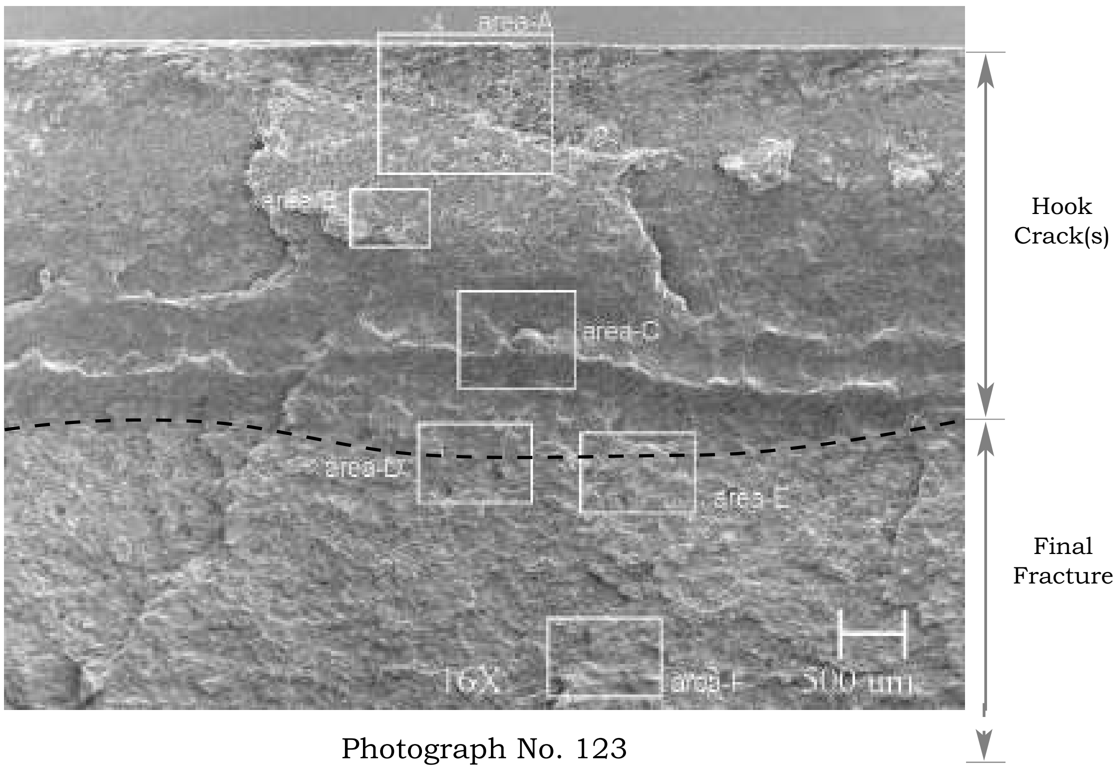


Photograph No. 121



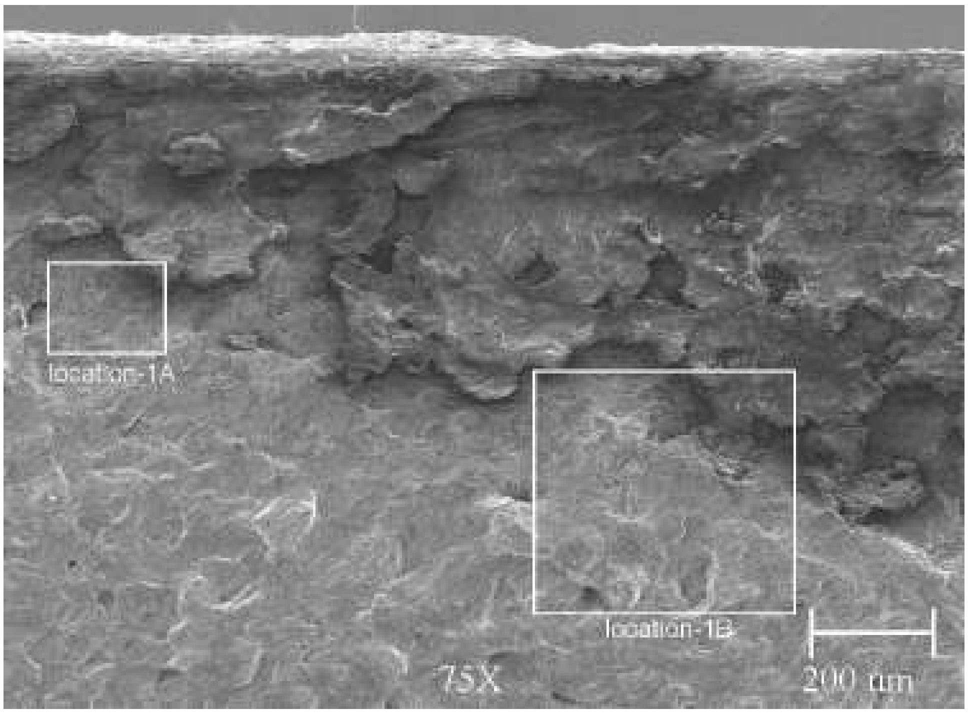
Photograph No. 122

The photographs display the mating fracture faces revealing some of the fracture origin sites at a distance between 20' 5-3/4" and 20' 7-1/2" from the north girth weld, which were later examined at higher magnifications using an SEM to characterize the fracture morphologies.



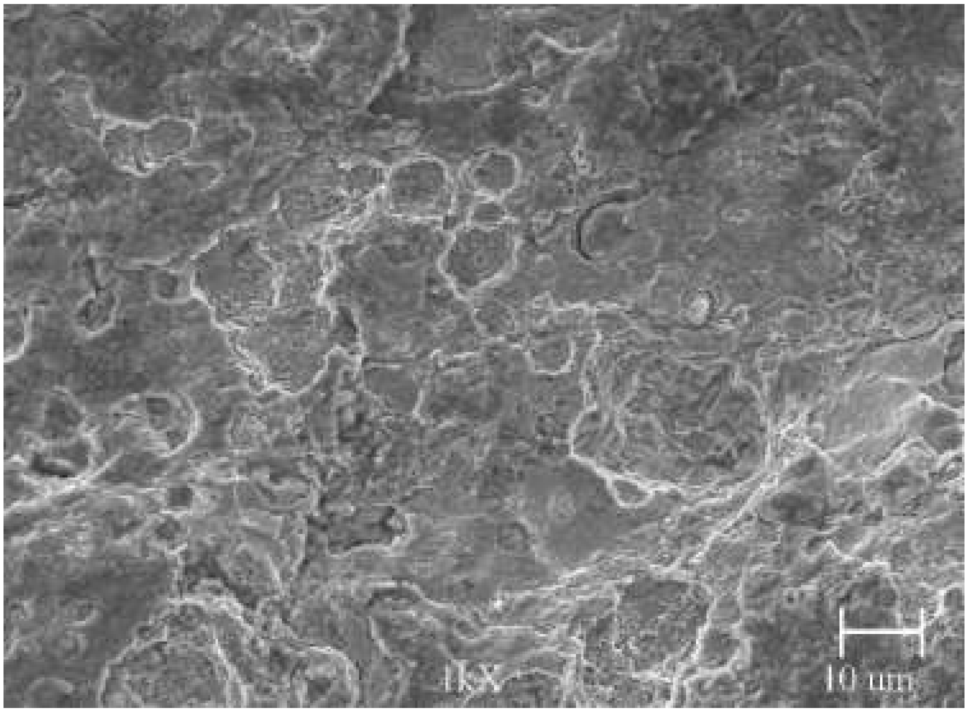
Photograph No. 123

The SEM fractograph taken of one of the final fracture origin sites at a distance of 20' 5-5/16" from the north girth weld shows an hook crack and the final fracture zone. The fracture locations within the rectangles were examined at high magnifications to further characterize the fracture morphologies. The dotted line denotes the transition zone between the hook cracks and the final fracture.

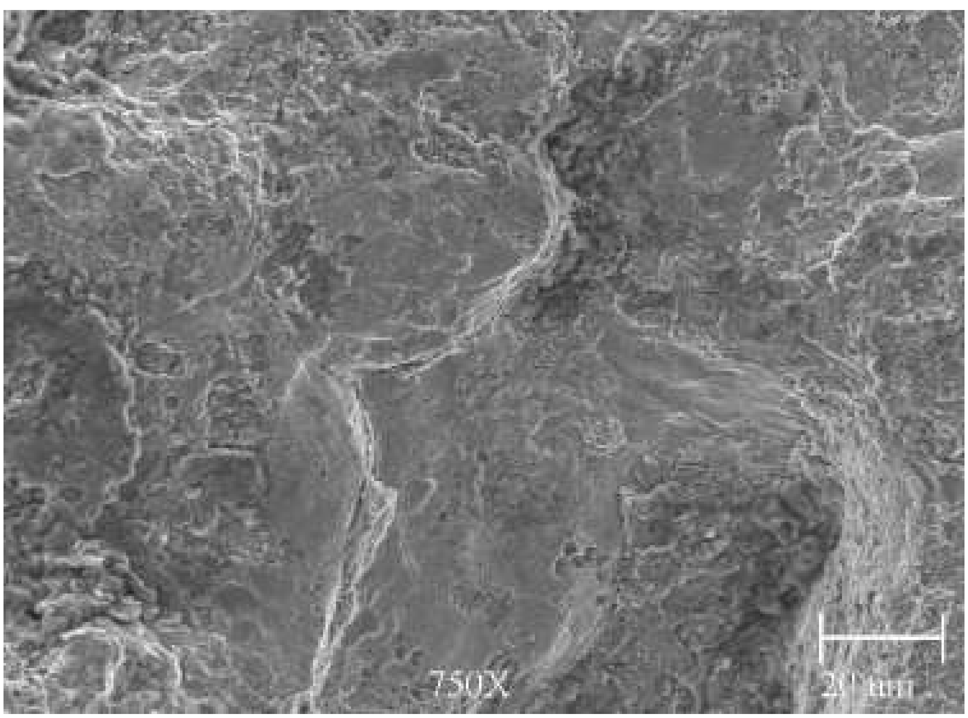


Area-A
Photograph No. 124

The SEM fractograph taken of the Area-A of the hook crack near the O.D. surface, as displayed in Photograph No. 123, displays essentially a nondescript featureless fracture surface. Note the absence of any fracture features, likely due to the metal-to-metal contact from the mating fracture faces of the crack and post-crack oxidation. The fracture locations labeled as Location-1A and Location-1B were examined at higher magnifications to further characterize the fracture morphology.

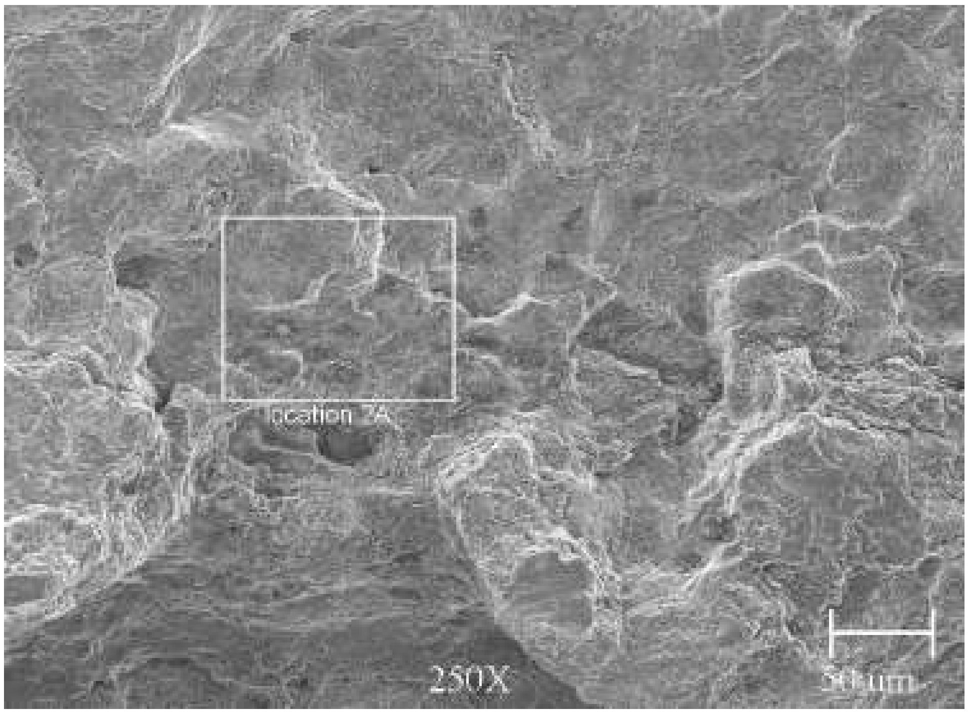


Area-A, Location-1A
Photograph No. 125



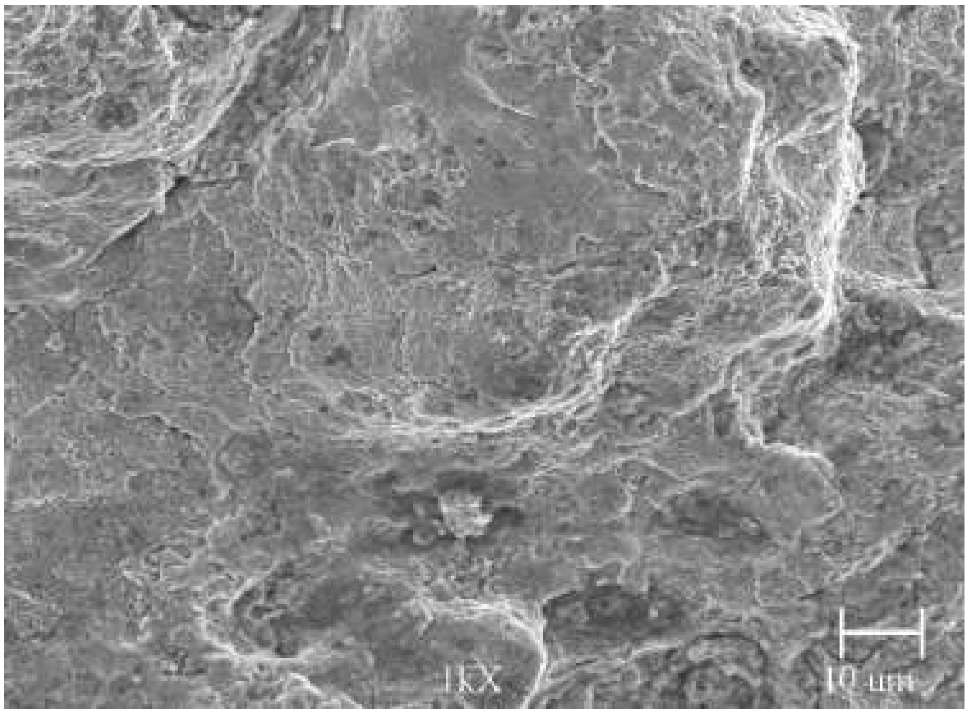
Area-A, Location-1B
Photograph No. 126

The SEM fractographs of the two (2) fracture locations labeled as Location-1A and Location-1B in Area-A of the hook crack zone near the O.D. display tightly adhered oxidation product, suggesting that the crack had occurred some time prior to the final fracture.



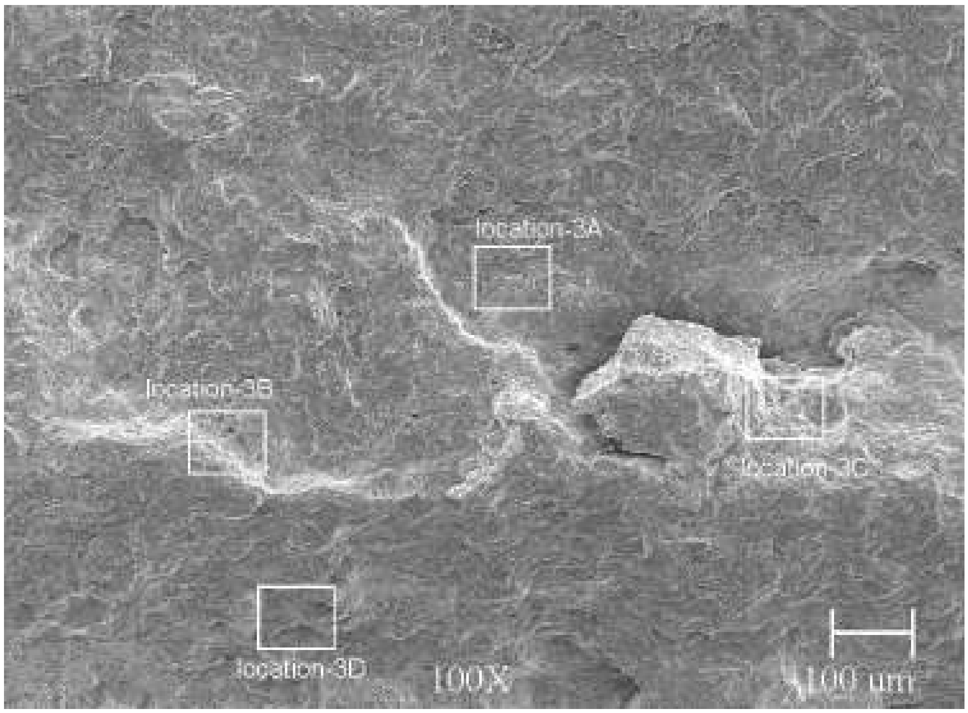
Area-B
Photograph No. 127

The SEM fractograph taken of the Area-B of the hook crack zone, as displayed in Photograph No. 123, reveals a nondescript, featureless fracture surface. The fracture location labeled as Location-2A was examined at higher magnification to further characterize the fracture morphology.



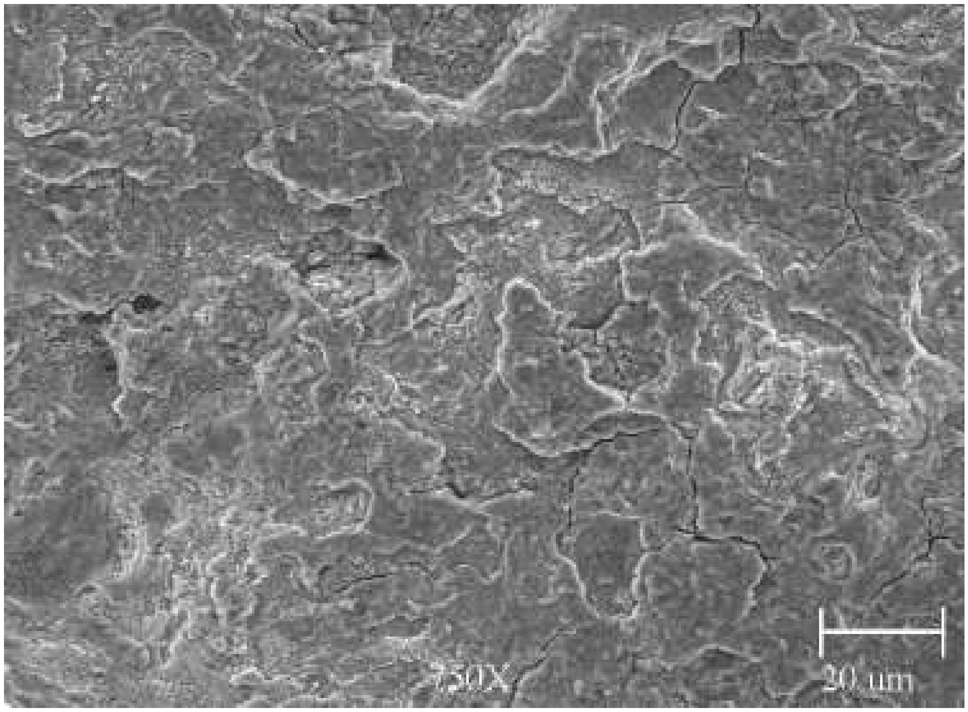
Area-B, Location-2A
Photograph No. 128

The SEM fractograph taken of the Area-B at Location-2A of the hook crack zone, as displayed in Photograph No. 127, reveals tightly adhered oxidation product on the fracture surface.

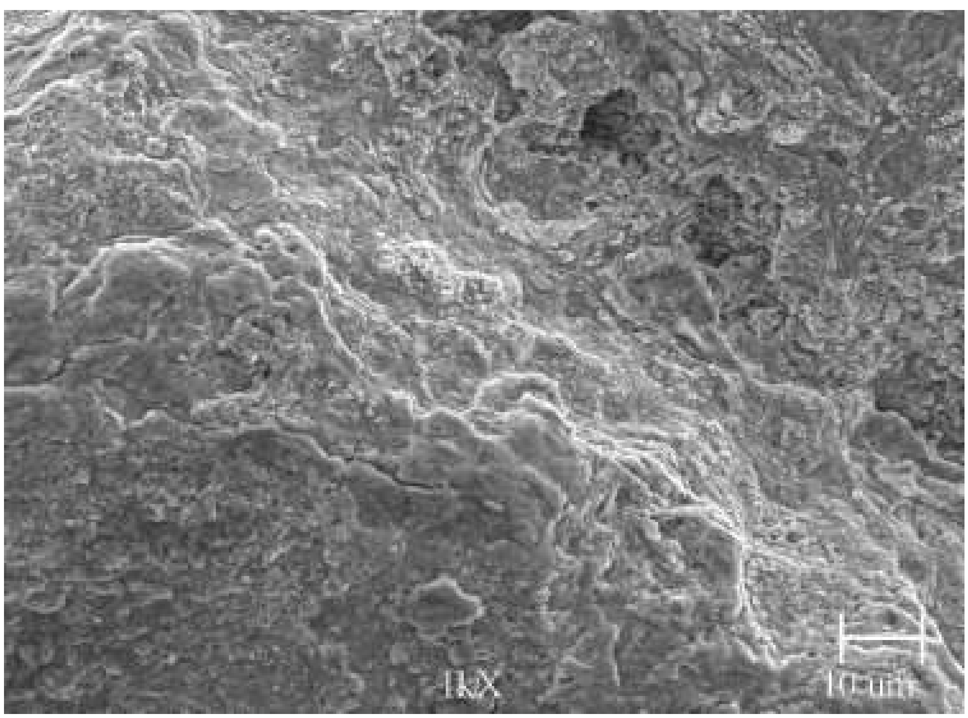


Area-C
Photograph No. 129

The SEM fractograph taken of the Area-C of the hook crack zone, as displayed in Photograph No. 123, reveals a nondescript, featureless fracture surface. The fracture locations, labeled as Location-3A, Location-3B, Location-3C, and Location-3D, were examined at higher magnifications to further characterize the fracture morphologies.

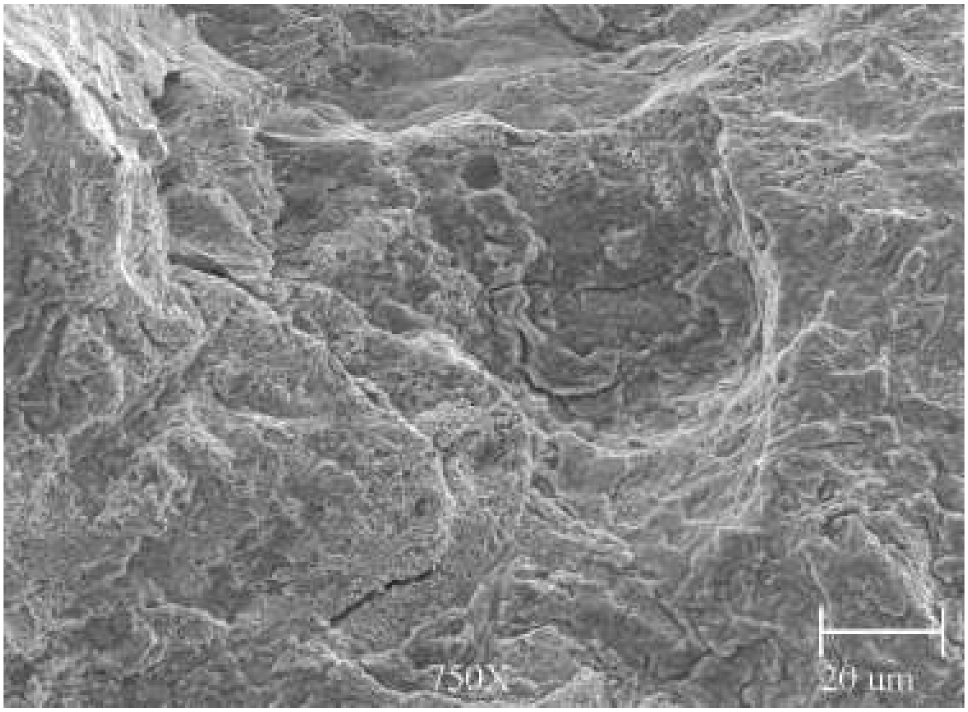


Area-C, Location-3A
Photograph No. 130

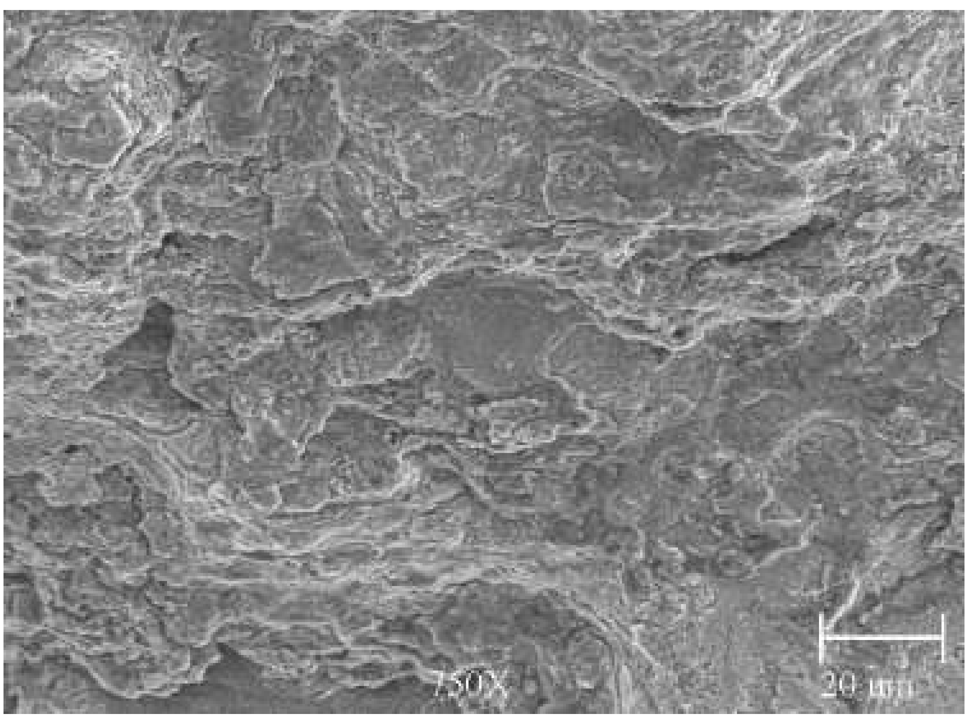


Area-C, Location-3B
Photograph No. 131

The SEM fractographs taken of the Area-C at Location-3A and Location-3B of the hook crack zone, as displayed in Photograph No. 129, reveal tightly adhered oxidation product.

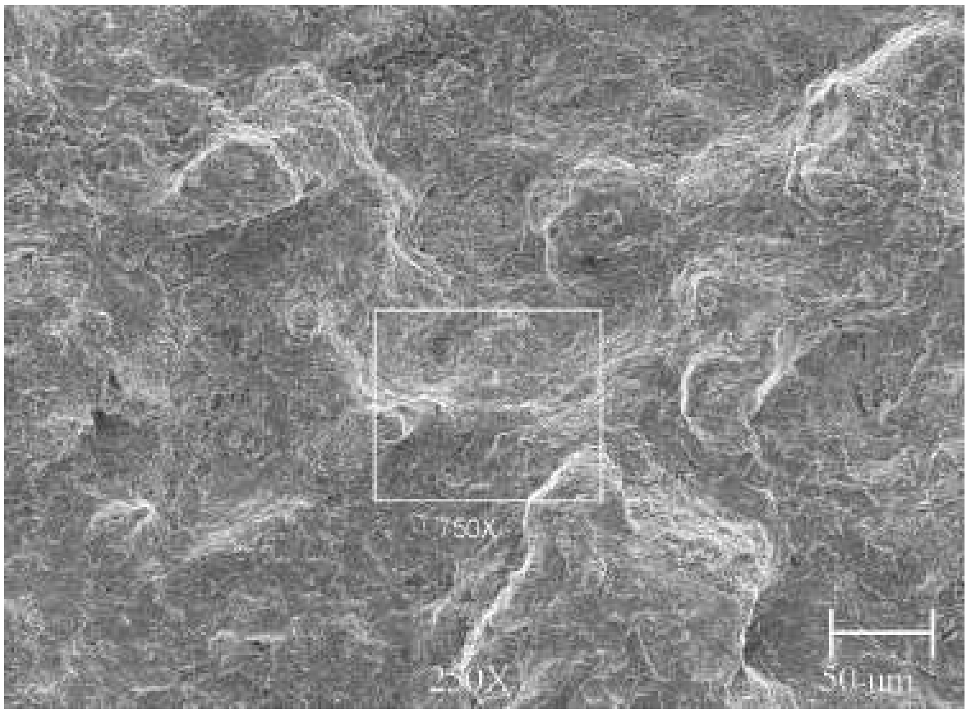


Area-C, Location-3C
Photograph No. 132



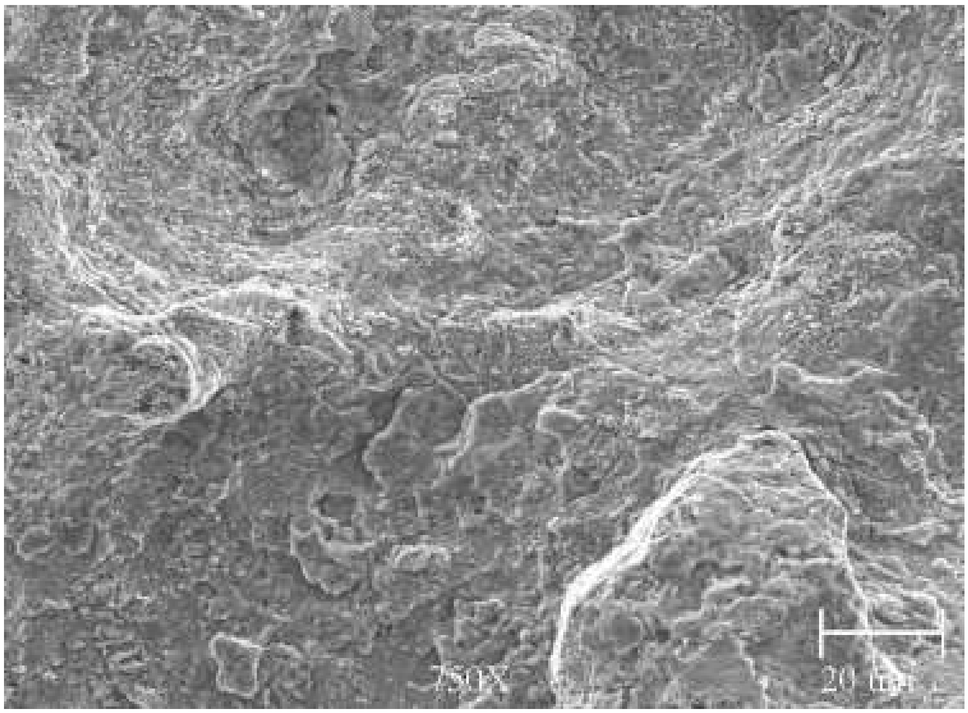
Area-C, Location-3D
Photograph No. 133

The SEM fractographs taken of the Area-C at Location-3C and Location-3D of the hook crack zone, as displayed in Photograph No. 129, reveal tightly adhered oxidation product.



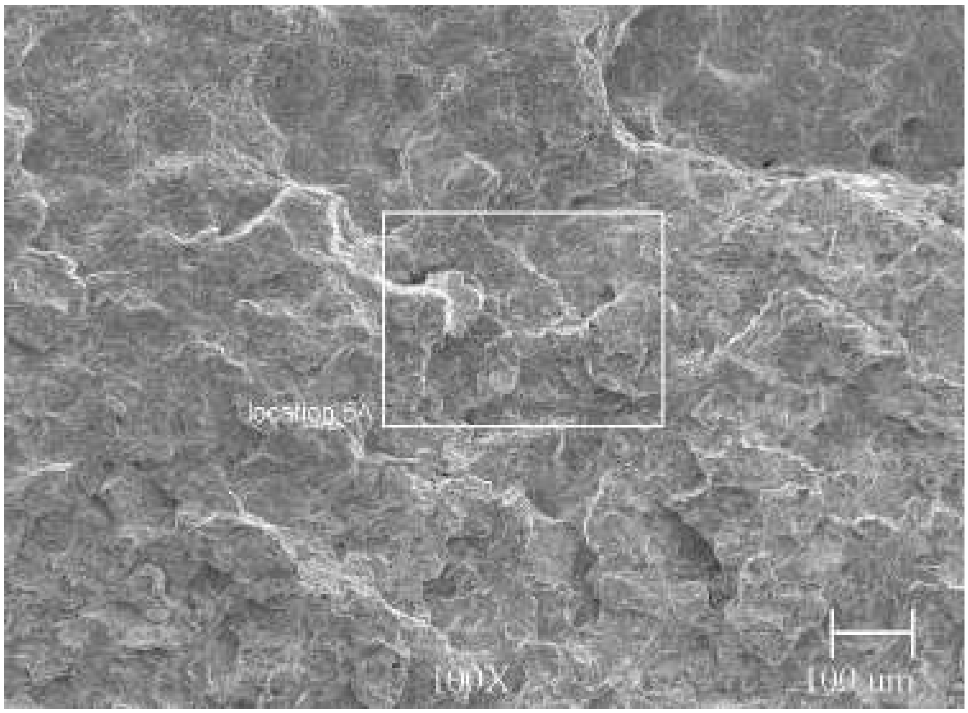
Area-D
Photograph No. 134

The SEM fractograph taken of the Area-D of the hook crack zone, as displayed in Photograph No. 123, reveals a nondescript, featureless fracture surface. The fracture location within the rectangle was examined at a higher magnifications to characterize the fracture morphology.



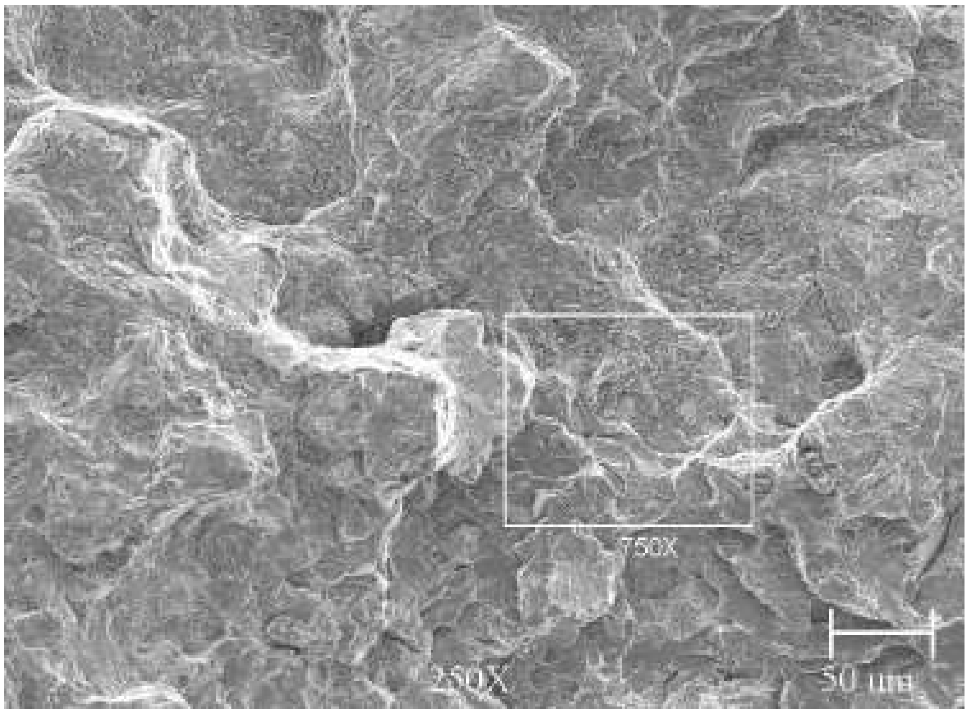
Area-D within the rectangle
Photograph No. 135

The SEM fractograph taken of the Area-D within the rectangle of the hook crack zone, as displayed in Photograph No. 134, reveals tightly adhered oxidation product.



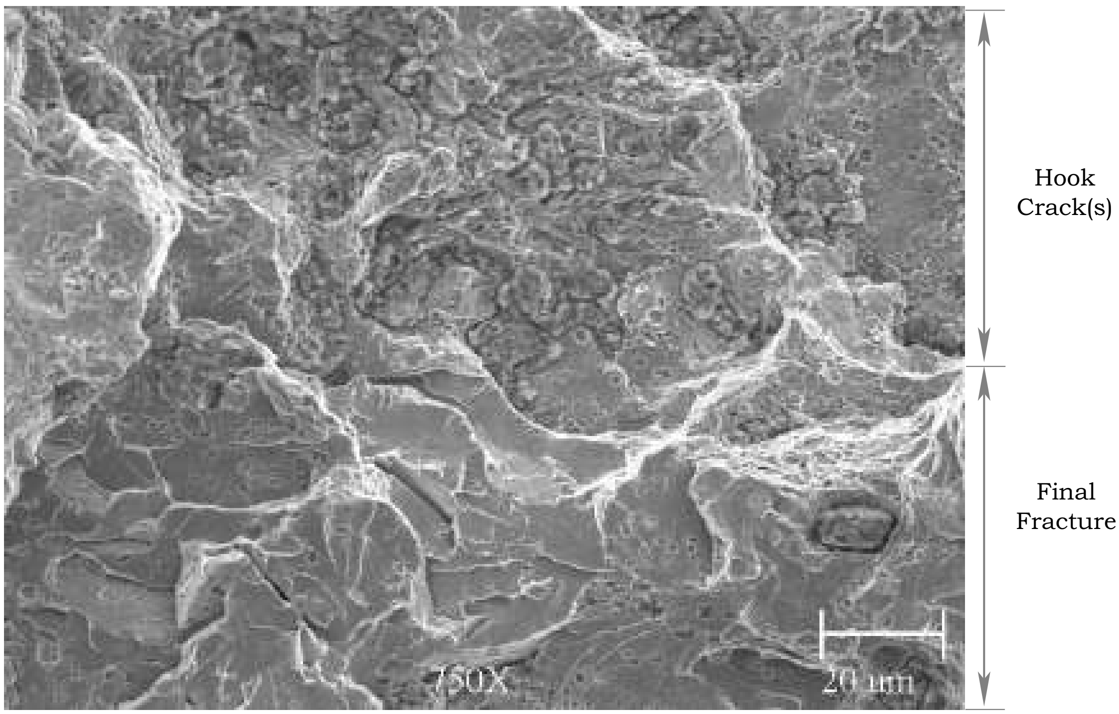
Area-E
Photograph No. 136

The SEM fractograph taken of the Area-E in the transition zone between the hook crack and the final fracture zones, as displayed in Photograph No. 123, reveals a nondescript, featureless fracture surface. The fracture location labeled as Location-5A was examined at higher magnification to characterize the fracture morphology.



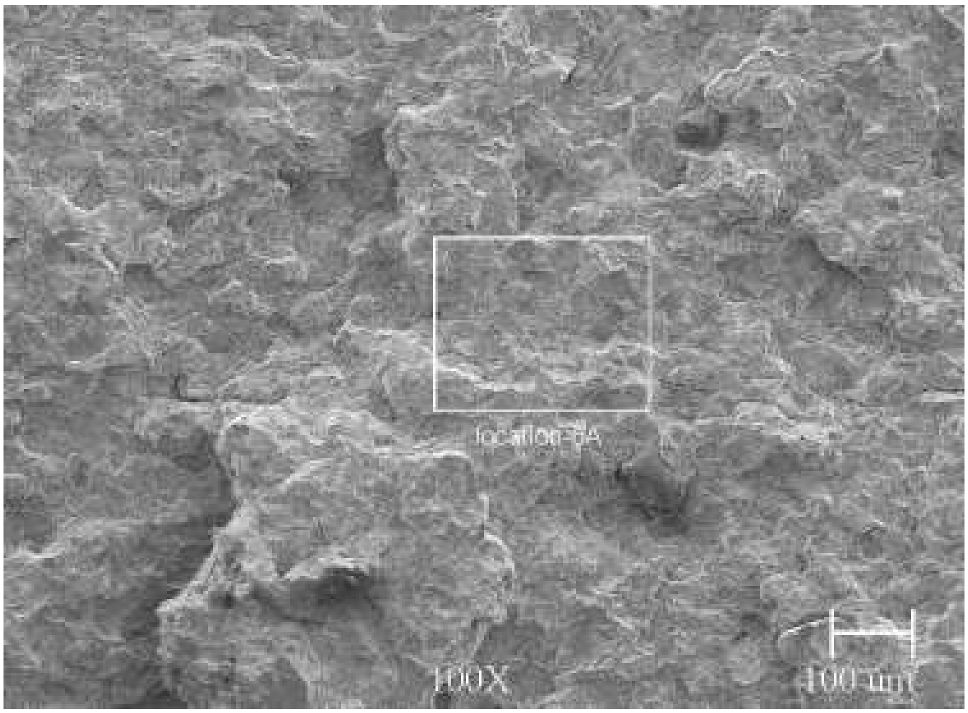
Area-E, Location-5A
Photograph No. 137

The SEM fractograph taken of the Area-E at Location-5A displays some evidence of oxidation product in the hook crack and evidence of quasi-cleavage separation in the final fracture zone, indicative of pre-existing crack and final brittle fracture, respectively.



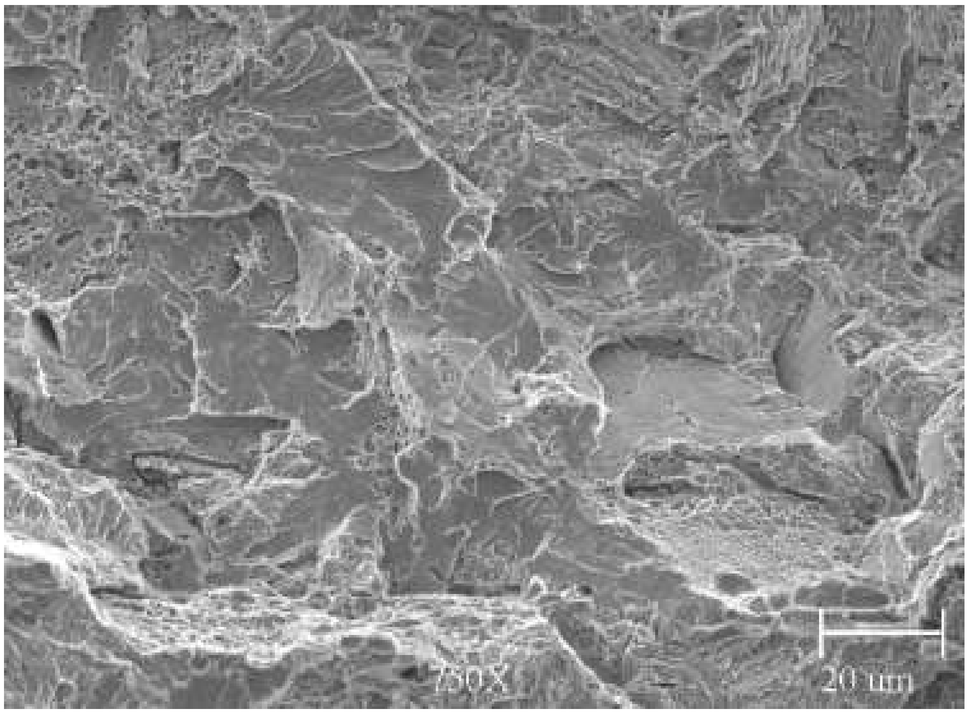
Area-E, Location-5A, Location within rectangle
Photograph No. 138

The SEM fractograph taken of the Area-E at Location-5A, as displayed in Photograph No. 137, confirms the oxidation on the hook cracks and the final fracture in the brittle manner.



