BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 1 OF 88

LABORATORY REPORT-LS3 BOTTOM

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REPORT ISSUED TO:

Jim McVay	**Robert J. Hall**	**Robert Parker**

SAMPLE DESCRIPTION: A heat exchanger failed and a test protocol was developed for the failure analysis of the component. This test protocol and its addendum, as of this date and contained in Attachment 1, were developed and signed by Tesoro Companies, Division of Occupational Safety and Health and U.S. Chemical Safety Board. FirstEnergy BETA Laboratory was selected as the referee test laboratory to perform the testing requirements of the test protocol. The test protocol was not specific as to the test samples to be removed from the heat exchanger or the test locations/test parameters for each specific test within the test sample. Therefore it was agreed

> "The laboratory, acting as a referee laboratory, will be supplied the locations to take the test samples and the type of test and test parameters to be performed at each location on the test sample, i.e. magnification, hardness load/test method. The signatory parties or their technical representatives that are present in the laboratory at the time shall make those decisions and give that information directly to the laboratory. Comments from other technical experts will be considered and factored into the signatory parties or their technical representative's decisions but all decisions on protocol or samples shall remain as decisions of the signatory parties or their representatives."

Additionally it was determined that BETA laboratory as a referee test laboratory is to report the data obtained but not give any interpretation or conclusion on any data, or on details in the photo.

On June 5, 2010 the heat exchanger arrived at Halvorsen Company's warehouse, in a June 11, 2010 meeting locations were selected for sample removal and on June 12, 2010 samples were cut by Halvorsen for submittal to BETA laboratory. The results of the receipt inspection for the heat exchanger at Halvorsen Companies warehouse are contained in report FirstEnergy's report titled M10198- Receipt dated July 30, 2010.

This report is the first of a series on the failed parts of the 6600E heat exchanger. The LS# and CS# refer to longitudinal and circumferential weld seams while the part number refers to the chain of custody number.

BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 2 OF 88

LABORATORY REPORT-LS3 BOTTOM

TEST PERFORMED: The tests on the heat exchanger parts included visual examination, chemical analysis via Vacuum Spectrosmetry and LECO carbon, macro and micro-hardness measurements, wall thickness measurements, magnetic and dye penetrant inspection, photomicroscopy, Scanning Electron Microscopy (SEM) fractography and local chemical analysis via Energy Dispersive Analysis of X-rays (EDS). The details of the apparatus utilized and the test procedures are given in Table 1 and Attachment 2.

TEST RESULTS: The heat exchanger weld seams had been previous labeled as shown in Figure 1 and the same labeling was used for this report. A piece labeled 14 (LS3 Bottom) contained the complete LS 3 bottom fracture and about 20 and 13 inches of the fracture in CS3 and CS4 respectively, as shown in Figure 2 was received at BETA Lab for testing. The visual appearance of the CS3 fracture edge is shown in Figure 3. The approximately 84 inches of the LS3 fracture edge are shown in Figures 4-8. Figure 9 shows the fracture edge of CS4.

The ID surface of part 14 was wet fluorescent magnetic particle inspected by others and numerous indications were found. The Indications are circled in Figures 10-13.

Eight locations were selected, by others, for metallurgical mounting. The locations on piece 14 and the photos of the etched mounts are shown in Figures 14-16. The mounts were examined in the un-etched and etched conditions and photomicrographs were taken as selected by others. The photomicrographs are shown in Figures 17-51. Additionally some of the mounts were examined in the scanning electron microscope as shown in Figures 23, 42, and 51.

Samples of the can 2, can 3 and the ID and OD crowns of CS2, and LS3 were obtained and chemically analyzed. The can is the designation for the rolled plate that has been longitudinally welded to make a cylinder. The various cylinders or cans are then welded together with circumferential welds to make the heat exchanger shell The results of those chemical analyses are detailed in Table 2.

Four locations were selected for SEM fractography but the fracture surface was very heavily coated with scale/corrosion product, as shown in Figure 52-55. The fracture surfaces of 14-SEM1, SEM2 and SEM3 were cleaned with the following procedure and the as cleaned surfaces are shown in Figures 52-55.

1. Alconox, ultrasonic, up to 5 minutes, rinse with warm water
2. Inhibited HCl, ultrasonic, 30 – 60 seconds, rinse with warm water
3. Alconox, ultrasonic, approximately 30 seconds, rinse with warm water
4. Inhibited HCl, ultrasonic, approximately 15 – 30 seconds, rinse with warm water
5. Alconox, ultrasonic, approximately 30 seconds, rinse with warm water
6. Methanol, ultrasonic, approximately 10 seconds

The Alconox solution was made up from approximately 35g/l and the inhibited HCl was made up of 6N HCl inhibited with 5g/l of 1,3 Di-n-butyl-2 thiourea

BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 3 OF 88

LABORATORY REPORT-LS3 BOTTOM

The SEM photomicrograph of the as cleaned surface is shown in Figure 56.
Additional samples, as shown in Figure 57, were cut to evaluate a cathodic cleaning method. The surfaces cleaned by the following procedure are shown in Figure 57. When the surfaces were examined under the SEM they disclosed scale or cleaned areas of chemical attack. The cathodic cleaning procedures included:

14 T1a: Total accumulated time was 1 hour on 7/12/2010

1. 10% w/v NaOH + 1% Na2CO3 + 1% Alconox @ ~ 3 – 4 V, 600 mamps
2. Alconox (~ 4 % W/V) Ultrasonically for ~ 5 minutes
3. 3% H2SO4 to desmut for ~ 10 – 15 seconds
4. Flush and rinse with acetone

14 T1b: Total accumulated time was 2.5 hours on 7/13/2010

1. Immersion in 85% H3PO4 (conc. Orthophosphoric acid)
2. Approximately every 10 – 15 minutes, rinse and ultrasonic in Alconox solution to evaluate.
3. Flush and rinse with acetone

The T-2 sample was alternately dipped in liquid nitrogen and heated to 180 degrees C for 6 cycles and the as processed surface is shown in Figure 57.

The results of the chemical cleaning, cathodic cleaning and thermal shock tests were discussed with the signature parties and all SEM work of the oxidized fracture surfaces was placed on HOLD.

Rockwell hardness testing was performed at approximately the mid wall on transverse section for can 2 and can 3 plate material and the results are reported in Table 3. 8dditionally micro-hardness measurements in the 500gm Vickers scale were performed, as directed, on some of the mounts. The locations where the traverses were performed are shown in Figure 57 and the data is presented in Tables 8-14.

BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 4 OF 88

LABORATORY REPORT-LS3 BOTTOM

TABLE 1
TESTS PERFORMED
(See Attachment 2 for Test/Equipment Specifications)

TEST	METHOD OR INSTRUMENT	PERFORMED BY	LOCATION, DATE	RESULTS LOCATION
VISUAL EXAMINATION	LECO SZH STEREO MACROSCOPE OR PORTRAIT CAMERA	J. BLOUGH	HALVORSEN & BETA, VARIOUS	TEST RESULTS
CHEMICAL ANALYSIS	THERMO ARL-3460 OE SPECTROMETER	M. TASCAR	BETA, VARIOUS	TABLE 2
CHEMICAL ANALYSIS – SEM/EDS	CAMSCAN SCANNING ELECTRON MICROSCOPE WITH IXRF EDS2000 ENERGY DISPERSIVE X-RAY SPECTROMETER	C. HOLP	BETA, JULY 14, 2010	Figure 51
Carbon Analysis	Leco Carbon/Sulfur Determination CS-444	M. Belviso	BETA, 6/15/10	Table 2
ROCKWELL HARDNESS	Wilson Rockwell 524THardness Tester	M. Tascar	BETA, 7/26/10	Table 3
KNOOP/VICKERS, SEMI-MACRO VICKERS	INSTRON TUKON 2100B HARDNESS TESTER, MODEL T2100BR1942	M. TASCAR	BETA, VARIOUS	TABLES 6-12 AND FIGURE 58
OPTICAL METALLOGRAPHY	LECO PMG-3 OPTICAL MICROSCOPE	J. BLOUGH	BETA, VARIOUS	FIGURES 17-51
FRACTOGRAPHY	CAMSCAN SCANNING ELECTRON MICROSCOPE WITH IXRF EDS2000 ENERGY DISPERSIVE X-RAY SPECTROMETER	C. HOLP	BETA, VARIOUS	FIGURE 56
WET MAGNETIC PARTICLE TESTING	WET FLUORESCENT AC YOKE	TEAM INDUSTRIAL SERVICE ,MICHAEL BUCKLEY	BETA, 6-15-2010	ATTACHMENT 3
WALL THICKNESS	MICROMETER	M. TASCAR	BETA, 6/15 & 7/26/10	TABLE 4 & 5

BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 5 OF 88

LABORATORY REPORT-LS3 BOTTOM

TABLE 2
CHEMICAL ANALYSIS FOR BASE METAL AND WELD DEPOSITS

SAMPLE IDENTIFICATION	CHEMICAL COMPOSITION, WT. %											
	C	SI	P	S	MN	NI	CR	MO	V	CU	CO	AL
14-3 CAN 2	0.26	0.23	0.008	0.019	0.59	0.12	0.12	0.02	<0.001	0.18	0.01	0.01
14-3 CAN 3	0.26	0.23	0.008	0.021	0.60	0.12	0.13	0.02	<0.001	0.18	0.01	0.01
SA- 515 GRADE 70	0.31 MAX	0.13-0.45	0.035 MAX	0.035 MAX	1.30 MAX	NS	NS	NS	NS	NS	NS	NS
14-CS3 OD CROWN	0.08	0.57	0.011	0.018	1.14	0.05	0.08	0.01	0.002	0.15	0.01	0.005
14-CS3 ID WELD SURFACE	0.09	0.64	0.017	0.022	1.31	0.05	0.09	0.01	0.002	0.24	0.01	0.005
14-LS3 OD CROWN	0.10	0.50	0.011	0.019	1.12	0.06	0.08	0.01	0.001	0.14	0.01	0.005
14-LS3 ID WELD SURFACE	0.16	0.37	0.010	0.021	1.04	0.08	0.09	0.02	0.001	0.14	0.01	0.005
SFA 5.1 (E7016, E7018)*	NS	0.75 MAX	NS	NS	1.60 MAX	0.30 MAX	0.20 MAX	0.30 MAX	0.08 MAX	NS	NS	NS
SFA 5.17 (EM11K)	0.07-0.15	0.65-0.85	0.030 MAX	0.025 MAX	1.00-1.50	NS	NS	NS	NS	0.35	NS	NS
SFA 5.17 (EL12)	0.04-0.14	0.10 MAX	0.030 MAX	0.030 MAX	0.25-0.60	NS	NS	NS	NS	0.35	NS	NS
SFA 5.17 (EM12K)	0.05-0.15	0.10-0.35	0.030 MAX	0.030 MAX	0.80-1.25	NS	NS	NS	NS	0.35	NS	NS

NS = NOT SPECIFIED

ALL ANALYSIS IS OPTICAL EMISSION SPECTROSCOPY EXCEPT THE CARBON WHICH IS LECO

NO ALLOYS OR WELD WIRE GRADES WERE SPECIFIED SO TYPICAL ARE PRESENTED

* TOTAL OF MN+NI+CR+MO+V 1.75 MAX

SA-515 SPECIFICATION FOR PRESSURE VESSEL PLATES, CARBON STEEL, FOR INTERMEDIATE-AND HIGHER-TEMPERATURE SERVICE – JULY 2003 ADDENDUM

SFA 5.1 SPECIFICATION FOR CARBON STEEL ELECTRODES FOR SHIELD METAL ARC WELDING-JULY 2003 ADDENDUM

SFA 5.17 SPECIFICATION FOR CARBON STEEL ELECTRODES AND FLUXES FOR SUBMERGED ARC WELDING- JULY 2003 ADDENDUM

TABLE 3
ROCKWELL (HRB) HARDNESS MEASUREMENTS ON PLATE CROSS SECTIONS

SAMPLE IDENTIFICATION	HARDNESS			
	MINIMUM	MAXIMUM	AVERAGE	NUMBER OF INDENTATIONS
14 CAN 2	82.3	83.5	83.1	7
14 CAN 3	82.5	83.7	83.1	7

BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 6 OF 88

LABORATORY REPORT-LS3 BOTTOM

TABLE 4
WALL THICKNESS MEASUREMENTS LS3 FRACTURE

Location Number from UT reading	2 inch from fracture (inch)		Location Number from UT reading	2 inch from fracture (inch)		Location Number from UT reading	2 inch from fracture (inch)		Location Number from UT reading	2 inch from fracture (inch)	
0			22	0.847		44	0.857		66	0.861	
2	0.839		24	0.857		46	0.850		68	0.864	
4	0.841		26	0.852		48	0.860		70	0.858	
6	0.829		28	0.853		50	0.858		72	0.859	
8	0.837		30	0.850		52	0.860		74	0.863	
10	0.848		32	0.855		54	0.864		76	0.861	
12	0.852		34	0.858		56	0.862		78	0.837	
14	0.851		36	0.857		58	0.863		80	0.831	
16	0.850		38	0.854		60	0.866		82	0.852	
18	0.848		40	0.853		62	0.866		84	0.852	
20	0.848		42	0.853		64	0.861				

TABLE 5
WALL THICKNESS MEASUREMENTS FOR ADJOINING CS3 and CS4 FRACTURES

CS3			CS4	
Location Number from UT reading*	2 inch from fracture (inch)		Location Number from UT reading*	2 inch from fracture (inch)
0	NM		0	NM
2	NM		2	0.846
4	NM		4	0.848
6	NM		6	0.856
8	0.787		8	0.862
10	0.798		10	0.852
12	0.827			
14	0.830			
16	0.841			

NM= not measurable because fracture is closer than 2 inches
* marked in the field by others

BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 7 OF 88

LABORATORY REPORT-LS3 BOTTOM

TABLE 6
MICRO-HARDNESS MEASUREMENTS MOUNT M1 CS3
VICKERS 500Gm UNLESS OTHERWISE SPECIFIIED

M1 OD Line 500 HV	M1 OD Line *10Kg* HV	Location	M1 Cusp Line HV	Locations	M1 ID Line HV	Locations	M1 Can 3 HAZ HV	Locations
189	182	BM Can2						
188	180	BM Can2						
186	184	BM Can2						
187	NA	BM Can2						
			200	Can2 Haz Leg				
			201	Can2 Haz Leg				
			190	Can2 Haz Leg				
206	200	FG Haz	190	Can2 Haz Leg	198	Can2 FG Haz Leg		
197	206	FG Haz	203	Can2 FG Haz	200	Can2 FG Haz Leg		
206		FG Haz	196	Can2 FG Haz	190	Can2 FG Haz Leg		
212		FG Haz	196	Can2 FG Haz	188	Can2 FG Haz Leg		
215	215	CG Haz	192	Can2 FG Haz	243	Can2 CG Haz Leg		
226	212	CG Haz	194	Can2 FG Haz	212	Can2 CG Haz Leg		
215		CG Haz	193	Can2 FG Haz	218	Can2 CG Haz Leg		
225		CG Haz	197	Can2 FG Haz	210	Can2 CG Haz Leg		
198	191	Weld Traverse	175	Weld Traverse	194	Weld Traverse	186	Can3 Diag Bottom Weld Traverse
189	191	Weld Traverse	177	Weld Traverse	202	Weld Traverse	192	Can3 Diag Bottom Weld Traverse
195	182	Weld Traverse	172	Weld Traverse	202	Weld Traverse	191	Can3 Diag Bottom Weld Traverse
176	193	Weld Traverse	175	Weld Traverse	182	Weld Traverse	192	Can3 Diag Bottom Weld Traverse
193	191	Weld Traverse	178	Weld Traverse	182	Weld Traverse (Haz)	186	Can3 Diag Bottom Weld Traverse
198	NA	Weld Traverse					210	Can3 Diag Top Weld Traverse

BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 8 OF 88

LABORATORY REPORT-LS3 BOTTOM

TABLE 6 CONTINUED

192		Weld Traverse							198	Can3 Diag Top Weld Traverse
202		Weld Traverse							217	Can3 Diag Top Weld Traverse
207		Weld Traverse							217	Can3 Diag Top Weld Traverse
									209	Can3 Diag Top Weld Traverse
220	231	CG Haz							201	Can3 Diag Haz
237		CG Haz							191	Can3 Diag Haz
248		CG Haz							188	Can3 Diag Haz
239		CG Haz							192	Can3 Diag Haz
201		FG Haz		193	Can3 FG Haz		198	FG Haz Leg	186	Can3 Diag Haz
216	217	FG Haz		191	Can3 FG Haz		197	FG Haz Leg	224	Can3 Diag Haz
210	215	FG Haz		192	Can3 FG Haz		193	FG Haz Leg		
208	NA	FG Haz		191	Can3 FG Haz		201	FG Haz Leg		
193	182	BM Can3								
191	180	BM Can3								
192	177	BM Can3								
200	194	BM Can3								

NA= not applicable
BM = Base Metal, FG= Fine Grain, HAZ= Heat Affected Zone, CG = Coarse Grain

BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 9 OF 88

LABORATORY REPORT-LS3 BOTTOM

TABLE 7
MICRO-HARDNESS MEASUREMENTS MOUNT M3 LS3
VICKERS 500Gm

M3 OD Line HV	Location	M3 Cusp Line HV	Locations	M3 ID Line HV		M3 Can 3 fracture HV	Locations
223	Weld (Near Edge)	239	Weld (Near Edge)	188	ID Weld Near Fracture	255	Diag OD Weld Near Fracture
203	OD Weld	248	Cusp Weld	192	ID Weld Near Fracture	206	Diag OD Weld Near Fracture
207	OD Weld	246	Cusp Weld	215	ID Weld	201	Diag OD Weld Near Fracture
219	OD Weld	236	Cusp Weld	209	ID Weld	220	Diag OD Weld Near Fracture
209	OD Weld	221	Cusp Weld	219	ID Weld	178	Diag ID Weld Near Fracture
229	OD Weld			203	ID Weld	185	Diag ID Weld Near Fracture
230	OD Weld					211	Diag ID Weld Near Fracture
240	OD FG Haz	245	CG Haz	228	ID CG Haz Leg @ Fracture	217	Diag ID Weld Near Fracture
232	OD FG Haz	227	CG Haz	223	ID CG Haz Leg @ Fracture	221	Diag ID Weld Near Fracture
234	OD FG Haz	236	CG Haz	229	ID CG Haz Leg @ Fracture		
234	OD FG Haz	242	CG Haz	235	ID CG Haz Leg @ Fracture		
234	OD LG Haz	219	Cusp Haz Leg	204	ID FG Haz Leg		
239	OD LG Haz	211	Cusp Haz Leg	210	ID FG Haz Leg		
227	OD LG Haz	225	Cusp Haz Leg	213	ID FG Haz Leg		
242	OD LG Haz	226	Cusp Haz Leg	203	ID FG Haz Leg		

BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 10 OF 88

LABORATORY REPORT-LS3 BOTTOM

TABLE 7 CONTINUED

				203	ID CG Haz Leg
				209	ID CG Haz Leg
				207	ID CG Haz Leg
				209	ID CG Haz Leg
218	OD BM	182	Cusp BM		
212	OD BM	189	Cusp BM		
208	OD BM	193	Cusp BM		
214	OD BM	215	Cusp BM		

BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 11 OF 88

LABORATORY REPORT-LS3 BOTTOM

TABLE 8
MICRO-HARDNESS MEASUREMENTS MOUNT M4 LS3
VICKERS 500Gm

M4 Right Vertical Line HV	Location		M4 Left Vertical line HV	Locations
181	BM		193	BM
183	BM		184	BM
184	BM		189	BM
186	BM		192	BM
204	FG Haz		188	FG Haz
190	FG Haz		193	FG Haz
191	FG Haz		184	FG Haz
188	FG Haz		201	FG Haz
194	Weld CG		210	Weld CG
187	Weld CG		195	Weld CG
181	Weld CG		200	Weld CG
204	Weld CG (@ Fracture)		198	Weld CG (@ Fracture)

BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 12 OF 88

LABORATORY REPORT-LS3 BOTTOM

TABLE 9
MICRO-HARDNESS MEASUREMENTS MOUNT M5 CS4
VICKERS 500Gm

M5 Vertical Line HV	Location		M5 Horizontal Line HV	Locations		M5 Fracture Line HV	Locations
138	BM		152	BM		110	Diag BM (Near Fracture)
138	BM		143	BM		117	Diag BM (Near Fracture)
143	BM		149	BM		124	Diag BM (Near Fracture)
136	BM		133	BM		129	Diag BM (Near Fracture)
143	BM					140	Diag BM (Near Fracture)
145	OD Weld		139	Weld			
135	OD Weld		139	Weld			
139	OD Weld		139	Weld			
132	OD Weld		137	Weld			
136	OD Weld (Near Surface)						

BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 13 OF 88

LABORATORY REPORT-LS3 BOTTOM

TABLE 10
MICRO-HARDNESS MEASUREMENTS MOUNT M6
VICKERS 500Gm

M6 OD Line HV	Location	M6 Cusp Line HV	Locations	M6 ID Line HV		M6 Can 3 HAZ HV	Locations
174	OD Weld Can2 BM	176	Cusp Can2 BM			181	Diag Can2 BM (Close to Weld) (ID)
176	OD Weld Can2 BM	175	Cusp Can2 BM			201	Diag Can2 BM (Close to Weld)
175	OD Weld Can2 BM	174	Cusp Can2 BM			223	Diag Can2 BM (Close to Weld)
188	OD Weld Can2 BM	172	Cusp Can2 BM			210	Diag Can2 BM (Close to Weld)
		200	Cusp Can2 BM			211	Diag Can2 BM (Close to Weld)
						191	Diag Can2 BM (Close to Weld) (OD)
192	OD Weld	188	Cusp Weld	175	ID Weld		
183	OD Weld	182	Cusp Weld	171	ID Weld		
179	OD Weld	184	Cusp Weld	179	ID Weld		
183	OD Weld	180	Cusp Weld	180	ID Weld		
184	OD Weld			182	ID Weld		
208	OD Weld Can3 BM	203	Cusp Can3 BM				
224	OD Weld Can3 BM	195	Cusp Can3 BM				
216	OD Weld Can3 BM	192	Cusp Can3 BM				
212	OD Weld Can3 BM	196	Cusp Can3 BM				

BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 14 OF 88

LABORATORY REPORT-LS3 BOTTOM

TABLE 11
MICRO-HARDNESS MEASUREMENTS MOUNT TO VICKERS 500Gm

TO OD Line HV	Location		TO ID Line HV	Locations
137	Weld		139	Weld
134	Weld		142	Weld
134	Weld		147	Weld
140	Weld		142	Weld
141	BM @ Weld		142	BM @ Weld
143	BM @ Weld		149	BM @ Weld
143	BM @ Weld		131	BM @ Weld
149	BM @ Weld		129	BM @ Weld
148	BM @ Weld		135	BM @ Weld
			135	BM @ Weld
143	BM		146	BM
141	BM		146	BM
146	BM		141	BM
140	BM		140	BM

BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 15 OF 88

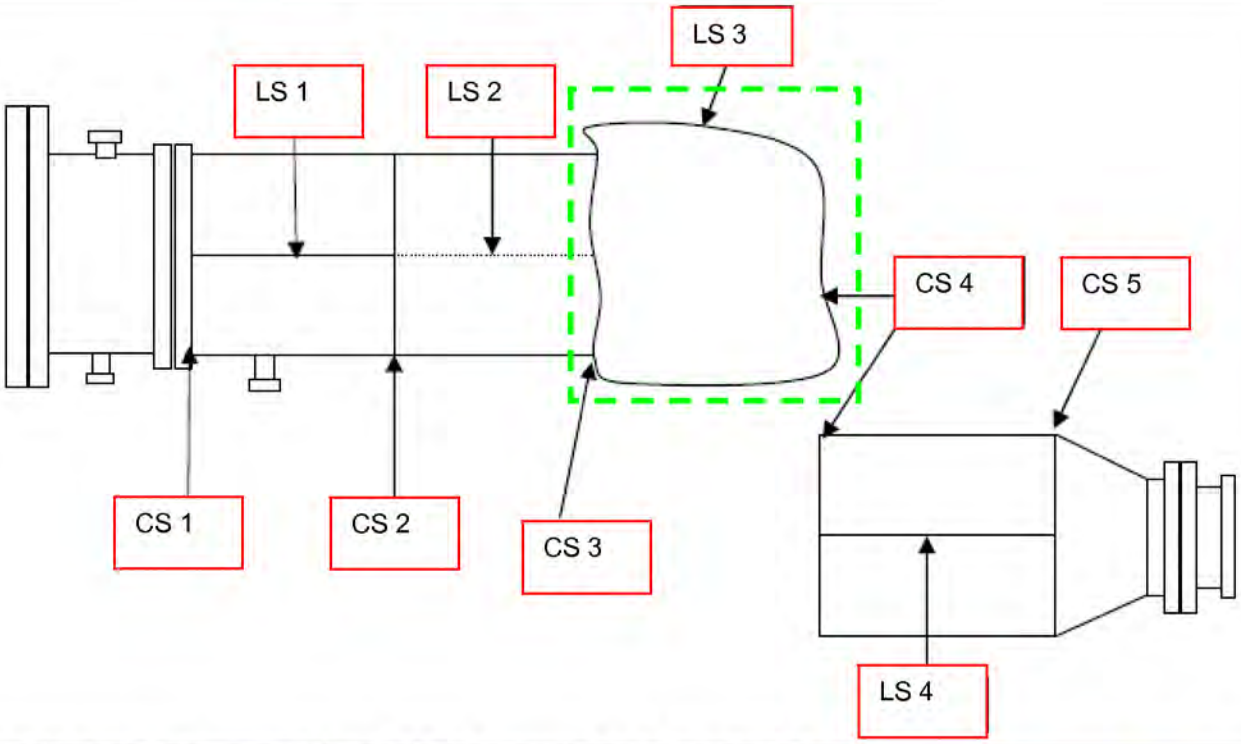
LABORATORY REPORT-LS3 BOTTOM

TABLE 12
SUMMARY OF MICRO-HARDNESS MEASUREMENTS
TABLE 7-11
VICKERS 500Gm

	M1 CS3	M3 LS3	M4 LS3	M5 CS4	M6 CS3	TO LS3
Base Metal 2	180-189				172-223	
Base Metal 3	177-200	182-215	181-193	133-152	203-224	129-149
Base Metal 4				110-140		
HAZ 2	190-243					
HAZ 3	186-224	203-245	181-204			
Weld Metal	172-210	178-255		132-145	171-192	134-147

BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 16 OF 88

LABORATORY REPORT-LS3 BOTTOM



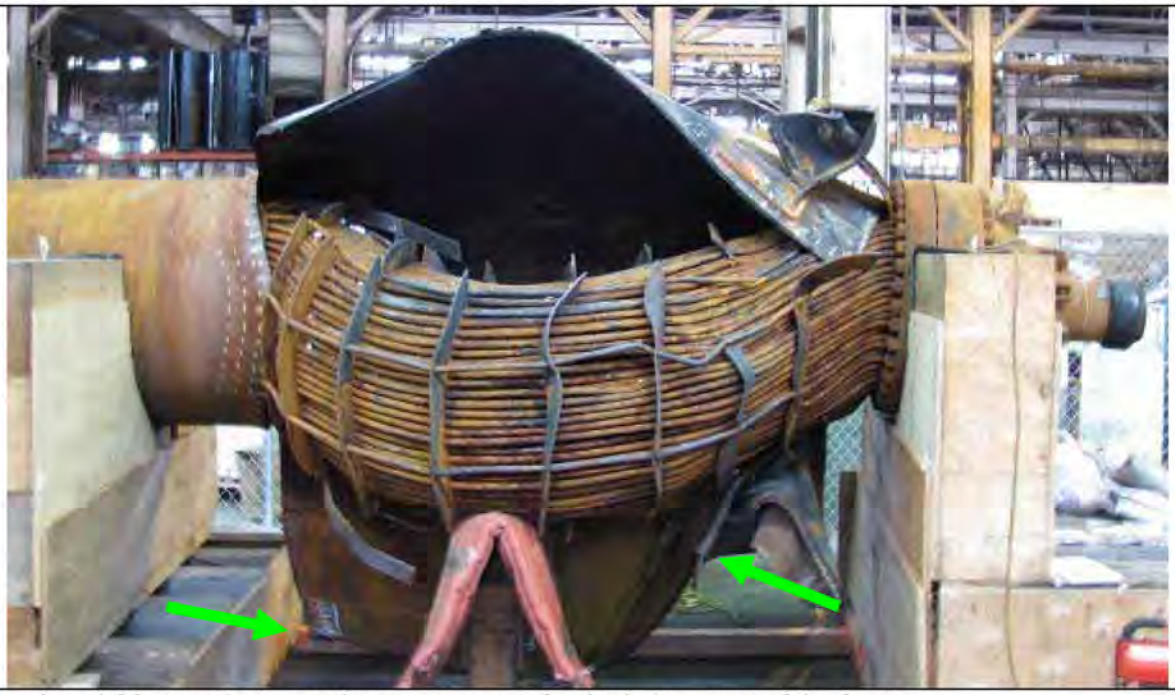
Sketch of main heat exchanger Cans 1-3 and separated back head can 4

