ANNEX A

LASER SCAN IMAGES AND PHOTOGRAPHS OF CORROSION FEATURES TESTED IN THE CURRENT TEST PROGRAM

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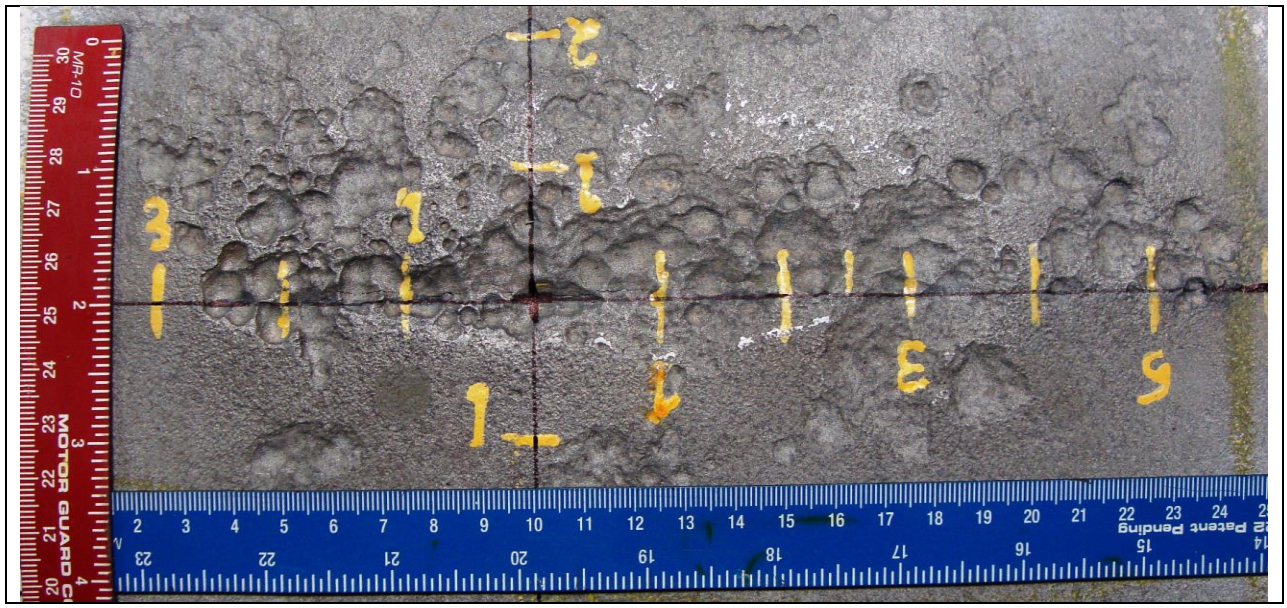


Figure 1: Test #16 – 42% Corrosion photograph

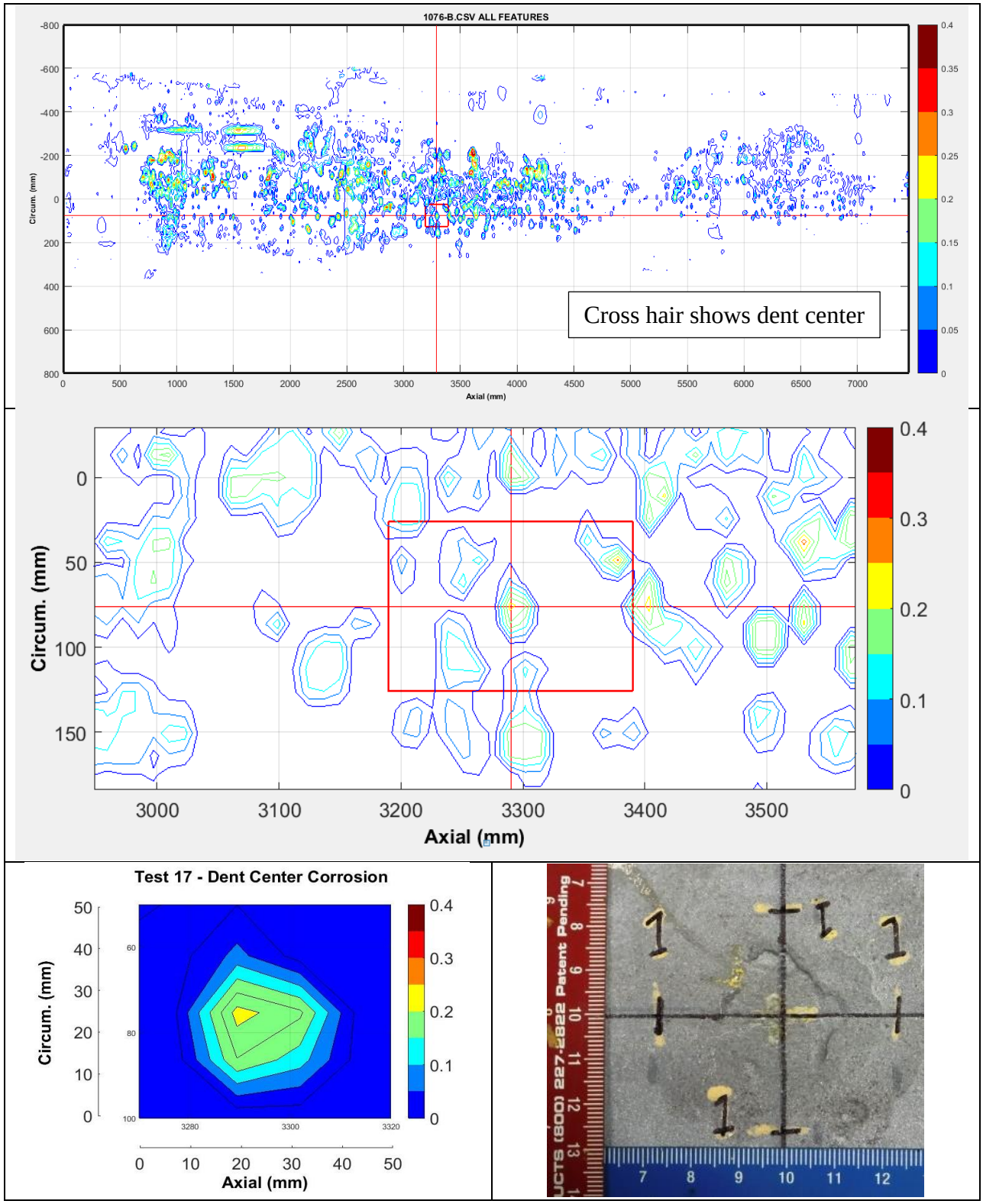


Figure 2: Test #17 – 17% Corrosion scan and photograph

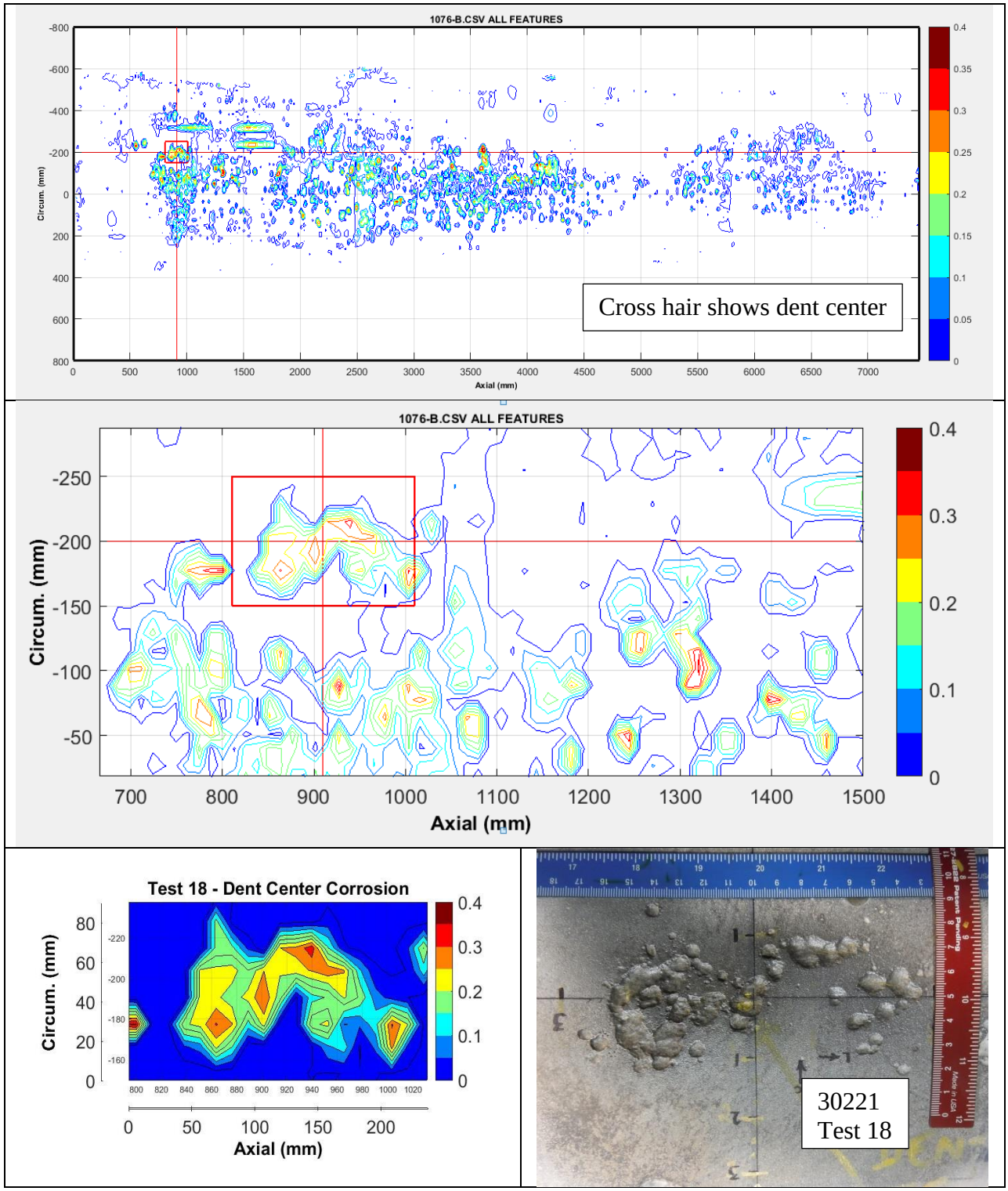


Figure 3: Test #18 – 30% Corrosion scan and photograph

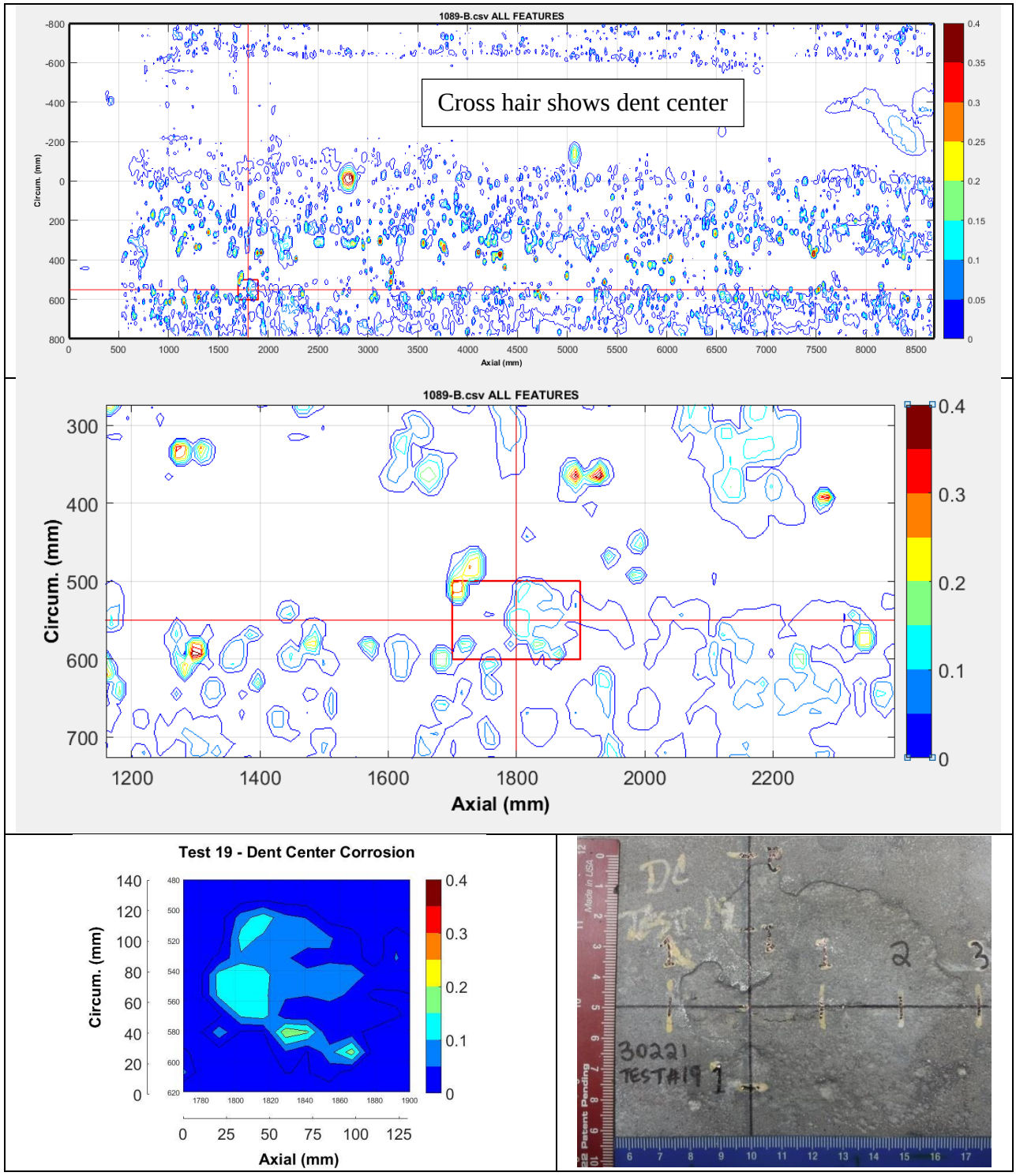
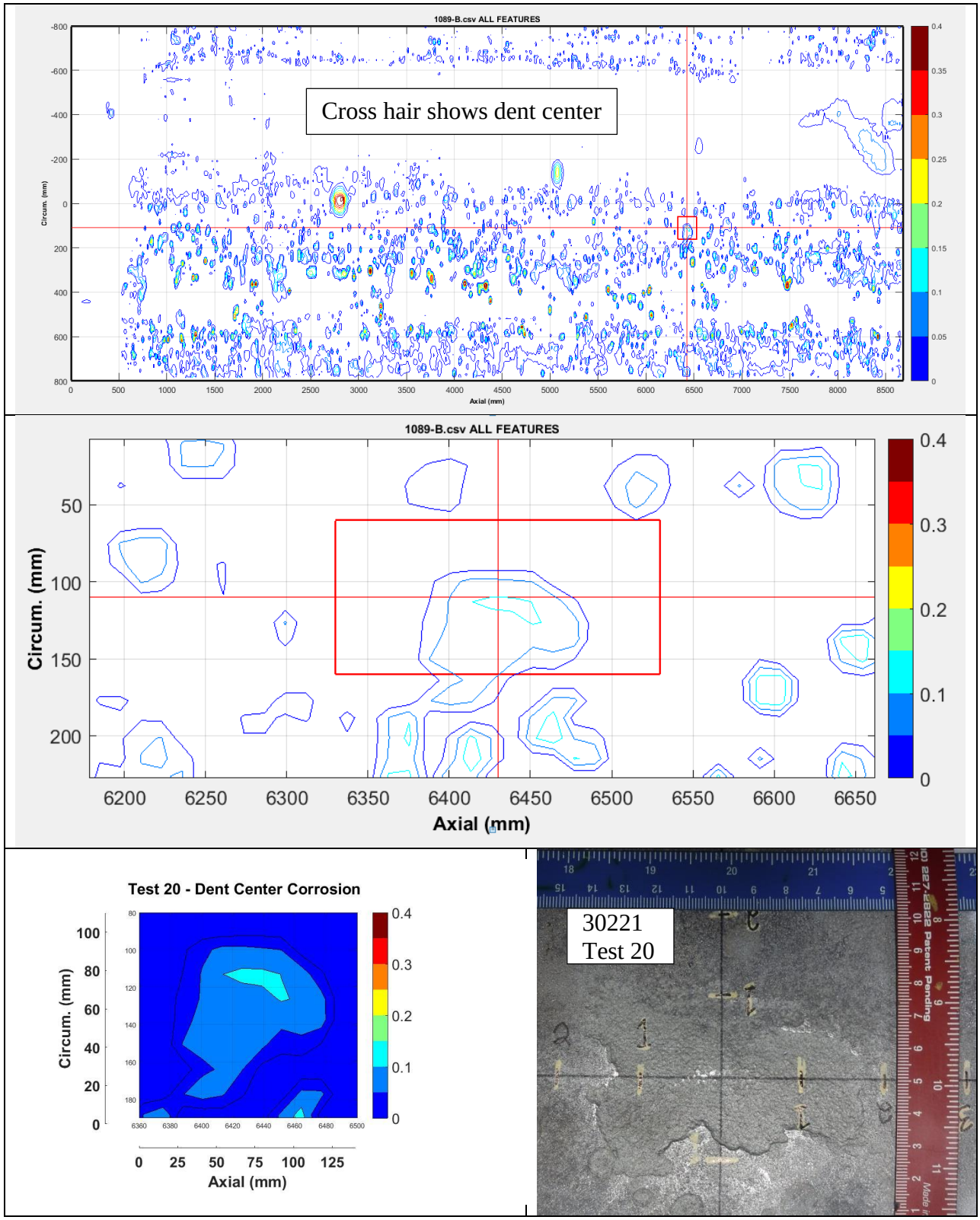


Figure 4: Test #19 – 16% Corrosion scan and photograph



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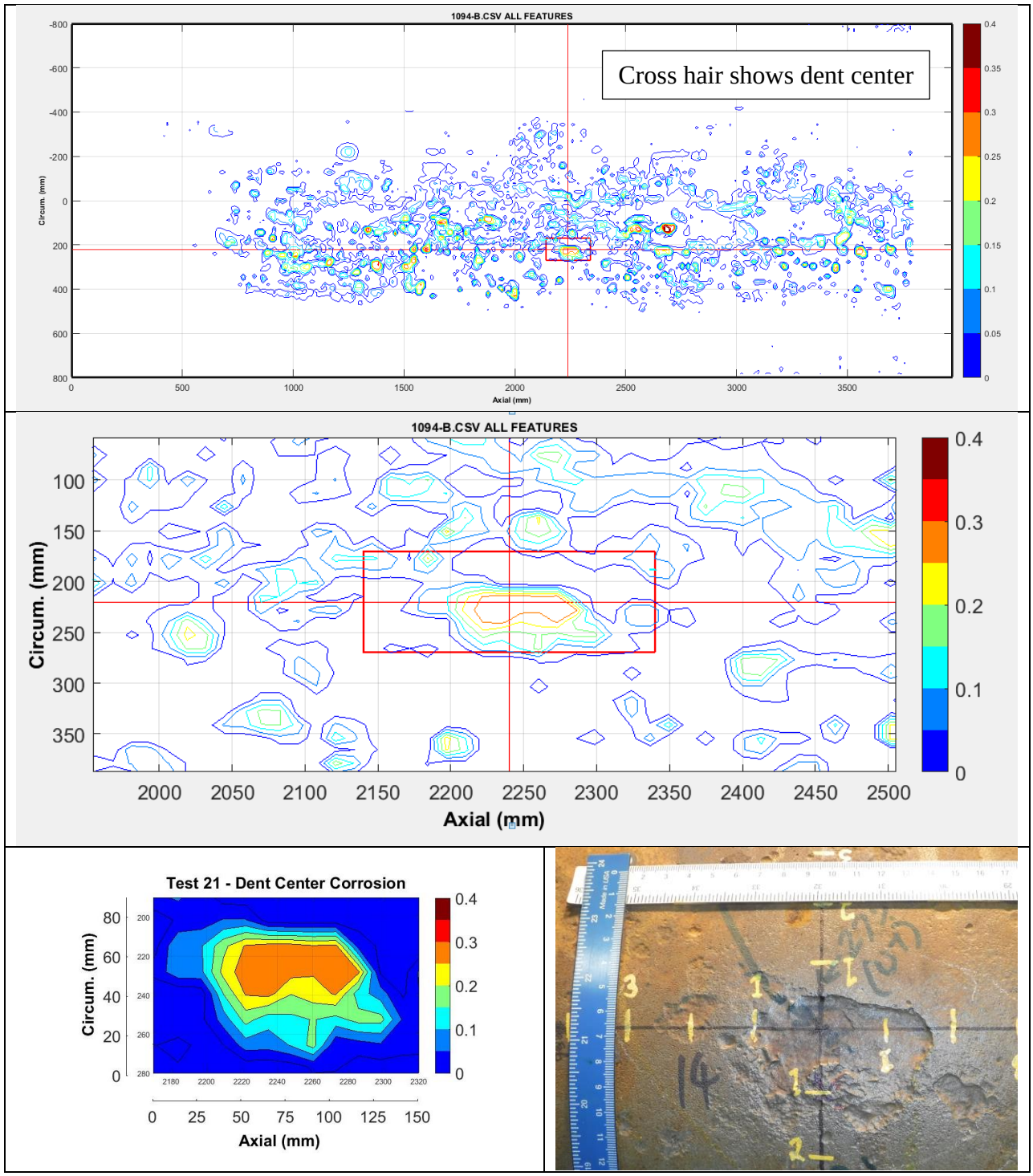
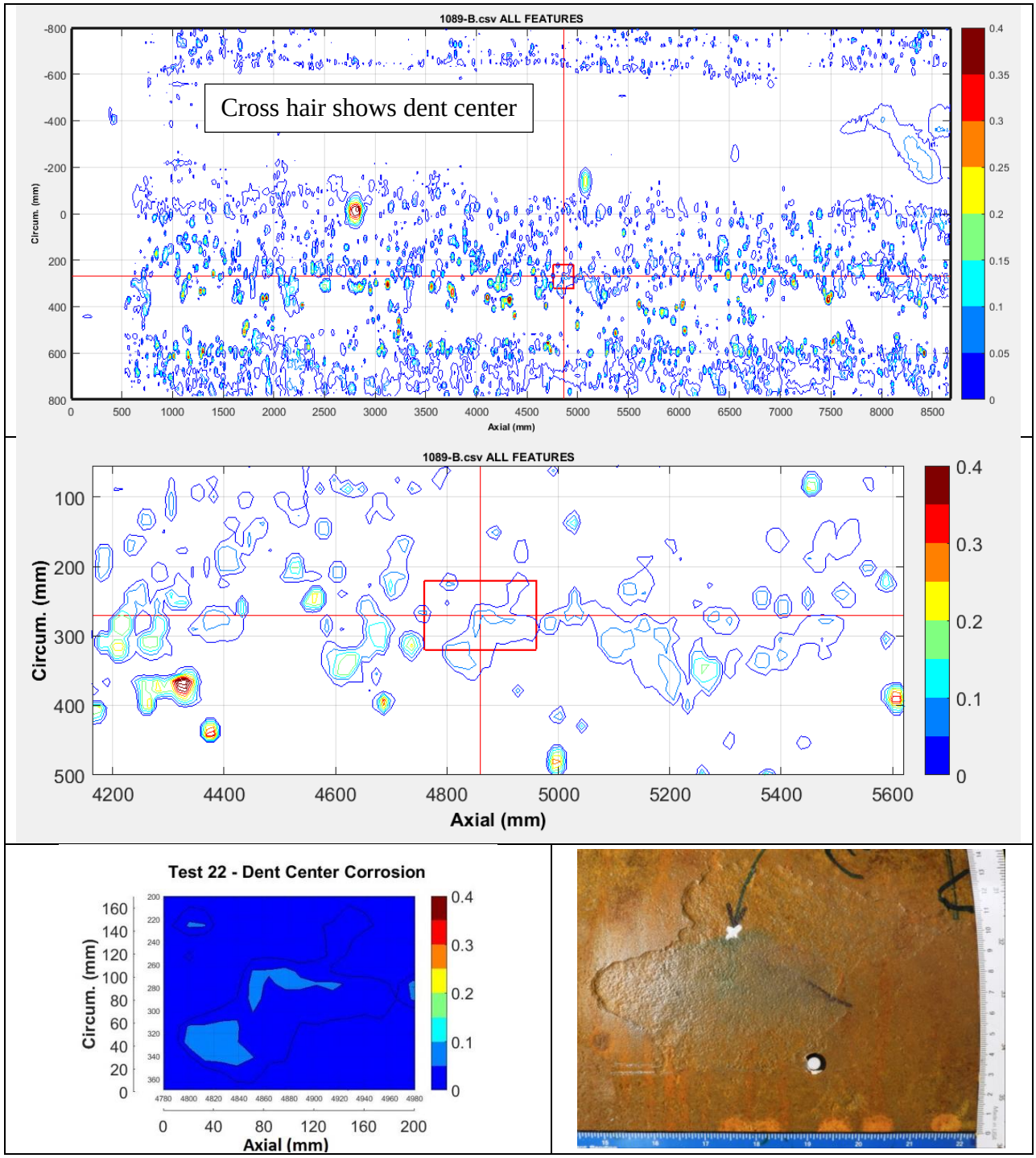


Figure 6: Test #21 – 26% Corrosion scan and photograph



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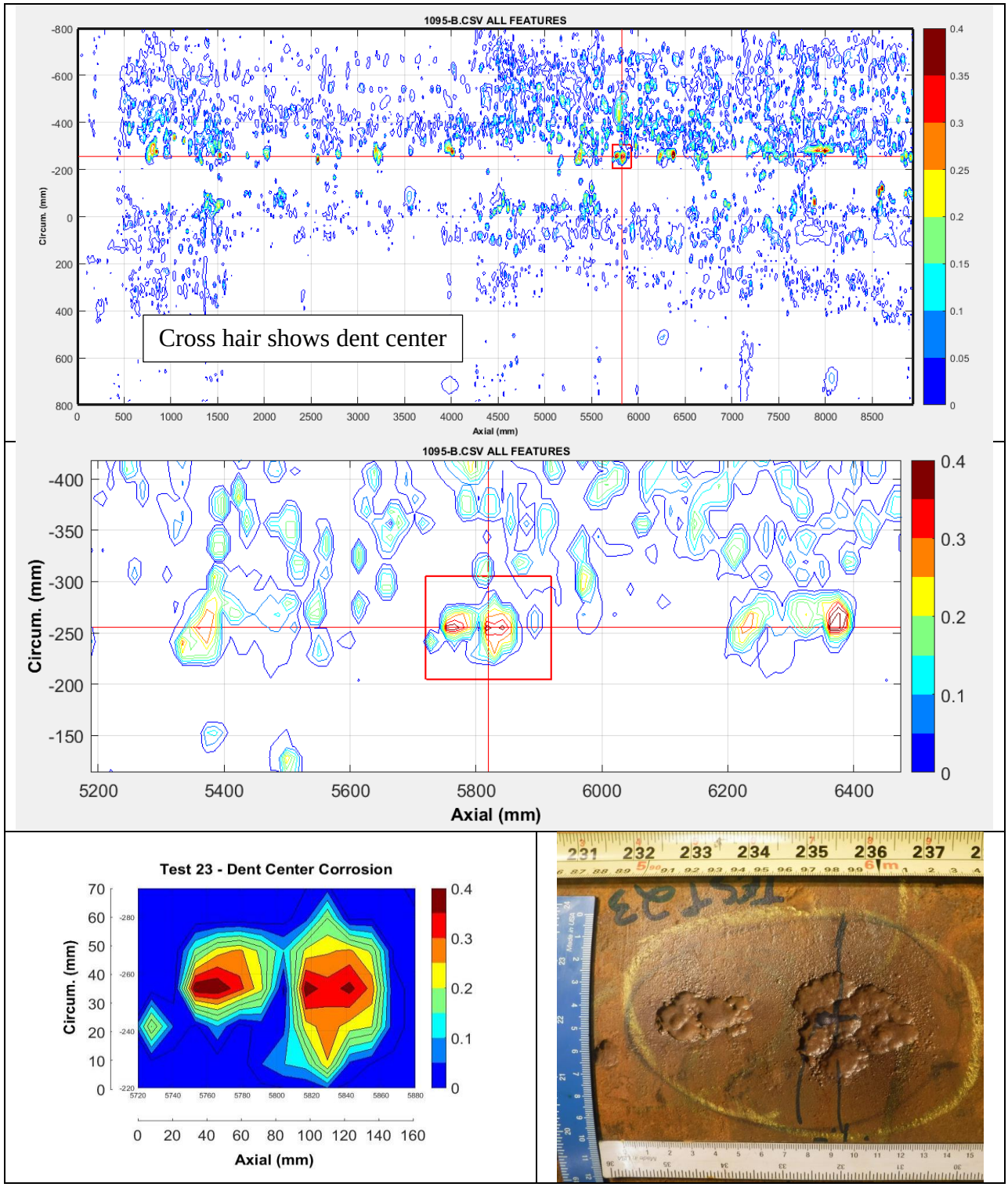
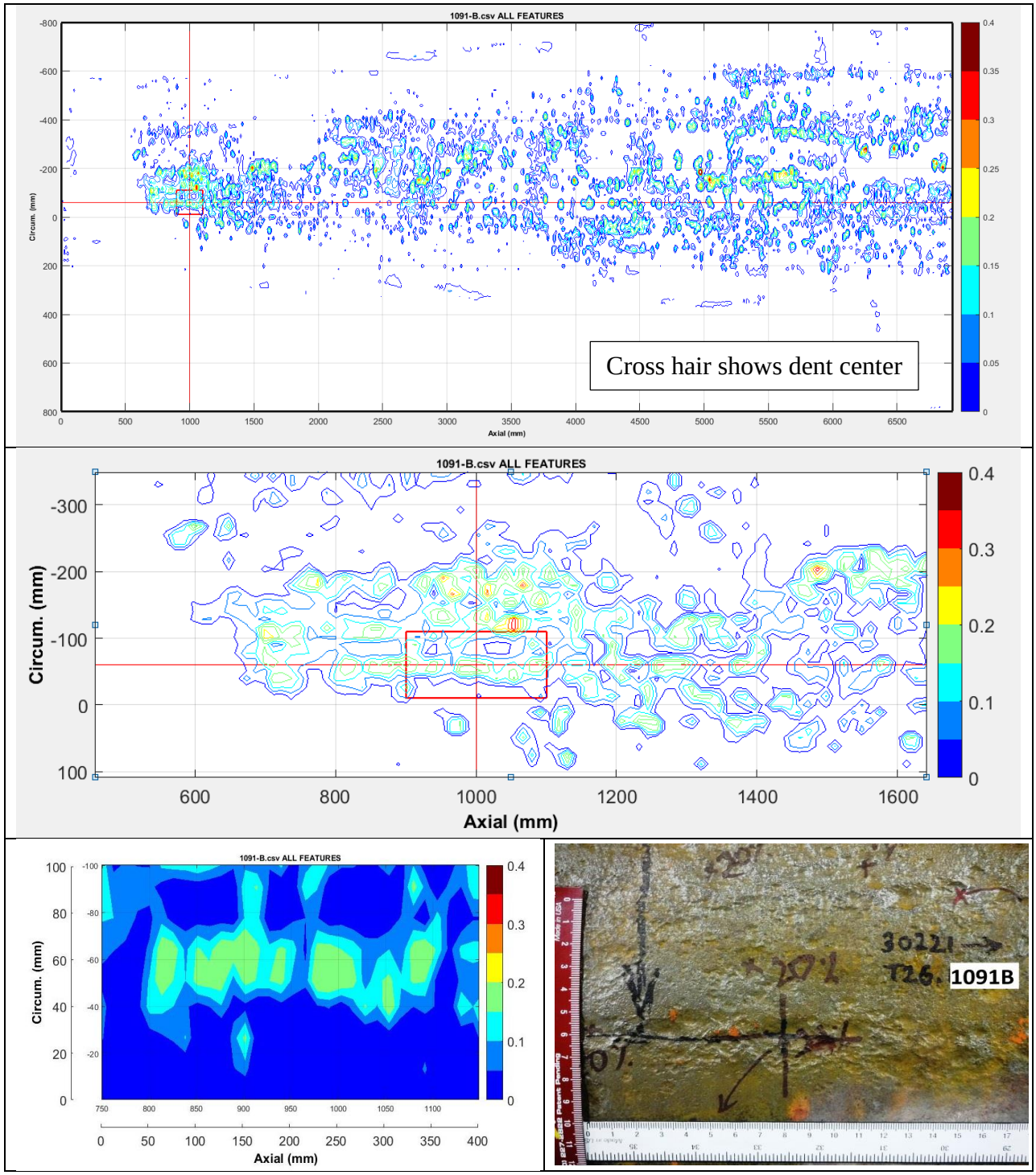