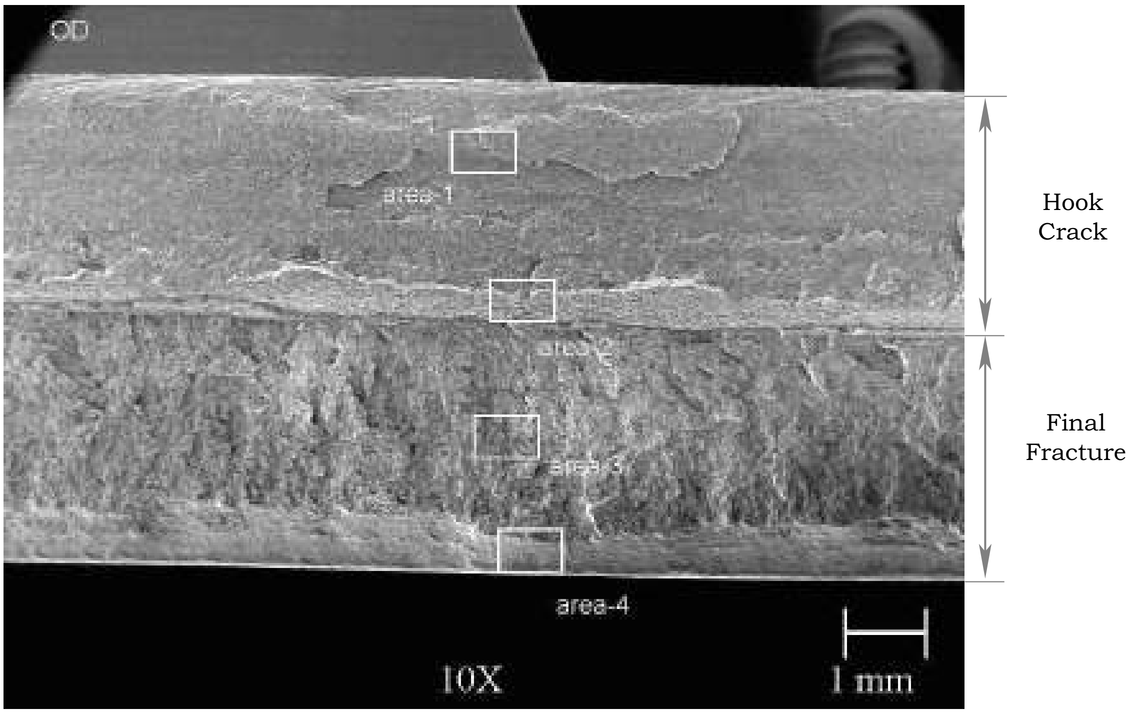
Area-F
Photograph No. 139

The SEM fractograph taken of the Area-F of the final fracture zone, as shown in Photograph No. 123, displays unresolved cleavage separation fracture features and faint evidence of ductile microvoid coalescence.



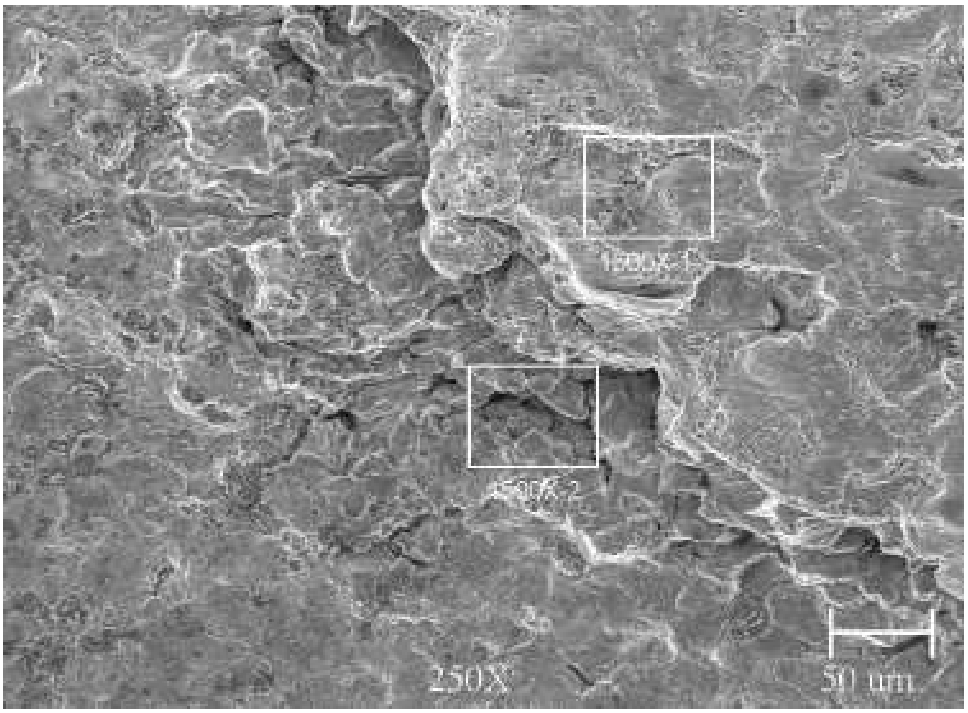
Area-F, Location-6A
Photograph No. 140

The SEM fractograph taken of the Area-F at Location-6A of the final fracture zone confirm the presence of predominantly brittle failure with some isolated areas of ductile failure, as indicated by the presence of cleavage separation and patches of microvoid coalescence, respectively.



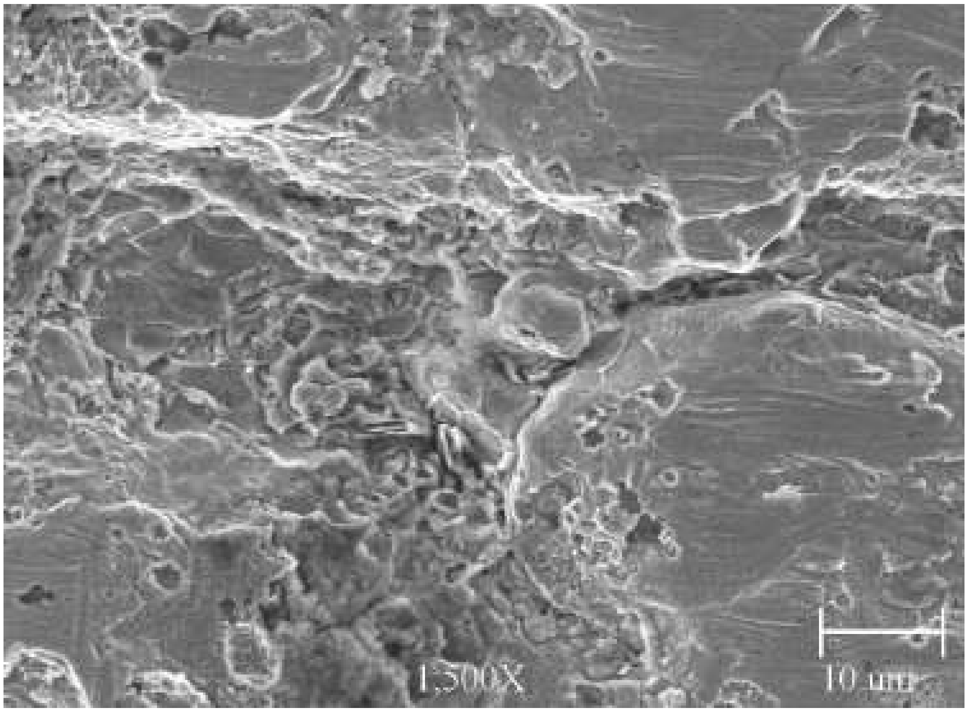
Photograph No. 141

The SEM fractograph taken of the several fracture origin sites at a distance of 20' 6-3/4" from the north girth weld shows an hook crack and the final fracture zone. The fracture areas within the rectangles were examined at higher magnifications to further characterize the fracture morphologies.

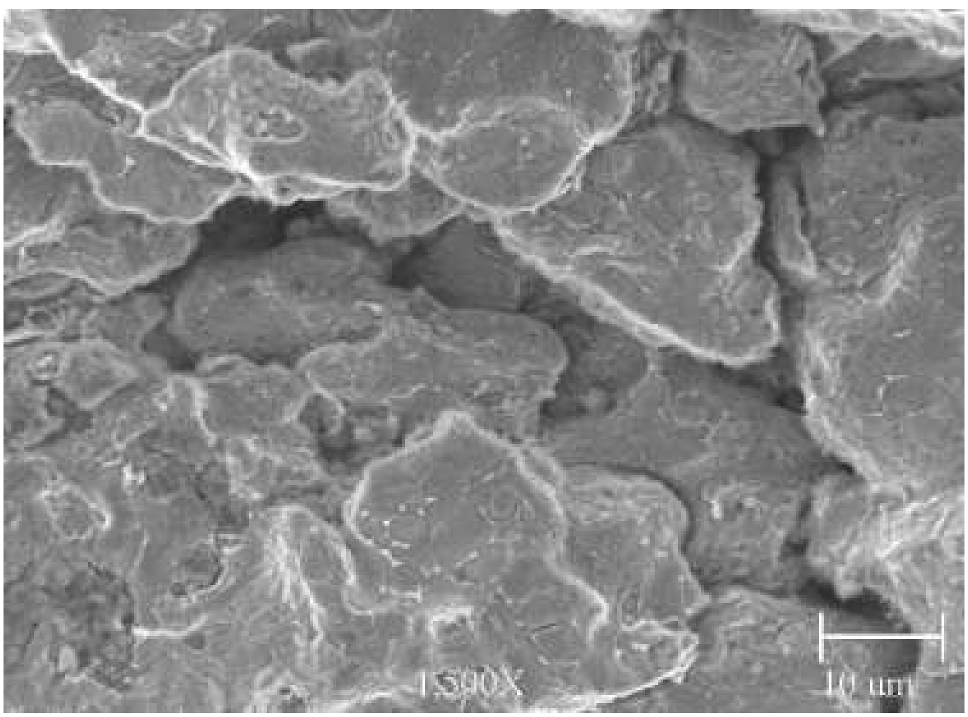


Area-1
Photograph No. 142

The SEM fractograph taken of the Area-1 of the hook crack fracture zone, as displayed in Photograph No. 141, reveals a highly oxidized fracture surface. The fracture areas, labeled as 1 and 2, were examined at higher magnification to further characterize the fracture morphologies.

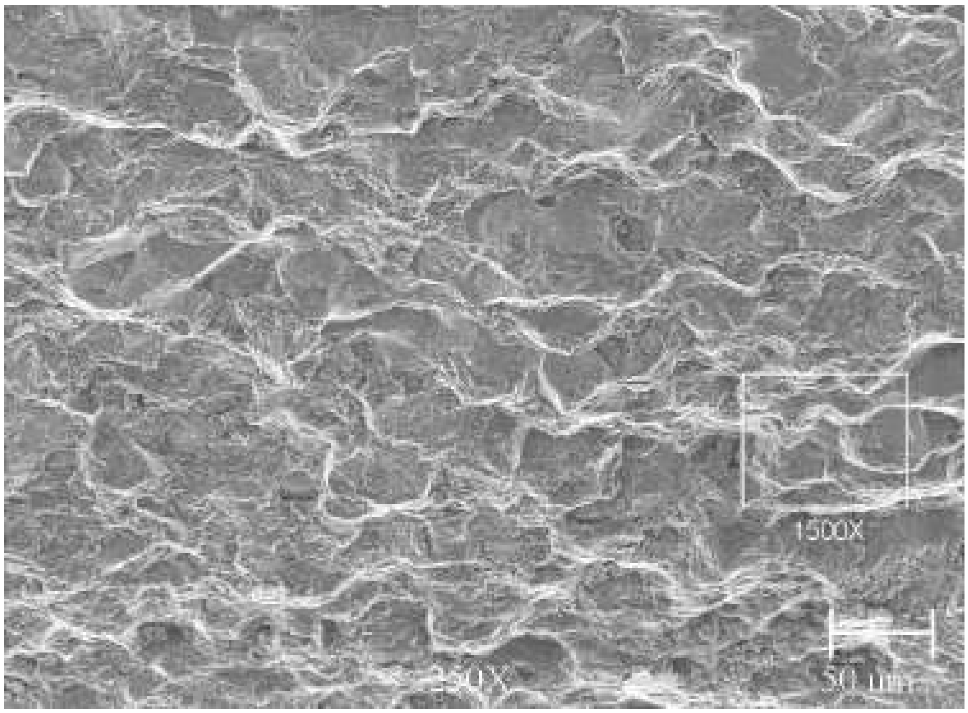


Area-1, Location-1
Photograph No. 143



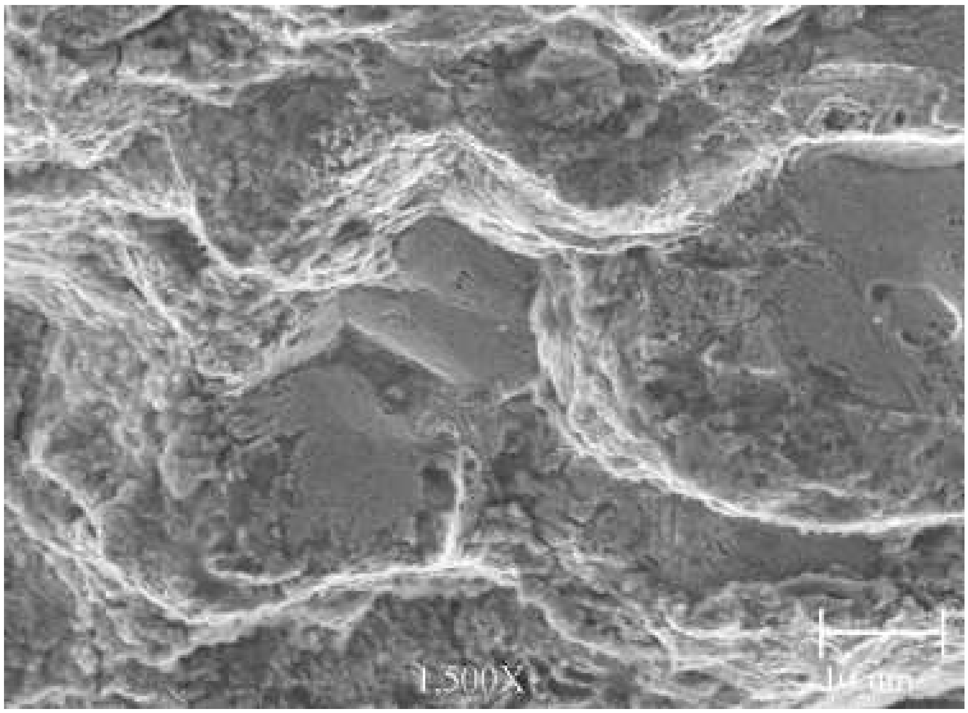
Area-1, Location-2
Photograph No. 144

The SEM fractographs taken of the fracture zones labeled as Location-1 and Location-2 in Area-1 of the hook crack reveal a highly oxidized surface and evidence of what appears to be intergranular fracture in a very small fracture zone, respectively. The intergranular fracture may have resulted along the ferrite grain boundaries.



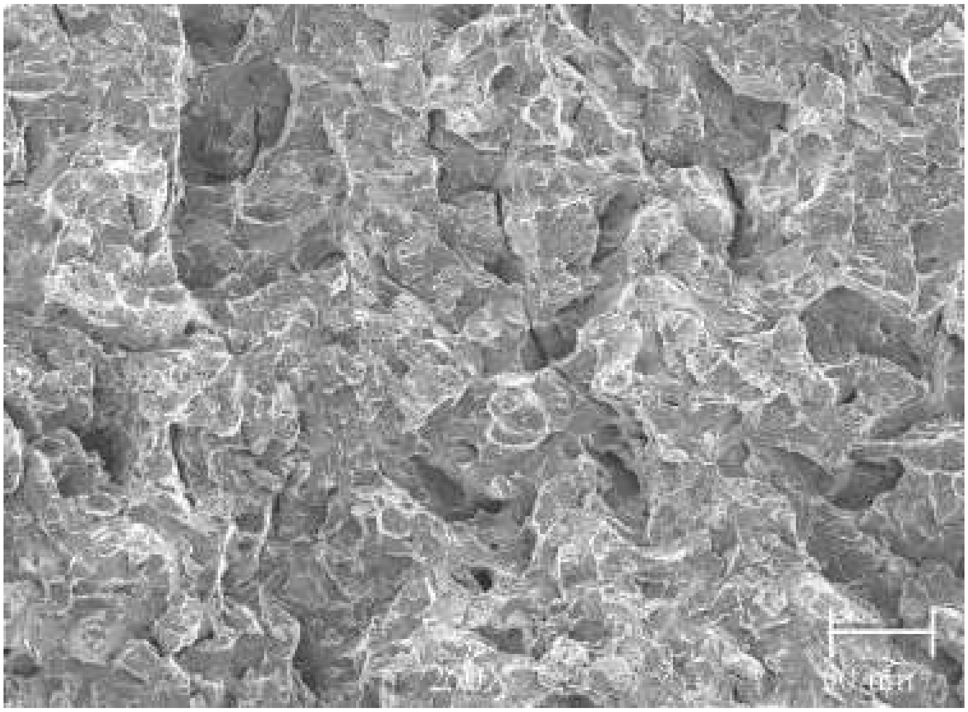
Area-2
Photograph No. 145

The SEM fractograph taken of the Area-2 of the hook crack, as displayed in Photograph No. 141, reveals the tightly adhered oxidation product. The area within the rectangle was examined at higher magnification to further characterize the fracture morphology.

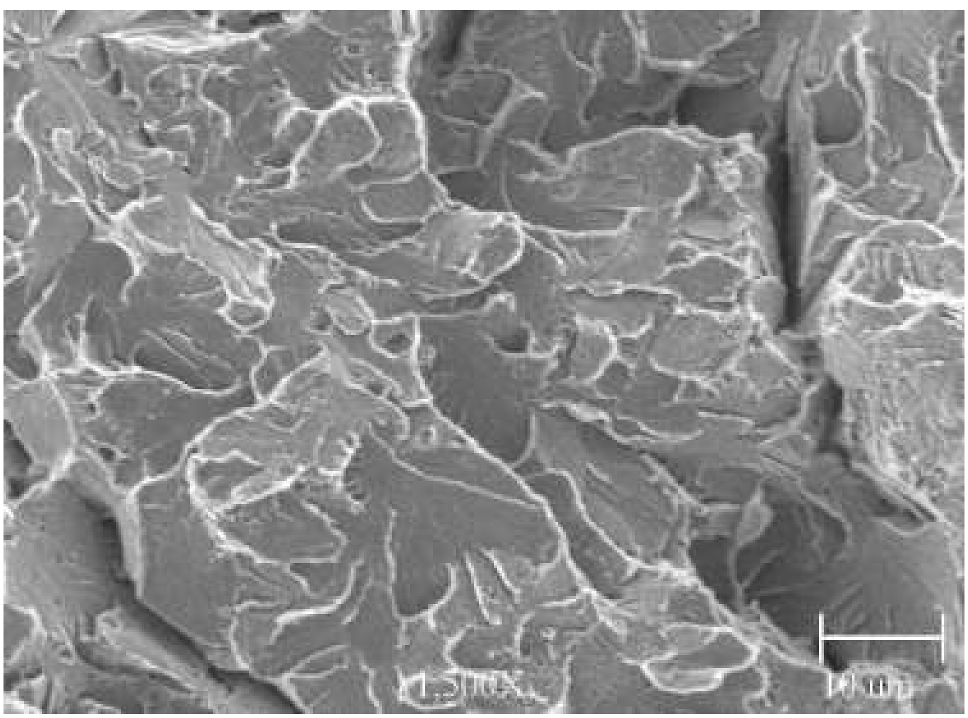


Area-2, within the rectangle
Photograph No. 146

The SEM fractograph taken of the Area-2 within the rectangle in the hook crack, as displayed in Photograph No. 145, reveals a nondescript, featureless fracture surface covered with tightly adhered oxidation product.

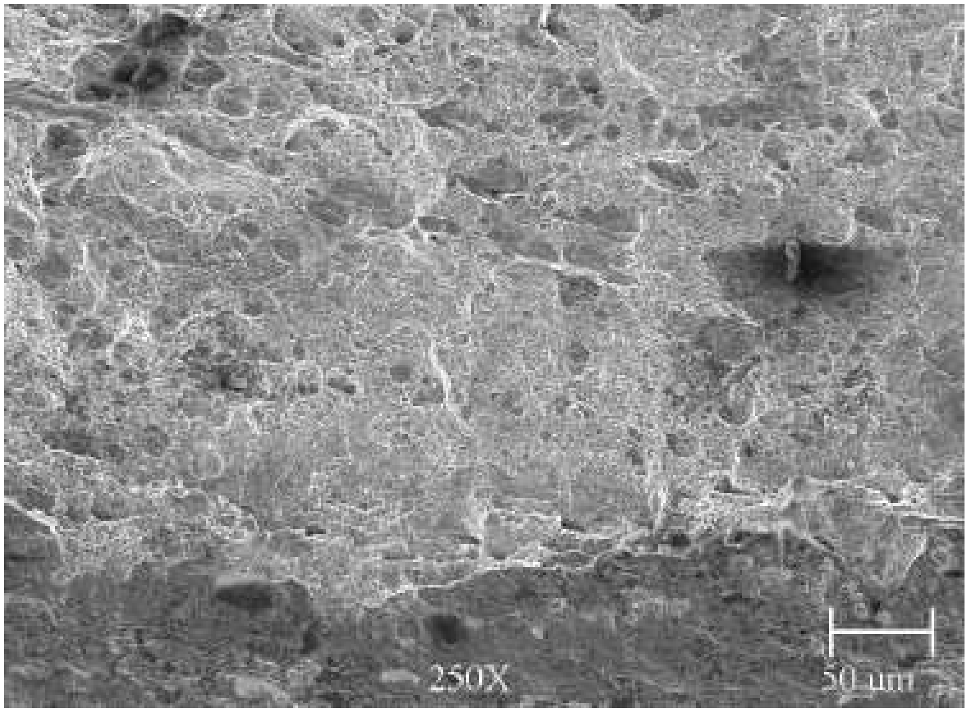


Area-3
Photograph No. 147

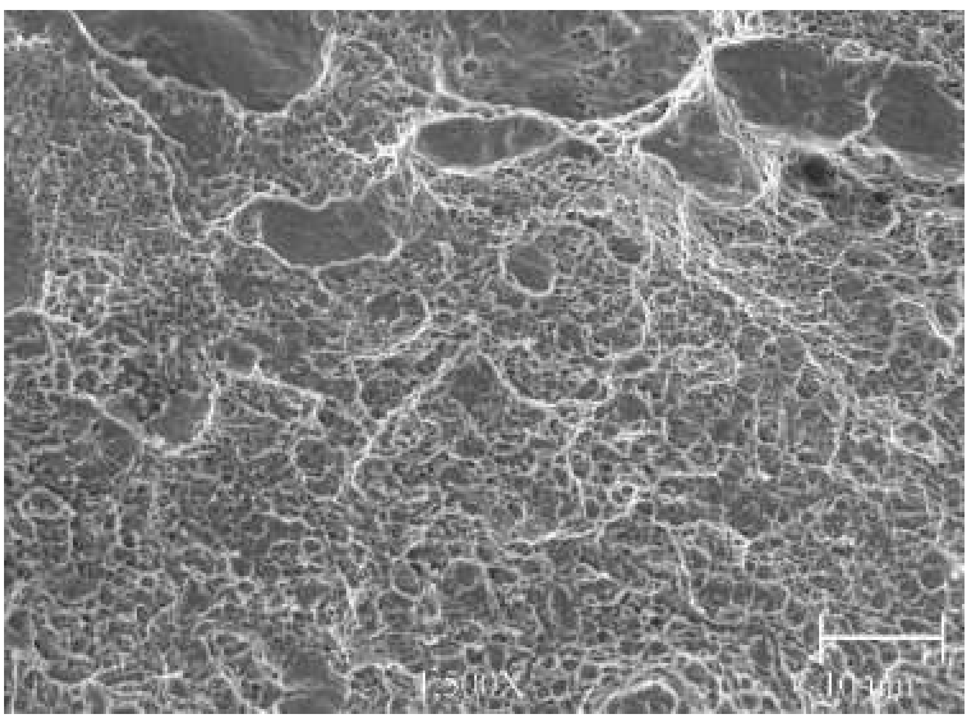


Area-3
Photograph No. 148

The SEM fractographs taken of the Area-3 of the final fracture zone, as displayed in Photograph No. 141, reveal cleavage separation, indicative of brittle failure.

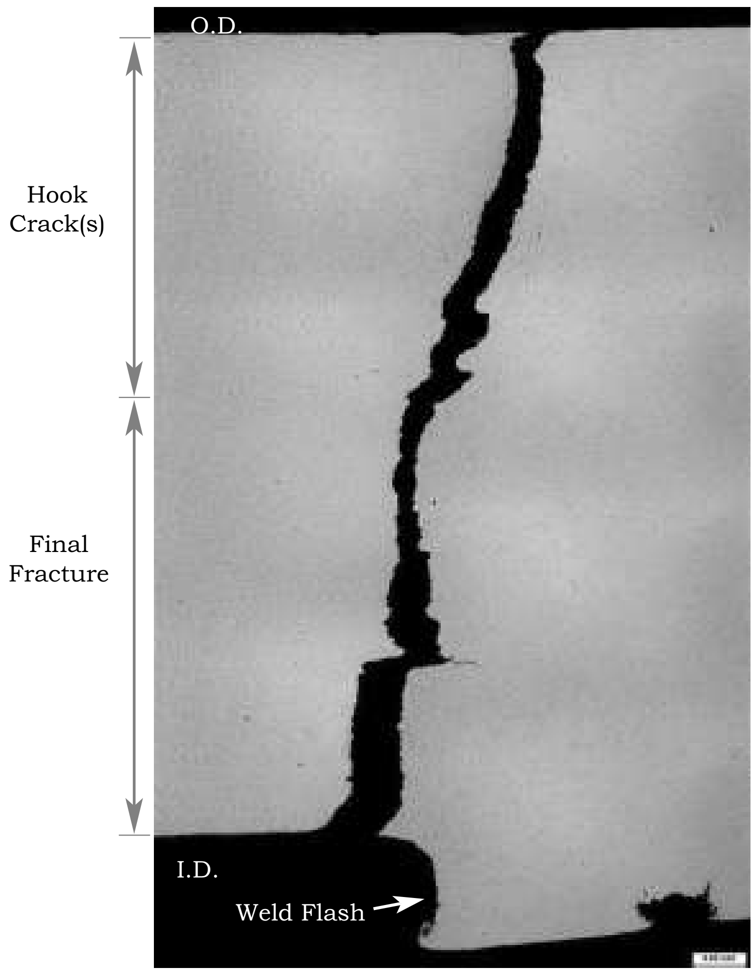


Area-4
Photograph No. 149



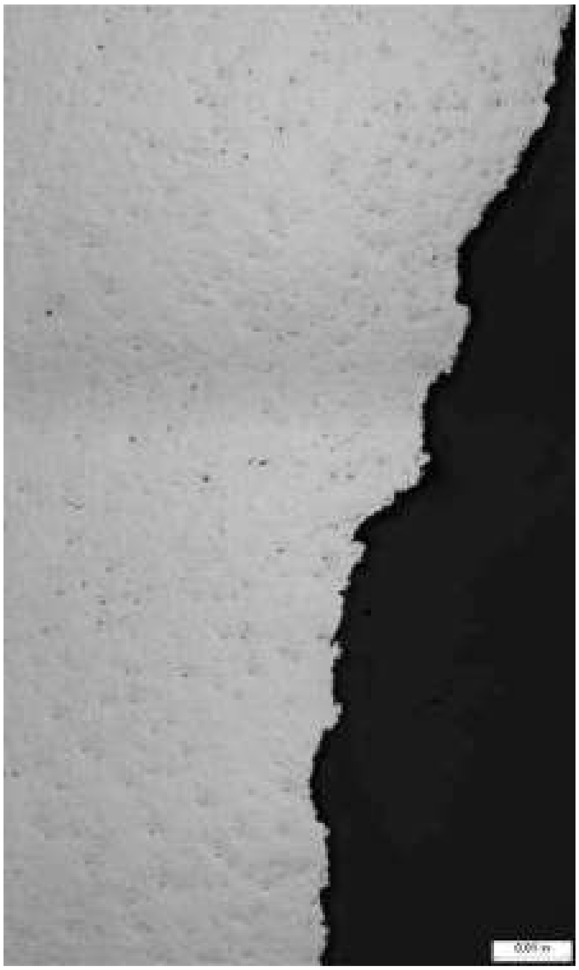
Area-4
Photograph No. 150

The SEM fractographs taken of the Area-4 of the final shear fracture zone at the I.D. of the pipe reveal evidence of microvoid coalescence, indicative of rapid ductile failure.

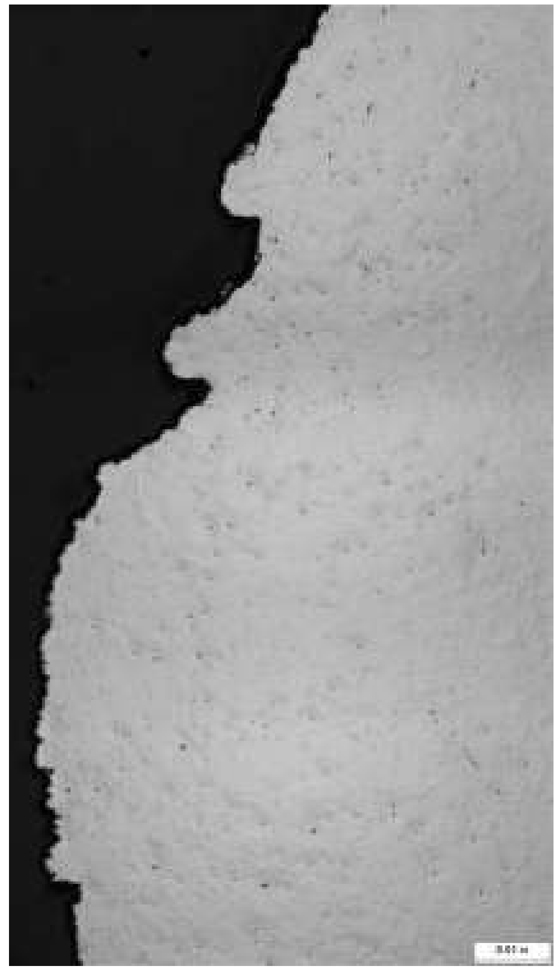


20' 4-7/8" from the North Girth Weld
As-polished, ~25x
Photograph No. 151

A composite view of the mating cross-sections removed through the fracture origins area at a distance of 20' 4-7/8" from the north girth weld and prepared for metallographic examination displays evidence of nonmetallic inclusions along the fracture faces and also parallel to the fusion line near the upper half of the pipe wall. Note that the weld flash on the I.D. surface of the pipe was not trimmed off flush with the I.D. surface.

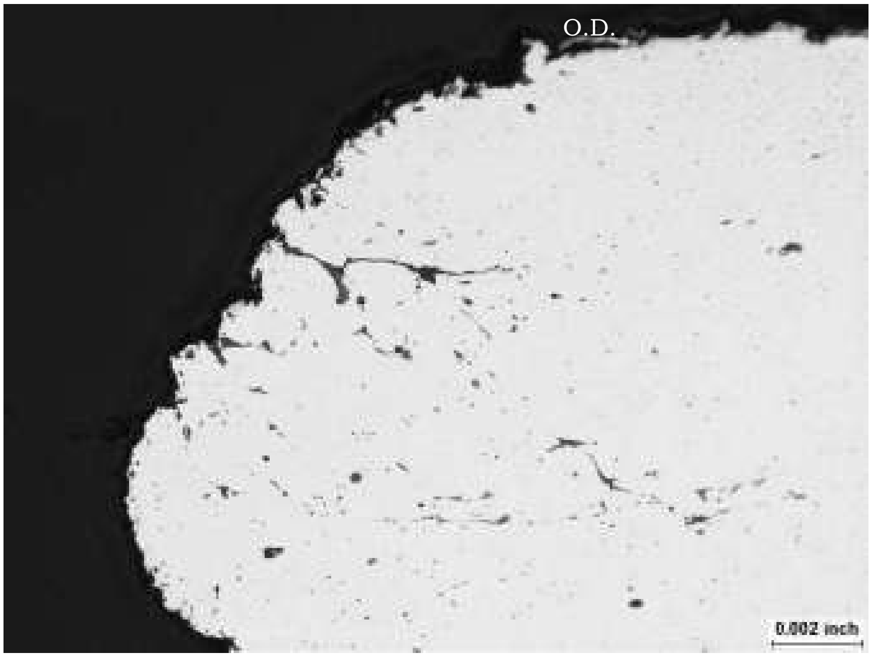


20' 4-7/8" from the North Girth Weld
As-polished, ~50x
Photograph No. 152

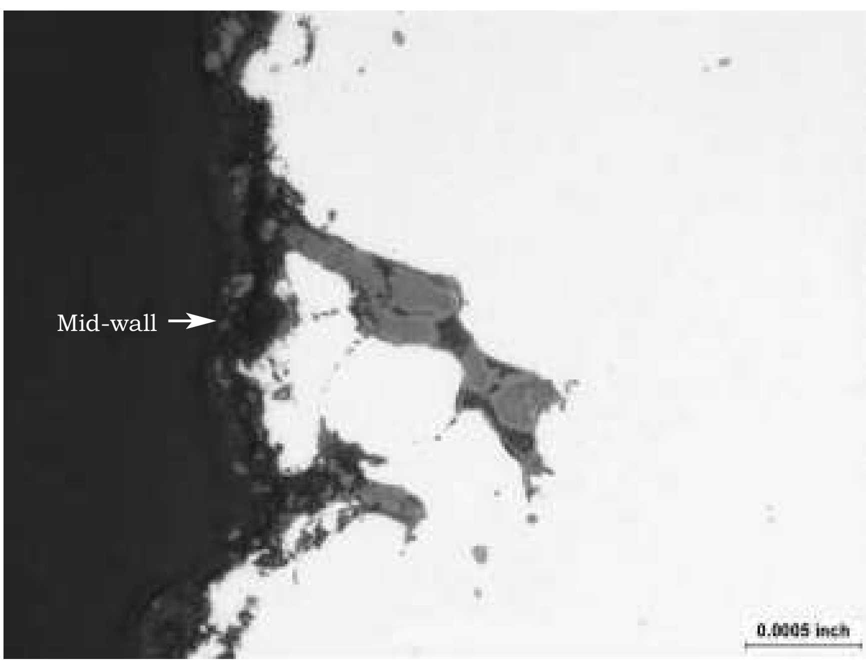


20' 4-7/8" from the North Girth Weld
As-polished, ~50x
Photograph No. 153

The micrographs display the upturned inclusions essentially parallel to the fusion line in the ERW upset/HAZ area, as well as along the fracture faces. Note that vertically aligned inclusions are one of the main contributing factors to the formation of hook cracks.

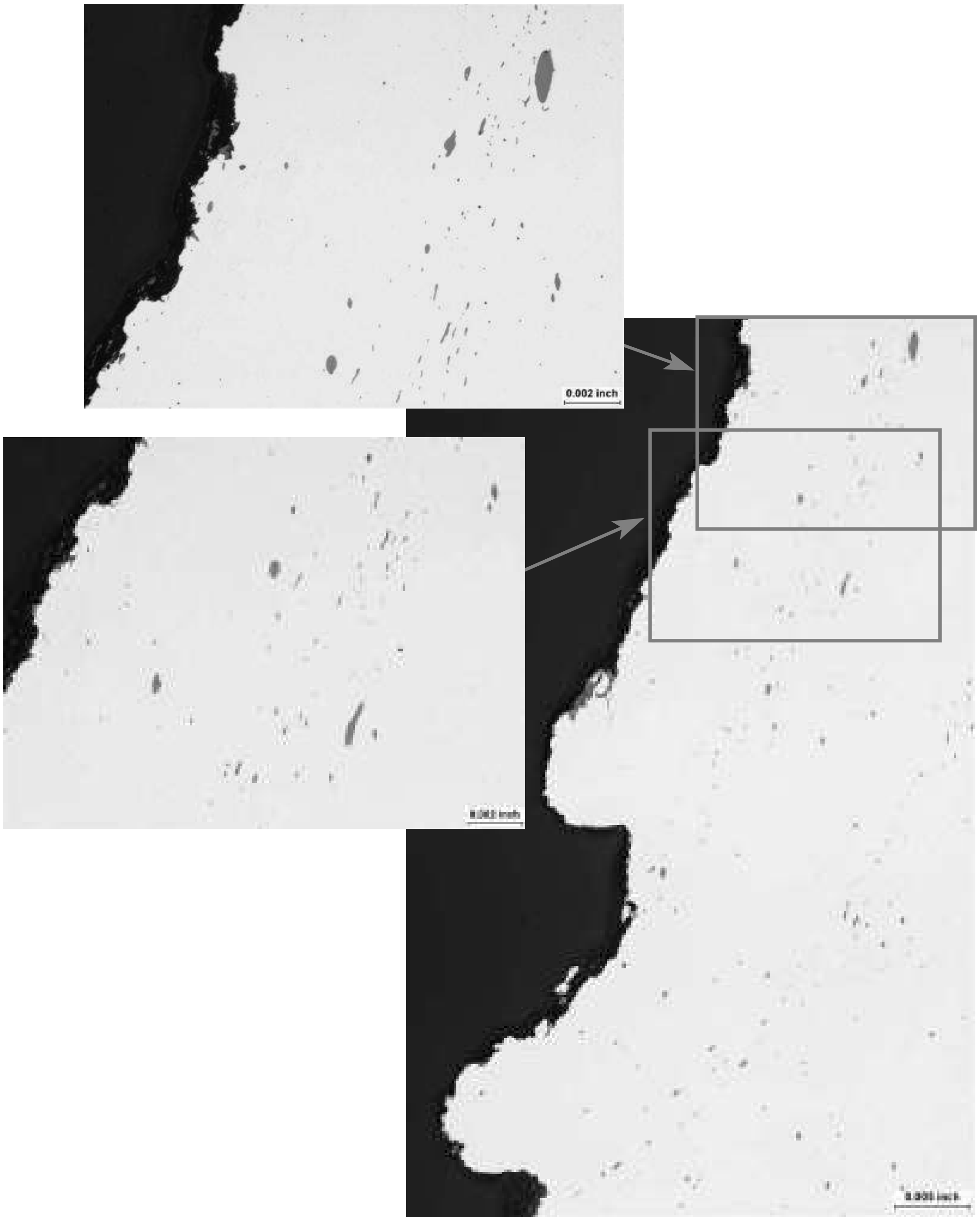


20' 4-7/8" from the North Girth Weld
As-polished, ~200x
Photograph No. 154



20' 4-7/8" from the North Girth Weld
As-polished, ~1000x
Photograph No. 155

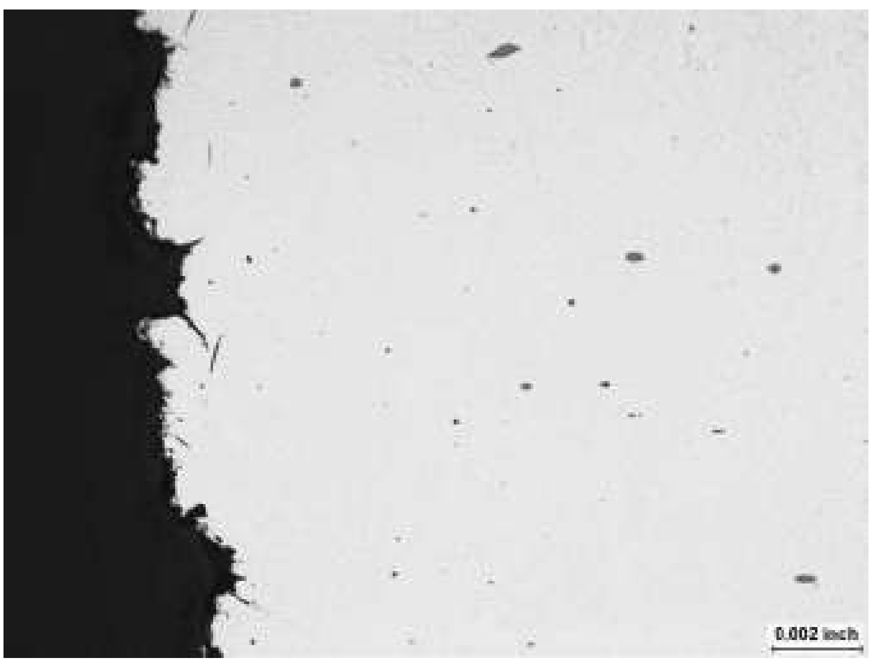
The micrographs display evidence of folds at the O.D. surface at the fusion line, which was apparently not fully fused, and the presence of post-fracture oxidation at the mid-wall area along the hook crack fracture face.



20' 4-7/8" from the North Girth Weld
As-polished, ~100x
Photograph No. 156

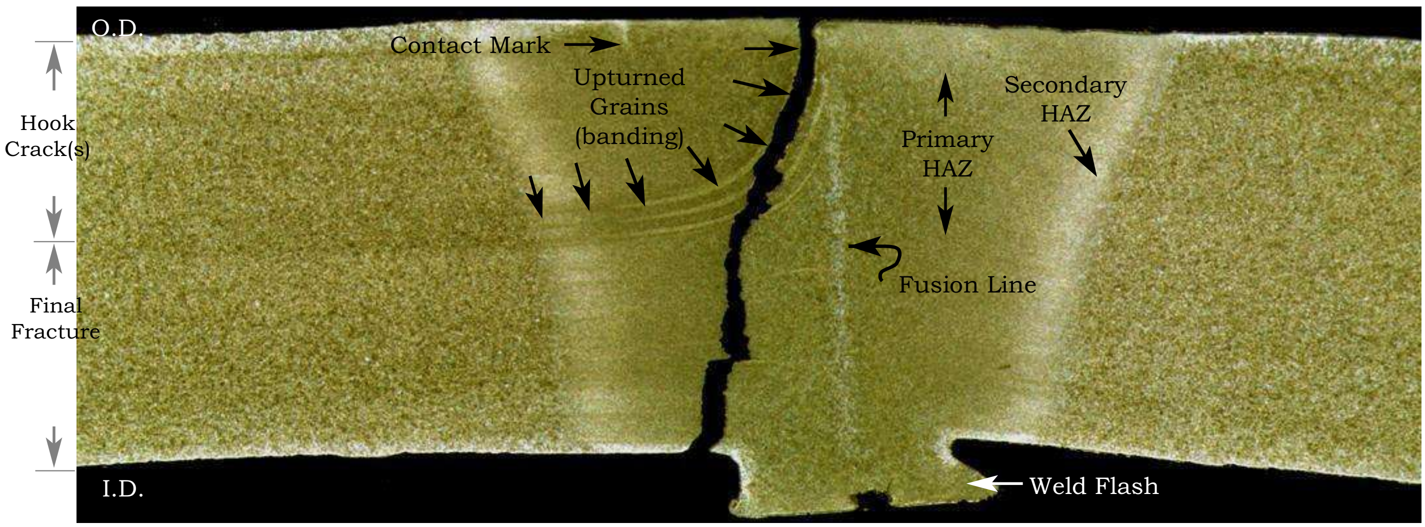
The micrographs display an excessive amount of elongated manganese sulfide inclusions in the diagonal and vertical planes in the upset/HAZ area of the ERW seam. Note the hook crack along and through the realigned inclusions.

20' 4-7/8" from the North Girth Weld
As-polished, ~200x
Photograph No. 157



20' 4-7/8" from the North Girth Weld
As-polished, ~200x
Photograph No. 158

The micrographs display the manganese sulfide inclusions in the axial direction of the pipe near the I.D. surface of the ERW, which were not affected by the welding process.

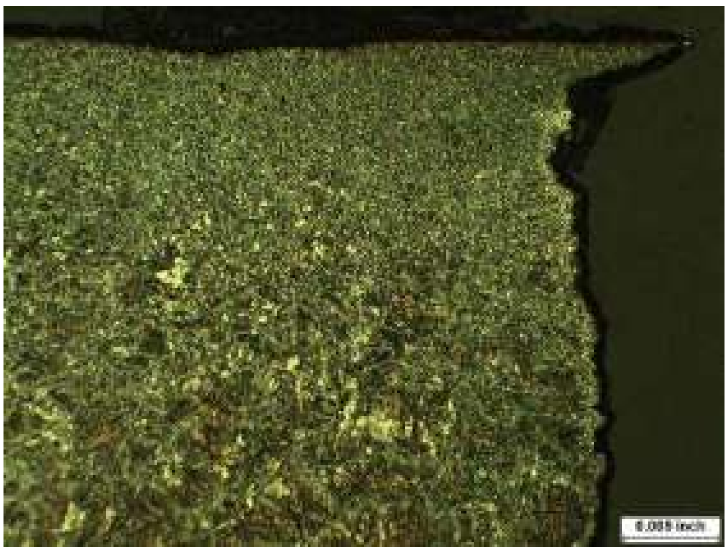


20' 4-7/8" from the North Girth Weld
2% Nital etch, ~20x
Photograph No. 159

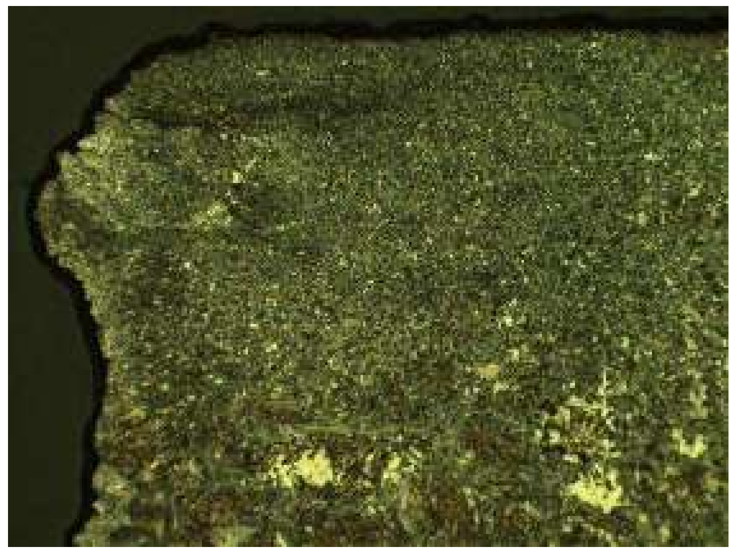
A composite view of the mating cross-sections removed through the fracture origins area at a distance of 20' 4-7/8" from the north girth weld and prepared for metallographic evaluation shows hook cracks along the brittle upturned bands in the upset/HAZ area, and the final failure from the tip(s) of the hook crack(s). Again, note that the weld flash was not trimmed off flush with the I.D. surface.