Overall main heat exchanger with "fish mouth " rupture primarily along LS3 and CS4 as shown by green box above

FIGURE 1 Un-packed main heat exchanger

BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 17 OF 88

LABORATORY REPORT-LS3 BOTTOM



Fracture along LS3 seam between the green arrows for the bottom part of the fracture

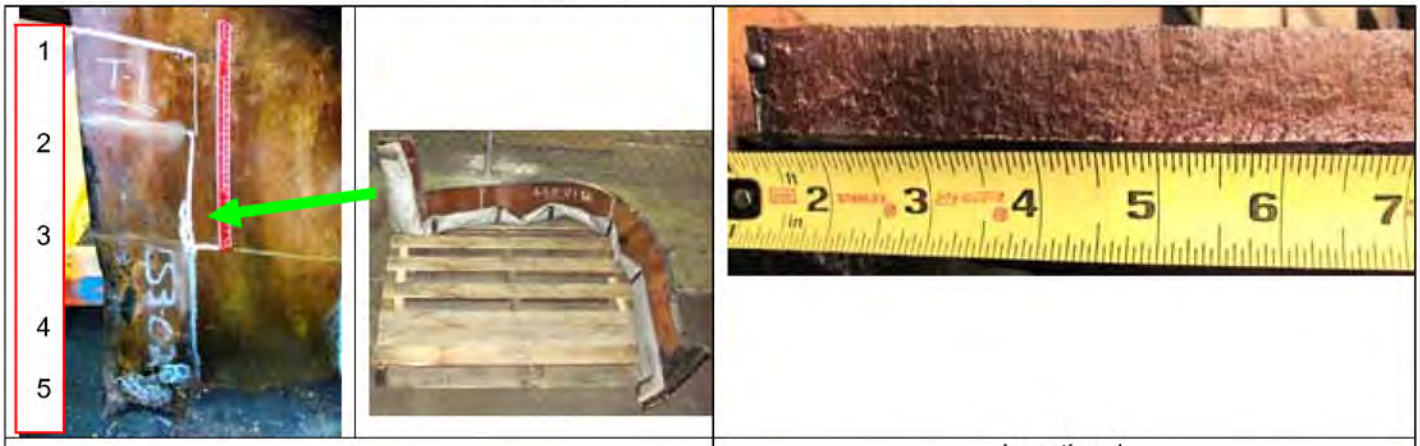
Plasma arc cutting LS3 bottom fracture out

LS3-01 Bottom piece with fracture edge protected

FIGURE 2 Removal of LS3-01Bottom-note a rectangular shaped portion of CS3 on the left and a triangular shaped portion of CS4 on the right were removed

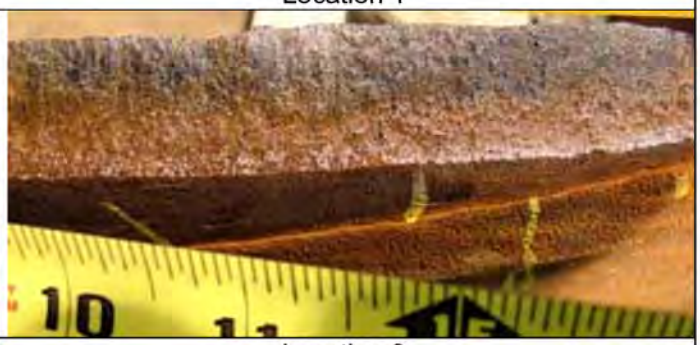
BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 18 OF 88

LABORATORY REPORT-LS3 BOTTOM



Location 1

Location 2



Location 3

Location 4

Location 5

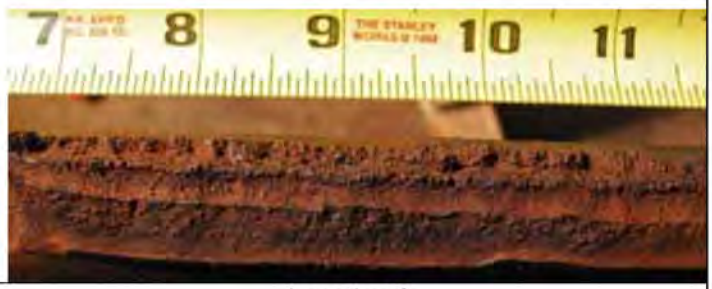
FIGURE 3 Photos of the fracture along CS3 with the locations as shown in the upper left (ID on top)

BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 19 OF 88

LABORATORY REPORT-LS3 BOTTOM

Location 1

Location 2



Location 3

Location 4

Location 5

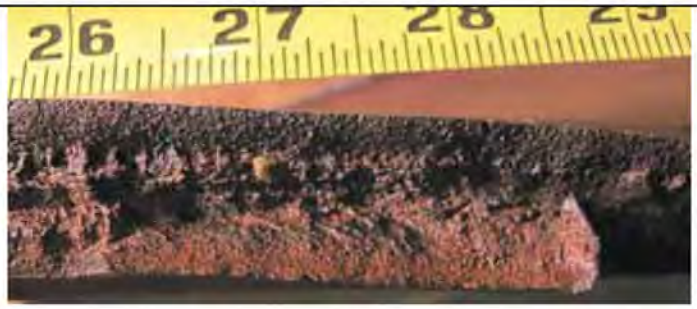
Location 6

Location 7

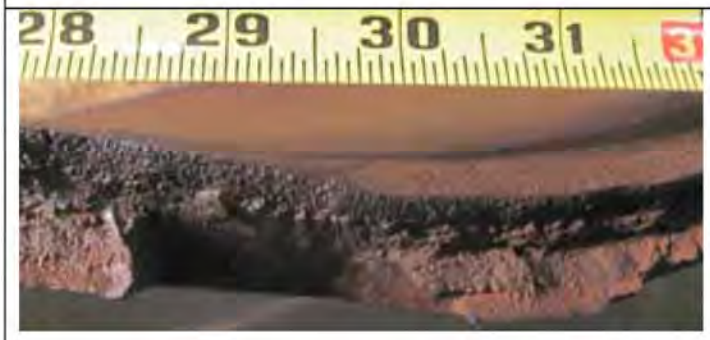
FIGURE 4 Photos of the fracture along LS3 from CS3 corner with the locations as shown in the upper left (ID on top)

BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 20 OF 88

LABORATORY REPORT-LS3 BOTTOM



Location 8



Location 9

Location 10

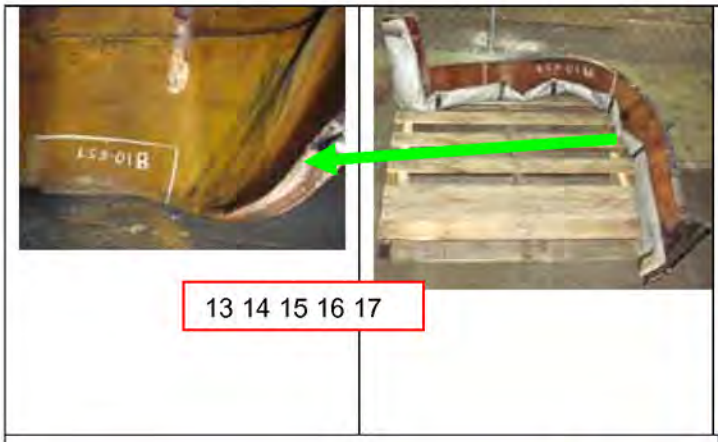
Location 11

Location 12

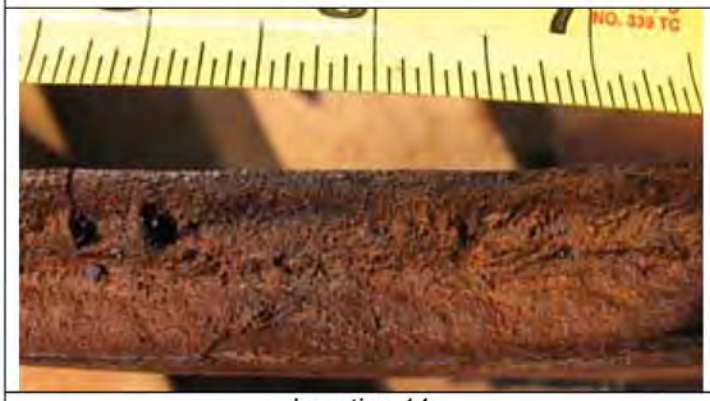
FIGURE 5 Photos of the fracture along LS3 from CS3 corner with the locations as shown in the upper left (ID on top)

BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 21 OF 88

LABORATORY REPORT-LS3 BOTTOM

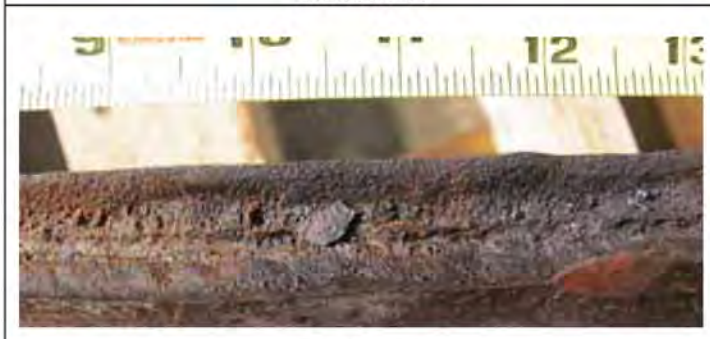


Location 13



Location 14

Location 15



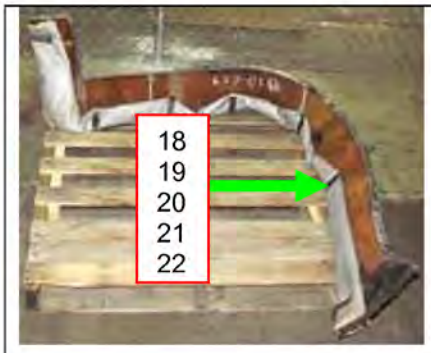
Location 16

Location 17

FIGURE 6 Photos of the fracture along LS3 from center of the fish mouth with the locations as shown in the upper left (ID on top)

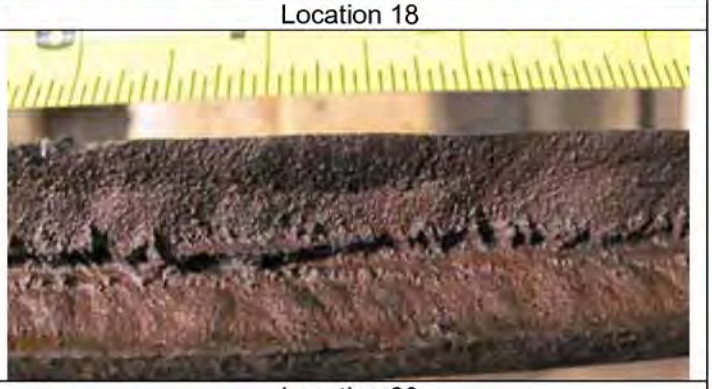
BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 22 OF 88

LABORATORY REPORT-LS3 BOTTOM



Location 18

Location 19



Location 20

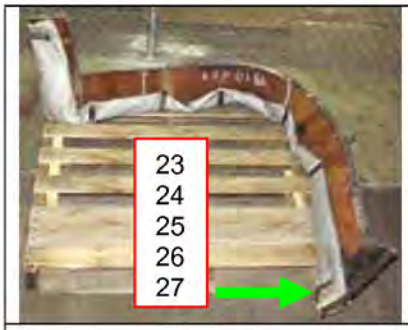
Location 21

Location 22

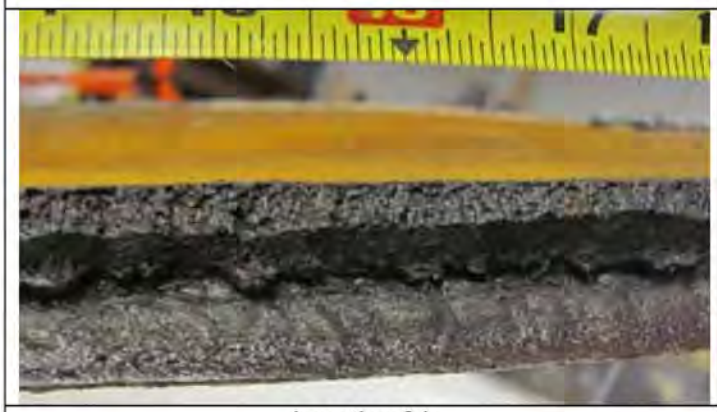
FIGURE 7 Photos of the fracture along LS3 from Figure 6 towards CS4 corner (ID on top)

BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 23 OF 88

LABORATORY REPORT-LS3 BOTTOM

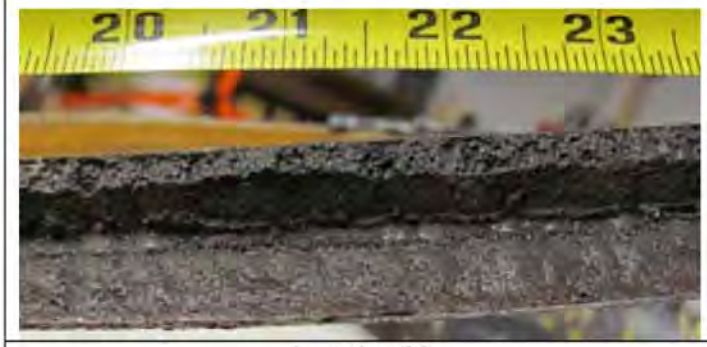


Location 23



Location 24

Location 25



Location 26

FIGURE 8 Photos of the fracture along LS3 from Figure 7 to CS4 corner (ID on top)

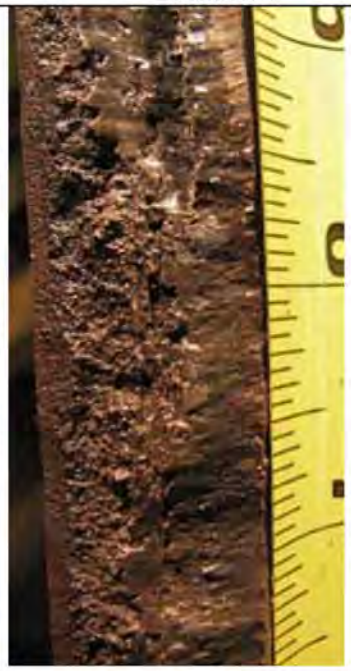
BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 24 OF 88

LABORATORY REPORT-LS3 BOTTOM

Location 2

Location 4

Location 1

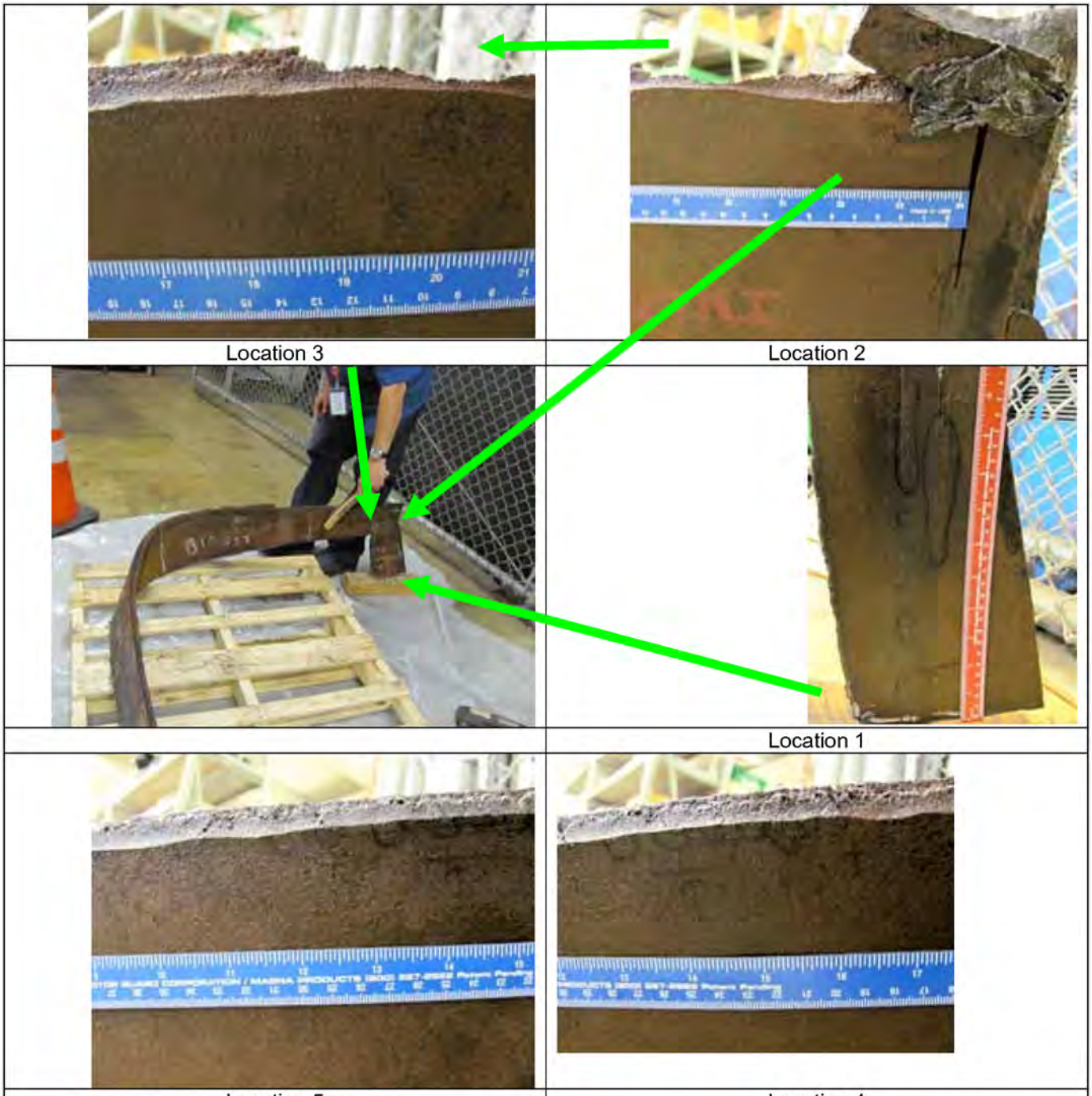


Location 3

FIGURE 9 Photos of the fracture along CS4 from LS3 CS4 corner as shown in the upper right (scale against OD)

BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 25 OF 88

LABORATORY REPORT-LS3 BOTTOM



Location 3 | Location 2

Location 1

Location 5 | Location 4

FIGURE 10 Magnetic Particle inspection indications circled (fracture on top and looking at ID surface)

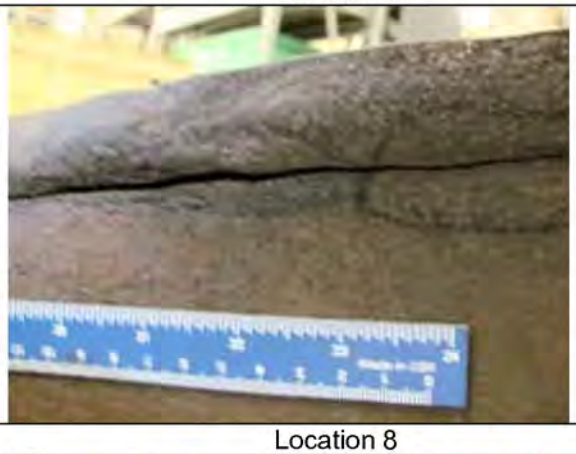
BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 26 OF 88

LABORATORY REPORT-LS3 BOTTOM

Location 7

Location 6

Location 9



Location 8

Location 11

Location 10

FIGURE 11 Magnetic Particle inspection indications circled (fracture on top and looking at ID surface)

BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 27 OF 88

LABORATORY REPORT-LS3 BOTTOM

Location 13

Location 12

Location 15

Location 14

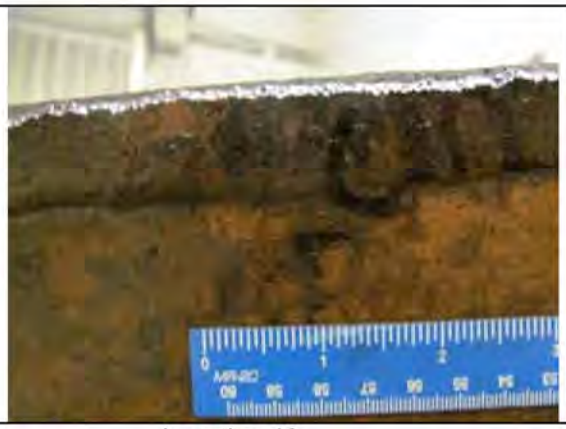
Location 17

Location 16

FIGURE 12 Magnetic Particle inspection indications circled (fracture on top and looking at ID surface)

BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 28 OF 88

LABORATORY REPORT-LS3 BOTTOM



Location 19

Location 18

Location 21

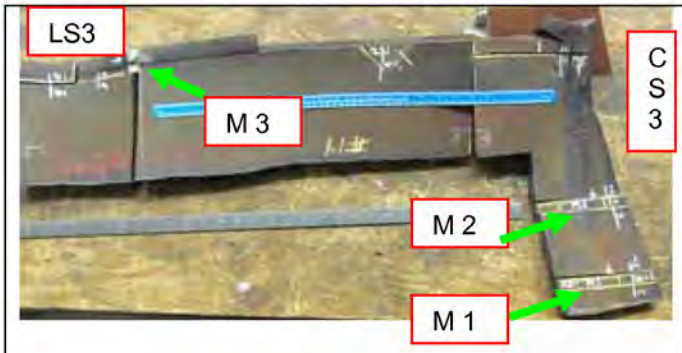
Location 20

Location 22

FIGURE 13 Magnetic Particle inspection indications circled (fracture on top and looking at ID surface)

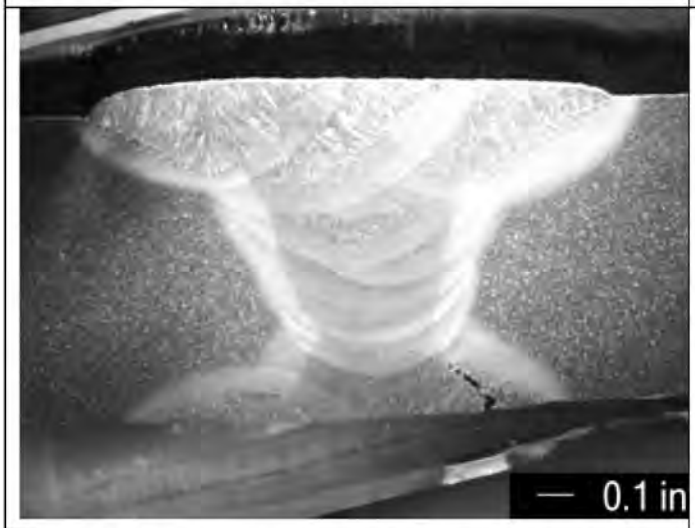
BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 29 OF 88

LABORATORY REPORT-LS3 BOTTOM



Looking at ID surface LS3 top and CS3 right side

Mount M1 transverse through CS3 can 3 on left and can 2 on right – ID on bottom



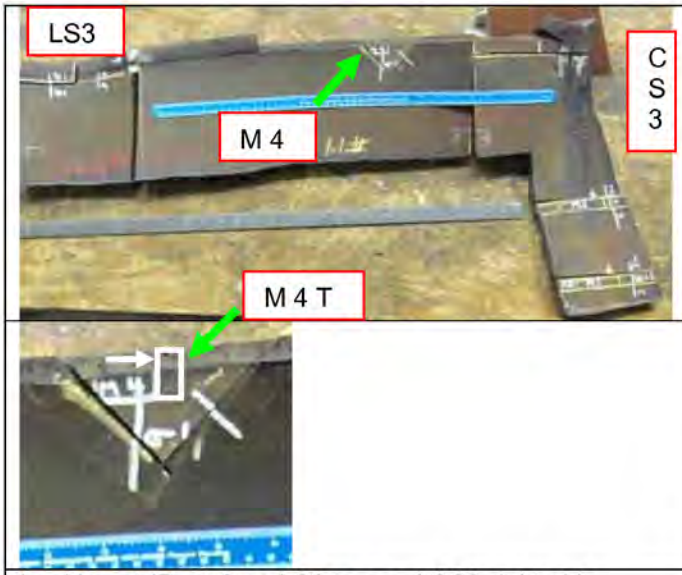
Mount M 2 transverse through CS3 can 3 on left and can 2 on right- ID on bottom

Mount M 3 transverse through LS3 can 3 on left and can 3 fracture on right- ID on bottom

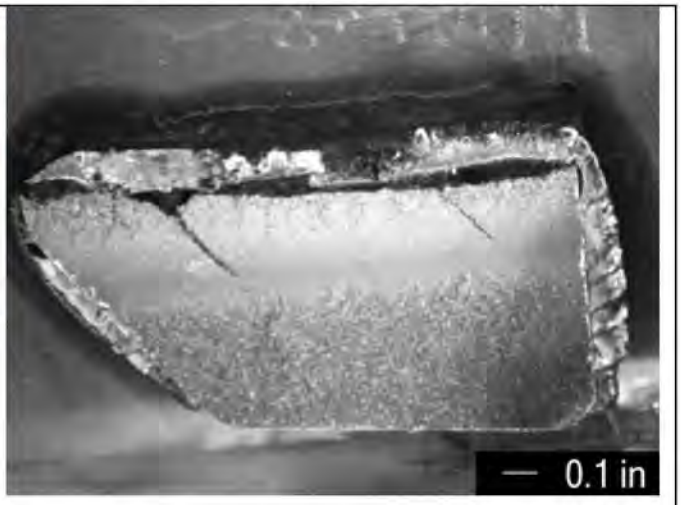
FIGURE 14 Mounts for CS3 and LS3 welds with ID on the bottom of each mount

BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 30 OF 88

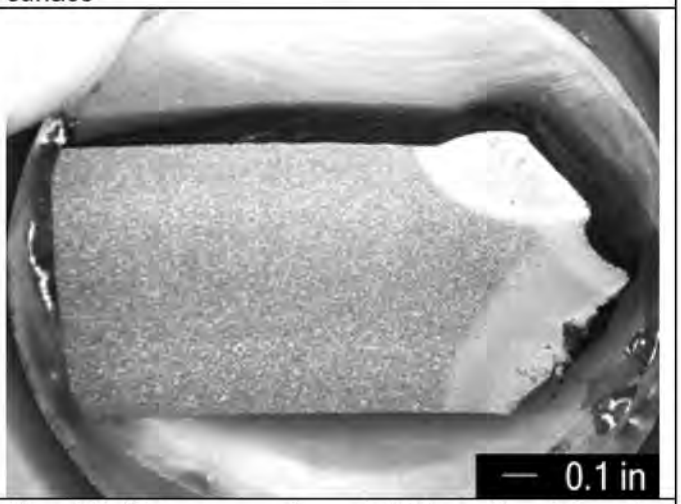
LABORATORY REPORT-LS3 BOTTOM



Looking at ID surface LS3 top and CS3 right side



Mount M 4 longitudinal face of LS3 with the fracture on top and can 3 on bottom –Polishing down on ID surface