Figure 8: Test #23 – 39% Corrosion scan and photograph



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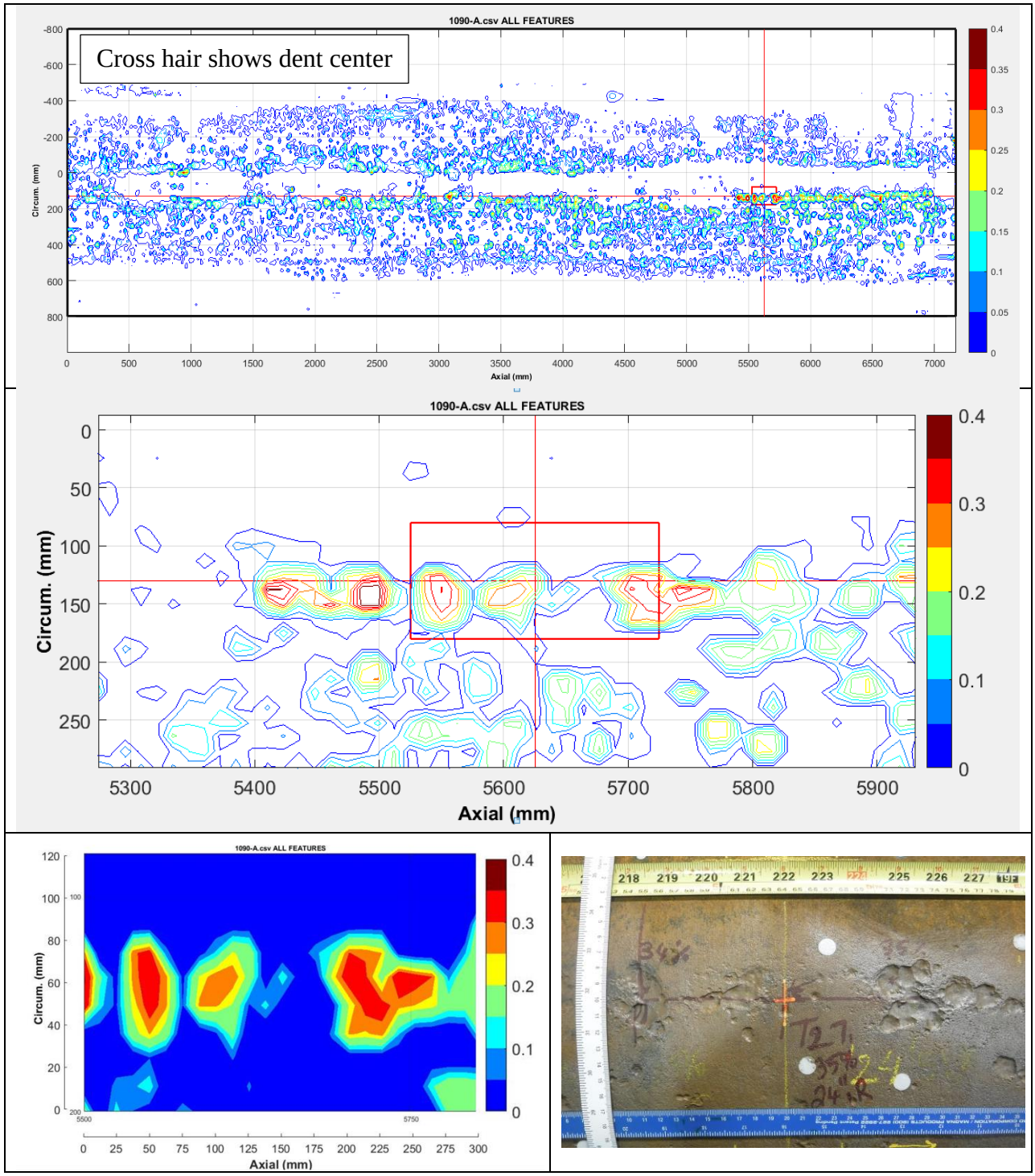

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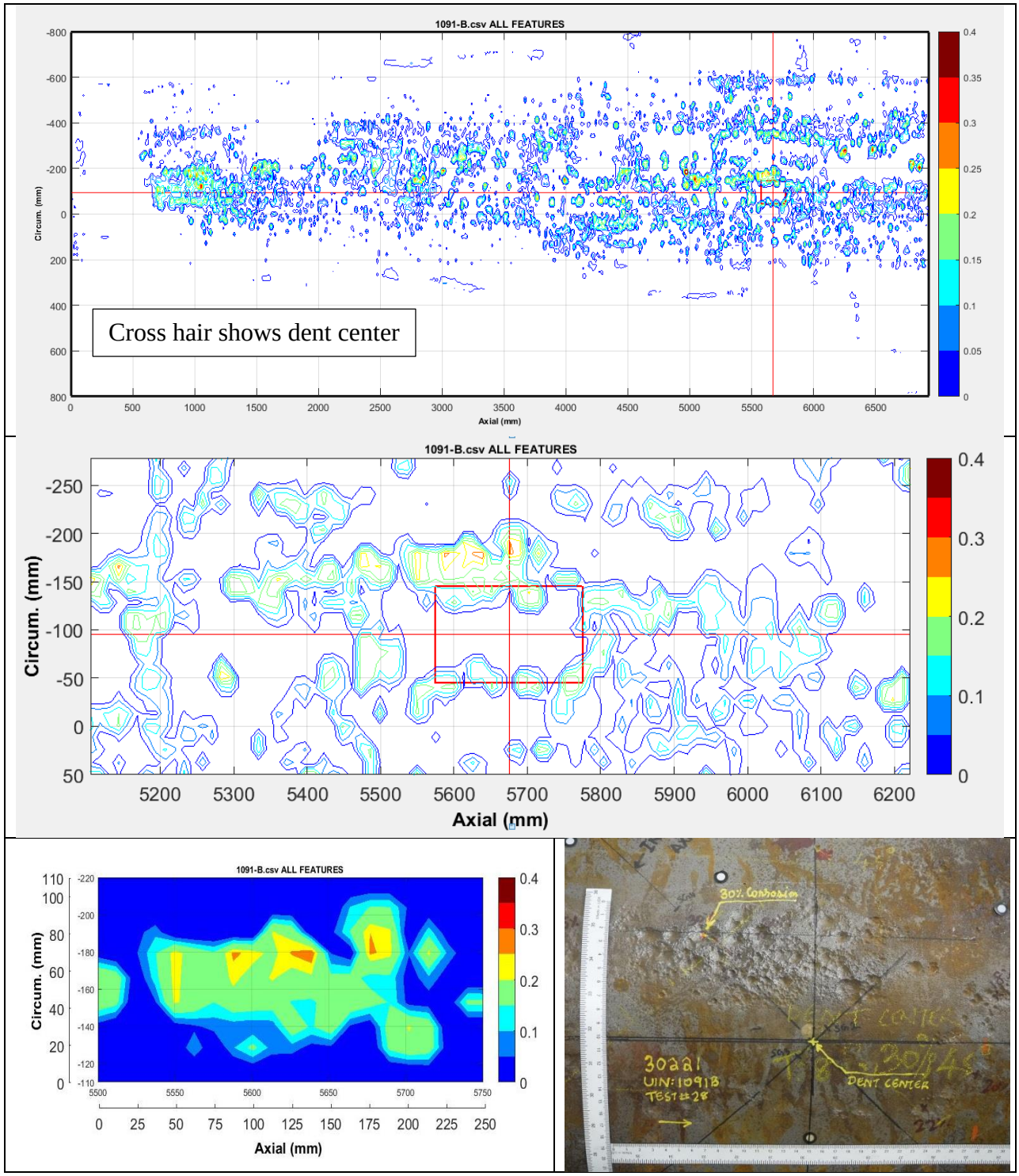

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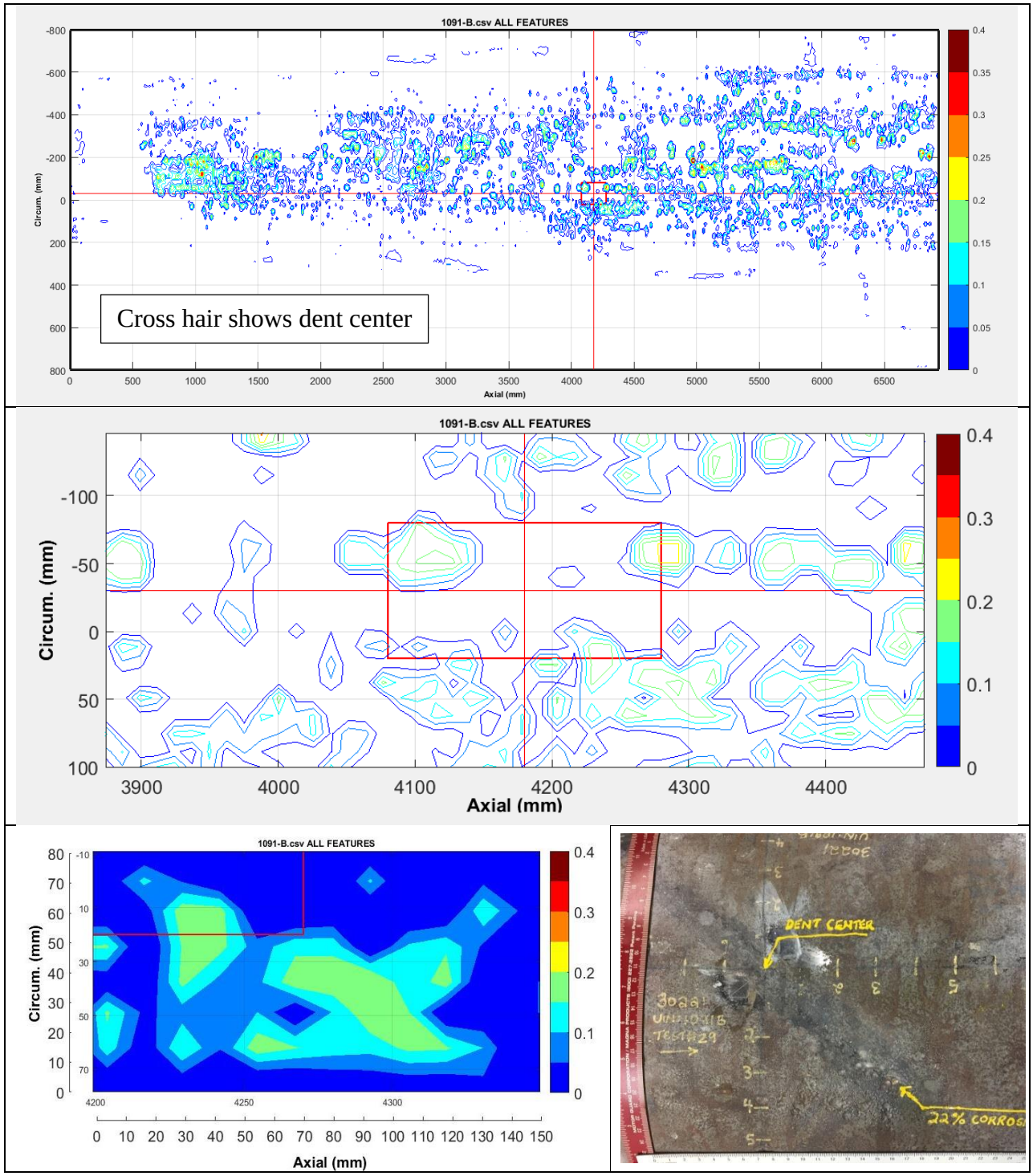

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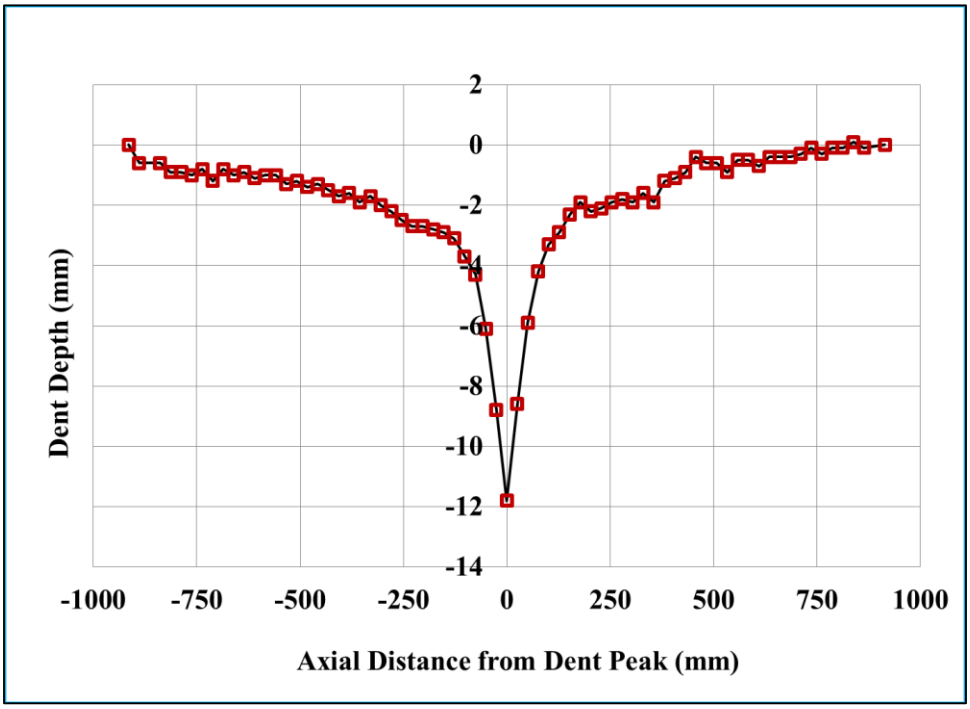

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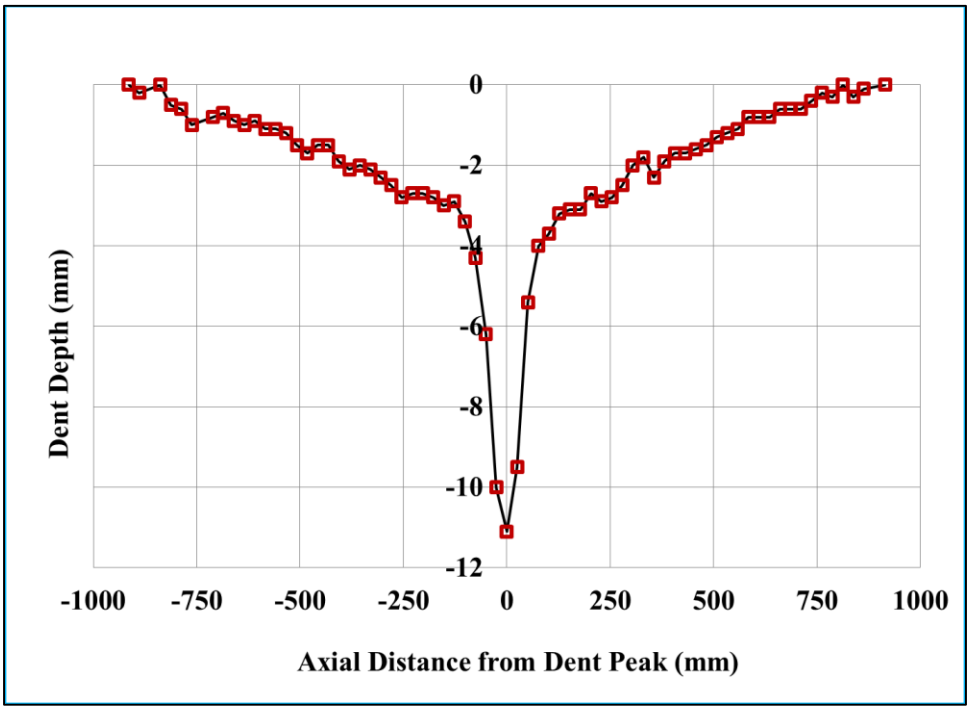


Figure 2: Test # 2 - Dent Axial Profile at the end of test

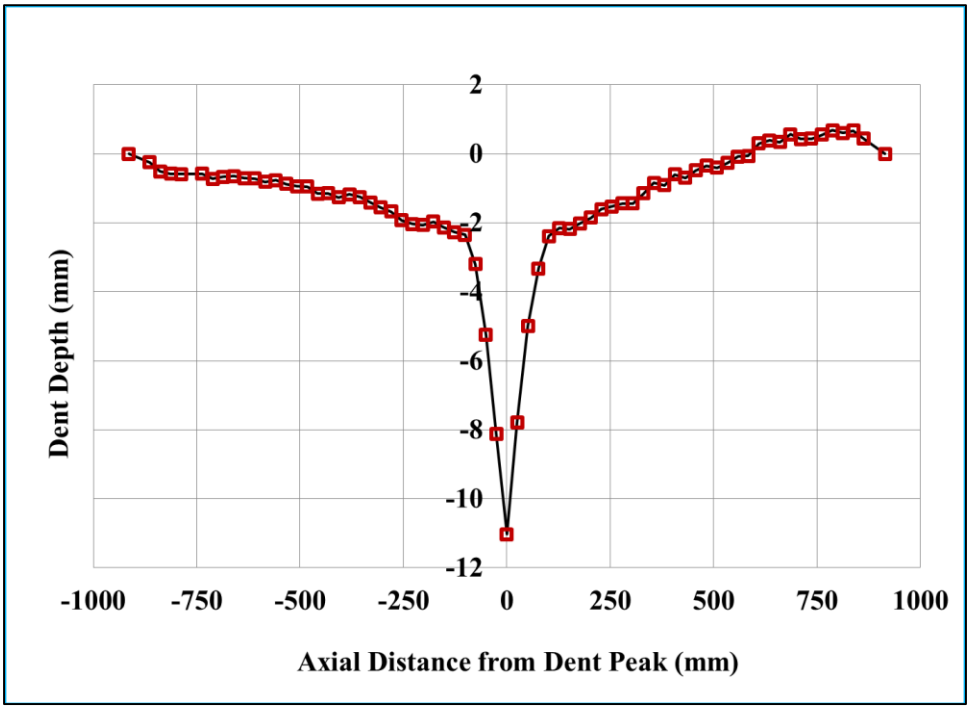


Figure 3: Test # 5 - Dent Axial Profile at the end of test

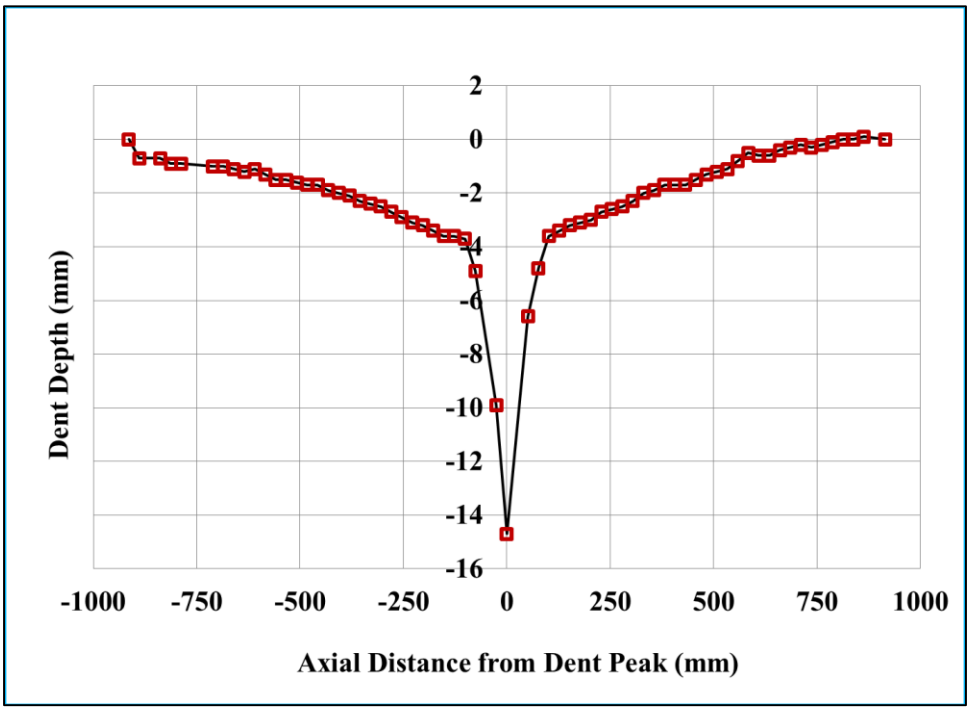


Figure 4: Test # 6 - Dent Axial Profile at the end of test

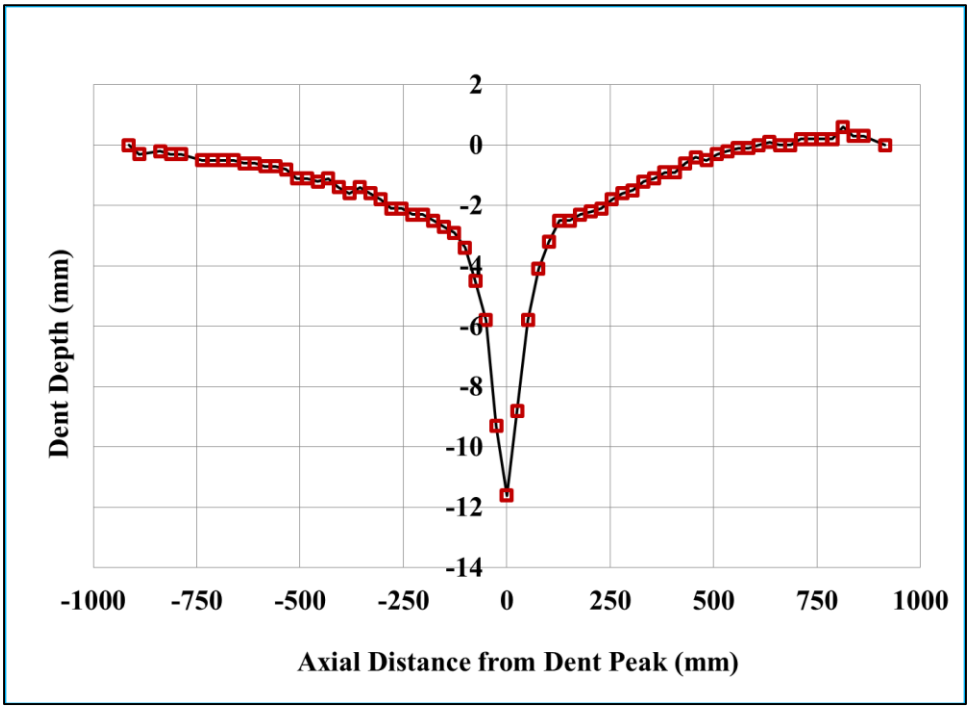


Figure 5: Test # 9 - Dent Axial Profile at the end of test

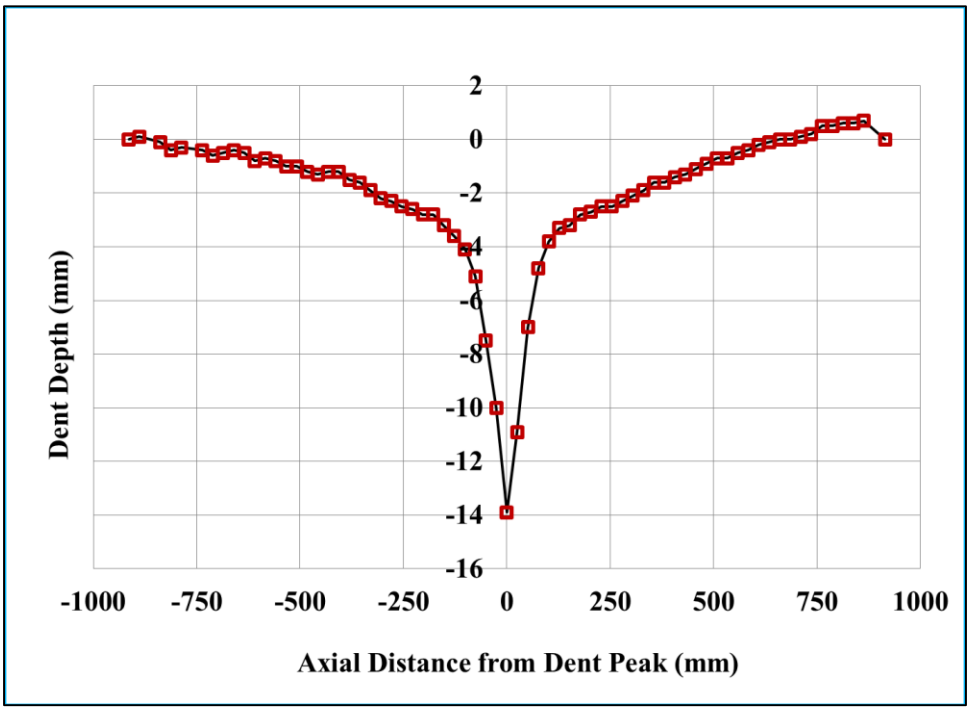
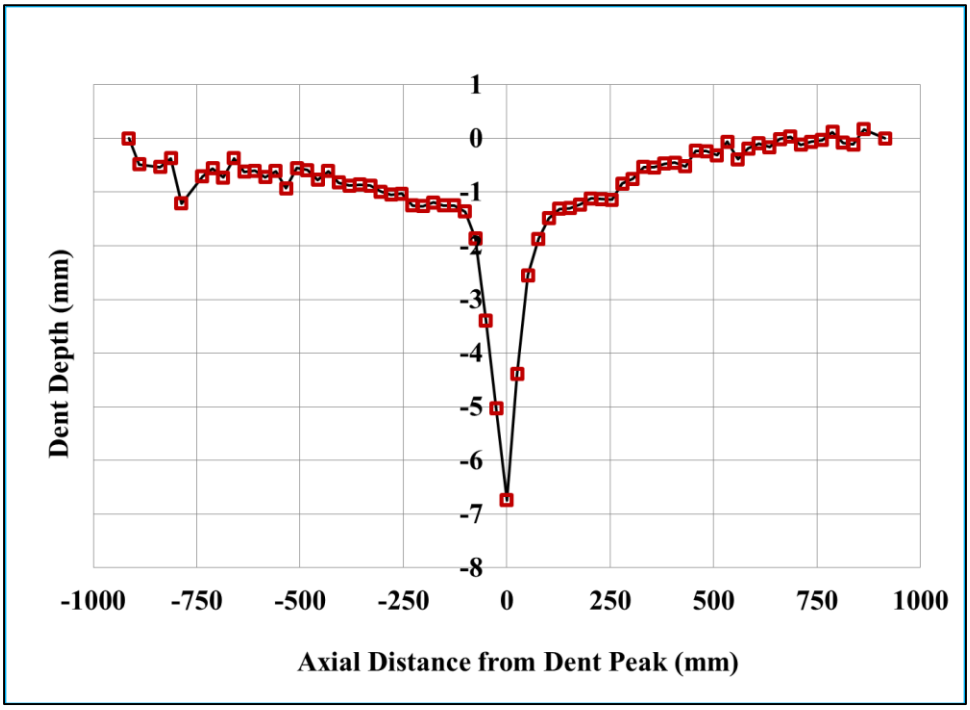