20' 4-7/8" from the North Girth Weld
2% Nital etch, ~25x
Photograph No. 160

The micrograph displays a hook crack through the upturned bands, which consists of untempered brittle martensite in the upset/HAZ of the ERW seam.



20' 4-7/8" from the North Girth Weld
2% Nital etch, ~100x
Photograph No. 161



20' 4-7/8" from the North Girth Weld
2% Nital etch, ~100x
Photograph No. 162

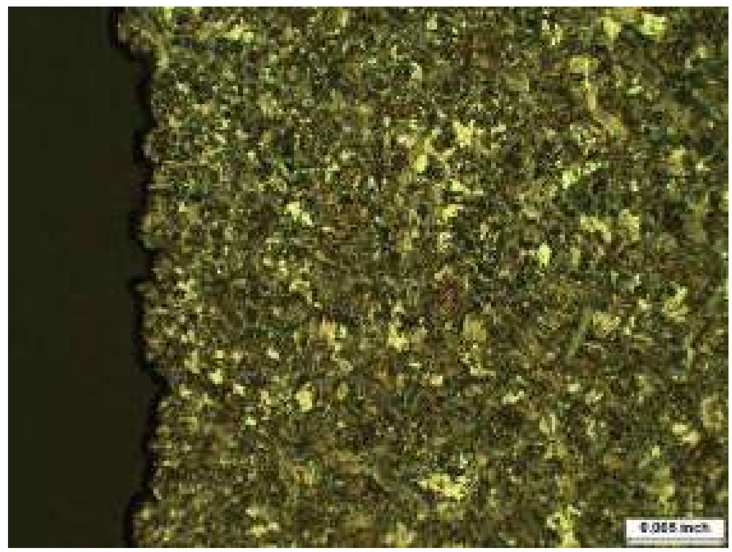
The micrographs display the mating fracture faces of hook cracks near the O.D. of the ERW joint. The microstructure consists of grain boundary ferrite and unresolved bainite with some acicular martensite.

20' 4-7/8" from the North Girth Weld
2% Nital etch, ~100x
Photograph No. 163

20' 4-7/8" from the North Girth Weld
2% Nital etch, ~100x
Photograph No. 164

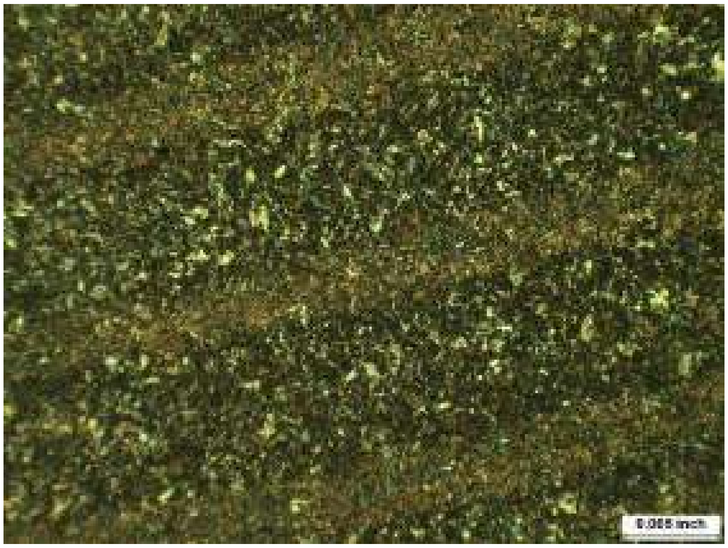
The micrographs display the mating fracture faces of the hook cracks near the mid-wall of the ERW joint. Note the presence of mix-microstructure in the upset/HAZ of the ERW seam. The upturned bands consist of essentially untempered brittle martensite and the matrix outside of the bands consists of ferrite and unresolved bainite.

20' 4-7/8" from the North Girth Weld
2% Nital etch, ~100x
Photograph No. 165

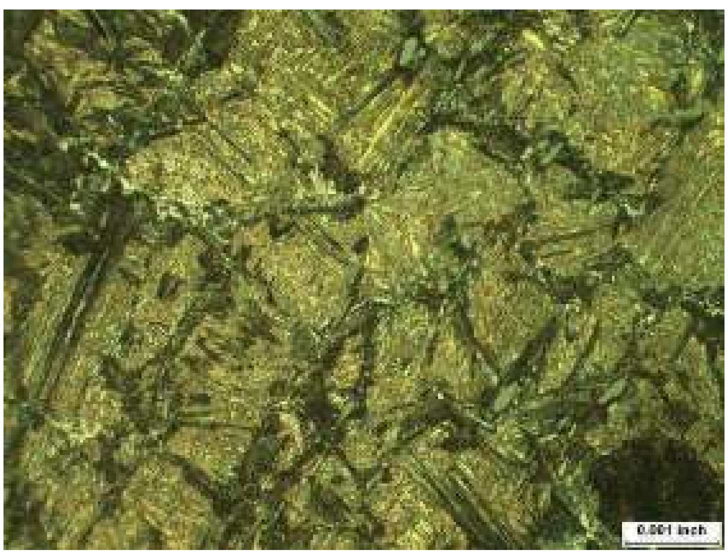


20' 4-7/8" from the North Girth Weld
2% Nital etch, ~100x
Photograph No. 166

The micrographs display the mating fracture faces of the final crack near the I.D. of the ERW joint. Note the presence of mix-microstructure in the HAZ of the ERW seam consisting of patches of untempered acicular martensite, grain boundary ferrite, and unresolved bainite.



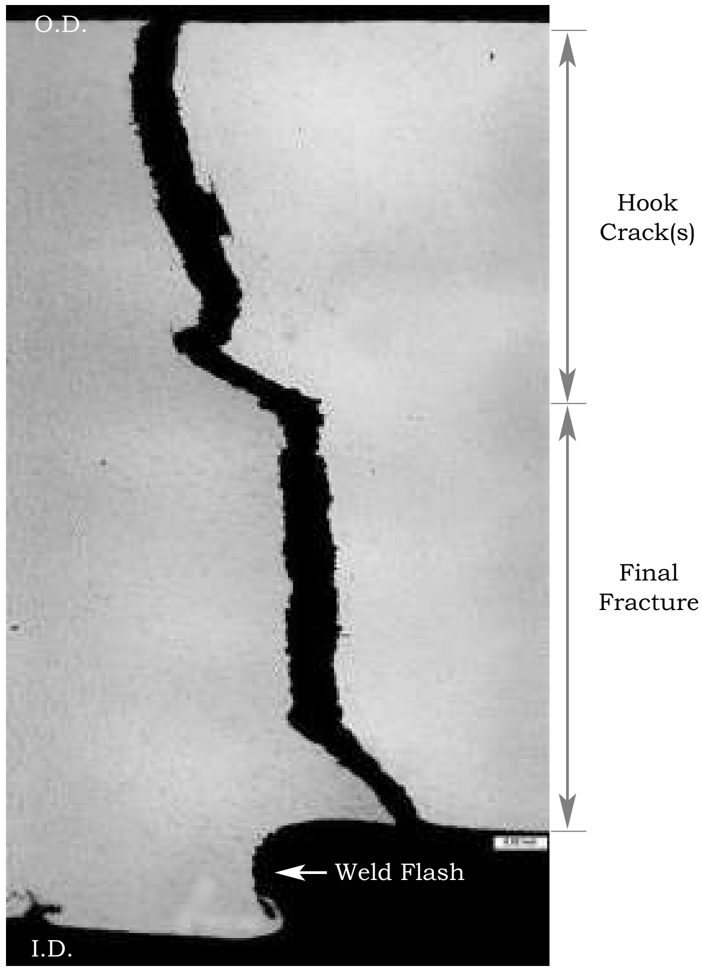
20' 4-7/8" from the North Girth Weld
2% Nital etch, ~100x
Photograph No. 167



20' 4-7/8" from the North Girth Weld
2% Nital etch, ~500x
Photograph No. 168

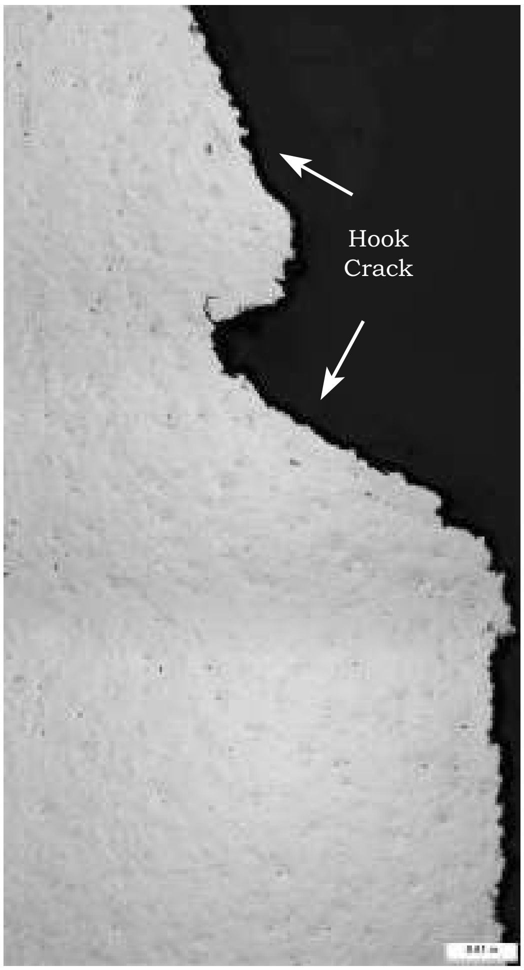
20' 4-7/8" from the North Girth Weld
2% Nital etch, ~500x
Photograph No. 169

The micrographs display the microstructure of the material in the upset/HAZ between the O.D. and the mid-wall where the upturned bands were formed during the ERW seam manufacturing, consisting of the untempered brittle martensite in the banded area and essentially grain boundary ferrite and unresolved bainite with some patches of untempered martensite in the non-banded area.

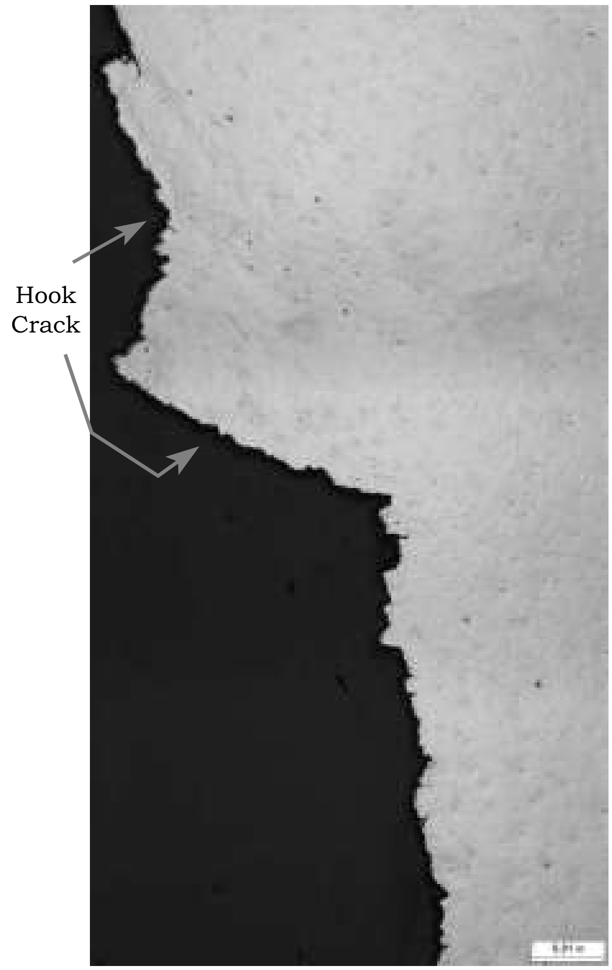


20' 6-13/16" from the North Girth Weld
As-polished, ~25x
Photograph No. 170

A composite view of the mating cross-sections removed through the fracture origins area at a distance of 20' 6-13/16" from the north girth weld and prepared for metallographic examination displays evidence of nonmetallic inclusions along the fracture faces, and also parallel to the fusion line near the upper half of the pipe wall. Note that the weld flash on the I.D. surface was not trimmed off flush with the I.D. surface of the pipe.

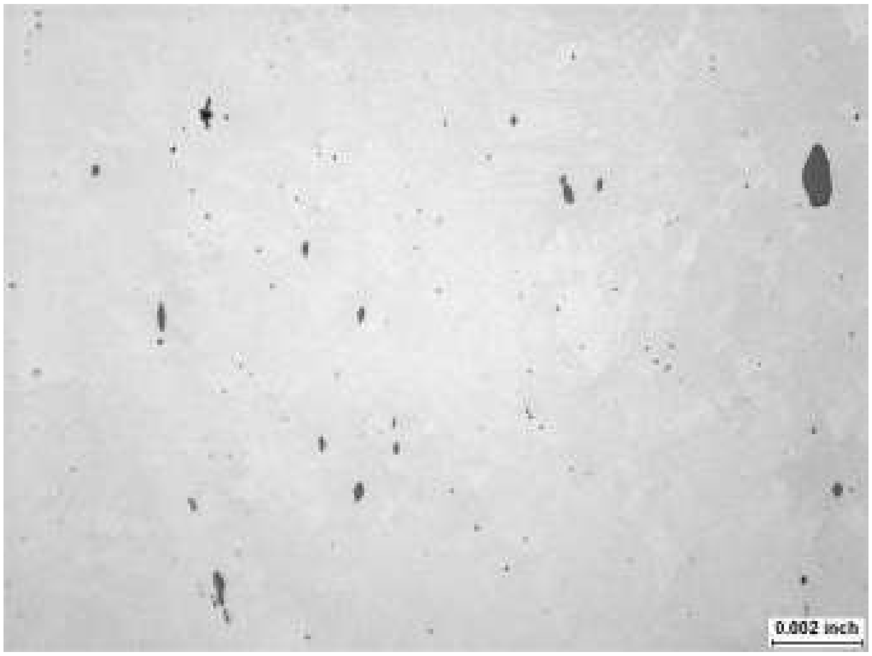


20' 6-13/16" from the North Girth Weld
As-polished, ~50x
Photograph No. 171

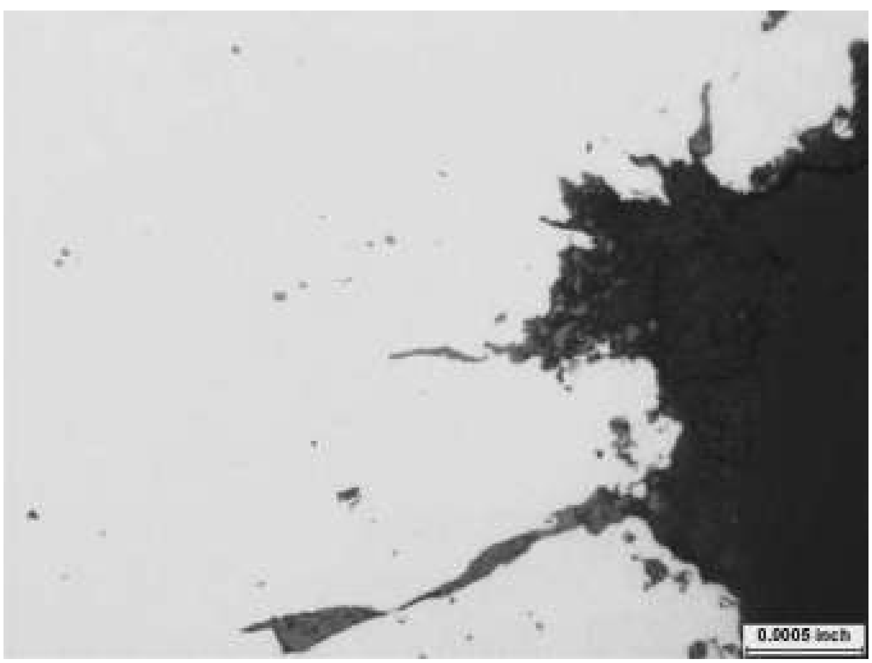


20' 6-13/16" from the North Girth Weld
As-polished, ~50x
Photograph No. 172

The micrographs display the upturned inclusions essentially parallel to the fusion line in the ERW upset/HAZ area, as well as along the fracture faces.

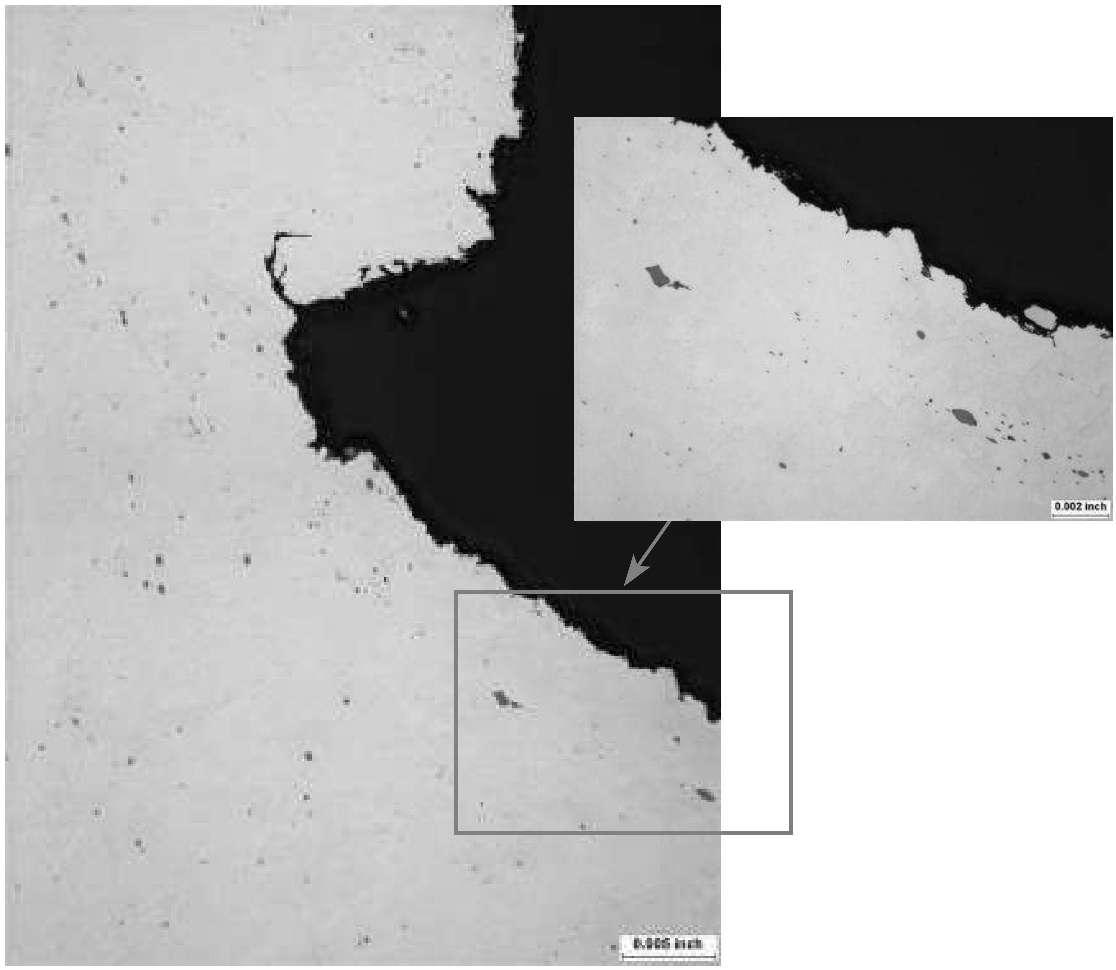


20' 6-13/16" from the North Girth Weld
As-polished, ~200x
Photograph No. 173



20' 6-13/16" from the North Girth Weld
As-polished, ~1000x
Photograph No. 174

The micrographs display the presence of several manganese sulfide inclusions aligned parallel to the fusion line and evidence of some post-hook crack oxidation along the fracture face near the mid-wall.

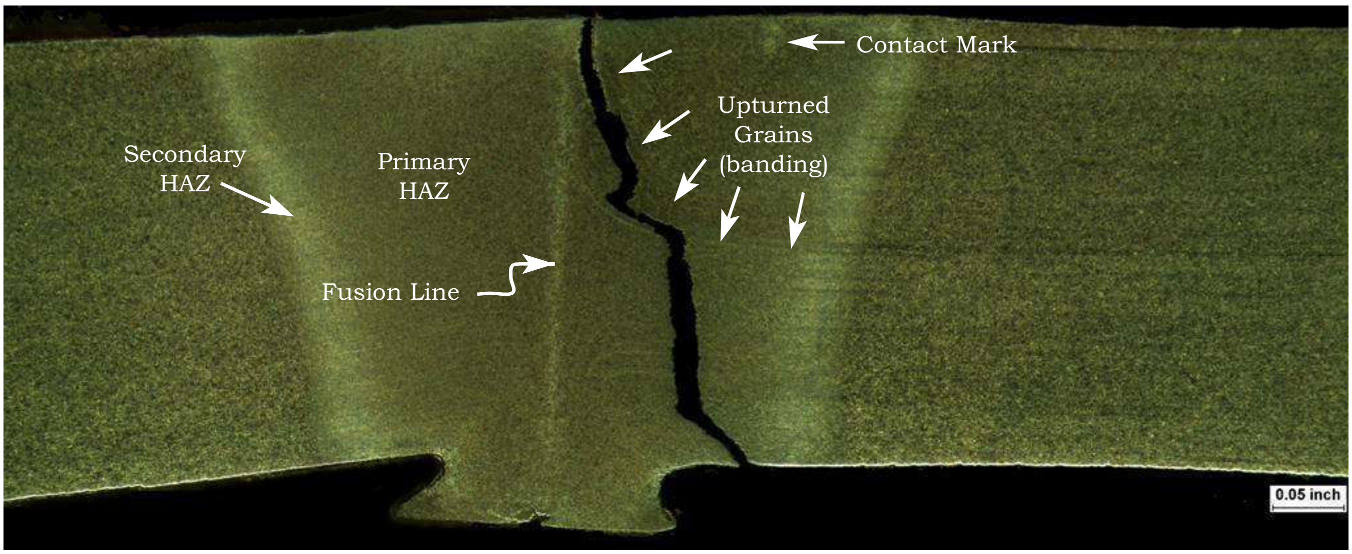


20' 6-13/16" from the North Girth Weld
As-polished, ~100x
Photograph No. 175

The micrographs display an excessive amount of elongated manganese sulfide inclusions aligned in the diagonal and vertical planes in the upset/HAZ area of the ERW seam. Note the hook crack(s) along and through the realigned inclusions.

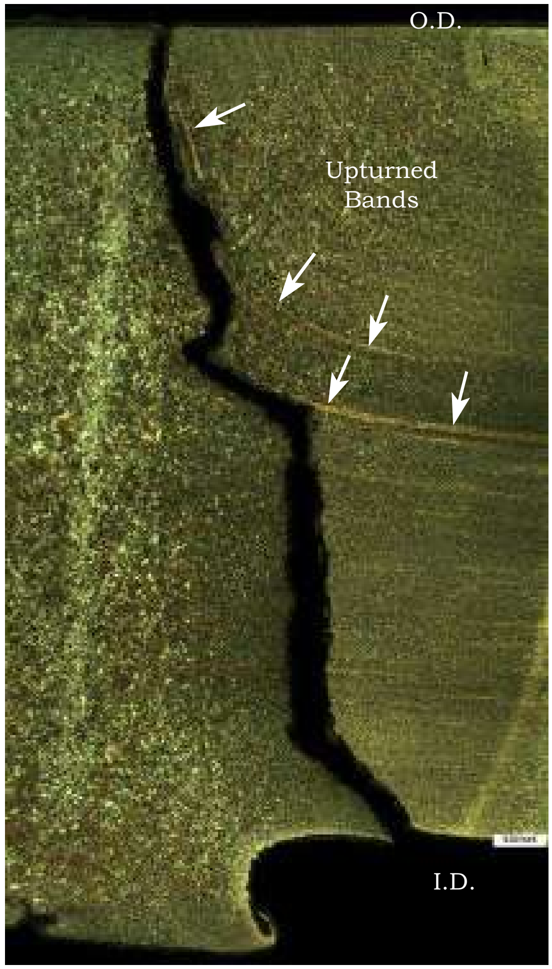
20' 6-13/16" from the North Girth Weld
As-polished, ~200x
Photograph No. 176

The micrograph displays the manganese sulfide inclusions in the axial direction of the pipe near the I.D. surface of the ERW, which were not affected by the welding process.



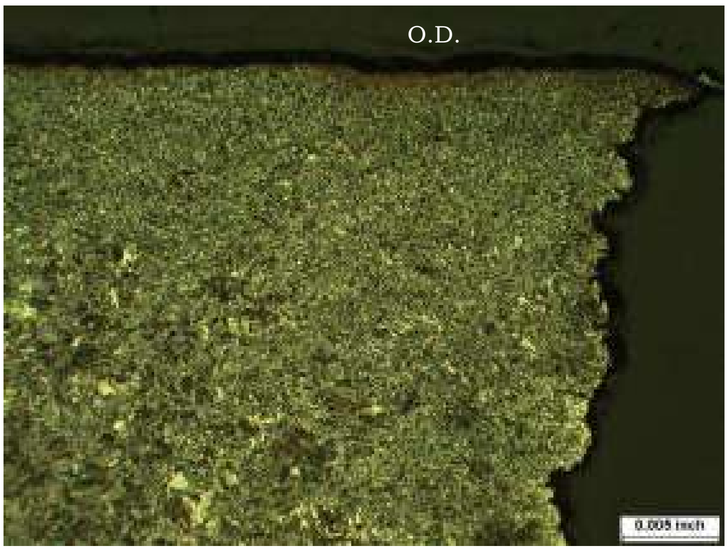
20' 6-13/16" from the North Girth Weld
2% Nital etch, ~20x
Photograph No. 177

The composite view of the mating cross-sections removed through the fracture origins area at a distance of 20' 6-13/16" from the north girth weld and prepared for metallographic evaluation shows hook crack(s) following the upturned grains and inclusions in the upset/HAZ area.



20' 6-13/16" from the North Girth Weld
2% Nital etch, ~25x
Photograph No. 178

The micrograph displays the hook crack(s) following the upturned bands, which consists of untempered brittle martensite.



20' 6-13/16" from the North Girth Weld
2% Nital etch, ~100x
Photograph No. 179

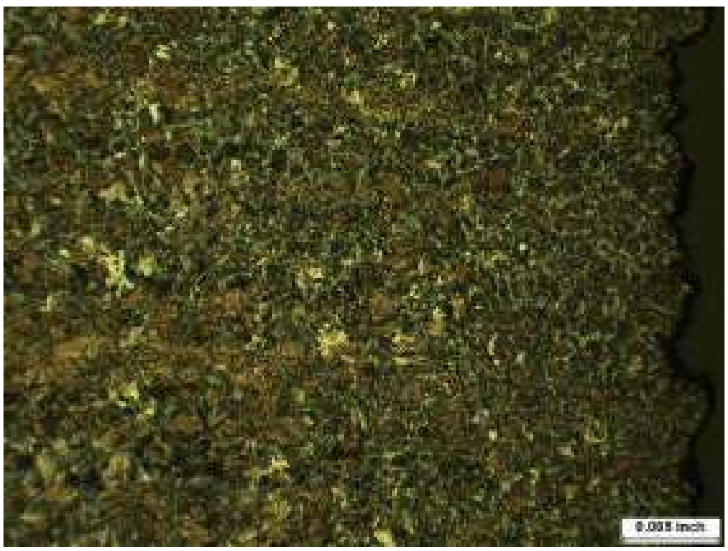
20' 6-13/16" from the North Girth Weld
2% Nital etch, ~100x
Photograph No. 180

The micrographs display the mating faces of the hook crack(s) at the O.D. in the ERW seam. The microstructure consists of grain boundary ferrite and unresolved bainite with some acicular martensite.

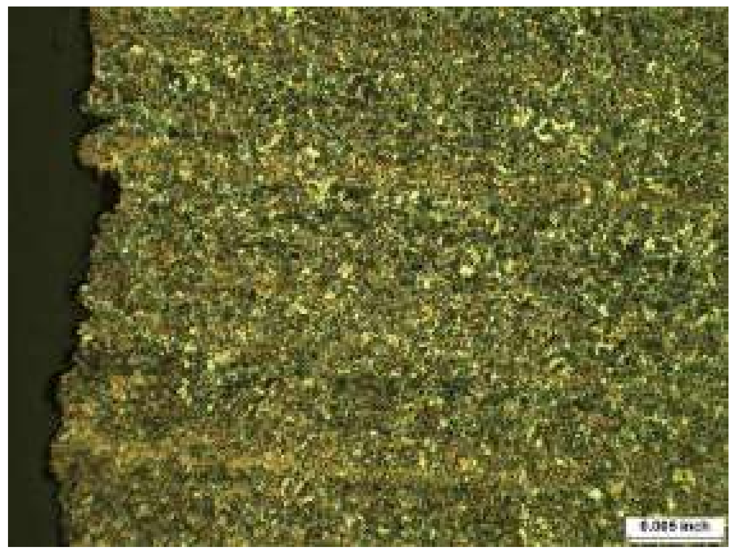
20' 6-13/16" from the North Girth Weld
2% Nital etch, ~100x
Photograph No. 181

20' 6-13/16" from the North Girth Weld
2% Nital etch, ~100x
Photograph No. 182

The micrographs display hook crack(s) following the upturned bands of acicular martensite and manganese sulfide inclusions.

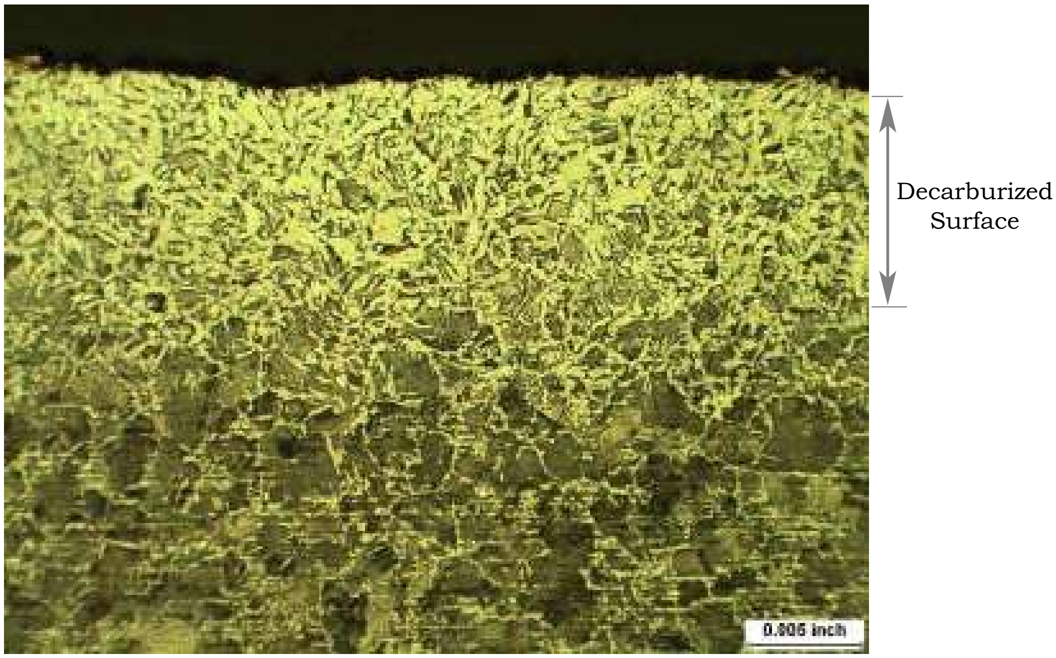


20' 6-13/16" from the North Girth Weld
2% Nital etch, ~100x
Photograph No. 183

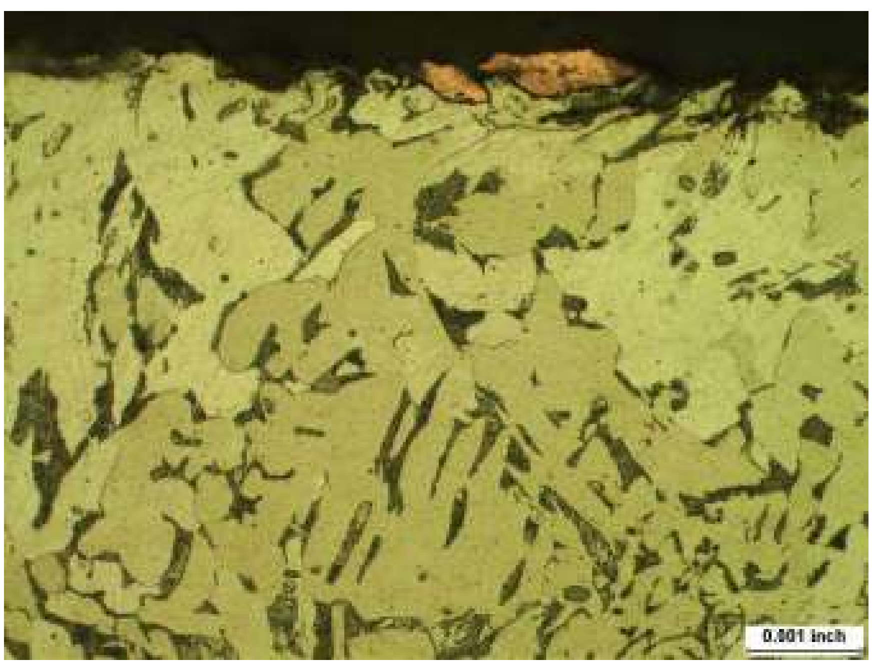


20' 6-13/16" from the North Girth Weld
2% Nital etch, ~100x
Photograph No. 184

The micrographs display the mating fracture faces of the final fracture near the I.D. of the ERW joint. The microstructure consists of grain boundary ferrite, unresolved bainite, and bands of acicular untempered martensite.

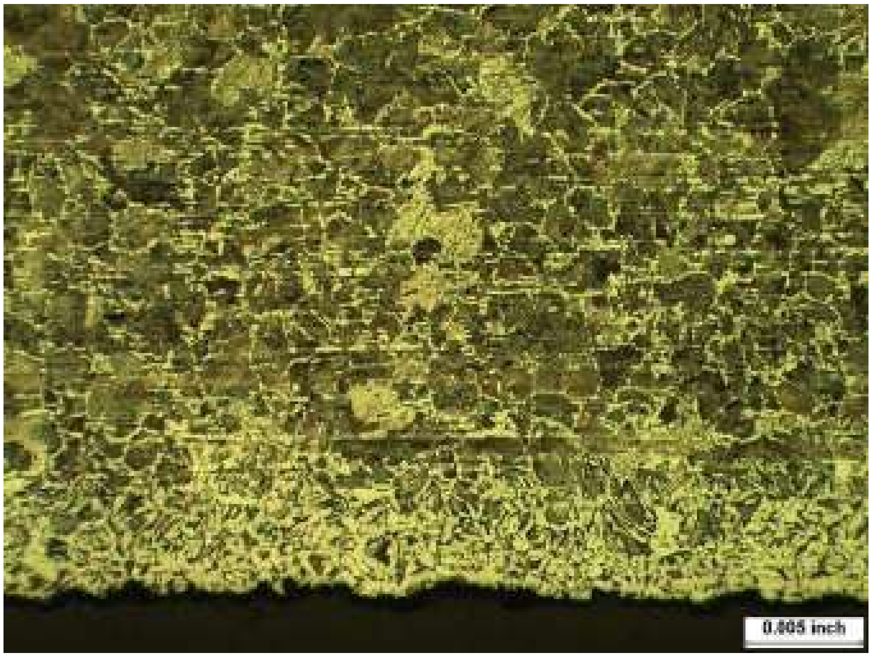


20' 6-13/16" from the North Girth Weld
2% Nital etch, ~100x
Photograph No. 185



20' 6-13/16" from the North Girth Weld
2% Nital etch, ~500x
Photograph No. 186

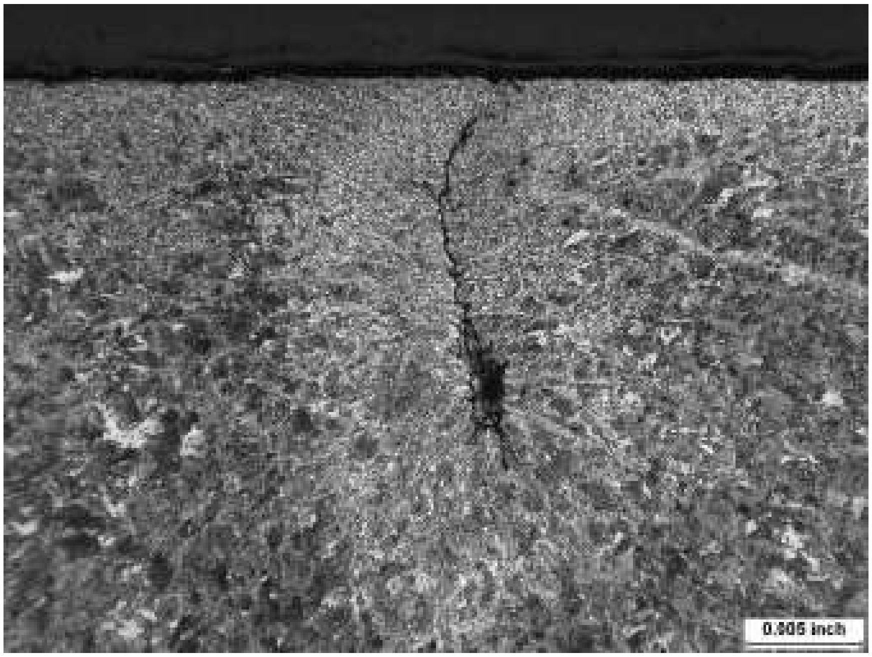
The micrographs display the evidence of surface decarburization along the O.D. surface near the ERW seam and the presence of copper from the electrode contact during the initial seam welding of the pipe.



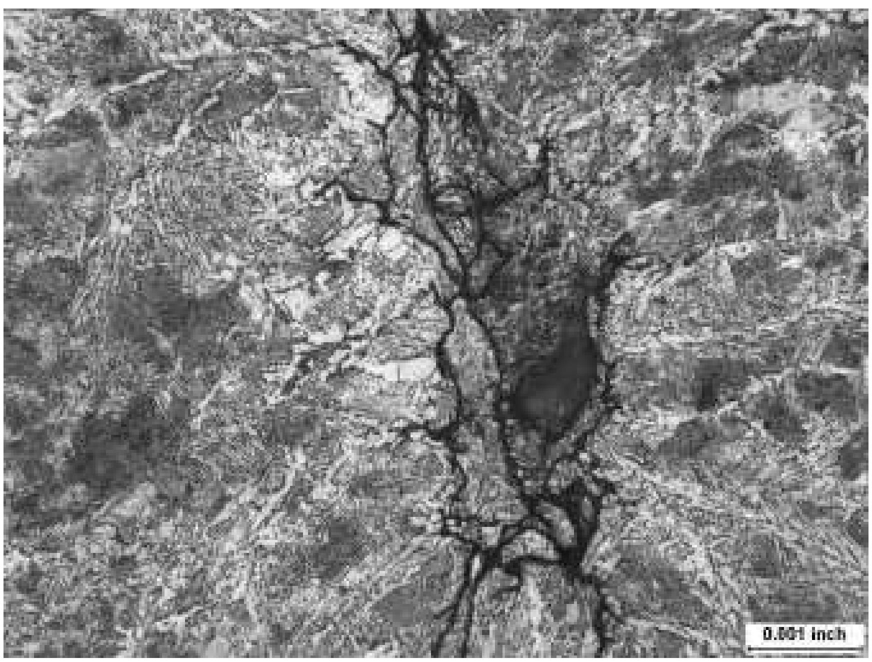
20' 6-13/16" from the North Girth Weld
2% Nital etch, ~100x
Photograph No. 187

20' 6-13/16" from the North Girth Weld
2% Nital etch, ~500x
Photograph No. 188

The micrographs display the evidence of surface decarburization along the I.D. surface near the ERW seam.

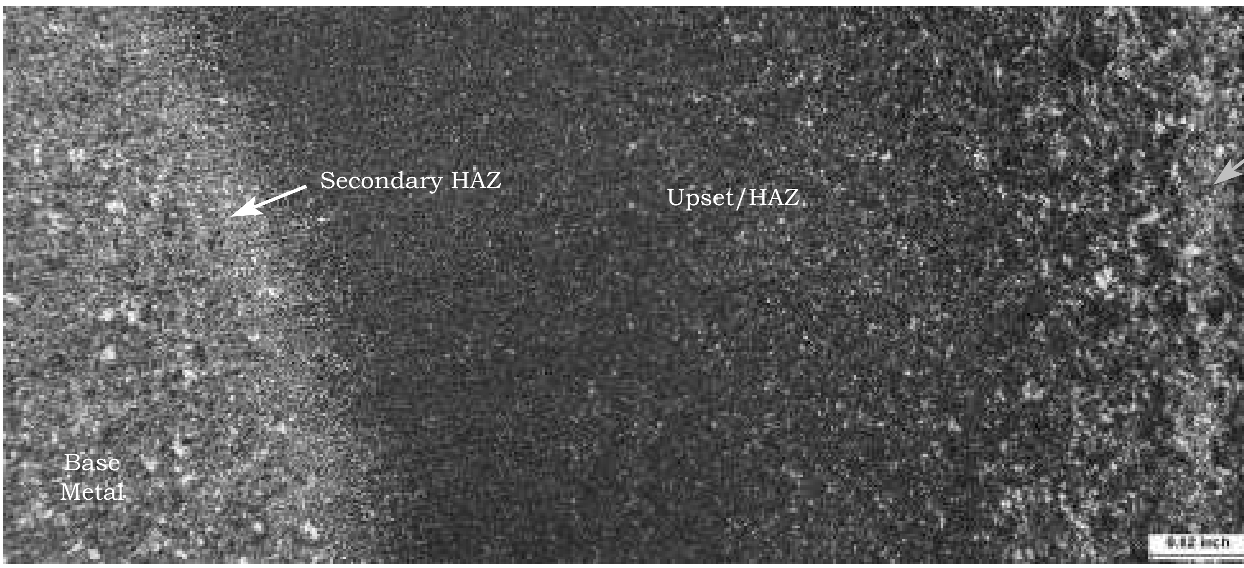


20' 6-13/16" from the North Girth Weld
2% Nital etch, ~100x
Photograph No. 189



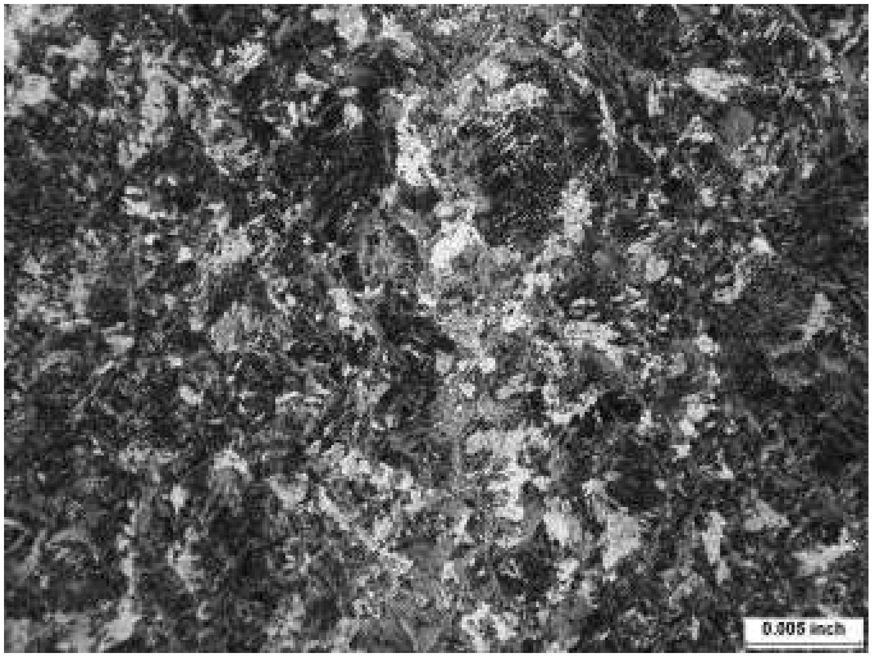
20' 6-13/16" from the North Girth Weld
2% Nital etch, ~500x
Photograph No. 190

The micrographs display one of the contact marks which resulted from the electrical contact between the electrode supplying the welding current and the pipe surface. Note cracks through resolidified metal near the ERW seam within the primary HAZ.