Mount M 4T transverse through LS3 can 3 on left and fracture on right, ID on the bottom

FIGURE 15 Mounts M1, M2 and M3 for CS3 and LS3 welds

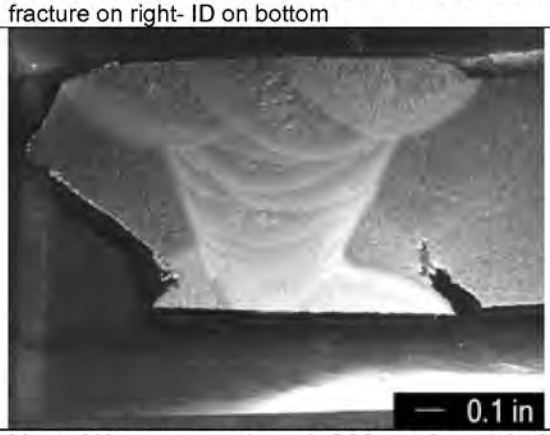
BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 31 OF 88

LABORATORY REPORT-LS3 BOTTOM

Looking at OD surface, on right is LS3 and CS4 corner

Mount M5 transverse through CS4 can 3 on left and CS4 fracture on right- ID on bottom

Looking at ID surface LS3 top and CS3 right



Mount M6 transverse through CS3 can 3 on right CS3 fracture on left- ID on bottom

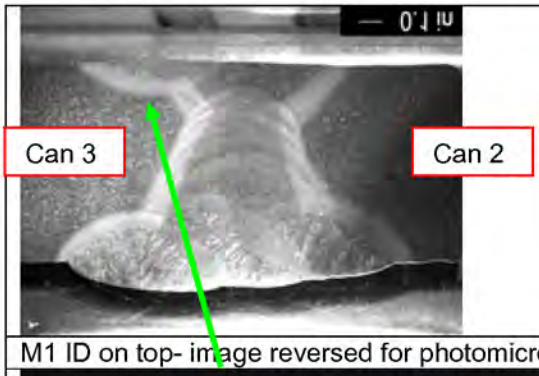
Looking at OD surface LS3 top and CS4 right

Mount T0 transverse through LS3 can 3 on left fracture on right- ID on bottom

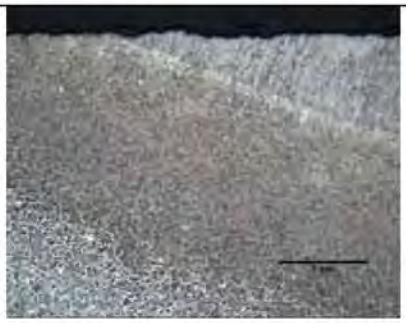
FIGURE 16 Mounts M4, M4T and TO for LS3, CS3 and CS4 welds

BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 32 OF 88

LABORATORY REPORT-LS3 BOTTOM

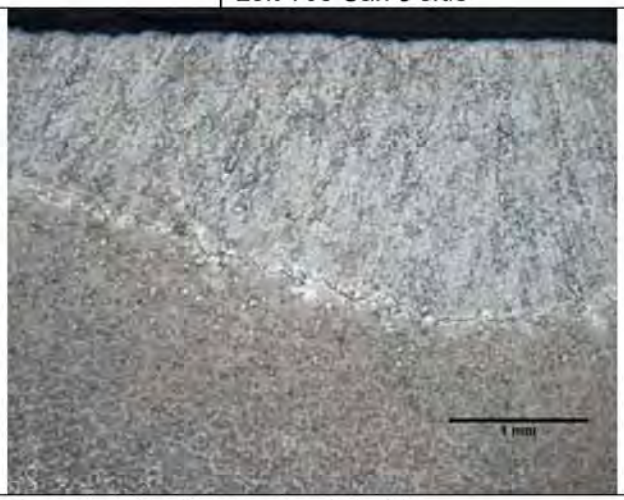


M1 ID on top- image reversed for photomicrographs

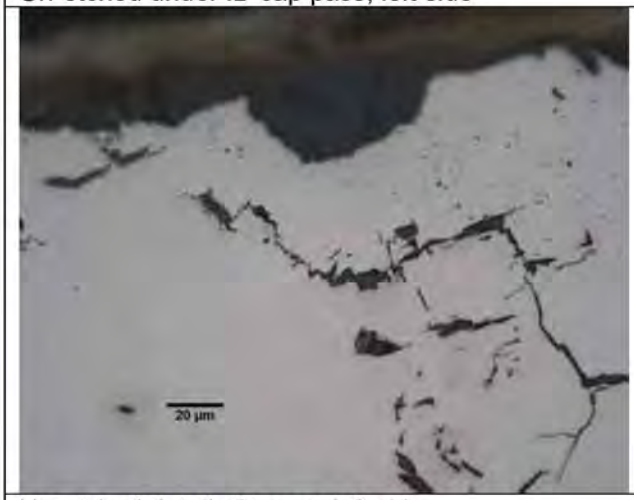


Left Toe Can 3 side

Un-etched under ID cap pass, left side



Etched under ID cap pass, left side



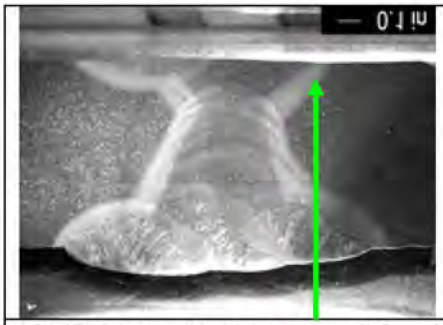
Un-etched detail of toe on left side

Etched detail of toe on left side, magnification different

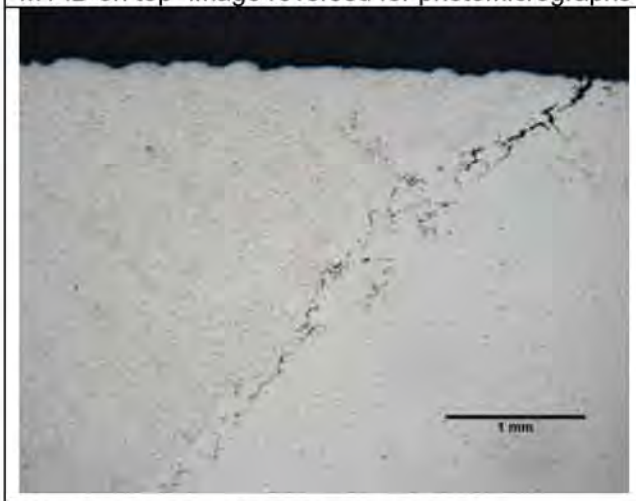
FIGURE 17 Un-etched and etched left side toe of the weld on ID surface for can 3 in M1 on CS3 weld

BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 33 OF 88

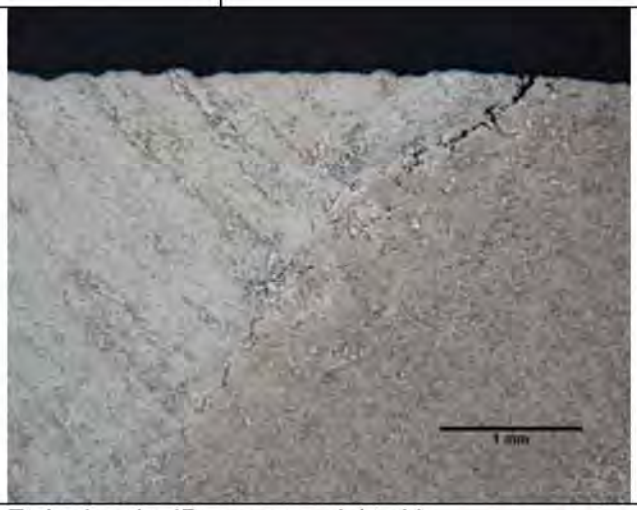
LABORATORY REPORT-LS3 BOTTOM



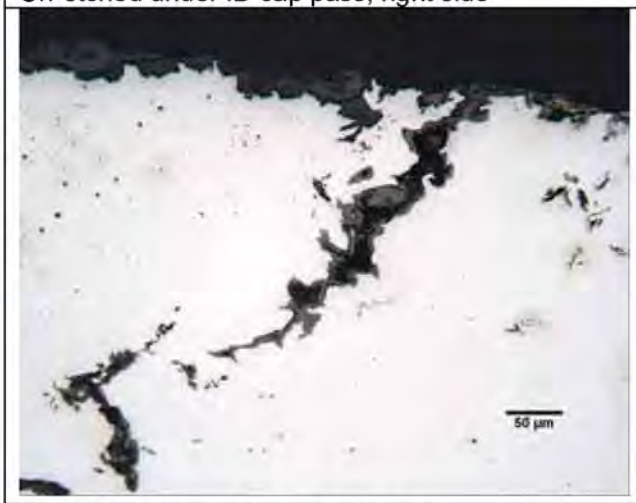
M1 ID on top- image reversed for photomicrographs



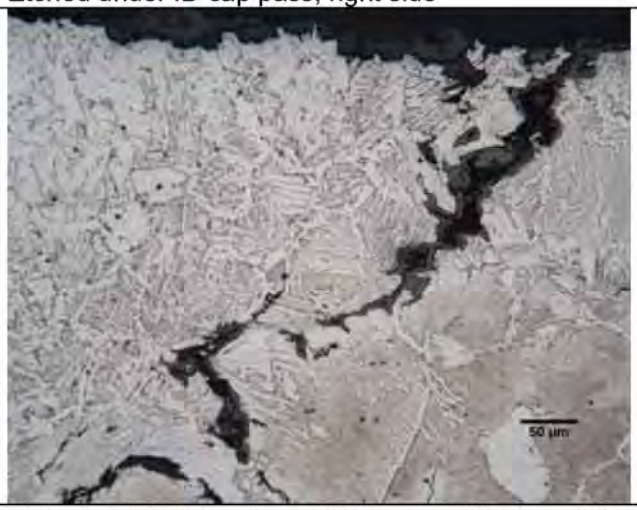
Un-etched under ID cap pass, right side



Etched under ID cap pass, right side



Un-etched detail of toe on right side



Etched detail of toe on right side, magnification different

FIGURE 18 Un-etched and etched right side toe of the weld on ID surface from can 2 in M1 on CS3 weld

BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 34 OF 88

LABORATORY REPORT-LS3 BOTTOM

M1 ID on top- image reversed for photomicrographs

Un-etched under ID cap pass, right side

Etched under ID cap pass, right side

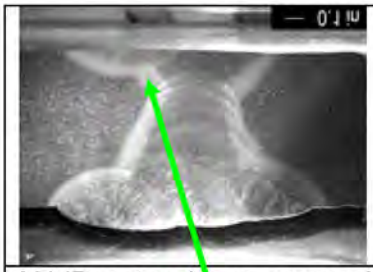
Un-etched detail under ID cap pass, right side

Etched detail under ID cap pass, right side

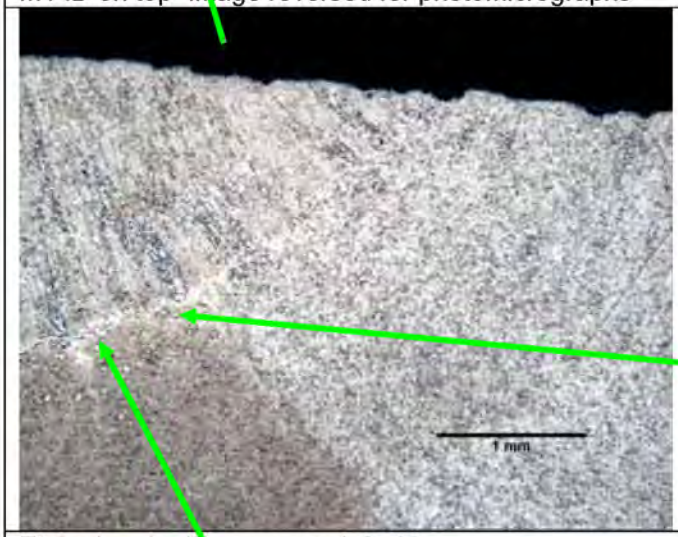
FIGURE 19 Un-etched and etched right side under cap of the weld in can 2 in M1 on CS3 weld

BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 35 OF 88

LABORATORY REPORT-LS3 BOTTOM

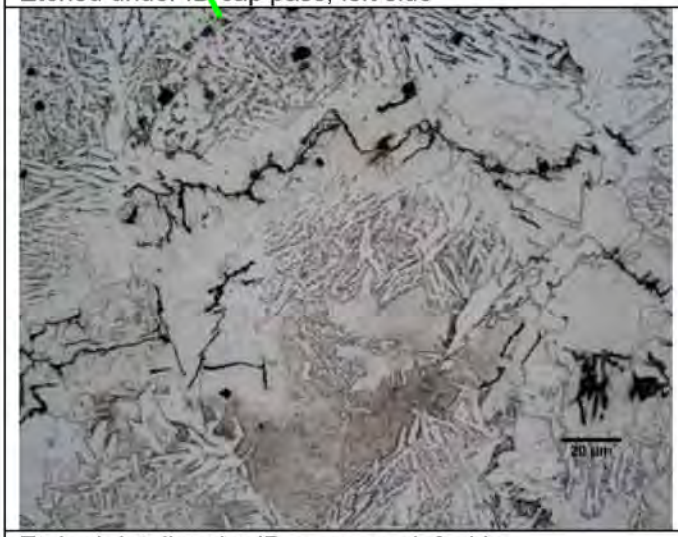


M1 ID on top- image reversed for photomicrographs



Etched under ID cap pass, left side

Etched under ID cap pass, left side



Etched detail under ID cap pass, left side

FIGURE 20 Un-etched and etched right side under cap of the weld from can 3 in M1 on CS3 weld

BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 36 OF 88

LABORATORY REPORT-LS3 BOTTOM

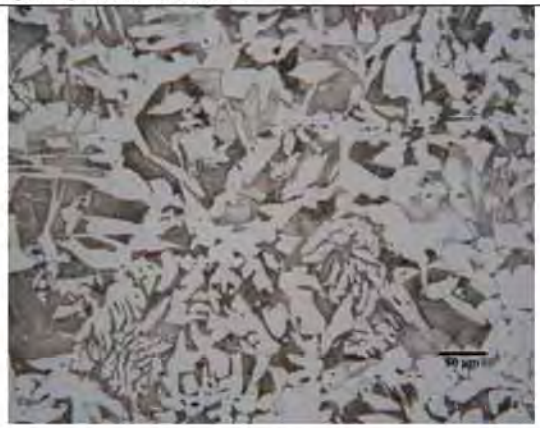
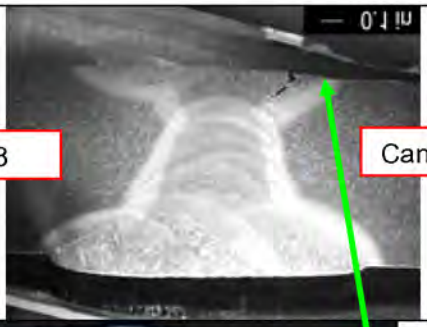
	
Can 2 Base Metal ID	Can 3 Base Metal ID
	
Can 2 Base Metal Middle	Can 2 Base Metal Middle
	
Can 2 Base Metal OD	Can 3Base Metal OD

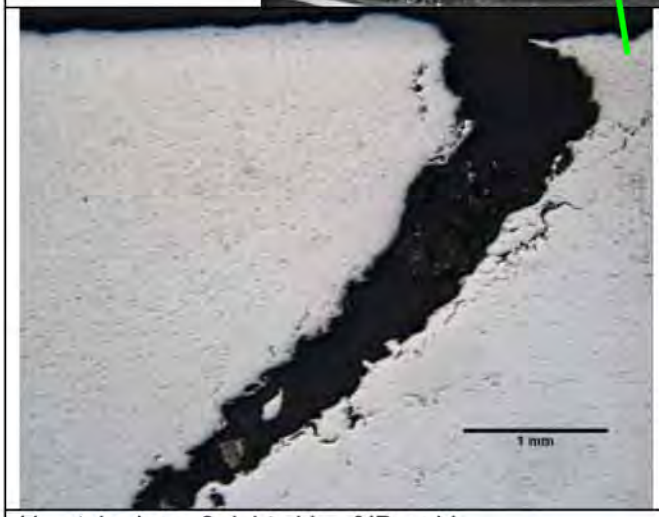
FIGURE 21 Can 2 and Can 3 Base Metal in M1

BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 37 OF 88

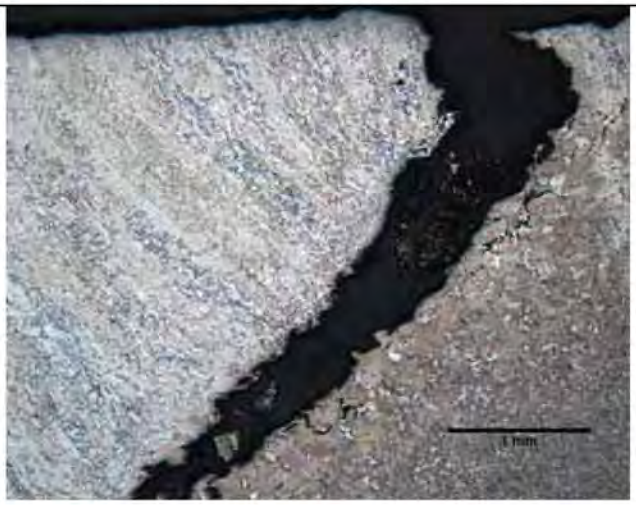
LABORATORY REPORT-LS3 BOTTOM



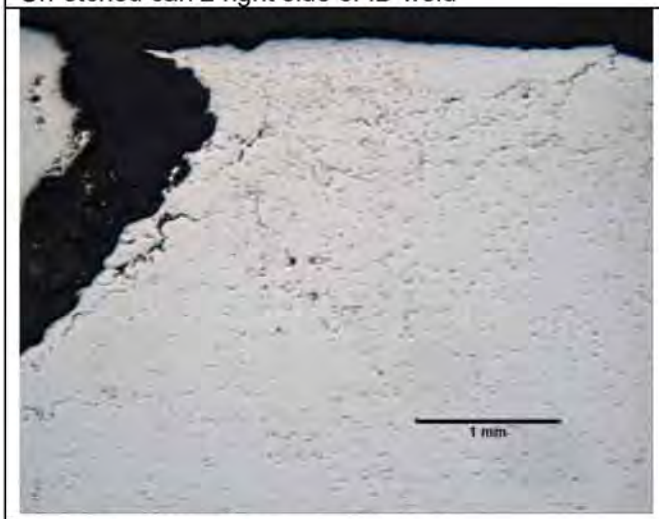
M2 ID on top- image reversed for photomicrographs



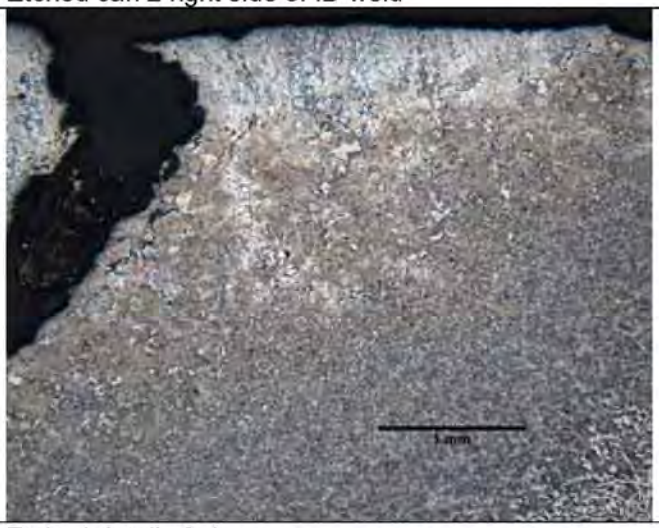
Un-etched can 2 right side of ID weld



Etched can 2 right side of ID weld



Un-etched detail of above

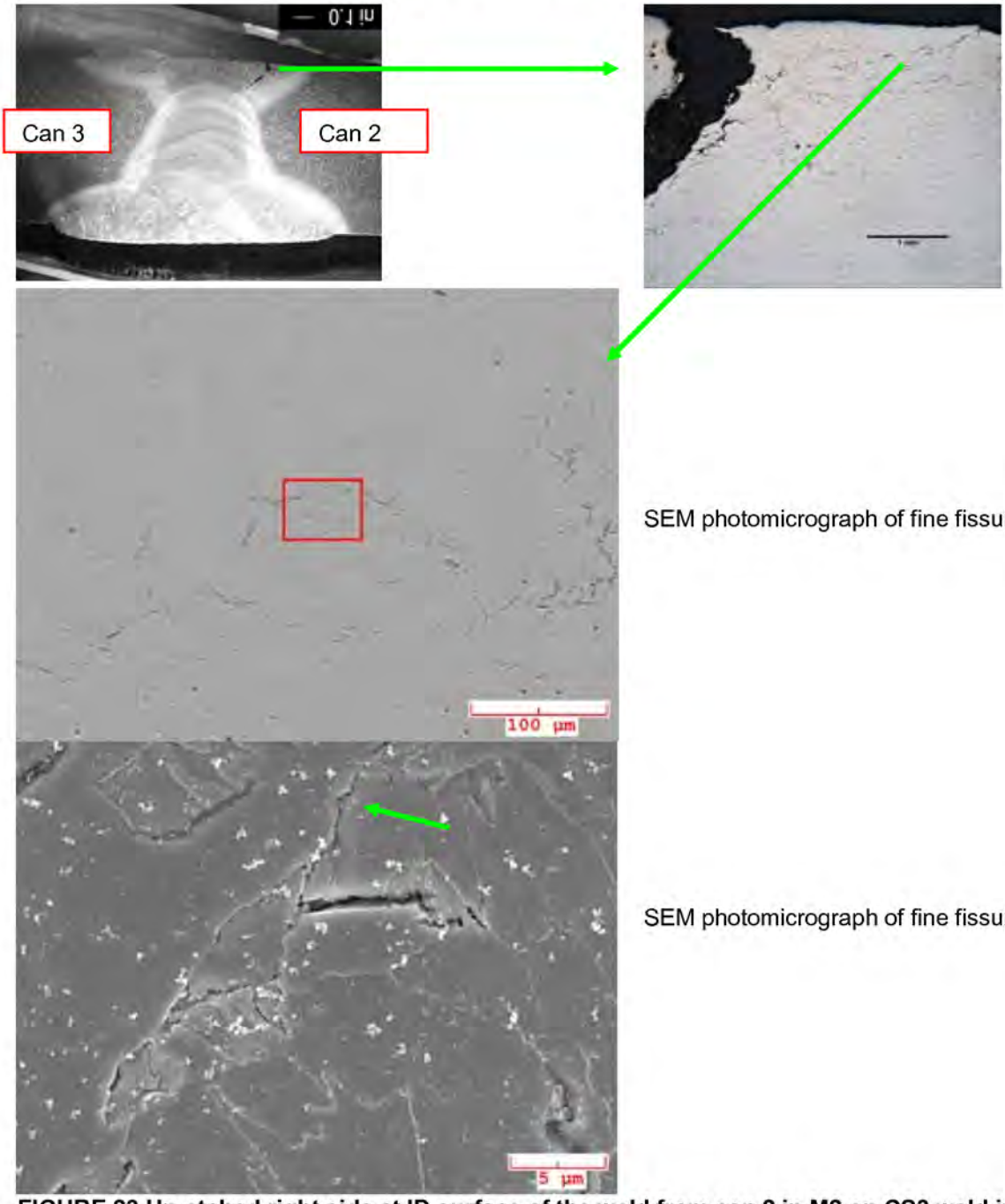


Etched detail of above

FIGURE 22 Un-etched and etched right side at ID surface of the weld from can 2 in M2 on CS3 weld

BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 38 OF 88

LABORATORY REPORT-LS3 BOTTOM



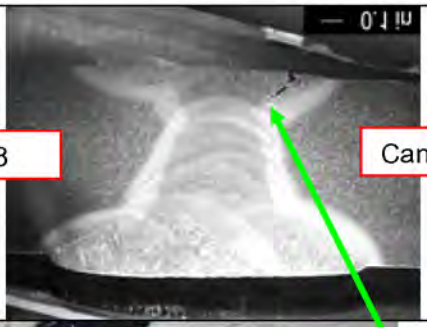
SEM photomicrograph of fine fissures

SEM photomicrograph of fine fissures-

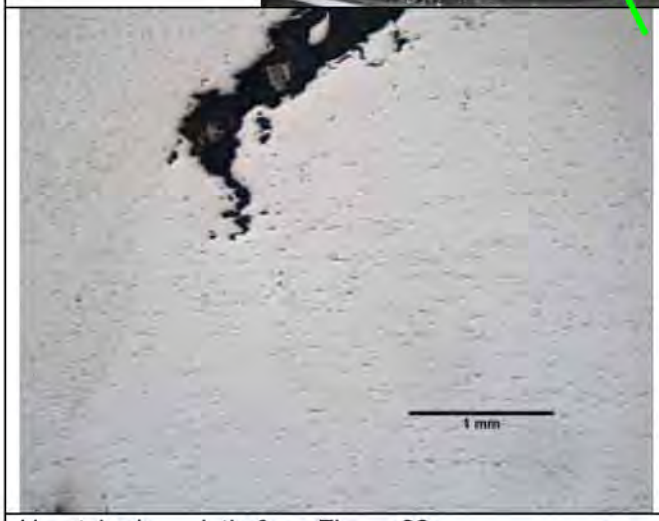
FIGURE 23 Un-etched right side at ID surface of the weld from can 2 in M2 on CS3 weld in the SEM

BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 39 OF 88

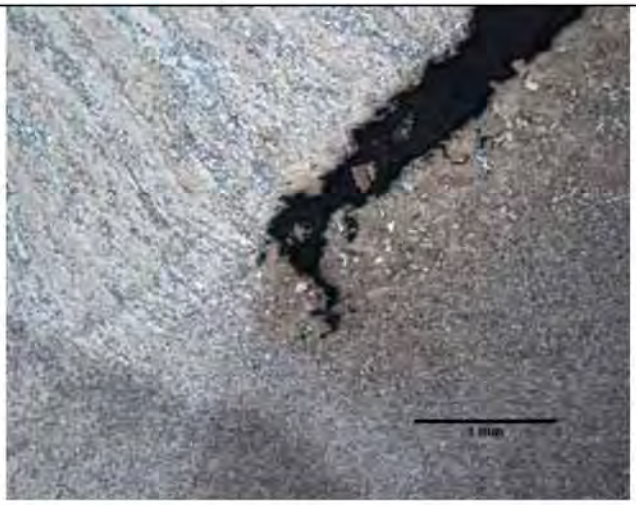
LABORATORY REPORT-LS3 BOTTOM



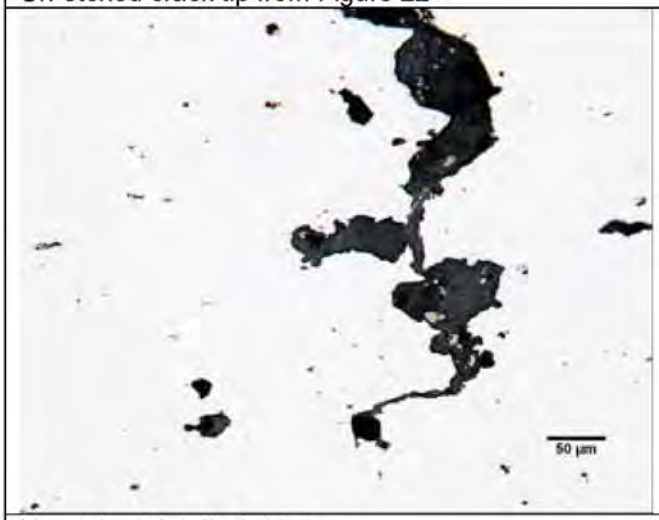
M2 ID on top- image reversed for photomicrographs