Figure 6: Test # 10 - Dent Axial Profile at the end of test



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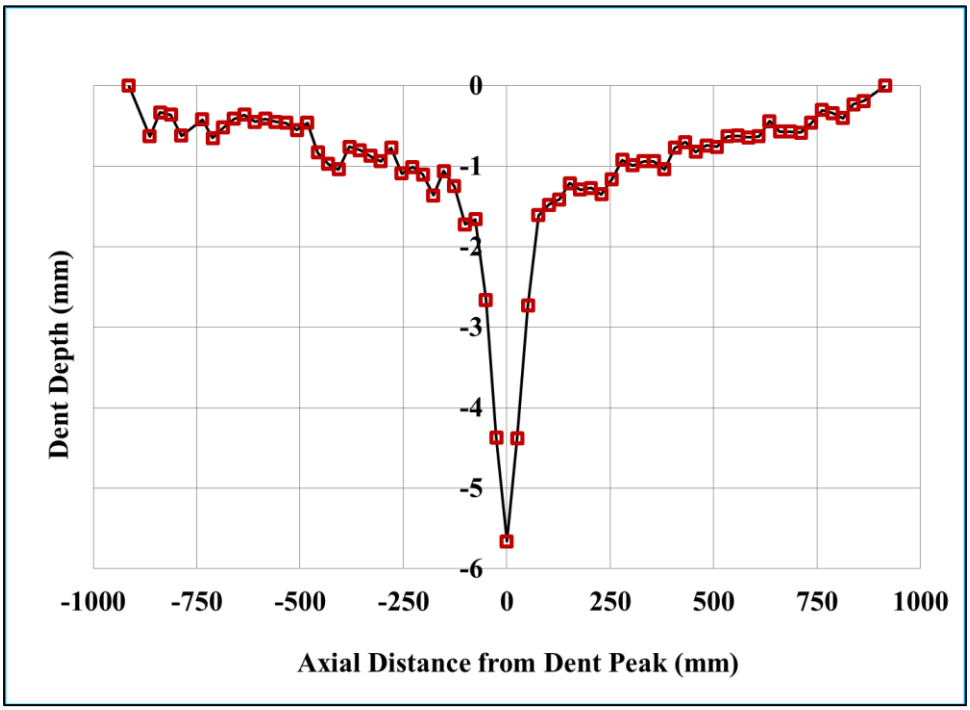

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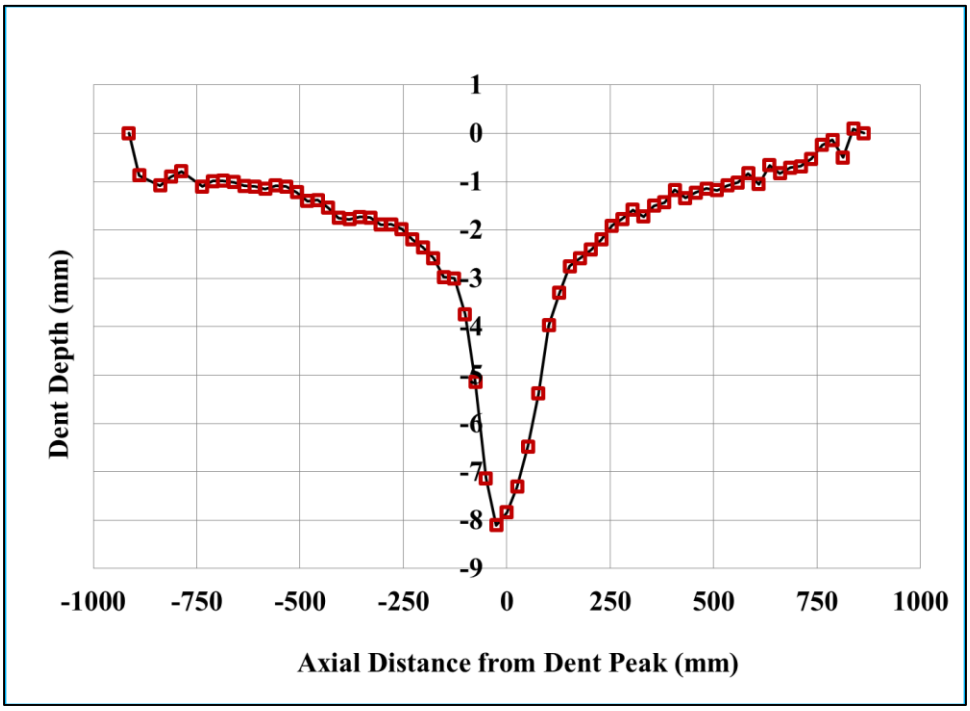

Figure 9: Test # 14 - Dent Axial Profile at the end of test

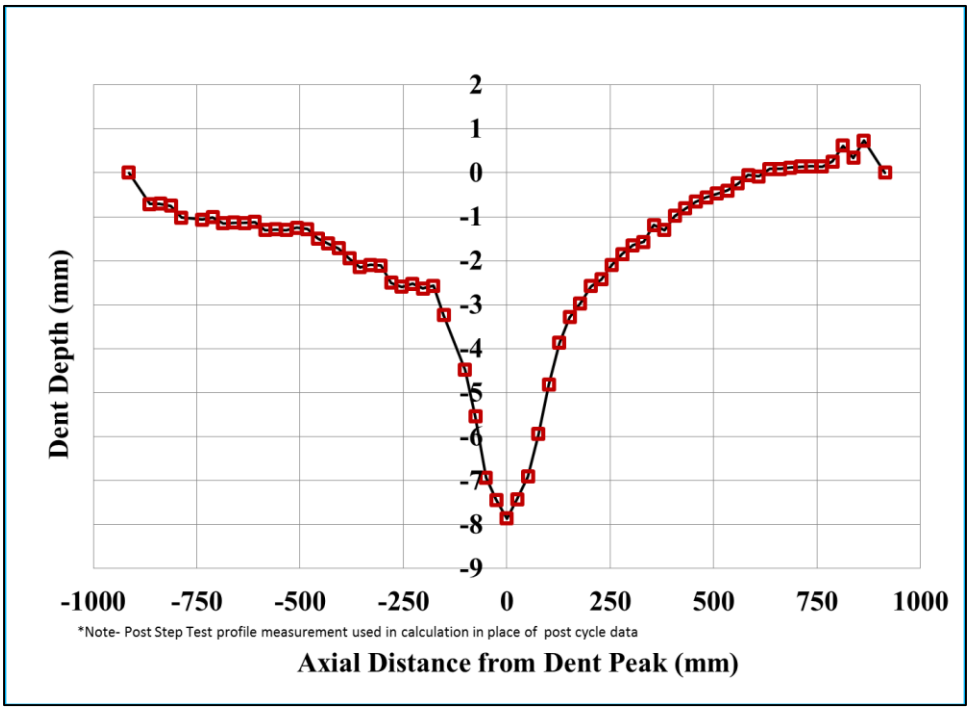

Figure 10: Test # 15 - Dent Axial Profile at the end of test

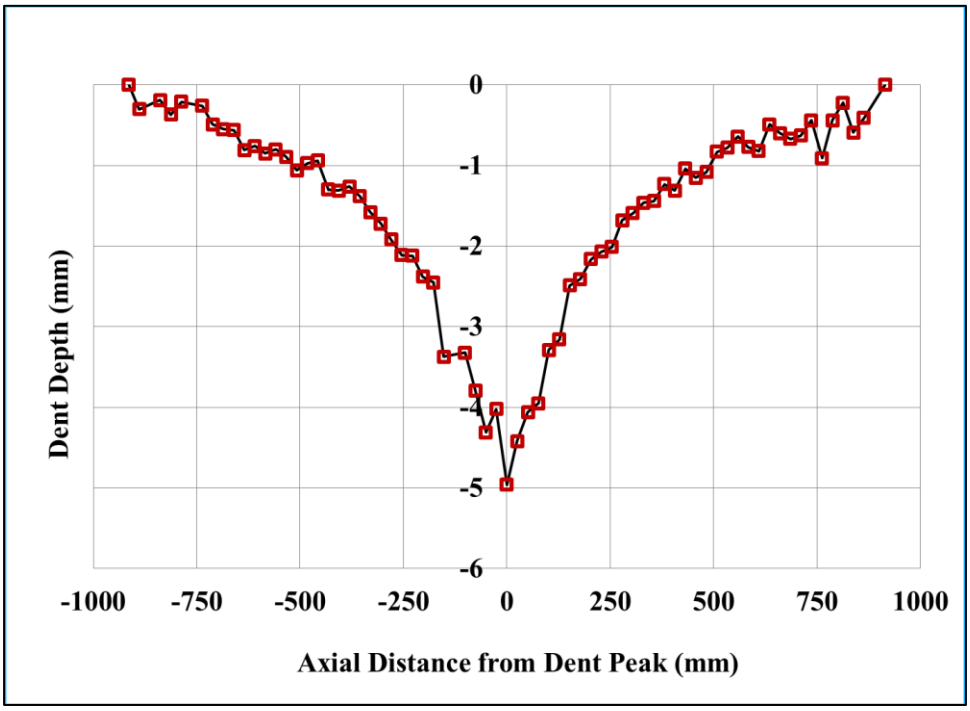

Figure 11: Test # 16 - Dent Axial Profile at the end of test

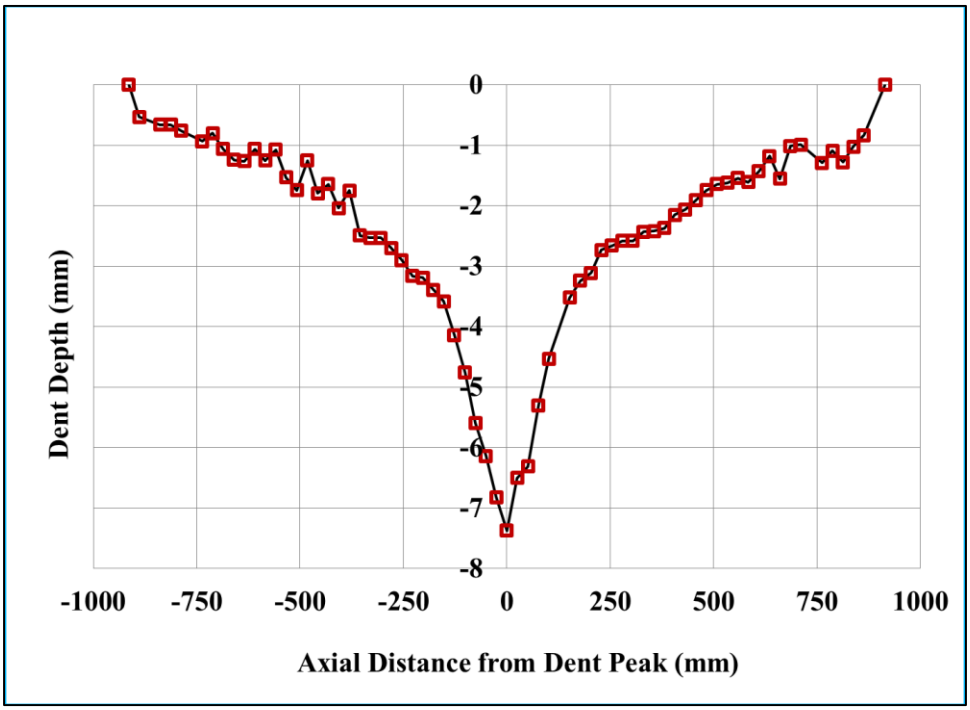

Figure 12: Test # 17 - Dent Axial Profile at the end of test

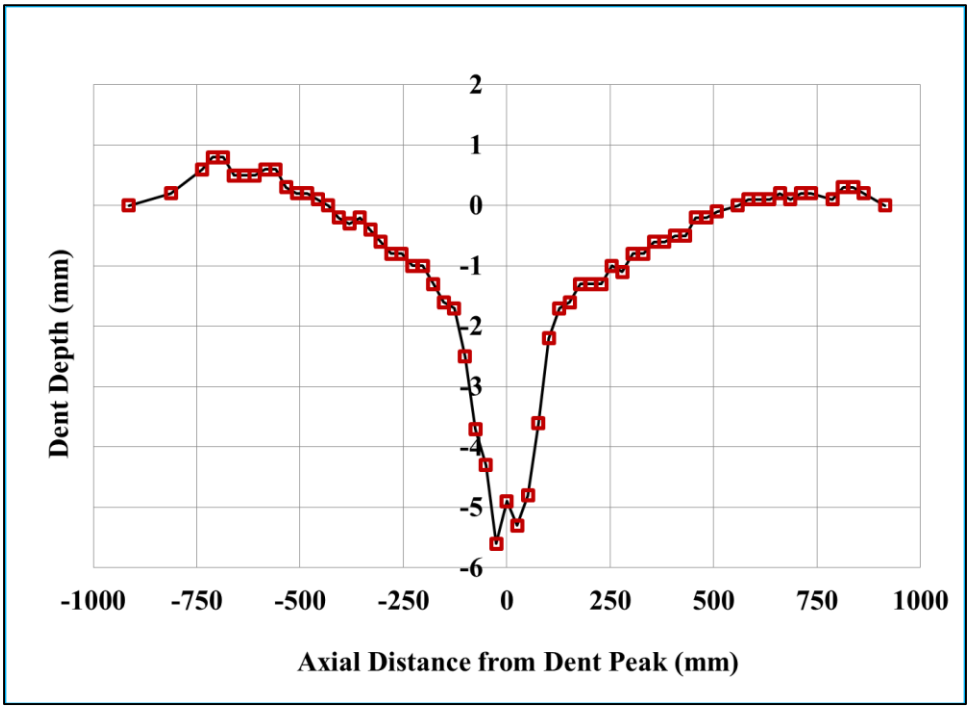

Figure 13: Test # 18 - Dent Axial Profile at the end of test

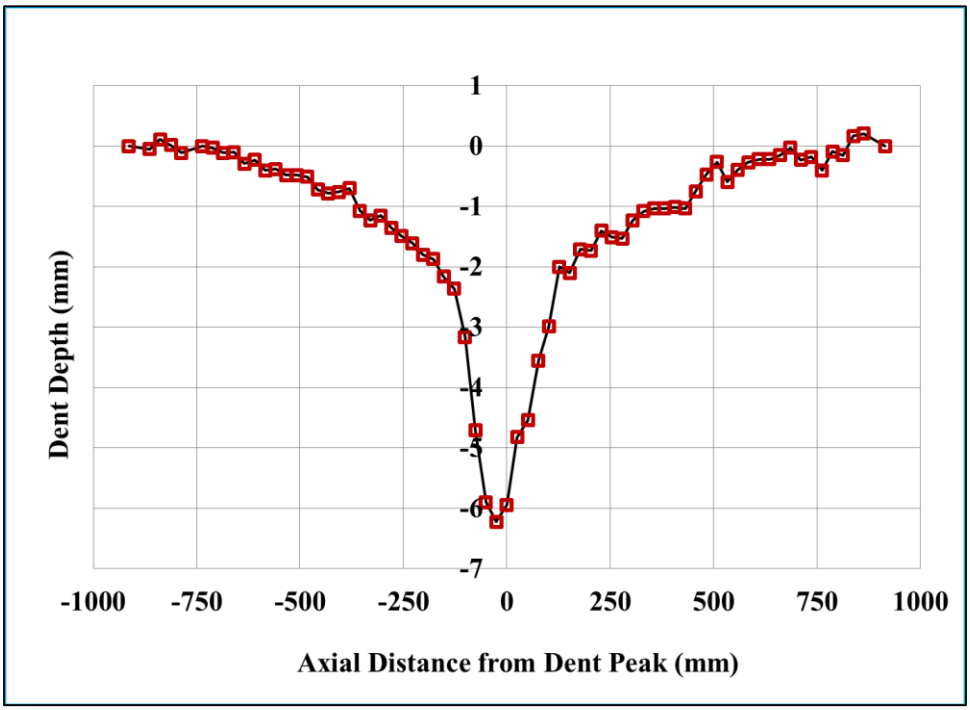

Figure 14: Test # 19 - Dent Axial Profile at the end of test

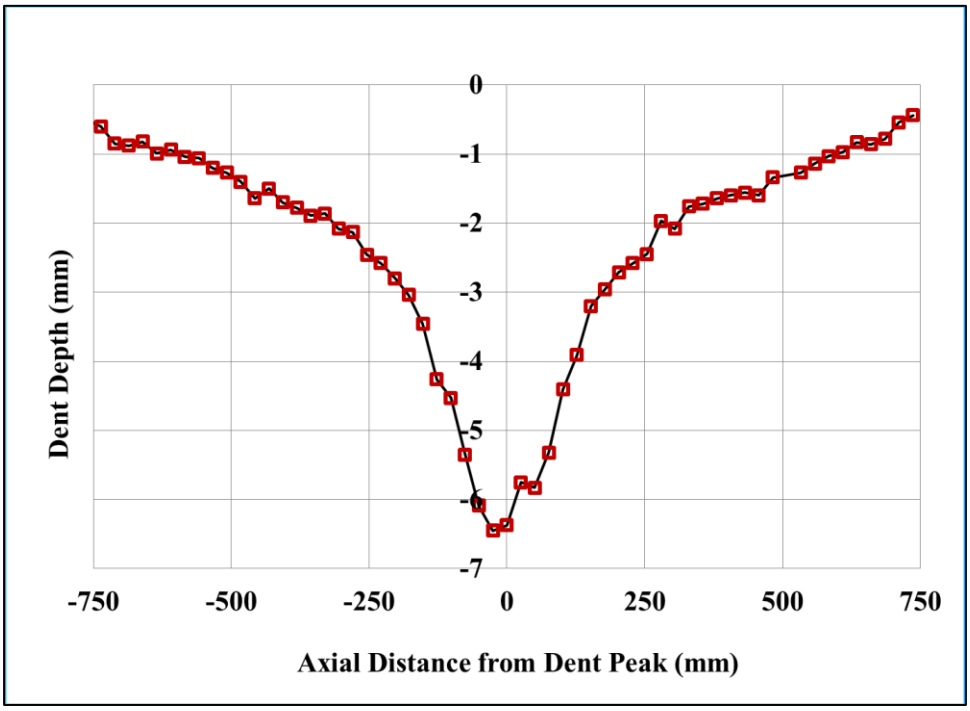

Figure 15: Test # 20 - Dent Axial Profile at the end of test

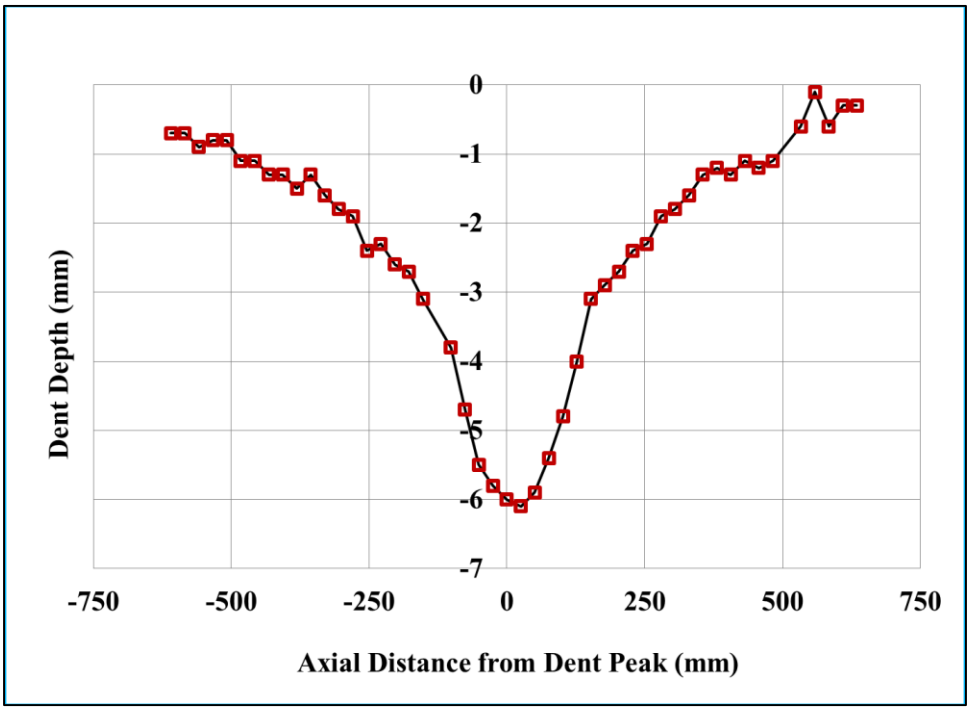

Figure 16: Test # 21 - Dent Axial Profile at the end of test

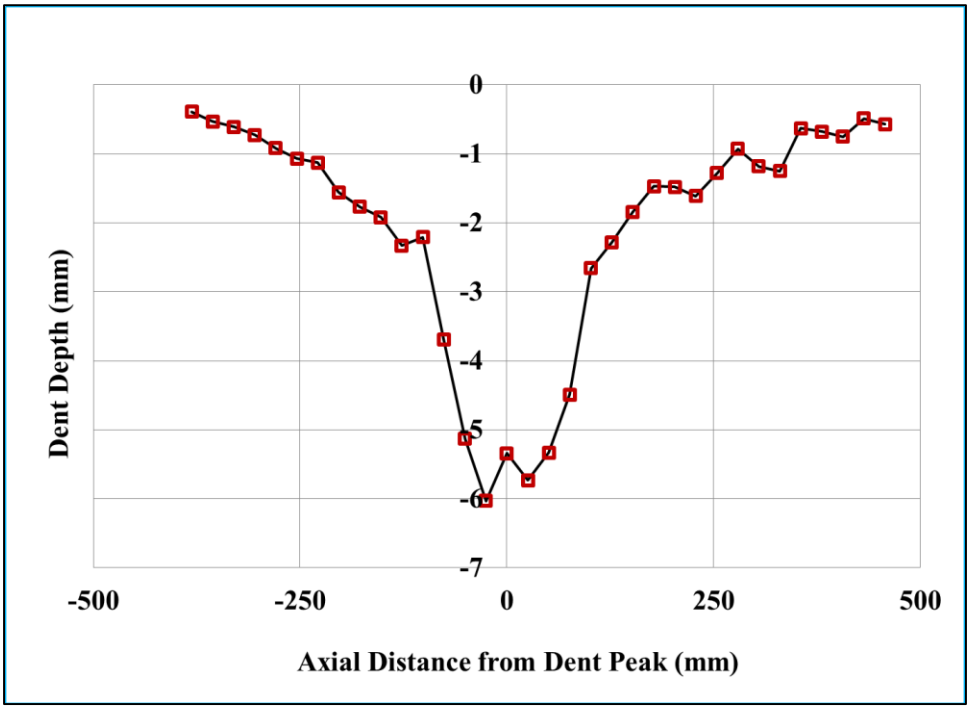

Figure 17: Test # 22 - Dent Axial Profile at the end of test

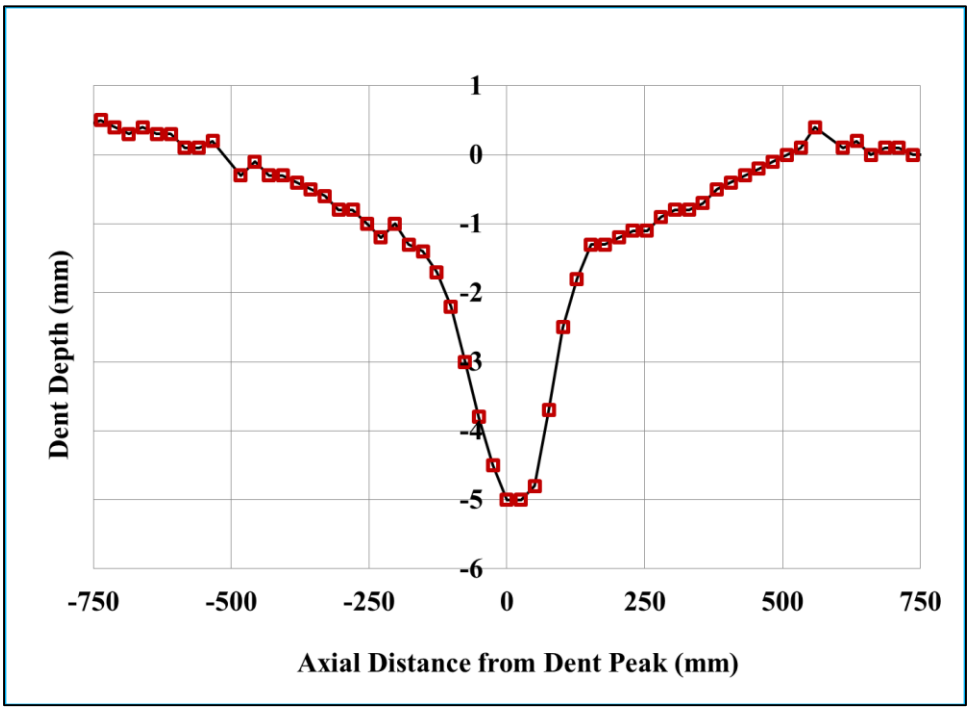

Figure 18: Test # 23 - Dent Axial Profile at the end of test

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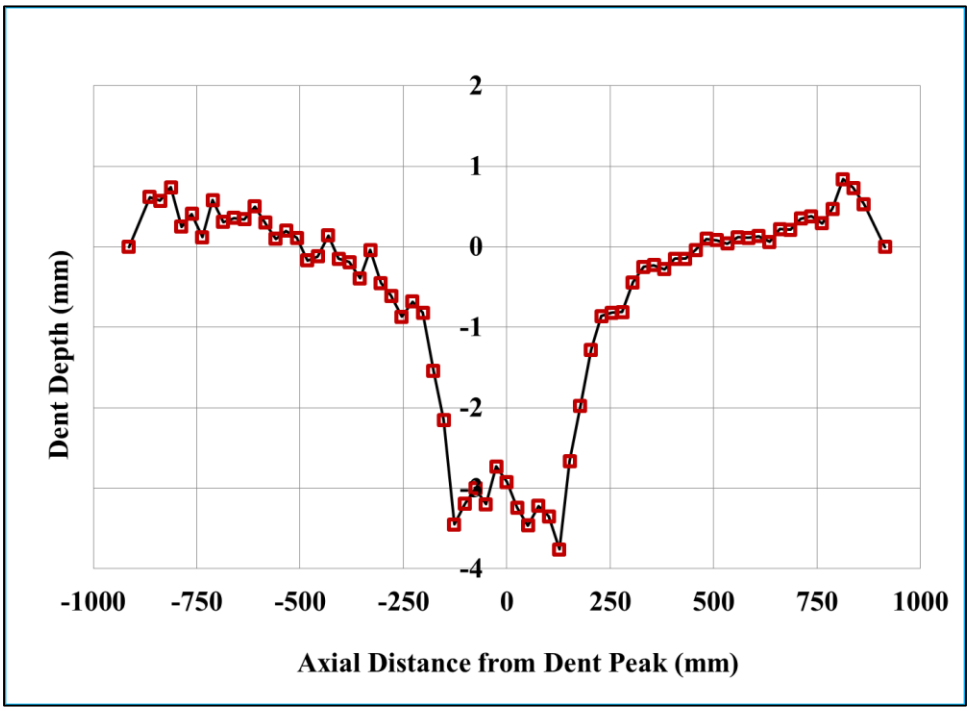

Figure 1: Test # 3 - Dent Axial Profile at the end of test after indenter removal

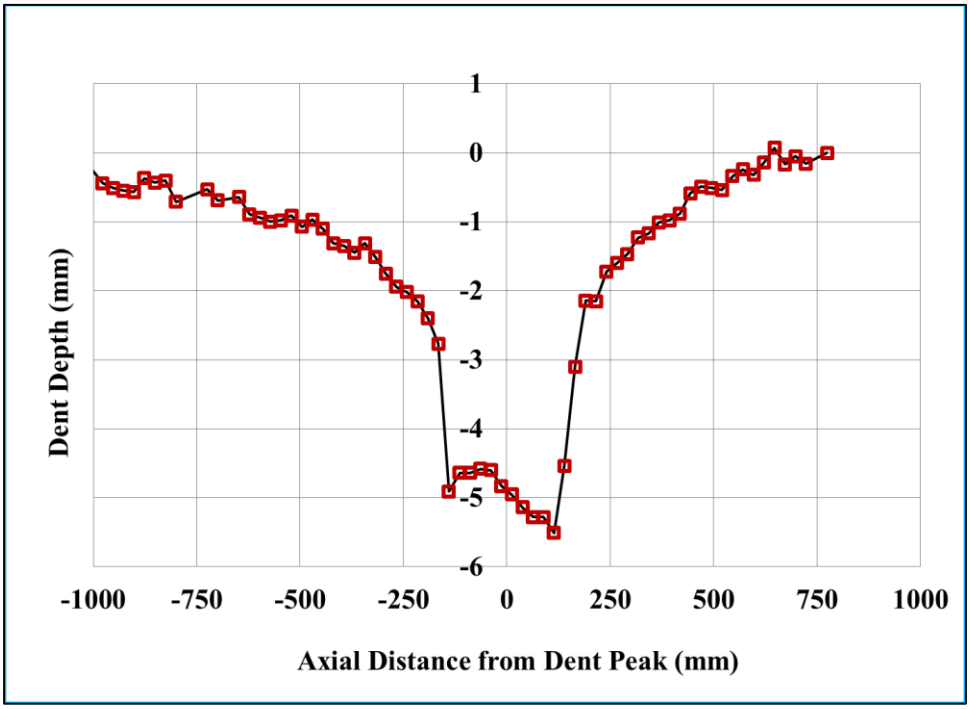

Figure 2: Test # 7 - Dent Axial Profile at the end of test after indenter removal