Fusion Line to Base Metal
2% Nital etch, ~25x
Photograph No. 191

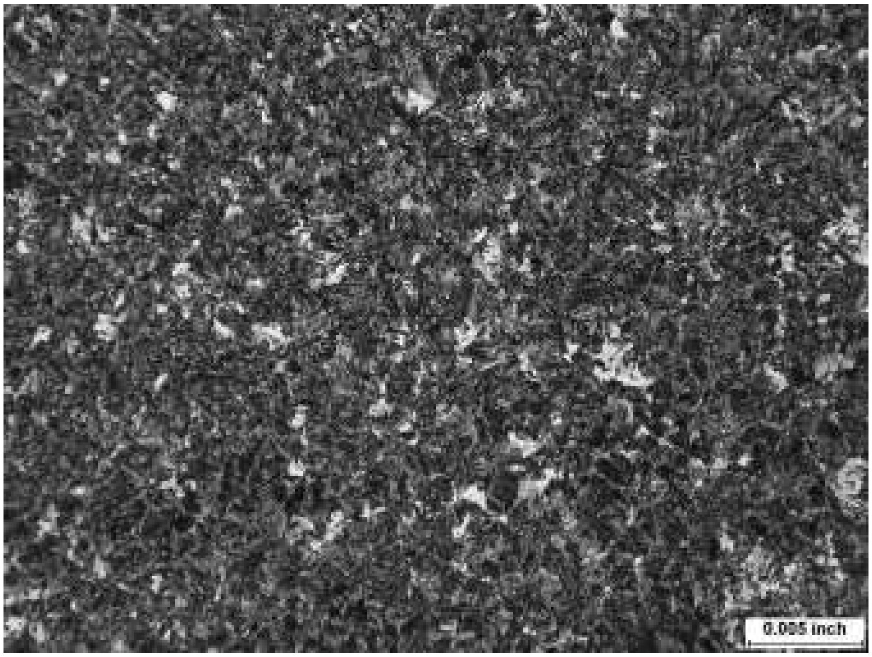
The micrograph displays the microstructural phases between the fusion line and the base metal of the ERW seam.



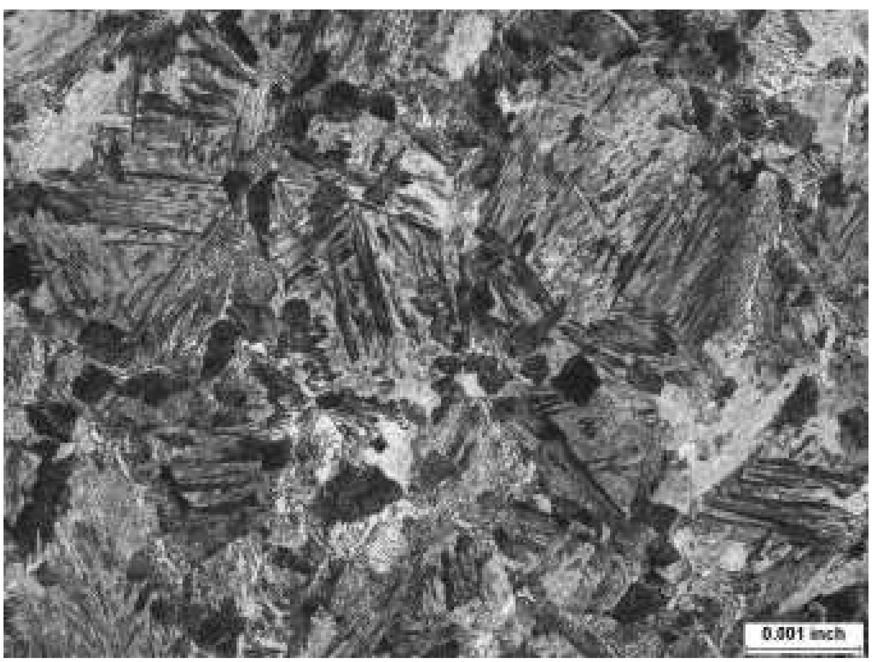
Fusion Line
2% Nital etch, ~100x
Photograph No. 192

Fusion Line
2% Nital etch, ~100x
Photograph No. 193

The micrographs display untempered bainitic/martensitic microstructure at the fusion line of the ERW seam.

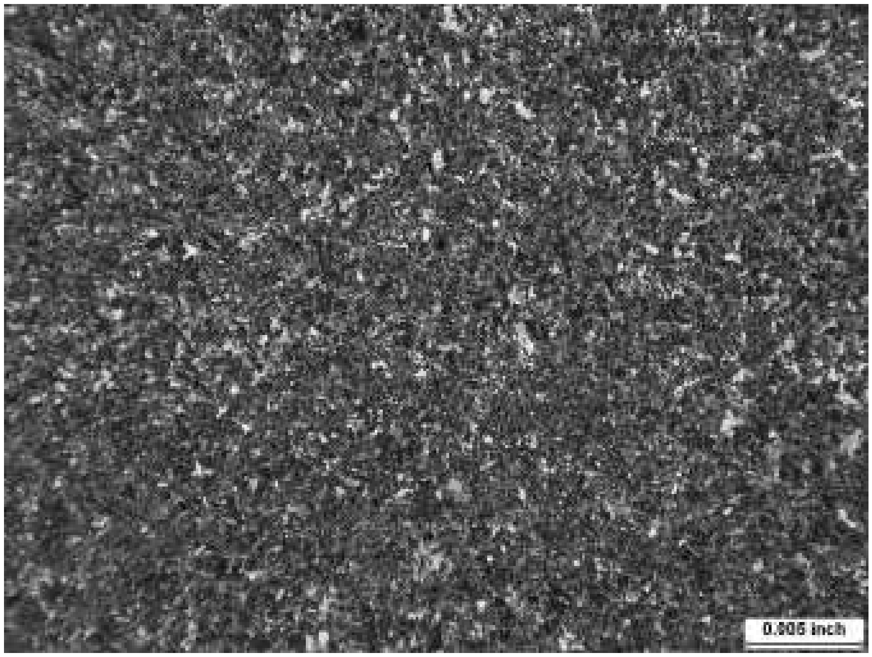


20' 6-13/16" from the North Girth Weld
2% Nital etch, ~100x
Photograph No. 194

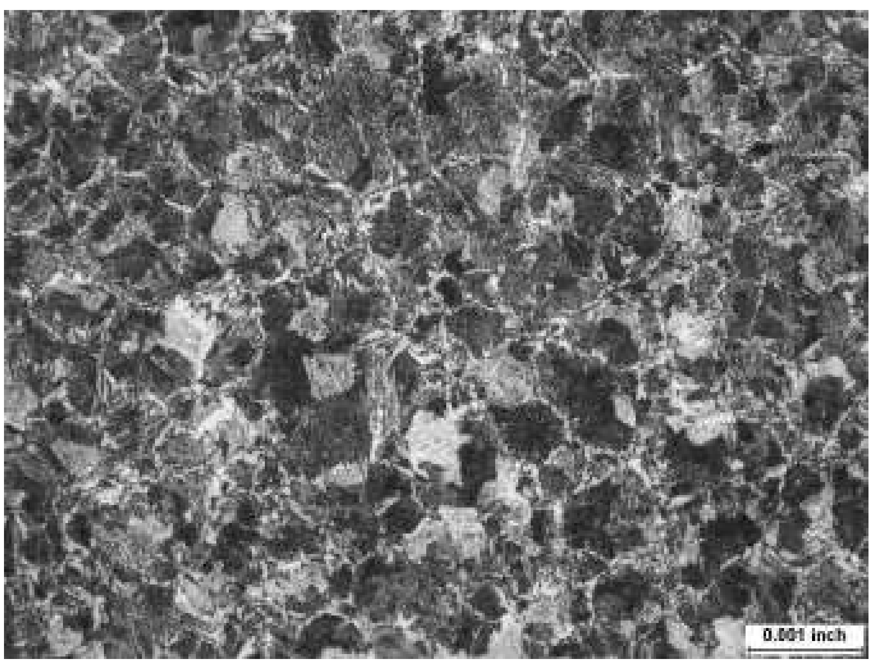


20' 6-13/16" from the North Girth Weld
2% Nital etch, ~500x
Photograph No. 195

The micrographs of the primary HAZ display mix-microstructure consisting of grain boundary ferrite and untempered acicular martensite.

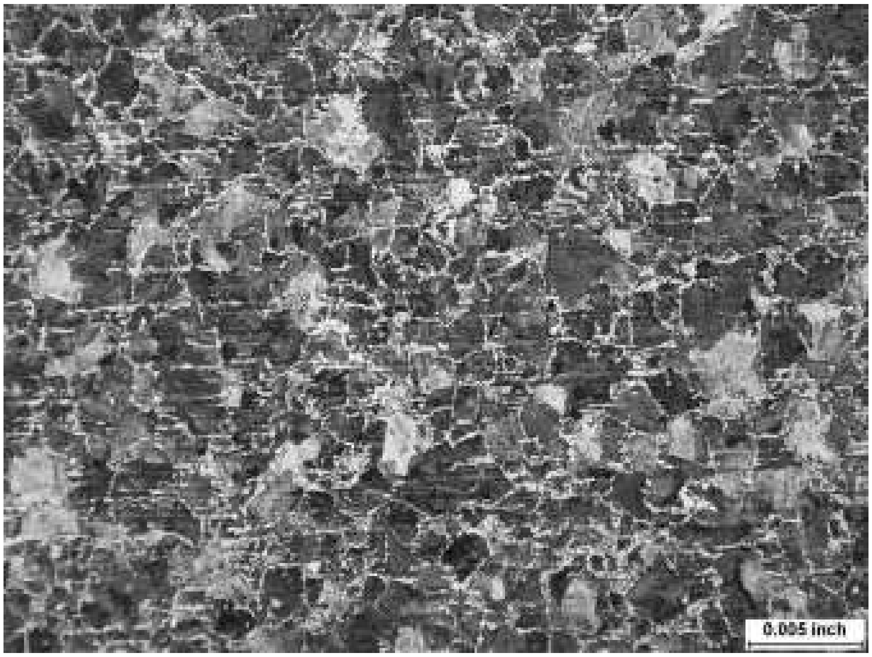


20' 6-13/16" from the North Girth Weld
2% Nital etch, ~100x
Photograph No. 196

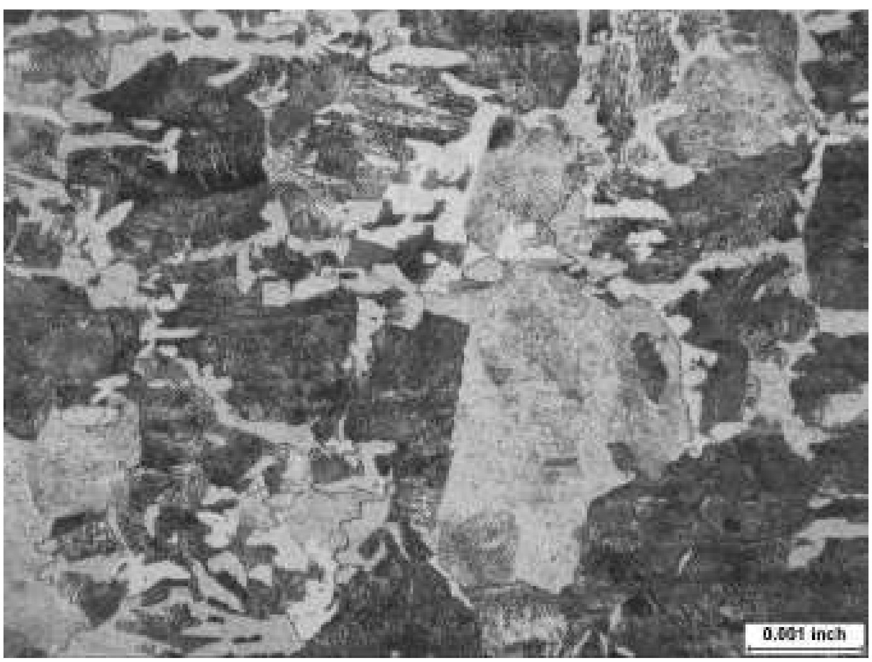


20' 6-13/16" from the North Girth Weld
2% Nital etch, ~500x
Photograph No. 197

The micrographs of the secondary HAZ display essentially the grain boundary ferrite and unresolved pearlite.



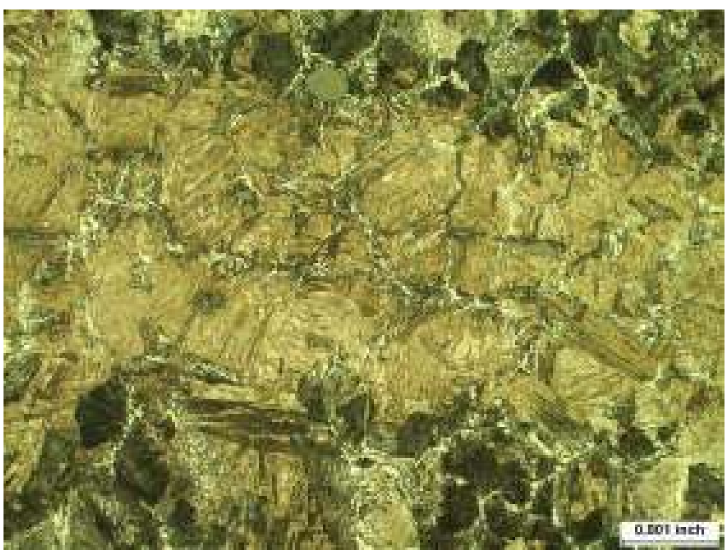
20' 6-13/16" from the North Girth Weld
2% Nital etch, ~100x
Photograph No. 198



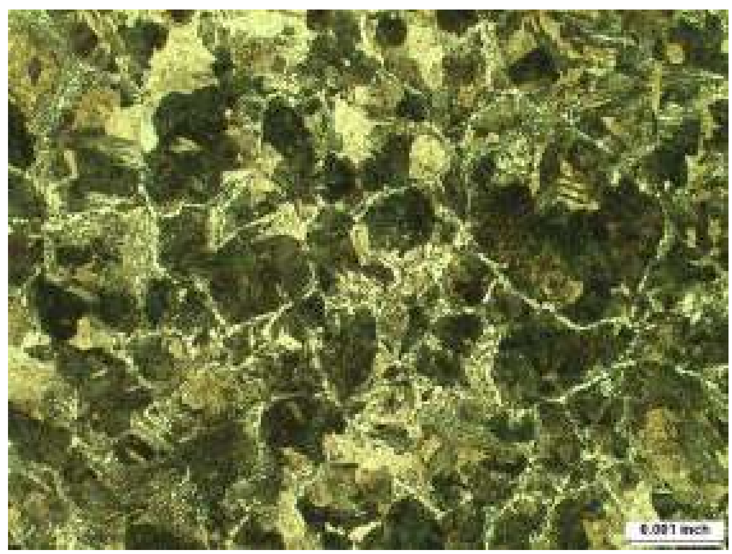
20' 6-13/16" from the North Girth Weld
2% Nital etch, ~500x
Photograph No. 199

The micrographs of the base metal display the grain boundary ferrite and lamellar pearlite.

20' 6-13/16" from the North Girth Weld
2% Nital etch, ~100x
Photograph No. 200



20' 6-13/16" from the North Girth Weld
2% Nital etch, ~500x
Photograph No. 201

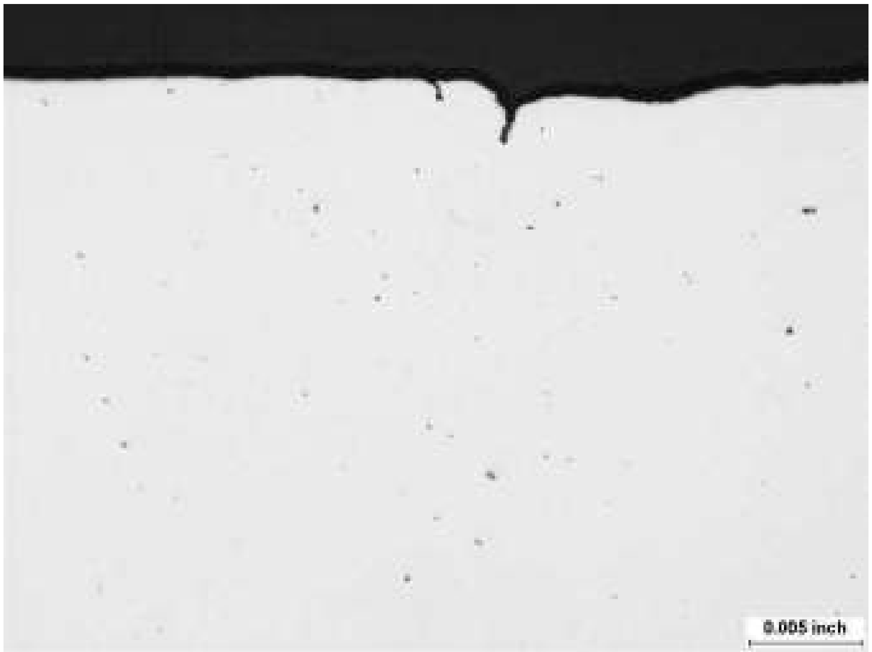


20' 6-13/16" from the North Girth Weld
2% Nital etch, ~500x
Photograph No. 202

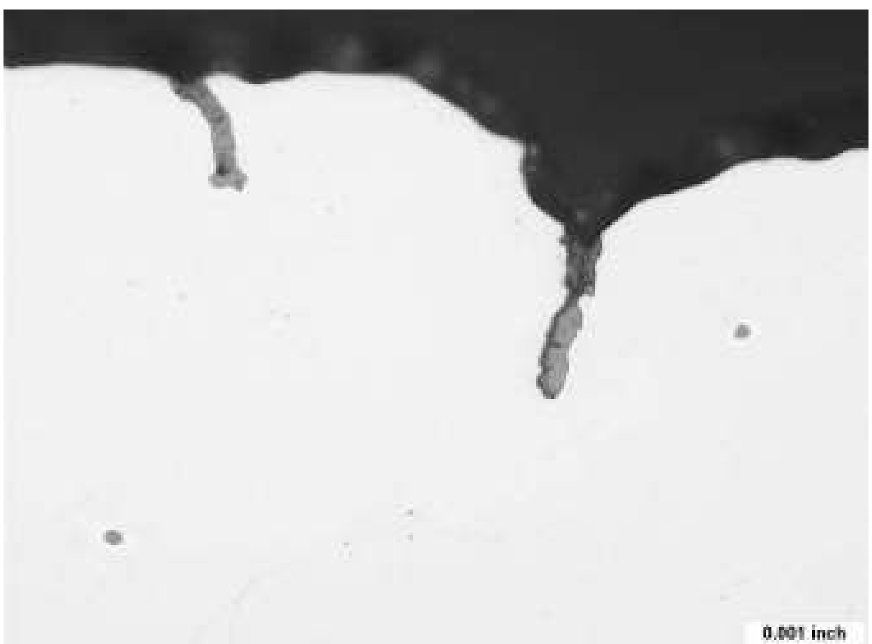
The photographs display banded microstructure in the ERW upset area adjacent to the fusion line, consisting of untempered acicular martensite with entrapped ferrite and ferrite with unresolved bainite in the adjacent non-banded matrix.

35' 8-1/2" from the North Girth Weld
As-polished, ~25x
Photograph No. 203

The micrograph of a cross-section removed from the intact ERW seam at a distance of 35' 8-1/2" from the north girth weld displays an excessive amount of manganese sulfide inclusions, some aligned parallel and diagonal to the fusion line during the seam welding process.



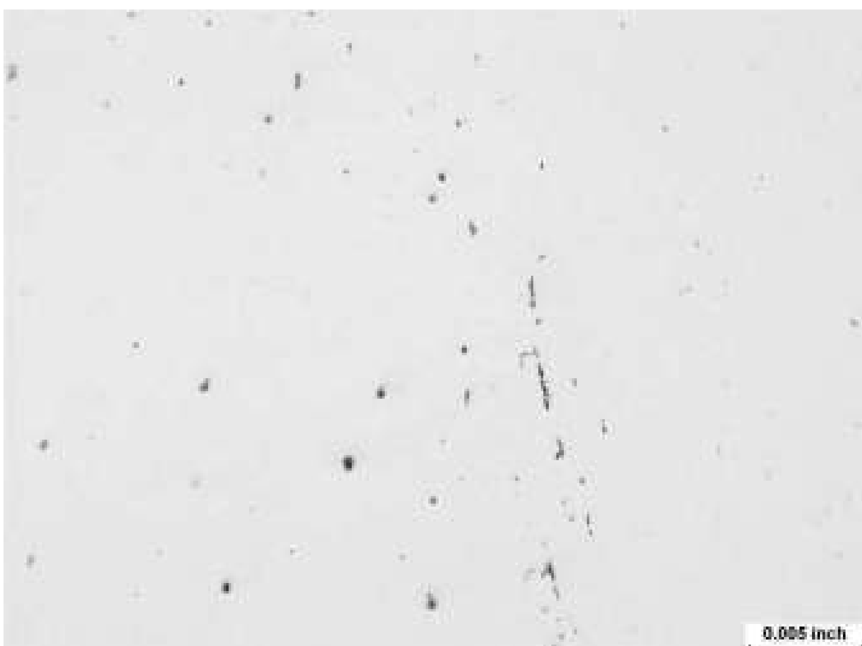
35' 8-1/2" from the North Girth Weld
As-polished, ~100x
Photograph No. 204



35' 8-1/2" from the North Girth Weld
As-polished, ~500x
Photograph No. 205

The micrographs display evidence of some oxidation to a shallow depth of 0.0015" in the upset/HAZ.

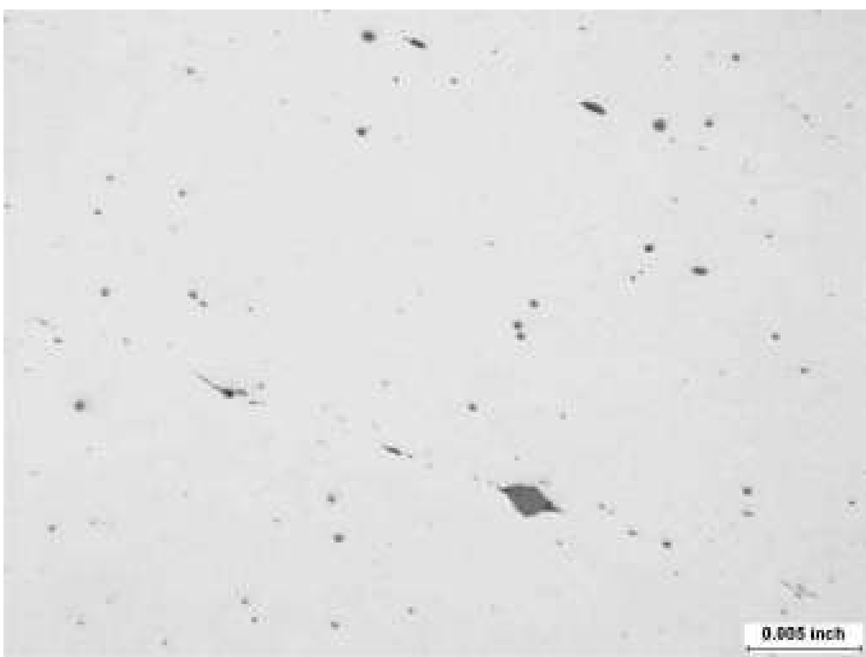
35' 8-1/2" from the North Girth Weld
As-polished, ~100x
Photograph No. 206



35' 8-1/2" from the North Girth Weld
As-polished, ~100x
Photograph No. 207

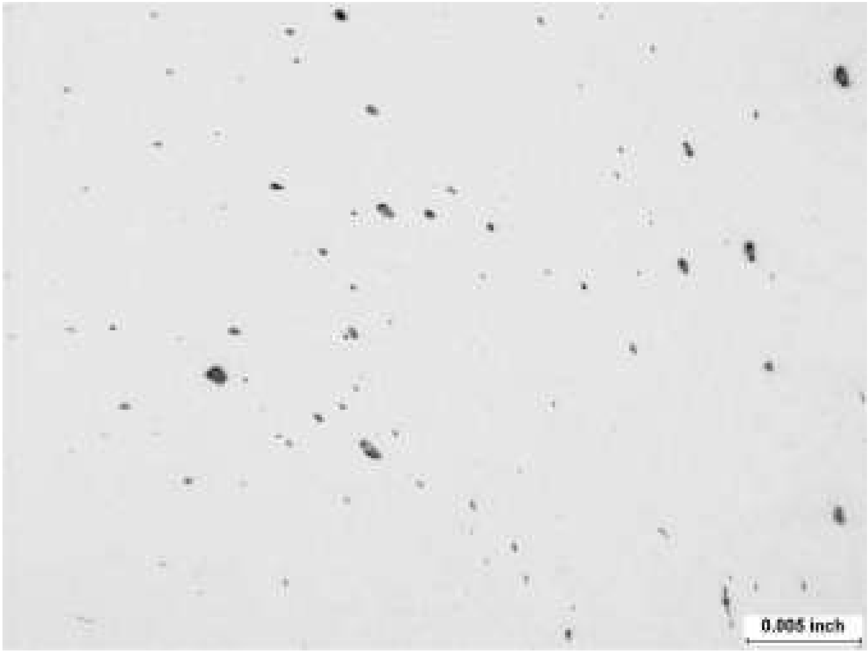
The micrographs display an excessive amount of manganese sulfide inclusions aligned parallel and diagonal to the fusion line in the upset/HAZ near the O.D. of the ERW seam joint.

35' 8-1/2" from the North Girth Weld
As-polished, ~100x
Photograph No. 208

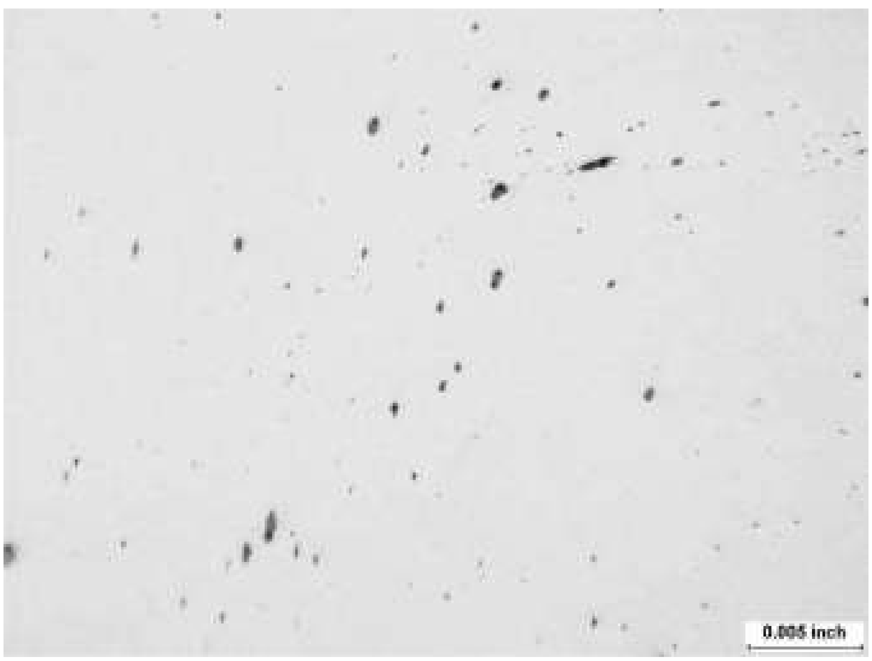


35' 8-1/2" from the North Girth Weld
As-polished, ~100x
Photograph No. 209

The micrographs display an excessive amount of manganese sulfide inclusions aligned parallel and diagonal to the fusion line in the upset/HAZ near the mid-wall of the ERW seam joint.

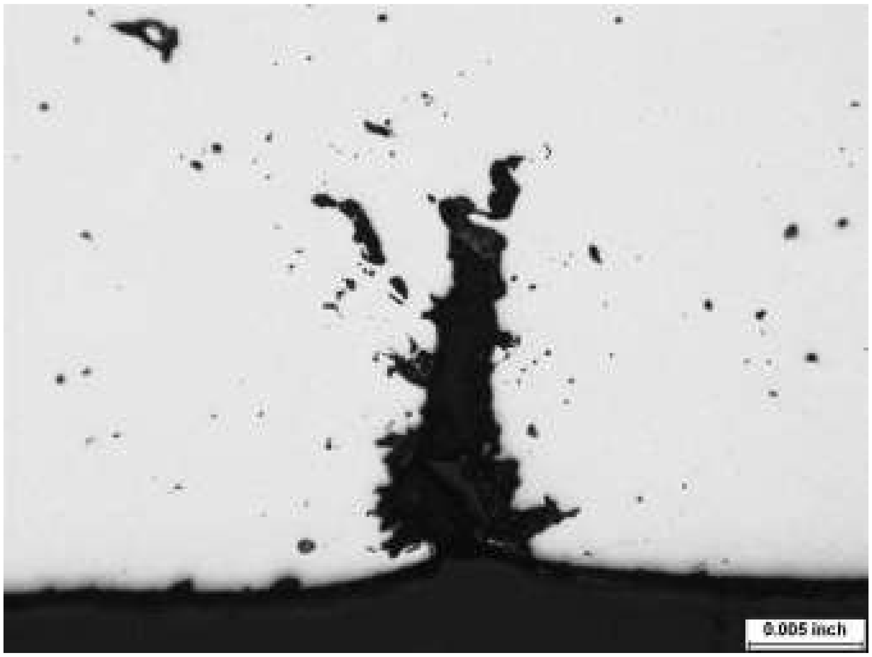


35' 8-1/2" from the North Girth Weld
As-polished, ~100x
Photograph No. 210

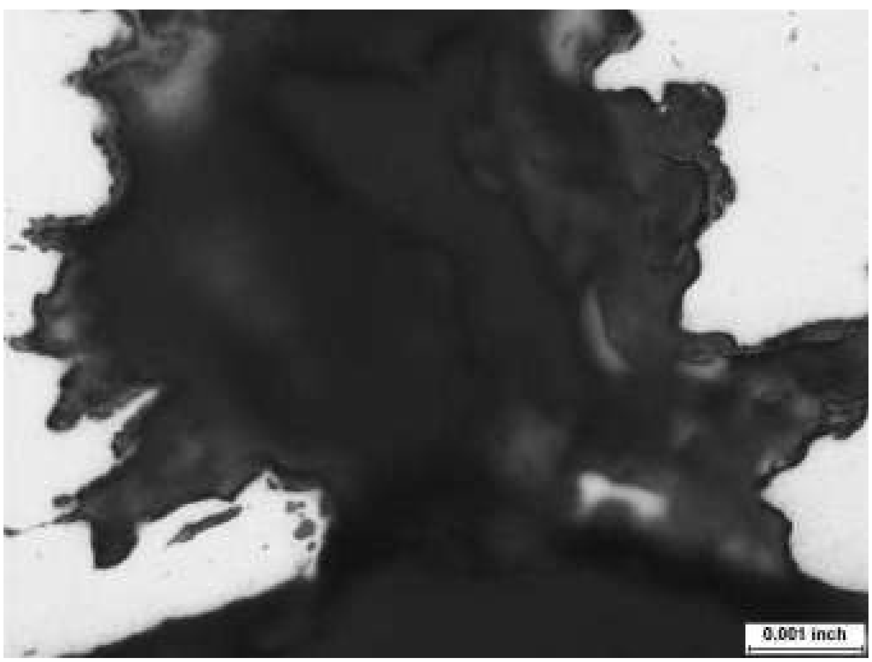


35' 8-1/2" from the North Girth Weld
As-polished, ~100x
Photograph No. 211

The micrographs display an excessive amount of manganese sulfide inclusions, many of them aligned parallel and diagonal to the fusion line in the upset/HAZ near the I.D. of the ERW seam joint.

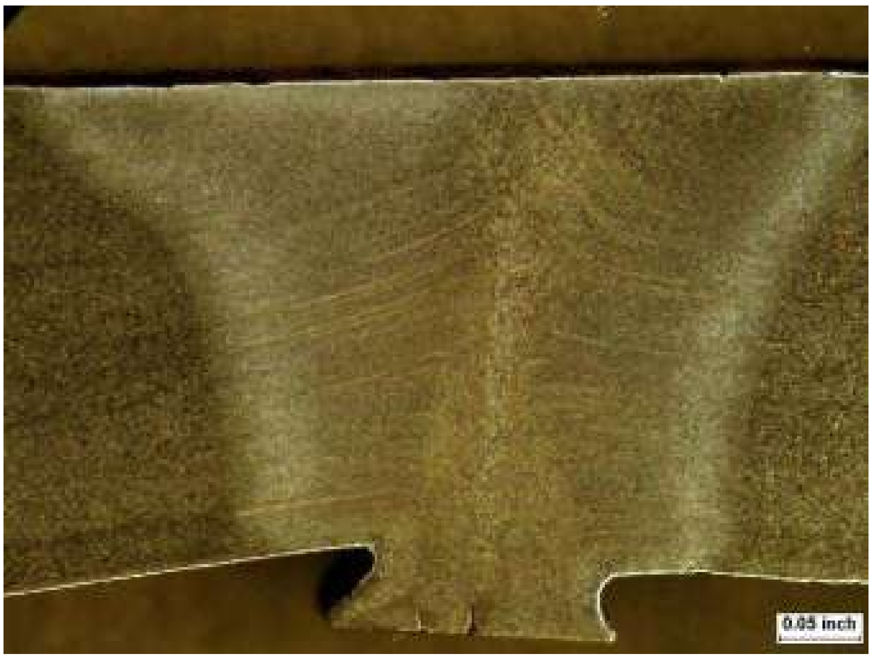


35' 8-1/2" from the North Girth Weld
As-polished, ~100x
Photograph No. 212



35' 8-1/2" from the North Girth Weld
As-polished, ~500x
Photograph No. 213

The micrographs display unfused, expelled weld flash near the I.D. of the ERW seam joint.

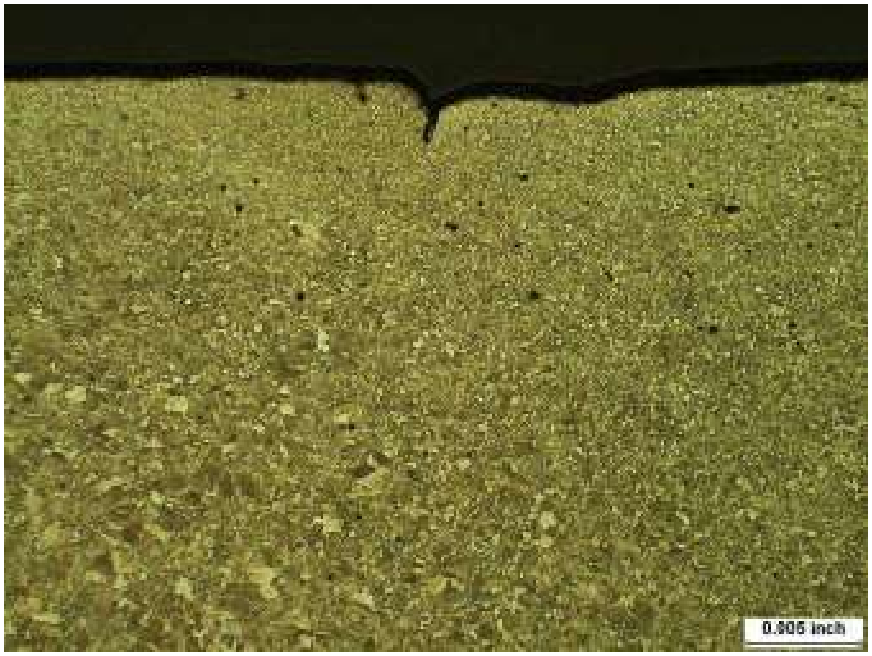


35' 8-1/2" from the North Girth Weld
2% Nital etch, ~20x
Photograph No. 214

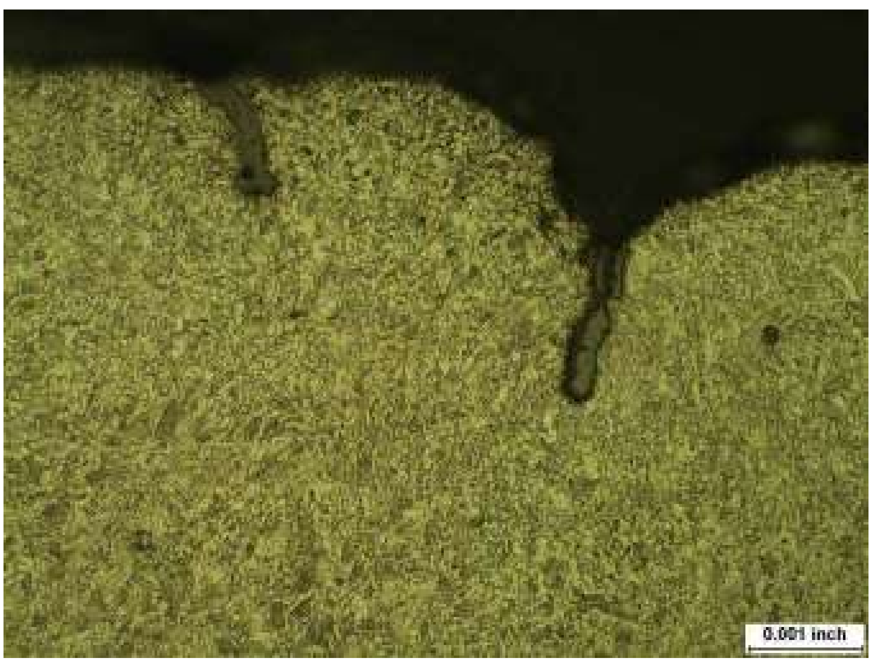
The micrograph of the cross-section removed through the intact ERW seam at a distance of 35' 8-1/2" from the north girth weld and prepared for metallographic examination shows upturned as well as downturned bands in the upset/HAZ, with some bands aligned parallel to the fusion line.

35' 8-1/2" from the North Girth Weld
2% Nital etch, ~25x
Photograph No. 215

The micrograph displays a composite view of the ERW seam cross-section following etching in a 2% Nital solution revealing some upturned grains parallel to the fusion line.

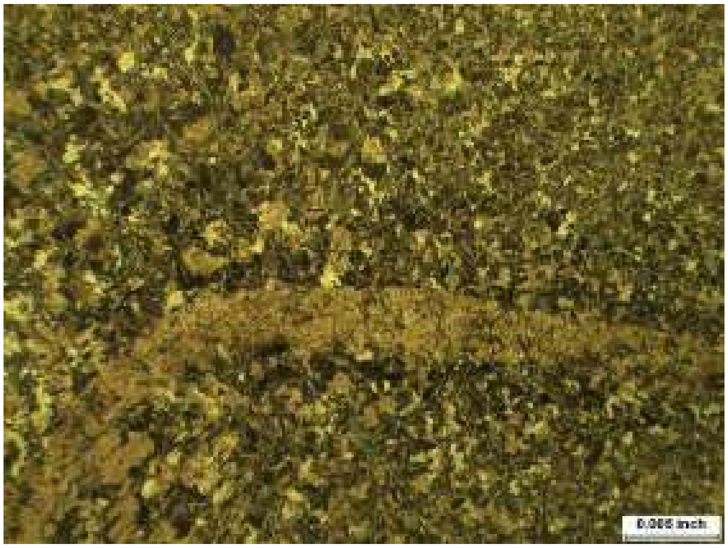


35' 8-1/2" from the North Girth Weld
2% Nital etch, ~100x
Photograph No. 216



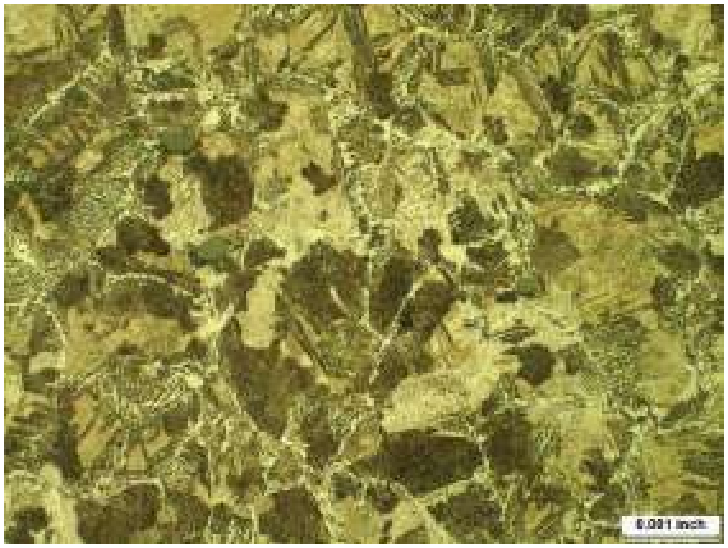
35' 8-1/2" from the North Girth Weld
2% Nital etch, ~500x
Photograph No. 217

The micrographs display evidence of some oxidation near the O.D. in the upset/HAZ of the ERW seam joint. The microstructure near the O.D. consists of essentially ferrite and pearlite.



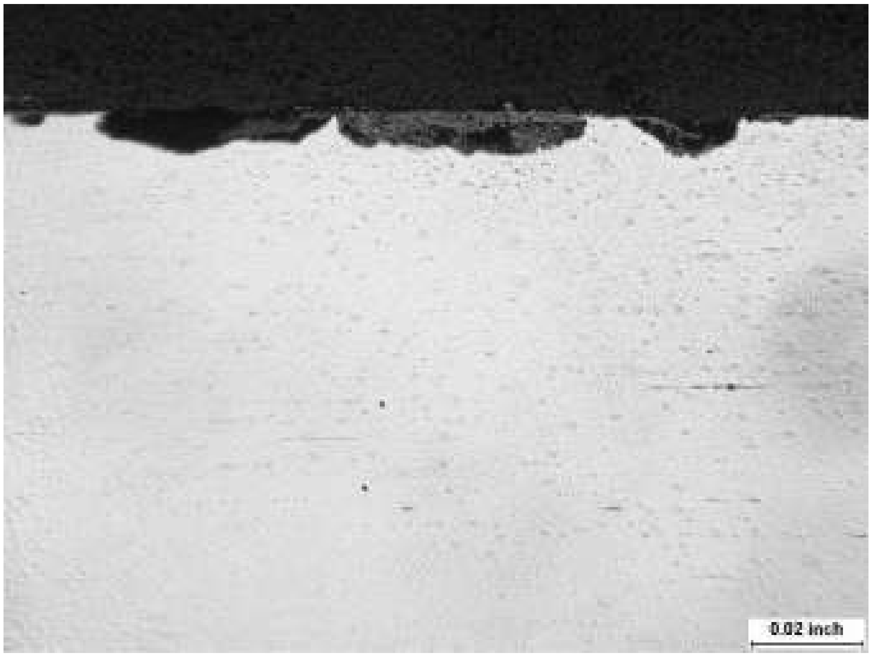
35' 8-1/2" from the North Girth Weld
2% Nital etch, ~100x
Photograph No. 218

35' 8-1/2" from the North Girth Weld
2% Nital etch, ~500x
Photograph No. 219

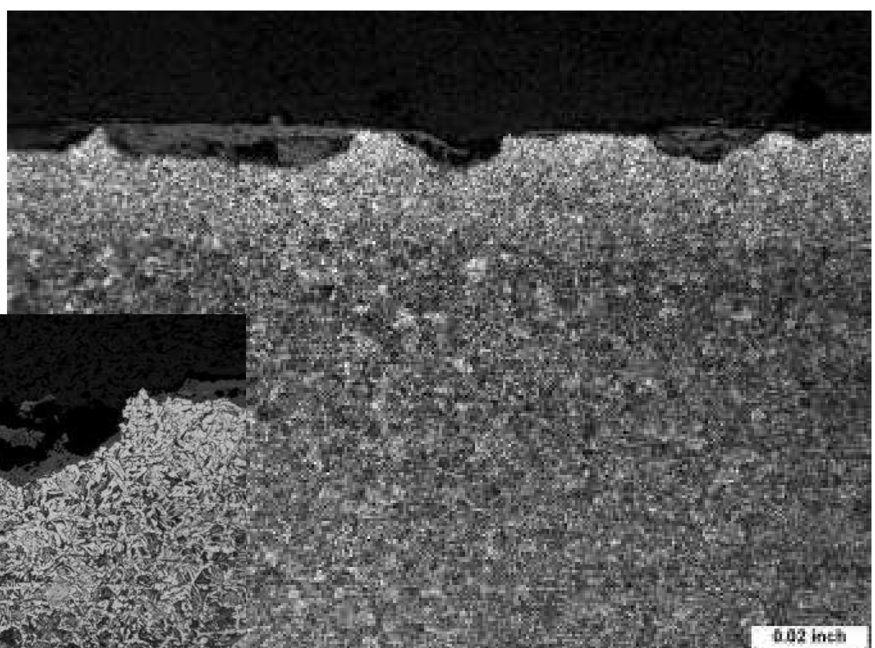


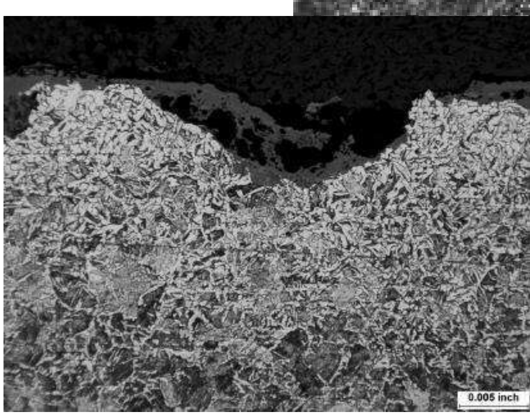
35' 8-1/2" from the North Girth Weld
2% Nital etch, ~500x
Photograph No. 220

The micrographs display untempered brittle martensite in the bands in the upset/HAZ of the ERW seam joint.