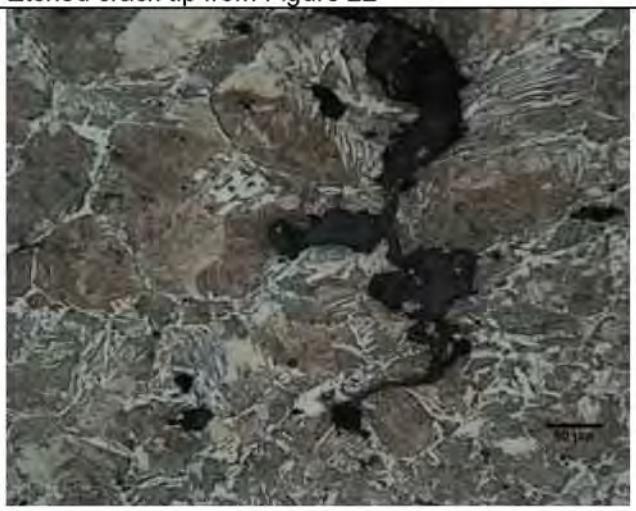
Un-etched crack tip from Figure 22



Etched crack tip from Figure 22



Un-etched detail of above



Etched detail of above

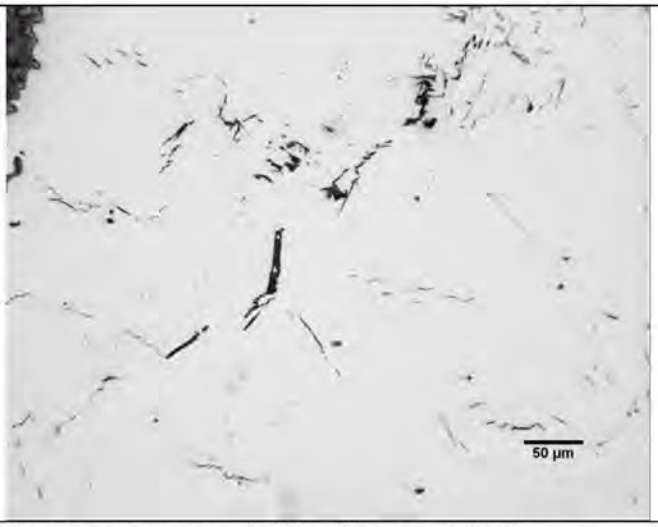
FIGURE 24 Un-etched and etched crack tip from can 2 in M2 on CS3 weld

BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 40 OF 88

LABORATORY REPORT-LS3 BOTTOM

M2 ID on top- image reversed for photomicrographs

Un-etched near crack ID on weld metal side-



Un-etched near crack ID on Base metal side

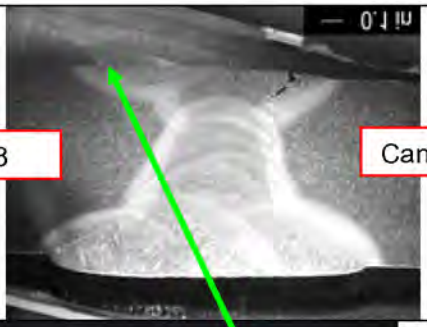
Etched near crack ID on weld metal side

Etched near crack on Base metal side

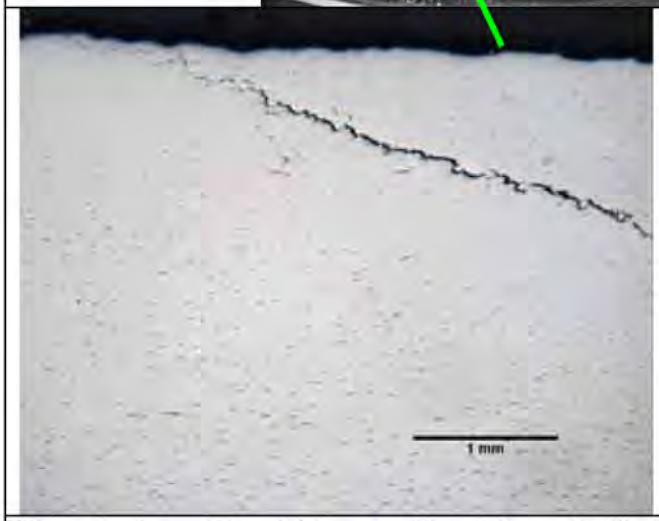
FIGURE 25 Un-etched and etched crack at the ID surface from can 2 in M2 on CS3 Weld

BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 41 OF 88

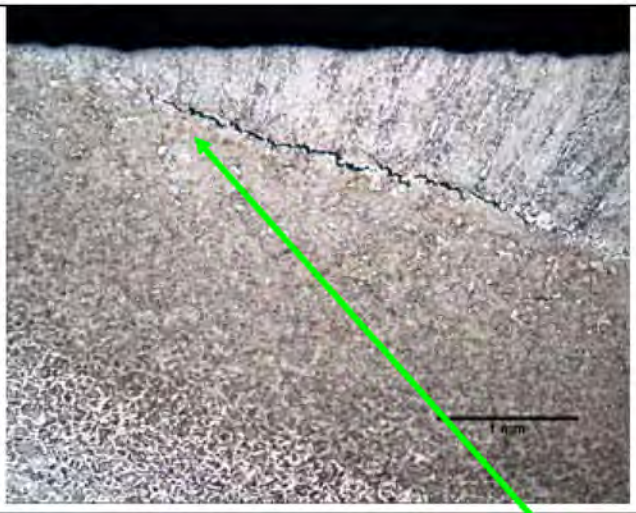
LABORATORY REPORT-LS3 BOTTOM



M2 ID on top- image reversed for photomicrographs



Un-etched near Toe of ID cap weld on left can 3 side



Etched near Toe of ID cap weld on left can 3 side

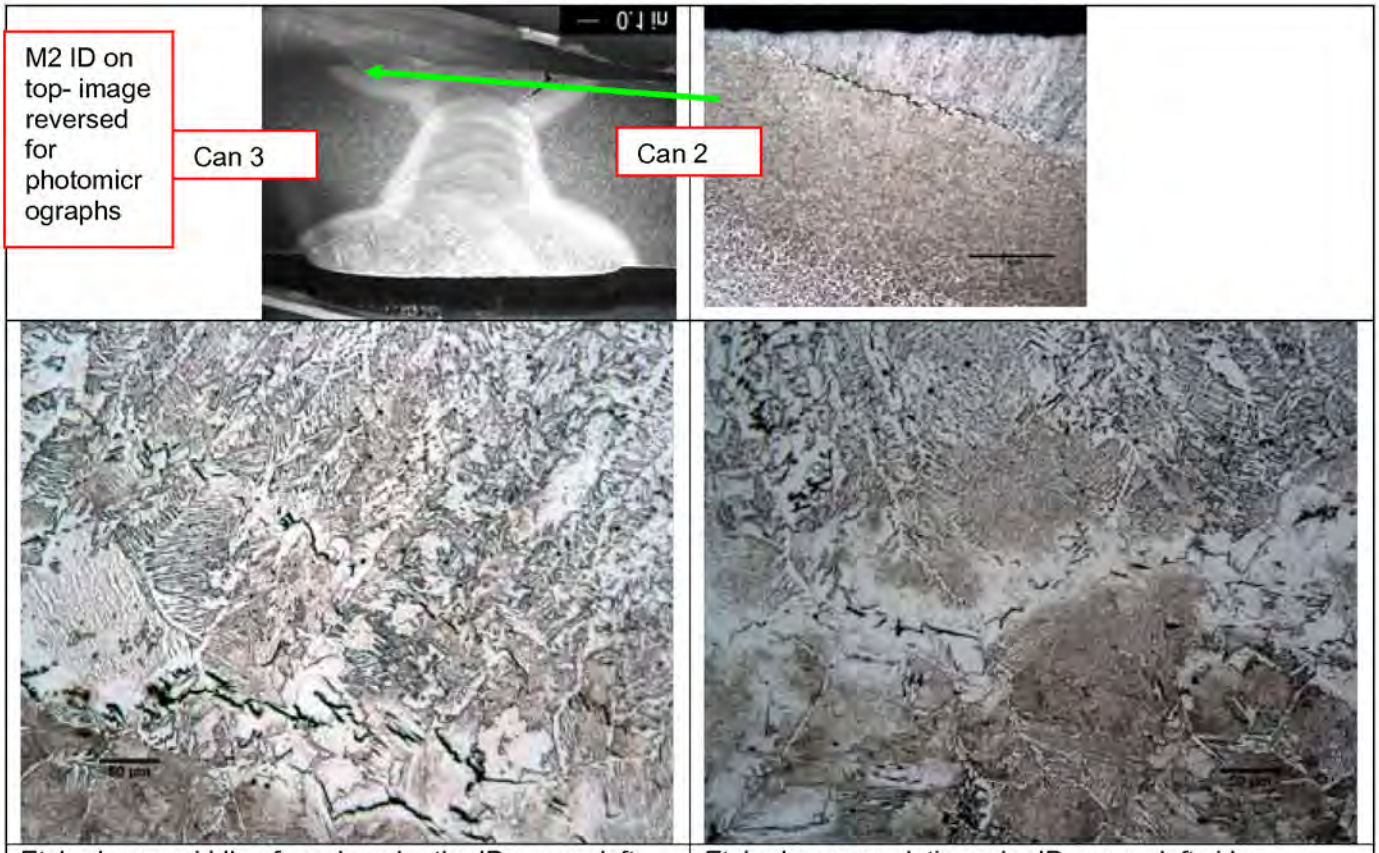
Etched detail of toe of ID cap weld above right

Etched detail of crack above

FIGURE 26 Un-etched and etched crack under ID cap pass on left side can 3 in M2 on CS3 weld

BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 42 OF 88

LABORATORY REPORT-LS3 BOTTOM



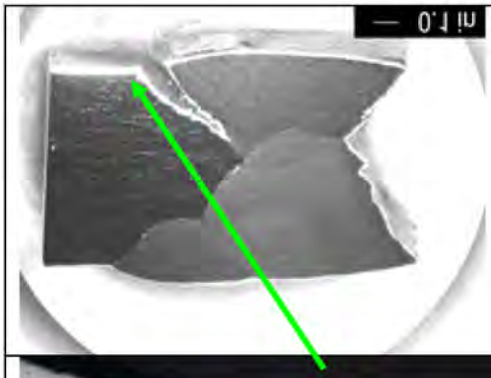
Etched near middle of crack under the ID cap on left side

Etched near crack tip under ID cap on left side

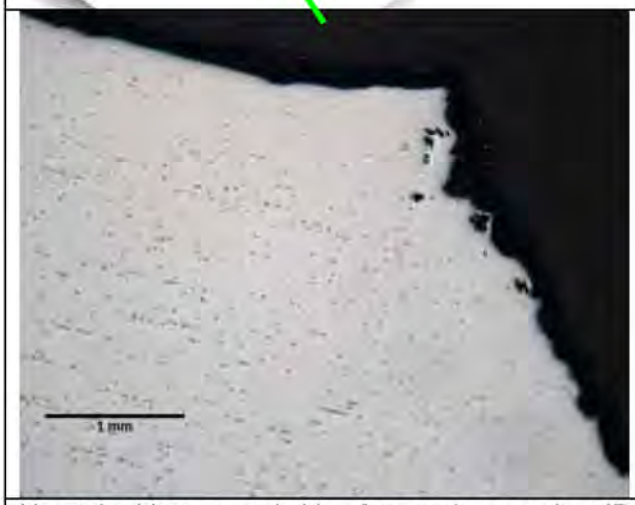
FIGURE 27 Etched crack under ID cap in M2 on CS3 weld

BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 43 OF 88

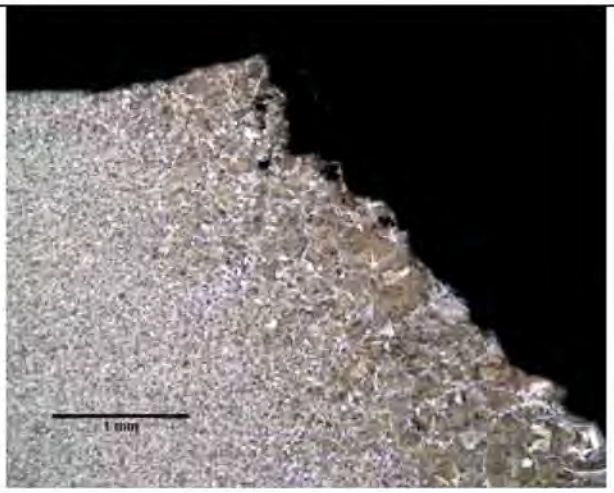
LABORATORY REPORT-LS3 BOTTOM



M3 ID on top- image reversed for photomicrographs



Un-etched base metal side of secondary crack at ID



Etched base metal side of secondary crack at ID

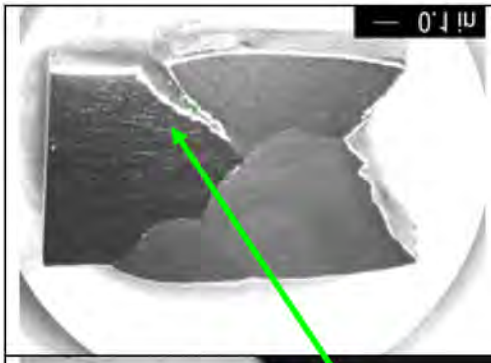
Un-etched base metal side of secondary crack near ID

Etched base metal side of secondary crack at ID

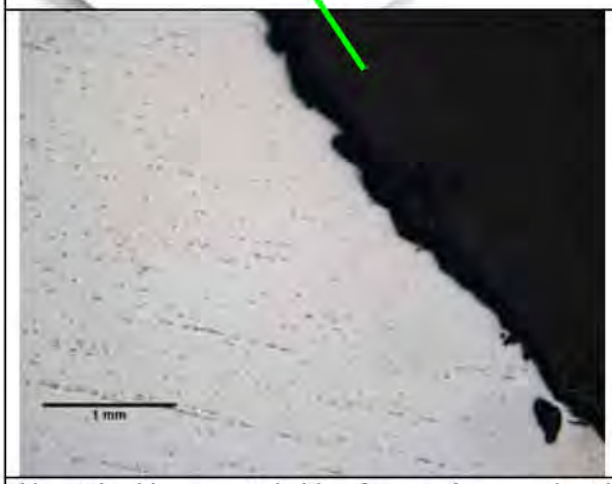
FIGURE 28 Secondary crack in M3 on base metal side can 3 on LS3 fracture

BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 44 OF 88

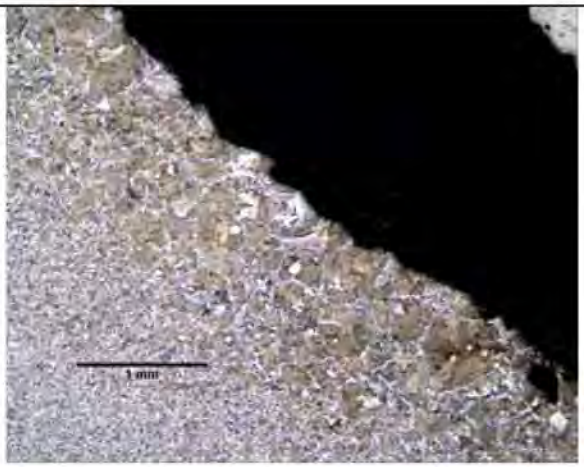
LABORATORY REPORT-LS3 BOTTOM



M3 ID on top- image reversed for photomicrographs

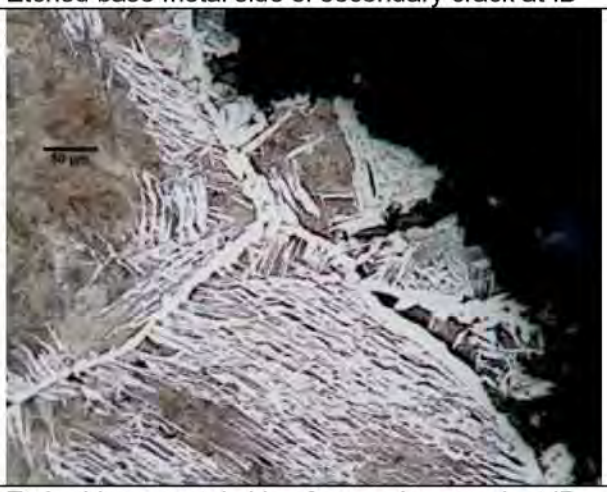


Un-etched base metal side of secondary crack at ID



Etched base metal side of secondary crack at ID

Un-etched base metal side of secondary crack near ID

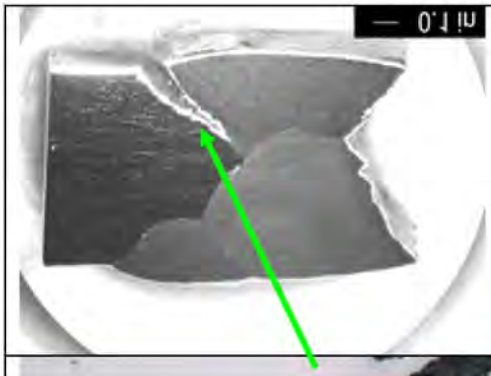
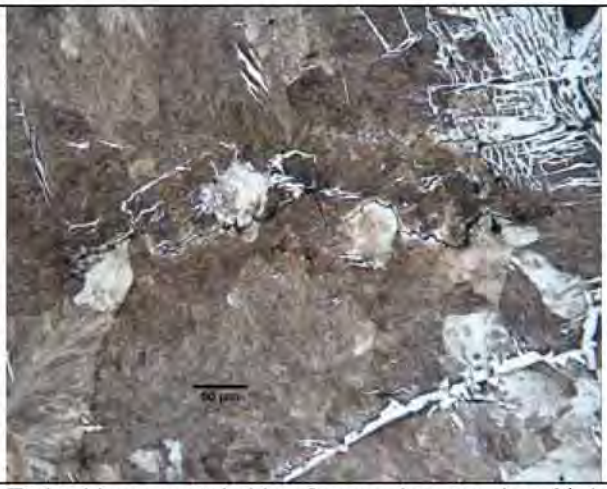
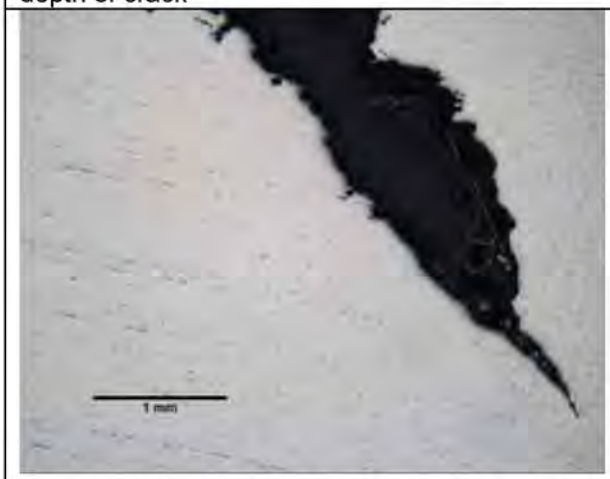
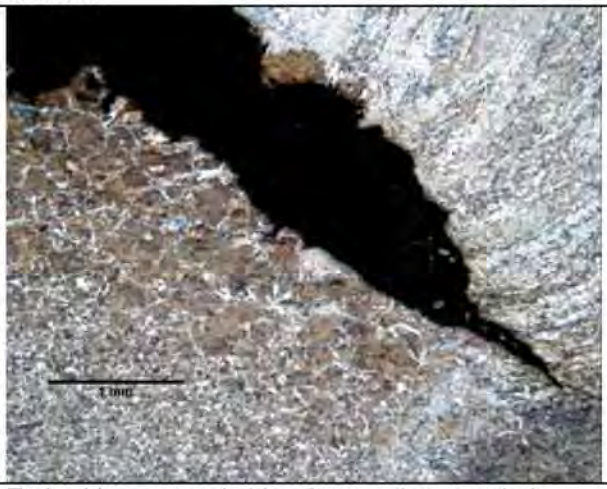


Etched base metal side of secondary crack at ID

FIGURE 29 Secondary crack in M3 on base metal side can 3 on LS3 fracture

BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 45 OF 88

LABORATORY REPORT-LS3 BOTTOM

<table>
<tr><td>  </td><td>M3 ID on top- image reversed for photomicrographs</td></tr>
<tr><td>  </td><td>  </td></tr>
<tr><td>Un-etched base metal side of secondary crack at ¾ depth of crack</td><td>Etched base metal side of secondary crack at ¾ depth of crack</td></tr>
<tr><td>  </td><td>  </td></tr>
<tr><td>Un-etched base metal side of secondary crack tip</td><td>Etched base metal side of secondary crack tip</td></tr>
<tr><td colspan="2">FIGURE 30 Secondary crack in M3 on base metal side can 3 on LS3 fracture</td></tr>
</table>

BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 46 OF 88

LABORATORY REPORT-LS3 BOTTOM

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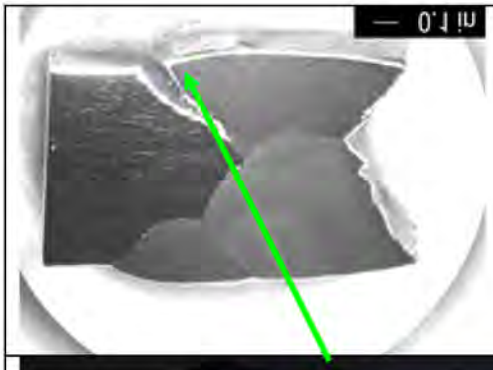
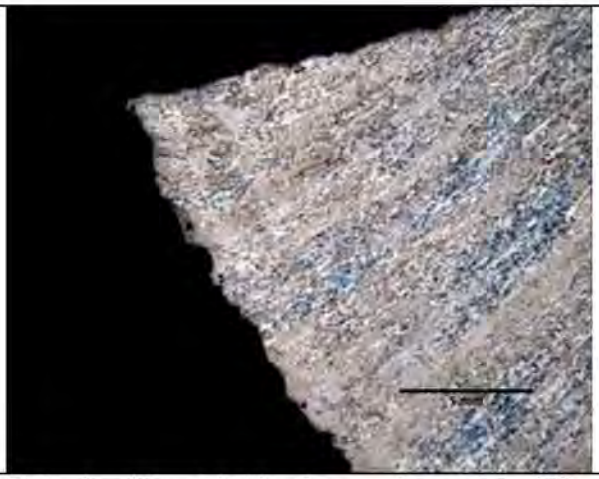
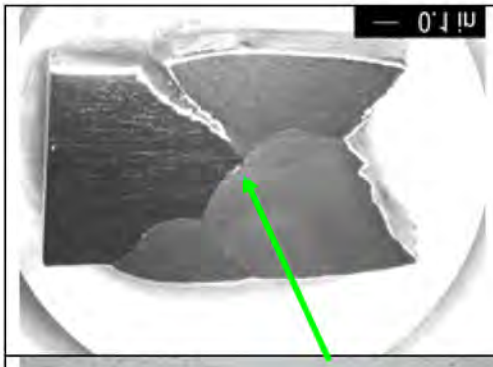
<tr><td>  </td><td>M3 ID on top- image reversed for photomicrographs</td></tr>
<tr><td>  </td><td>  </td></tr>
<tr><td>Un-etched weld metal side of secondary crack at ID cr</td><td>Etched weld metal side of secondary crack at ID</td></tr>
<tr><td>  </td><td>  </td></tr>
<tr><td>Detail of Un-etched weld metal side of secondary crack at ID</td><td>Detail of etched weld metal side of secondary crack at ID</td></tr>
<tr><td colspan="2">FIGURE 31 Secondary crack in M3 on base metal side can 3 on LS3 fracture</td></tr>
</table>

BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 47 OF 88

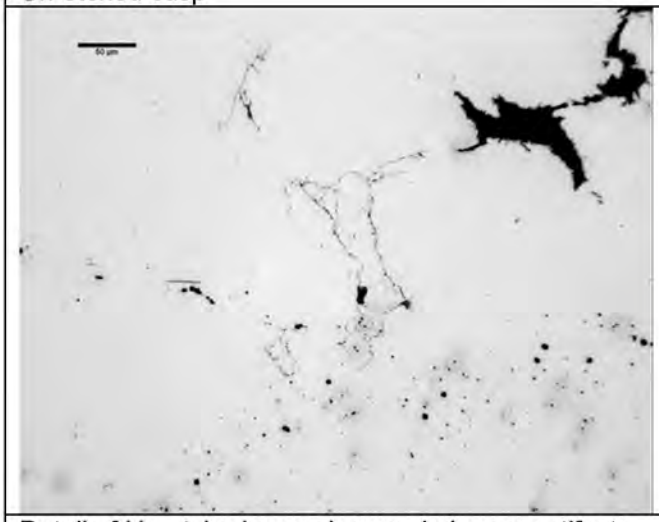
LABORATORY REPORT-LS3 BOTTOM



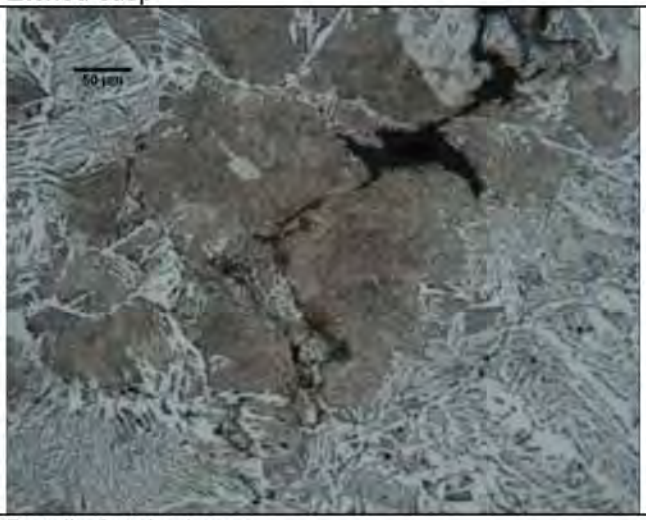
M3 ID on top- image reversed for photomicrographs

Un-etched cusp

Etched cusp



Detail of Un-etched cusp- brown circles are artifacts

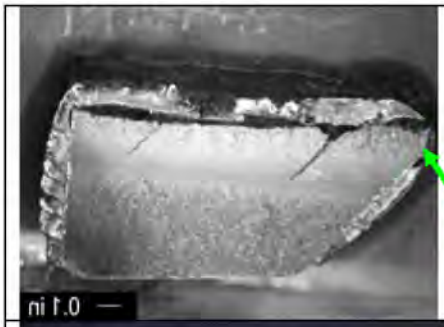


Detail of etched cusp

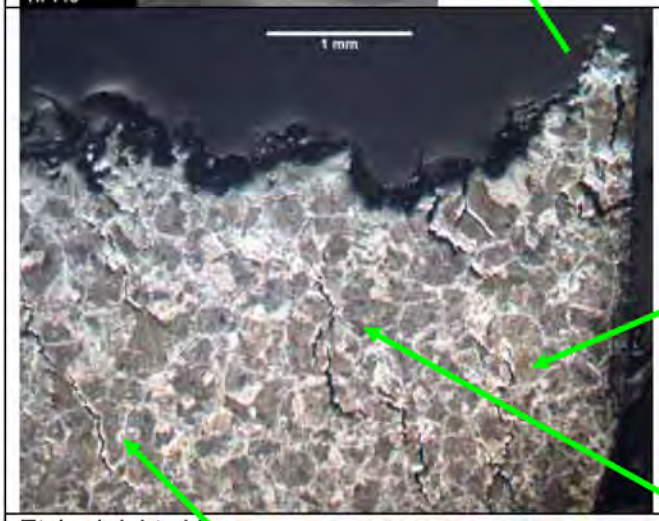
FIGURE 32 Secondary crack in M3 on base metal side can 3 on LS3 fracture

BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 48 OF 88

LABORATORY REPORT-LS3 BOTTOM

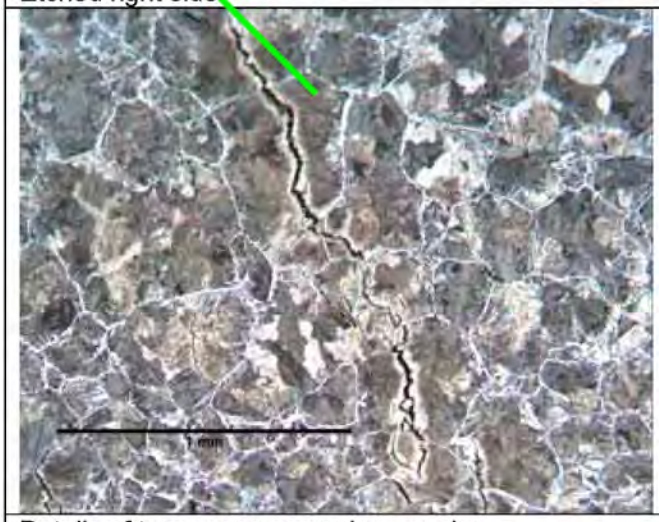


M4 fracture on top looking at ID surface - image reversed for photomicrographs

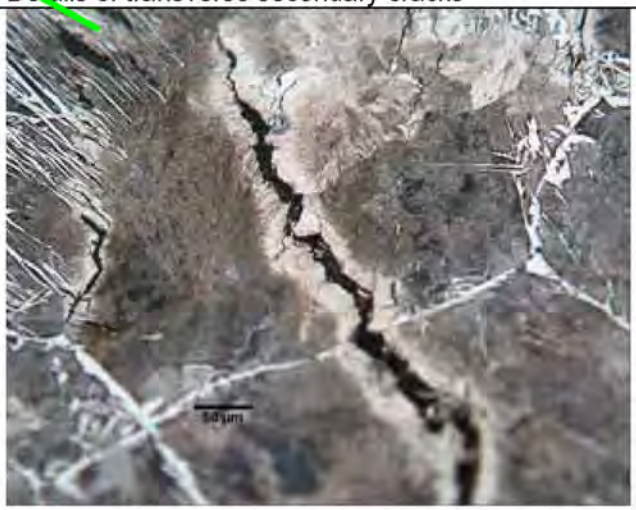


Etched right side

Details of transverse secondary cracks



Details of transverse secondary cracks

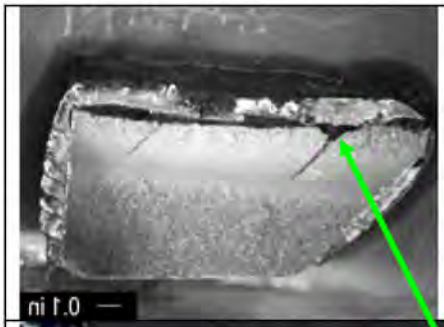


Details of transverse secondary cracks

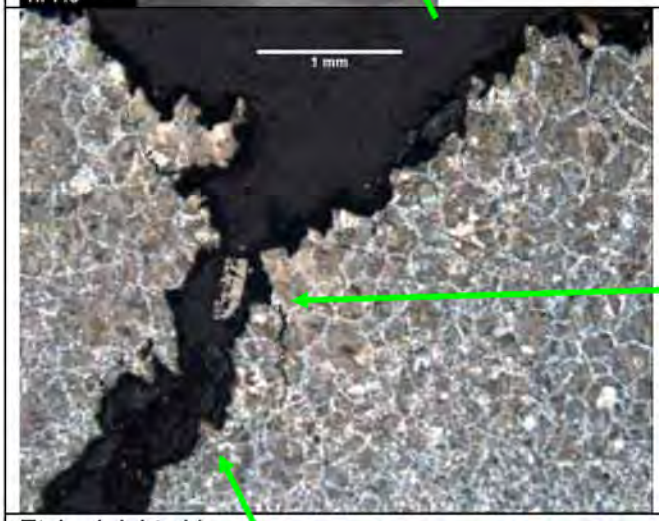
FIGURE 33 ID surface polished for M4, fracture surface at top on LS3 fracture

BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 49 OF 88

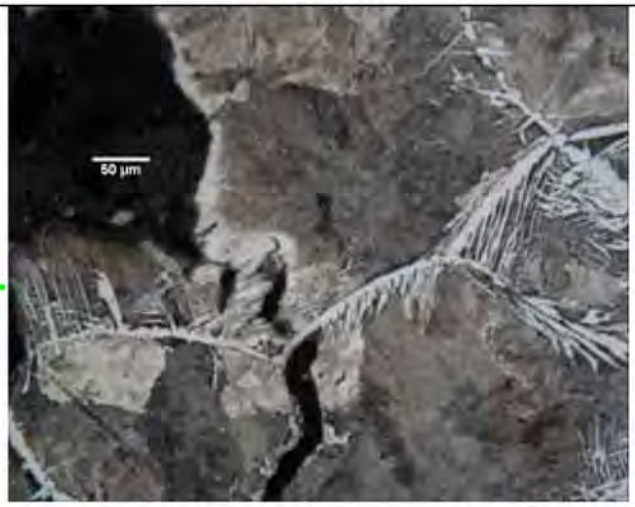
LABORATORY REPORT-LS3 BOTTOM



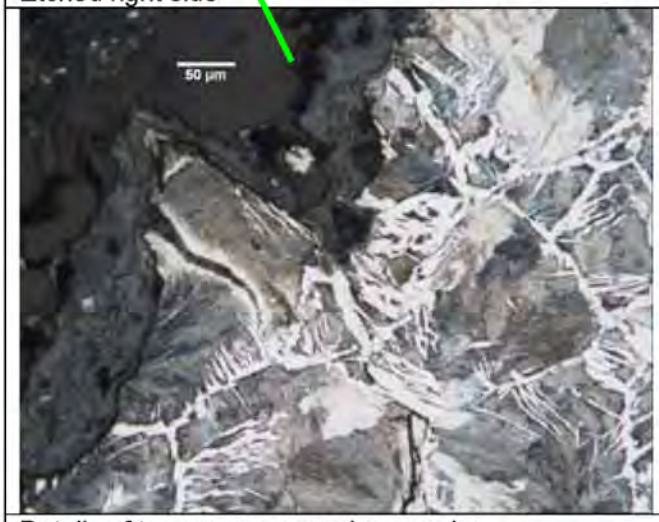
M4 fracture on top looking at ID surface - image reversed for photomicrographs



Etched right side



Details of transverse secondary cracks



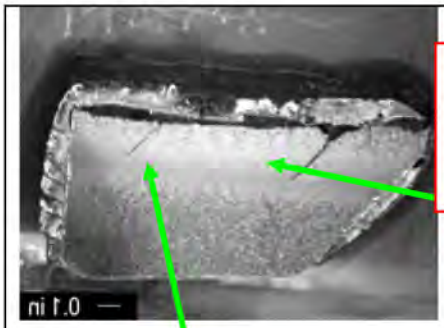
Details of transverse secondary cracks

Details of transverse secondary cracks

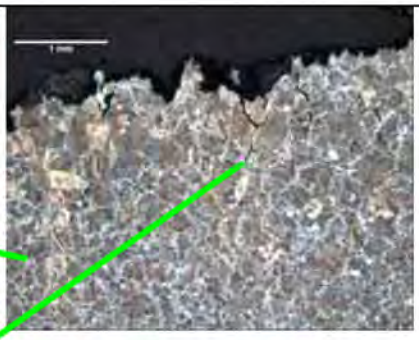
FIGURE 34 ID surface polished for M4, fracture surface at top on LS3 fracture

BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 50 OF 88

LABORATORY REPORT-LS3 BOTTOM

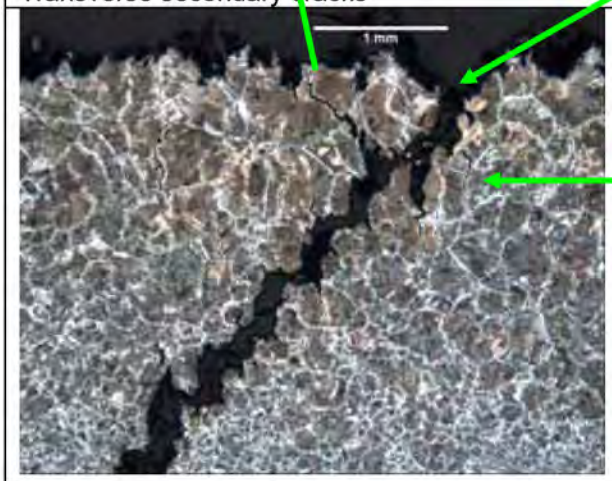


M4 fracture on top looking at ID surface - image reversed for photomicrographs

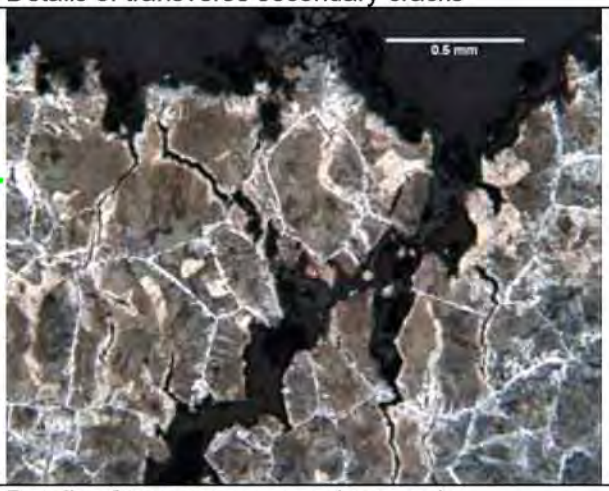


Transverse secondary cracks

Details of transverse secondary cracks



Transverse secondary cracks

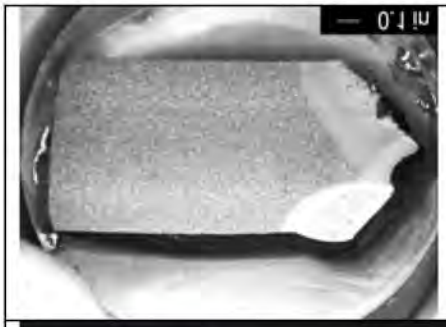


Details of transverse secondary cracks

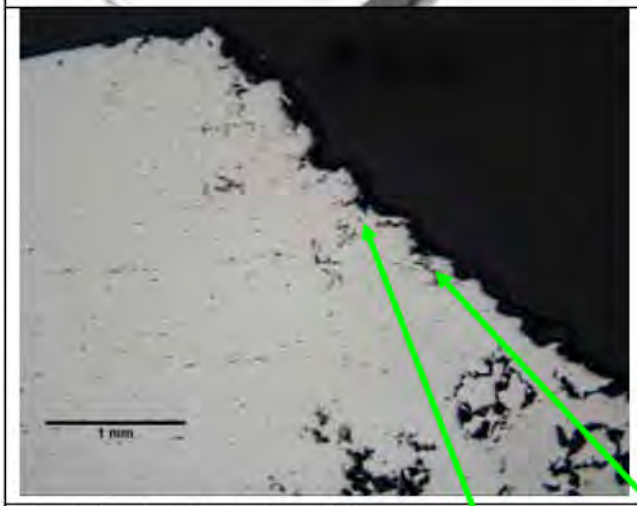
FIGURE 35 ID surface polished for M4, fracture surface at top on LS3 fracture

BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 51 OF 88

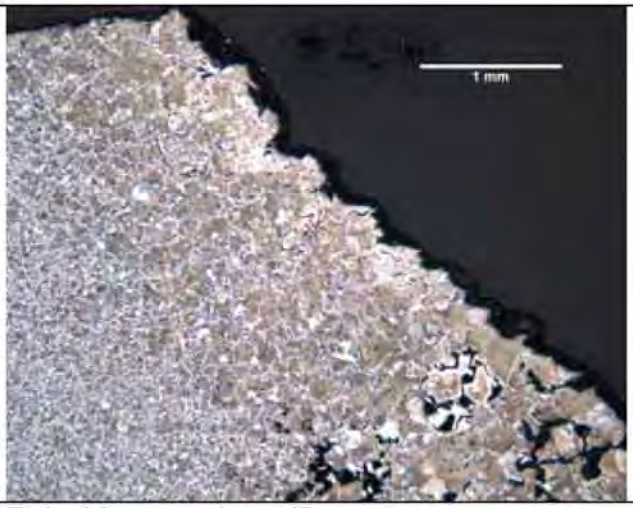
LABORATORY REPORT-LS3 BOTTOM



M4T fracture on right, ID at top - image reversed for photomicrographs

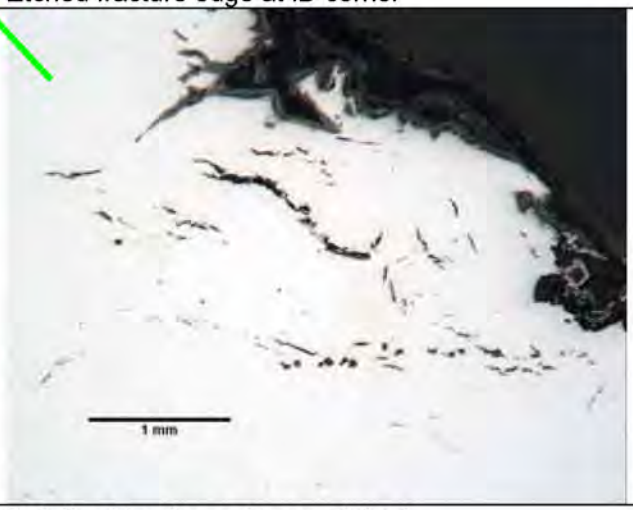


Un-etched fracture edge at ID corner



Etched fracture edge at ID corner

Details of fracture edge- etched

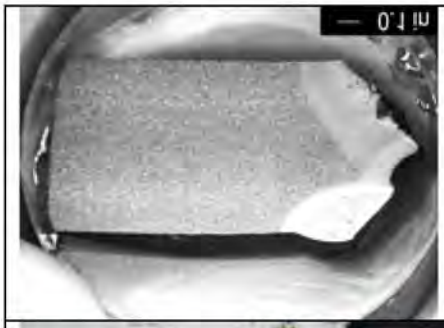


Details of fracture edge un-etched

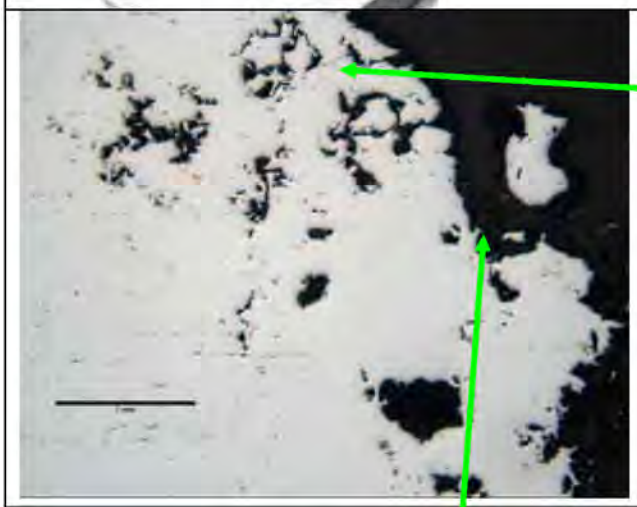
FIGURE 36 Transverse mount M4T, ID on top, fracture surface at right- ID fracture edge on CS4 fracture

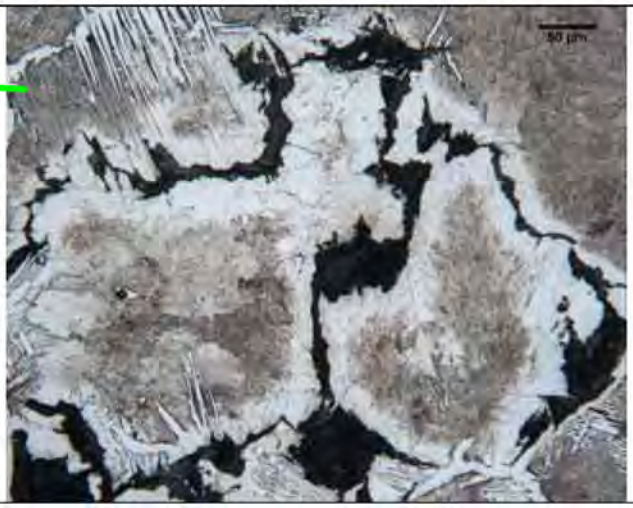
BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 52 OF 88

LABORATORY REPORT-LS3 BOTTOM



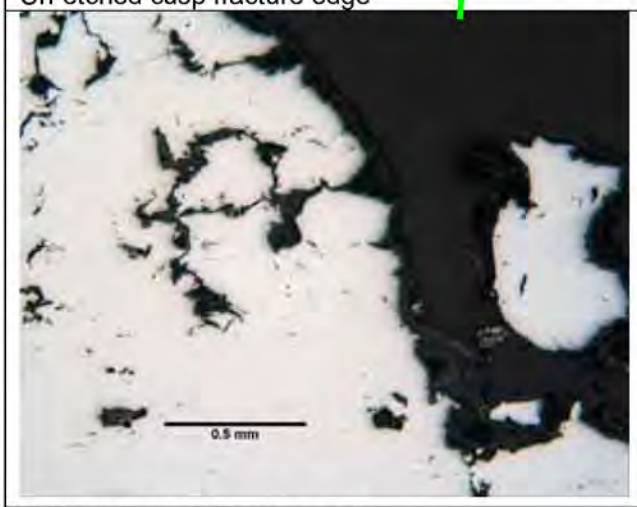
M4T fracture on right, ID at top - image reversed for photomicrographs





Un-etched cusp fracture edge

Etched detail of cusp



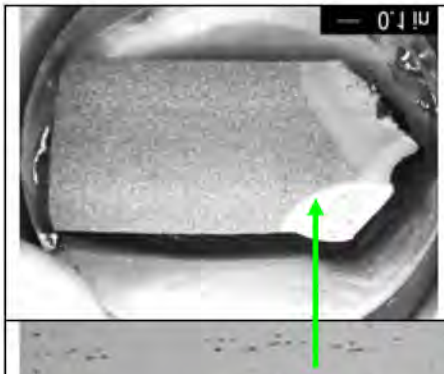
Un-etched cusp fracture edge

Etched cusp fracture edge

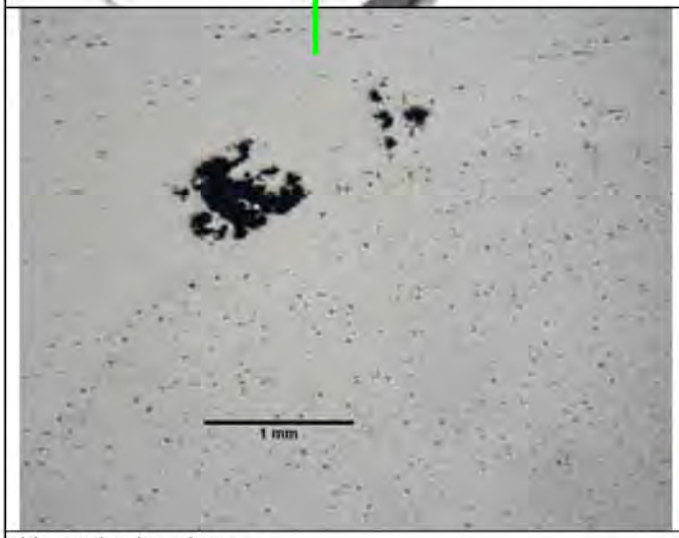
FIGURE 37 Transverse mount M4T, ID on top, fracture surface at right- weld cusp area on CS4 fracture

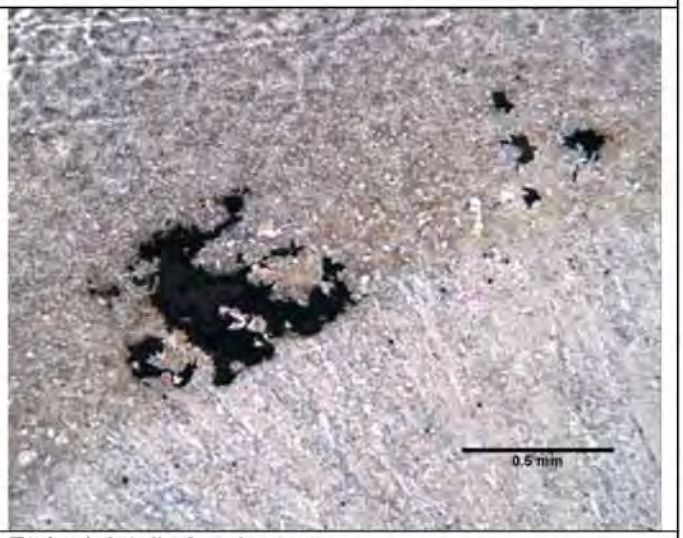
BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 53 OF 88

LABORATORY REPORT-LS3 BOTTOM



M4T fracture on right, ID at top - image reversed for photomicrographs





Un-etched under cap

Etched detail of under cap

FIGURE 38 Transverse mount M4T, ID on top, fracture surface at right- under cap pass on OD on CS4 weld

BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 54 OF 88

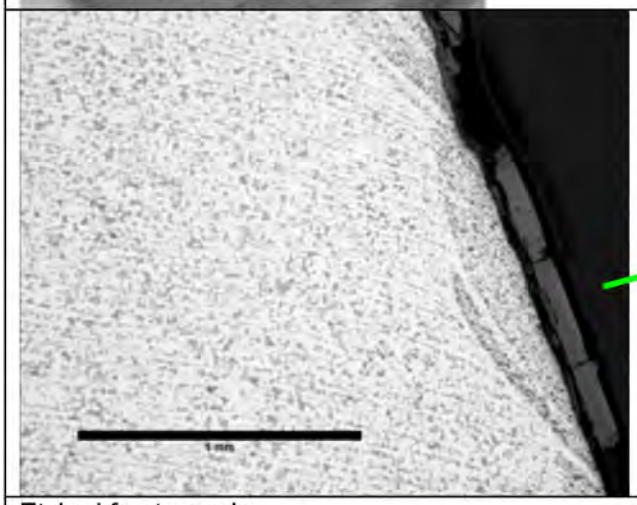
LABORATORY REPORT-LS3 BOTTOM

<table>
<tr><td>  </td><td>M5 fracture on right, ID at top - image reversed for photomicrographs</td></tr>
<tr><td> 
</td><td> 
</td></tr>
<tr><td>Un-etched ID corner at fracture</td><td>Un-etched fracture edge</td></tr>
<tr><td>  </td><td> 
</td></tr>
<tr><td>Un-etched fracture edge</td><td>Etched fracture edge slightly lower</td></tr>
<tr><td colspan="2">FIGURE 39 Transverse M5 mount on CS4 weld on CS4 fracture</td></tr>
</table>

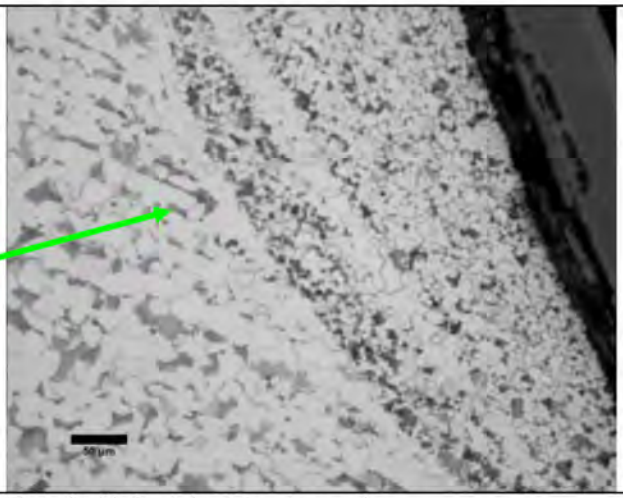
BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 55 OF 88

LABORATORY REPORT-LS3 BOTTOM

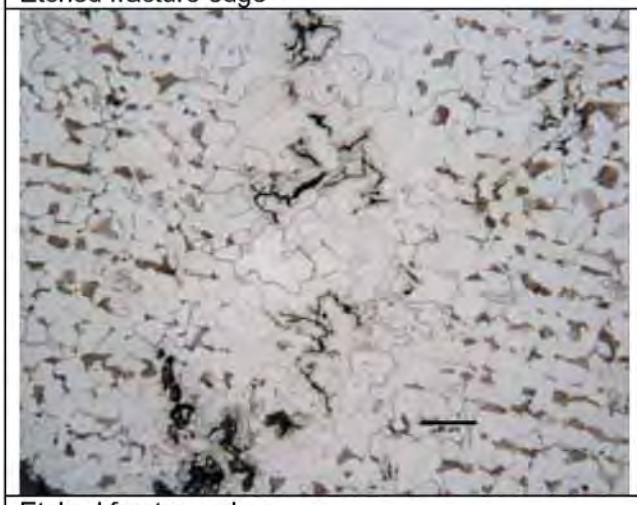
M5 fracture on right, ID at top - image reversed for photomicrographs



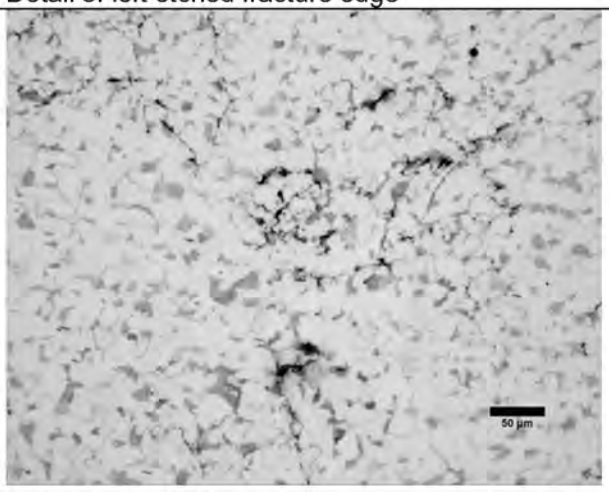
Etched fracture edge



Detail of left etched fracture edge



Etched fracture edge



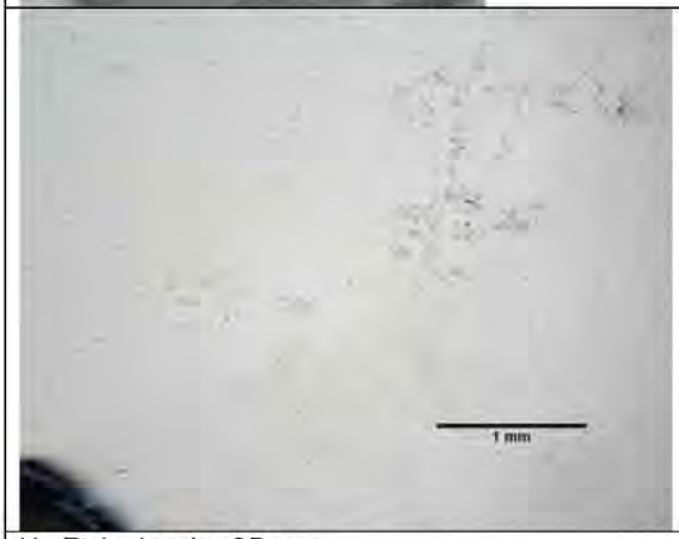
Etched near fracture edge

FIGURE 40 Transverse M5 mount on CS4 weld on CS4 fracture

BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 56 OF 88

LABORATORY REPORT-LS3 BOTTOM

M5 fracture on right, ID at top - image reversed for photomicrographs



Un-Etched under OD cap

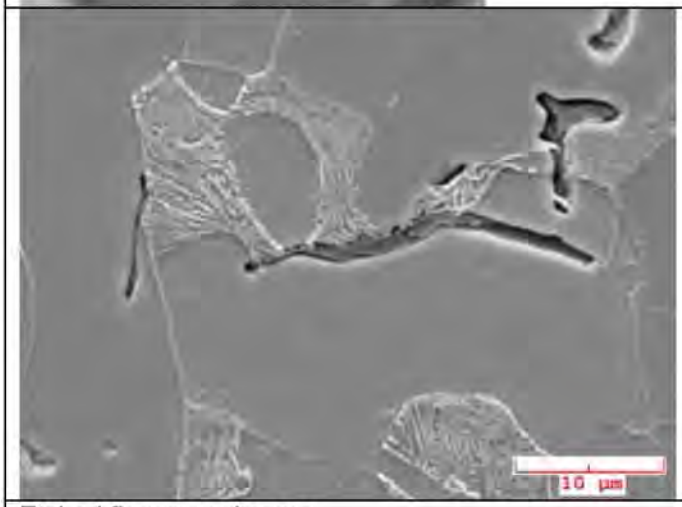
Detail un-etched under OD cap

FIGURE 41Transverse M5 mount on CS4 weld on CS4 fracture

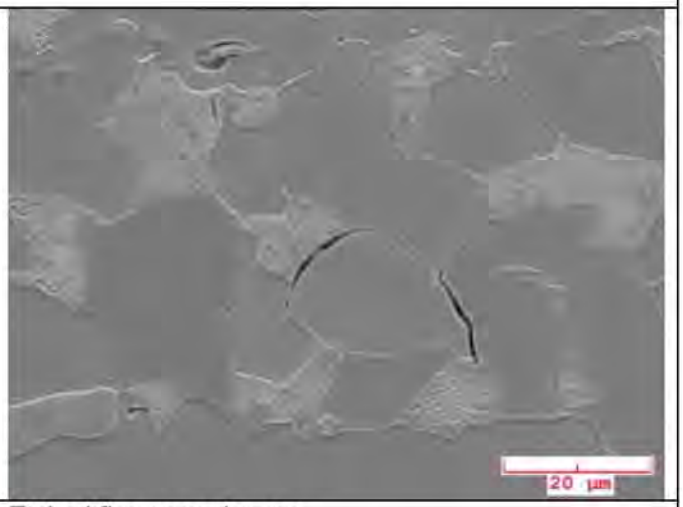
BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 57 OF 88