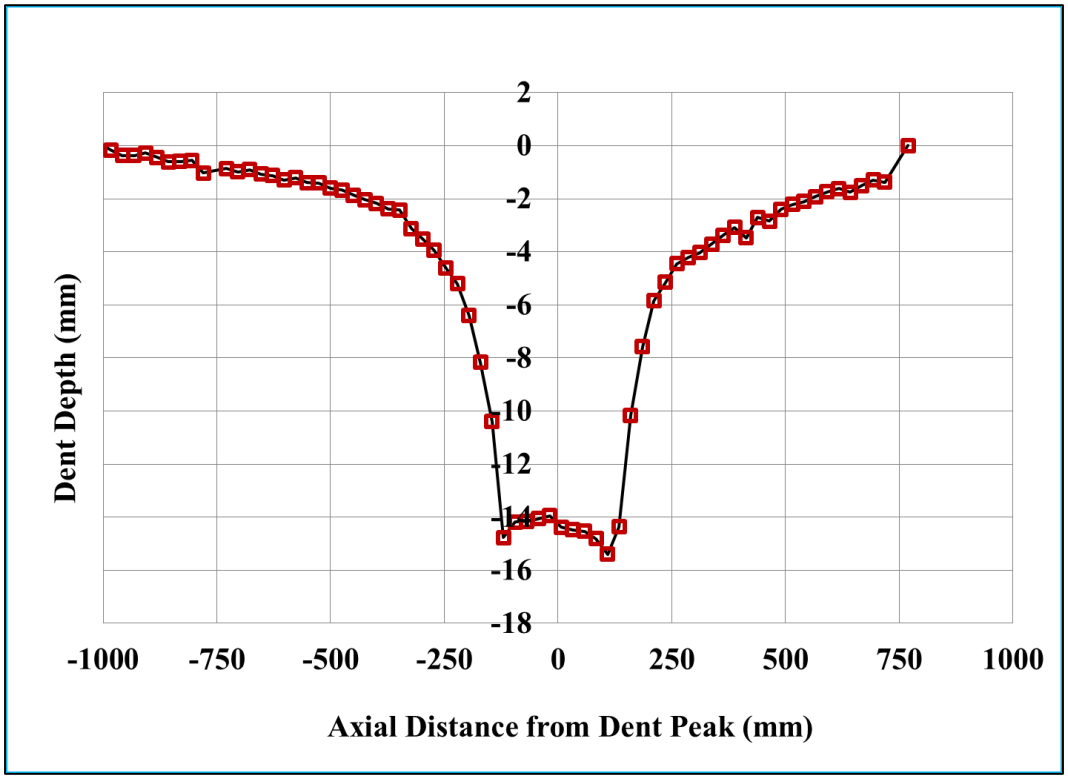

Figure 3: Test # 8 - Dent Axial Profile at the end of test after indenter removal

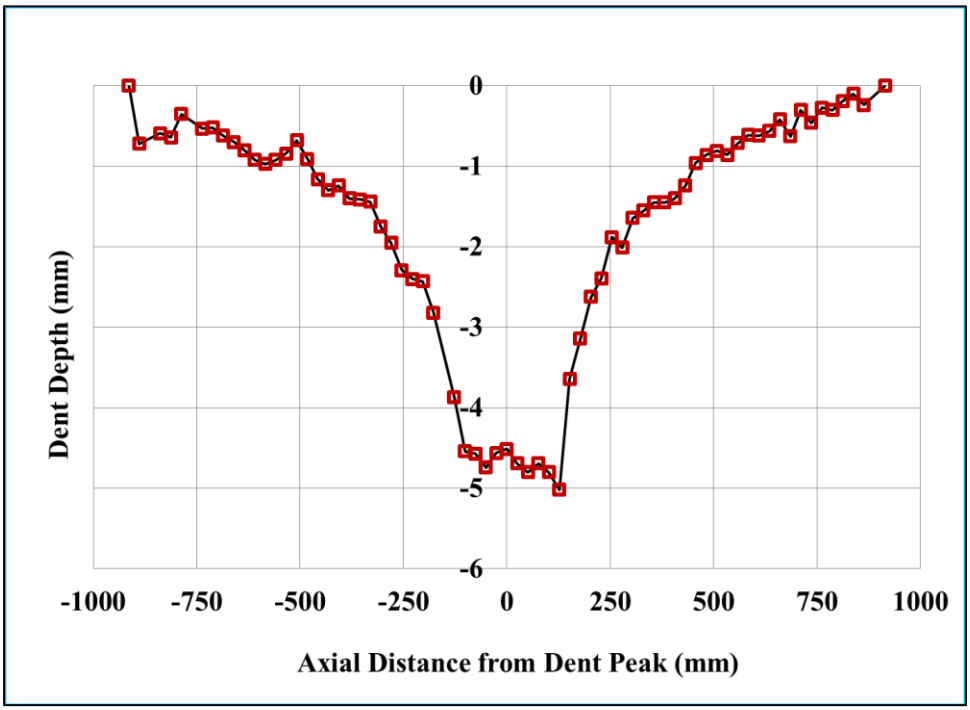

Figure 4: Test # 12 - Dent Axial Profile at the end of test after indenter removal

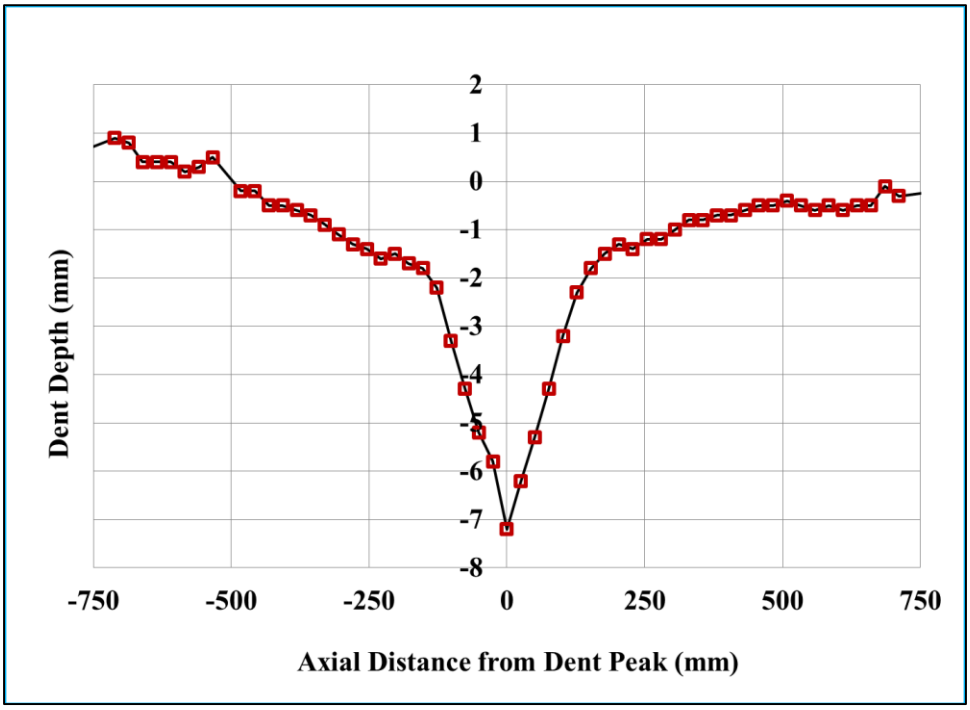

Figure 5: Test # 24 - Dent Axial Profile at the end of test after indenter removal

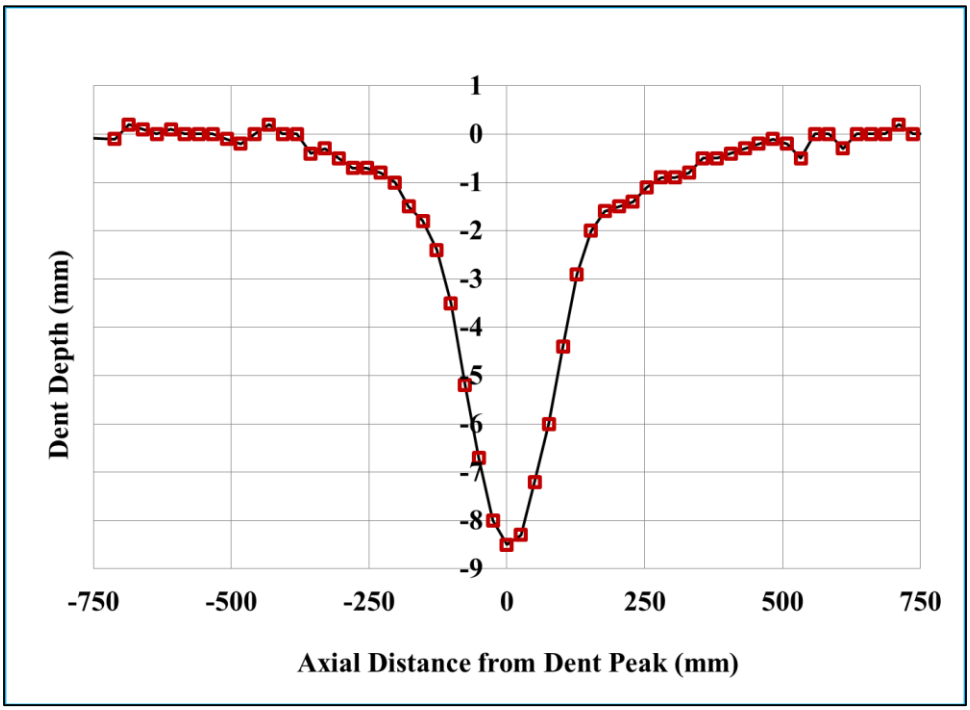

Figure 6: Test # 25 - Dent Axial Profile at the end of test after indenter removal

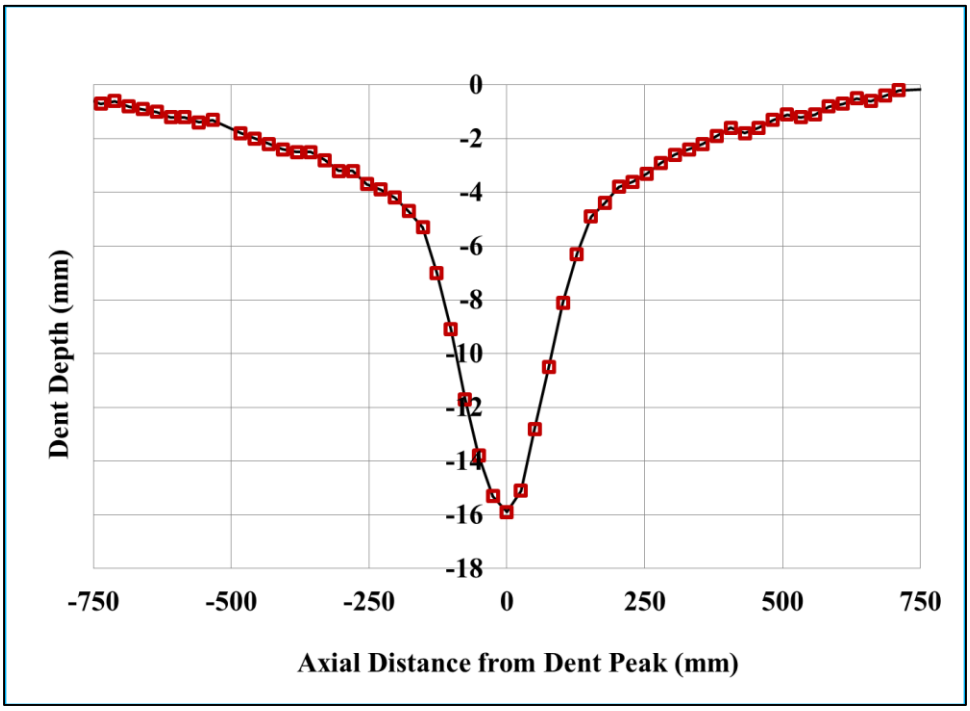

Figure 7: Test # 26 - Dent Axial Profile at the end of test after indenter removal

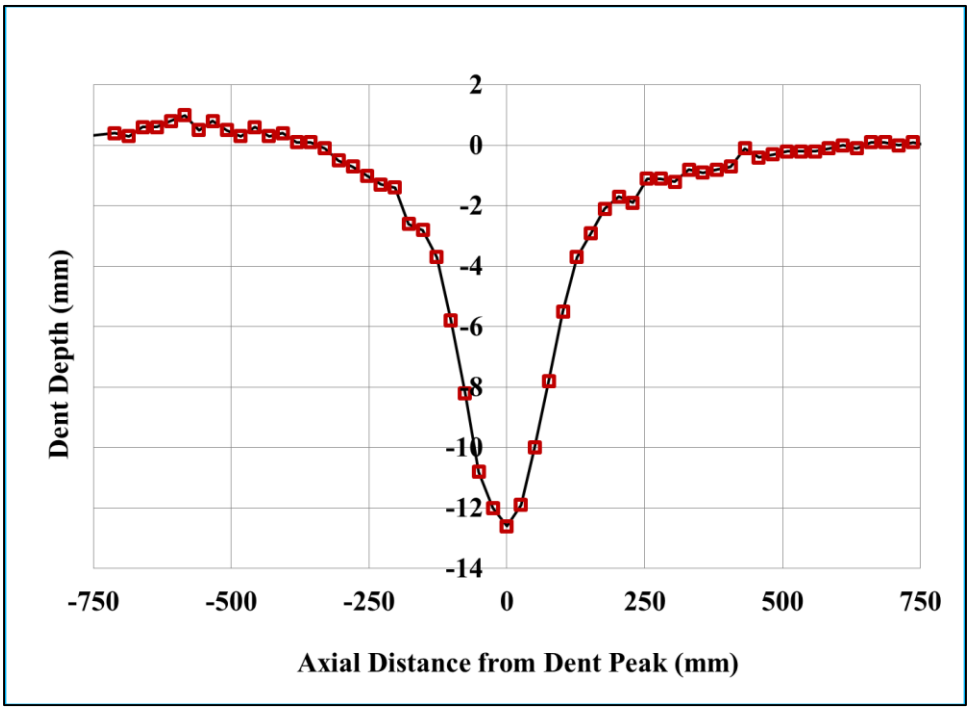

Figure 8: Test # 27 - Dent Axial Profile at the end of test after indenter removal

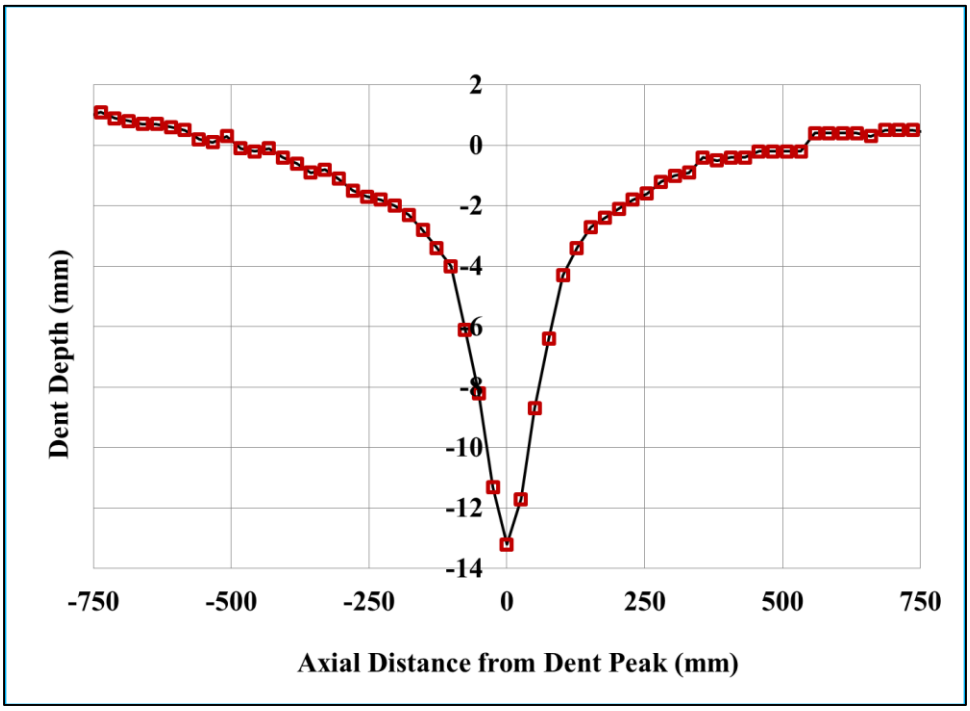

Figure 9: Test # 28 - Dent Axial Profile at the end of test after indenter removal

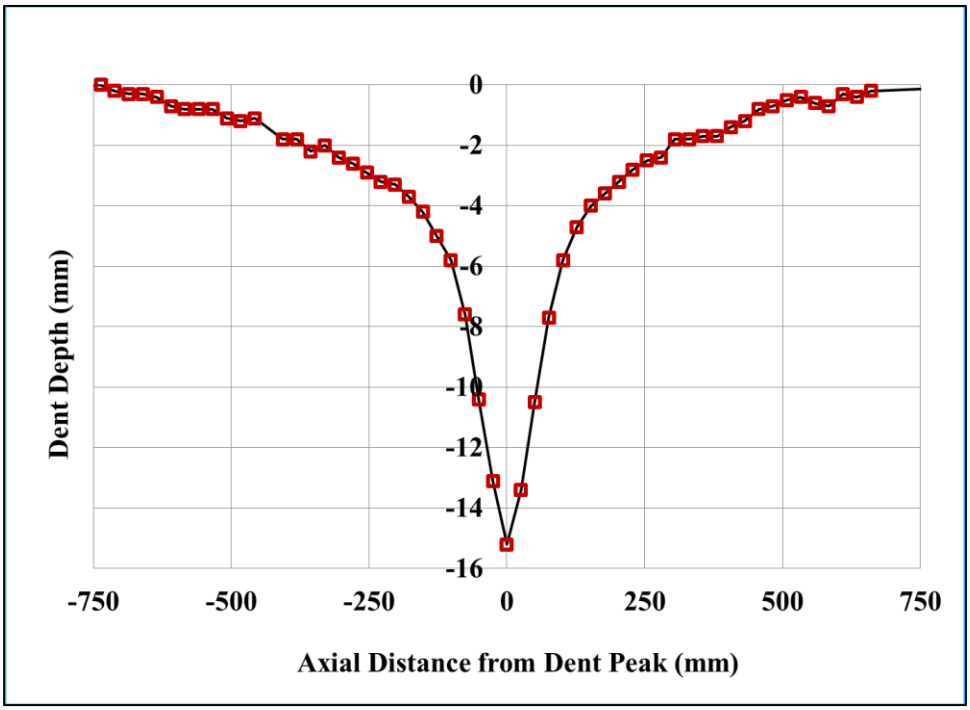

Figure 10: Test # 29 - Dent Axial Profile at the end of test after indenter removal

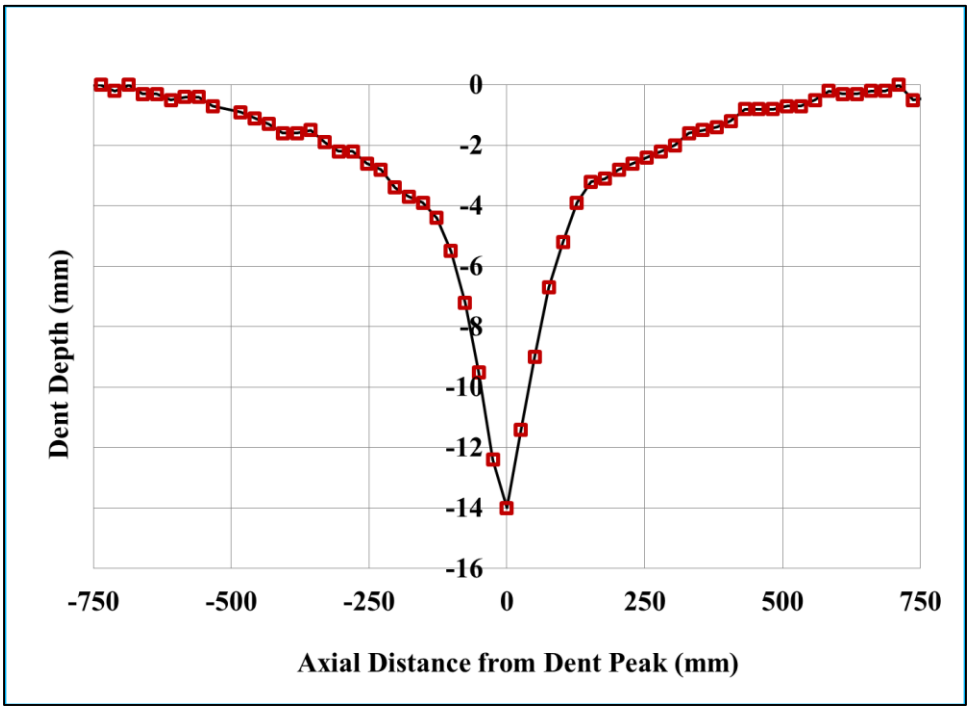

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Table 1: Test # 1 – Indentation and Cyclic Strains

Longitudinal distance from dent center (mm)		Transverse distance from the dent center (mm)		Indentation Strain		Cyclic Strain Range	
Fill Side	**Empty Side**	**3:00 Side**	**9:00 Side**	**Axial Gauge (micro-strain)**	**Hoop Gauge (micro-strain)**	**Axial Gauge (micro-strain)**	**Hoop Gauge (micro-strain)**
	762			455	-846	333	1059
	102			11081	-11775	-102	2022
	51			7946	-18309	335	2760
Center Gauge				N/A	N/A	3203	2523
			102	-391	-11959	164	870
			150	-23957	23686	373	-558

Table 2: Test # 2 – Indentation and Cyclic Strains

Longitudinal distance from dent center (mm)		Transverse distance from the dent center (mm)		Indentation Strain		Cyclic Strain Range	
Fill Side	**Empty Side**	**3:00 Side**	**9:00 Side**	**Axial Gauge (micron-strain)**	**Hoop Gauge (micron-strain)**	**Axial Gauge (micron-strain)**	**Hoop Gauge (micron-strain)**
	762			782	-1085	373	1406
	51			7204	-19609	18	2507
	30			-2306	-21771	1446	3335
			150	N/A	N/A	1574	66
			178	N/A	N/A	367	-774

Table 3: Test # 3 – Indentation and Cyclic Strains

Longitudinal distance from dent center (mm)		Transverse distance from the dent center (mm)		Indentation Strain		Cyclic Strain Range	
Fill Side	**Empty Side**	**3:00 Side**	**9:00 Side**	**Axial Gauge (micron-strain)**	**Hoop Gauge (micron-strain)**	**Axial Gauge (micron-strain)**	**Hoop Gauge (micron-strain)**
	762			-215	-790	586	1460
	150			-319	-5361	546	-185
150				-431	-8161	493	-519
	125		25	-2042	-2760	-905	656
			102	-838	16	156	1534
		102		-798	136	178	1649
			479	646	630	399	714
		479		678	582	445	852

Table 4: Test # 4 – Indentation and Cyclic Strains

				Indentation Strain		Cyclic Strain Range	
Longitudinal distance from dent center (mm)		Transverse distance from the dent center (mm)		Axial Gauge (micron-strain)	Hoop Gauge (micron-strain)	Axial Gauge (micron-strain)	Hoop Gauge (micron-strain)
Fill Side	Empty Side	3:00 Side	9:00 Side				
	762			-184	-1253	648	1448
	150			1053	-19402	718	-393
	125		25	-5289	-2290	-1324	1031
125		25		-8879	-423	-1177	1312
			102	-1500	1795	-2	1217
		479		941	822	546	874
			479	902	718	544	854

Table 5: Test # 5 – Indentation and Cyclic Strains

				Indentation Strain		Cyclic Strain Range	
Longitudinal distance from dent center (mm)		Transverse distance from the dent center (mm)		Axial Gauge (micron-strain)	Hoop Gauge (micron-strain)	Axial Gauge (micron-strain)	Hoop Gauge (micron-strain)
Fill Side	Empty Side	3:00 Side	9:00 Side				
	762			503	-806	299	1272
	102			10562	-11711	-170	2433
	51			8289	-17742	361	3159
	25		102	-694	-11927	895	1045
25		102		-3781	-20527	1394	1717

Table 6: Test # 6 – Indentation and Cyclic Strains

				Indentation Strain		Cyclic Strain Range	
Longitudinal distance from dent center (mm)		Transverse distance from the dent center (mm)		Axial Gauge (micron-strain)	Hoop Gauge (micron-strain)	Axial Gauge (micron-strain)	Hoop Gauge (micron-strain)
Fill Side	Empty Side	3:00 Side	9:00 Side				
	762			726	-1117	341	1119
	51			10052	-19513	160	3281
	30			2984	-23055	1266	3398
	25		150	-10156	3071	187	-333
25		150		-6661	11943	740	-174
			479	1436	909	373	1149
15				N/A	N/A	2663	2948

Table 7: Test # 7 – Indentation and Cyclic Strains

				Indentation Strain		Cyclic Strain Range	
Longitudinal distance from dent center (mm)		Transverse distance from the dent center (mm)		Axial Gauge (micron-strain)	Hoop Gauge (micron-strain)	Axial Gauge (micron-strain)	Hoop Gauge (micron-strain)
Fill Side	Empty Side	3:00 Side	9:00 Side				
770				-152	-814	604	1464
158				88	-3893	714	377
133		25		-1253	-2457	-730	834
117		25		-3614	-2465	-674	670
8			102	-742	152	126	1530

Table 8 Test # 8 – Indentation and Cyclic Strains

				Indentation Strain		Cyclic Strain Range	
Longitudinal distance from dent center (mm)		Transverse distance from the dent center (mm)		Axial Gauge (micron-strain)	Hoop Gauge (micron-strain)	Axial Gauge (micron-strain)	Hoop Gauge (micron-strain)
Fill Side	Empty Side	3:00 Side	9:00 Side				
762				-128	-1356	632	1324
158				3215	-15908	925	120
125		25		-8632	-2425	-1298	1077
	125		25	-9015	-1795	-854	1598
			102	-1516	1819	36	1324

Table 9: Test # 9 – Indentation and Cyclic Strains

				Indentation Strain		Cyclic Strain Range	
Longitudinal distance from dent center (mm)		Transverse distance from the dent center (mm)		Axial Gauge (micron-strain)	Hoop Gauge (micron-strain)	Axial Gauge (micron-strain)	Hoop Gauge (micron-strain)
Fill Side	Empty Side	3:00 Side	9:00 Side				
762				511	-941	337	1047
51				8879	-18405	239	2601
			150	-8839	5194	122	-50
Center Gauge				N/A	N/A	1663	1207

Table 10: Test # 10 – Indentation and Cyclic Strains

				Indentation Strain		Cyclic Strain Range	
Longitudinal distance from dent center (mm)		**Transverse distance from the dent center (mm)**		**Axial Gauge (micron-strain)**	**Hoop Gauge (micron-strain)**	**Axial Gauge (micron-strain)**	**Hoop Gauge (micron-strain)**
Fill Side	**Empty Side**	**3:00 Side**	**9:00 Side**				
762				598	-1125	293	1155
51				8576	-18676	170	3143
			178	-4595	11201	N/A	N/A
Center Gauge				N/A	N/A	2688	3558

Table 11: Test # 11 – Indentation and Cyclic Strains

				Indentation Strain		Cyclic Strain Range	
Longitudinal distance from dent center (mm)		**Transverse distance from the dent center (mm)**		**Axial Gauge (micron-strain)**	**Hoop Gauge (micron-strain)**	**Axial Gauge (micron-strain)**	**Hoop Gauge (micron-strain)**
Fill Side	**Empty Side**	**3:00 Side**	**9:00 Side**				
762				136	-439	337	1217
55				7491	-12576	203	2270
20				-3766	-19458	1107	2551
			90	-15828	7371	692	664

Table 12: Test # 12 – Indentation and Cyclic Strains

				Indentation Strain		Cyclic Strain Range	
Longitudinal distance from dent center (mm)		**Transverse distance from the dent center (mm)**		**Axial Gauge (micron-strain)**	**Hoop Gauge (micron-strain)**	**Axial Gauge (micron-strain)**	**Hoop Gauge (micron-strain)**
Fill Side	**Empty Side**	**3:00 Side**	**9:00 Side**				
762				-192	-646	564	1364
150				-431	-3175	632	475
125			25	-1388	-2808	-778	1286