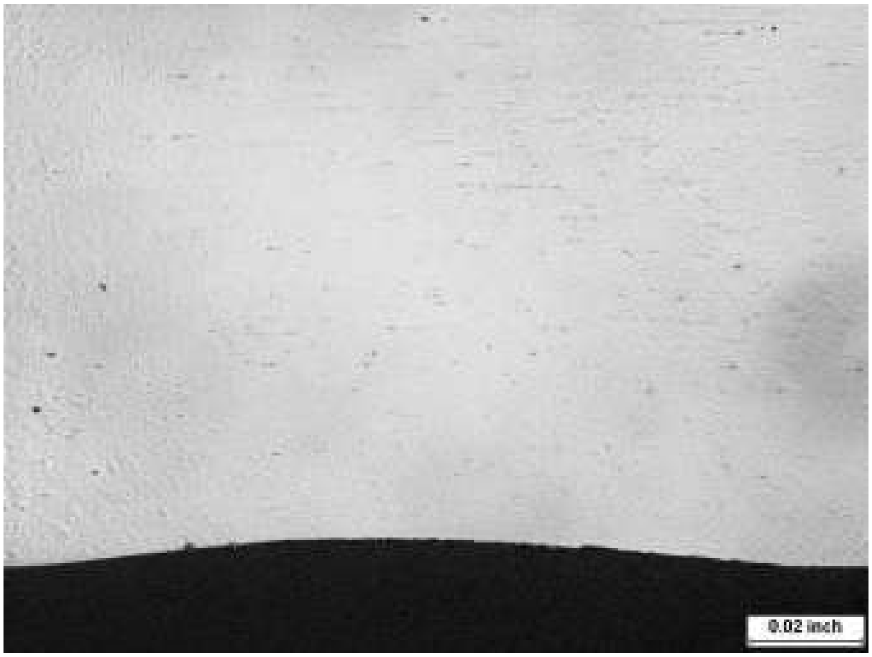
As-polished, ~25x
Photograph No. 221



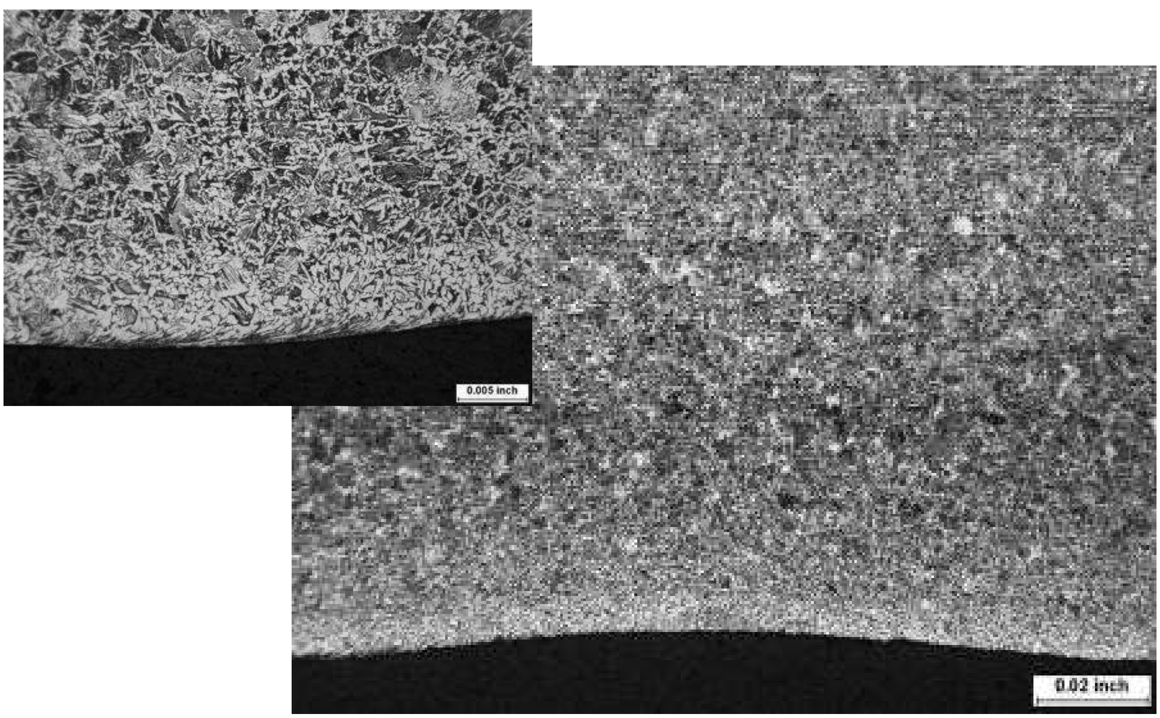


2% Nital etch, ~25x
Photograph No. 222

The micrographs display the microstructural condition at a representative area of the O.D. surface of the pipe, showing the loss of material due to pitting corrosion and the corrosion products adhered to the surface. The insert photograph shows a higher magnification view of a single corrosion pit. The maximum depth of the corrosion pits at this location measured 0.008".

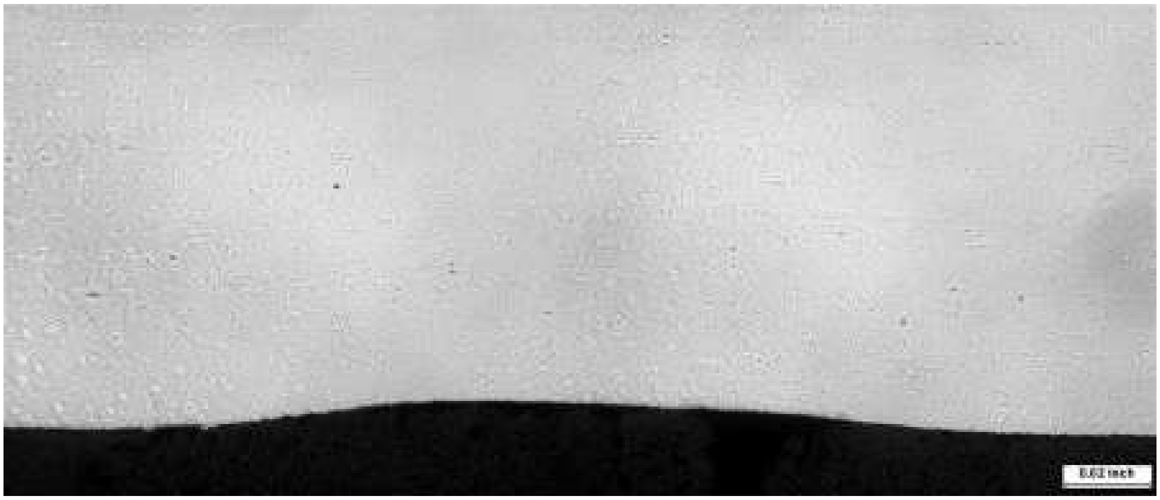


As-polished, ~25x
Photograph No. 223

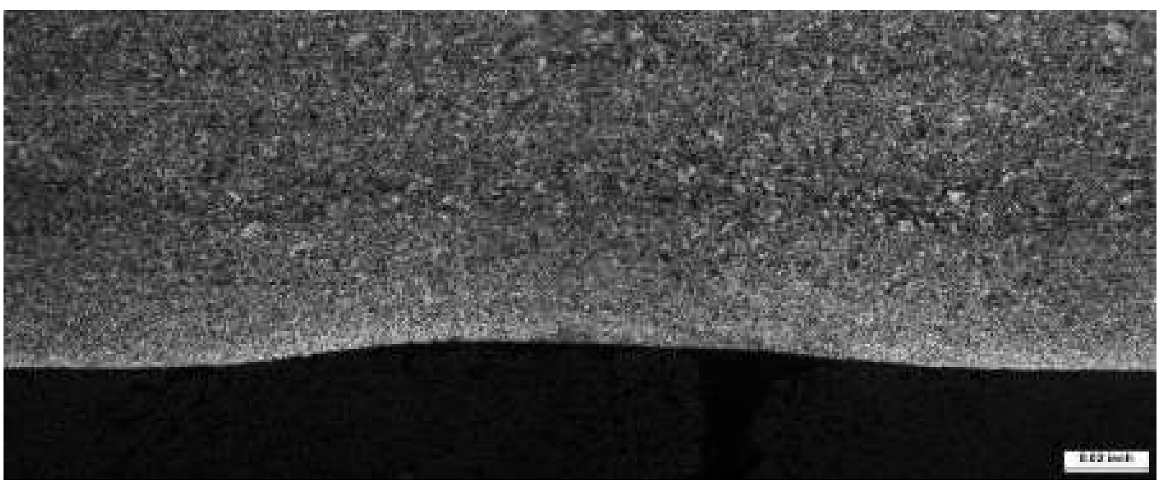


2% Nital etch, ~25x
Photograph No. 224

The micrographs display the microstructural condition at a representative area of the I.D. surface of the pipe, showing one of the shallow indentations observed during the visual examination. Note the uniform layer of partial decarburization on the I.D. surface and the grain flow deformation shown in the insert photograph, both indicating that the shallow depression is due to a mechanical indentation, most likely when the pipe was manufactured, and not corrosion pitting. The impression measured 0.137" wide and 0.005" deep.



As-polished, ~25x
Photograph No. 225



2% Nital etch, ~25x
Photograph No. 226

The composite micrographs display the microstructural condition at another representative area of the I.D. surface of the pipe, showing one of the shallow indentations observed during the visual examination. Note the uniform layer of partial decarburization on the I.D. surface, indicating that the shallow depression is due to a mechanical indentation, most likely when the pipe was manufactured, and not corrosion pitting. The impression measured 0.189" wide and 0.007" deep.

HURST METALLURGICAL RESEARCH LABORATORY, INC.
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Phone (817) 283-4981, Metro 267-3421, Fax: Metro (817) 267-4234
Located in the Dallas/Fort Worth Metroplex

DIMENSIONAL MEASUREMENTS REPORT

TO:

ExxonMobil Pipeline Company

SPECIFIED MATERIAL:

API STD. 5-L, 10th Edition, August 1945, Electric Welded, Open Hearth Steel, Grade B, & ANSI/API Spec. 5L, 44th Edition, October 1, 2007, PSL 1, Welded Pipe, Grade X42

TEST METHOD:

Measured using a calibrated and certified micrometer

DATE OF RECEIPT:

April 16, 2013

P.O. NO.:

UCG/451007854

LABORATORY TEST NO.:

CN0413055

IDENTIFICATION:

33' 11-1/2" long Fractured Section of a 20" O.D. x 0.312" wall Pipe; Removed from Milepost 314.77 in the Conway to Corsicana Pegasus Crude Oil Pipeline after it Failed in Service in Mayflower, Arkansas; Installed in 1947 to 1948

Circumference Location of Measurement		I.D. Measurement Distance from North Girth Weld		
Begins	Ends	-6"	271"	371"
12:00	6:00	19.352"	19.366"	19.392"
1:30	7:30	19.463"	19.375"	19.457"
3:00	9:00	19.353"	19.390"	19.357"
4:30	10:30	19.365"	19.354"	19.437"
Calculated Out of Roundness		0.111"	0.036"	0.100"
API 5L, 44th Edition, Table 10, Pipe Except End Out-of-Roundness Tolerance for Nominal D = 20"				0.400"

THIS IS TO CERTIFY THAT THE ABOVE ARE THE ACTUAL RESULTS OF THE SUBMITTED SAMPLE(S) PREPARED AND TESTED IN ACCORDANCE WITH THE REQUIREMENTS OF THE APPLICABLE SPECIFICATION(S), THE HMRL Q.A. MANUAL, FIFTH EDITION AND ITS IMPLEMENTING PROCEDURES, AS APPLICABLE.

TESTED BY:

Micah Montgomery
Laboratory Technician

May 8, 2013

M. J. Madhani, Chief Metallurgist

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Phone (817) 283-4981, Metro 267-3421, Fax: Metro (817) 267-4234
Located in the Dallas/Fort Worth Metroplex

DIMENSIONAL MEASUREMENTS REPORT

TO:
ExxonMobil Pipeline Company

DATE OF RECEIPT:
April 16, 2013

SPECIFIED MATERIAL:
API STD. 5-L, 10th Edition, August 1945, Electric Welded, Open Hearth Steel, Grade B, & ANSI/API Spec. 5L, 44th Edition, October 1, 2007, PSL 1, Welded Pipe, Grade X42

P.O. NO.:
UCG/451007854

TEST METHOD:
Measured using a calibrated and certified micrometer

LABORATORY TEST NO.:
CN0413055-1

IDENTIFICATION:
33' 11-1/2" long Fractured Section of a 20" O.D. x 0.312" wall Pipe; Removed from Milepost 314.77 in the Conway to Corsicana Pegasus Crude Oil Pipeline after it Failed in Service in Mayflower, Arkansas; Installed in 1947 to 1948

Distance from North Girth Weld (feet)	(inches)	Wall Thickness at Crack (inches) West	East	Distance from North Girth Weld (feet)	(inches)	Wall Thickness at Crack (inches) West	(East	Distance from North Girth Weld (feet)	(inches)	Wall Thickness at Crack (inches) West	East
	40	0.316	0.312		116	0.317	0.313	16	192	0.319	0.315
	42	0.317	0.317		118	0.317	0.314		194	0.320	0.315
	44	0.317	0.311	10	120	0.318	0.313		196	0.318	0.314
	46	0.312	0.311		122	0.316	0.313		198	0.318	0.314
4	48	0.311	0.312		124	0.317	0.313		200	0.319	0.315
	50	0.311	0.314		126	0.318	0.314		202	0.319	0.314
	52	0.316	0.312		128	0.319	0.313	17	204	0.319	0.313
	54	0.313	0.311		130	0.318	0.314		206	0.319	0.315
	56	0.313	0.311	11	132	0.317	0.314		208	0.320	0.315
	58	0.313	0.312		134	0.317	0.314		210	0.319	0.316
5	60	0.315	0.312		136	0.317	0.314		212	0.320	0.313
	62	0.313	0.313		138	0.318	0.315		214	0.320	0.313
	64	0.313	0.312		140	0.318	0.315	18	216	0.319	0.313
	66	0.313	0.311		142	0.319	0.314		218	0.318	0.315
	68	0.314	0.311	12	144	0.319	0.315		220	0.318	0.314
	70	0.314	0.310		146	0.319	0.317		222	0.318	0.313
6	72	0.315	0.311		148	0.320	0.315		224	0.317	0.315
	74	0.314	0.312		150	0.320	0.314		226	0.318	0.313
	76	0.317	0.313		152	0.320	0.314	19	228	0.318	0.313
	78	0.315	0.313		154	0.320	0.315		230	0.318	0.312
	80	0.315	0.312	13	156	0.320	0.314		232	0.318	0.313
	82	0.315	0.314		158	0.321	0.315		234	0.319	0.314
7	84	0.315	0.312		160	0.319	0.315		236	0.318	0.314
	86	0.316	0.314		162	0.319	0.313		238	0.316	0.313
	88	0.314	0.314		164	0.319	0.313	20	240	0.318	0.312
	90	0.315	0.313		166	0.318	0.313		242	0.317	0.313
	92	0.316	0.313	14	168	0.319	0.315		244	0.317	0.311
	94	0.317	0.314		170	0.320	0.316		246	0.316	0.311
8	96	0.316	0.314		172	0.318	0.315		248	0.316	0.311
	98	0.315	0.314		174	0.319	0.314		250	0.316	0.311
	100	0.317	0.314		176	0.318	0.314	21	252	0.317	0.311
	102	0.316	0.314		178	0.319	0.315		254	0.315	0.312
	104	0.317	0.314	15	180	0.319	0.313		256	0.316	0.312
	106	0.317	0.318		182	0.318	0.313		258	0.315	0.312
9	108	0.315	0.314		184	0.320	0.315		260	0.315	0.313
	110	0.317	0.315		186	0.320	0.316		262	0.315	0.313
	112	0.316	0.315		188	0.320	0.315	22	264	0.314	0.311
	114	0.317	0.314		190	0.319	0.315		266	*	0.311

*Unable to measure due to geometry of crack tip.

THIS IS TO CERTIFY THAT THE ABOVE ARE THE ACTUAL RESULTS OF THE SUBMITTED SAMPLE(S) PREPARED AND TESTED IN ACCORDANCE WITH THE REQUIREMENTS OF THE APPLICABLE SPECIFICATION(S), THE HMRL Q.A. MANUAL, FIFTH EDITION AND ITS IMPLEMENTING PROCEDURES, AS APPLICABLE.

TESTED BY:
Micah Montgomery
Laboratory Technician

April 24, 2013

M. J. Madhani, Chief Metallurgist

HURST METALLURGICAL RESEARCH LABORATORY, INC.
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Phone (817) 283-4981, Metro 267-3421, Fax: Metro (817) 267-4234
Located in the Dallas/Fort Worth Metroplex

DIMENSIONAL MEASUREMENTS REPORT

TO:
ExxonMobil Pipeline Company

DATE OF RECEIPT:
April 16, 2013

SPECIFIED MATERIAL:
API STD. 5-L, 10th Edition, August 1945, Electric Welded, Open Hearth Steel, Grade B, &
ANSI/API Spec. 5L, 44th Edition, October 1, 2007, PSL 1, Welded Pipe, Grade X42

P.O. NO.:
UCG/451007854

TEST METHOD:
Measured using an Optical Stereomicroscope and calibrated Image Analysis Software

LABORATORY TEST NO.:
CN0413055

IDENTIFICATION:
33' 11-1/2" long Fractured Section of a 20" O.D. x 0.312" wall Pipe; Removed from Milepost 314.77 in the Conway to Corsicana Pegasus Crude Oil Pipeline after it Failed in Service in Mayflower, Arkansas; Installed in 1947 to 1948

Distance from	Depth of Cracks Below Surface (inches)		Distance from	Depth of Cracks Below Surface (inches)		Distance from	Depth of Cracks Below Surface (inches)	
North Girth Weld	O.D.	I.D.	North Girth Weld	O.D.	I.D.	North Girth Weld	O.D.	I.D.
19' 10"	*	*	20' 2"	0.109	*	20' 6"	0.135	*
19' 10-1/8"	0.078	*	20' 2-1/8"	0.102	*	20' 6-1/8"	0.144	*
19' 10-1/4"	0.079	*	20' 2-1/4"	0.104	*	20' 6-1/4"	0.137	*
19' 10-3/8"	0.087	*	20' 2-3/8"	0.093	*	20' 6-3/8"	0.137	*
19' 10-1/2"	0.093	*	20' 2-1/2"	0.104	*	20' 6-1/2"	0.141	0.017
19' 10-5/8"	0.082	*	20' 2-5/8"	0.107	*	20' 6-5/8"	0.141	0.030
19' 10-3/4"	0.098	*	20' 2-3/4"	0.108	*	20' 6-3/4"	0.138	0.030
19' 10-7/8"	0.091	*	20' 2-7/8"	0.116	*	20' 6-7/8"	0.129	0.050
19' 11"	0.112	*	20' 3"	0.124	*	20' 7"	0.141	0.029
19' 11-1/8"	0.104	*	20' 3-1/8"	0.124	*	20' 7-1/8"	0.150	0.025
19' 11-1/4"	0.107	*	20' 3-1/4"	0.133	*	20' 7-1/4"	0.148	0.027
19' 11-3/8"	0.105	*	20' 3-3/8"	0.128	*	20' 7-3/8"	0.150	*
19' 11-1/2"	0.113	*	20' 3-1/2"	0.136	*	20' 7-1/2"	0.141	*
19' 11-5/8"	0.107	*	20' 3-5/8"	0.144	*	20' 7-5/8"	0.098	*
19' 11-3/4"	0.102	*	20' 3-3/4"	0.148	*	20' 7-3/4"	0.092	*
19' 11-7/8"	0.092	*	20' 3-7/8"	0.141	*	20' 7-7/8"	0.078	*
20'	0.102	*	20' 4"	0.140	*	20' 8"	0.133	*
20' 1/8"	0.099	*	20' 4-1/8"	0.136	*	20' 8-1/8"	0.138	*
20' 1/4"	0.102	*	20' 4-1/4"	0.142	*	20' 8-1/4"	0.136	*
20' 3/8"	0.101	*	20' 4-3/8"	0.140	*	20' 8-3/8"	0.132	*
20' 1/2"	0.125	*	20' 4-1/2"	0.137	*	20' 8-1/2"	0.131	*
20' 5/8"	0.110	*	20' 4-5/8"	0.140	*	20' 8-5/8"	0.138	*
20' 3/4"	0.109	*	20' 4-3/4"	0.135	*	20' 8-3/4"	0.140	*
20' 7/8"	0.104	*	20' 4-7/8"	0.135	*	20' 8-7/8"	0.133	*
20' 1"	0.094	*	20' 5"	0.133	*	20' 9"	0.111	*
20' 1-1/8"	0.117	*	20' 5-1/8"	0.113	*	20' 9-1/8"	0.140	*
20' 1-1/4"	0.112	*	20' 5-1/4"	0.123	*	20' 9-1/4"	0.078	*
29' 1-3/8"	0.103	*	20' 5-3/8"	0.125	*	20' 9-3/8"	0.091	*
20' 1-1/2"	0.114	*	20' 5-1/2"	0.140	*	20' 9-1/2"	0.086	*
20' 1-5/8"	0.109	*	20' 5-5/8"	0.138	*	20' 9-5/8"	0.085	*
20' 1-3/4"	0.103	*	20' 5-3/4"	0.135	*	20' 9-3/4"	0.074	*
20' 1-7/8"	0.106	*	20' 5-7/8"	0.138	*	20' 9-7/8"	0.079	*

*No hook cracks at this location.

THIS IS TO CERTIFY THAT THE ABOVE ARE THE ACTUAL RESULTS OF THE SUBMITTED SAMPLE(S) PREPARED AND TESTED IN ACCORDANCE WITH THE REQUIREMENTS OF THE APPLICABLE SPECIFICATION(S), THE HMRL Q.A. MANUAL, FIFTH EDITION AND ITS IMPLEMENTING PROCEDURES, AS APPLICABLE.

TESTED BY:
Susan Dalrymple-Ely
Susan Dalrymple-Ely
Materials Analyst

April 26, 2013

M. J. Madhani
M. J. Madhani, Chief Metallurgist

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Located in the Dallas/Fort Worth Metroplex

DIMENSIONAL MEASUREMENTS REPORT

TO:
ExxonMobil Pipeline Company
SPECIFIED MATERIAL:
API STD. 5-L, 10th Edition, August 1945, Electric Welded, Open Hearth Steel, Grade B, & ANSI/API Spec. 5L, 44th Edition, October 1, 2007, PSL 1, Welded Pipe, Grade X42
TEST METHOD:
Measured using an Optical Stereomicroscope and calibrated Image Analysis Software

DATE OF RECEIPT:
April 16, 2013
P.O. NO.:
UCG/451007854
LABORATORY TEST NO.:
CN0413055

IDENTIFICATION:
33' 11-1/2" long Fractured Section of a 20" O.D. x 0.312" wall Pipe; Removed from Milepost 314.77 in the Conway to Corsicana Pegasus Crude Oil Pipeline after it Failed in Service in Mayflower, Arkansas; Installed in 1947 to 1948

Distance from North Girth Weld	Depth of Cracks Below Surface (inches) O.D.	I.D.	Distance from North Girth Weld	Depth of Cracks Below Surface (inches) O.D.	I.D.	Distance from North Girth Weld	Depth of Cracks Below Surface (inches) O.D.	I.D.
20' 10"	0.077	*	21' 3"	0.027	0.057	21' 8"	*	0.068
20' 10-1/8"	0.085	*	21' 3-1/8"	0.031	*	21' 8-1/8"	*	0.078
20' 10-1/4"	0.075	*	21' 3-1/4"	0.052	*	21' 8-1/4"	*	0.079
20' 10-3/8"	0.057	0.081	21' 3-3/8"	0.118	*	21' 8-3/8"	*	0.079
20' 10-1/2"	0.060	0.083	21' 3-1/2"	0.124	0.088	21' 8-1/2"	*	0.085
20' 10-5/8"	0.069	0.091	21' 3-5/8"	0.130	0.094	21' 8-5/8"	*	0.088
20' 10-3/4"	0.064	0.088	21' 3-3/4"	0.130	0.091	21' 8-3/4"	*	0.082
20' 10-7/8"	0.061	0.088	21' 3-7/8"	0.122	0.086	21' 8-7/8"	*	0.092
20' 11"	0.055	*	21' 4"	0.133	0.091	21' 9"	*	0.080
20' 11-1/8"	0.038	*	21' 4-1/8"	0.134	*	21' 9-1/8"	*	0.071
20' 11-1/4"	0.036	*	21' 4-1/4"	0.135	*	21' 9-1/4"	*	0.057
20' 11-3/8"	0.044	*	21' 4-3/8"	0.135	*	21' 9-3/8"	*	*
20' 11-1/2"	*	*	21' 4-1/2"	0.140	*	21' 9-1/2"	*	*
20' 11-5/8"	*	*	21' 4-5/8"	0.138	*	21' 9-5/8"	*	*
20' 11-3/4"	*	*	21' 4-3/4"	0.124	*	21' 9-3/4"	*	*
20' 11-7/8"	*	*	21' 4-7/8"	0.126	*	21' 9-7/8"	*	*
21'	*	*	21' 5"	0.117	*	21' 10"	*	*
21' 1/8"	*	*	21' 5-1/8"	0.112	*	21' 10-1/8"	*	*
21' 1/4"	*	*	21' 5-1/4"	0.133	*	21' 10-1/4"	*	*
21' 3/8"	0.039	*	21' 5-3/8"	0.130	*	21' 10-3/8"	*	*
21' 1/2"	0.029	*	21' 5-1/2"	0.120	*	21' 10-1/2"	*	*
21' 5/8"	0.040	*	21' 5-5/8"	0.112	0.044	21' 10-5/8"	*	*
21' 3/4"	0.016	*	21' 5-3/4"	0.119	0.095	21' 10-3/4"	*	*
21' 7/8"	0.028	*	21' 5-7/8"	0.126	0.096	21' 10-7/8"	*	*
21' 1"	0.038	*	21' 6"	0.122	0.092	21' 11"	*	*
21' 1-1/8"	0.038	*	21' 6-1/8"	0.107	0.087	21' 11-1/8"	*	*
21' 1-1/4"	0.062	*	21' 6-1/4"	0.106	0.084	21' 11-1/4"	*	*
21' 1-3/8"	0.029	*	21' 6-3/8"	0.110	0.070	21' 11-3/8"	*	*
21' 1-1/2"	0.088	*	21' 6-1/2"	0.112	*	21' 11-1/2"	*	*
21' 1-5/8"	0.077	*	21' 6-5/8"	0.099	*	21' 11-5/8"	*	*
21' 1-3/4"	0.082	*	21' 6-3/4"	0.083	*	21' 11-3/4"	*	*
21' 1-7/8"	0.060	*	21' 6-7/8"	0.089	*	21' 11-7/8"	*	*
21' 2"	0.112	*	21' 7"	0.091	0.046	22"	*	*
21' 2-1/8"	0.110	0.085	21' 7-1/8"	0.092	0.038			
21' 2-1/4"	0.110	0.097	21' 7-1/4"	0.084	0.031			
21' 2-3/8"	0.104	0.098	21' 7-3/8"	0.092	0.039			
21' 2-1/2"	0.103	0.095	21' 7-1/2"	0.096	0.067			
21' 2-5/8"	0.037	0.085	21' 7-5/8"	0.093	0.060			
21' 2-3/4"	0.044	0.080	21' 7-3/4"	0.043	0.065			
21' 2-7/8"	0.037	0.062	21' 7-7/8"	*	0.064			

*No hook cracks at this location.

THIS IS TO CERTIFY THAT THE ABOVE ARE THE ACTUAL RESULTS OF THE SUBMITTED SAMPLE(S) PREPARED AND TESTED IN ACCORDANCE WITH THE REQUIREMENTS OF THE APPLICABLE SPECIFICATION(S), THE HMRL Q.A. MANUAL, FIFTH EDITION AND ITS IMPLEMENTING PROCEDURES, AS APPLICABLE.

TESTED BY:
Susan Dalrymple-Ely
Susan Dalrymple-Ely
Materials Analyst

April 26, 2013

M. J. Madhani
M. J. Madhani, Chief Metallurgist

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Phone (817) 283-4981, Metro 267-3421, Fax: Metro (817) 267-4234
Located in the Dallas/Fort Worth Metroplex

DIMENSIONAL MEASUREMENTS OF HOOK CRACKS

TO:

ExxonMobil Pipeline Company

SPECIFIED MATERIAL:

API STD. 5-L, 10th Edition, August 1945, Electric Welded, Open Hearth Steel, Grade B, & ANSI/API Spec. 5L, 44th Edition, October 1, 2007, PSL 1, Welded Pipe, Grade X42

TEST METHOD:

Calibrated Image Analysis Software

DATE OF RECEIPT:

April 16, 2013

P.O. NO.:

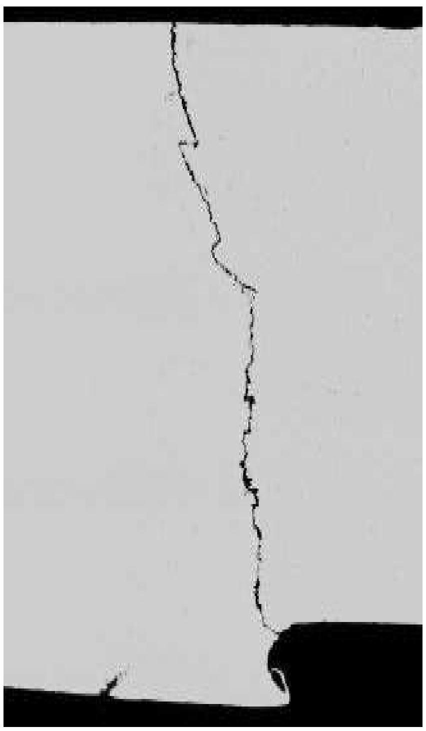
UCG/451007854

LABORATORY TEST NO.:

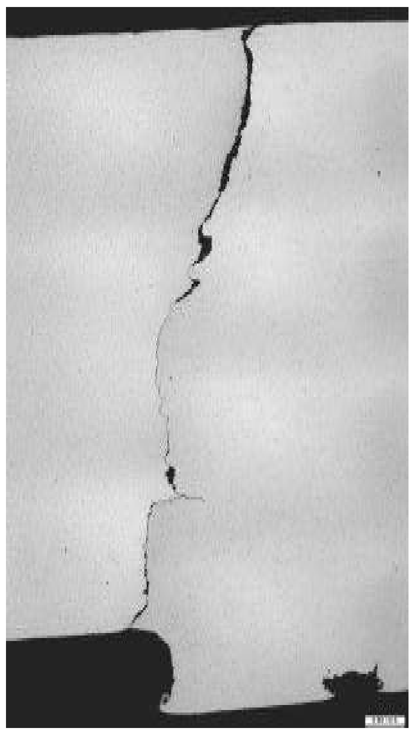
CN0413055

IDENTIFICATION:

33' 11-1/2" long Fractured Section of a 20" O.D. x 0.312" wall Pipe; Removed from Milepost 314.77 in the Conway to Corsicana Pegasus Crude Oil Pipeline after it Failed in Service in Mayflower, Arkansas; Installed in 1947 to 1948



20' 3-3/4"



20' 4-7/8"

20' 5-1/2"

Distance from the North Gird Weld	Hook Crack Width			Hook Crack Depth
	Minimum	Average	Maximum	
20' 3-3/4"	0.0008"	0.0013"	0.0023"	0.145"
20' 4-7/8"	0.0018"	0.0028"	0.0038"	0.145"
20' 5-1/2"	0.0006"	0.0016"	0.0031"	0.133"

Note: The maximum hook crack depth where measured on the fracture surface was measured to be 0.150", as recorded in Table 3.

THIS IS TO CERTIFY THAT THE ABOVE ARE THE ACTUAL RESULTS OF THE SUBMITTED SAMPLE(S) PREPARED AND TESTED IN ACCORDANCE WITH THE REQUIREMENTS OF THE APPLICABLE SPECIFICATION(S), THE HMRL Q.A. MANUAL, FIFTH EDITION AND ITS IMPLEMENTING PROCEDURES, AS APPLICABLE.

TESTED BY:
Clint Myers
Clint Myers
Staff Metallurgist

May 14, 2013

M. J. Madhani
M. J. Madhani, Chief Metallurgist

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Located in the Dallas/Fort Worth Metroplex

MICROHARDNESS TEST REPORT

TO:
ExxonMobil Pipeline Company

DATE OF RECEIPT:
April 16, 2013

SPECIFIED MATERIAL:
API STD. 5-L, 10th Edition, August 1945, Electric Welded, Open Hearth Steel, Grade B, & ANSI/API Spec. 5L, 44th Edition, October 1, 2007, PSL 1, Welded Pipe, Grade X42

TEST METHOD:
ASTM E384-11$^{\epsilon 1}$

P.O. NO.:
UCG/451007854

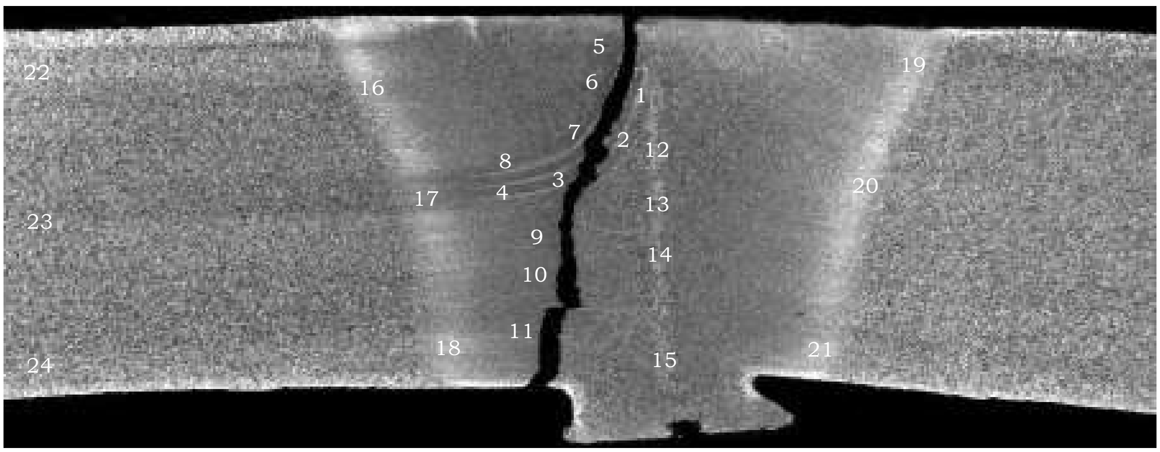
SCALE:
Vickers

LOAD FORCE:
500 g

INDENTER:
Vickers

LABORATORY TEST NO.:
CN0413055

IDENTIFICATION:
33' 11-1/2" long Fractured Section of a 20" O.D. x 0.312" wall Pipe; Removed from Milepost 314.77 in the Conway to Corsicana Pegasus Crude Oil Pipeline after it Failed in Service in Mayflower, Arkansas; Installed in 1947 to 1948; Test Location: 20' 4-7/8" from the North Girth Weld



Indentation Number	Test Location	Hardness, HV500g	Conversion to Rockwell Scale
1	Hardened Upturned Martensitic Grains	549	52 HRC
2		560	53 HRC
3		574	54 HRC
4		509	50 HRC
5	Hook Crack(s)	279	27 HRC
6		285	28 HRC
7		308	31 HRC
8		295	29 HRC
9	Final Fracture (Primary HAZ)	280	27 HRC
10		298	29 HRC
11		280	27 HRC

Indentation Number	Test Location	Hardness, HV500g	Conversion to Rockwell Scale
12	ERW Fusion Line	408	42 HRC
13		492	49 HRC
14		399	41 HRC
15		335	34 HRC
16	Secondary HAZ	225	97 HRB
17		240	20 HRC
18		226	98 HRB
19		248	22 HRC
20		240	100 HRB
21		240	100 HRB
22	Base Metal	206	94 HRB
23		228	98 HRB
24		218	96 HRB

Test was performed using calibrated Wilson Tukon Model 230 Tester, S/N 892214. Rockwell hardness numbers converted from Knoop or Vickers scales are approximations based on ASTM E 140-07 and are typically higher than the hardness values obtained using the actual scale.

THIS IS TO CERTIFY THAT THE ABOVE ARE THE ACTUAL RESULTS OF THE SUBMITTED SAMPLE(S) PREPARED AND TESTED IN ACCORDANCE WITH THE REQUIREMENTS OF THE APPLICABLE SPECIFICATION(S), THE HMRL Q.A. MANUAL, FIFTH EDITION AND ITS IMPLEMENTING PROCEDURES, AS APPLICABLE.

TESTED BY:
J. E.

DATE TESTED:
May 10, 2013

Joseph Eskew, C.W.I., Laboratory Services Manager

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MICROHARDNESS TEST REPORT

TO:
ExxonMobil Pipeline Company

DATE OF RECEIPT:
April 16, 2013

SPECIFIED MATERIAL:
API STD. 5-L, 10th Edition, August 1945, Electric Welded, Open Hearth Steel, Grade B, & ANSI/API Spec. 5L, 44th Edition, October 1, 2007, PSL 1, Welded Pipe, Grade X42

TEST METHOD:
ASTM E384-11$^{\epsilon 1}$

P.O. NO.:
UCG/451007854

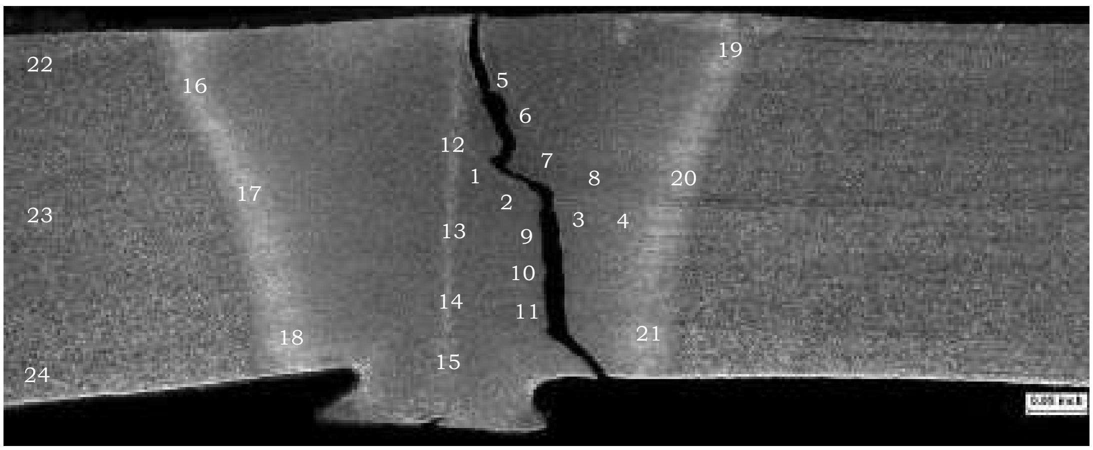
SCALE:
Vickers

LOAD FORCE:
500 g

INDENTER:
Vickers

LABORATORY TEST NO.:
CN0413055

IDENTIFICATION:
33' 11-1/2" long Fractured Section of a 20" O.D. x 0.312" wall Pipe; Removed from Milepost 314.77 in the Conway to Corsicana Pegasus Crude Oil Pipeline after it Failed in Service in Mayflower, Arkansas; Installed in 1947 to 1948; Test Location: 20' 6-13/16" from the North Girth Weld



Indentation Number	Test Location	Hardness, HV500g	Conversion to Rockwell Scale
1	Hardened Upturned Martensitic Grains	483	48 HRC
2		483	48 HRC
3		499	49 HRC
4		502	49 HRC
5	Hook Crack(s)	281	27 HRC
6		293	29 HRC
7		310	31 HRC
8		297	29 HRC
9	Final Fracture (Primary HAZ)	338	34 HRC
10		265	25 HRC
11		298	29 HRC

Indentation Number	Test Location	Hardness, HV500g	Conversion to Rockwell Scale
12	ERW Fusion Line	303	30 HRC
13		342	35 HRC
14		330	33 HRC
15		299	30 HRC
16	Secondary HAZ	255	23 HRC
17		231	98 HRB
18		246	22 HRC
19		233	99 HRB
20		258	24 HRC
21		231	98 HRB
22	Base Metal	223	97 HRB
23		250	22 HRC
24		237	100 HRB

Test was performed using calibrated Wilson Tukon Model 230 Tester, S/N 892214. Rockwell hardness numbers converted from Knoop or Vickers scales are approximations based on ASTM E 140-07 and are typically higher than the hardness values obtained using the actual scale.

THIS IS TO CERTIFY THAT THE ABOVE ARE THE ACTUAL RESULTS OF THE SUBMITTED SAMPLE(S) PREPARED AND TESTED IN ACCORDANCE WITH THE REQUIREMENTS OF THE APPLICABLE SPECIFICATION(S), THE HMRL Q.A. MANUAL, FIFTH EDITION AND ITS IMPLEMENTING PROCEDURES, AS APPLICABLE.

TESTED BY:
J. E.

DATE TESTED:
May 10, 2013

Joseph Eskew, C.W.I., Laboratory Services Manager

HURST METALLURGICAL RESEARCH LABORATORY, INC.
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Phone (817) 283-4981, Metro 267-3421, Fax: Metro (817) 267-4234
Located in the Dallas/Fort Worth Metroplex

MICROHARDNESS TEST REPORT

TO:
ExxonMobil Pipeline Company

DATE OF RECEIPT:
April 16, 2013

SPECIFIED MATERIAL:
API STD. 5-L, 10th Edition, August 1945, Electric Welded, Open Hearth Steel, Grade B, & ANSI/API Spec. 5L, 44th Edition, October 1, 2007, PSL 1, Welded Pipe, Grade X42

TEST METHOD:
ASTM E384-11$^{\epsilon 1}$

P.O. NO.:
UCG/451007854

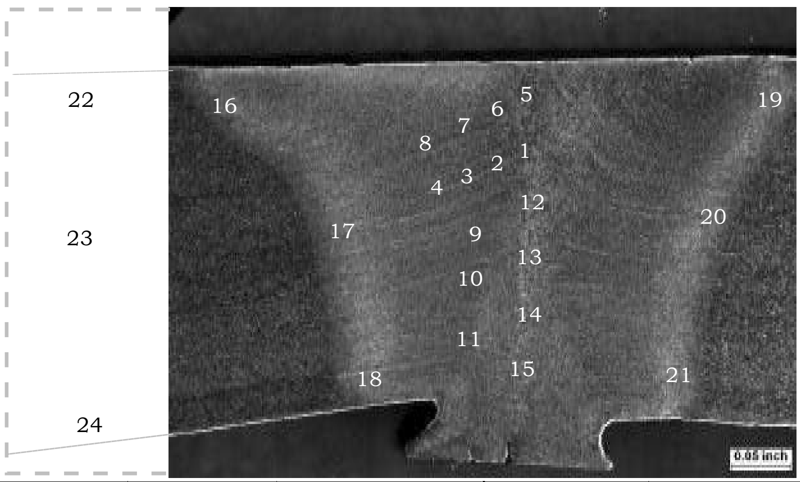
SCALE:
Vickers

LOAD FORCE:
500 g

INDENTER:
Vickers

LABORATORY TEST NO.:
CN0413055

IDENTIFICATION:
19' 10" long Intact Section of a 20" O.D. x 0.312" wall Pipe; Removed from Milepost 314.77 in the Conway to Corsicana Pegasus Crude Oil Pipeline after it Failed in Service in Mayflower, Arkansas; Installed in 1947 to 1948; Test Location: 35' 8-1/2" from the North Girth Weld



Indentation Number	Test Location	Hardness, HV500g	Conversion to Rockwell Scale
1	Hardened Upturned Martensitic Grains	580	54 HRC
2		586	54 HRC
3		391	40 HRC
4		444	45 HRC
5	Primary HAZ	256	23 HRC
6		253	23 HRC
7		276	27 HRC
8		269	26 HRC
9		283	28 HRC
10		241	21 HRC
11		254	23 HRC

Indentation Number	Test Location	Hardness, HV500g	Conversion to Rockwell Scale
12	ERW Fusion Line	334	34 HRC
13		295	29 HRC
14		374	38 HRC
15		516	50 HRC
16	Secondary HAZ	237	100 HRB
17		241	21 HRC
18		228	98 HRB
19		253	23 HRC
20		234	99 HRB
21		219	97 HRB
22	Base Metal	232	99 HRB
23		231	99 HRB
24		249	22 HRC

Test was performed using calibrated Wilson Tukon Model 230 Tester, S/N 892214. Rockwell hardness numbers converted from Knoop or Vickers scales are approximations based on ASTM E 140-07 and are typically higher than the hardness values obtained using the actual scale.

THIS IS TO CERTIFY THAT THE ABOVE ARE THE ACTUAL RESULTS OF THE SUBMITTED SAMPLE(S) PREPARED AND TESTED IN ACCORDANCE WITH THE REQUIREMENTS OF THE APPLICABLE SPECIFICATION(S), THE HMRL Q.A. MANUAL, FIFTH EDITION AND ITS IMPLEMENTING PROCEDURES, AS APPLICABLE.

TESTED BY: J. E.