LABORATORY REPORT-LS3 BOTTOM

M5 fracture on right, ID at top - image reversed for photomicrographs



Etched fissure under cap

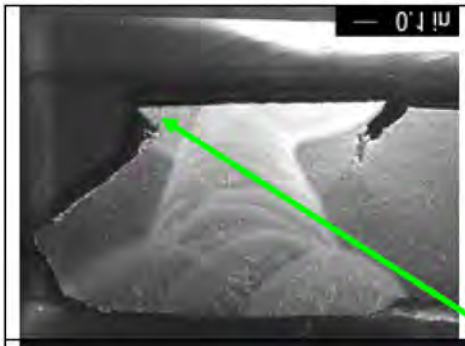


Etched fissure under cap

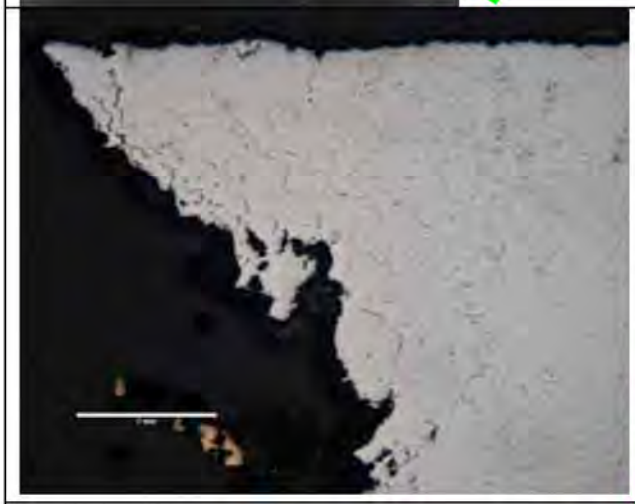
FIGURE 42 Transverse M5 mount on CS4 weld on CS4 fracture-SEM Photomicrographs

BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 58 OF 88

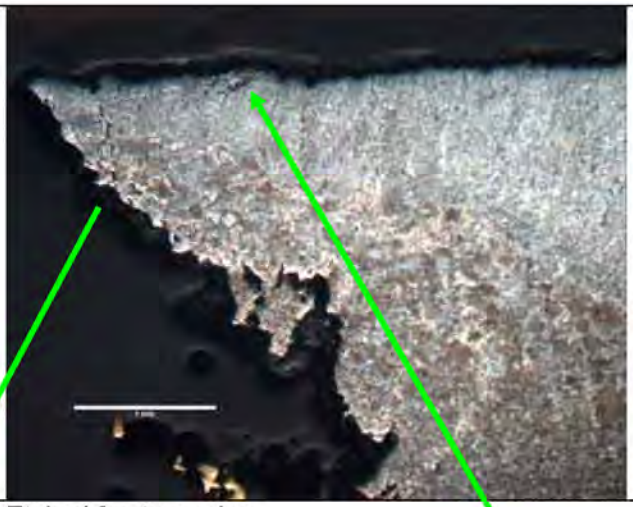
LABORATORY REPORT-LS3 BOTTOM



M6 fracture on left, ID at top - image reversed for photomicrographs

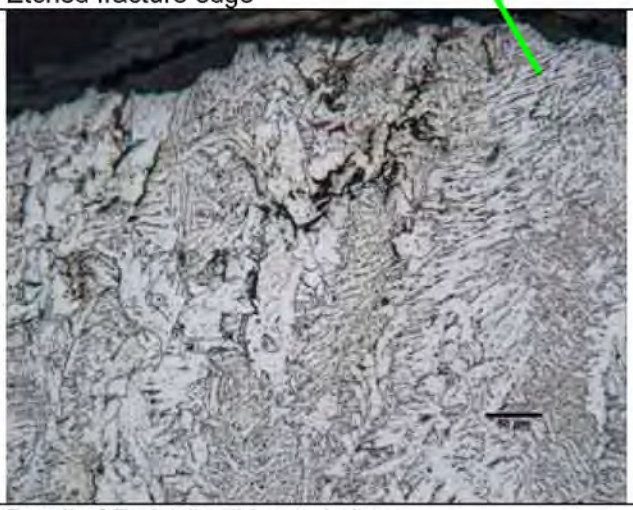


Un-Etched fracture edge



Etched fracture edge

Details of Etched fracture edge above

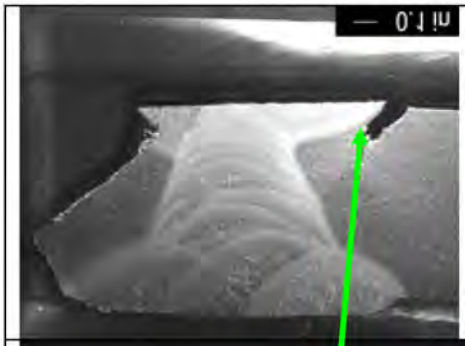


Detail of Etched weld metal above

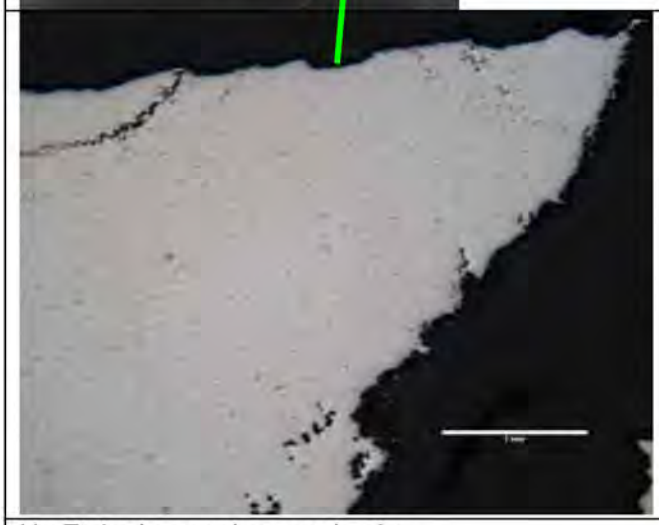
FIGURE 43 Transverse M6 mount on CS3 weld

BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 59 OF 88

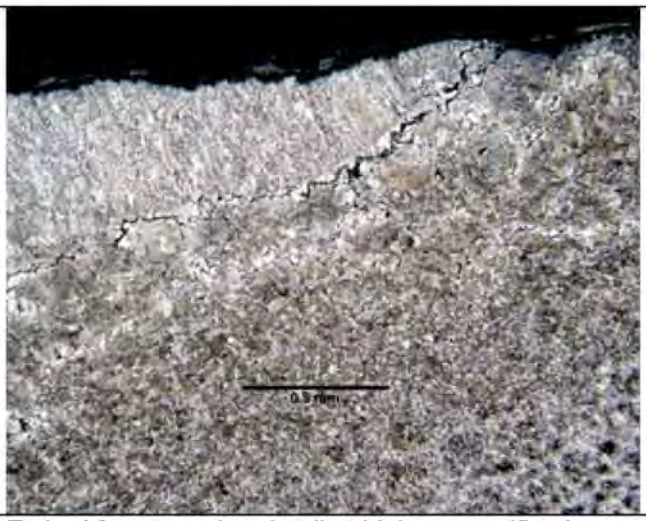
LABORATORY REPORT-LS3 BOTTOM



M6 fracture on left, ID at top - image reversed for photomicrographs



Un-Etched secondary crack edge



Etched fracture edge detail at higher magnification

Detail of Etched weld metal above

FIGURE 44 Transverse M6 mount on CS3 weld

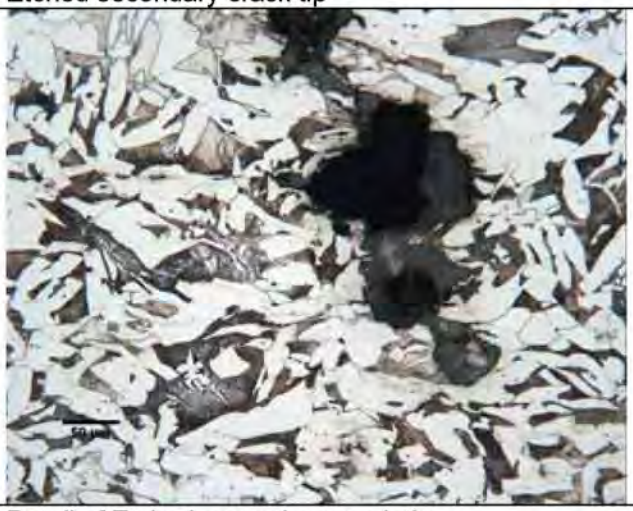
BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 60 OF 88

LABORATORY REPORT-LS3 BOTTOM

M6 fracture on left, ID at top - image reversed for photomicrographs

Un-Etched secondary crack tip

Etched secondary crack tip

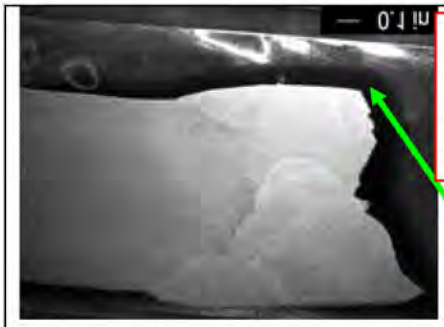


Detail of Etched secondary crack tip

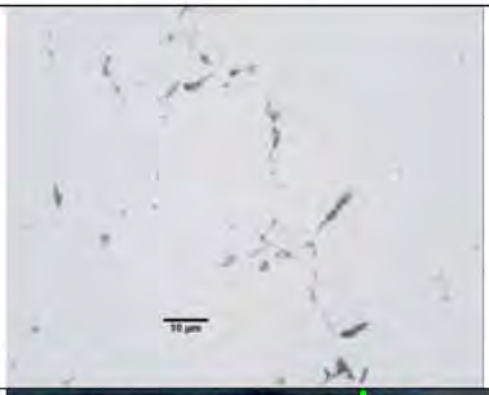
FIGURE 45 Transverse M6 mount on CS3 weld

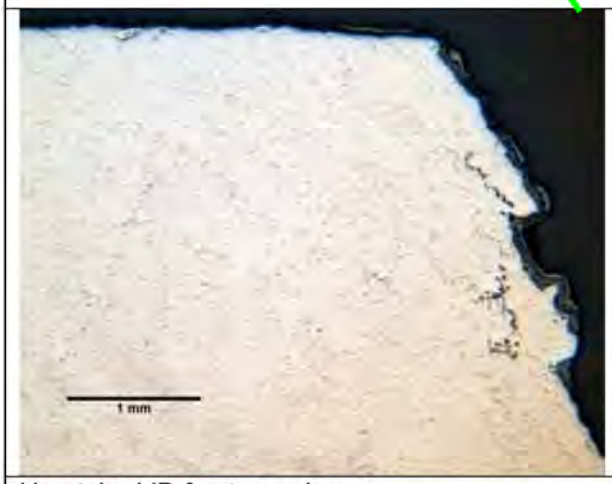
BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 61 OF 88

LABORATORY REPORT-LS3 BOTTOM

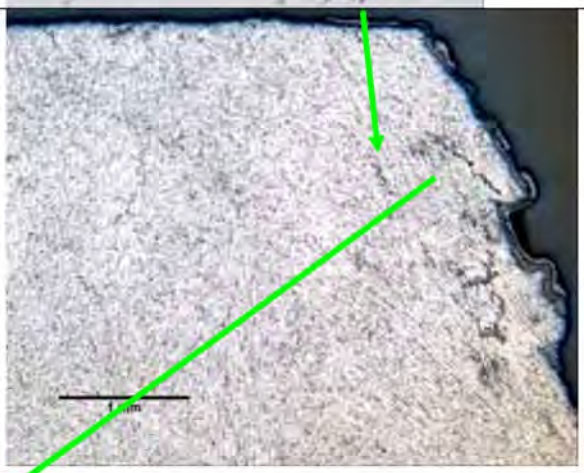


TO fracture on right, ID at top - image reversed for photomicrographs

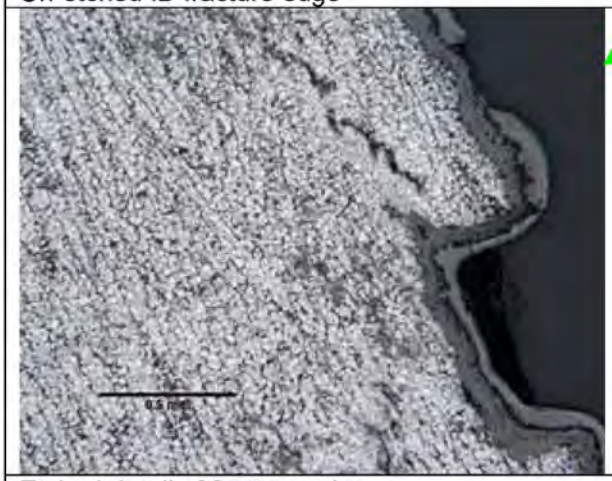




Un-etched ID fracture edge



Etched ID fracture edge



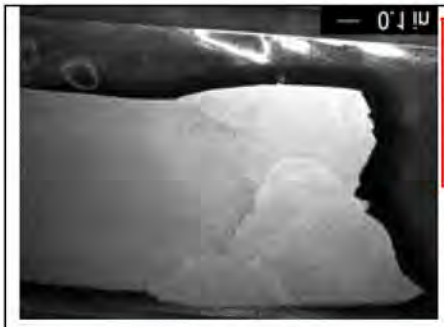
Etched detail of fracture edge

Further detail of fracture edge at left

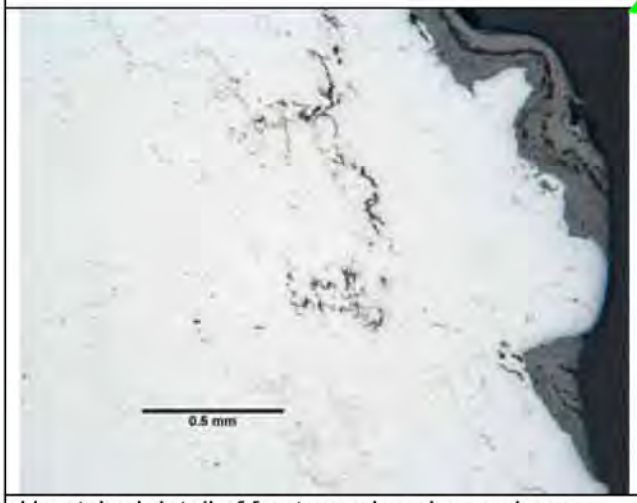
FIGURE 46 Transverse mount TO on LS3 near CS4

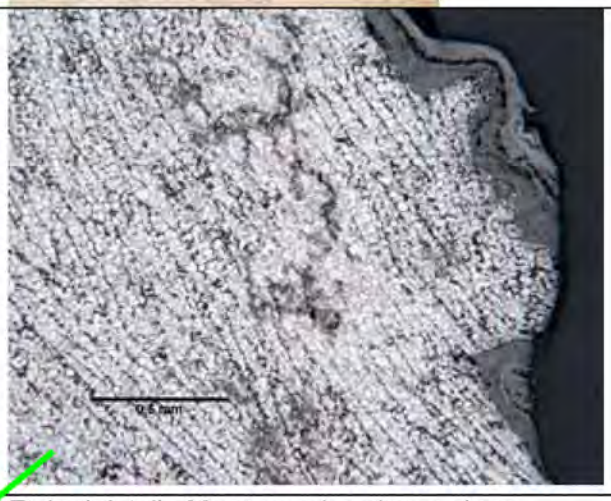
BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 62 OF 88

LABORATORY REPORT-LS3 BOTTOM



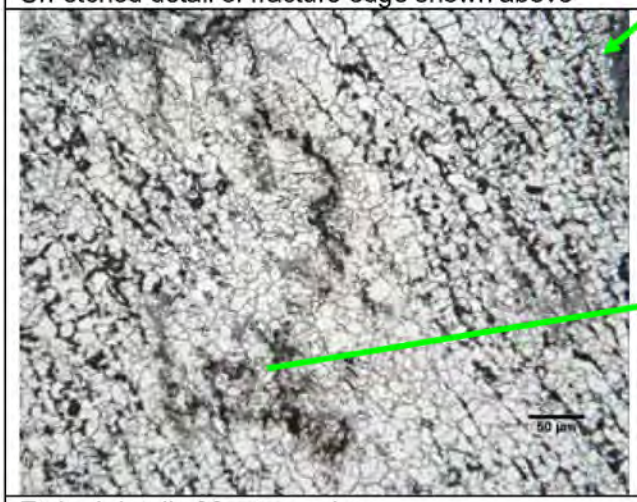
TO fracture on right, ID at top - image reversed for photomicrographs

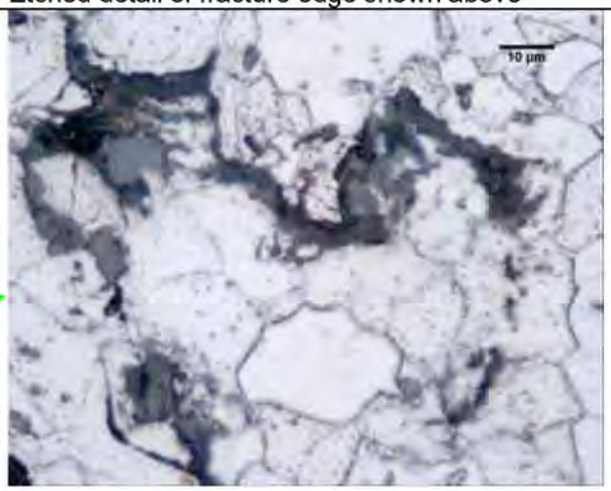




Un-etched detail of fracture edge shown above

Etched detail of fracture edge shown above





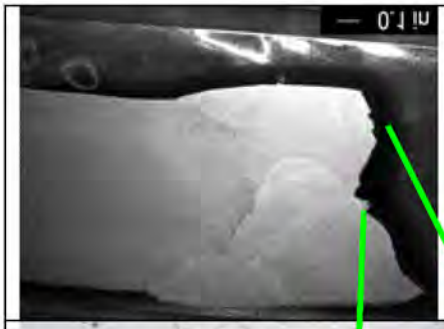
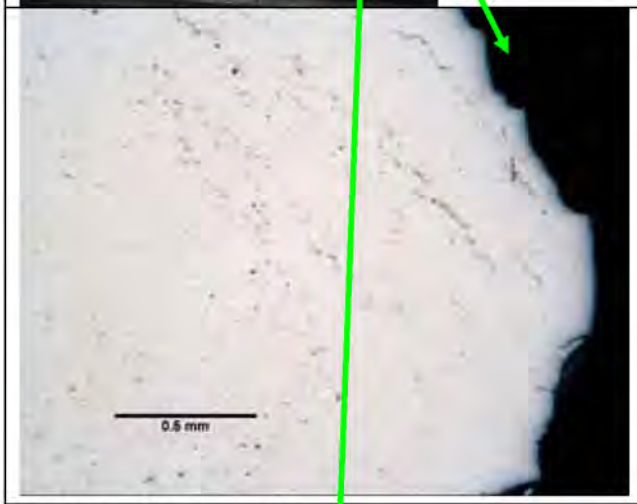
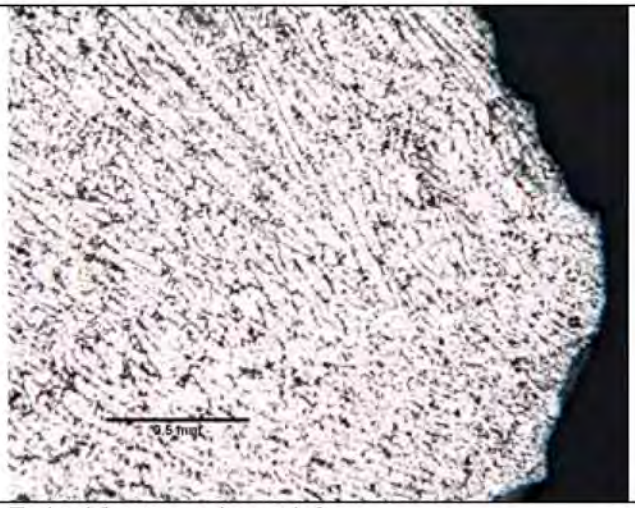
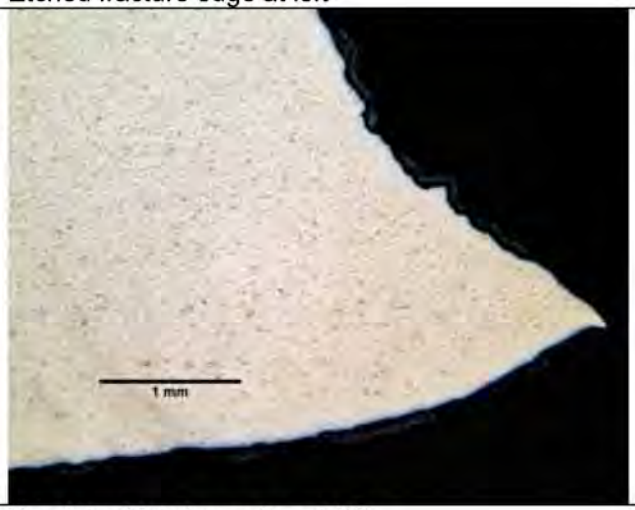
Etched detail of fracture edge

Further detail of fracture edge at left

FIGURE 47 Transverse mount TO on LS3 near CS4

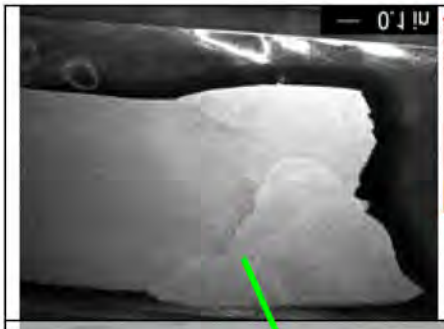
BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 63 OF 88

LABORATORY REPORT-LS3 BOTTOM

<table>
<tr><td>  </td><td>TO fracture on right, ID at top - image reversed for photomicrographs</td></tr>
<tr><td> 
</td><td>  </td></tr>
<tr><td>Un-etched fracture edge</td><td>Etched fracture edge at left</td></tr>
<tr><td>  </td><td> 
</td></tr>
<tr><td>Etched of fracture edge below one above</td><td>Un-etched fracture edge at OD</td></tr>
<tr><td colspan="2">FIGURE 48 Transverse mount TO on LS3 near CS4</td></tr>
</table>

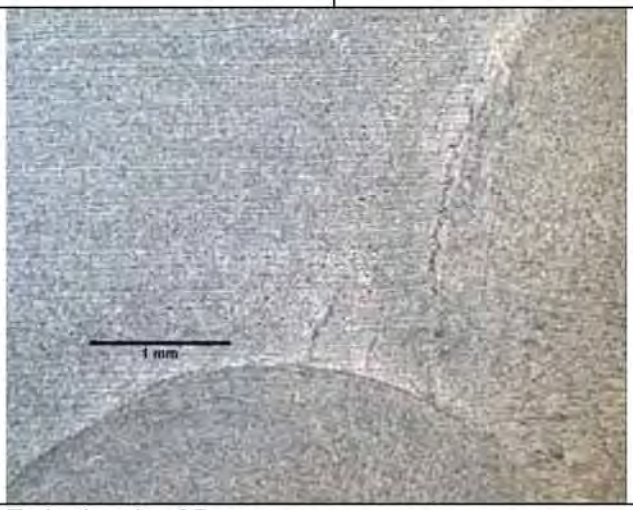
BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 64 OF 88

LABORATORY REPORT-LS3 BOTTOM

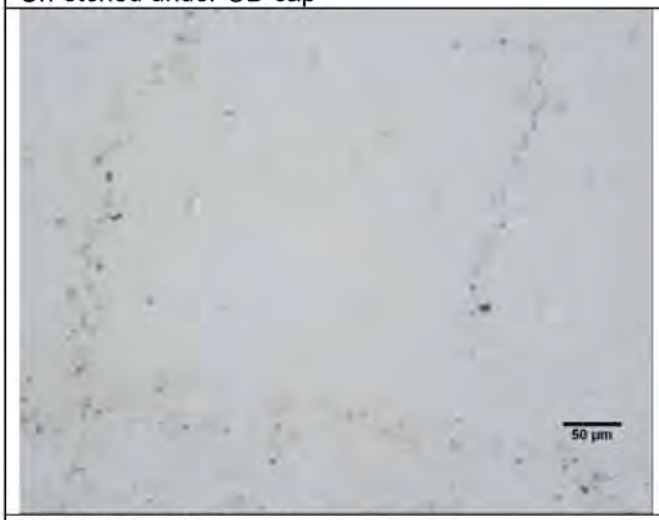


TO fracture on right, ID at top - image reversed for photomicrographs

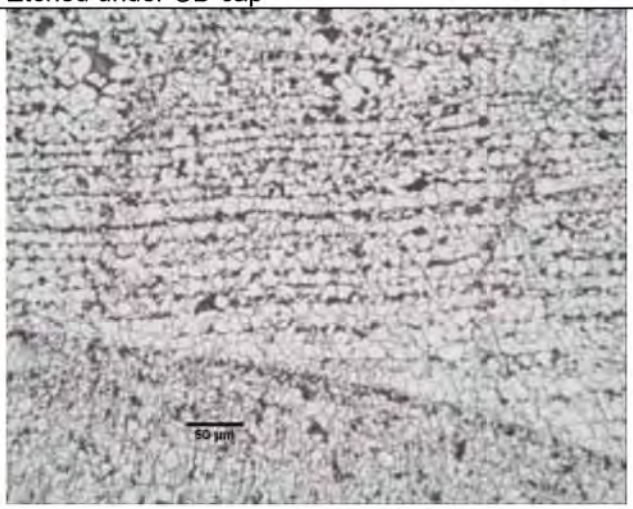
Un-etched under OD cap



Etched under OD cap



Un-Etched detail under cap



Etched detail under cap

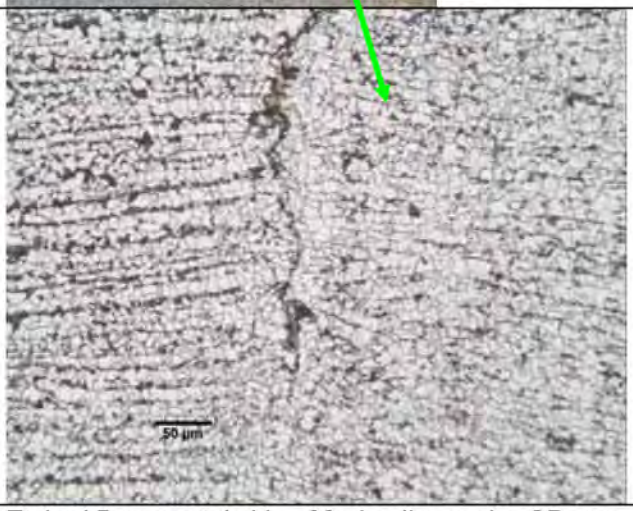
FIGURE 49 Transverse mount TO on LS3 near CS4

BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 65 OF 88

LABORATORY REPORT-LS3 BOTTOM

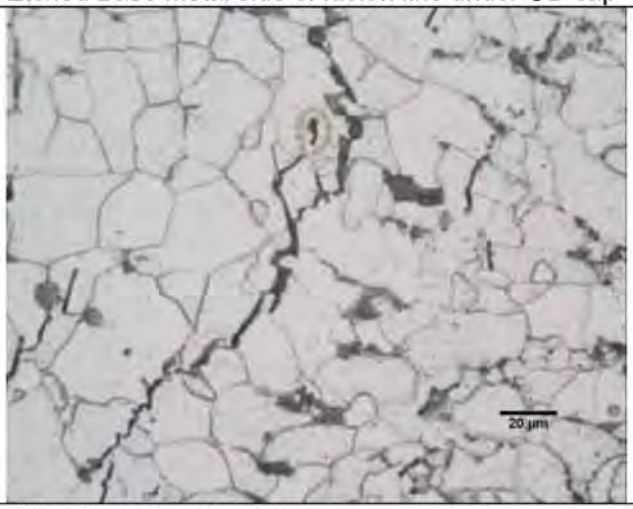
TO fracture on right, ID at top - image reversed for photomicrographs

Un-etched Base metal side of fusion line under OD cap



Etched Base metal side of fusion line under OD cap

Un-Etched detail of tip above



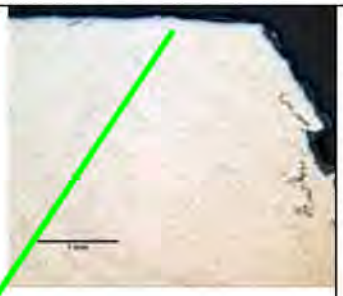
Etched detail of tip above

FIGURE 50 Transverse mount TO on LS3 near CS4

BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 66 OF 88

LABORATORY REPORT-LS3 BOTTOM

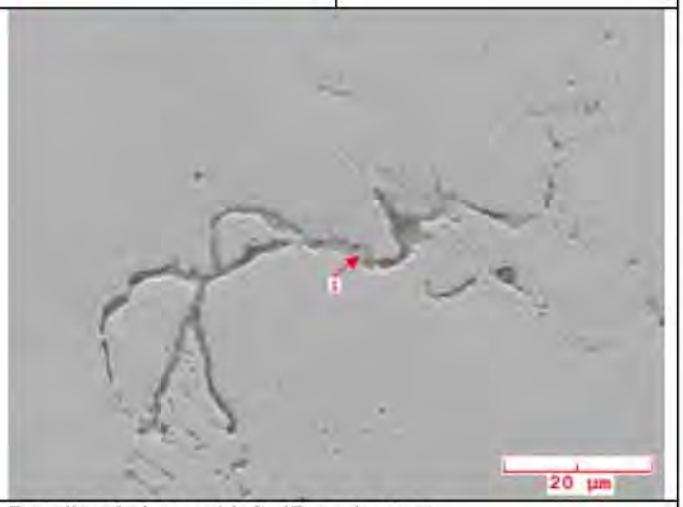
TO fracture on right, ID on top



Elt.	Line	Conc	Units	
S	Ka	28.7	wt.%	
Cr	Ka	1.5	wt.%	
Mn	Ka	2.0	wt.%	
Fe	Ka	67.8	wt.%	

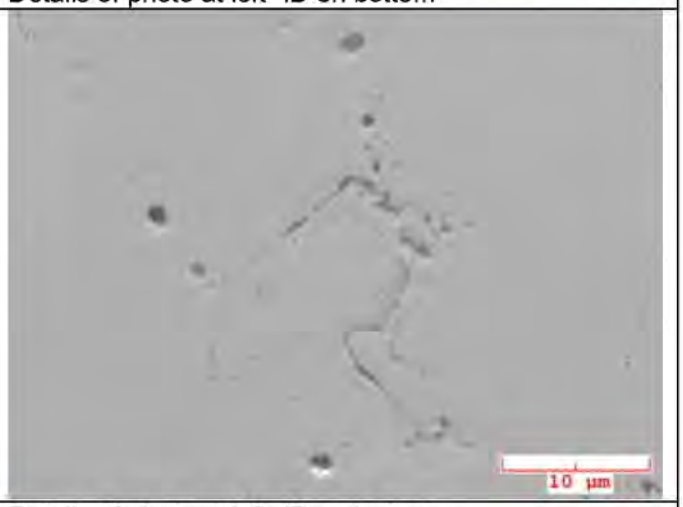
Particle 1 below

Un-etched near ID surface in weld metal- ID on bottom



Details of photo at left- ID on bottom

Un-etched near ID surface in weld metal –ID on bottom



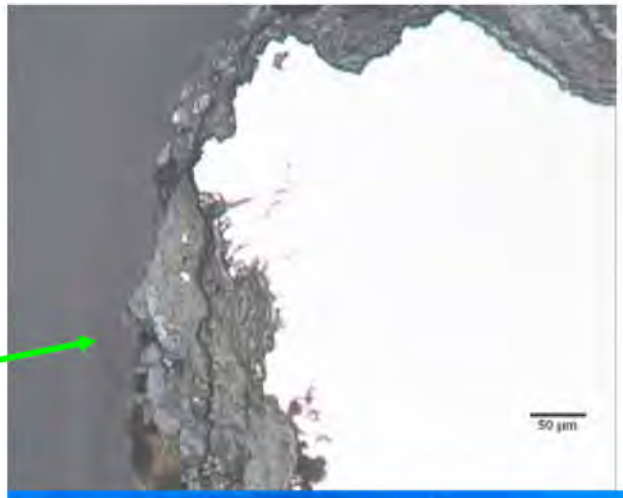
Details of photo at left- ID on bottom

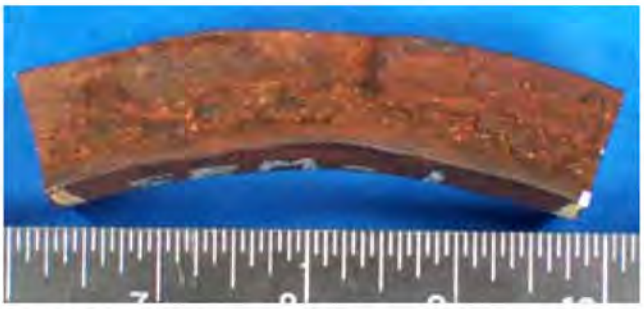
FIGURE 51 Transverse mount TO on LS3 near CS4- SEM photomicrographs- note SEM images are 180 degrees with optical photomicrographs

BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 67 OF 88

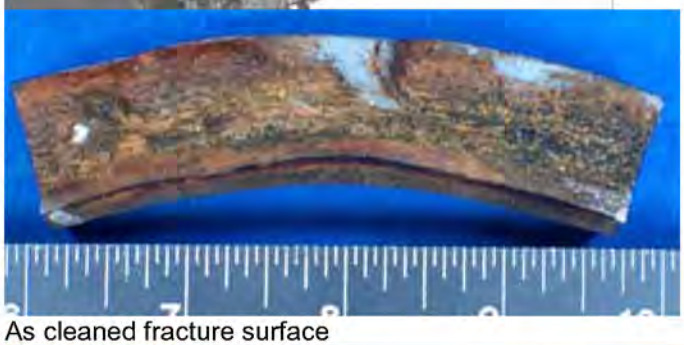
LABORATORY REPORT-LS3 BOTTOM

Mount M3 with oxide on after cutting and mounting



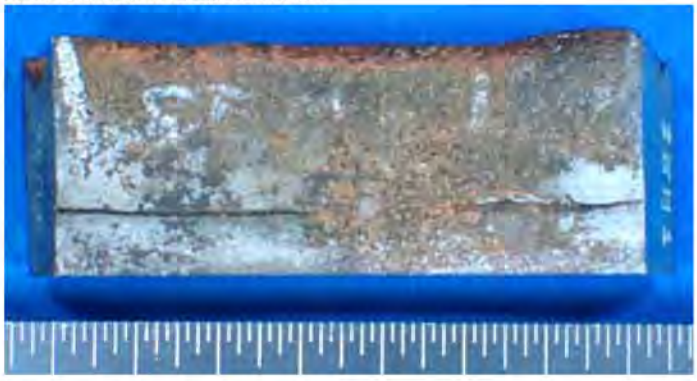


As received fracture surface



As cleaned fracture surface

As received ID surface



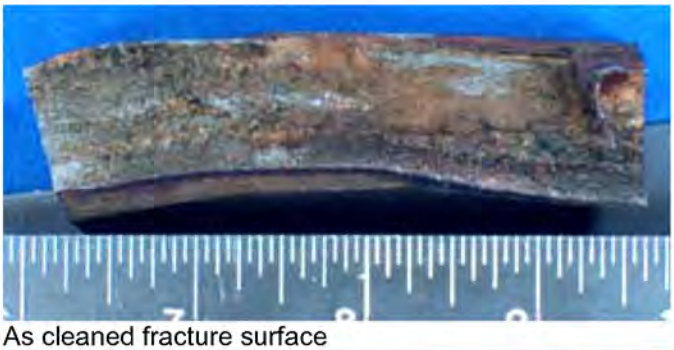
As cleaned ID surface

FIGURE 52 Sample selected for SEM fractography in as received and partial cleaning condition-SEM1

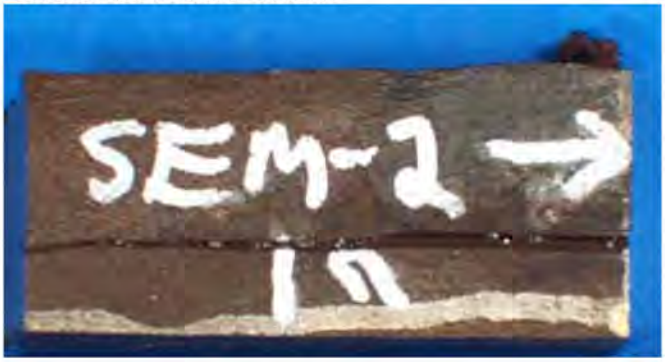
BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 68 OF 88

LABORATORY REPORT-LS3 BOTTOM

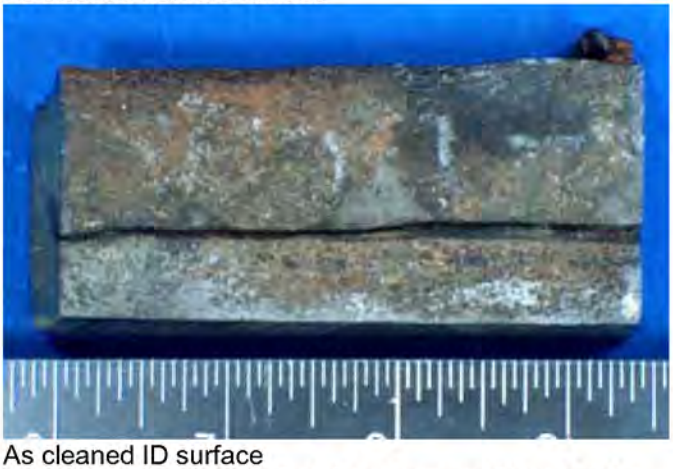
As received fracture surface



As cleaned fracture surface



As received ID surface

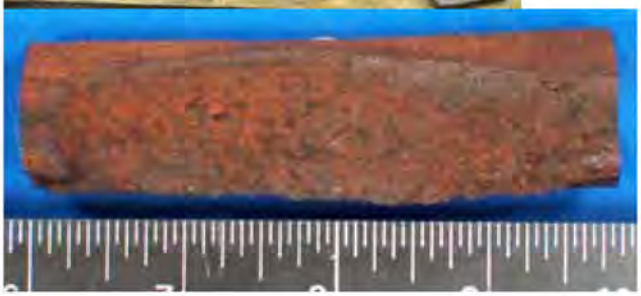


As cleaned ID surface

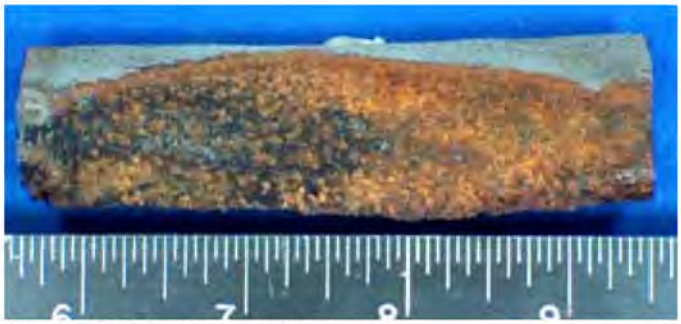
FIGURE 53 Sample selected for SEM fractography in as received and partial cleaning condition-SEM2

BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 69 OF 88

LABORATORY REPORT-LS3 BOTTOM

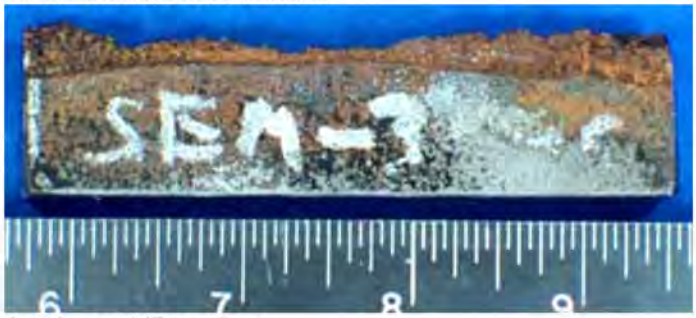


As received fracture surface



As cleaned fracture surface

As received ID surface



As cleaned ID surface

FIGURE 54 Sample selected for SEM fractography in as received and partial cleaning condition-SEM3

BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 70 OF 88

LABORATORY REPORT-LS3 BOTTOM

As received fracture surface

As received ID surface-note junction with of LS3 top horizontal and CS3 vertical

As received OD surface

FIGURE 55 Sample selected for SEM fractography in as received (sample not cleaned)-SEM4

BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 71 OF 88

LABORATORY REPORT-LS3 BOTTOM

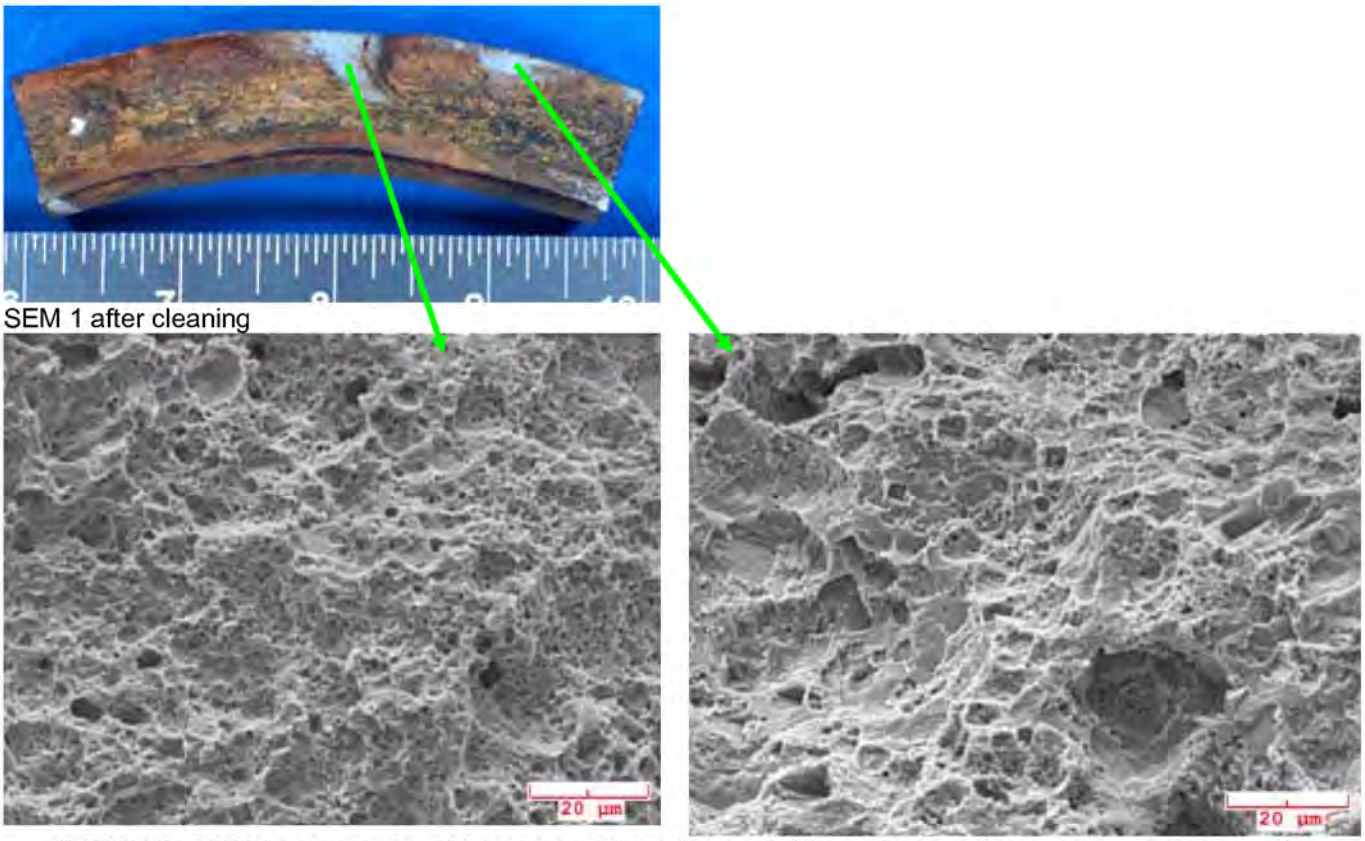
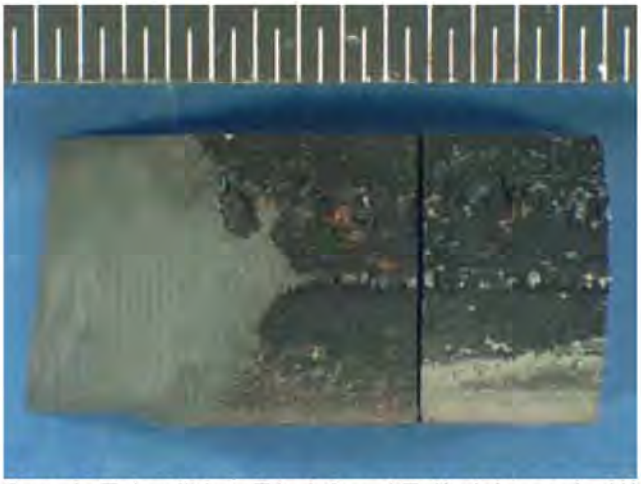


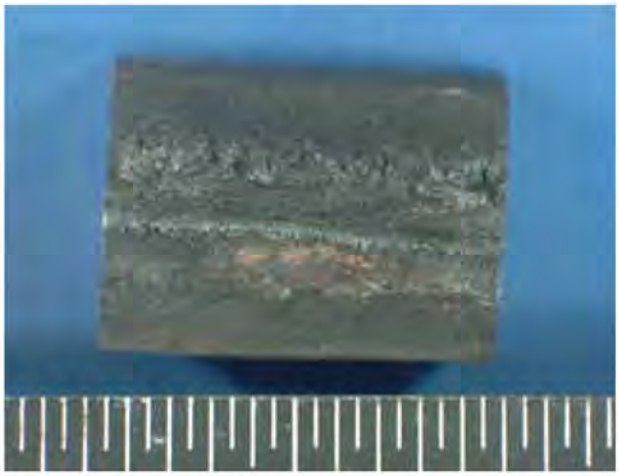
FIGURE 56 SEM fractography of two areas where the scale/corrosion products were removed on the fracture surface of SEM1

BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 72 OF 88

LABORATORY REPORT-LS3 BOTTOM



Sample T-1 split into T1a left and T-1b right- scale 1/16”

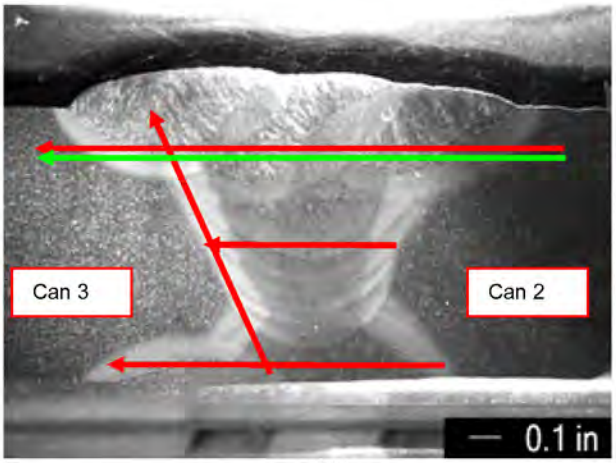


Sample T-2- scale 1/16”

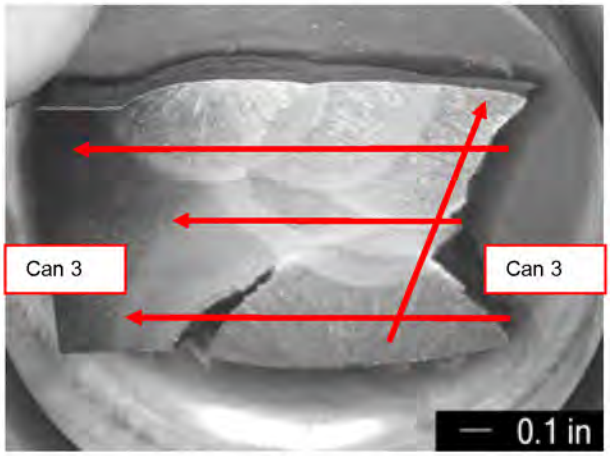
FIGURE 57 Cleaning test method samples T-1a, T1b and T-2

BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 73 OF 88

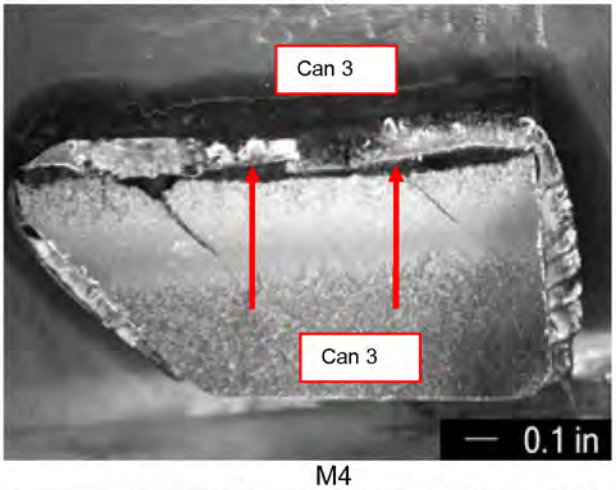
LABORATORY REPORT-LS3 BOTTOM



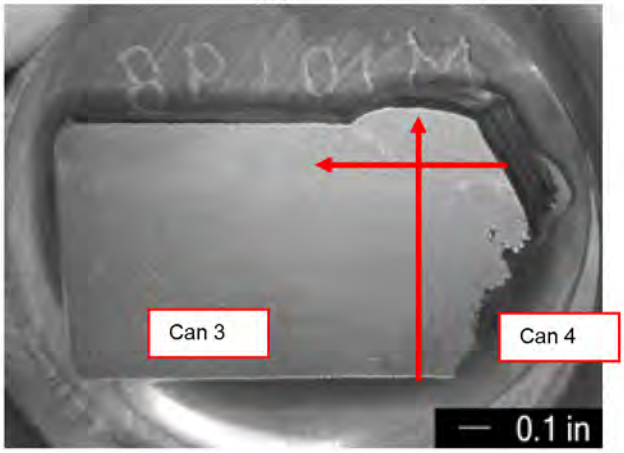
M1



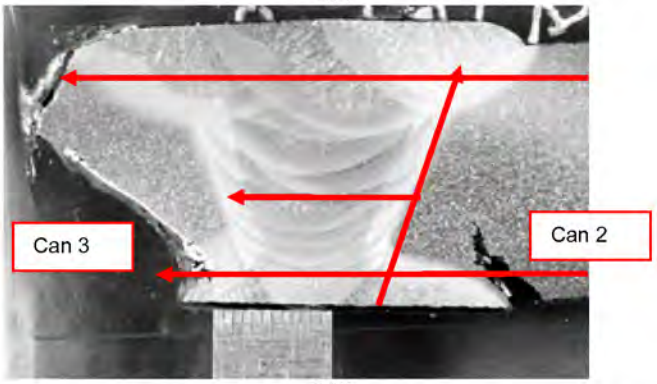
M3



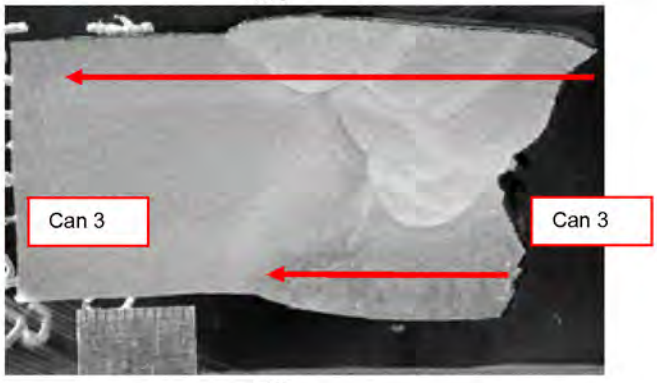
M4



M5



M6



TO

FIGURE 58 Vickers micro-hardness Traverse (Red) Lines for Data in Table 6 thru 11-green line is 10Kg Vickers

Tesoro Exchanger E Failure Examination Protocol

Part 1. Field Visual and Nondestructive Examination

Part 1 of this protocol identifies visual and non-destructive testing that is approved to be conducted on the shell of exchanger 6600-E by a contractor acceptable to the parties to this agreement. Prior to performing any visual inspection or non-destructive testing, 3 business days notice must be provided to all parties to the agreement to allow the opportunity to observe. Parties to this agreement may elect not to perform aspects of the visual inspection or non-destructive testing described in this protocol. Should parties identify the need to conduct additional inspection or non-destructive testing not described in Part 1 of this protocol, 2 days notice must be provided to all parties to this agreement in order to register any objections.

Detailed visual inspection and testing will not be permitted until the equipment is placed in the secure evidence storage location.

All field visual and nondestructive tests shall be appropriately documented indicating examinations performed, scope of examinations, test equipment used in examinations, results of testing and the qualifications of the examiner as appropriate. All reports will be signed and dated by the examiner(s). Data reports shall be distributed within 48 hours of examinations by the third party conducting these examinations to all parties simultaneously. No party shall have the opportunity to review any data results in advance of the other parties. Any part requesting clarification or correction of anything in the report shall submit their request to all parties.

Data generated as a result of the execution of this protocol will be shared with all parties to the agreement simultaneously. Visual inspection reports, analysis or conclusion will not be shared.

Each party conducting field visual and nondestructive examination shall be assigned a unique set of alpha-numeric sets of markings. The format of the markings shall be AXXX, BXXX, CXXX, etc. The markings shall be applied to the external surfaces of the shell only and shall be permanent in nature (etch, stamp, etc.). Any markings shall be applied at least two (2) inches from any fracture surface. The markings shall be used for purposes described in Part 1 of this protocol and may also be used to identify locations of specific areas of interest determined by any examination conducted in Part 1. Each party using the markings shall supply a drawing identifying unique markings used and locations of these markings on the shell for information to all parties.