Table 13: Test # 13 – Indentation and Cyclic Strains

				Indentation Strain		Cyclic Strain Range	
Longitudinal distance from dent center (mm)		Transverse distance from the dent center (mm)		Axial Gauge (micron-strain)	Hoop Gauge (micron-strain)	Axial Gauge (micron-strain)	Hoop Gauge (micron-strain)
Fill Side	Empty Side	3:00 Side	9:00 Side				
762				239	-104	441	1362
55				7483	-10898	189	2276
20				-1572	-17367	1093	2537
			90	-16625	7435	766	864
Center Gauge				N/A	N/A	2005	2569

Table 14: Test # 14 – Indentation and Cyclic Strains

				Indentation Strain		Cyclic Strain Range	
Longitudinal distance from dent center (mm)		Transverse distance from the dent center (mm)		Axial Gauge (micron-strain)	Hoop Gauge (micron-strain)	Axial Gauge (micron-strain)	Hoop Gauge (micron-strain)
Fill Side	Empty Side	3:00 Side	9:00 Side				
762				527	-343	187	772
105				14727	-21109	-369	2238
			110	-7962	4906	158	-32
			400	782	630	191	776
26				N/A	N/A	1141	3512

Table 15: Test # 15 – Indentation and Cyclic Strains

				Indentation Strain		Cyclic Strain Range	
Longitudinal distance from dent center (mm)		Transverse distance from the dent center (mm)		Axial Gauge (micron-strain)	Hoop Gauge (micron-strain)	Axial Gauge (micron-strain)	Hoop Gauge (micron-strain)
Fill Side	Empty Side	3:00 Side	9:00 Side				
762				112	-1340	191	888
120				5648	-18261	140	2022
			125	-3446	N/A	56	-174
			400	782	838	164	754
56				N/A	N/A	584	2824

Table 16: Test # 16 – Indentation and Cyclic Strains

				Indentation Strain		Cyclic Strain Range	
Longitudinal distance from dent center (mm)		Transverse distance from the dent center (mm)		Axial Gauge (micron-strain)	Hoop Gauge (micron-strain)	Axial Gauge (micron-strain)	Hoop Gauge (micron-strain)
Fill Side	Empty Side	3:00 Side	9:00 Side				
762				88	-1316	231	939
135				5337	-13809	173	1707
			110	-5992	8847	189	16

Table 17: Test # 17 – Indentation and Cyclic Strains

				Indentation Strain		Cyclic Strain Range	
Longitudinal distance from dent center (mm)		Transverse distance from the dent center (mm)		Axial Gauge (micron-strain)	Hoop Gauge (micron-strain)	Axial Gauge (micron-strain)	Hoop Gauge (micron-strain)
Fill Side	Empty Side	3:00 Side	9:00 Side				
737				48	-1492	174	909
135				4795	-14152	150	1879
			110	-5154	8488	195	-142

Table 18: Test # 18 – Indentation and Cyclic Strains

				Indentation Strain		Cyclic Strain Range	
Longitudinal distance from dent center (mm)		Transverse distance from the dent center (mm)		Axial Gauge (micron-strain)	Hoop Gauge (micron-strain)	Axial Gauge (micron-strain)	Hoop Gauge (micron-strain)
Fill Side	Empty Side	3:00 Side	9:00 Side				
762				646	-176	193	899
105				15261	-21891	-323	1677
			110	-8847	18995	96	-491
			400	750	622	197	744

Table 19: Test # 19 – Indentation and Cyclic Strains

				Indentation Strain		Cyclic Strain Range	
Longitudinal distance from dent center (mm)		Transverse distance from the dent center (mm)		Axial Gauge (micron-strain)	Hoop Gauge (micron-strain)	Axial Gauge (micron-strain)	Hoop Gauge (micron-strain)
Fill Side	Empty Side	3:00 Side	9:00 Side				
762				551	-184	233	822
105				15852	-22601	-329	2216
	105			13682	-18492	-191	2042
			110	N/A	N/A	92	-544

Table 20: Test # 20 – Indentation and Cyclic Strains

				Indentation Strain		Cyclic Strain Range	
Longitudinal distance from dent center (mm)		Transverse distance from the dent center (mm)		Axial Gauge (micron-strain)	Hoop Gauge (micron-strain)	Axial Gauge (micron-strain)	Hoop Gauge (micron-strain)
Fill Side	Empty Side	3:00 Side	9:00 Side				
508				176	-2385	207	1037
120				N/A	N/A	142	2068
	120			7603	N/A	138	2124
			110	-5281	10020	178	-118

Table 21: Test # 21 – Indentation and Cyclic Strains

				Indentation Strain		Cyclic Strain Range	
Longitudinal distance from dent center (mm)		Transverse distance from the dent center (mm)		Axial Gauge (micron-strain)	Hoop Gauge (micron-strain)	Axial Gauge (micron-strain)	Hoop Gauge (micron-strain)
Fill Side	Empty Side	3:00 Side	9:00 Side				
508				359	-1093	170	1049
	135			4834	-12708	104	2062
135				3335	-8169	128	1821
			110	-1524	7778	144	-90

Table 22: Test # 22 – Indentation and Cyclic Strains

				Indentation Strain		Cyclic Strain Range	
Longitudinal distance from dent center (mm)		Transverse distance from the dent center (mm)		Axial Gauge (micron-strain)	Hoop Gauge (micron-strain)	Axial Gauge (micron-strain)	Hoop Gauge (micron-strain)
Fill Side	Empty Side	3:00 Side	9:00 Side				
508				838	-830	174	963
120				-255	1859	1765	-219
	120			14910	-19234	-351	2090
			110	-14807	12724	128	-580

Table 23: Test # 23 – Indentation and Cyclic Strains

				Indentation Strain		Cyclic Strain Range	
Longitudinal distance from dent center (mm)		Transverse distance from the dent center (mm)		Axial Gauge (micron-strain)	Hoop Gauge (micron-strain)	Axial Gauge (micron-strain)	Hoop Gauge (micron-strain)
Fill Side	Empty Side	3:00 Side	9:00 Side				
508				854	-846	804	138
	105			16937	-23143	-263	1905
105				16641	-22337	-287	1823
			110	-9525	17974	90	-419

Table 24: Test # 24 – Indentation and Cyclic Strains

				Indentation Strain			Cyclic Strain Range		
Longitudinal distance from dent center (mm)		Transverse distance from the dent center (mm)		Axial Gauge (micron-strain)	Hoop Gauge (micron-strain)	45 Deg (micron-strain)	Axial Gauge (micron-strain)	Hoop Gauge (micron-strain)	45 Deg (micron-strain)
Fill Side	Empty Side	3:00 Side	9:00 Side						
508				-32	-1372	N/A	441	1272	N/A
11			11	-4196	-12198	N/A	-582	-10	-606
	11	11		-2369	-6893	-7547	-309	417	N/A
	100		100	-1332	1939	1324	-479	802	433
100		100		-1460	2154	N/A	-1009	666	N/A

Table 25: Test # 25 – Indentation and Cyclic Strains

				Indentation Strain		Cyclic Strain Range	
Longitudinal distance from dent center (mm)		Transverse distance from the dent center (mm)		Axial Gauge (micron-strain)	Hoop Gauge (micron-strain)	Axial Gauge (micron-strain)	Hoop Gauge (micron-strain)
Fill Side	Empty Side	3:00 Side	9:00 Side				
508				-32	-1340	441	1272
	110			2561	-8751	666	-582
110				2226	-7108	-479	433
	35	100		-1237	4045	-606	-10
			100	4523	-1572	-1009	802
	508			N/A	N/A	-309	417

Table 26: Test # 26 – Indentation and Cyclic Strains

				Indentation Strain		Cyclic Strain Range	
Longitudinal distance from dent center (mm)		Transverse distance from the dent center (mm)		Axial Gauge (micron-strain)	Hoop Gauge (micron-strain)	Axial Gauge (micron-strain)	Hoop Gauge (micron-strain)
Fill Side	Empty Side	3:00 Side	9:00 Side				
508				-1516	32	1316	483
	35	110		-1723	4803	-269	1015
35		110		-1731	5090	-349	1021
		100		-2345	5568	-385	953
		400		574	638	433	668

Table 27: Test # 27 – Indentation and Cyclic Strains

				Indentation Strain		Cyclic Strain Range	
Longitudinal distance from dent center (mm)		Transverse distance from the dent center (mm)		Axial Gauge (micron-strain)	Hoop Gauge (micron-strain)	Axial Gauge (micron-strain)	Hoop Gauge (micron-strain)
Fill Side	Empty Side	3:00 Side	9:00 Side				
508				-1460	40	1245	463
35		100		-1388	4204	-335	806
	35	100		-1500	4372	-367	1091
			100	-1867	4962	-429	1061

Table 28: Test # 28 – Indentation and Cyclic Strains

				Indentation Strain		Cyclic Strain Range	
Longitudinal distance from dent center (mm)		Transverse distance from the dent center (mm)		Axial Gauge (micron-strain)	Hoop Gauge (micron-strain)	Axial Gauge (micron-strain)	Hoop Gauge (micron-strain)
Fill Side	Empty Side	3:00 Side	9:00 Side				
	508			8	-1356	397	1286
	11	11		-2154	-12708	-351	116
11		11		-3175	-10499	-251	213
	100	100		-1540	2393	-610	820
100			100	-1221	2122	-335	744

Table 29: Test # 29 – Indentation and Cyclic Strains

				Indentation Strain		Cyclic Strain Range	
Longitudinal distance from dent center (mm)		Transverse distance from the dent center (mm)		Axial Gauge (micron-strain)	Hoop Gauge (micron-strain)	Axial Gauge (micron-strain)	Hoop Gauge (micron-strain)
Fill Side	Empty Side	3:00 Side	9:00 Side				
508				-32	-1444	427	1330
	11	11		-2258	-10060	-361	201
11		11		-2242	-11903	-385	112
100			100	-1229	2074	-509	806

Table 30: Test # 30 – Indentation and Cyclic Strains

				Indentation Strain		Cyclic Strain Range	
Longitudinal distance from dent center (mm)		Transverse distance from the dent center (mm)		Axial Gauge (micron-strain)	Hoop Gauge (micron-strain)	Axial Gauge (micron-strain)	Hoop Gauge (micron-strain)
Fill Side	Empty Side	3:00 Side	9:00 Side				
508				-80	-1500	489	1326
	11		11	-1851	-9110	-407	102
11		11		-2537	-11679	-740	102
	100		100	-1181	1460	-774	1209
100			100	-1149	1356	-740	624
508			81	-152	-838	790	423

ANNEX D

MAGNETIC PARTICLE INSPECTION (MPI)

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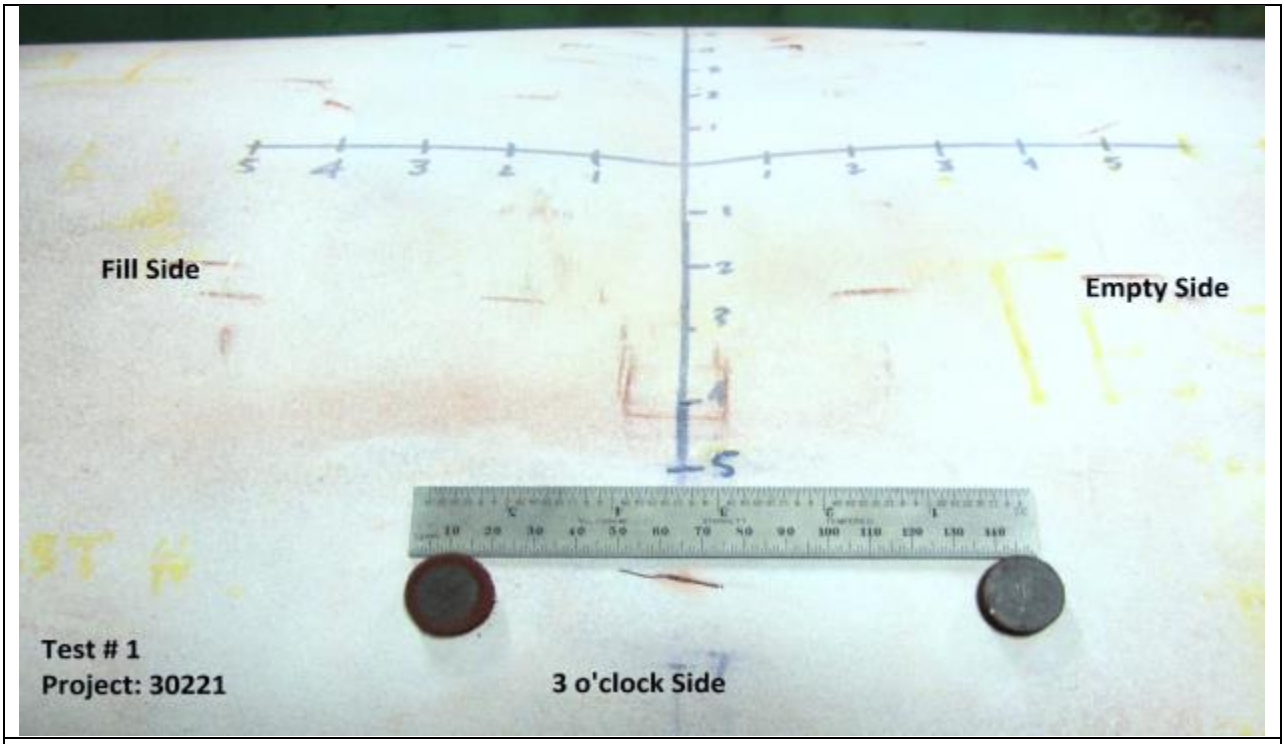
D. MPI Photographs for each test specimen (OD & ID)

D.1 Plain Dents

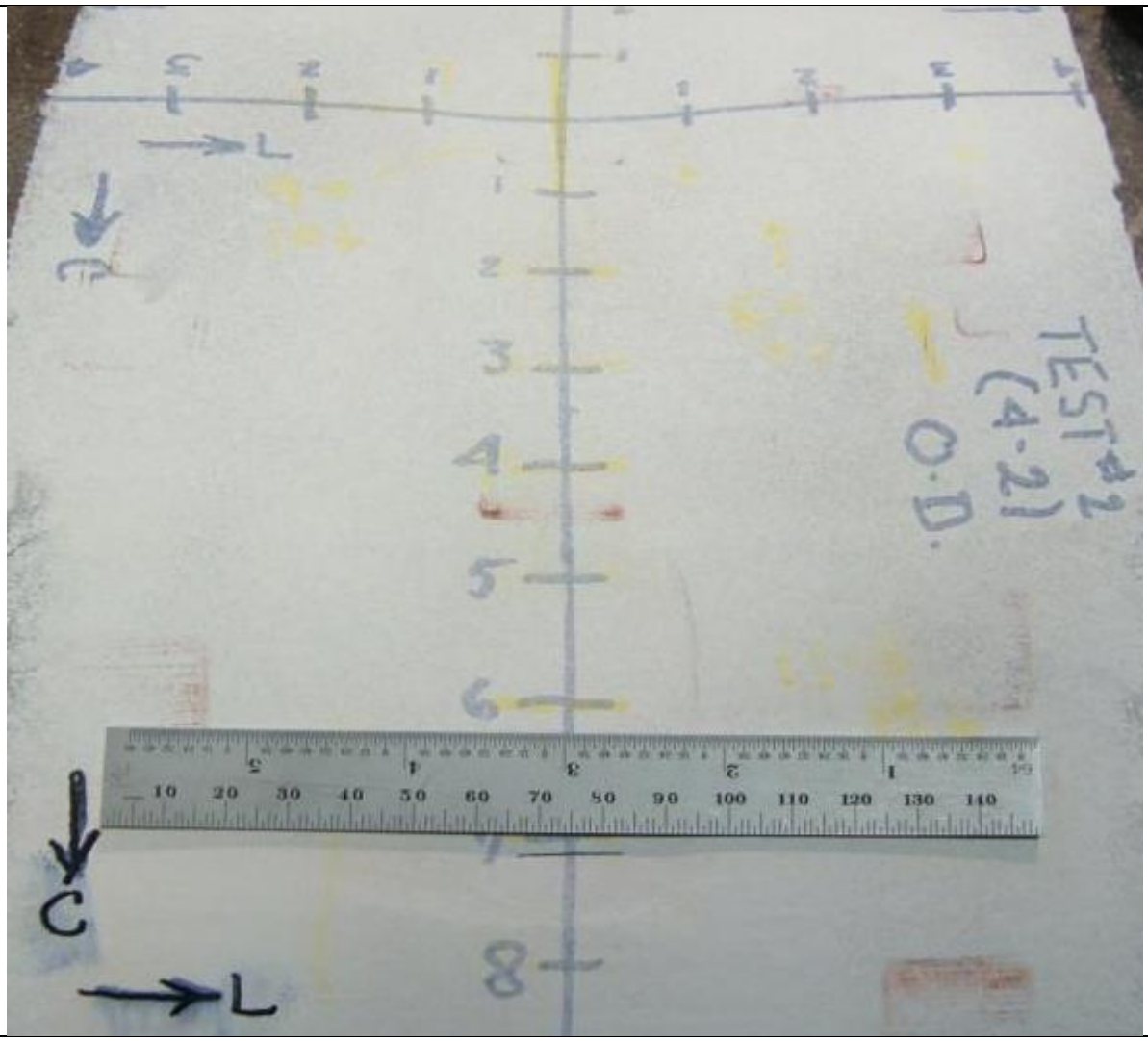


(a)

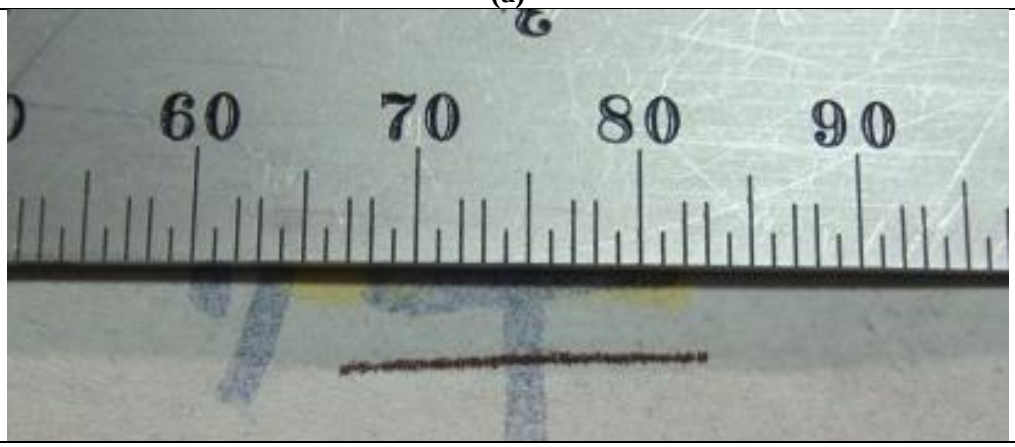
(b)

(c)

Figure 1: Test # 1 – Plain Dent – MPI of OD and ID – Pipe D
(a) Axial ID crack as seen on the OD Surface
(b) OD Surface, (Enlarged crack photograph)
(c) ID Surface, (Enlarged crack photograph)

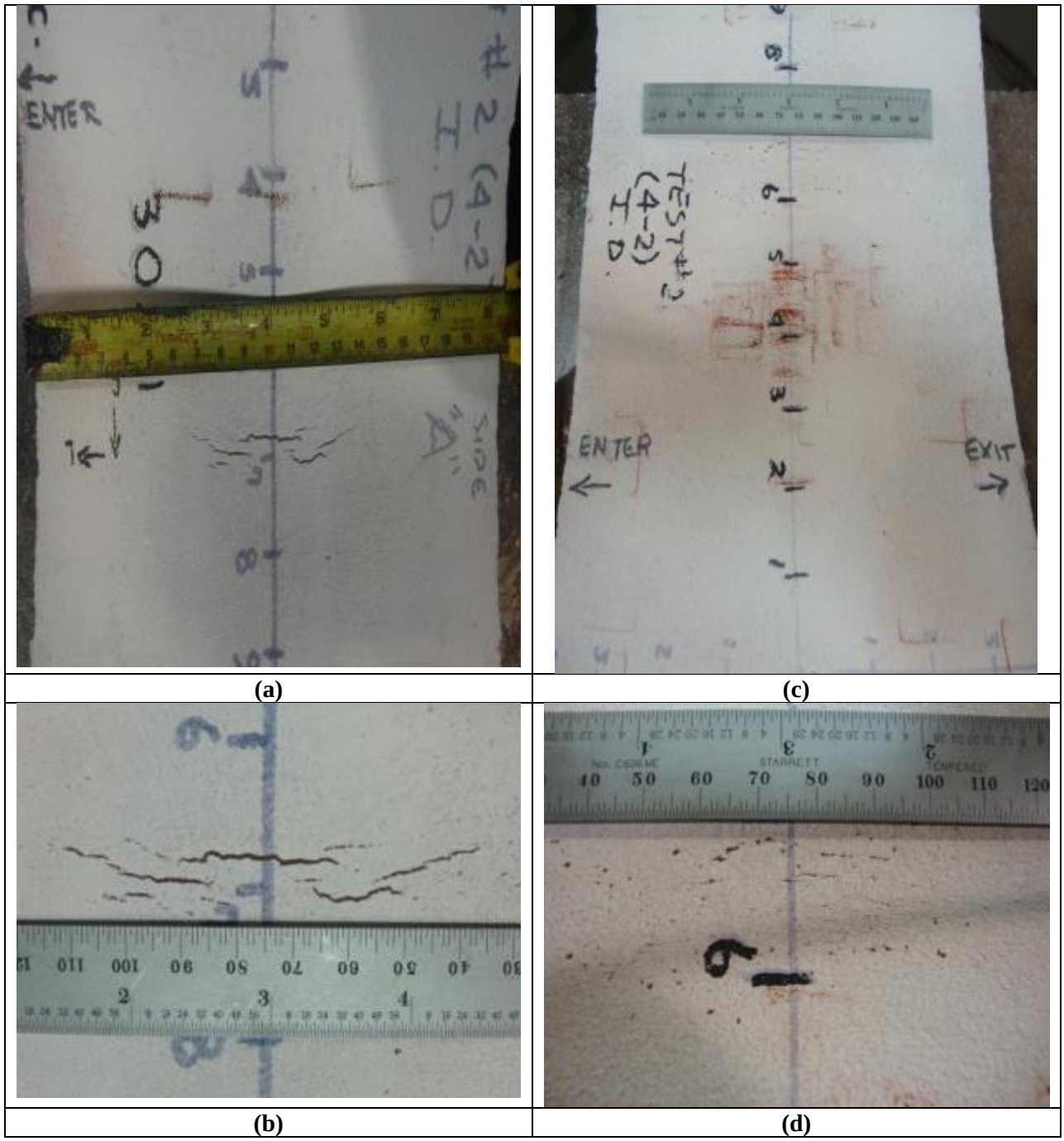


(a)



(b)

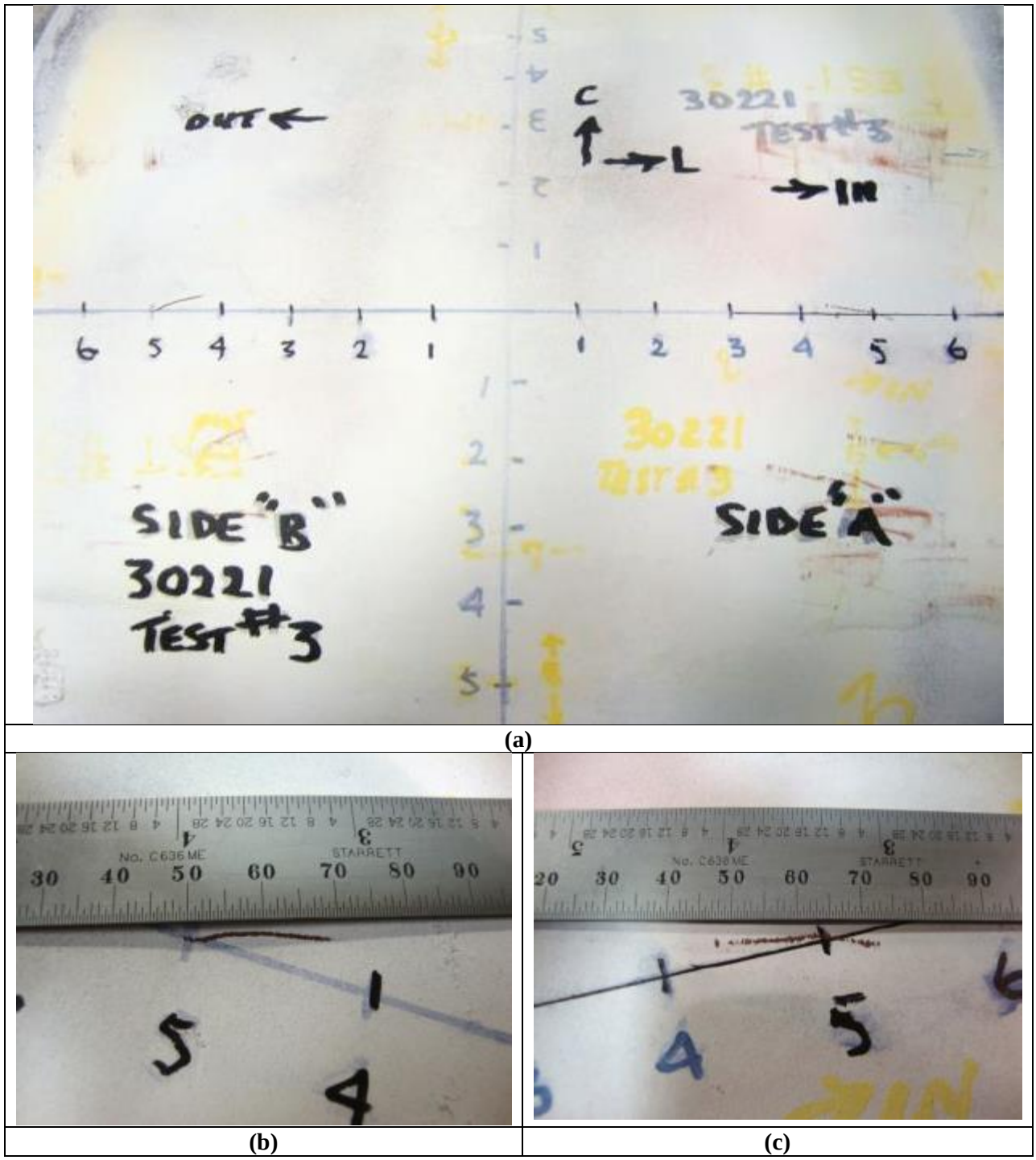
Figure 2: Test # 2 - Plain Dent – OD MPI – Pipe D
(a) Axial ID crack as seen on the OD Surface (b) OD Surface, (Enlarged crack photograph)



(a) **(c)**

(b) **(d)**

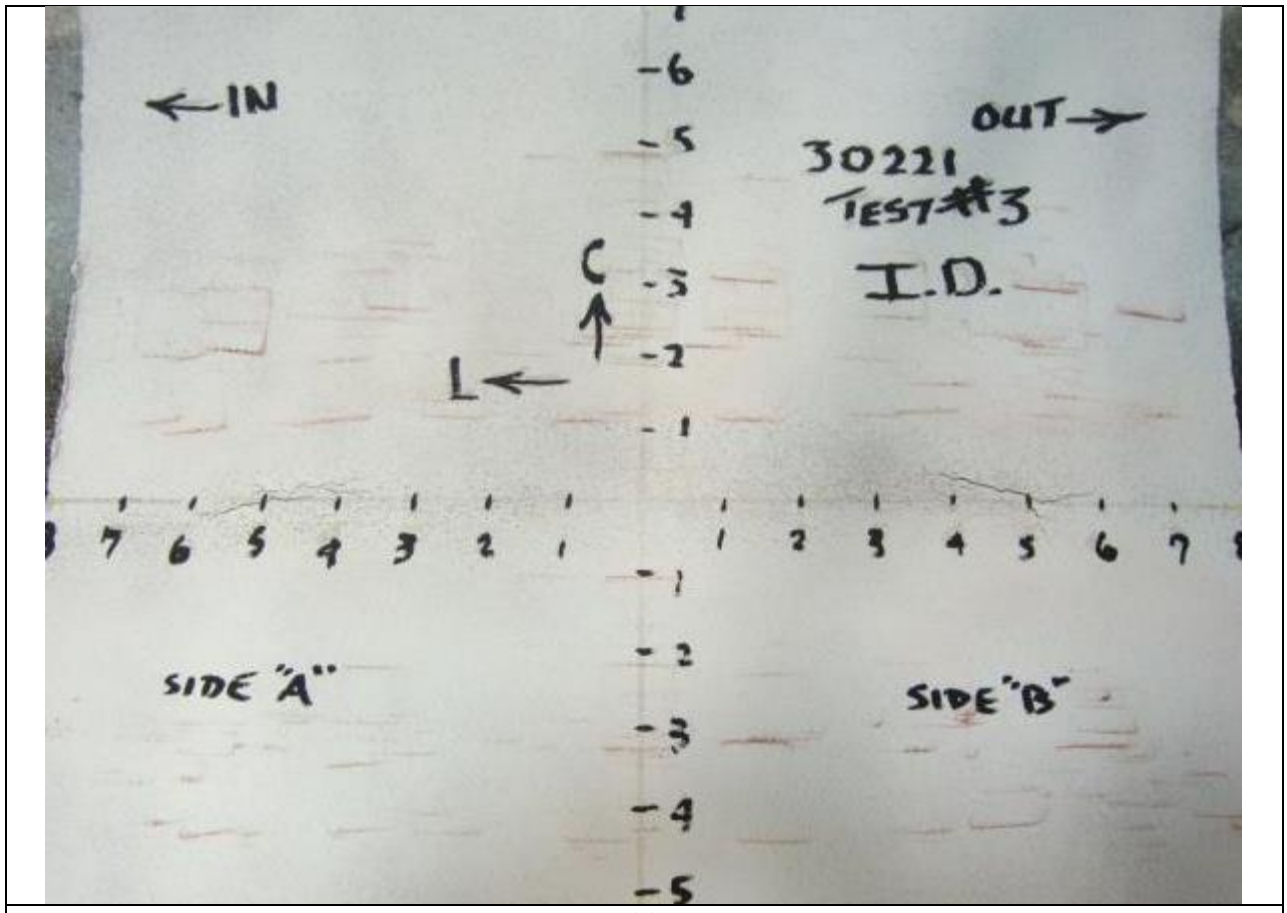
Figure 3: Test # 2 - Plain Dent – ID MPI – Pipe D
(a) Axial ID crack as seen on the ID Surface (Side A)
(b) ID Surface, (Enlarged crack photograph) (Side A)
(c) Axial ID crack as seen on the ID Surface (Side B)
(d) ID Surface, (Enlarged crack photograph) (Side B)