DATE TESTED: May 10, 2013

Joseph Eskew, C.W.I., Laboratory Services Manager

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Located in the Dallas/Fort Worth Metroplex

TENSILE TEST REPORT

TO:
ExxonMobil Pipeline Company

DATE OF RECEIPT:
April 16, 2013

SPECIFIED MATERIAL:
API STD. 5-L, 10th Edition, August 1945, Electric Welded, Open Hearth Steel, Grade B, & ANSI/API Spec. 5L, 44th Edition, October 1, 2007, PSL 1, Welded Pipe, Grade X42

P.O. NO.:
UCG/451007854

TEST METHOD:
Prepared per: API STD. 5-L, 10th Edition, August 1945, Sections 24 - 27, & ANSI/API Spec. 5L, 44th Edition, October 1, 2007, Section 10.2.3 and Fig. 5b
Tested per: ASTM A370-12a

LABORATORY TEST NO.:
PT0413163 - ERW

ACCEPTANCE CRITERION:
API STD. 5-L, 10th Edition, August 1945, Table 3, Electric Welded, Open Hearth Steel, Grade B, & ANSI/API Spec. 5L, 44th Edition, October 1, 2007, PSL 1, Table 6, Welded Pipe, Grade X42

IDENTIFICATION:
19' 10" long Intact Section of a 20" O.D. x 0.312" wall Pipe; Removed from Milepost 314.77 in the Conway to Corsicana Pegasus Crude Oil Pipeline after it Failed in Service in Mayflower, Arkansas; Installed in 1947 to 1948

SAMPLE NUMBER	SPECIMEN IDENTIFICATION	TEST SPECIMEN DIMENSIONS			ULTIMATE STRESS		YIELD STRESS (0.5% OFFSET)		% ELONG. IN 2"	FRACTURE LOCATION
		DIAMETER/ WIDTH, in	THICKNESS, in	AREA, in²	LOAD, lbf	STRESS, psi	LOAD, lbf	STRESS, psi		
1	Transverse - ERW Seam, Weld Flash Included	1.503	0.294	0.442	44,754	101,000	34,016	77,000	4	H.A.Z.
2		1.501	0.295	0.443	41,394	93,500	34,938	79,000	5	H.A.Z.
3		1.508	0.294	0.443	45,191	102,000	37,194	84,000	23	Base Metal
1	Transverse - ERW Seam, Weld Flash Removed	1.509	0.282	0.426	36,353	85,500	31,104	73,000	3	H.A.Z.
2		1.509	0.281	0.424	36,341	85,500	31,858	75,000	3	H.A.Z.
3		1.504	0.281	0.423	39,172	92,500	32,440	77,000	5	H.A.Z.

REQUIREMENTS

	LOAD, lbf	STRESS, psi	LOAD, lbf	STRESS, psi	% ELONG. IN 2"	FRACTURE LOCATION
API 5-L, 10th Edition, Table 3, Electric Welded, Open Hearth Steel, Grade B		60,000 minimum				
API 5L, 44th Edition, PSL 1, Table 6, Welded Pipe, Grade X42		60,200 minimum				

REMARKS:

Test specimens meet the tensile requirements for API 5L ERW pipe at the time the pipe was manufactured, as well as the current version of API 5L for ERW Pipe, in accordance with the above referenced acceptance criterion.

Transverse tensile test specimens were flattened as per API 5L test methods prior to machining and testing.

Test was performed using Instron Satec Systems tensile machine S/N 1189.

THIS IS TO CERTIFY THAT THE ABOVE ARE THE ACTUAL RESULTS OF THE SUBMITTED SAMPLE(S) PREPARED AND TESTED IN ACCORDANCE WITH THE REQUIREMENTS OF THE APPLICABLE SPECIFICATION(S), THE HMRL Q.A. MANUAL, FIFTH EDITION AND ITS IMPLEMENTING PROCEDURES, AS APPLICABLE.

TESTED BY:
Josh Thomas
Laboratory Technician

DATE TESTED:
May 1, 2013

Joseph Eskew, C.W.I., Laboratory Services Manager

HURST METALLURGICAL RESEARCH LABORATORY, INC.
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Located in the Dallas/Fort Worth Metroplex

TENSILE TEST REPORT

TO:

ExxonMobil Pipeline Company

DATE OF RECEIPT:

April 16, 2013

SPECIFIED MATERIAL:

API STD. 5-L, 10th Edition, August 1945, Electric Welded, Open Hearth Steel, Grade B, & ANSI/API Spec. 5L, 44th Edition, October 1, 2007, PSL 1, Welded Pipe, Grade X42

P.O. NO.:

UCG/451007854

TEST METHOD:

Prepared per: API STD. 5-L, 10th Edition, August 1945, Sections 24 - 27, & ANSI/API Spec. 5L, 44th Edition, October 1, 2007, Section 10.2.3 and Fig. 5b
Tested per: ASTM A370-12a

LABORATORY TEST NO.:

PT0413163 - T

ACCEPTANCE CRITERION:

API STD. 5-L, 10th Edition, August 1945, Table 3, Electric Welded, Open Hearth Steel, Grade B, & ANSI/API Spec. 5L, 44th Edition, October 1, 2007, PSL 1, Table 6, Welded Pipe, Grade X42

IDENTIFICATION:

19' 10" long Intact Section of a 20" O.D. x 0.312" wall Pipe; Removed from Milepost 314.77 in the Conway to Corsicana Pegasus Crude Oil Pipeline after it Failed in Service in Mayflower, Arkansas; Installed in 1947 to 1948

SAMPLE NUMBER	SPECIMEN IDENTIFICATION	TEST SPECIMEN DIMENSIONS			ULTIMATE STRESS		YIELD STRESS (0.5% OFFSET)		% ELONG. IN 2"	FRACTURE LOCATION
		DIAMETER/ WIDTH, in	THICKNESS, in	AREA, in^2	LOAD, lbf	STRESS, psi	LOAD, lbf	STRESS, psi		
1	Transverse - 90° from ERW Seam	1.494	0.296	0.442	38,440	87,000	26,343	59,500	30	
2		1.503	0.297	0.446	38,628	86,500	26,288	59,000	31	
3		1.510	0.293	0.442	39,329	89,000	27,386	62,000	28	
1	Transverse - 180° from ERW Seam	1.507	0.306	0.461	40,051	87,000	28,967	63,000	28	
2		1.508	0.307	0.463	39,620	85,500	27,856	60,000	28	
3		1.501	0.306	0.459	40,254	87,500	29,443	64,000	28	

REQUIREMENTS

API 5-L, 10th Edition, Table 3, Electric Welded, Open Hearth Steel, Grade B		60,000 minimum		35,000 min.	*	
API 5L, 44th Edition, PSL 1, Table 6, Welded Pipe, Grade X42		60,200 minimum		42,100 min.	27 min.	

REMARKS:

Test specimens meet the tensile requirements for API 5L ERW pipe at the time the pipe was manufactured, as well as the current version of API 5L for ERW Pipe, in accordance with the above referenced acceptance criterion.

Transverse tensile test specimens were flattened as per API 5L test methods prior to machining and testing.

*The required minimum elongation specified in Table 3 of API STD. 5-L, 10th Edition is illegible on the available paper copy.

Test was performed using Instron Satec Systems tensile machine S/N 1189.

THIS IS TO CERTIFY THAT THE ABOVE ARE THE ACTUAL RESULTS OF THE SUBMITTED SAMPLE(S) PREPARED AND TESTED IN ACCORDANCE WITH THE REQUIREMENTS OF THE APPLICABLE SPECIFICATION(S), THE HMRL Q.A. MANUAL, FIFTH EDITION AND ITS IMPLEMENTING PROCEDURES, AS APPLICABLE.

TESTED BY:

Josh Thomas
Laboratory Technician

DATE TESTED:

May 1, 2013

Joseph Eskew, C.W.I., Laboratory Services Manager

HURST METALLURGICAL RESEARCH LABORATORY, INC.
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Phone (817) 283-4981, Metro 267-3421, Fax: Metro (817) 267-4234
Located in the Dallas/Fort Worth Metroplex

TENSILE TEST REPORT

TO:

ExxonMobil Pipeline Company

SPECIFIED MATERIAL:

API STD. 5-L, 10th Edition, August 1945, Electric Welded, Open Hearth Steel, Grade B, & ANSI/API Spec. 5L, 44th Edition, October 1, 2007, PSL 1, Welded Pipe, Grade X42

TEST METHOD:

Prepared per: API STD. 5-L, 10th Edition, August 1945, Sections 24 - 27, & ANSI/API Spec. 5L, 44th Edition, October 1, 2007, Section 10.2.3 and Fig. 5b
Tested per: ASTM A370-12a

DATE OF RECEIPT:

April 16, 2013

P.O. NO.:

UCG/451007854

LABORATORY TEST NO.:

PT0413163 - L

ACCEPTANCE CRITERION:

API STD. 5-L, 10th Edition, August 1945, Table 3, Electric Welded, Open Hearth Steel, Grade B, & ANSI/API Spec. 5L, 44th Edition, October 1, 2007, PSL 1, Table 6, Welded Pipe, Grade X42

IDENTIFICATION:

19' 10" long Intact Section of a 20" O.D. x 0.312" wall Pipe; Removed from Milepost 314.77 in the Conway to Corsicana Pegasus Crude Oil Pipeline after it Failed in Service in Mayflower, Arkansas; Installed in 1947 to 1948

SAMPLE NUMBER	SPECIMEN IDENTIFICATION	TEST SPECIMEN DIMENSIONS			ULTIMATE STRESS		YIELD STRESS (0.5% OFFSET)		% ELONG. IN 2"	FRACTURE LOCATION
		DIAMETER/ WIDTH, in	THICKNESS, in	AREA, in²	LOAD, lbf	STRESS, psi	LOAD, lbf	STRESS, psi		
1	Longitudinal - 90° from ERW Seam	1.504	0.286	0.430	38,346	89,000	27,764	64,500	31	
2		1.507	0.290	0.437	39,155	90,000	29,107	66,500	31	
3		1.503	0.294	0.442	40,043	90,500	30,203	68,500	31	

REQUIREMENTS

Requirement	Ultimate Load	Ultimate Stress	Yield Load	Yield Stress	% Elong.	Fracture Location
API 5-L, 10th Edition, Table 3, Electric Welded, Open Hearth Steel, Grade B		60,000 minimum		35,000 min.	*	
API 5L, 44th Edition, PSL 1, Table 6, Welded Pipe, Grade X42		60,200 minimum		42,100 min.	27 min.	

REMARKS:

Test specimens meet the tensile requirements for API 5L ERW pipe at the time the pipe was manufactured, as well as the current version of API 5L for ERW Pipe, in accordance with the above referenced acceptance criterion.

*The required minimum elongation specified in Table 3 of API STD. 5-L, 10th Edition is illegible on the available paper copy.

Test was performed using Instron Satec Systems tensile machine S/N 1189.

THIS IS TO CERTIFY THAT THE ABOVE ARE THE ACTUAL RESULTS OF THE SUBMITTED SAMPLE(S) PREPARED AND TESTED IN ACCORDANCE WITH THE REQUIREMENTS OF THE APPLICABLE SPECIFICATION(S), THE HMRL Q.A. MANUAL, FIFTH EDITION AND ITS IMPLEMENTING PROCEDURES, AS APPLICABLE.

TESTED BY:

Josh Thomas
Laboratory Technician

DATE TESTED:

May 1, 2013

Joseph Eskew, C.W.I., Laboratory Services Manager

HURST METALLURGICAL RESEARCH LABORATORY, INC.
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Located in the Dallas/Fort Worth Metroplex

TENSILE TEST REPORT

TO:

ExxonMobil Pipeline Company

DATE OF RECEIPT: April 16, 2013

P.O. NO.: UCG/451007854

LABORATORY TEST NO.: PT0413160

SPECIFIED MATERIAL:
API STD. 5-L, 10th Edition, August 1945, Electric Welded, Open Hearth Steel, Grade B, & ANSI/API Spec. 5L, 44th Edition, October 1, 2007, PSL 1, Welded Pipe, Grade X42

TEST METHOD:
Prepared per: API STD. 5-L, 10th Edition, August 1945, Sections 24 - 27, & ANSI/API Spec. 5L, 44th Edition, October 1, 2007, Section 10.2.3 and Table 21
Tested per: ASTM A370-12a

ACCEPTANCE CRITERION:
API STD. 5-L, 10th Edition, August 1945, Table 3, Electric Welded, Open Hearth Steel, Grade B, & ANSI/API Spec. 5L, 44th Edition, October 1, 2007, PSL 1, Table 6, Welded Pipe, Grade X42

IDENTIFICATION:

19' 10" long Intact Section of a 20" O.D. x 0.312" wall Pipe; Removed from Milepost 314.77 in the Conway to Corsicana Pegasus Crude Oil Pipeline after it Failed in Service in Mayflower, Arkansas; Installed in 1947 to 1948

SPECIMEN IDENTIFICATION	TEST SPECIMEN DIMENSIONS			ULTIMATE STRESS		YIELD STRESS (0.5% OFFSET)		% ELONG. IN 2"	% R. IN A.
	DIAMETER/ WIDTH, in	THICKNESS, in	AREA, in²	LOAD, lbf	STRESS, psi	LOAD, lbf	STRESS, psi		
Transverse - 90° from ERW Seam	0.245	0.300	0.0735	6,326	86,000	4,169	56,500	27	
Transverse - 180° from ERW Seam	0.253	0.307	0.0777	6,492	83,500	4,503	58,000	22	
REQUIREMENTS									
API 5-L, 10th Edition, Table 3, Electric Welded, Open Hearth Steel, Grade B					60,000 minimum		35,000 min.	*	
API 5L, 44th Edition, PSL 1, Table 6, Welded Pipe, Grade X42					60,200 minimum		42,100 min.	27 min.	

*The required minimum elongation specified in Table 3 of API STD. 5-L, 10th Edition is illegible on the available paper copy.

SPECIMEN IDENTIFICATION	TEST SPECIMEN DIMENSIONS			ULTIMATE STRESS		YIELD STRESS (0.5% OFFSET)		% ELONG. IN 2"	% R. IN A.
	DIAMETER/ WIDTH, in	THICKNESS, in	AREA, in²	LOAD, lbf	STRESS, psi	LOAD, lbf	STRESS, psi		
Transverse - ERW Seam, Weld Flash Removed	0.245	0.288	0.0732	7,289	99,500	4,765	65,000	21**	
REQUIREMENTS									
API 5-L, 10th Edition, Table 3, Electric Welded, Open Hearth Steel, Grade B					60,000 minimum				
API 5L, 44th Edition, PSL 1, Table 6, Welded Pipe, Grade X42					60,200 minimum				

**Fractured through the base metal.

Transverse tensile test specimens were not flattened.

Test was performed using Instron Satec Systems tensile machine S/N 1189.

THIS IS TO CERTIFY THAT THE ABOVE ARE THE ACTUAL RESULTS OF THE SUBMITTED SAMPLE(S) PREPARED AND TESTED IN ACCORDANCE WITH THE REQUIREMENTS OF THE APPLICABLE SPECIFICATION(S), THE HMRL Q.A. MANUAL, FIFTH EDITION AND ITS IMPLEMENTING PROCEDURES, AS APPLICABLE.

TESTED BY:
Josh Thomas
Laboratory Technician

DATE TESTED:
May 10, 2013

Joseph Eskew, C.W.I., Laboratory Services Manager

HURST METALLURGICAL RESEARCH LABORATORY, INC.
2111 West Euless Boulevard (Highway 10), Euless, Texas 76040-6707
Phone (817) 283-4981, Metro 267-3421, Fax: Metro (817) 267-4234
Located in the Dallas/Fort Worth Metroplex

IMPACT TEST REPORT

TO:

ExxonMobil Pipeline Company

DATE OF RECEIPT:

April 16, 2013

SPECIFIED MATERIAL:

API STD. 5-L, 10th Edition, August 1945, Electric Welded, Open Hearth Steel, Grade B, & ANSI/API Spec. 5L, 44th Edition, October 1, 2007, PSL 1, Welded Pipe, Grade X42

P.O. NO.:

UCG/451007854

TEST METHOD:

Prepared per: ANSI/API Spec. 5L, 44th Edition, October 1, 2007, Section 9.8
Tested per: ASTM A370-12a

LABORATORY TEST NO.:

CI0413062 - ERW

ACCEPTANCE CRITERION:

ANSI/API Spec. 5L, 44th Edition, October 1, 2007, Section 9.8 and Table 8, PSL 2 Pipe, Grade ≤X60

IDENTIFICATION:

19' 10" long Intact Section of a 20" O.D. x 0.312" wall Pipe; Removed from Milepost 314.77 in the Conway to Corsicana Pegasus Crude Oil Pipeline after it Failed in Service in Mayflower, Arkansas; Installed in 1947 to 1948

EFFECTIVE ENERGY:	SPECIMEN TYPE:	TEST TEMPERATURE:	SPECIMEN SIZE TESTED:
264 ft-lbf/358 Joules	Simple Beam, Type A	Various	10 mm x 5 mm

NO.	TEST TEMPERATURE	V-NOTCH LOCATION	IMPACT VALUES FOR SIZE TESTED, ft-lbf	LATERAL EXPANSION % Shear	LATERAL EXPANSION mils	REQUIREMENTS
1	Plus 95°F	ERW Seam Transverse	3	0	0	None Specified
2			2	0	1	
3			3	0	0	
1	Plus 80°F	ERW Seam Transverse	3	0	0	None Specified
2			2	0	0	
3			3	0	1	
1	Plus 65°F	ERW Seam Transverse	3	0	1	None Specified
2			2	0	0	
3			3	0	1	
1	Plus 32°F	ERW Seam Transverse	3	0	0	10 ft-lbf min. average energy 8 ft-lbf min. individual energy
2			3	0	0	
3			2	0	0	

Note that the CVN impact requirements are only specified for Type PSL 2 welded pipe, not Type PSL 1 welded pipe. No impact requirements are listed in the ASI STD 5-L, 10th Edition, August 1945.

THIS IS TO CERTIFY THAT THE ABOVE ARE THE ACTUAL RESULTS OF THE SUBMITTED SAMPLE(S) PREPARED AND TESTED IN ACCORDANCE WITH THE REQUIREMENTS OF THE APPLICABLE SPECIFICATION(S), THE HMRL Q.A. MANUAL, FIFTH EDITION AND ITS IMPLEMENTING PROCEDURES, AS APPLICABLE.

TESTED BY:
Josh Thomas
Laboratory Technician

DATE TESTED:
May 1, 2013

Joseph Eskew, C.W.I., Laboratory Services Manager

HURST METALLURGICAL RESEARCH LABORATORY, INC.
2111 West Euless Boulevard (Highway 10), Euless, Texas 76040-6707
Phone (817) 283-4981, Metro 267-3421, Fax: Metro (817) 267-4234
Located in the Dallas/Fort Worth Metroplex

IMPACT TEST REPORT

TO:

ExxonMobil Pipeline Company

SPECIFIED MATERIAL:

API STD. 5-L, 10th Edition, August 1945, Electric Welded, Open Hearth Steel, Grade B, & ANSI/API Spec. 5L, 44th Edition, October 1, 2007, PSL 1, Welded Pipe, Grade X42

TEST METHOD:

Prepared per: ANSI/API Spec. 5L, 44th Edition, October 1, 2007, Section 9.8
Tested per: ASTM A370-12a

DATE OF RECEIPT:

April 16, 2013

P.O. NO.:

UCG/451007854

LABORATORY TEST NO.:

CI0413062 - HAZ

ACCEPTANCE CRITERION:

ANSI/API Spec. 5L, 44th Edition, October 1, 2007, Section 9.8 and Table 8, PSL 2 Pipe, Grade ≤X60

IDENTIFICATION:

19' 10" long Intact Section of a 20" O.D. x 0.312" wall Pipe; Removed from Milepost 314.77 in the Conway to Corsicana Pegasus Crude Oil Pipeline after it Failed in Service in Mayflower, Arkansas; Installed in 1947 to 1948

EFFECTIVE ENERGY:	SPECIMEN TYPE:	TEST TEMPERATURE:	SPECIMEN SIZE TESTED:
264 ft-lbf/358 Joules	Simple Beam, Type A	Various	10 mm x 5 mm

NO.	TEST TEMPERATURE	V-NOTCH LOCATION	IMPACT VALUES FOR SIZE TESTED, ft-lbf	LATERAL EXPANSION % Shear	LATERAL EXPANSION mils	REQUIREMENTS
1	Plus 95°F	ERW Primary HAZ Transverse	3	0	3	None Specified
2			3	0	4	
3			4	5	6	
1	Plus 80°F	ERW Primary HAZ Transverse	5	5	7	None Specified
2			4	5	5	
3			8	5	5	
1	Plus 65°F	ERW Primary HAZ Transverse	3	0	2	None Specified
2			3	0	1	
3			5	0	2	
1	Plus 32°F	ERW Primary HAZ Transverse	4	0	0	10 ft-lbf min. average energy 8 ft-lbf min. individual energy
2			3	0	0	
3			4	0	0	

Note that the CVN impact requirements are only specified for Type PSL 2 welded pipe, not Type PSL 1 welded pipe. No impact requirements are listed in the ASI STD 5-L, 10th Edition, August 1945.

THIS IS TO CERTIFY THAT THE ABOVE ARE THE ACTUAL RESULTS OF THE SUBMITTED SAMPLE(S) PREPARED AND TESTED IN ACCORDANCE WITH THE REQUIREMENTS OF THE APPLICABLE SPECIFICATION(S), THE HMRL Q.A. MANUAL, FIFTH EDITION AND ITS IMPLEMENTING PROCEDURES, AS APPLICABLE.

TESTED BY: Josh Thomas
Laboratory Technician

DATE TESTED: May 1, 2013

Joseph Eskew, C.W.I., Laboratory Services Manager

HURST METALLURGICAL RESEARCH LABORATORY, INC.
2111 West Euless Boulevard (Highway 10), Euless, Texas 76040-6707
Phone (817) 283-4981, Metro 267-3421, Fax: Metro (817) 267-4234
Located in the Dallas/Fort Worth Metroplex

IMPACT TEST REPORT

TO:

ExxonMobil Pipeline Company

DATE OF RECEIPT: April 16, 2013

SPECIFIED MATERIAL:
API STD. 5-L, 10th Edition, August 1945, Electric Welded, Open Hearth Steel, Grade B, & ANSI/API Spec. 5L, 44th Edition, October 1, 2007, PSL 1, Welded Pipe, Grade X42

P.O. NO.: UCG/451007854

TEST METHOD:
Prepared per: ANSI/API Spec. 5L, 44th Edition, October 1, 2007, Section 9.8
Tested per: ASTM A370-12a

LABORATORY TEST NO.: CI0413062 - BM

ACCEPTANCE CRITERION:
ANSI/API Spec. 5L, 44th Edition, October 1, 2007, Section 9.8 and Table 8, PSL 2 Pipe, Grade ≤X60

IDENTIFICATION:
19' 10" long Intact Section of a 20" O.D. x 0.312" wall Pipe; Removed from Milepost 314.77 in the Conway to Corsicana Pegasus Crude Oil Pipeline after it Failed in Service in Mayflower, Arkansas; Installed in 1947 to 1948

EFFECTIVE ENERGY:	SPECIMEN TYPE:	TEST TEMPERATURE:	SPECIMEN SIZE TESTED:
264 ft-lbf/358 Joules	Simple Beam, Type A	Various	10 mm x 5 mm

NO.	TEST TEMPERATURE	V-NOTCH LOCATION	IMPACT VALUES FOR SIZE TESTED, ft-lbf	LATERAL EXPANSION % Shear	LATERAL EXPANSION mils	REQUIREMENTS
1	Plus 95°F	Base Metal Transverse	10	15	16	None Specified
2			10	10	12	
3			10	10	14	
1	Plus 80°F	Base Metal Transverse	9	5	9	None Specified
2			9	5	10	
3			9	5	13	
1	Plus 65°F	Base Metal Transverse	10	5	13	None Specified
2			10	5	14	
3			10	5	13	
1	Plus 32°F	Base Metal Transverse	8	5	8	10 ft-lbf min. average energy 8 ft-lbf min. individual energy
2			9	5	12	
3			9	5	10	
1	0°F	Base Metal Transverse	5	0	1	None Specified
2			4	0	2	
1	Minus 32°F		2	0	0	

Note that the CVN impact requirements are only specified for Type PSL 2 welded pipe, not Type PSL 1 welded pipe. No impact requirements are listed in the ASI STD 5-L, 10th Edition, August 1945.

THIS IS TO CERTIFY THAT THE ABOVE ARE THE ACTUAL RESULTS OF THE SUBMITTED SAMPLE(S) PREPARED AND TESTED IN ACCORDANCE WITH THE REQUIREMENTS OF THE APPLICABLE SPECIFICATION(S), THE HMRL Q.A. MANUAL, FIFTH EDITION AND ITS IMPLEMENTING PROCEDURES, AS APPLICABLE.

TESTED BY: Josh Thomas
Laboratory Technician

DATE TESTED: May 1, 2013

Joseph Eskew, C.W.I., Laboratory Services Manager

HURST METALLURGICAL RESEARCH LABORATORY, INC.
2111 West Euless Boulevard (Highway 10), Euless, Texas 76040-6707
Phone (817) 283-4981, Metro 267-3421, Fax: Metro (817) 267-4234
Located in the Dallas/Fort Worth Metroplex

CHEMICAL ANALYSIS REPORT

TO:

ExxonMobil Pipeline Company

SPECIFIED MATERIAL:

API STD. 5-L, 10th Edition, August 1945, Table 2, Electric Welded, Open Hearth Steel, Grade B, & ANSI/API Spec. 5L, 44th Edition, October 1, 2007, PSL 1, Table 4, Welded Pipe, Grade X42

TEST METHOD:

ASTM E415-08

DATE OF RECEIPT:

April 16, 2013

P.O. NO.:

UCG/451007854

LABORATORY TEST NO.:

SP0413046

IDENTIFICATION:

19' 10" long Intact Section of a 20" O.D. x 0.312" wall Pipe; Removed from Milepost 314.77 in the Conway to Corsicana Pegasus Crude Oil Pipeline after it Failed in Service in Mayflower, Arkansas; Installed in 1947 to 1948

ELEMENT WEIGHT %	Sample Tested		API 5-L, 10th Ed., Electric Weld Pipe, Open Hearth Steel, Grade B Spec.	API 5L, 44th Ed., PSL 1, Welded Pipe, Grade X42 Specification
Carbon[1]	0.30		0.30 max	0.26 max
Manganese	1.47		0.35 to 1.50	1.30 max
Phosphorus	0.017		0.045 max	0.030 max
Sulfur	0.031		0.06 max	0.030 max
Silicon	<0.01		[2]	[2]
Chromium	<0.01		[2]	0.50 max
Nickel	0.04		[2]	0.50 max
Molybdenum	<0.01		[2]	0.15 max
Copper	0.02		[2]	0.50 max
Aluminum	<0.01		[2]	[2]
Niobium	<0.01		[2]	[3]
Vanadium	<0.01		[2]	[3]
Titanium	<0.01		[2]	[3]
Iron	Base		Base	Base

REMARKS:

Material analyzed meets the chemical composition requirement for API 5L ERW pipe at the time the pipe was manufactured. However, it does not meet the above referenced current version of API 5L for ERW pipe, in accordance with the above referenced acceptance criterion.

[1]Test performed by HurstLab approved supplier and the results are outside the scope of accreditation for tests listed in A2LA Cert. #3152.01 and not covered by this accreditation.
[2]Analytical range not specified for element.
[3]Sum of Niobium + Vanadium + Tantalum = 0.15% maximum

Test was performed using Thermo Jarrell Ash AtomComp 81, S/N 26094 Optical Emission Spectrometer with Angstrom S-1000 readout and control system.

THIS IS TO CERTIFY THAT THE ABOVE ARE THE ACTUAL RESULTS OF THE SUBMITTED SAMPLE(S) PREPARED AND TESTED IN ACCORDANCE WITH THE REQUIREMENTS OF THE APPLICABLE SPECIFICATION(S), THE HMRL Q.A. MANUAL, FIFTH EDITION AND ITS IMPLEMENTING PROCEDURES, AS APPLICABLE.

TESTED BY:

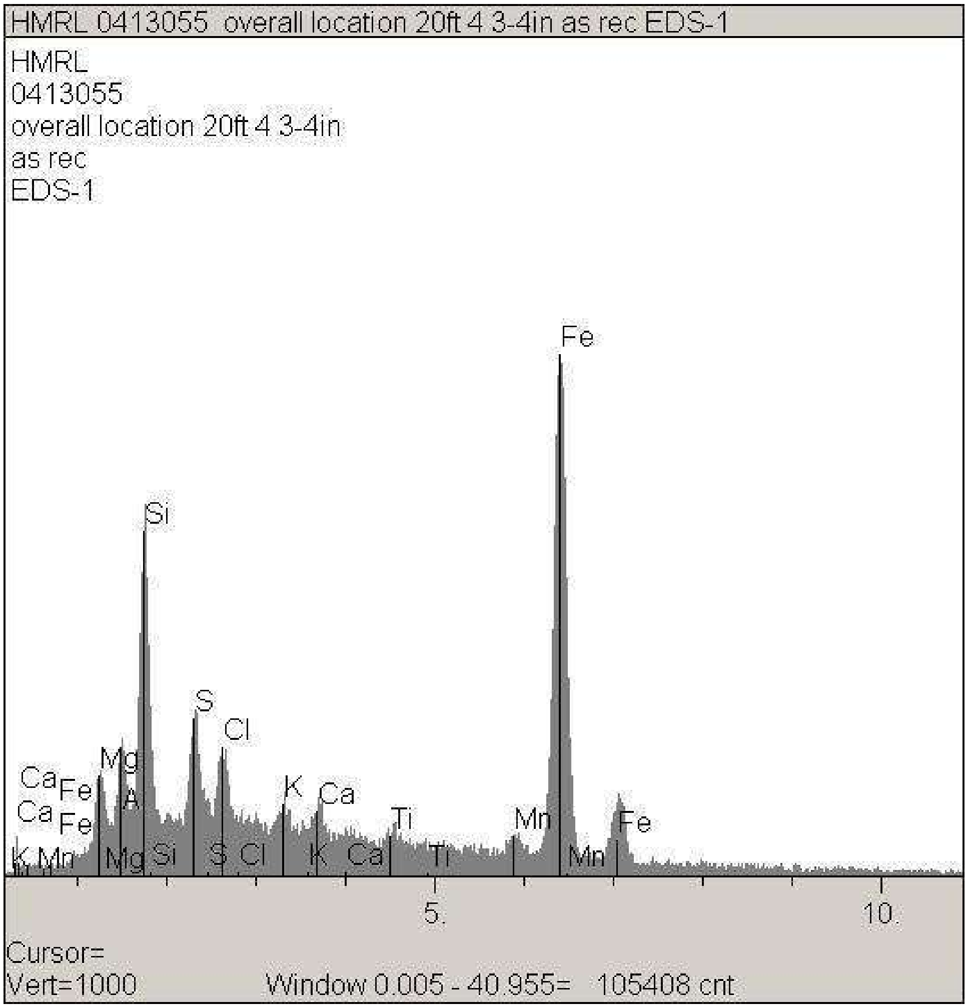
Brad Shepard, Chemist

DATE TESTED:

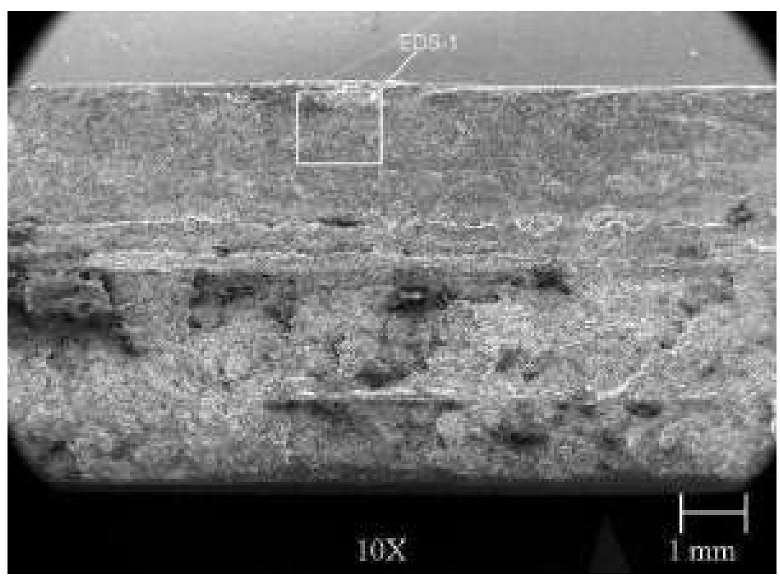
May 3, 2013

Joseph Eskew, C.W.I., Laboratory Services Manager

Table 16



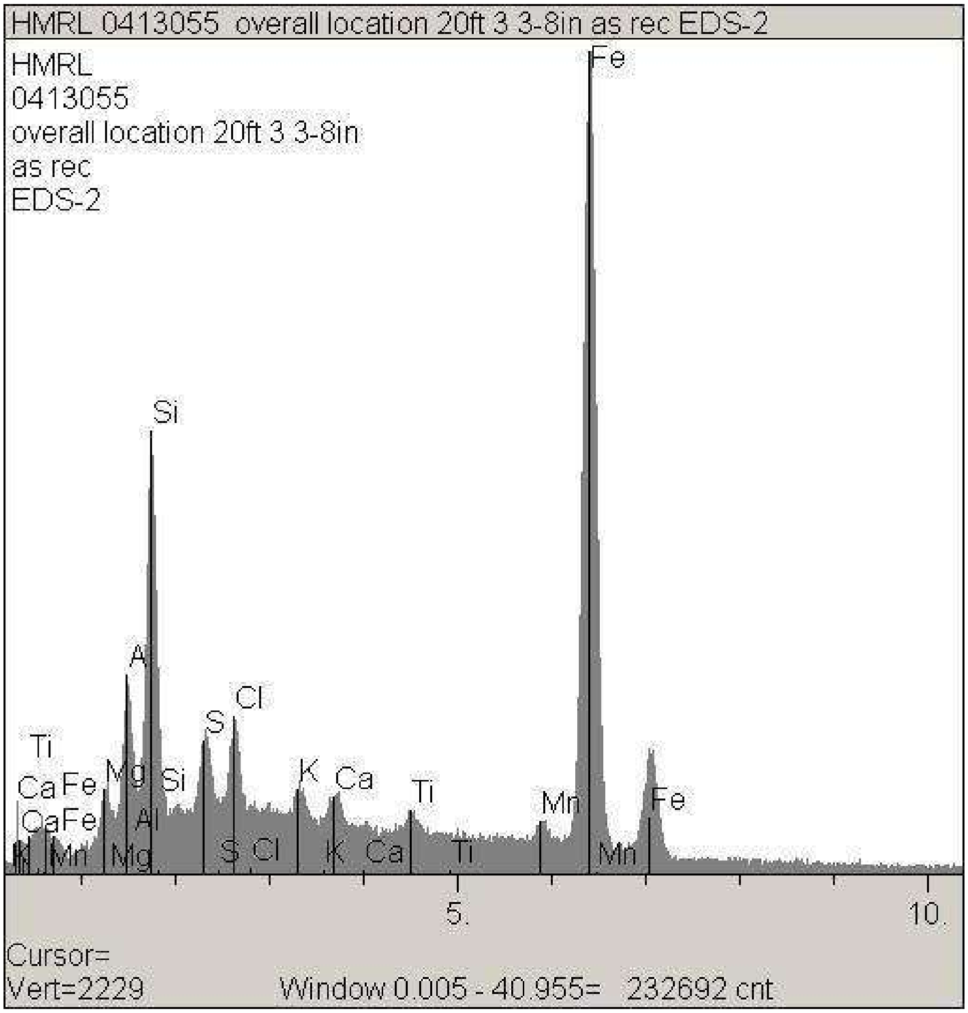
Elt.	Line	Intensity (c/s)	Error 2-sig	Conc, wt%
Mg	Ka	5.08	0.336	3.980
Al	Ka	5.50	0.350	3.484
Si	Ka	24.23	0.734	12.974
S	Ka	9.02	0.448	4.081
Cl	Ka	6.15	0.370	2.794
K	Ka	2.17	0.219	0.975
Ca	Ka	2.52	0.237	1.162
Ti	Ka	1.40	0.176	0.810
Mn	Ka	1.96	0.209	1.603
Fe	Ka	57.94	1.135	68.137
			Total	100.000



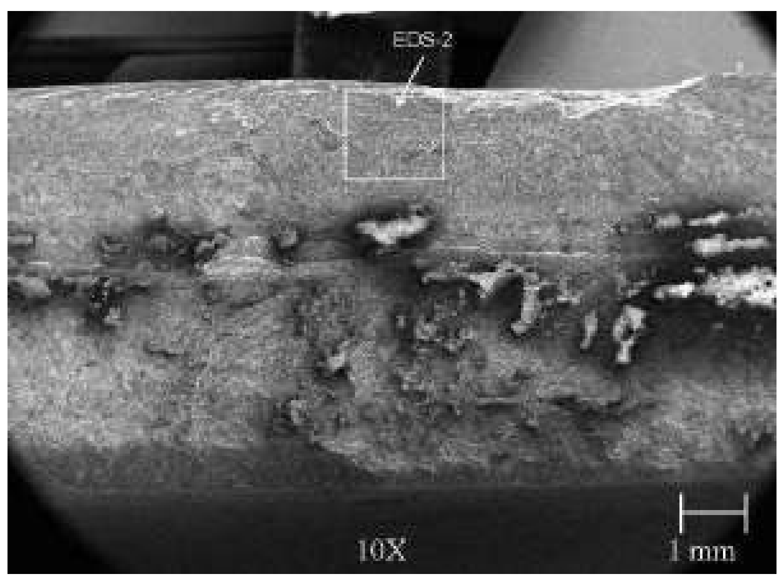
kV 15.0
Takeoff Angle 15.0˚
Elapsed Livetime 180.0

It should be noted that EDS analysis is a semi-quantitative test method and was used due to the extremely small sample size. The data obtained should not be used at face value, but only as comparative relative values only. The EDS analysis was performed by an HMRL approved supplier.

Table 17



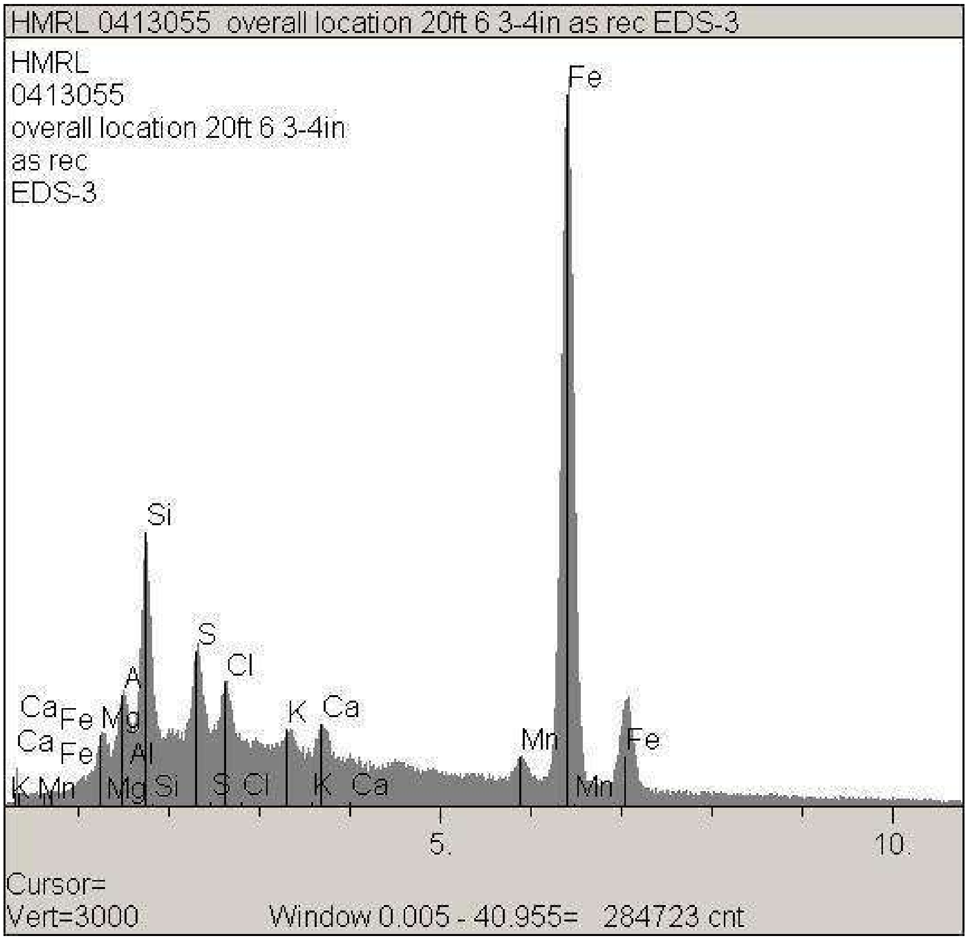
Elt.	Line	Intensity (c/s)	Error 2-sig	Conc, wt.%
Mg	Ka	7.65	0.412	1.925
Al	Ka	24.16	0.733	4.776
Si	Ka	71.09	1.257	12.032
S	Ka	15.28	0.583	2.144
Cl	Ka	17.20	0.618	2.377
K	Ka	6.45	0.379	0.883
Ca	Ka	6.23	0.372	0.874
Ti	Ka	4.76	0.325	0.836
Mn	Ka	4.33	0.310	1.056
Fe	Ka	202.41	2.121	73.097
			Total	100.000



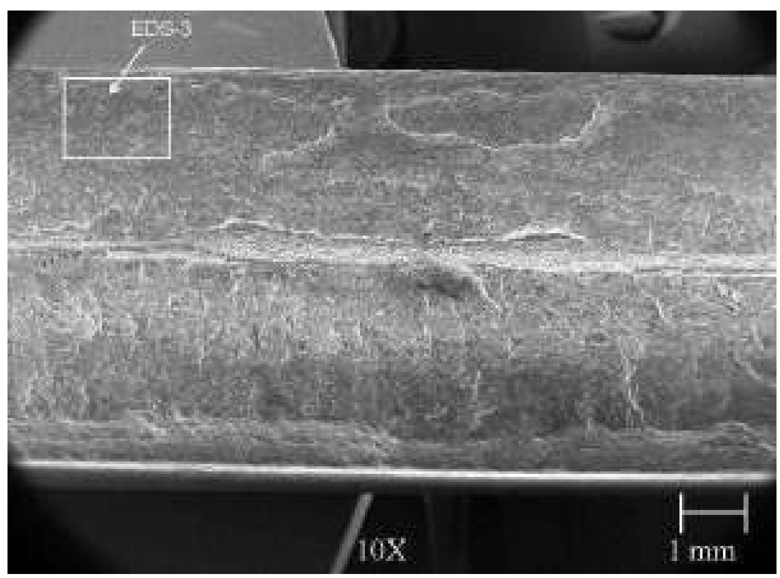
kV 15.0
Takeoff Angle 15.0˚
Elapsed Livetime 180.0

It should be noted that EDS analysis is a semi-quantitative test method and was used due to the extremely small sample size. The data obtained should not be used at face value, but only as comparative relative values only. The EDS analysis was performed by an HMRL approved supplier.