Field Visual Examination

1. Photographically document the heat exchanger in the "as-found" condition before initiating the metallurgical analysis. Documentation should include the following:
   - Any reference points needed
   - Fracture area and surface
   - Seams

BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 75 OF 88

LABORATORY REPORT-LS3 BOTTOM

Tesoro Exchanger E Failure Examination Protocol

- Welds
- Anomalies (dents, cracks, appurtenance)
- Manufacturing flaws or defects
- Pitting and/or evidence of corrosion on internal and external surfaces

2. Videotape the failed heat exchanger and surrounding heat exchangers and piping in the "as-found" condition. The videotape should similarly scan all items listed in (1) above. One scan should also offer a panoramic view of all affected surrounding equipment shot from a location immediately adjacent to the point of failure on the failed exchanger.

3. Perform an initial field visual examination of the internal and external surfaces in the "as-found" condition, and document any anomalies that may be present such as the following:
   - Cracks
   - Crevices
   - Dents
   - Gouges
   - Manufacturing defects
   - Pitting and/or evidence of corrosion on internal and external surfaces
   - Presence of corrosion products and/or deposits
   - Examine the surface for evidence of cracks
   - Examine for evidence of arc burns, grinding around the surface area near the fracture

Additional considerations

a. Fracture Surfaces: All fracture surfaces should be reviewed and photographed to check for:
   - thinning due to apparent corrosion
   - thinning due to necking
   - scaling (indicating an older crack)
   - beach or ratchet (chevron) marks pointing to the initiation site
   - proximity to welds and whether the crack propagates through weld metal, base metals or HAZs (Heat Affected Zones).
   - proximity to the end of the cladding
   - geometrical anomalies – e.g. gouges, sharp weld corners, mismatch, incomplete penetration of welds, etc

b. Characterization of Internal Corrosion: Visible thinning or pitting on shell, tubes and baffles. Record description of all visible areas, with:
   - locations of corrosion on shell with length from outlet tubesheet and height from the bottom of the exchanger),
   - appearance of corrosion type on shell – thinning , pitting, etc
   - descriptions of scales
   - estimates of depths of observable corrosion and scales.

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PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 76 OF 88

LABORATORY REPORT-LS3 BOTTOM

Tesoro Exchanger E Failure Examination Protocol

c. Characterization of Fouling or Other Deposits:
- Describe by color, volume, location, density, tenacity of adhering to surface, whether initiating on tubes or shell.
- Use initial photos for comparison to see if fouling has been affected by atmospheric and weather exposure in the last few weeks.
- Report any areas near fracture surface where the fouling seems to be removed due to the flow escaping from the fracture (to help define initial leak point).

d. Characterization of Distortion – Possible Pre- or Post-Explosion:
- Look for tube distortion such as pulling out of tubesheet or breaking behind tubesheet or baffles, or having contact with shell.
- Look for bundle distortion which may be an affect of the explosion, and may indicate the initial leak point.

e. Tracing Initial Leak Point by Surrounding Impingement or Damage:
- Inspect adjacent equipment in the direction of the rupture and cracking, and report any signs of flow impingement, high temperature exposures, explosion pressure-wave, etc.

Field Visual and Nondestructive Examination

1. Positive Materials Identification (PMI)

Perform PMI testing on all shell components and full penetration welds within two feet of the fracture surfaces using portable x-ray emission analyzers.
- Conduct all tests on external surfaces at least 6 inches away from all fracture surfaces.
- Conduct one test per weld located in the areas of interest on an external surface at least one foot away from all fracture surfaces.
- Unique numeric markings for identification purposes shall be made on the external surfaces of the shell where any PMI test was conducted.

2. Deposit Collection

Deposits from the lower section of the bundle and representative deposits found adhered to the shell shall be collected and stored in clean glass covered jars for subsequent laboratory analysis. Unique numeric markings for identification purposes shall be made on the external surfaces of the shell and on the surface of the bundle where the deposits were collected. Photographs should be taken of locations where deposits are to be removed prior to removal.

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PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 77 OF 88

LABORATORY REPORT-LS3 BOTTOM

Tesoro Exchanger E Failure Examination Protocol

Prior to collection of any samples, 3 business days notice shall be given to all parties to this agreement to provide the opportunity to observe sample collection. Analysis of collected samples must be approved by all parties to the agreement.

3. Field Crack Detection Ultrasonic Testing

   Conduct ultrasonic examination adjacent to all fracture surfaces using techniques suitable for stress corrosion cracking or other potential service cracking mechanisms. Phased array is preferred for macro-cracking and AUBT is preferred for fissuring due to HTHA.

4. Physical Measurements
   - Measure the wall thickness around fracture surfaces and any damaged areas. If corrosion is identified near or around the fracture surfaces, a "corrosion map" including reference points should be produced detailing the extent of the corrosion on the surfaces and the wall thicknesses in those areas. Measurements may be made using straight beam ultrasonic testing from the external surface.
   - Record any markings detected on the inside or outside surfaces of the shell. Record name plate data.
   - Measure rupture lengths tip-to-tip.
   - Measure the shortest circumferential distance from each fracture origin to the nearest longitudinal weld and any attachment weld or structural discontinuity, such as nozzles, saddle supports, tubesheets, etc.
   - Measure the axial distance from each fracture origin to the nearest circumferential weld, if any, and any attachment weld or structural discontinuity.
   - Map wall thickness of each sample within 12 inches of each rupture origin using straight beam ultrasonic testing. Measurements will be taken on a 2-inch square grid pattern that is centered on the fracture origin.

5. Shell Course Match Marking

   Suitable markings shall be made on external surfaces of shell sections on both sides of the separation at the circumferential weld to permit accurate recreation of the shell alignment of the two sections at the time of failure.

   A minimum of 3 business days notice shall be given to all parties to this agreement to allow the opportunity to be present and determine the location of the shell course match markings. Mutual agreement of the parties present is required prior to making shell course markings.

Part 2. Laboratory Examination

The 6600-E exchanger will be submitted to a laboratory acceptable to all parties in as found condition for disassembly, further testing and evaluation. The parties will agree on a protocol

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PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 78 OF 88

LABORATORY REPORT-LS3 BOTTOM

Tesoro Exchanger E Failure Examination Protocol

for disassembly and cutting prior to any such work. Some of the work below is redundant with the field inspections listed above and may be eliminated with concurrence from all parties if the field data is thought sufficient.

The laboratory will provide a schedule of activities and testing 3 business day prior to commencing any work to the parties to this agreement in order to receive the opportunity to be present and observe testing.

1. *Material Preparation for Shipment and Receipt*
   - All materials shall be photographed as found, once secured for shipping, and as received.
   - The 6600-E exchanger will be submitted to the laboratory in as found condition for disassembly, further testing and evaluation. . Spray fracture surfaces with clear lacquer (Krylon or Rustoleum clear spray) dissolvable in acetone to protect fracture surfaces from corrosion. Fracture surfaces shall be protected from mechanical damage during transport (e.g. a split rubber hose pressed along the edge of the sample).
   - The exchanger will be secured to a transport trailer, and protected by a hard cover (e.g. wood box or "conex" with the bottom removed) with a door secured by a tamperproof seal prior to shipment.
   - An inspection of the tamperproof seal will be documented on the chain of custody prior to shipment. The chain of custody will be signed by the representative of each interested party indicating the exchanger is ready for shipment
   - Shipping details will be provided to the lab of choice.
   - A representative of the laboratory will be present take receipt of the exchanger, photograph the as received condition and document any apparent shipping damage.
   - The exchanger and any samples collected will be stored in a secure indoor location.

Laboratory NDE Examinations

1. Take caliper readings for thickness of middle of plate and all edges and document. If there is pitting corrosion damage, pits within the area of interest will be counted and the pit length, width and depth will be recorded. Take macro hardness readings of each plate. If there is noticeable scale, take scale samples and preserve in clean glass jar.

2. Inspect the failed section for isolated cracks or colonies of cracks using nondestructive testing techniques. Carbon steel surfaces surrounding the rupture should be cleaned with an appropriate non-abrasive cleaner and subsequently inspected using a wet fluorescent magnetic particle inspection (WFMT) method. The circumferential weld should be examined by dye penetrant (PT) and WFMT (this weld was backcladded with austenitic material and there will be a carbon steel heat affected zone on one side and austenitic cladding on the other side of the weld).

3. Visually examine the fracture surfaces in detail to identify the characteristics of the fracture, the presence of any defect or anomaly, and the failure initiation point(s). Utilize a suitable

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PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 79 OF 88

LABORATORY REPORT-LS3 BOTTOM

Tesoro Exchanger E Failure Examination Protocol

method to thoroughly document the fracture surface including dimensional documentation. Suitable methods to document the fracture surface include, but are not limited to, the following:

- Foil method
- Photographs of macroscopic examination

Marking and Sample Selection for Analysis

1. Examine each tagged sample for areas where sections will be removed for further detailed analysis. The laboratory metallurgist with concurrence of all parties should determine the areas to sample for all analyses. Include areas directly opposite of any fractured weld/area to get both sides of the fracture.

2. Mark all areas chosen for further examination and label ID and OD. Include specimen side to be exposed when mounted.

3. Document those areas with macrophotographs, showing areas to be removed, ID tag, and reference measurements.

4. Mark all remote areas to be sampled for general chemical analysis and mechanical tests, including base metal, welds, and Heat Affected Zones (HAZ).

Fractographic/Metallographic Examination

1. Saw cutout sections to be mounted or looked at with Macroscope / optical light stereoscope, maintaining tag traceability and side to be examined.

2. Examine specimens with Macroscope and take pictures. If sample fracture surface was corroded before spraying with clear lacquer, then cut in half and keep one half and then take other half and remove lacquer with acetone and clean surface with a cleaning solution such as Endox. Then, examine specimens with Macroscope and take pictures. Retain some of the fracture surface of interest and go to Step 3.

3. Examine un-mounted and unpolished fracture surfaces of interest in an SEM at 5, 50, 100, 500, 1000 and 5000X to look for possible / likely initiation sites and clearly describe the fracture surface morphology (intergranular, cleavage, microvoid coalescence). Any deposit areas should be analyzed with EDS analysis.

4. Cold mount sample pieces in areas of interest for metallography.

5. Etch control numbers on each mount corresponding to original tags.

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BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 80 OF 88

LABORATORY REPORT-LS3 BOTTOM

Tesoro Exchanger E Failure Examination Protocol

6. Grind and polish the surface of each sample using a series of progressively finer grit papers and polishing wheels to obtain a surface suitable for examination under a metallurgical microscope with magnification at 50X, 100X, 200X, 500X, 1000X, and 1500X.

7. Examine each mount in the unetched condition under a Macroscope at 5 to 50X magnification.

8. Take photomicrographs and document any areas of interest. Areas of interest may include:
   - At or near the fracture origin
   - Fracture surfaces
   - Weld seams and HAZs
   - Anomalies
   - Areas with indications of defects or cracks identified through visual and/or non-destructive testing
   - Areas exhibiting "typical" microstructures of the base metal, weld metal, and heat-affected zone.

9. Examine each mount under a metallurgical microscope for a higher magnification view of any areas on the sample.

10. Photograph any areas of interest.

11. Surface etch each mount with a Nital 5% etch solution (for A515-70) and reexamine using both the macro and microscopes.

12. Mounts that contain alloys other than carbon steel may require different etch solutions or techniques.

13. Photograph and document all areas of interest.

14. Decide if any mounts are to be further examined using a Scanning Electron Microscope (SEM) either in the etched or unetched condition in the case of the mounts.

15. Photograph and document all areas of interest.

16. Perform EDS analysis of any scale or weld/base metal zone as required on the polished mount samples.

17. All weld joint cross section specimens should be given a series of microhardness tests starting in base metal and traveling through the weld HAZ and weld metal using a protocol to be provided by the lag. If there is a fracture surface in cross section in a mount, take a microhardness reading adjacent to the fracture surface. Then take microhardness on the mounted specimen that came from the other side of the particular fracture location and perform a microhardness adjacent to the fracture surface.

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BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 81 OF 88

LABORATORY REPORT-LS3 BOTTOM

Tesoro Exchanger E Failure Examination Protocol

During the course of examination metallographic samples should be examined to characterize and validate any issues specific to the failure such as:

- *Material specification, grade, and heat treatment*
- *Weld seam in area of fracture*
- *Weld seam in un-affected area*
- *Degradation of microstructure from service conditions*
- *Corrosion*
- *Indications of outside force damage*
- *Differences in microstructure based on op. temperature (which varies along the length of the shell)*

Mechanical Properties

Testing should be performed to determine the mechanical properties of the heat exchanger and any appurtenances. Mechanical properties of test specimens should not be taken from areas of the heat exchanger that have been plastically deformed as a result of the failure but shall include tests from all components within 2 feet of the fracture surfaces. These mechanical tests should at least include the following:

- Tensile Testing
- Charpy V-notch Impact Testing
- Chemical Analysis

1. Tensile Testing

Tensile test specimens should be prepared and tested in accordance with ASTM A370 (Mechanical Testing of Steel Products) for the shell base metal and weld seams to measure yield strength, ultimate tensile strength, and elongation. The shell base metal should, at a minimum be tested in the transverse direction, and weld seam specimens should be taken across the weld seam.

2. Charpy V-notch Impact Testing

Charpy V-notch (CVN) specimens should be prepared and tested in accordance with ASTM E23 (Notched Bar Impact Testing of Metallic Materials) to determine the toughness characteristics of in the transverse direction. Transition curves shall be produced with three (3) specimens at each temperature. Results from CVN testing may be reported in some or all of the following forms depending on the testing results:

- Upper-Shelf Energy (in ft-lbs and SI units)
- Lower-Shelf Energy (in ft-lbs and SI)
- Ductile-to-Brittle Transition Temperature (50% in °F) determined from graphical representation of testing results
- Fracture Appearance Transition Temperature (in °F) corresponding to 50 % shear

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PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 82 OF 88

LABORATORY REPORT-LS3 BOTTOM

Tesoro Exchanger E Failure Examination Protocol

- Lateral expansion (to measure notch toughness)

In some steels it may be difficult to measure percent shear because of "woody" fracture surfaces. In these cases it would be more appropriate to use lateral expansion and absorbed energy measurements to obtain a more accurate transition temperature.

Optional: If the charpy transition curves or fracture appearance displays any deviation from normal A515-70 material behavior, fracture mechanics testing should be performed to determine both static and dynamic fracture toughness. There are several standards and specimens that could be used and the appropriate test(s) should be agreed upon by all parties.

3. Chemical Analysis

Chemistry samples representative of all components within two feet of the fracture surfaces shall be taken and analyzed in accordance with ASTM Specification A20 / A20M compared to ASME Section II material specifications. Perform Leco analysis for carbon. A determination of carbon equivalent for each test shall be made.

Energy dispersive spectroscopy (EDS) and either x-ray diffraction (XRD) or x-ray photoelectron spectroscopy (XPS) analyses may be used to determine elements and compounds present in surface deposits that were collected during the visual examination if considered germane to the investigation. Other suitable test methods may also be used.

High Temperature Hot Hydrogen Testing (OPTIONAL)

If the initial analysis appears to indicate HTHA, then have small specimens removed and analyzed per the Materials Property Council (MPC) Moly-Hy Joint Industry Program protocol at University of Tennessee. This protocol involves cryo-cracking (cryogenic induced fracture after immersing in liquid nitrogen) after machining a small notch in the material (probably close to fracture surface) and then examining the fracture surface with SEM at high magnification (5,000 – 15,000X). Another part of the protocol is to measure the non-diffusible hydrogen to infer the CH_4 content.

Laboratory Results Reporting/Sample Retention

1. All laboratory tests, including photographs or sketches, should be documented and summarized in a complete lab report. No analysis or conclusions shall be provided.

2. The Laboratory Report should be signed by a P.E from the laboratory.

3. An electronic version (e.g. pdf, jpg) report shall be distributed by the third party conducting these examinations to all parties simultaneously within 72 hours of completion. No party shall have the opportunity to review any results in advance of the other parties. Any part requesting clarification or correction of anything in the report shall submit their request to all parties

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PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 83 OF 88

LABORATORY REPORT-LS3 BOTTOM

Tesoro Exchanger E Failure Examination Protocol

4. All samples that are cut, whether used or not and all samples analyzed shall be saved and stored in a manner that minimizes corrosion, by retaining in a container filled with desiccant or wrapping in plastic, etc.

5. The chain of custody form should be signed at all stages where the samples are handled within the lab or removed from the lab for any reason. Any markings/tags should be visible and retained.

James Darnell
Vice President, Health and Safety
Tesoro Companies

Signature — Date: 15 May 2010

Robert Parker
Compliance Manager
Division of Occupational Safety and Health

Signature — Date: 5-17-10

Robert J. Hall
Investigator-in-Charge
U.S. Chemical Safety Board

Signature — Date: 5-15-10

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PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 84 OF 88

LABORATORY REPORT-LS3 BOTTOM

Tesoro Exchanger E Failure Examination Protocol

Addendum-1: Additional Work for Part 1 of Protocol

Part 1. Field Visual and Nondestructive Examination

All field visual and nondestructive tests shall be appropriately documented indicating examinations performed, scope of examinations, test equipment used in examinations, results of testing and the qualifications of the examiner as appropriate. All reports will be signed and dated by the examiner(s). Data reports shall be distributed by the third party conducting these examinations to all parties simultaneously. No party shall have the opportunity to review any data results in advance of the other parties. Any party requesting clarification or correction of anything in the report shall submit their request to all parties. Data generated as a result of the execution of this protocol will be shared with all parties to the agreement simultaneously. Visual inspection reports, analysis or conclusion will not be shared.

Field Visual and Nondestructive Examination

Current work in the section:

3. Field Crack Detection Ultrasonic Testing

   Conduct ultrasonic examination adjacent to all fracture surfaces using techniques suitable for stress corrosion cracking or other potential service cracking mechanisms. Phased array is preferred for macro-cracking and AUBT is preferred for fissuring due to HTHA.

Additional work recommended for this section:

Exchanger E: Perform phased array ultrasonic inspection on all full penetration welds located between the point of failure and the shell to tubesheet flange weld with the exception of nozzle welds. Data reports for the additional work will be provided to all parties simultaneously within 24 hours of completion of the inspection.

James Darnell
Vice President, Health and Safety
Tesoro Companies

Signature — Date: 19 MAY 2010

Robert Parker
Compliance Manager
Division of Occupational Safety and Health

Signature FOR BOB PARKER — Date: 5-20-10

Robert J. Hall
Investigator-in-Charge
U.S. Chemical Safety Board

Signature — Date: 5-20-10

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BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 85 OF 88

LABORATORY REPORT-LS3 BOTTOM

Tesoro Exchanger E Failure Examination Protocol
Addendum – 3: Revisions/Lab Clarifications

This Addendum-3 to Exchanger E Failure Examination Protocol sets forth revisions to the original Inspection Protocol document.

1. The requirement to take caliper readings for thickness in the middle of the plate is deleted.

2. The requirement to take macro hardness readings on each plate will only apply to test plates supplied to the laboratory and not plates which remain attached to the heat exchanger.

3. The WFMT and PT shall be applied only to the ID surfaces in the vicinity of the fractures.

4. The fracture surfaces will be documented but the identification of the initiation point, the fracture mode and the interpretation of the fracture will be the responsibility of the signatory parties or their technical representatives.

5. Dimensional documentation of all fracture surfaces will be by inclusion of a scale in all photos.

6. The laboratory, acting as a referee laboratory, will be supplied the locations to take the test samples and the type of test and test parameters to be performed at each location on the test sample, i.e. magnification, hardness load/test method. The signatory parties or their technical representatives that are present in the laboratory at the time shall make those decisions and give that information directly to the laboratory. Comments from other technical experts will be considered and factored into the signatory parties or their technical representative's decisions but all decisions on protocol or samples shall remain as decisions of the signatory parties or their representatives.

7. The requirement for mounting samples on each side of any fractured weld /area will apply where convenient from the samples already cut out as of this date and will not apply to material still attached to the heat exchanger.

8. Since the fracture surfaces were not coated with any lacquer the requirement to cut each fracture sample in half, keeping one as is and cleaning only one half will not apply.

9. The acceptable cleaning methods for the SEM evaluation of the fracture surfaces are cathodic cleaning in mild alkaline or acid solution or alternatively Alconox and inhibited acid cycles. There is always a risk that extensive field corrosion has consumed the damage profile. One sample will be cleaned and evaluated in the SEM at any given time.

10. All magnifications listed in the test protocol are for equipment capability and the exact magnification and area of interest for all photomicrographs will be will be the responsibility of the signatory parties or their technical representatives present in the lab at the time.

11. A 2 % Nital etch solution is acceptable for use.

12. Because of all the deformation in the vicinity of the fractures the requirement to take the mechanical test specimens within 2 feet of the fractures is deleted.

BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 86 OF 88

LABORATORY REPORT-LS3 BOTTOM

Tesoro Exchanger E Failure Examination Protocol
Addendum – 3: Revisions/Lab Clarifications

13. The tensile and impact testing in the transverse direction is interpreted as transverse to the original plate rolling direction.

14. The requirement to simultaneously distribute the report within 72 hours of completion is deleted and the parties agree to a level 2 report, which contains descriptive text and captioned photos with the resultant assembly time being a function of the amount of data obtained but is typically 2-3 weeks. Any signatory party, its representative, or other party permitted to witness the laboratory testing may have the opportunity to see the data so long as there is no disruption to lab work but no one can have or make any copies of the laboratory work product prior to the Laboratory issuing the test report to the signatory parties.

James Darnell
Vice President, Health and Safety
Tesoro Companies

Signature 7-6-10 Date

Robert Parker
Compliance Manager
Division of Occupational Safety and Health

Signature 7-6-10 Date

Robert J. Hall
Investigator-In-Charge
U.S. Chemical Safety Board

Signature 7-6-10 Date

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PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 87 OF 88

LABORATORY REPORT-LS3 BOTTOM

Attachment2

TEST EQUIPMENT and PROCEDURES

TEST	INSTRUMENT & MODEL	CALIBRATION DUE DATE	BETA NO.	LSS PROCEDURE	
				NUMBER & TITLE	REV NO.
Failure Analysis	N/A	N/A	N/A	B0069 Failure Analysis	0
Chemical Analysis	Thermo ARL 3460 Optical Emission Spectrometer	Performance check prior to use	BETA 665	B0068 ARL 3460 Optical Emission Spectrometer Analysis	2
SEM/EDS	Amray Scanning Electron Microscope, Model: 1830T4, S/N: 18321002, with IXRF Energy Dispersive X-ray Spectrometer	*	BETA 386 BETA 755	B0064	*
SEM/EDS	Camscan Scanning Electron Microscope, Model: MV2300U, S/N: US0187039/VG0540181U with IXRF Energy Dispersive X-ray Spectrometer and x-ray Optics/AAT Detector	Sept. 3, 2010	BETA 602 BETA 756	B0047 CAMSCAN/IXRF SEM/EDS System	8
Rockwell Hardness	Wilson Rockwell 524T Hardness Tester, Model 83259910	Performance check prior to use	BETA 400	D0027 Wilson Rockwell Model 524T Hardness Tester	5
Rockwell Hardness	NewAge NI300-C Hardness Tester, Model 8150 S/N 951480	Performance check prior to use	BETA 897	D0052	*
Knoop/Vickers Hardness	Buehler Micromet II Digital Microhardness Tester, Model B-D58222	Performance check prior to use	BETA 401	D0028	*
Knoop/Vickers Hardness by Image Analysis	Buehler Micromet II Digital Microhardness Tester, Model B-D58222 with Buehler OmniMet Analysis System Program Version 9.0 Rev 3	Performance check prior to use	BETA 401 BETA 977	D0028	*
Field Hardness	Proceq Equotip Hardness Tester, Model 25-819	Performance check prior to use	BETA 428	D0016	*
Knoop/Vickers, Semi-Macro Vickers Hardness	Instron Tukon 2100B Hardness Tester, Model T2100BR1942	Performance check prior to use	BETA 2006	D0068 Instron Tukon 2100B Hardness Tester	0
Reagent Preparation^	N/A	N/A	N/A	C0005 Metallurgical Reagents ▲	1
Linear Measurements by Optical Methods	LECO PMG-3 Inverted Metallograph with Buehler OmniMet Analysis System Program Version 9.0 Rev 3	*	BETA 419 BETA 977	D0065	*
Average Grain Size	LECO PMG-3 Inverted Metallograph with Buehler OmniMet Analysis System Program Version 9.0 Rev 3	*	BETA 419 BETA 977	D0066	*
Dimensional	Starrett Micrometer Number 222	9/09/2010	BETA DLC-C-094	NA	NA
Dimensional	Starrett Vernier S/N 120 A	*	BETA 2005	NA	NA
Dimensional	Mitutoyo Digital Micrometer 342-361	*	BETA 884	NA	NA
Mass	Mettler AE-100 S/N C-31383	*	BETA 113	NA	NA
Mass	Sartorius LP-6200S	*	MLL 0009	NA	NA

*Denotes procedures or instruments not used in this report
▲ Etchant 5-1 2% Nital

BETA LAB NO.M10198- LS3 BOTTOM	TESORO REFINING AND MARKETING COMPANY ANACORTES REFINERY 10200 W. MARCH POINT ROAD T91WA4428 ANACORTES, WA 98221	CUSTOMER P.O. NO.: 4501667904
PART: 6600-E HEAT EXCHANGER LS 3 BOTTOM PART 14		DATE: JULY 30, 2010
		PAGE 88 OF 88

LABORATORY REPORT-LS3 BOTTOM

Attachment 3 TEAM Industrial Service NDE Report

TEAM® Industrial Services, Inc.
Providing Quality NDE and Heat Treating Services to Industries Worldwide

5901 Harper Road
Solon, OH 44139
(440) 498-9494

MT-FORM-05 Lab and Field Technique Sheets

MAGNETIC PARTICLE EXAMINATION TECHNIQUE SHEET

Client: FIRST ENERGY
Facility: 6670 BETA DRIVE, MAYFIELD VILLAGE OHIO
Client PO# 45342412
Project Description: WET MAGNETIC PARTICAL TESTING

Technician: MICHAEL BUCKLEY
Date: 6-15-10
Technique # 1
Job # 13103168

Item Data

☑ Weld ☐ Non-Weld ☐ Structural ☑ Initial Inspection ☐ Repair ☐ Final Inspection
☐ Other:

# of Parts: 60 Base Metal: S/A Filler Metal: S/A
Part Description: WELDS ON PLATES

Inspection Data

☐ Dry ☑ Wet ☐ Visible ☑ Fluorescent ☐ Circular ☑ Longitudinal 14AM (Color) 109612K (Batch / Lot #)

☑ AC ☐ DC ☐ Prods ☑ Yoke Prod Spacing: 3"-5" Amperage: FIXED

Equipment Type/Model: CONTOUR PROBE B 306 Serial No.: 17867
Cal. Due Date: 12-1-10 Examination Preparation Method: AS RECEIVED
Black Light S/N: 1693129 Intensity: N/A (uw/cm²) Light Meter: N/A (Type) / N/A (Serial No.)

Demagnetization Required? ☐ Yes ☑ No Method:

Inspection Results

Procedure: MT. ASME. N2 Rev. Acceptance Criteria: ASME SECTION III

Inspection Results Summary: INSPECTED 6 PLATES WITH WELDS. 3 PLATE PIECES WERE FOUND TO BE NONCONFORMING DUE TO LINEAR INDICATIONS THOSE PART NUMBERS ARE AS FOLLOWED LS3-01 BOTTOM LS3-01 TOP AND CS4-01. 3 PLATE PIECES WERE FOUND TO BE CONFORMING PART NUMBERS ARE AS FOLLOWED LS1-01 CS2-01 TEE AND PART# LS2-01 CS3-01 WENT TO 2 PIECES ANY INDICATION MARKED ON PIECES

☐ Accept ☐ Reject ☐ See Attachments

Reported by: [signature] Reviewed by: _____

Supervisor: _____ Contact: _____

NOTICE: This examination report reflects the actual NDT procedure which was conducted by TEAM personnel. Submission of this report is for informational purposes and does not reflect any guarantee of the part, inspection procedures, or standards and is subject to the limitations of each.

MT-FORM-05 Lab and Field Technique Sheet