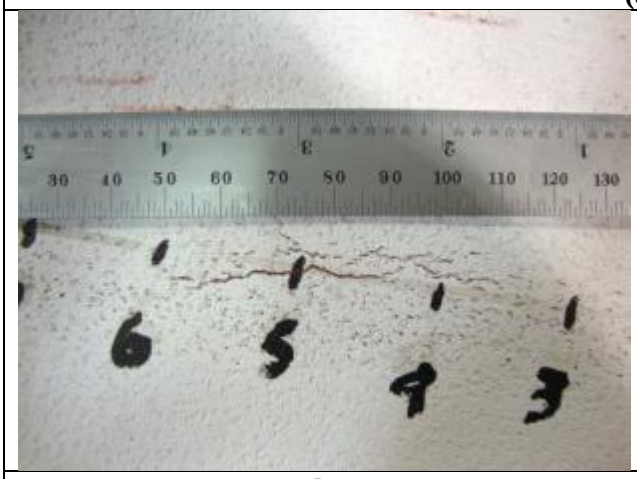
(a)

(b) (c)

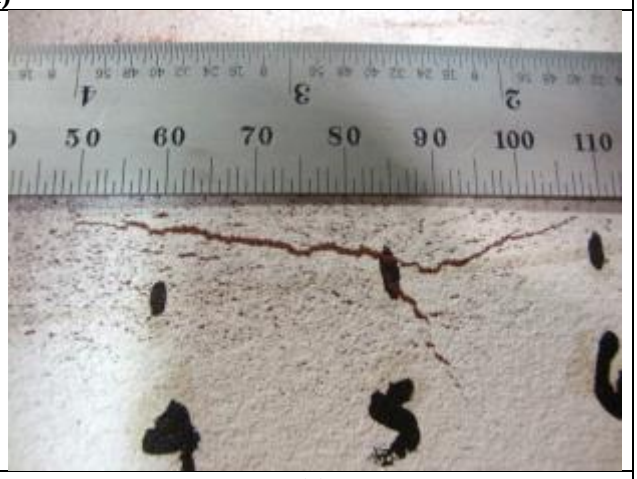
Figure 4: Test # 3 – Plain Dent – OD MPI – Pipe D
(a) Axial ID crack as seen on the OD Surface
(b) OD Surface, Enlarged crack photograph (Side A)
(c) OD Surface, Enlarged crack photograph (Side B)



(a)

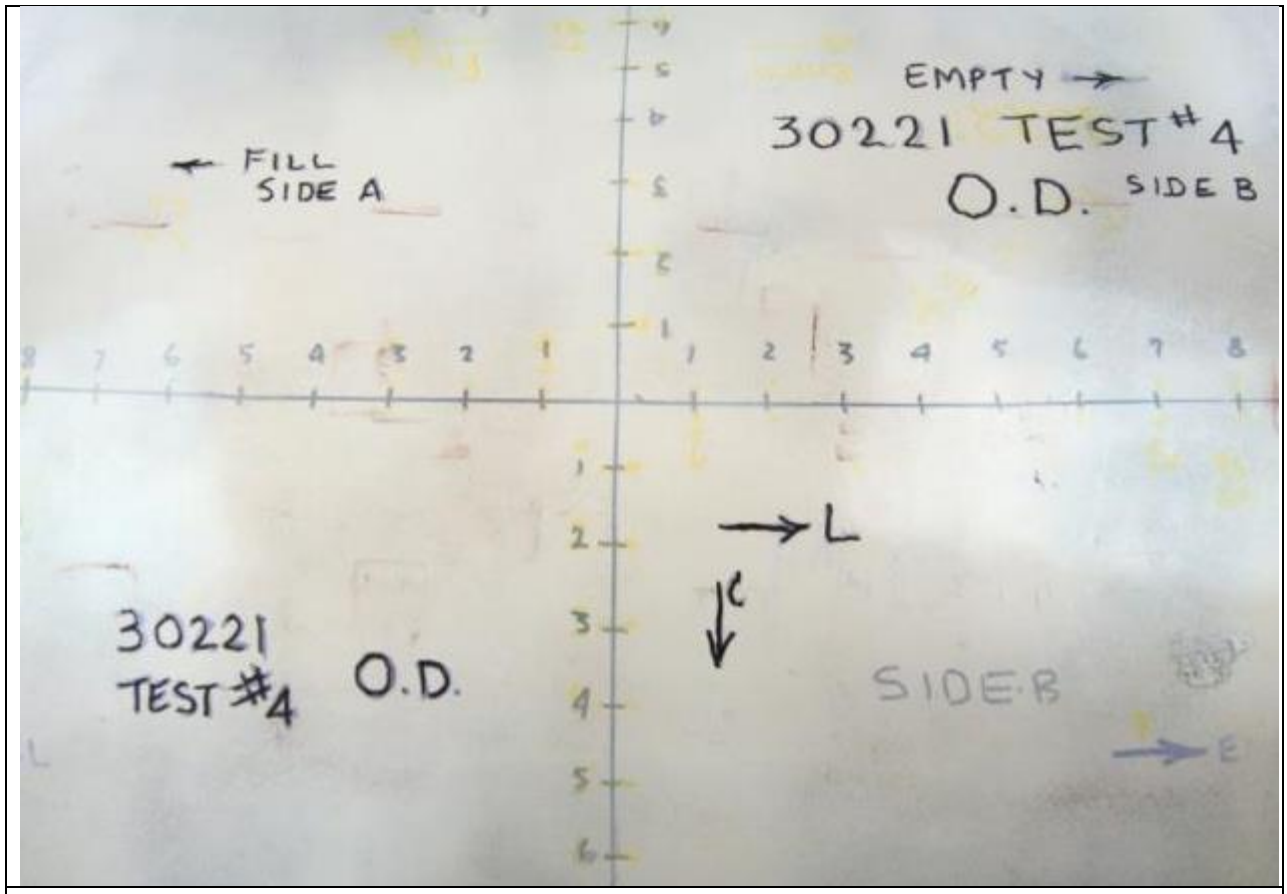


(b)



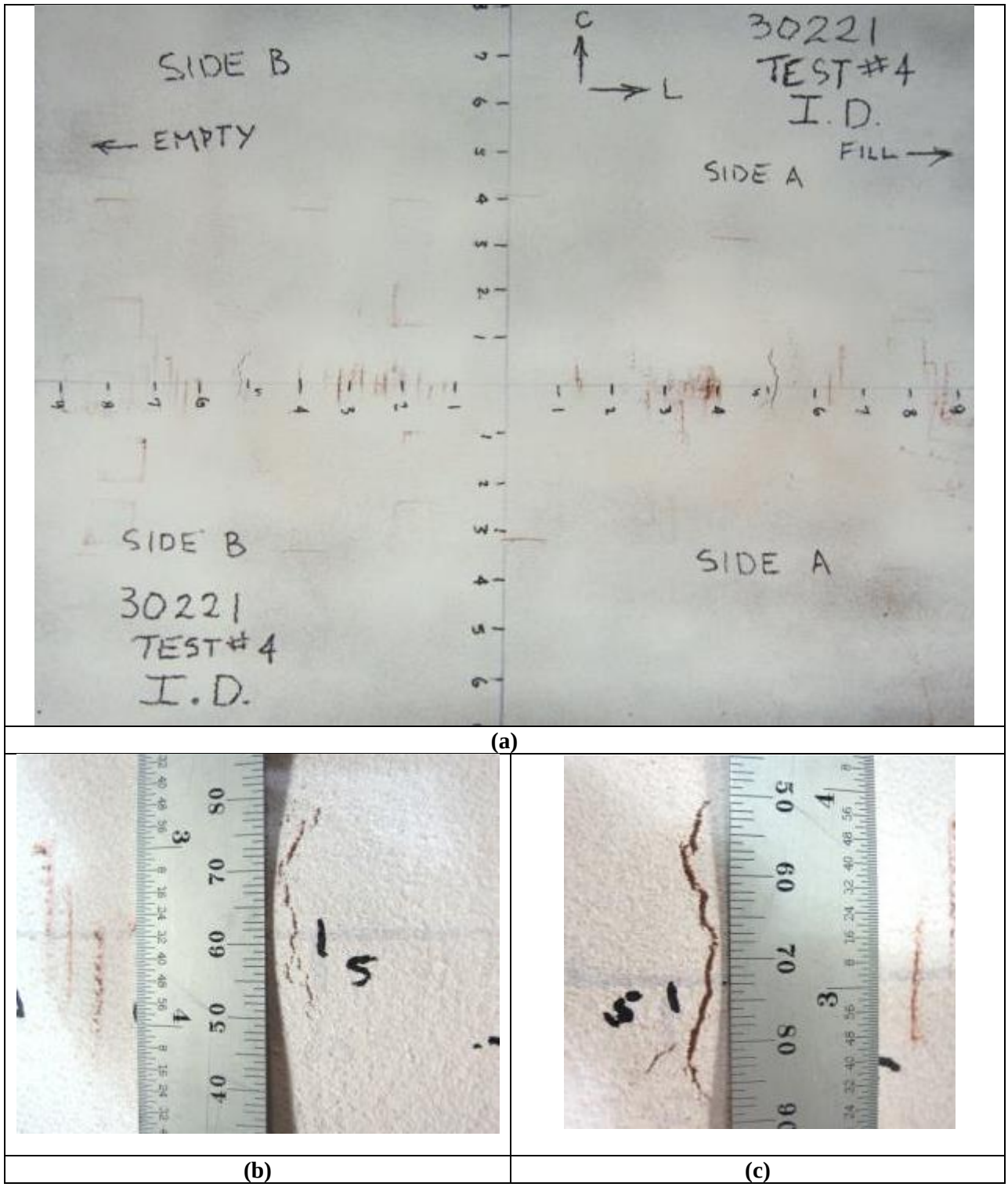
(c)

Figure 5: Test # 3 – Plain Dent – ID MPI – Pipe D
(a) Axial ID Crack as seen on the ID Surface
(b) ID Surface, Enlarged crack photograph (Side A)
(c) ID Surface, Enlarged crack photograph (Side B)



OD Surface (No Through crack)

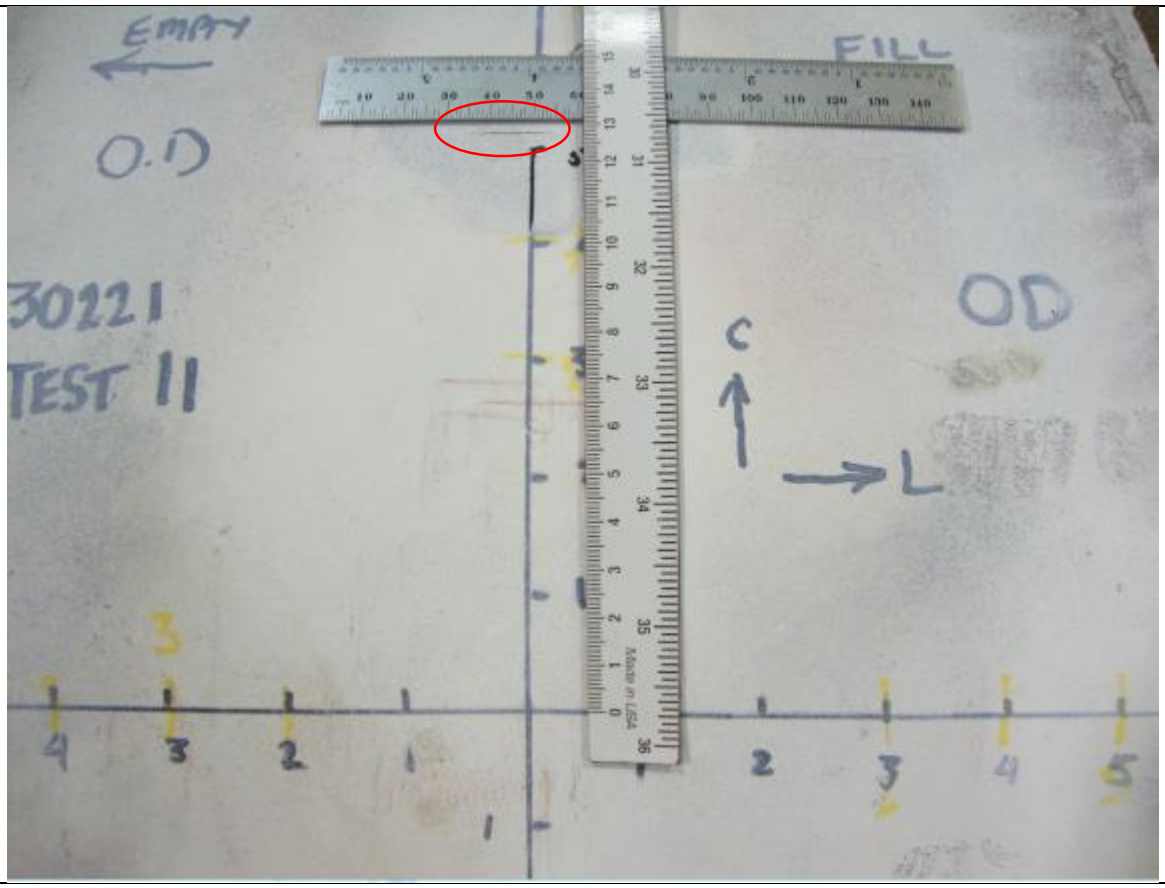
Figure 6: Test # 4 – Plain Dent - OD MPI – Pipe D



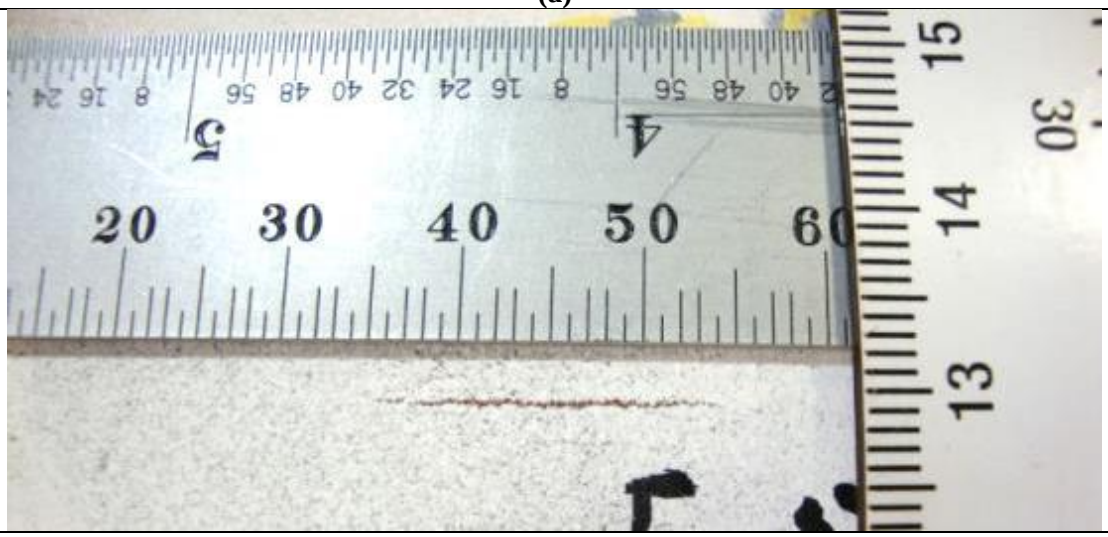
(a)

(b) **(c)**

Figure 7: Test # 4 – Plain Dent – ID MPI – Pipe D
(a) Circumferential ID crack as seen on the ID Surface
(b) ID Surface, Enlarged crack photograph (Side B)
(c) ID Surface, Enlarged crack photograph (Side A)

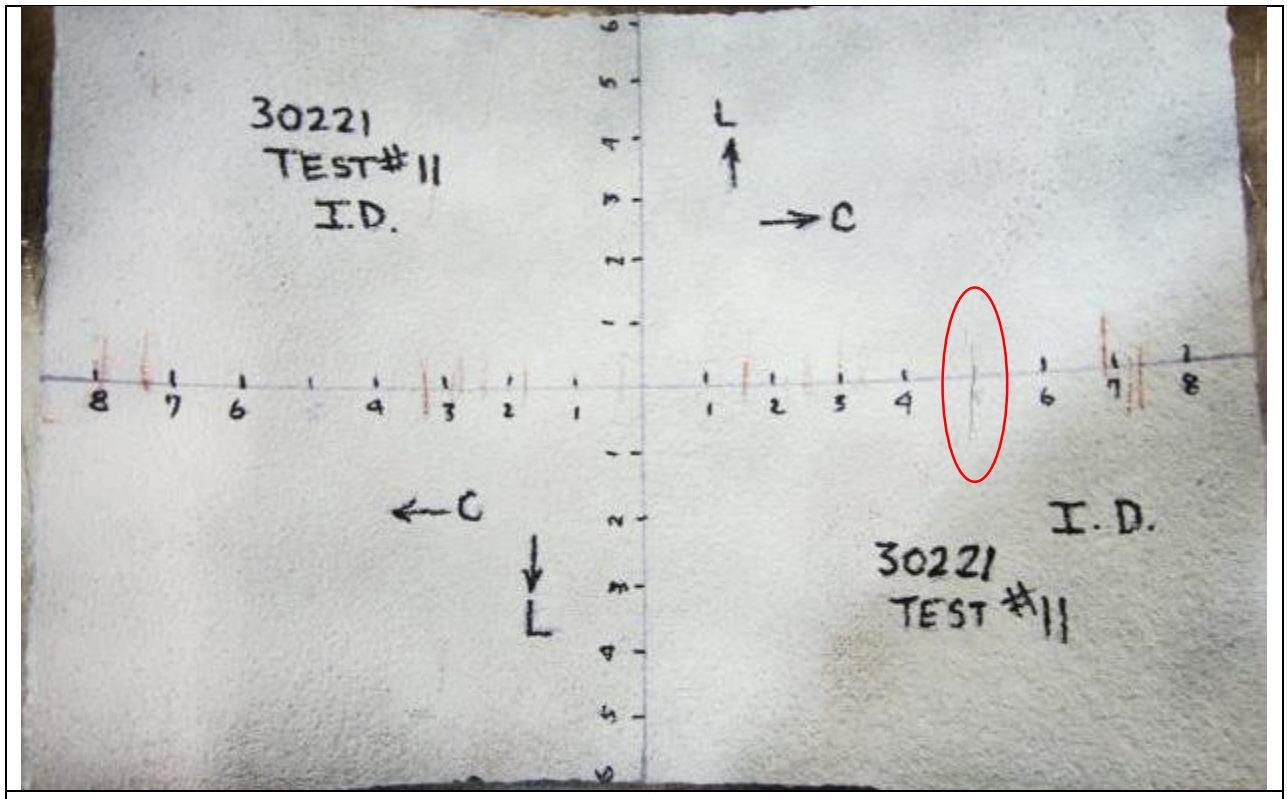


(a)

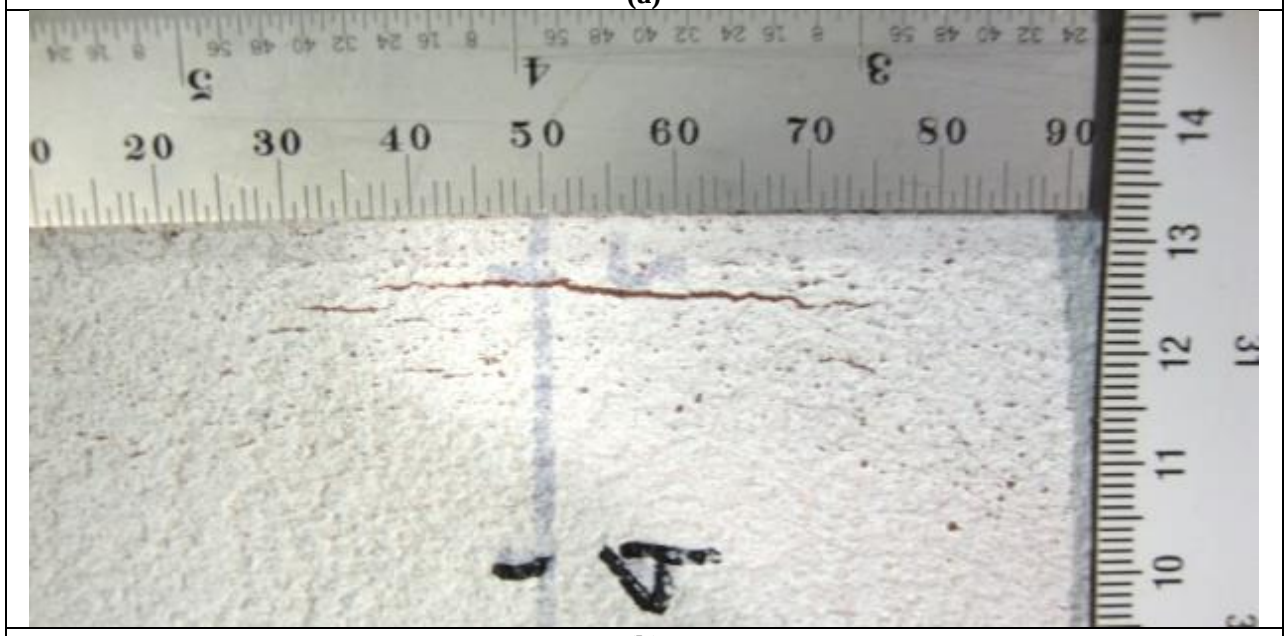


(b)

Figure 8: Test # 11 - Plain Dent – OD MPI – Pipe D
(a) Axial ID crack as seen on the OD Surface (b) OD Surface, Enlarged crack photograph

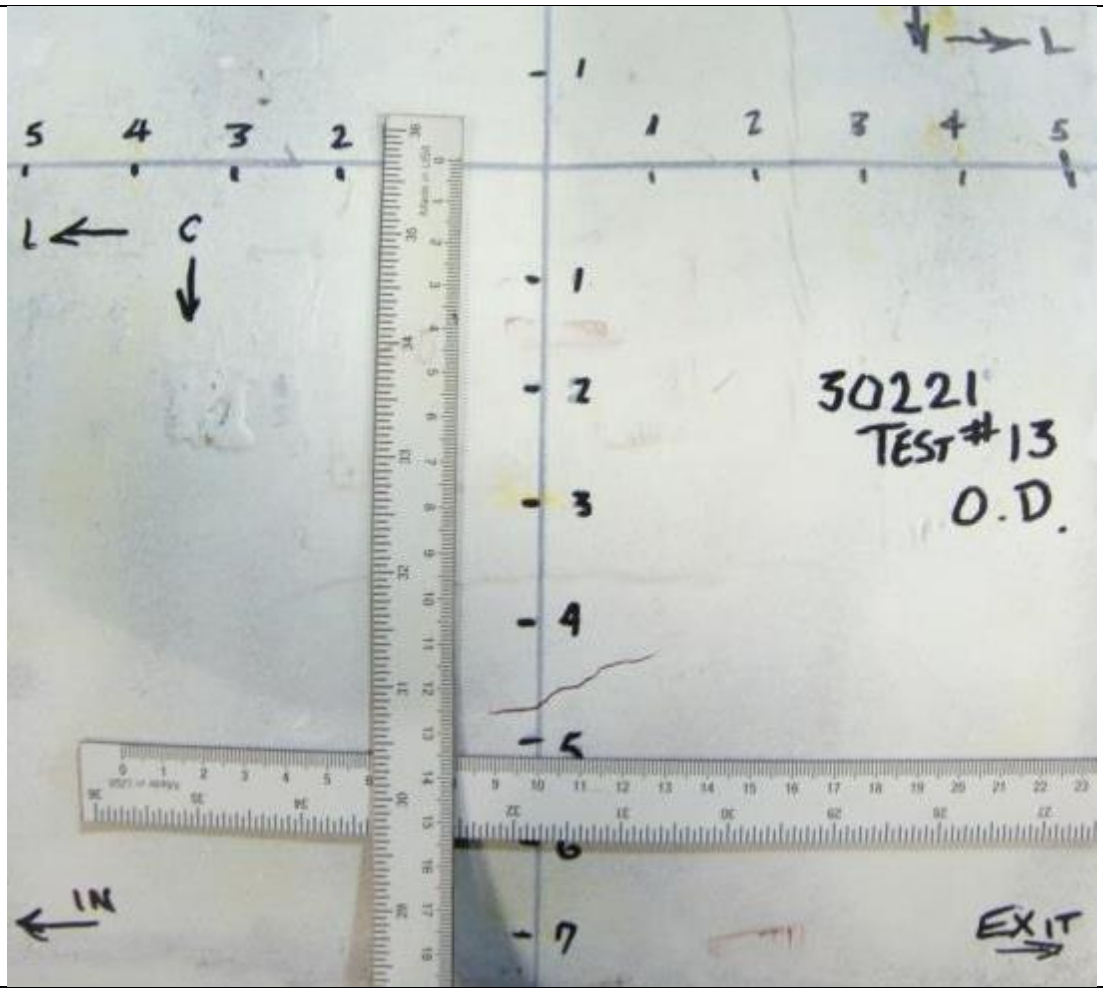


(a)

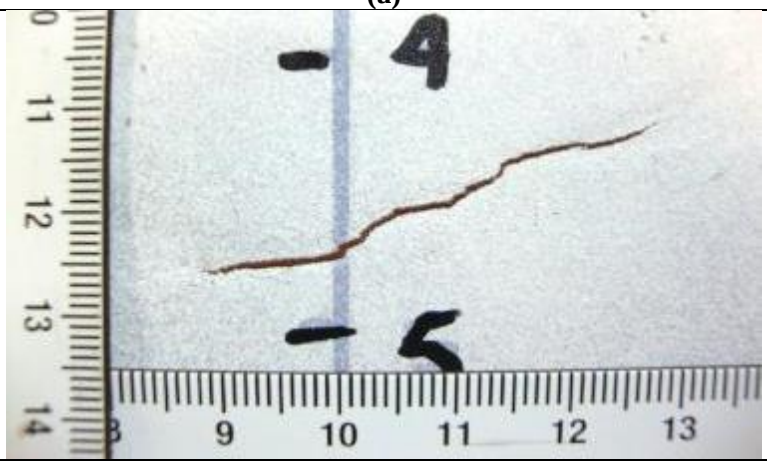


(b)

Figure 9: Test # 11 - Plain Dent – ID MPI – Pipe D
(a) Axial ID crack as seen on the ID Surface (b) ID Surface, Enlarged crack photograph

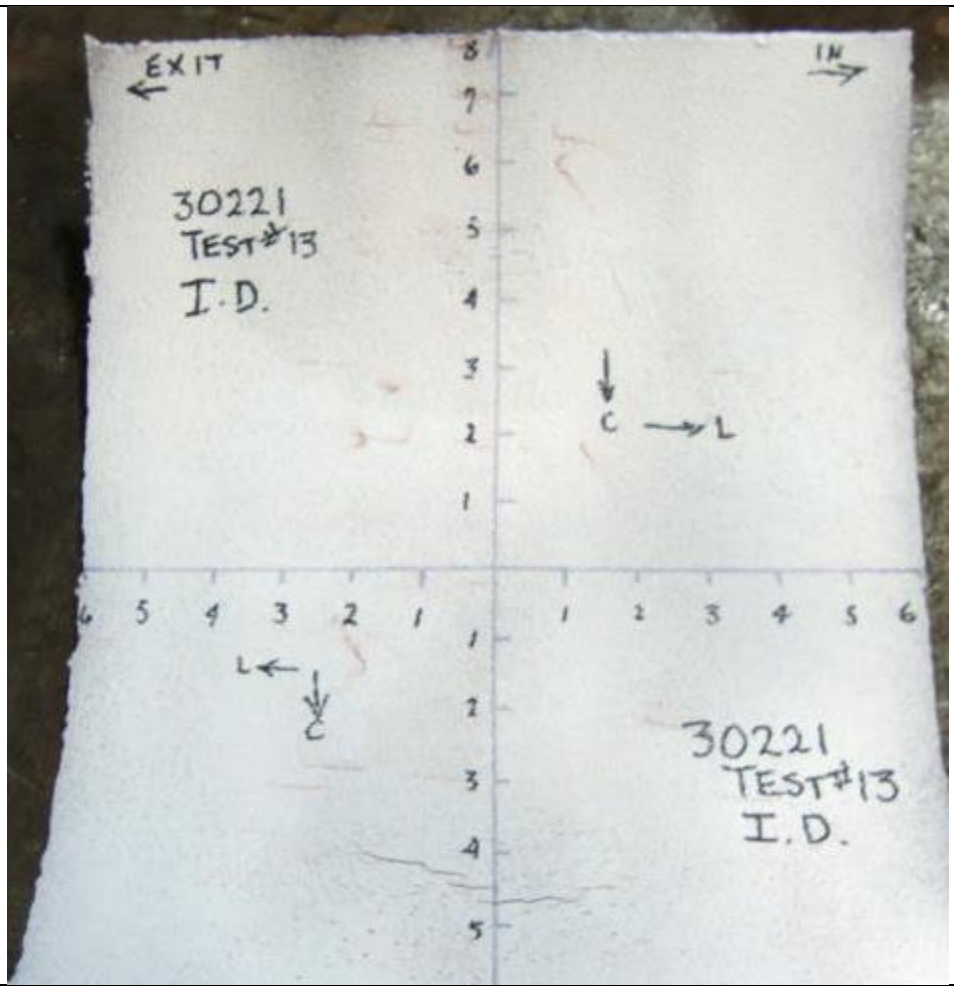


(a)