Table 18

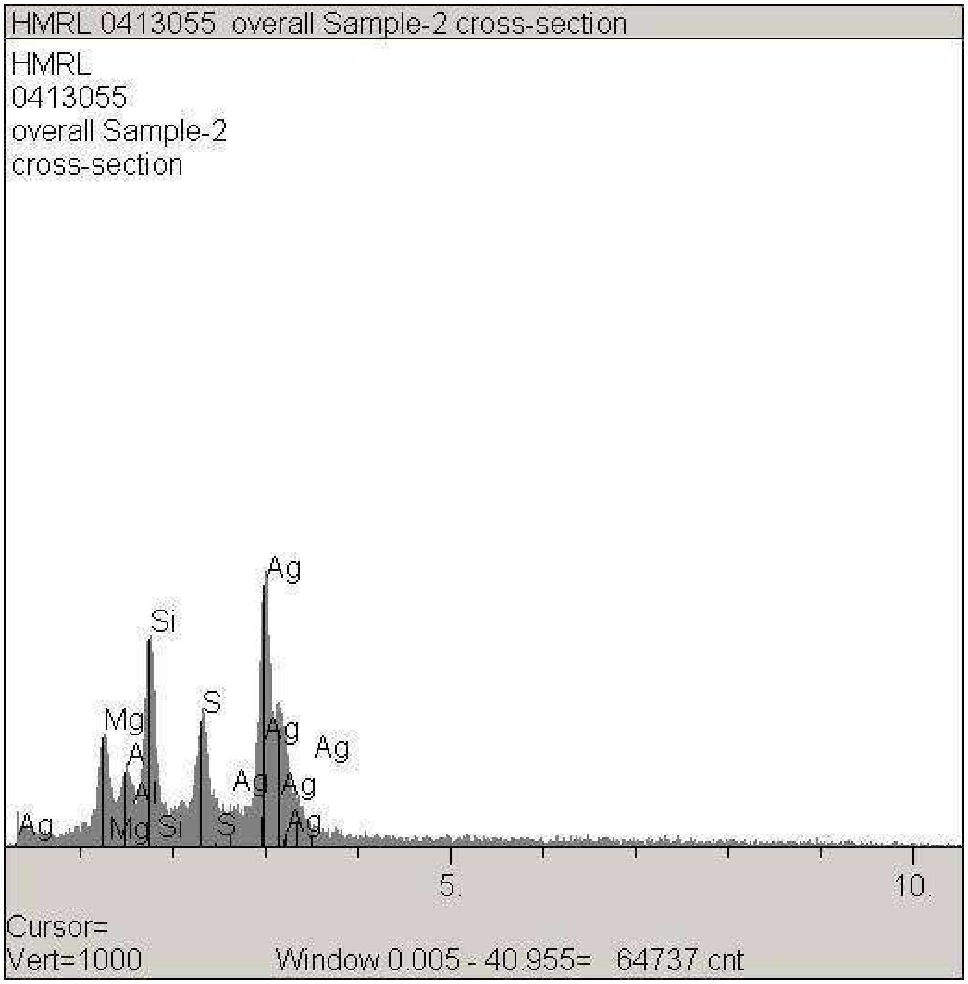


Elt.	Line	Intensity (c/s)	Error 2-sig	Conc, wt%
Mg	Ka	9.35	0.456	2.084
Al	Ka	17.90	0.631	3.118
Si	Ka	59.13	1.146	8.578
S	Ka	25.86	0.758	3.006
Cl	Ka	16.11	0.598	1.864
K	Ka	6.10	0.368	0.698
Ca	Ka	10.23	0.477	1.198
Mn	Ka	7.75	0.415	1.541
Fe	Ka	256.66	2.388	77.912
			Total	100.000

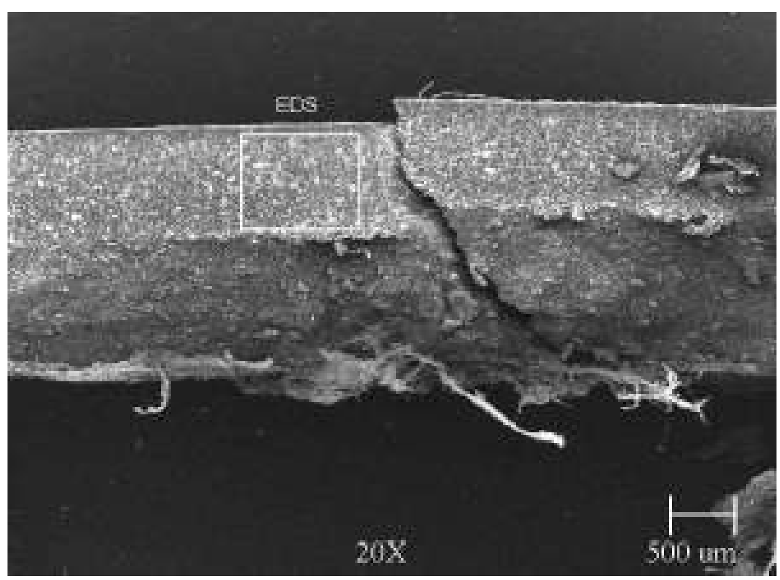


kV 15.0
Takeoff Angle 15.0°
Elapsed Livetime 180.0

It should be noted that EDS analysis is a semi-quantitative test method and was used due to the extremely small sample size. The data obtained should not be used at face value, but only as comparative relative values only. The EDS analysis was performed by an HMRL approved supplier.



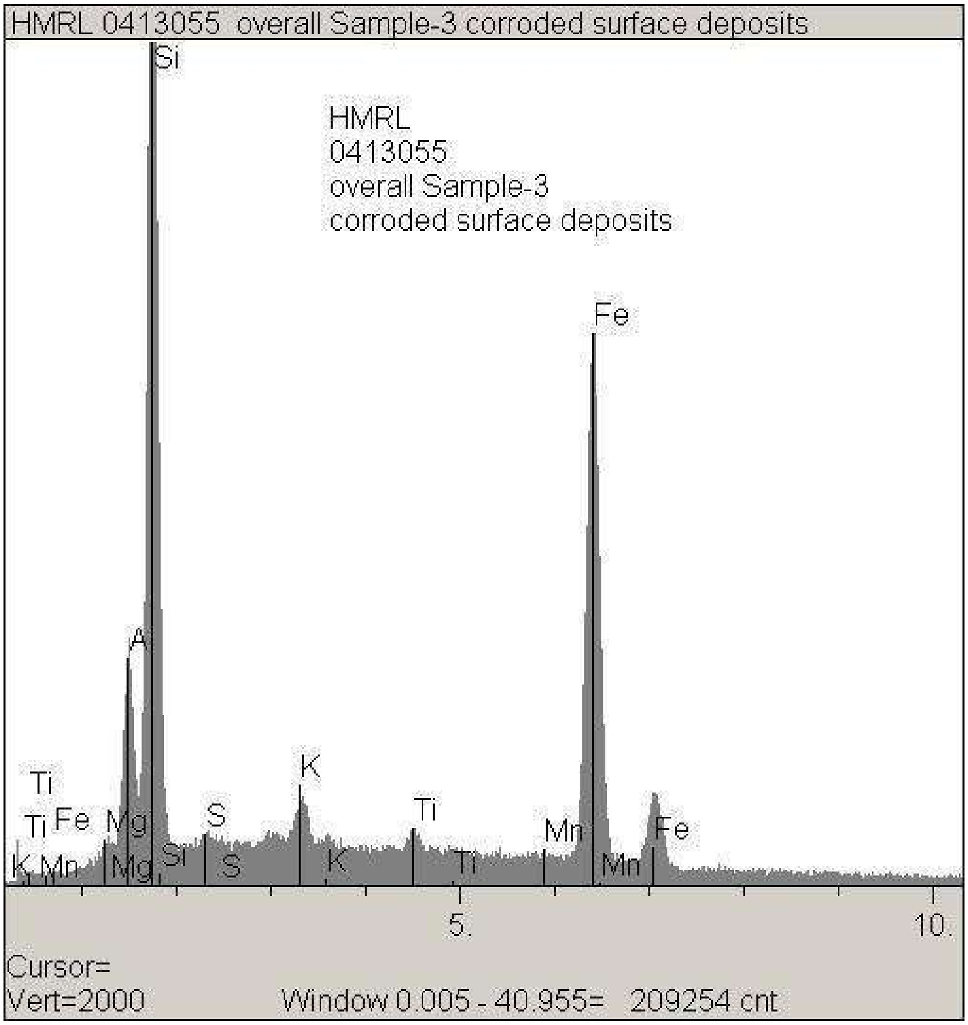
Elt.	Line	Intensity (c/s)	Error 2-sig	Conc, wt.%
Mg	Ka	6.51	0.380	14.522
Al	Ka	2.48	0.235	6.942
Si	Ka	14.98	0.577	42.773
S	Ka	9.15	0.451	35.763
Ag	La	0.00	0.000	0.000
			Total	100.000



kV 15.0
Takeoff Angle 15.0˚
Elapsed Livetime 180.0

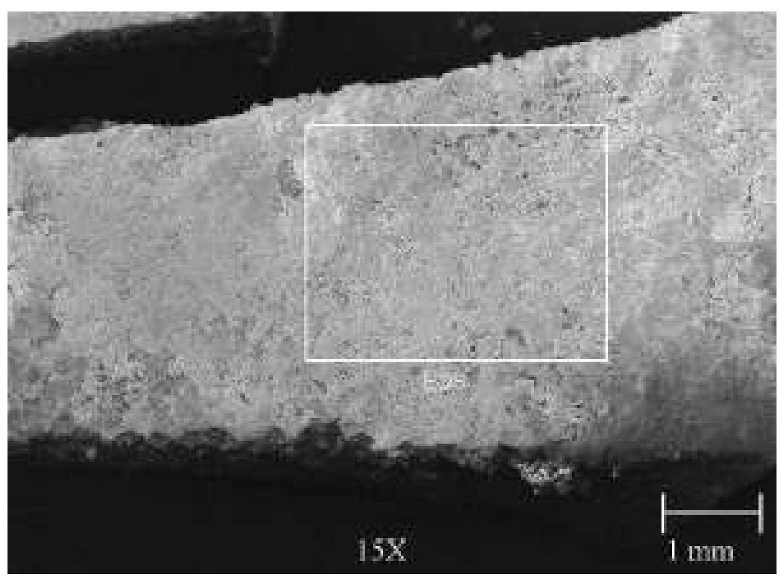
It should be noted that EDS analysis is a semi-quantitative test method and was used due to the extremely small sample size. The data obtained should not be used at face value, but only as comparative relative values only. The EDS analysis was performed by an HMRL approved supplier.

Table 20



Elt.	Line	Intensity (c/s)	Error 2-sig	Conc, wt.%
Mg	Ka	1.61	0.189	0.417
Al	Ka	33.01	0.856	6.783
Si	Ka	178.83	1.993	33.882
S	Ka	1.97	0.209	0.391
K	Ka	9.34	0.456	1.679
Ti	Ka	4.09	0.301	0.949
Mn	Ka	0.91	0.142	0.306
Fe	Ka	120.34	1.635	55.594
			Total	100.000

kV 15.0
Takeoff Angle 15.0°
Elapsed Livetime 180.0



It should be noted that EDS analysis is a semi-quantitative test method and was used due to the extremely small sample size. The data obtained should not be used at face value, but only as comparative relative values only. The EDS analysis was performed by an HMRL approved supplier.

Appendix I

PEGASUS LINE - CONWAY TO CORSICANA M.P. 314.77

MECHANICAL AND METALLURGICAL TESTING AND FAILURE ANALYSIS PROTOCOL

I. Objective: Perform mechanical and metallurgical testing and failure analysis of the failed pipe from the Affected Pipeline in the area of Mayflower, Arkansas pursuant to this protocol.

II. Background Information/Additional Requirements:

A. Pipe manufactured by Youngstown Sheet and Tube and installed in 1947-1948.

B. Grade API 5LX-42 (42,000 psi SMYS) Low Frequency DC ERW, 20" x 0.312" wall.

C. Pipe joint has been coated and cathodically protected since original construction.

D. Crude oil service from1947 to December 2002 when it was purged and idled with nitrogen. The line was the re-hydrotested and put back in crude service in 2006 to present.

E. The 2006 hydrostatic test pressure for the specimen was 1082 psig, and the corresponding pressure at time of failure was estimated at 708 psig.

F. Upon excavation, the pipe specimen shall be delivered to Hurst Metallurgical Research Laboratory, Inc. (Hurst Lab) at:
2111 West Euless Blvd. Euless,
TX 76040
Attn: Mahesh J. Madhani
817-283-4981

G. Prior to commencing the mechanical and metallurgical testing described herein, the Director of PHMSA Southwest Region shall be provided with the scheduled dates, times, and locations of the testing to allow a PHMSA representative to witness the testing.

H. All relevant pipe remnants (not consumed in process) will be preserved and stored in a secure location until returned to EMPCo. No material related to failed pipe will be disposed or scrapped by Hurst Lab.

I. All resulting reports in their entirety (including all media), whether draft or final, shall be distributed to EMPCo and the Director of PHMSA Southwest Region at the same time.

J. Attached is the Metallurgical Laboratory Failure Examination Protocol (05/08/2007) provided by PHMSA. Attachment 1 to PHMSA's protocol provides guidelines for custody transfer and transportation of physical evidence. Attachment 2 to PHMSA's protocol provides a worksheet for documenting physical measurements. These data collection forms should be used, and if not, ensure that the applicable information contained in those examples is recorded during the testing of the failed pipe.

K. Specimen Identification

1. A 34' Long Section of a failed 20" O.D. x 0.312" wall Pipe; Removed from Milepost 314.77 in the Conway to Corsicana segment of the Pegasus Crude Oil Pipeline after it failed in operation in Mayflower, Arkansas. Installed in 1947 to 1948

2. A 19'-10" Long Section of an intact 20" O.D. x 0.312" wall Pipe; Removed from Milepost 314.77 in the Conway to Corsicana segment of the Pegasus Crude Oil Pipeline . Installed in 1947 to 1948

III. Proposed Tests:

A. Visual and Nondestructive Examination

1. Photographically document the pipe segments in the as-received condition. Provide photos of the failed specimens indicating 12:00 o'clock position at top of pipe, milepost, and north/south ends of pipe section as installed in the pipeline. Further, this documentation should include, but is not limited to, the following:
a) Fracture face and area adjacent to fracture
b) Coating condition
c) Manufacturing flaws
d) Pitting and/or any evidence of internal/external corrosion
e) Cracks
f) Seams
g) Girth welds
h) Determine and mark the location of the electric resistance weld seam at end of each sample and determine if the failure falls within the electric resistance weld zone.
i) Record any markings detected on the inside and outside surfaces of the pipe.

2. Perform visual inspection on "as-received" condition and document any anomalies, including but not limited to the following:
a) Cracks and crevices
b) Condition of the ERW seam and girth weld
c) Dents, bends, and buckles
d) Gouges
e) Manufacturing defects

f) Coating condition, and any damages such as wrinkles or tents, or disbonding
g) Pitting and/or any evidence of internal/external corrosion
h) Evidence of arc burns and excessive grinding
i) Presence of corrosion deposits
j) Describe coating, and coating damage (disbonding) if any, in the vicinity of the fracture origin and at other locations in the failed pipe sample

3. Collect solid and liquid samples, if present, from the pipe surface and conduct chemical analysis and microbial tests on these samples as appropriate. Examples of these samples that may be collected are, but are not limited to, the following:
a) Liquid accumulated underneath the coating
b) Corrosion products from the interior/exterior surfaces of the pipe
c) Soil adhering to the pipe not contaminated by the crude release

4. The coating on the surfaces of the pipes will be removed by a third party, contracted directly by EMPCo. The coating shall be removed in such a manner that it will not be injurious to the pipe. Photographically document and visually inspect the pipe again following coating removal, as necessary, (see 1. and 2. above for guidance). Note any disbondment or possible adhesion problems with coating.

Attachment 2 to PHMSA's protocol provides a worksheet for documenting physical measurements.

EMPCo's proposed coating removal procedure/JSA document is provided as a supplement to this protocol. This document was previously provided to PHMSA to address coating removal; for the pipe extraction work. Extreme care will be taken to prevent any permanent mechanical damage to the pipe section. The use of a resin hammer will be initially used on a non-fractured intact pipe to remove the coating. If removal of the coating is not possible by the use of a resin hammer, a steel hammer may be used. The removal of the coating will be observed by Hurst Lab personnel. In addition, a meeting will be held with the coating removal team prior to the removal of the coating to instruct the personnel that the integrity of the pipe is maintained. A representative of Hurst Lab will be present to monitor coating removal in its entirety.

B. Physical Measurements

1. Verify roundness and geometry of pipe at the extremities and closer to the failed surface.

2. Perform a "map" of ultrasonic thickness measurements within 12 inches upstream and downstream of each end of the rupture if possible, and along the entire length of the rupture. Measurements will be taken around the entire circumference along the length of the pipe as specified. At each 2" interval, measurements will be taken at 30 locations evenly spaced around the circumference of the pipe. The ultrasonic tests shall be conducted at this Hurst Lab by Bonded Inspections, Inc.

3. Various dimensions of the fractured and intact pipes will be measured using micrometers or other suitable measuring devices. Measurements will include but are not limited to such as:
a) Diameter and wall thickness at areas adjacent to the failure, as well as visually intact areas of the pipe
b) The length of any cracks or ruptures
c) Axial distance from crack origins and/or tips to the nearest girth weld

C. Chemical Analysis

1. Chemical analysis of the pipe shall be performed using the Optical Emission Spectroscopic (OES) test method in accordance with ASTM E415-08, to determine the weight percent (wt%) of carbon, manganese, phosphorus, sulfur, silicon, chromium, nickel, molybdenum, copper, and aluminum, as well as any other elements common to API 5L line pipe steels.

Note: Both the latest edition of API 5L and the edition in effect at the time of manufacture shall be referenced as the standard for comparison.

D. Mechanical Properties

1. Mechanical testing involving yield strength, ultimate tensile strength, and elongation should be performed on pipe material that has not been plastically deformed during service. These tests will be performed in accordance with ASTM A370-12a for the pipe base metal and weld seams.

2. The transverse tensile test specimen blanks will be flattened prior to machining and testing, as allowed in API 5L. All tensile test specimens will be 1-
1/2" wide over the 2" long gauge area, and the yield stress will be calculated at a 0.5% offset. The minimum specimens that shall be prepared and tested are as follows:
a) 1 transverse test specimen, removed through the ERW

seam b) 1 transverse test specimen, removed 90o from the

ERW seam correct

c) 1 transverse test specimen, removed 180° from the ERW seam
d) 1 longitudinal test specimen, removed 90° from the ERW seam
Note: Both the latest edition of API 5L and the edition in effect at the time of manufacture shall be referenced as the standard for comparison.

3. Impact Tests
For Charpy V-notch (CVN) impact testing, testing should be performed in accordance with ASTM A370-12a to determine the toughness characteristics of the ERW seam and the base metal of the pipe. Multiple sets of 3 transverse 10 mm x 6.67 mm (2/3 size) or 10 mm x 5 mm (1/2 size) CVN impact test specimens will be prepared and tested at various temperatures to establish the

upper-shelf energy (in ft-lbf), the lower-shelf energy (in ft-lbf), and the ductile- to-brittle transition temperature for the base metal and, if possible, the ERW seam. The lateral expansion (in mils) and the percent shear will also be reported. CVN impact values used to develop the S-curve will be provided down to a minimum temperature of 32°F. Minimum operating temperature of the pipeline during winter months could be 45 degrees F in extreme cases. Therefore, it is preferable to have the CVN values (S-curve) down to 32°F provided. Longitudinal CVN values are not needed unless specifically asked for.

It should be noted that representative CVN impact values for the ERW seam may be difficult to obtain, and that the values can vary considerably throughout the welded joint and along the pipe.

Note: Both the latest edition of API 5L and the edition in effect at the time of manufacture shall be referenced as the standard for comparison.

E. Metallographic Examinations

1. Perform metallographic examination and take photomicrographs of areas such as the following:
a) At or near the fracture origin
b) Fracture surface
c) Weld seams
d) Areas identified as defects or cracks during visual and/or nondestructive examination
e) Areas away from the fracture surface showing typical microstructures of the base metal, weld metal, and heat-affected zone

2. Metallographic samples should be examined to validate any issues specific to the failure such as the following: pipe grade, weld seam in area of fracture, weld seam in unaffected area, corrosion, and indication of outside mechanical damage.

F. Microhardness Surveys

1. Perform Knoop microhardness profiles at areas at or near the fracture origin and the weld seam (converted to Brinell hardness values). Microhardness surveys shall be conducted on metallographically prepared cross-sections in accordance with ASTM E384-11, to determine the hardness at appropriate locations such as the base metal, heat affected zone, and fusion line of the ERW seam at the fracture origin and away from the fracture.

G. Fractographic Examination

1. Visually examine the fracture surface in detail to identify the characteristics of the fracture, the nature of the original defect, and the failure initiation point(s).

2. Sections of the fracture surfaces will be removed as necessary to allow for detailed low magnification visual examination and photographic documentation of the fracture morphology. If possible, the fracture will be determined to be the result of brittle or ductile overload, fatigue propagated cracking, or the result of combined effects of stress and environment.

3. If necessary, small sections of the fracture surface at pertinent areas will be examined and photographed at high magnification using a Scanning Electron Microscope (SEM) by Anastas Technical Services in Houston, TX.

H. Corrosion Examination

1. Surface deposits and residues associated with the fracture area and adjacent areas should be collected and analyzed, if possible, to characterize and determine the origin of the deposits. Attachment 2 to PHMSA's protocol provides a worksheet for documenting chemical analysis results of corrosion products.

2. Based on the results of the visual, non-destructive, and metallographic examinations, the presence of corrosion should be documented, and the type and characteristics of any corrosion present should be evaluated. Remaining strength calculations (RSTRENG/ASME B31G) may be performed on corroded areas to support the failure investigation.

3. If an in-line inspection (ILI) tool has inspected the failure site in the past, investigation of the ILI log and report can provide information relevant to corrosion growth rate. The operator may not have this information immediately available, but it may be desirable to do this research. In the case of finding the anomaly present in the past ILI report, it is important to understand the operator's excavation criteria in effect at the time of the ILI and the application of RSTRENG calculations and anomaly interaction criteria.

I. Data Analysis and Report Publication

1. Data analysis will include a review of the provided background and service history, if available, analysis of the test data generated through the aforementioned tests and evaluations, the review of the available standards and specifications applicable to the pipe, and metallurgical research.

2. Both the latest edition of API 5L (45th Edition) and the edition in effect at the time the pipe was manufactured (10th Edition) will be referenced as standards for comparison. For the purposes of identifying test specimens, the longitudinal direction will be considered to be along the axis of the pipe.

3. The final report containing our findings will then be published to the agreed-upon parties.

Appendix II

The photograph displays the pipe sections in the as-received condition with the protective wrapping on the outside surface of the pipe sections that was applied to prevent any damage during transportation.

The photographs display two (2) perspective views of the pipe section in the as-received condition.

The photograph displays the pipe section, a drum containing the coating material that was removed in the field prior to sectioning of the cracked pipe and a bag containing possible calcareous deposit.

The photographs display two (2) pipe sections during the unloading process. There was no evidence of any transportation related damage to the pipe sections.

THIS MEMORANDUM is an acknowledgement that a Bill of Lading has been issued and is not the Original Bill of Lading nor a copy or duplicate, covering the property named herein, and is intended solely for filing or record.

Shipper's No. ____________

(Carrier) ____________ SCAC. ____________ Carrier's No. ____________

Received, subject to the classifications and tariffs in effect on the date of the Bill of Lading:

at ____________, date ____________ from ____________

TO: (Mail or street address of consignee for purposes of notification only)
Consignee Hurst Metallurgical
Street 2111 West Euless Blvd (Hwy 10)
Destination Hurst TX Zip
Route:

FROM: Mayflower + Conway to Hou
Shipper
Street Mob + Cixoin
Origin Conway Ark Zip

Delivering Carrier: | Trailer Initial/Number: | U.S. DOT Hazmat Reg. Number:

No. of Packages	HM	Description of articles, special marks, and exceptions	Hazard Class	I.D. Number	Packing Group	*Weight (subject to correction)	Class or Rate	Labels Required (or exemption)	Check Column
2		Pipes & ~~1 Bag Dirt~~							
1		55 gallon drain							
1		Bag Dirt							

Remit C.O.D. to:
Address:
City: State: Zip:

C.O.D. Amount: $
C.O.D. Fee: Prepaid ☐ Collect ☐ $
Charges Advanced $
Freight Charges: Prepaid ☐ Collect ☐

PLACARDS REQUIRED | PLACARDS SUPPLIED ☐ YES ☐ NO—FURNISHED BY CARRIER
DRIVER'S SIGNATURE:

SHIPPER:
PER: Reeid N Markham DATE: 4/16/2013

CARRIER: Armstrong
PER: DATE: 4-16-13

EMERGENCY RESPONSE TELEPHONE NUMBER: ( )

Permanent post office address of shipper

RPBOL-25 (rev. 980211) Published by RoadPro 3

Attachment C

Evidence Control Log

ExxonMobil Pipeline Company
Pegasus Pipeline, Mayflower, AR

Tag #	Date Recovered	Description	Photo #
2	4/15/2013	South of Damaged Section Pipe ~20'	100-0320 278

Date	Action (eg. Shipped, returned, testing, etc.)	Destination	Person/Organization	Signatures
4/15	x-fer	Conway Station	T. Armstrong Trucking	Released: KDM [signature]
				Accepted: [signature]
				Released: MITCH WILSON
				Accepted:
4/15	X-fer	Conway Station	EP Fletcher Security	Released: [signature]
				Accepted: [signature]
4/16	X-fer	Conway Station	Frankie Tucker Security	Released: [signature]
				Accepted: [signature]
4/16	X-fer	Conway Station	T. Armstrong Trucking	Released: [signature]
				Accepted: C. Young
			4/16/2013 3:30PM	Released:
			M. J. MADHANI	Accepted: [signature]
				Released:
				Accepted:
				Released:
				Accepted:

Attachment C

Evidence Control Log

ExxonMobil Pipeline Company
Pegasus Pipeline, Mayflower, AR

Tag #	Date Recovered	Description	Photo #
4	4/14/2013	Pipe Coating in Black Barrel	

Date	Action (eg. Shipped, returned, testing, etc.)	Destination	Person/Organization	Signatures
4/16	Shipped	Hurst Lab	J. Armstrong Trucking	Released: [signature] KDM
			C. Young	Accepted: C. Young
				Released:
				Accepted:
4/16	Received	Hurst Lab	X	Released:
		4/16/2013 3:30PM	M.J. MADHANI	Accepted: X MJ Madhani
				Released:
				Accepted:
				Released:
				Accepted:
				Released:
				Accepted:
				Released:
				Accepted:
				Released:
				Accepted:

Attachment C

Evidence Control Log				ExxonMobil Pipeline Company Pegasus Pipeline, Mayflower, AR
Tag #	Date Recovered	Description		Photo #
3	4/15/2013	Surface Deposit		100-0315 273
Date	Action (eg. Shipped, returned, testing, etc.)	Destination	Person/Organization	Signatures
4/15	X-fer	Conway Station	T.Armstrong Trucking	Released: KDM [signature]
				Accepted: [signature]
				Released: MITCH WKSON
				Accepted:
4/15	X-fer	Conway Station	Ed Fletcher Security	Released: [signature]
				Accepted: [signature]
4/16	X-fer	Conway Station	Frankie Tucker Security	Released: [signature]
				Accepted: [signature]
4/16	X-fer	Conway Station	T Armstrong Trucking	Released: [signature]
				Accepted: C. Young
				Released:
		4/16/2013 3:30PM	MG Madhani	Accepted: [signature]
				Released:
				Accepted:
				Released:
				Accepted:

Attachment C

Evidence Control Log

ExxonMobil Pipeline Company
Pegasus Pipeline, Mayflower, AR

Tag #	Date Recovered	Description	Photo #
1	4/15/2013	[illegible] Damaged Joint ~34'	100-0319 277

Date	Action (eg. Shipped, returned, testing, etc.)	Destination	Person/Organization	Signatures
4/15	X-fer	Conway Station	T. Armstrong Trucking	Released: KDM [signature]
				Accepted: [signature]
				Released: MITCH WILSON
				Accepted:
4/15	X-fer	Conway Station	Ed Fletcher	Released: [signature]
			Security	Accepted: [signature]
4/16	X-fer	Conway Station	Frankie Tucker	Released: [signature]
			Security	Accepted: J. F. Tuch
4-16	X-fer	Conway Station	T. Armstrong Trucking	Released: J. A. Tuck
				Accepted: J.C. Young
			4/16/2013 3:30 PM	Released:
			M J MADHANI	Accepted: M J Madhani
				Released:
				Accepted:
				Released:
				Accepted:

Appendix III

COATING REMOVAL TASK

Extreme care will be taken to prevent any permanent mechanical damage to the pipe section. The use of a resin hammer will be initially used on a non-fractured intact pipe to remove the coating. If removal of the coating is not possible by the use of a resin hammer, a steel hammer may be used. The removal of the coating will be observed by HurstLab personnel. In addition, a meeting will be held with the coating removal team prior to the removal of the coating to instruct the personnel.

The undersigned understands the importance of using extreme care in removing the pipe coating.

Print Name	Signature	Date
Argenis Hernandez	[signature]	4-22-13
Federico Olvera	Federico Olvera	4-22-13
Ausencio Camisaca	[signature]	4-22-13
Laureano Mirafuentes	L. Mirafuentes	4-22-13
Billy C. Hartley	[signature]	4-22-13

The photographs display the coating removal that was carried by impacting with steel or composite hammers.

The photographs display the hand removal process of the coating which remained on the pipe after initial removal with hammer.

The photograph displays the initial coating removal process.

The photograph displays the careful hand removal process of the coating adjacent to the crack.

Appendix IV

SGS PIINDE

ExxonMobil Pipeline

Inline Inspection Tool Correlation NDE Report

GE (PII/TFI) / Run Date: July 2012

US Reference:	**16310+25.62**	ODO to U/S GW:	**81602.14**
Distance to US Reference:	4501.09		
ODO to Primary Anomaly: 81627.98	Dig # 12	Upstream Girth Weld #:	**17290**

Project: **HURST LAB EVALUATION**

Pipe Description / Nominals: (20.000" 0.312" X42)

Segment: **Conway to Corsica**

	U/S Joint	Anomaly Joint	D/S Joint
Joint Length:	NA	NA	NA
LS Circ Position:	0°	360°	0°

Inspection Area Dimensions

Length of Pipe Examined: 24.67'

Axial Start: -1.00' End: 23.67'

Circ Start: 0° End: 360°

Conditions:

Soil pH: NA

Top of Ditch P-S: NA

Btm of Ditch P-S: NA

Soil Resistivity: na ohm/cm

Seam Type: SAW [ ] FW [ ] ERW [X] DSAW [ ] SMLS [ ] Lap [ ]

Coating Type: Tape [ ] FBE [ ] Coal Tar [X]

Actual Profile Data: T1 316 T2 312 TW 383 WW 520 WH 0

NDE Methods

Visual [X] WCAMT [ ] UT-FAST [ ] UT-0 Degree [X] UT-Shear [ ] UT- Phased Array [ ]

Anomaly Information

	Log Start (ft)	Log length (in)	Log circ start (°)	Log circ extent (in)	Log Depth (%)	Start of Ind (ft)	End of Ind (ft)	Axial Length of Ind (in)	Circ start (°)	Circ end (°)	Circ extent (in)	Pipe Thk at Ind (mils)	Max Ind Depth (mils)	Depth, Max %	Pipe or weld	ID, OD or Mid	Flaw Type	Grind Length (in)	NDE Method	NDE Comments or Remarks
1						4.12	4.72	7.2	195	197	0.3	313	153	48.9%	Pipe	MID	Ind	NA	UT	See Remarks Below
2																				
3																				
4																				
5																				

NG=Not Given NV= Not Verified NA= Not Applicable VI= Verified by Dig Inspector

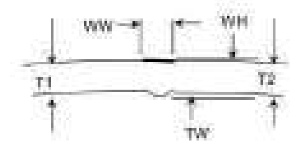
NDE Remarks:

CMAPPs (AUT) ultrasonic thickness measurements were taken from 12 inches upstream of the girth weld and from 12 inches downstream of the rupture for 360 degrees around the pipe surface. In addition, CMAPPs thickness measurements were also taken around the entire circumference along the length of pipe where surface conditions allowed meaningful measurements to be recorded.

No internal corrosion areas were indentified during the ultrasonic examination.

Anomaly 1 appears to be a laminar-type inclusion in the pipe wall.

Thickness Profile of Long Seam



Repair Type:	Sleeve Number 1	Start:	End:	
Repair Type:	Sleeve Number 2	Start:	End:	

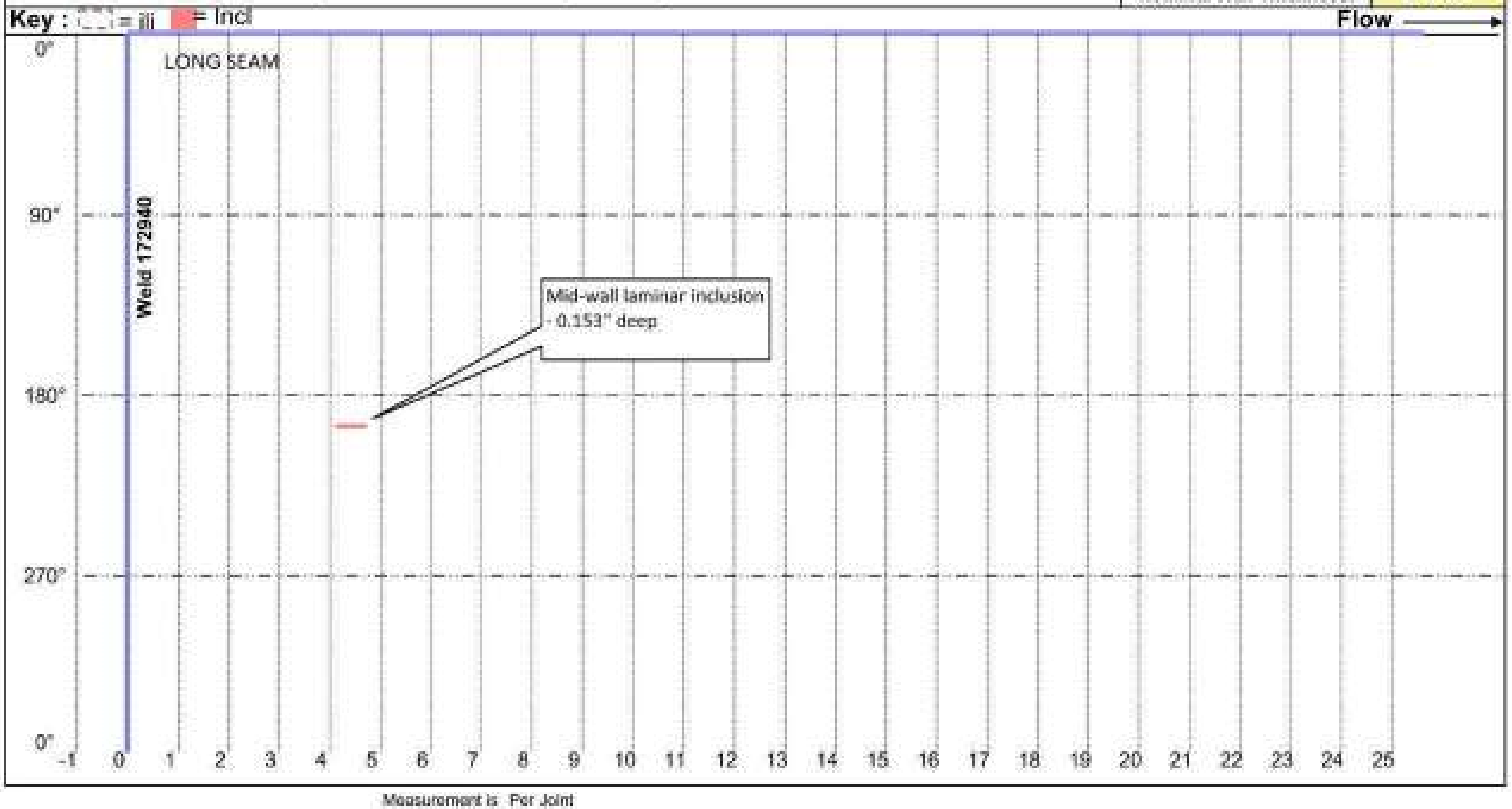
A = Type "A" sleeve; B = Type "B" Sleeve; C = Clockspring; N = No repair required

Date of Exam	Technician	Certification(s)	
5/1/13	**Jeff Hecht**	**Lvl III**	

SGS PIINDE	ExxonMobil Pipeline Inline Inspection Tool Correlation NDE Report GE (PII/TFI) / Run Date: July 2012	US Reference:	16310+25.62	ODO to U/S GW:	81602.14
		Distance to US Reference:	4501		
		ODO to Primary Anomaly	Dig #	Upstream GW #	
		81627.98	12	17290	

Graphical Representation of Pipe Body Anomalies - Plan View

Pipe:	20.000" X42
Nominal Wall Thickness:	0.312"



Date of Exam	Technician	Certification(s)	
5/1/2013	Jeff Hecht	Lvl III	

SGS / PiNDE	ExxonMobil Pipeline Inline Inspection Tool Correlation NDE Report GE (PII/TFI) / Run Date: July 2012	US Reference:	16310+25.62	ODO to U/S GW:	81602.14
		Distance to US Reference:	4501.09		
		ODO to Primary Anomaly	Dig #	Upstream Girth Weld #:	
		81627.98	12	17290	

Description of photograph

General site photo - Pipe looking Upstream

Description of photograph

Scan Area for Grid 141 Scan (Downstream 12")

Date of Exam	Technician	Certification(s)	
5/1/2013	Jeff Hecht	Lvl III	

SGS PiiNDE	ExxonMobil Pipeline Inline Inspection Tool Correlation NDE Report GE (PII/TFI) / Run Date: July 2012	US Reference: 16310+25.62 Distance to US Reference: 4501.09		ODO to U/S GW: 81602.14
		ODO to Primary Anomaly: 81627.98	Dig #: 12	Upstream Girth Weld #: 17290

Description of photograph

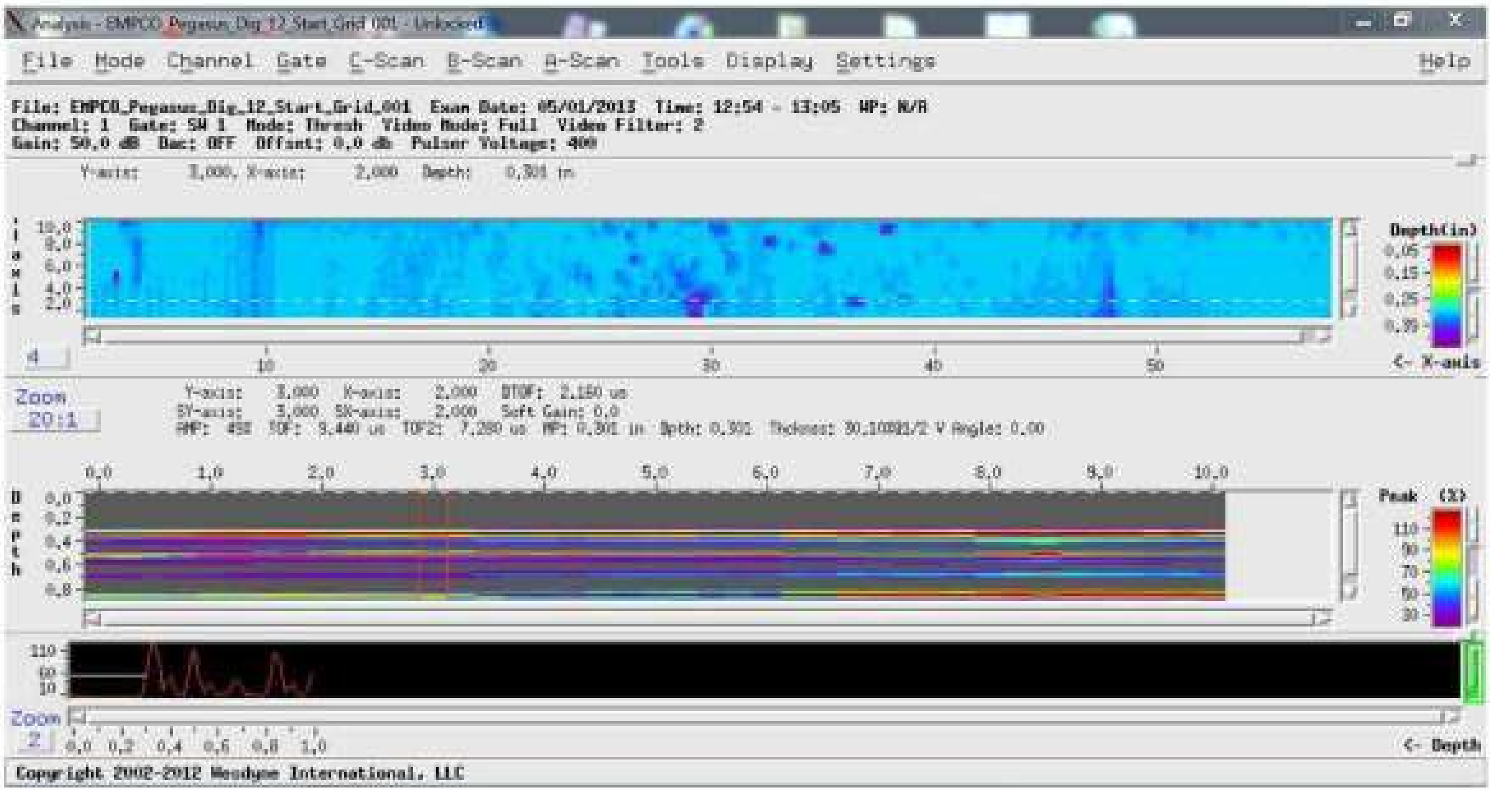
Scan Area for Grid 1 Area (12" upstream of GW)

Description of photograph

Anomaly 1 Area Marked on Pipe for Sectioning

Date of Exam	Technician	Certification(s)	
5/1/2013	Jeff Hecht	Lvl III	

SGS PIiNDE	ExxonMobil Pipeline Inline Inspection Tool Correlation NDE Report GE (PII/TFI) / Run Date: July 2012	US Reference:	16310+25.62	ODO to U/S GW:	81602.14
		Distance to US Reference:	4501.09		
		ODO to Primary Anomaly	Dig #	Upstream Girth Weld #:	
		81627.98	12	17290	

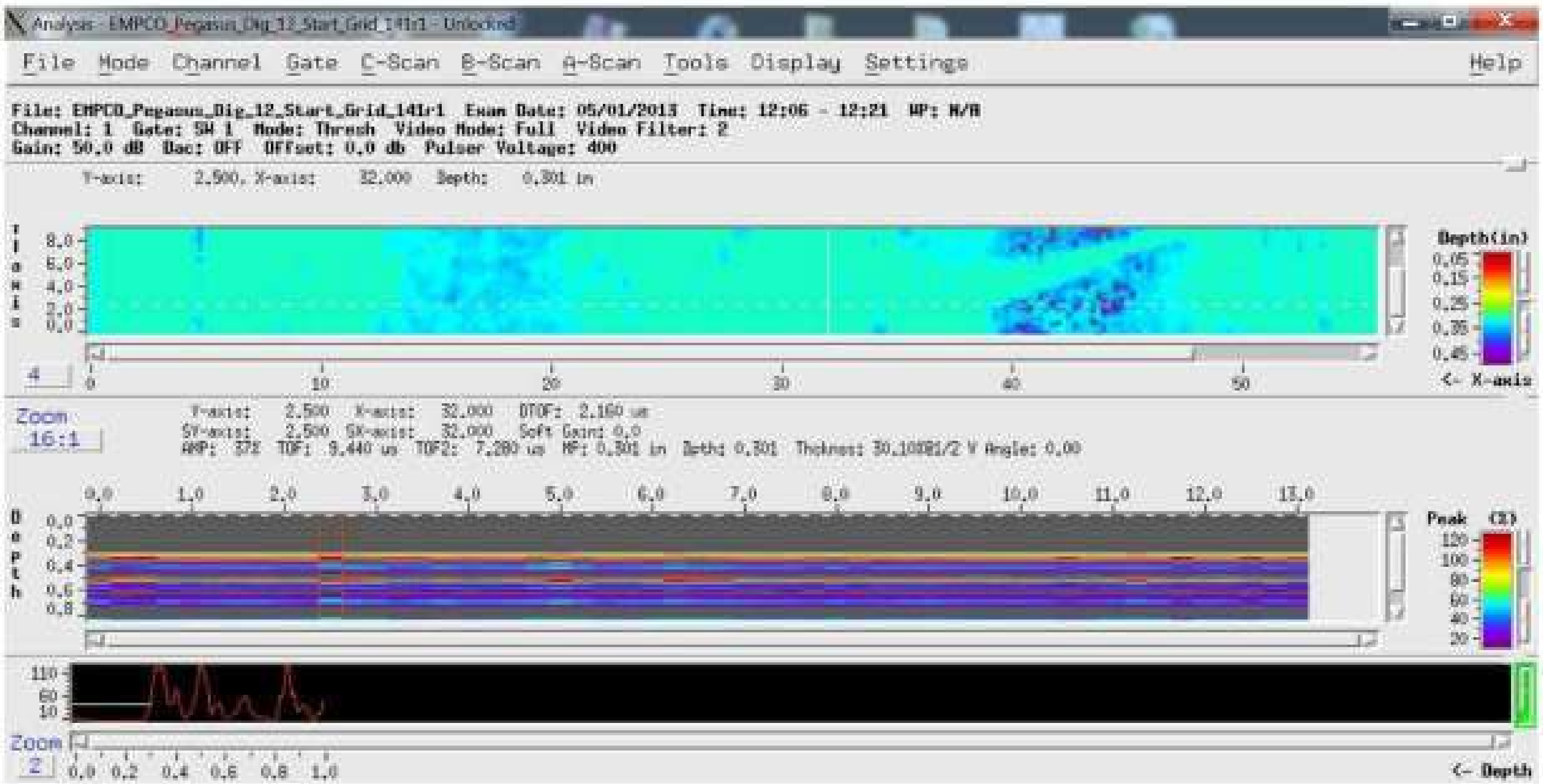


Grid 1 Area Scan

Date of Exam	Technician	Certification(s)	
5/1/2013	Jeff Hecht	Lvl III	

SGS PIiNDE

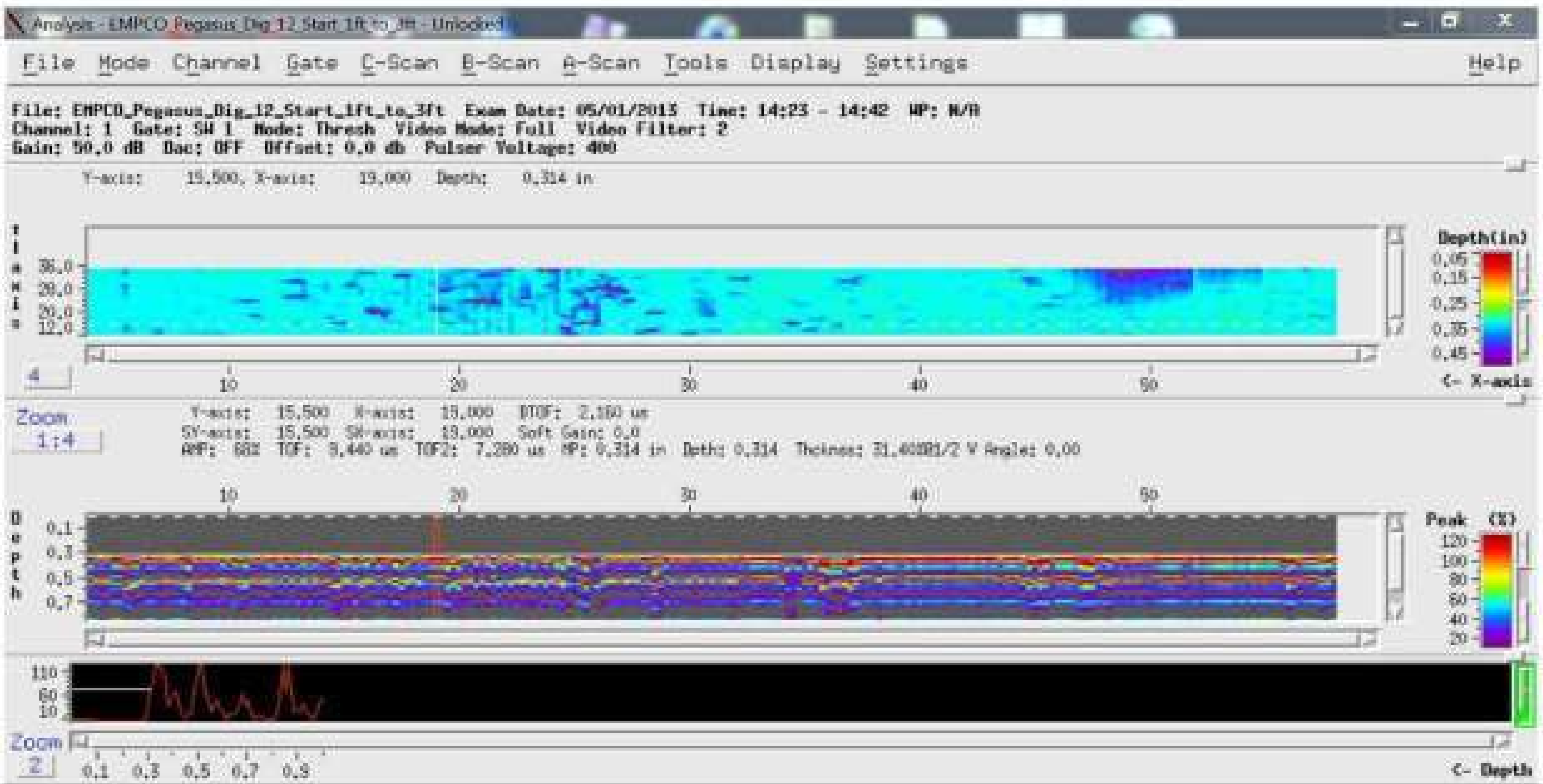
ExxonMobil Pipeline **Inline Inspection Tool Correlation NDE Report** **GE (PII/TFI) / Run Date: July 2012**	US Reference:	**16310+25.62**		ODO to U/S GW:	**81602.14**
	Distance to US Reference:	**4501.09**			
	ODO to Primary Anomaly		Dig #	Upstream Girth Weld #:	
	81627.98		12	**17290**	