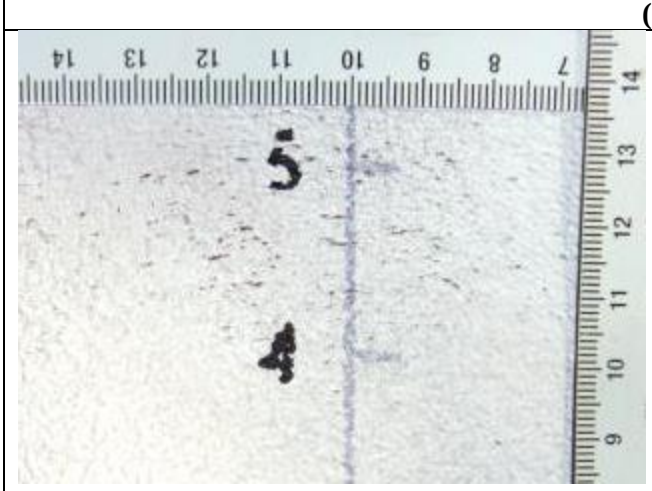


(b)

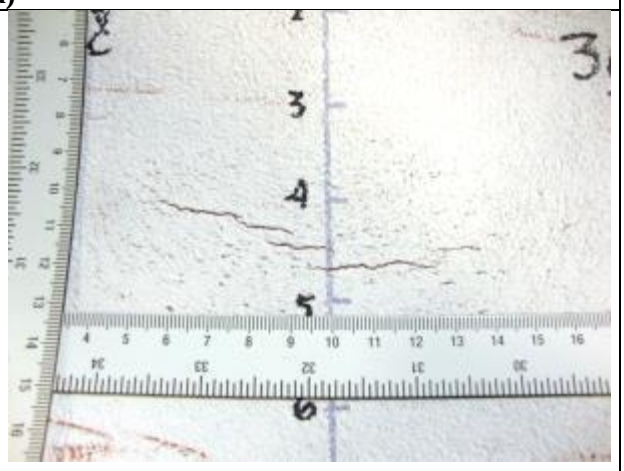
Figure 10: Test # 13 – Plain Dent – OD MPI – Pipe D
(a) Axial ID crack as seen on the OD Surface (b) OD Surface, Enlarged crack photograph



(a)

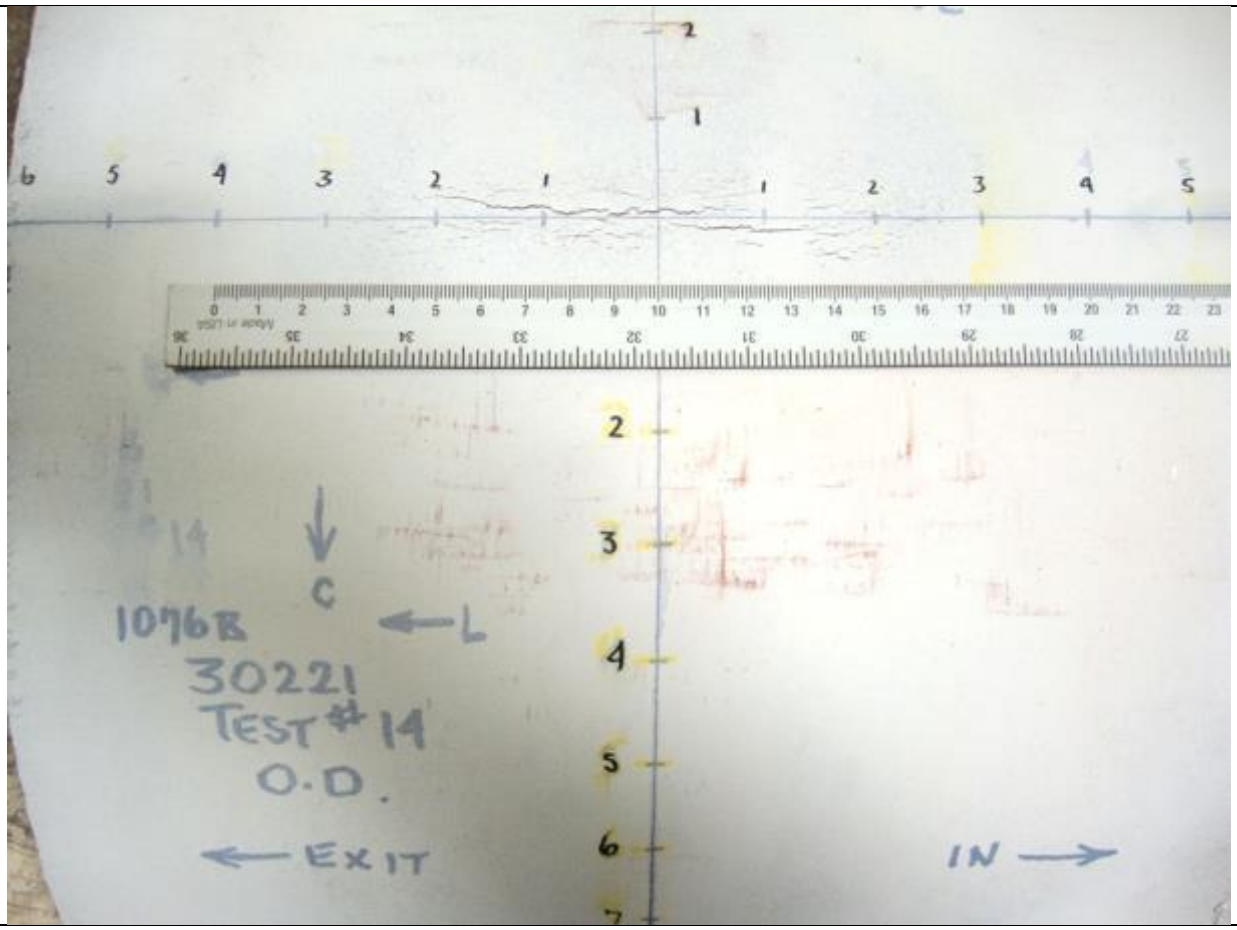


(b)

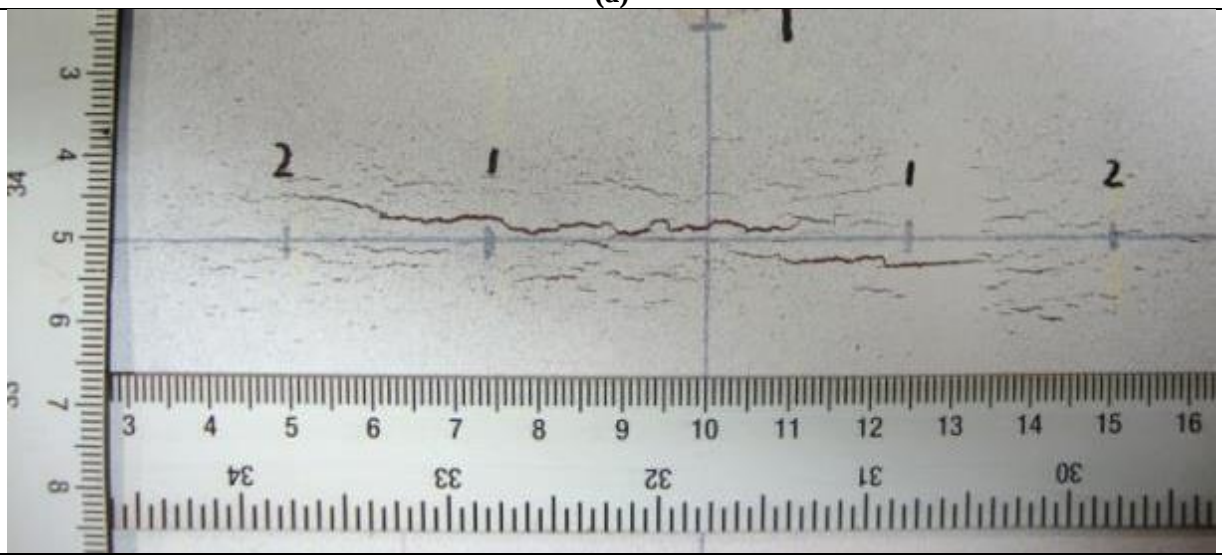


(c)

Figure 11: Test # 13 – Plain Dent – ID MPI – Pipe D
(a) Axial ID cracks as seen on the ID Surface
(b) ID Surface, Enlarged crack photograph - Crack cluster 1
(c) ID Surface, Enlarged crack photograph - Crack 2

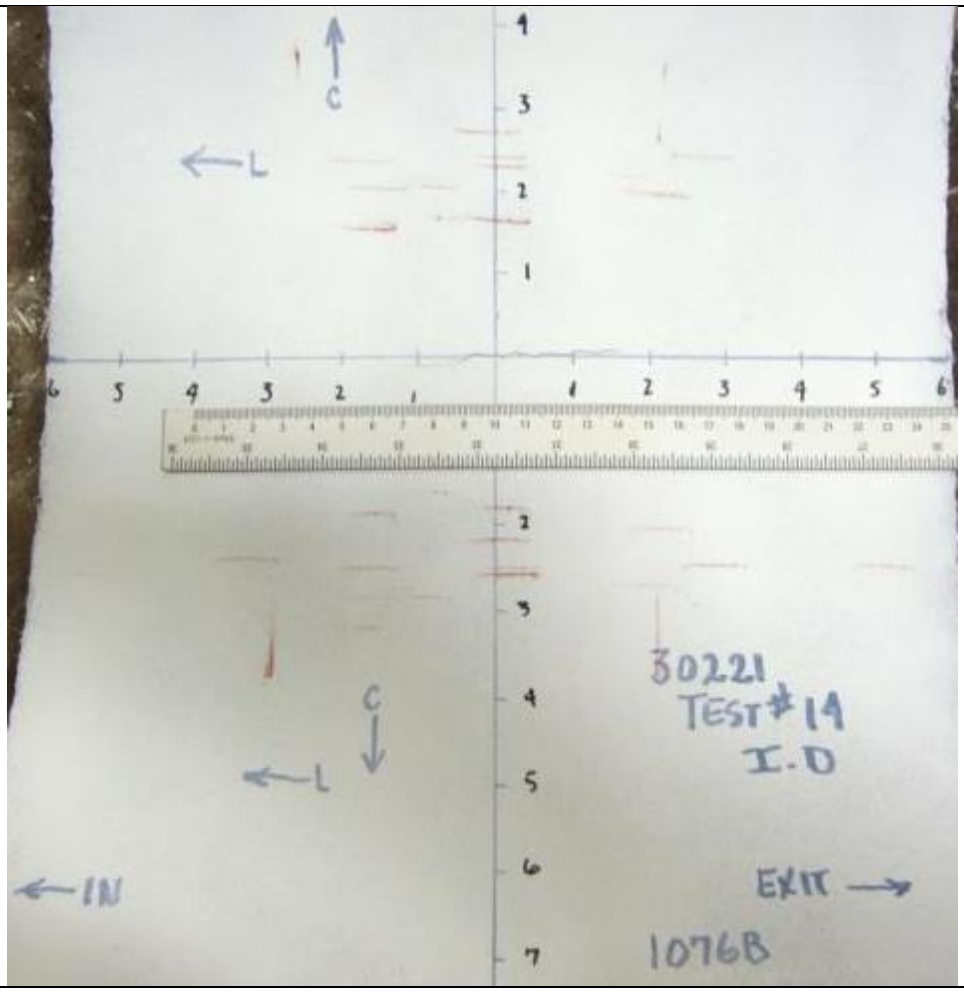


(a)

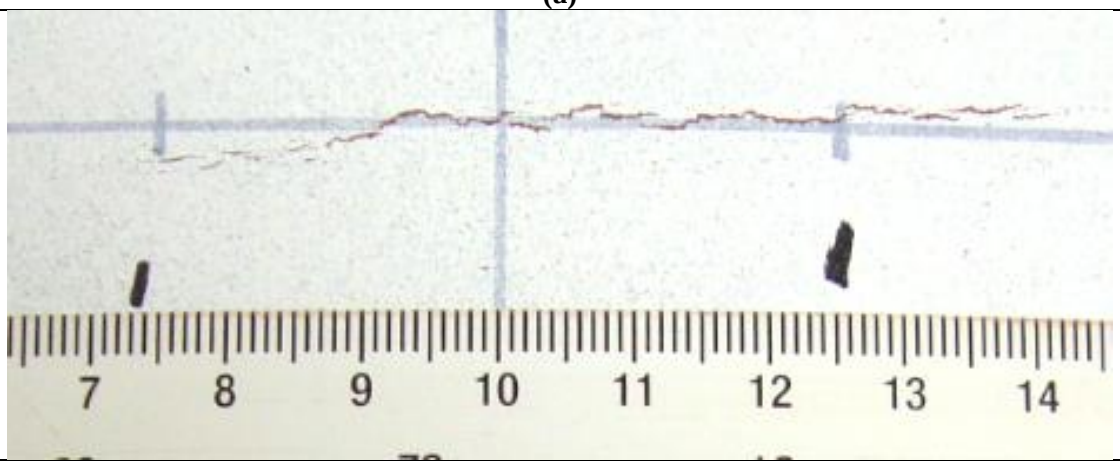


(b)

Figure 12: Test # 14 - Plain Dent – OD MPI – Pipe F
(a) Axial OD crack as seen on the OD Surface OD Surface, Enlarged crack photograph

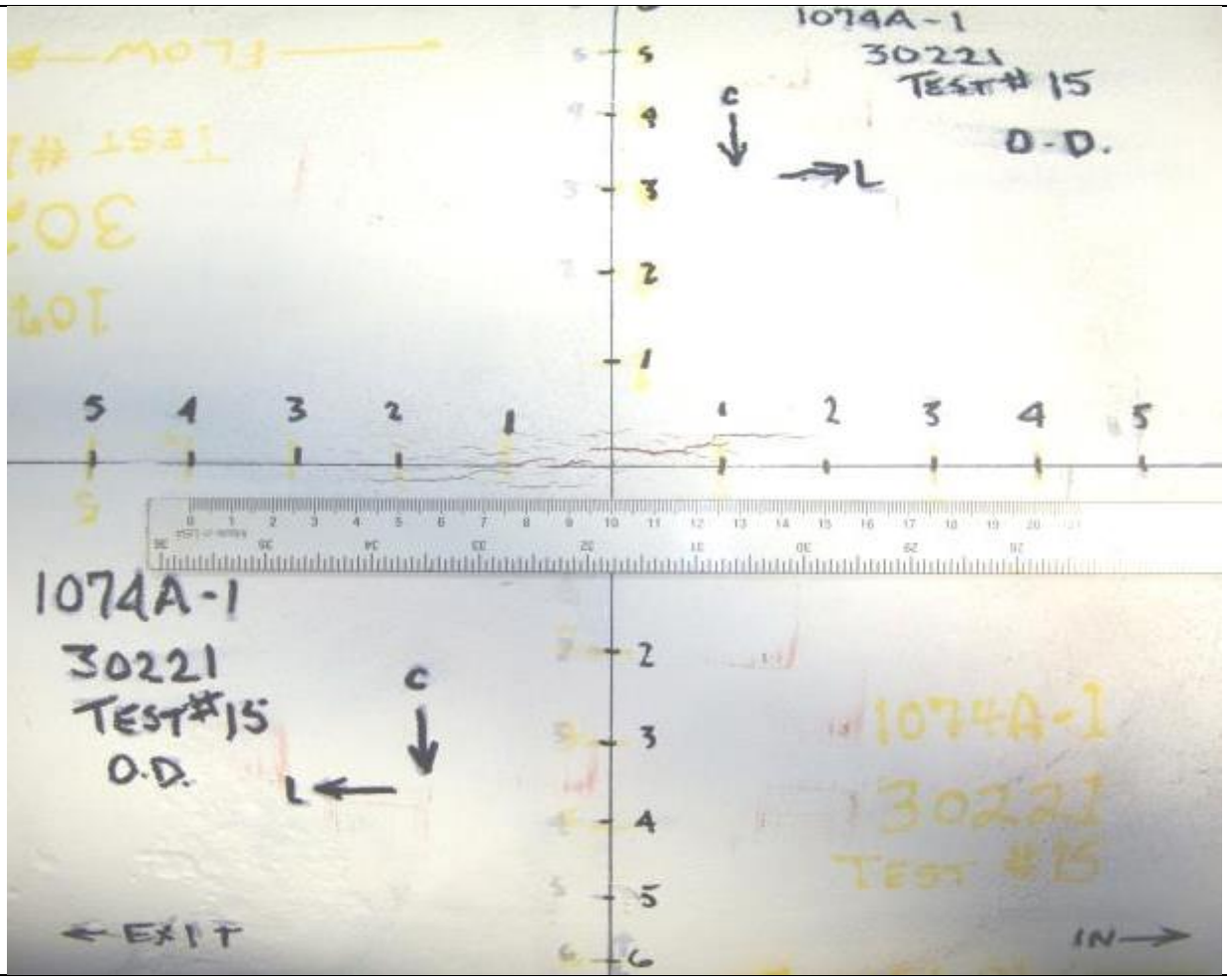


(a)

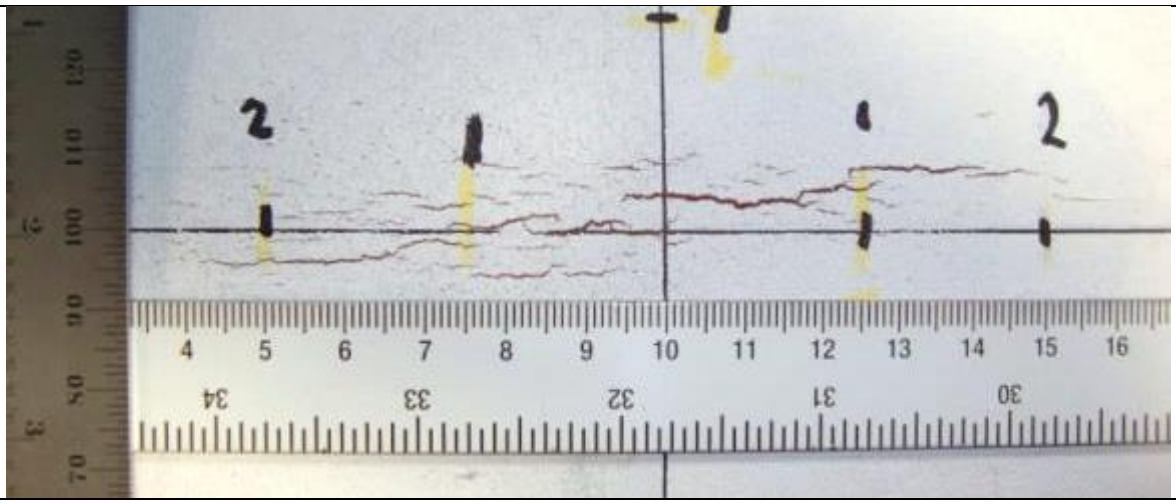


(b)

Figure 13: Test # 14 - Plain Dent – ID MPI – Pipe F
(a) Axial OD crack as seen on the ID Surface (b) ID Surface, Enlarged crack photograph

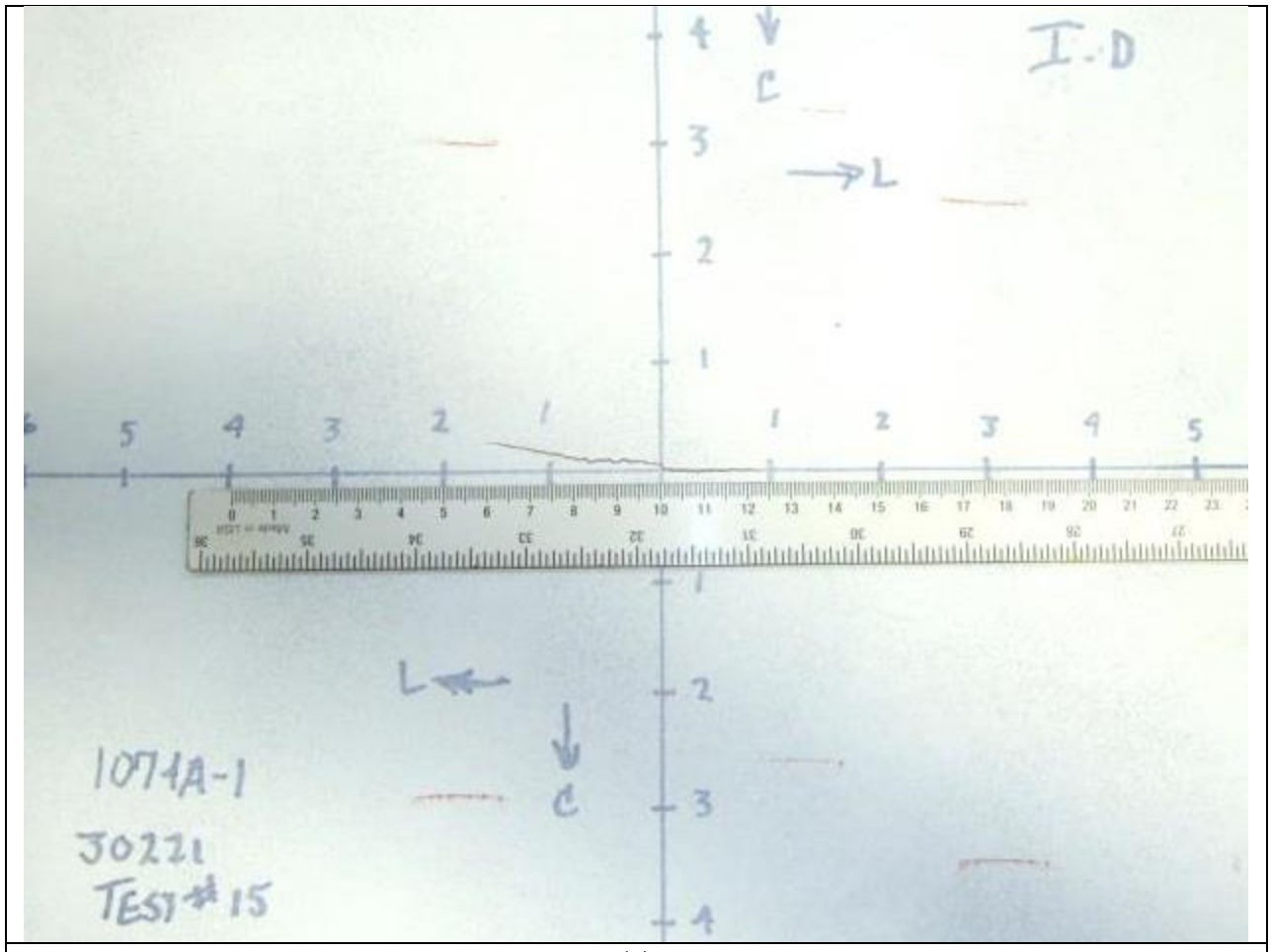


Test # 15:

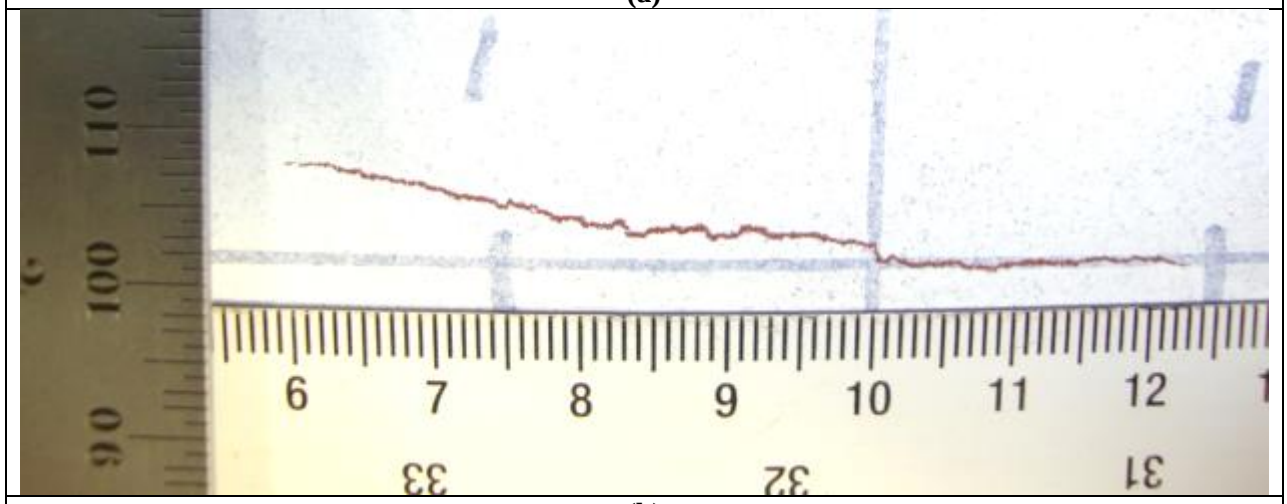


(b)

Figure 14: Test # 15 - Plain Dent – OD MPI – Pipe F
(a) Axial OD crack as seen on the OD Surface (b) OD Surface, Enlarged crack photograph

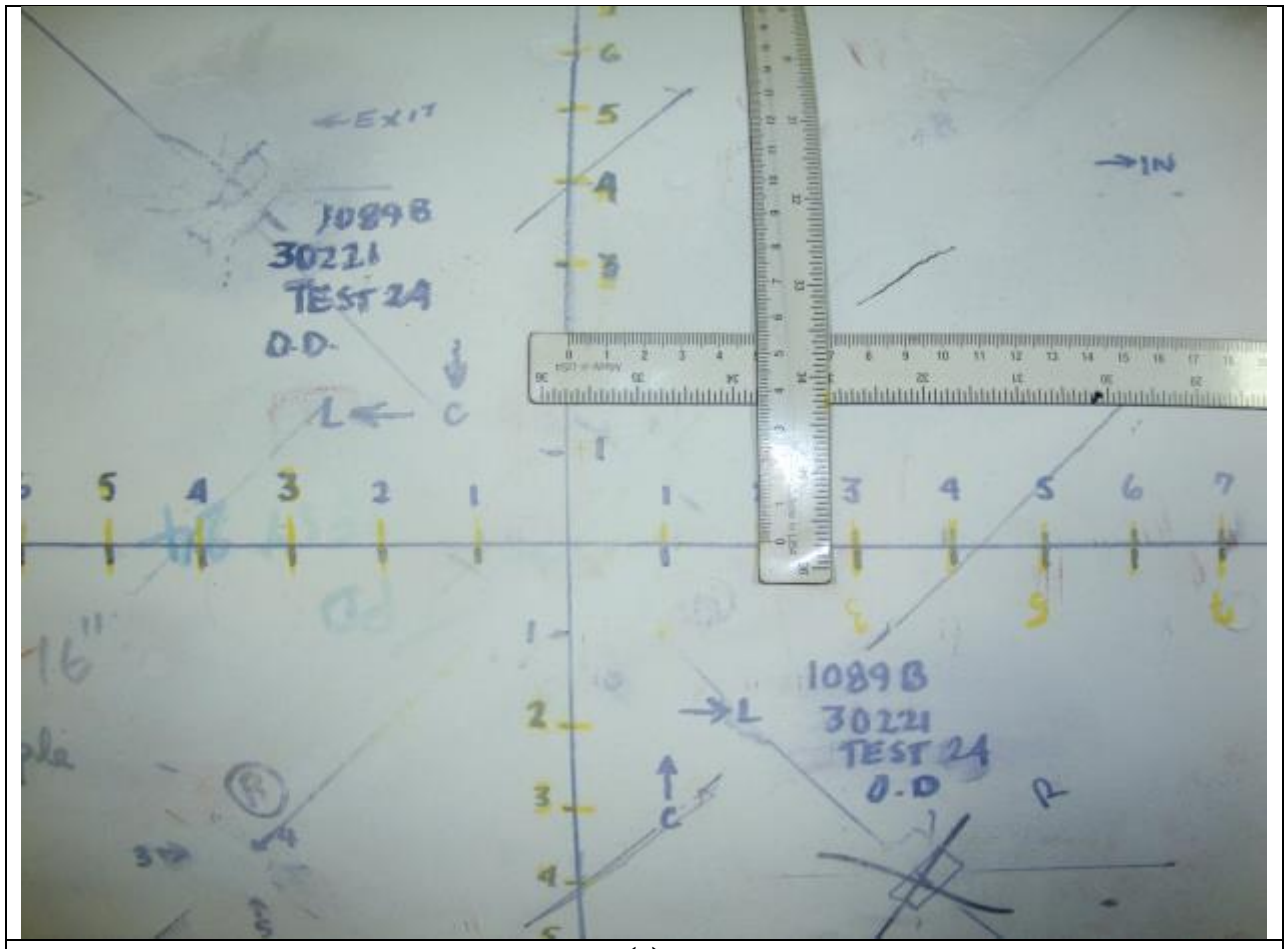


(a)