Grid 141 Area Scan

Date of Exam	Technician	Certification(s)	
5/1/2013	**Jeff Hecht**	**Lvl III**	

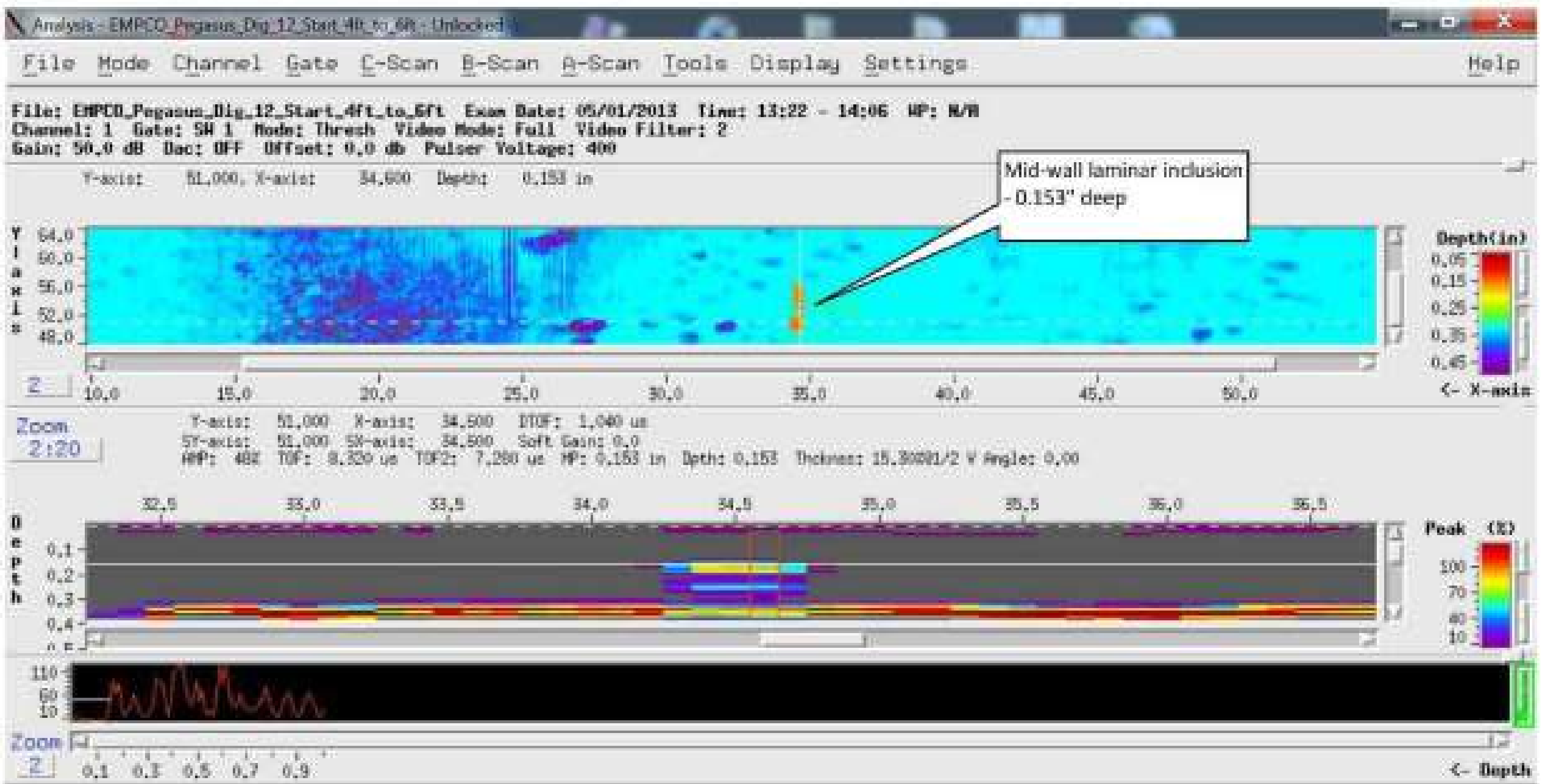
SGS PIINDE	ExxonMobil Pipeline Inline Inspection Tool Correlation NDE Report GE (PII/TFI) / Run Date: July 2012	US Reference:	16310+25.62	ODO to U/S GW:	81602.14
		Distance to US Reference:	4501.09		
		ODO to Primary Anomaly	Dig #	Upstream Girth Weld #:	
		81627.98	12	17290	



Scan from 1 ft to 3 ft

Date of Exam	Technician	Certification(s)	
5/1/2013	Jeff Hecht	Lvl III	

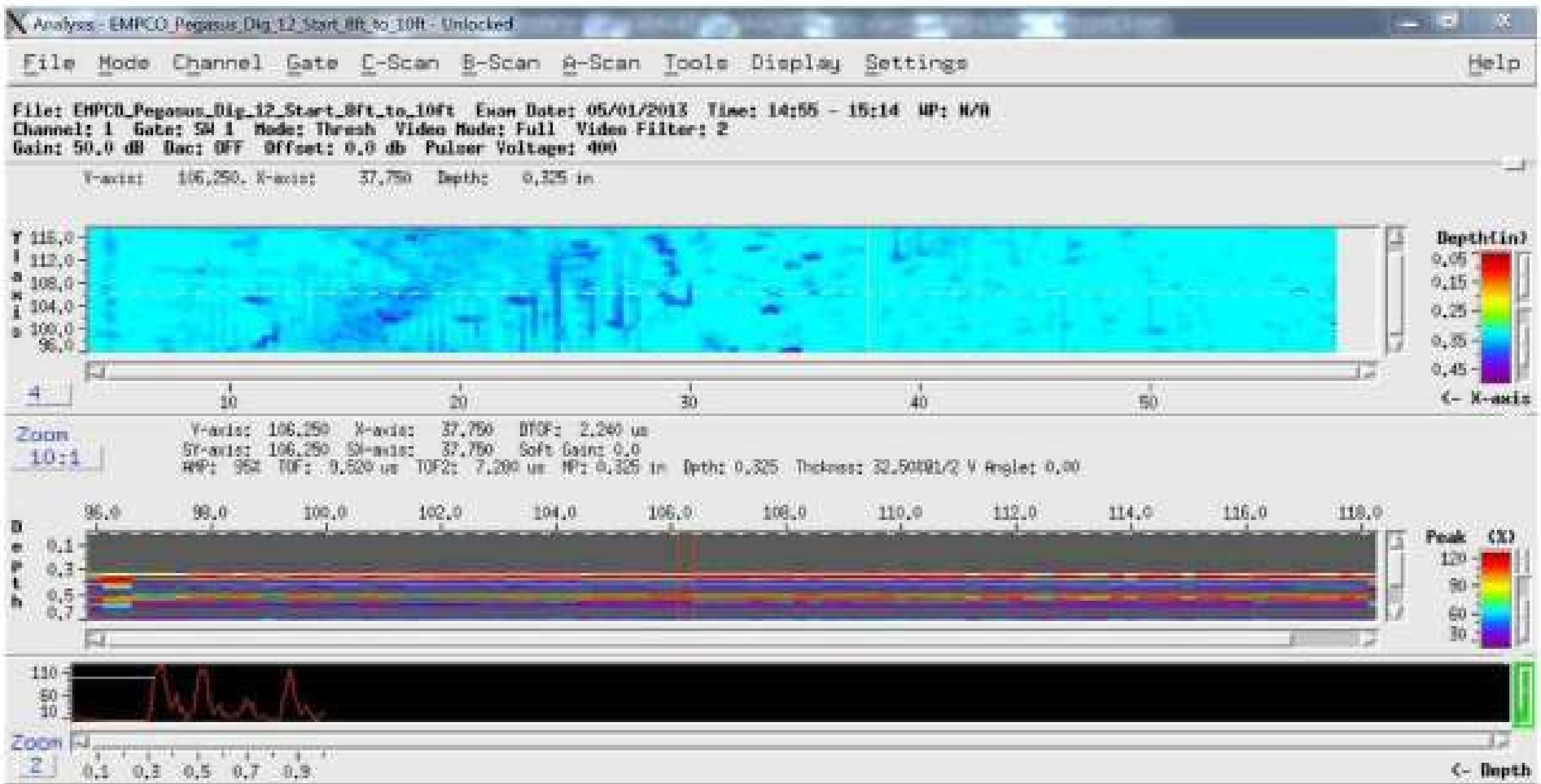
SGS / PIiNDE	ExxonMobil Pipeline Inline Inspection Tool Correlation NDE Report GE (PII/TFI) / Run Date: July 2012	US Reference:	16310+25.62	ODO to U/S GW:	81602.14
		Distance to US Reference:	4501.09		
		ODO to Primary Anomaly	Dig #	Upstream Girth Weld #:	
		81627.98	12	17290	



Scan from 4 ft to 6ft (Anomaly Area)

Date of Exam	Technician	Certification(s)	
5/1/2013	Jeff Hecht	Lvl III	

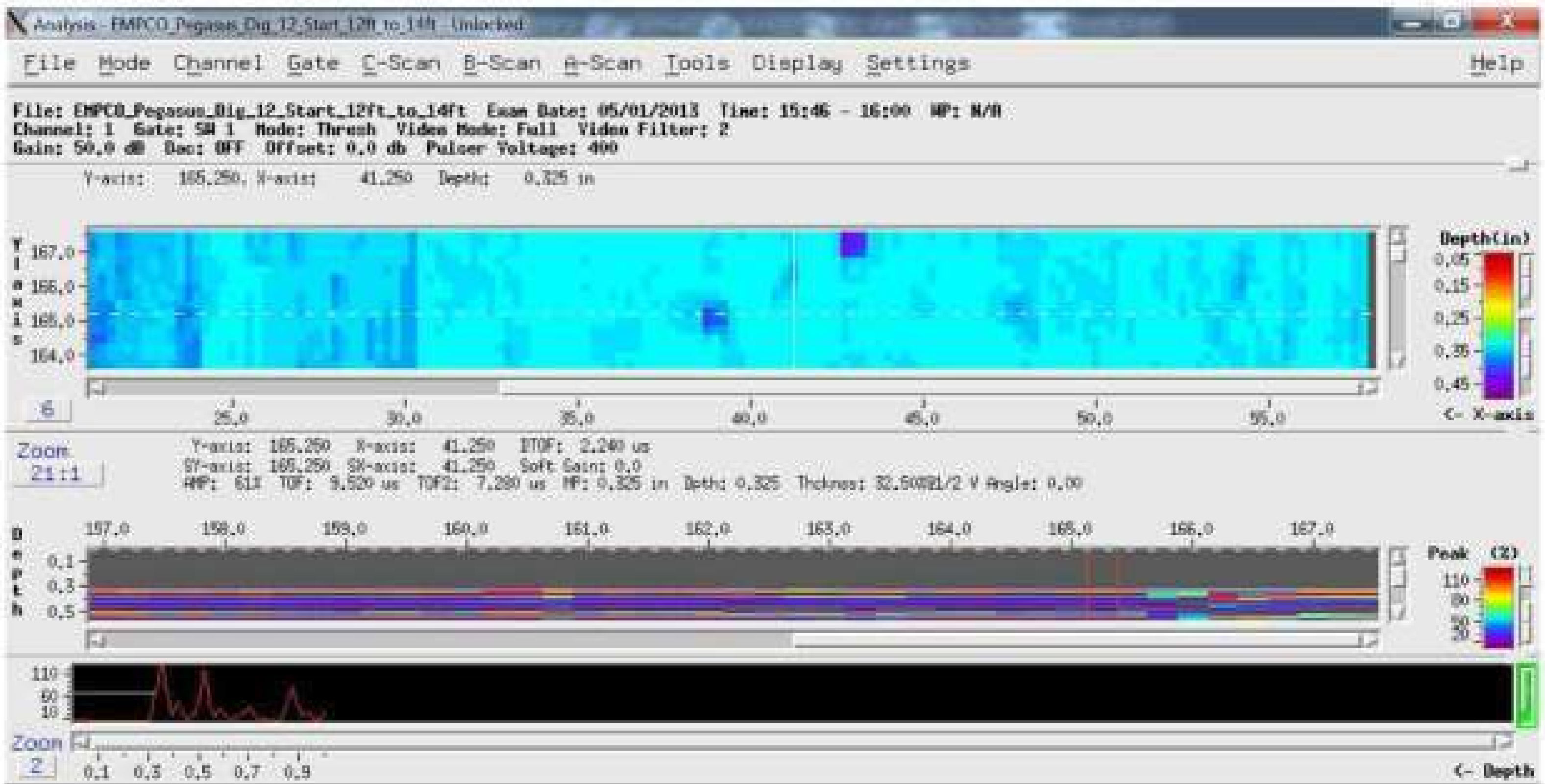
ExxonMobil Pipeline Inline Inspection Tool Correlation NDE Report GE (PII/TFI) / Run Date: July 2012	US Reference:	16310+25.62	ODO to U/S GW:	81602.14
	Distance to US Reference:	4501.09		
	ODO to Primary Anomaly	Dig #	Upstream Girth Weld #:	
	81627.98	12	17290	



Scan from 8ft to 10ft

Date of Exam	Technician	Certification(s)	
5/1/2013	Jeff Hecht	Lvl III	

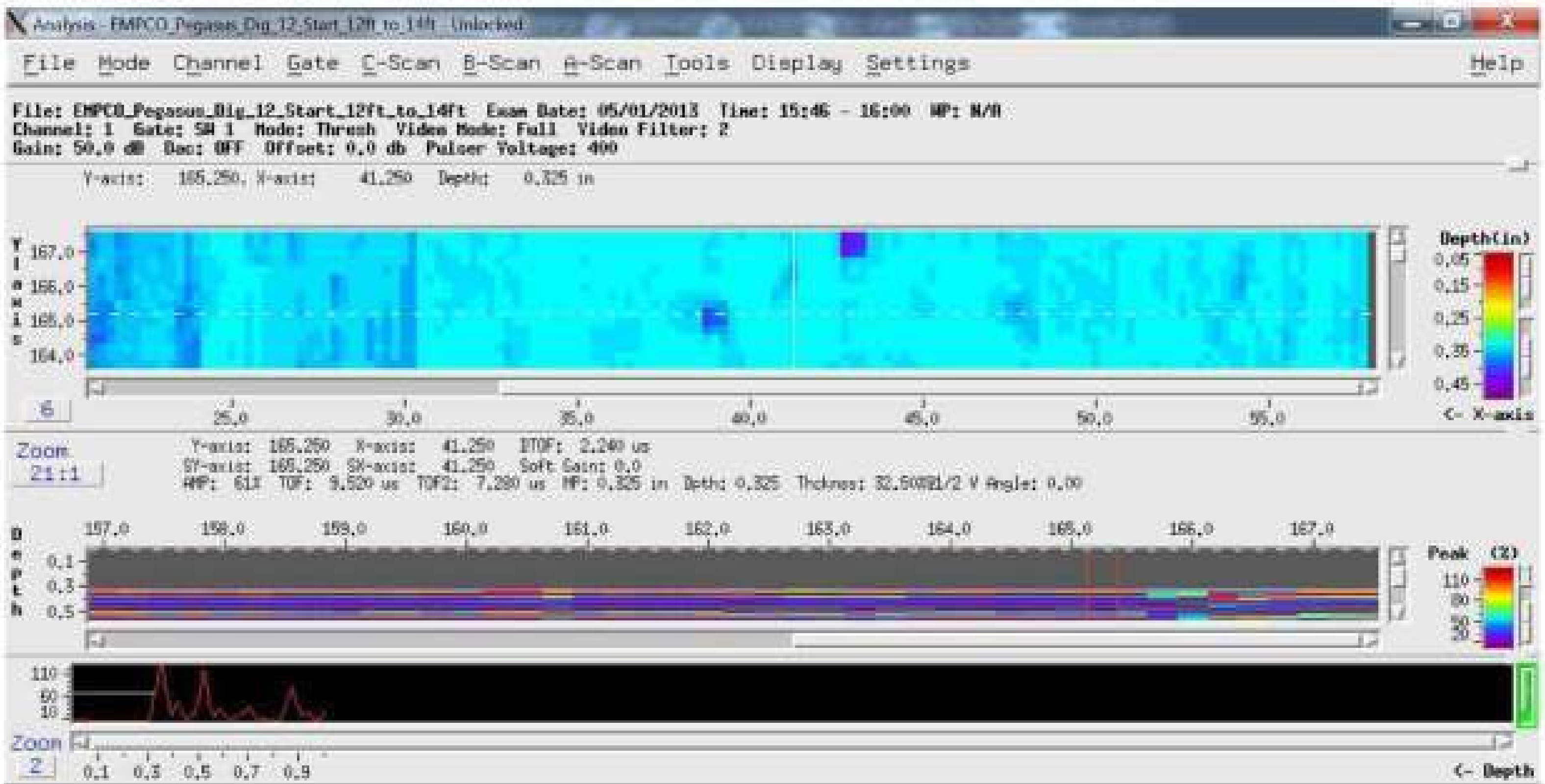
SGS / PIiNDE	ExxonMobil Pipeline Inline Inspection Tool Correlation NDE Report GE (PII/TFI) / Run Date: July 2012	US Reference:	16310+25.62	ODO to U/S GW:	81602.14
		Distance to US Reference:	4501.09		
		ODO to Primary Anomaly	Dig #	Upstream Girth Weld #:	
		81627.98	12	17290	



Scan from 12ft to 14ft

Date of Exam	Technician	Certification(s)	
5/1/2013	Jeff Hecht	Lvl III	

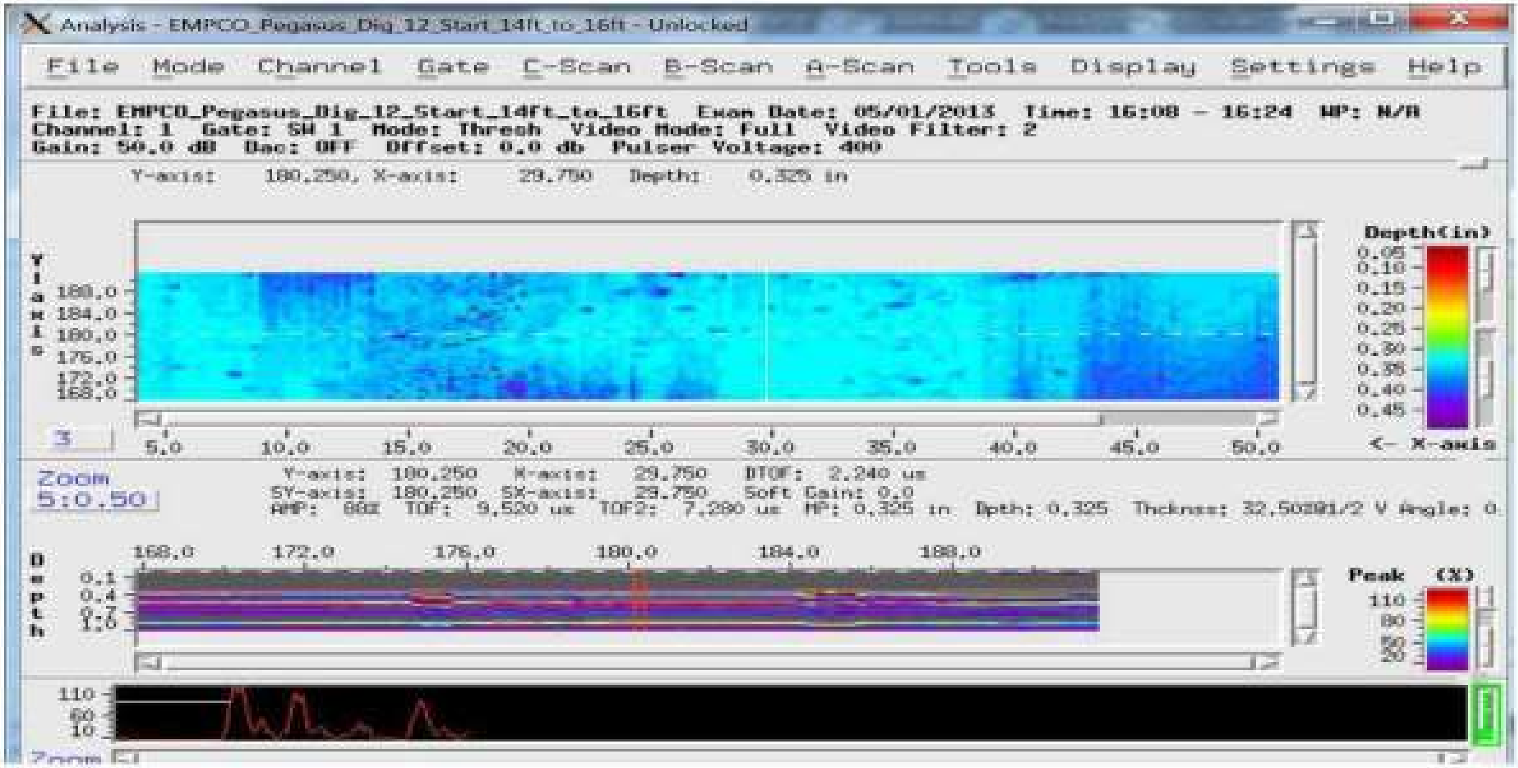
SGS PIiNDE	ExxonMobil Pipeline Inline Inspection Tool Correlation NDE Report GE (PII/TFI) / Run Date: July 2012	US Reference:	16310+25.62	ODO to U/S GW:	81602.14
		Distance to US Reference:	4501.09		
		ODO to Primary Anomaly	Dig #	Upstream Girth Weld #:	
		81627.98	12	17290	



Scan from 12ft to 14ft

Date of Exam	Technician	Certification(s)	
5/1/2013	Jeff Hecht	Lvl III	

SGS PIINDE	ExxonMobil Pipeline Inline Inspection Tool Correlation NDE Report GE (PII/TFI) / Run Date: July 2012	US Reference:	16310+25.62	ODO to U/S GW:	81602.14
		Distance to US Reference:	4501.09		
		ODO to Primary Anomaly	Dig #	Upstream Girth Weld #:	
		81627.98	12	17290	



Scan from 14ft to 18ft

Date of Exam	Technician	Certification(s)	
5/1/2013	Jeff Hecht	Lvl III	

SGS
PIINDE

ExxonMobil Pipeline

Inline Inspection Tool Correlation NDE Report

GE (PII/TFI) / Run Date: July 2012

US Reference:	**16310 + 25.62ft**	ODO to U/S GW:	**81602.14**
Distance to US Reference:	4501.09		
ODO to Primary Anomaly 81627.98	Dig # 12	Upstream Girth Weld #: **17290**	

Project: **HURST LAB EVALUATION**   Pipe Description / Nominals: (**20.000" 0.312" X42**)   Segment: **Conway to Corsicana**

	U/S Joint	Anomaly Joint	D/S Joint
Joint Length:	NV	NV	NV
LS Circ Position:	NV	12:00	NV

Inspection Area Dimensions

Length of Pipe Examined: 24.67'
Axial Start: -1.00' End: 23.67'
Circ Start: 0° End: 360°

Conditions:
Soil pH: NA
Top of Ditch P-S: NA
Btm of Ditch P-S: NA
Soil Resistivity: NA ohm/cm

Seam Type: SAW [ ] FW [ ] ERW [X] DSAW [ ] SMLS [ ] Lap [ ]

Coating Type: Tape [ ] FBE [ ] Coal Tar [X]

Actual Profile Data:
T1: 316 T2: 312 TW: 383 WW: 520 WH: 0

NDE Methods

Visual [X] WCAMT [X] UT-FAST [X] UT-0 Degree [X] UT-Shear [X] UT- Phased Array [X]

Anomaly Information

	Log Start (ft)	Log length (in)	Log circ start (clk)	Log circ extent (in)	Log Depth (%)	Start of Ind (ft)	End of Ind (ft)	Axial Length of Ind (in)	Circ start (clk)	Circ end (clk)	Circ extent (in)	Pipe Thk at Ind (mils)	Max Ind Depth (mils)	Depth, Max %	Pipe or weld	ID, OD or Mid	Flaw Type	Grind Length (in)	NDE Method	NDE Comments or Remarks
1																				See Remarks Below
2																				
3							N													
4									A											
5																				

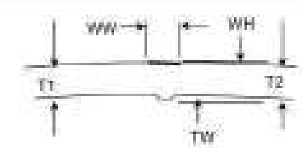
NG=Not Given   NV= Not Verified   NA= Not Applicable   VI= Verified by Dig Inspector

NDE Remarks:

A "map" of ultrasonic thickness measurements were taken from 12 inches upstream of the girth weld to 12 inches downstream of the rupture for 360 degrees around the pipe surface.
The thickness measurements were taken around the entire circumference along the length of pipe at 2 inch grid intervals.
No internal corrosion areas were indentified during the ultrasonic examination. The pipe thickness readings varied from 0.288" to 0.316" along the pipe.

The grid rows identified as "A" and "AE" on the thickness map represent the 2" areas immediately adjacent to the rupture face. Column "7" represents the upstream girth weld cap. (A1 to AE147)

Thickness Profile of Long Seam



Repair type		Sleeve area	Start	End

A = Type "A" sleeve; B = Type "B" Sleeve; C = Clockspring; N = No repair required

Date of Exam	Technician	Certification(s)	
4/28/2013 to 5/1/2013	**Jeff Hecht**	**Level III**	

SGS / PiNDE	ExxonMobil Pipeline	US Reference:	16310 + 25.62ft	ODO to U/S GW:	81602.14
	Inline Inspection Tool Correlation NDE Report	Distance to US Reference:	4501.09		
		ODO to Primary Anomaly	Dig #	Upstream Girth Weld #:	
	GE (PII/TFI) / Run Date: July 2012	81627.98	12	17290	

Description of photograph

Grided Pipe looking upstream

(pipe gridded 12" downstream of rupture).

Description of photograph

Downstream Girthweld End of pipe
(pipe gridded 12" upstream of girthweld)

Date of Exam	Technician	Curtification(s)	
4/28/2013 to 5/1/2013	Jeff Hecht	Level III	

Conway_Corsicana Odo 81627.98 Dig 12

2" GRID

Conway to Corsicana

HURST LAB

	1	2	3	4	5	6	7	8	9	10	11	12
A	302	299	301	313	312	310	US GIRTH WELD	314	315	312	313	313
B	313	301	300	310	309	313		303	310	313	310	301
C	312	311	310	311	316	320		313	313	313	313	316
D	301	310	310	309	308	303		309	311	300	303	311
E	310	311	311	308	310	310		310	308	309	310	310
F	314	314	314	315	310	310		311	309	311	310	311
G	307	306	305	305	308	308		308	308	312	309	310
H	312	314	308	307	306	310		308	312	311	310	312
I	318	312	312	313	313	313		316	316	313	316	304
J	303	311	308	310	311	312		314	312	312	313	314
K	310	305	305	306	305	308		312	313	310	309	309
L	305	310	308	310	310	307		312	311	312	311	312
M	310	306	307	310	309	308		312	310	312	311	310
N	310	310	306	305	310	308		310	311	313	311	311
O	306	310	308	308	309	309		310	311	312	312	312
P	308	307	309	307	309	310		310	311	312	311	311
Q	306	309	310	308	310	309		310	311	312	311	310
R	308	307	309	308	310	310		311	310	312	312	310
S	306	309	308	308	310	311		310	310	310	310	312
T	302	309	308	310	310	310		310	310	312	309	309
U	310	308	309	310	310	312		310	310	312	310	310
V	312	310	310	308	308	311		308	308	308	309	310
W	308	310	310	309	310	309		310	310	309	311	309
X	310	309	309	309	310	312		310	312	311	310	310
Y	310	309	309	309	309	309		310	307	307	309	309
Z	308	303	306	306	306	309		310	306	307	302	308
AA	308	307	306	306	306	306		309	310	307	307	308
AB	304	304	304	312	303	311		310	310	303	302	312
AC	305	307	307	303	303	307		310	311	303	303	303
AD	309	304	306	307	308	308		310	310	308	309	309
AE	305	307	307	303	303	307		310	311	303	303	303

Conway_Corsicana Odo 81627.98 Dig 12 **2" GRID**

Conway to Corsicana

HURST LAB

13	14	15	16	17	18	19	20	21	22	23	24	25
314	316	316	316	315	318	318	305	318	317	318	313	316
312	317	314	320	320	311	307	315	317	315	316	313	306
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303	309	311	304	304	315	314	313	312	312	305	305	305
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310	310	308	310	303	304	305	312	312	312	310	310	310
315	313	303	313	313	313	314	313	312	312	310	310	311
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313	312	310	305	313	313	315	314	315	314	313	313	313
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311	312	313	311	312	312	312	313	314	312	310	313	314
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312	310	311	312	310	310	310	310	311	312	312	312	312
311	311	312	311	310	313	311	311	310	312	313	311	310
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308	308	307	308	308	308	308	309	309	309	309	309	309
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305	312	310	310	305	305	305	305	310	305	306	311	312

Conway_Corsicana Odo 81627.98 Dig 12 **2" GRID**

Conway to Corsicana

HURST LAB

26	27	28	29	30	31	32	33	34	35	36	37	38
316	316	313	312	304	306	312	304	312	312	314	314	314
314	318	317	302	303	312	312	314	312	312	311	311	312
314	313	316	304	310	312	311	311	311	312	312	312	313
304	311	306	312	311	312	313	312	312	312	313	312	311
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310	303	310	314	312	314	312	305	305	304	303	313	305
310	311	303	310	311	312	314	312	312	314	314	314	314
315	315	306	308	305	304	303	314	314	314	309	302	304
310	312	312	311	303	314	308	305	308	314	309	311	311
312	312	312	308	314	305	309	310	303	314	311	311	311
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312	309	309	310	310	305	305	305	306	306	307	307	307
309	310	310	312	312	306	305	304	306	308	309	309	312
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Conway_Corsicana Odo 81627.98 Dig 12
Conway to Corsicana
HURST LAB

2" GRID

39	40	41	42	43	44	45	46	47	48	49	50	51
315	312	314	314	314	314	314	308	308	308	312	314	314
312	312	306	312	305	312	312	312	307	305	312	306	308
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311	306	308	308	311	312	312	314	306	312	314	314	313
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312	312	312	312	313	312	312	312	312	312	312	312	312
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312	312	312	312	313	312	312	312	312	312	312	312	312
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312	311	312	311	312	312	311	312	312	312	311	311	311
311	310	310	310	310	310	310	311	312	310	312	312	312

Conway_Corsicana Odo 81627.98 Dig 12 **2" GRID**

Conway to Corsicana

HURST LAB

52	53	54	55	56	57	58	59	60	61	62	63	64
314	314	308	307	306	308	312	305	312	308	312	309	307
312	312	305	305	305	305	305	307	304	308	309	304	308
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305	312	306	312	312	306	307	307	309	308	309	308	309
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Conway_Corsicana Odo 81627.98 Dig 12
Conway to Corsicana
HURST LAB

2" GRID

65	66	67	68	69	70	71	72	73	74	75	76	77
307	309	310	309	310	309	309	309	309	310	310	310	310
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309	309	312	303	309	309	305	309	305	309	309	308	305
307	306	309	306	307	307	308	309	309	307	306	309	309
308	309	309	310	310	305	312	311	305	305	306	309	312
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306	312	313	312	309	307	312	310	312	310	312	314	315
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Conway_Corsicana Odo 81627.98 Dig 12
Conway to Corsicana
HURST LAB

2" GRID

78	79	80	81	82	83	84	85	86	87	88	89	90
308	311	312	311	312	312	313	310	312	310	310	311	310
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Conway_Corsicana Odo 81627.98 Dig 12
Conway to Corsicana
HURST LAB

2" GRID

91	92	93	94	95	96	97	98	99	100	101	102	103
311	310	310	311	310	310	309	311	310	312	311	312	312
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Conway_Corsicana Odo 81627.98 Dig 12
Conway to Corsicana
HURST LAB

2" GRID

104	105	106	107	108	109	110	111	112	113	114	115	116
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Conway_Corsicana Odo 81627.98 Dig 12
Conway to Corsicana
HURST LAB

2" GRID

117	118	119	120	121	122	123	124	125	126	127	128	129
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Conway_Corsicana Odo 81627.98 Dig 12
Conway to Corsicana
HURST LAB

2" GRID

130	131	132	133	134	135	136	137	138	139	140	141	142
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Conway_Corsicana Odo 81627.98 Dig 12 **2" GRID**
Conway to Corsicana
HURST LAB

143	144	145	146	147
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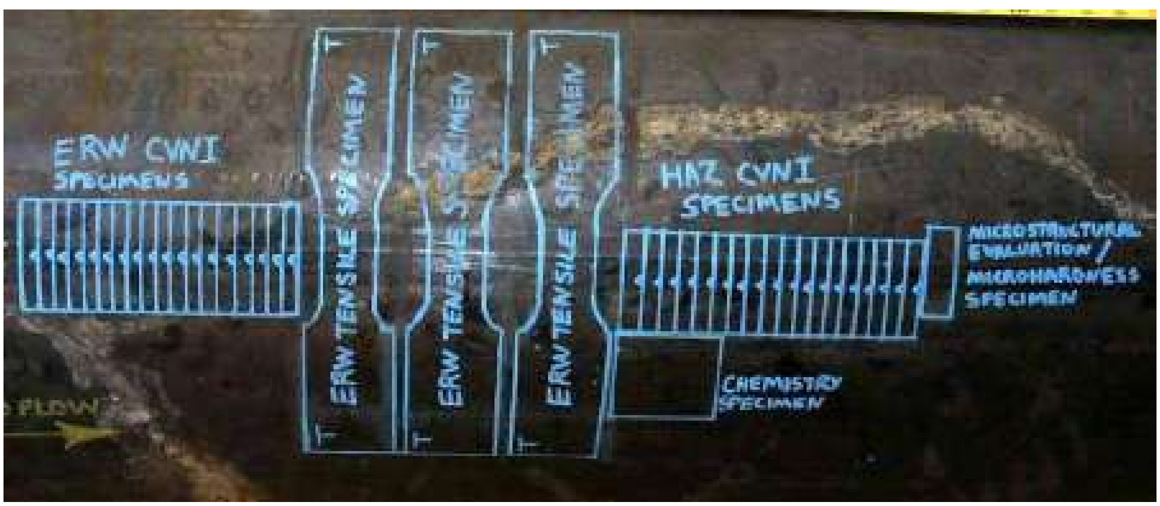
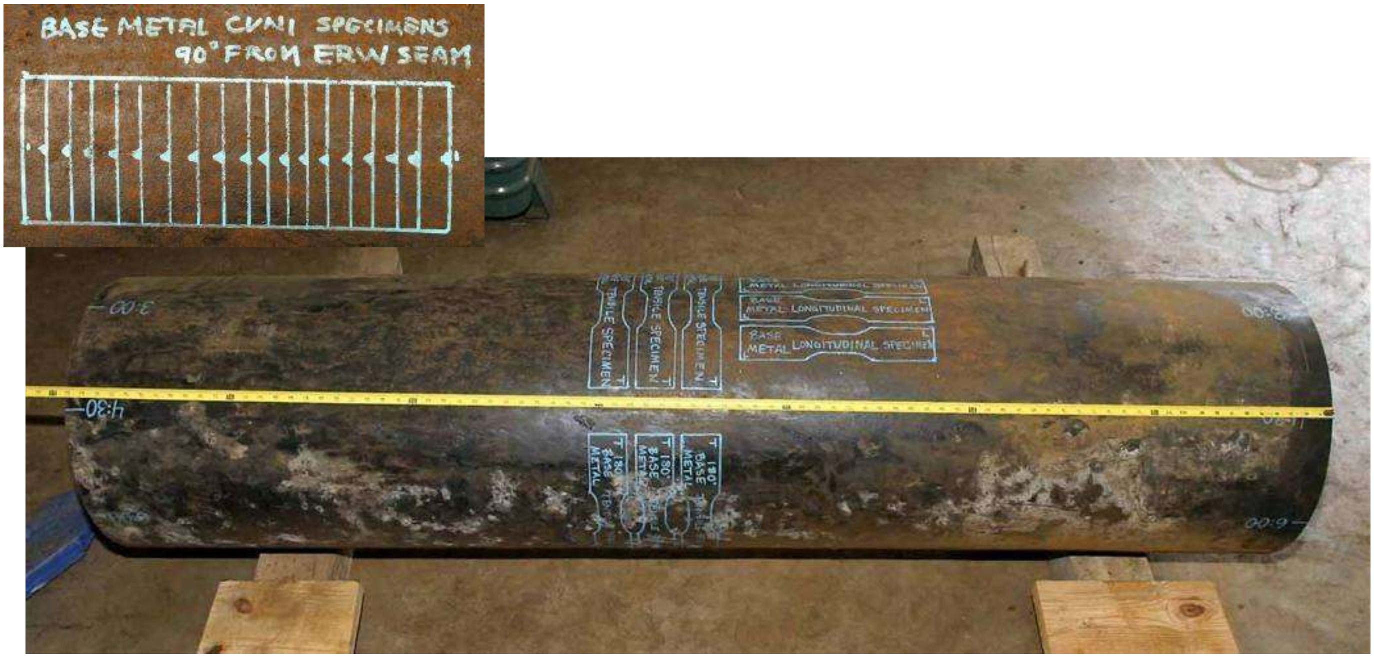
311	310	310	310	310

Appendix V

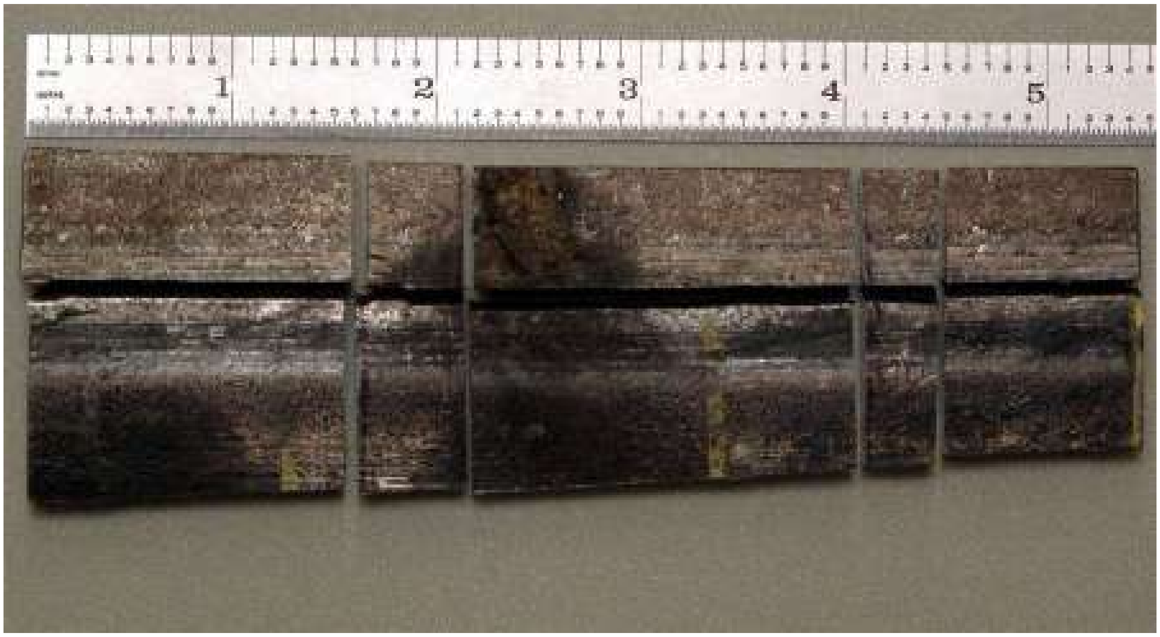


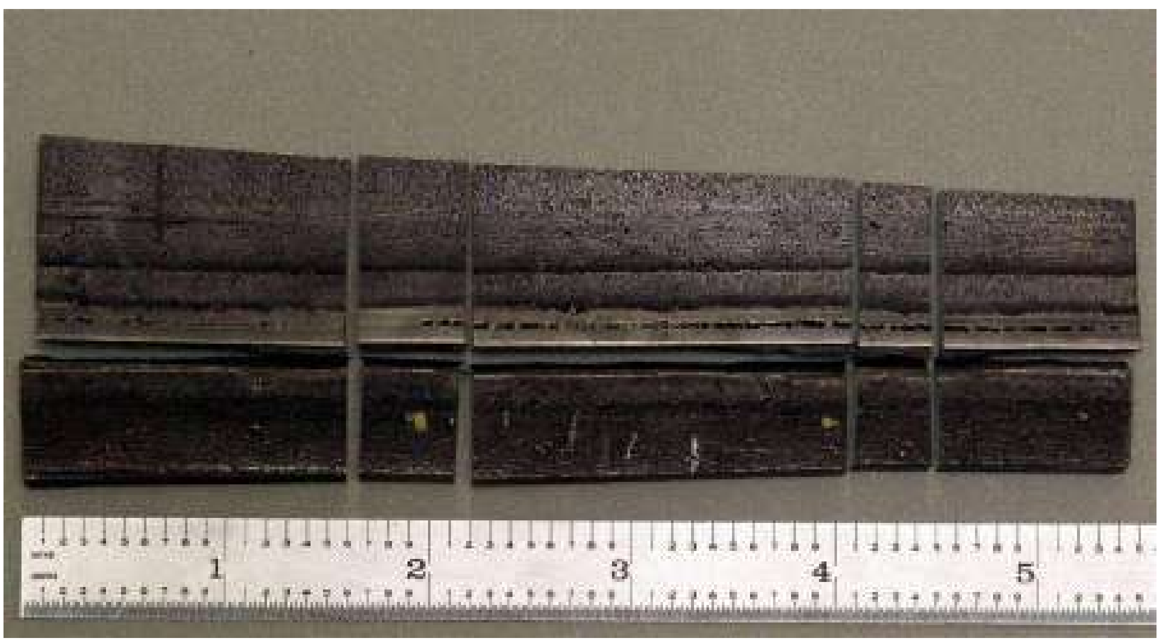
The photographs display an overall view of the area along the ERW seam on the intact 19' 10" long section of the pipe, and a closer view of the area where the ERW seam test specimens were removed from.



The photographs display an overall view of the area opposite the ERW seam on the intact 19' 10" long section of the pipe, showing where the longitudinal and transverse base metal test specimens were removed from. The insert photograph shows the location of the base metal CVN impact test specimens.

The photograph displays the test specimens that were removed from the intact 19' 10" long section of pipe, after machining and prior to testing. The various test specimens were machined and tested in accordance with ASTM A370-12a and the applicable sections of each edition of API 5L.





The photographs display the O.D. and I.D. surface, respectively, at the locations where the cross-sections were removed through the fractured area of the ERW seam and metallographically prepared for microstructural evaluation.