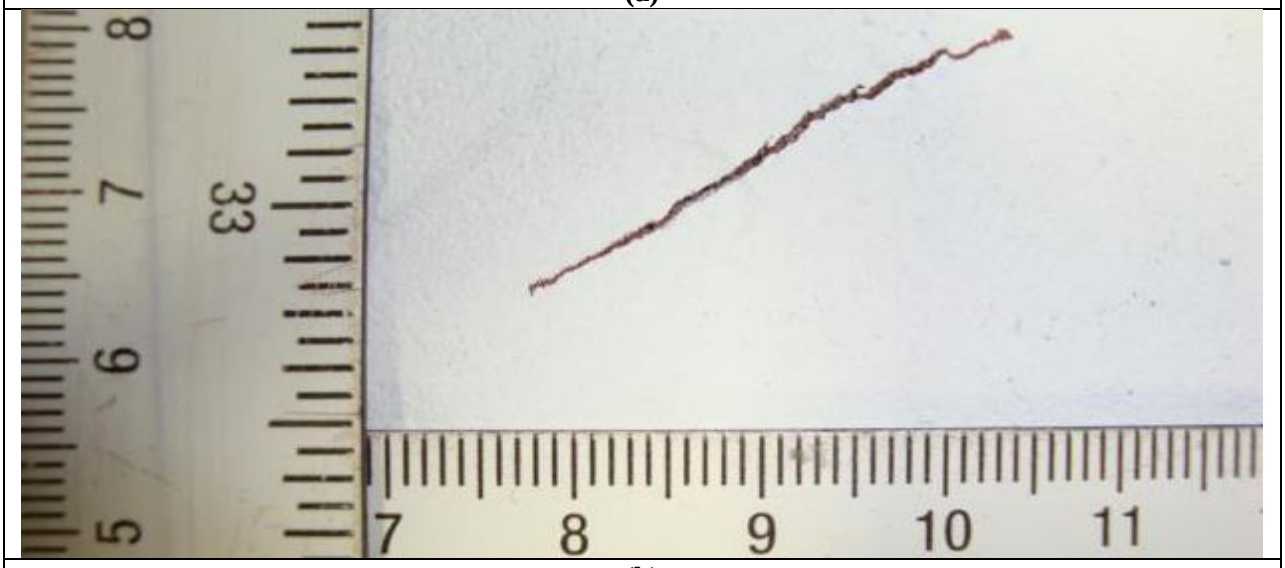


(b)

Figure 15: Test # 15 - Plain Dent – ID MPI – Pipe F
(a) Axial OD crack as seen on the ID Surface (b) ID Surface, Enlarged crack photograph

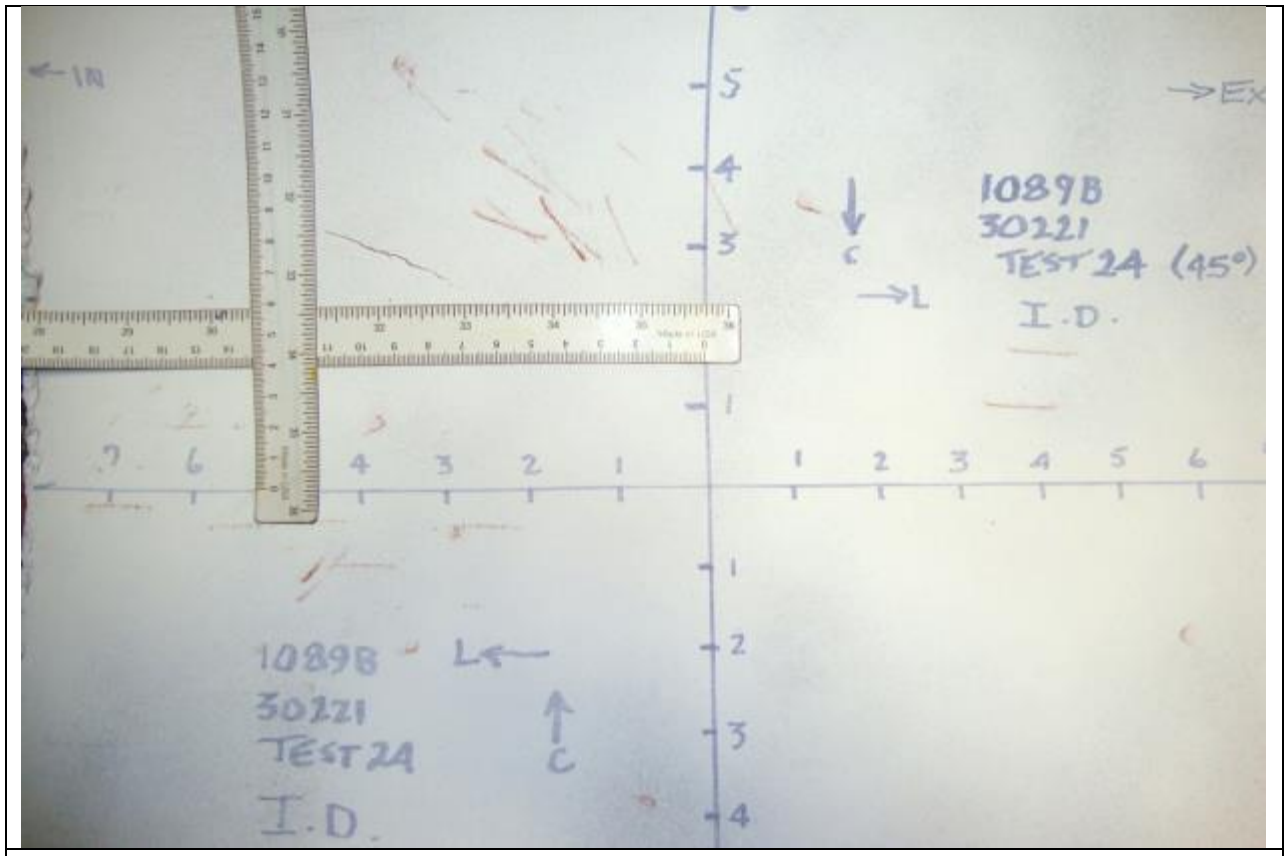


(a)

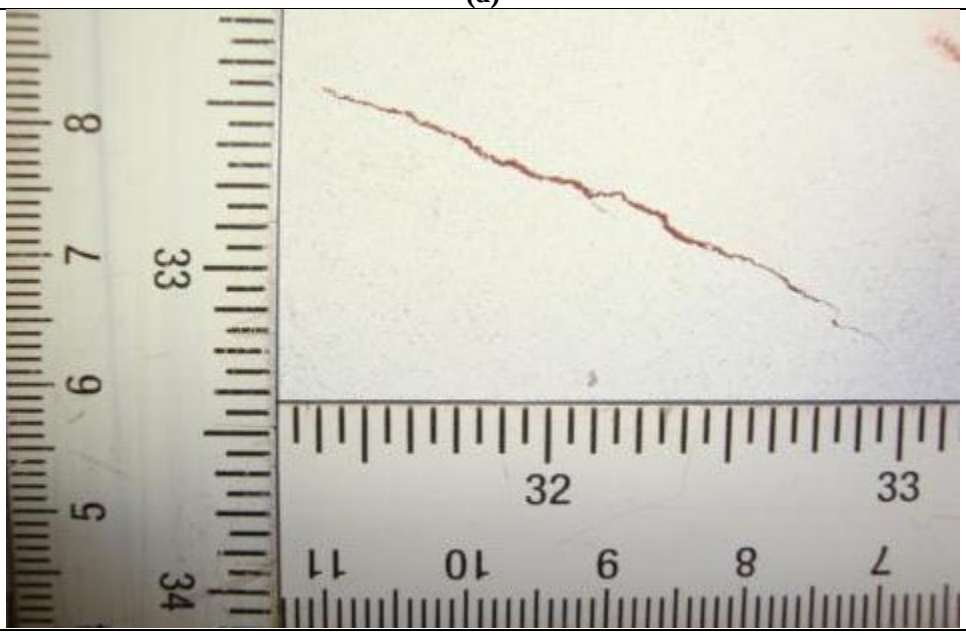


(b)

Figure 16: Test # 24 - Plain Dent – OD MPI – Pipe F
(a) 32 degree angle ID crack as seen from the OD Surface (b) OD Surface, Enlarged crack photograph

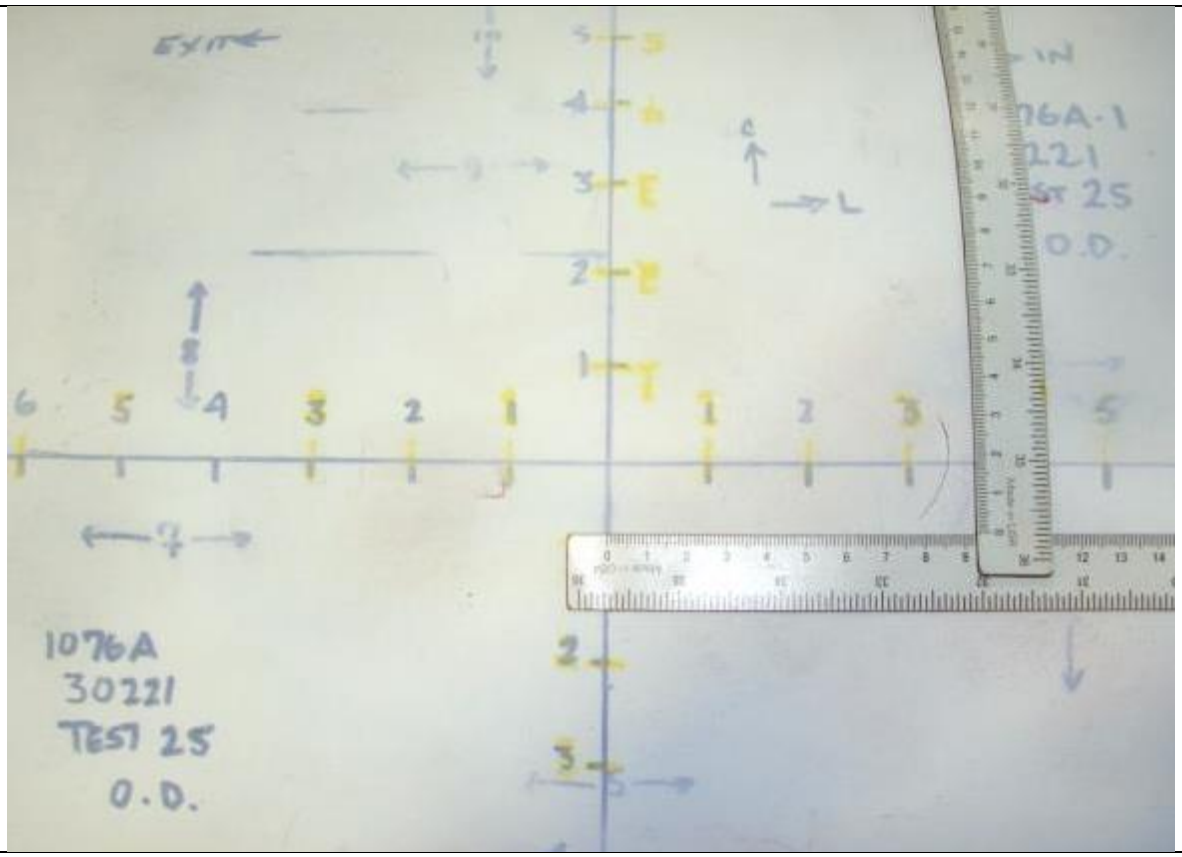


(a)

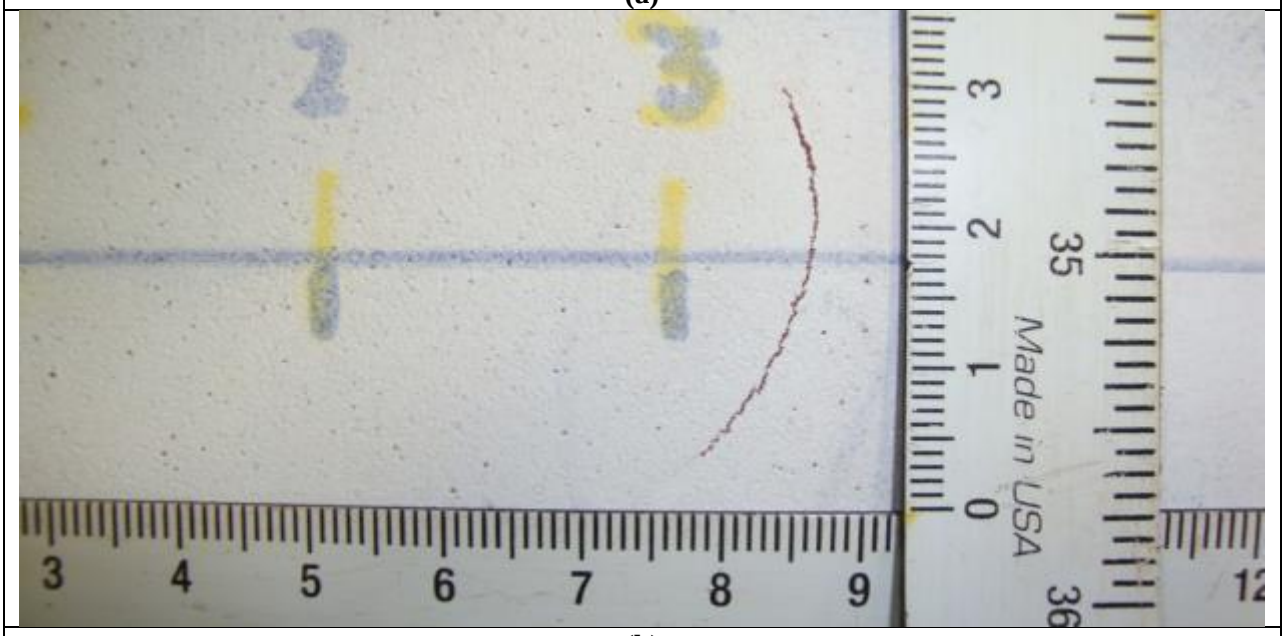


(b)

Figure 17: Test # 24 - Plain Dent – ID MPI – Pipe F
(a) 32 degree angle ID crack as seen from the ID Surface (b) ID Surface, Enlarged crack photograph

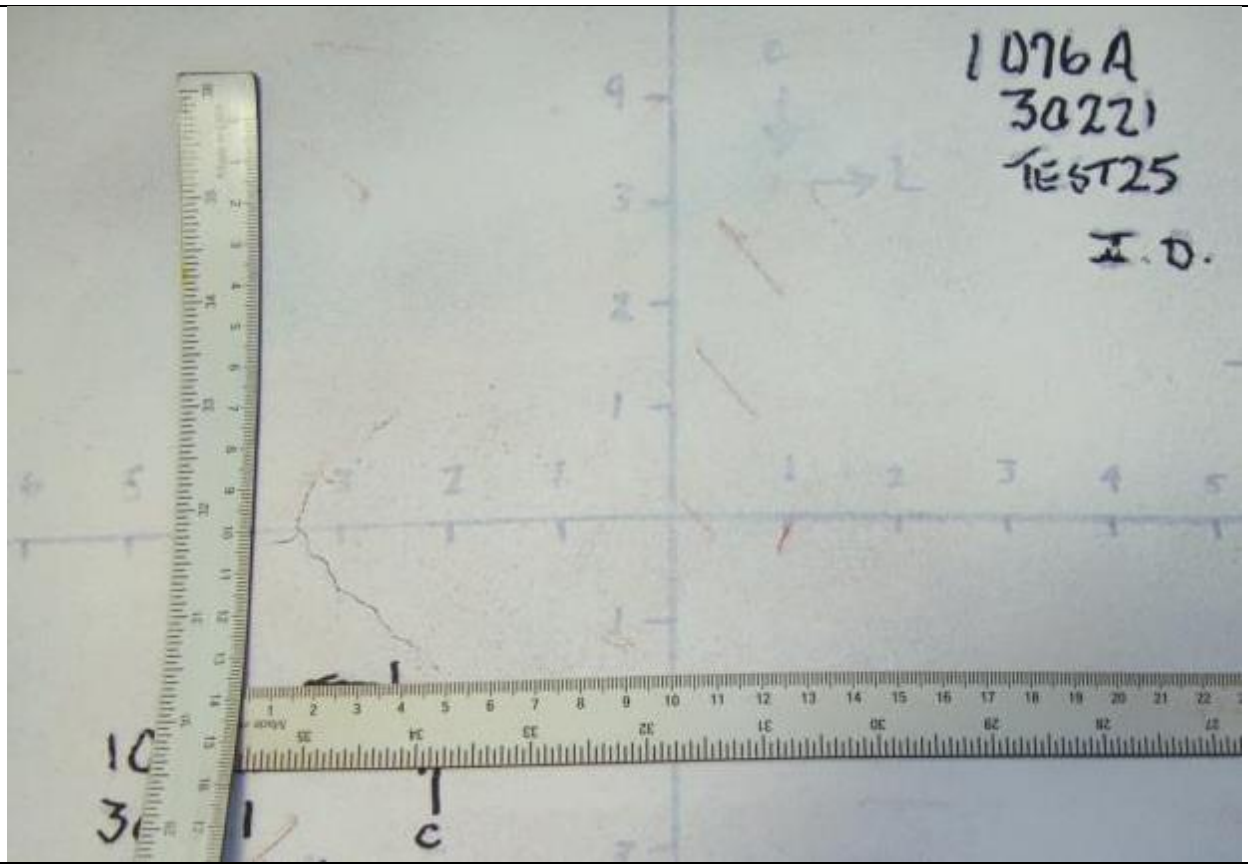


(a)

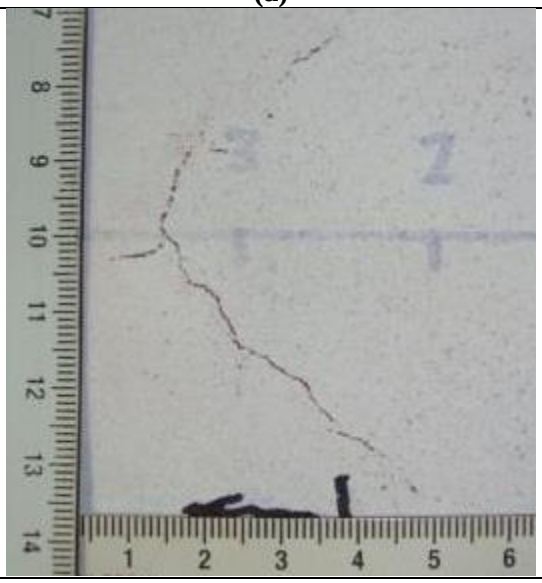


(b)

Figure 18: Test # 25 - Plain Dent – OD MPI – Pipe F
(a) Circumferential ID crack as seen on OD Surface (b) OD Surface, Enlarged crack photograph



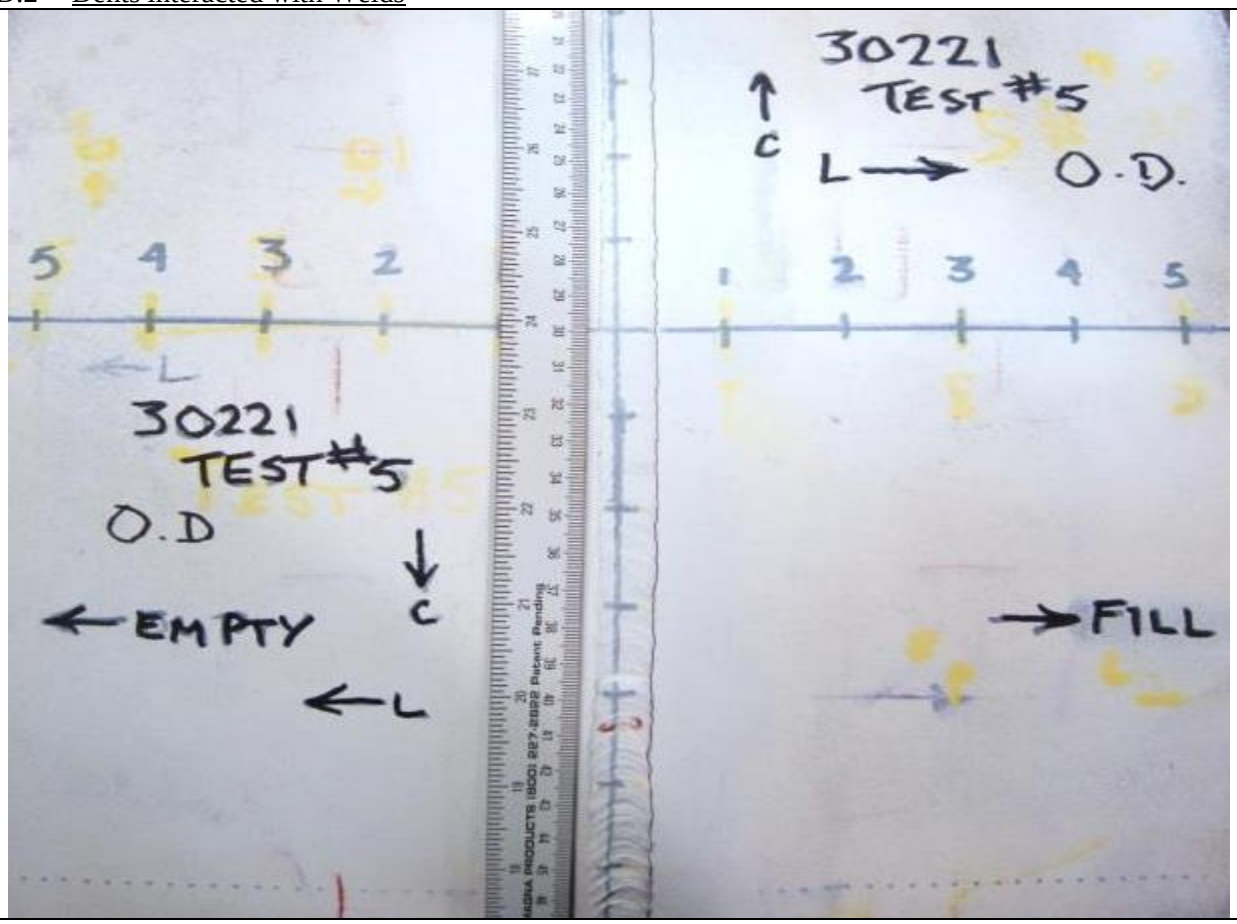
(a)



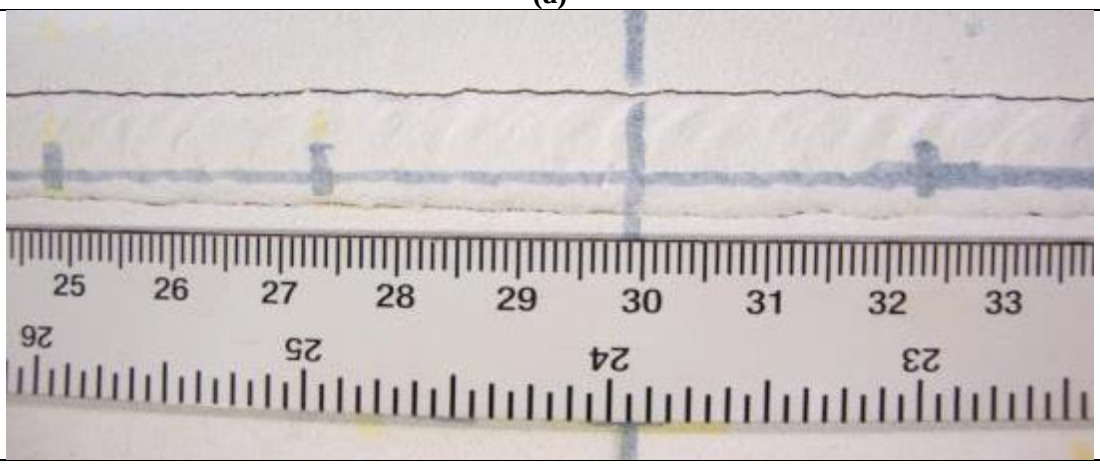
(b)

Figure 19: Test # 25 - Plain Dent – ID MPI – Pipe F
(a) Circumferential ID crack as seen on ID Surface (b) ID Surface, Enlarged crack photograph

D.2 Dents interacted with Welds

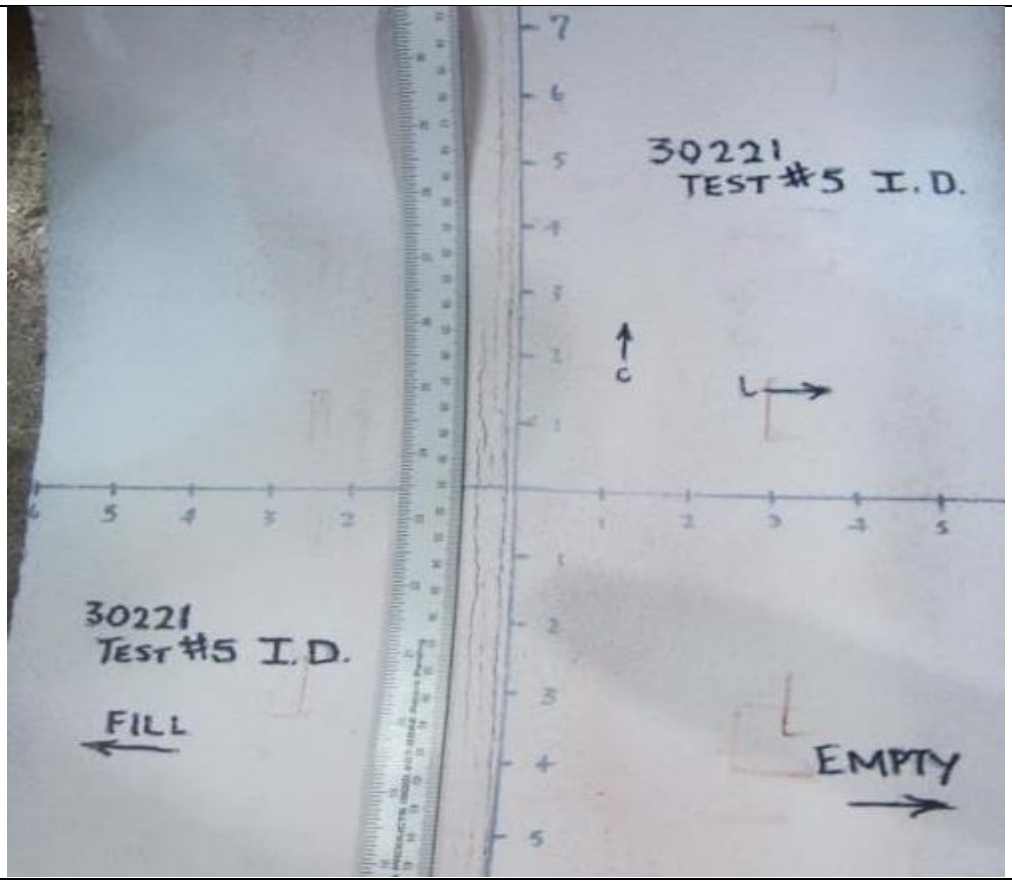


(a)

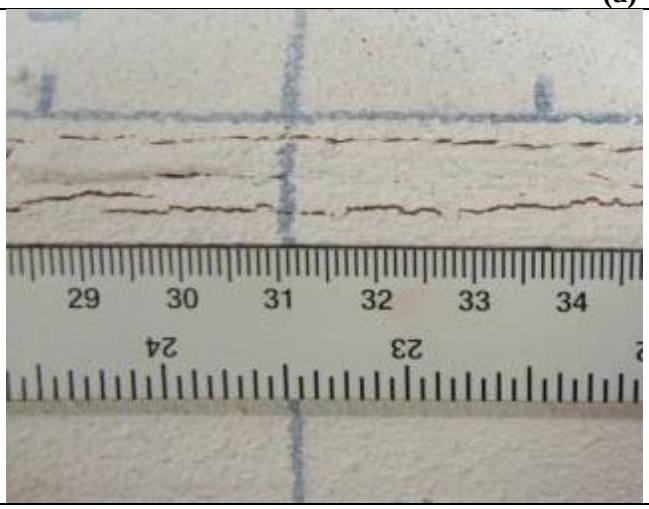


(b)

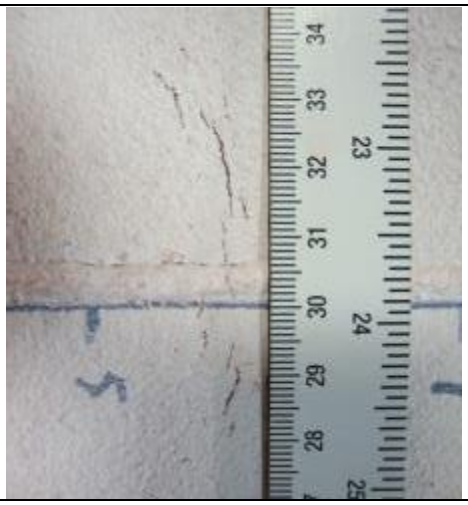
Figure 20: Test # 5 – Dent interacted with GW - OD MPI – Pipe D
(a) Circumferential OD crack as seen on the OD Surface
(b) OD Surface, (Enlarged crack photograph - Fill Side Girth Weld Toe)



(a)

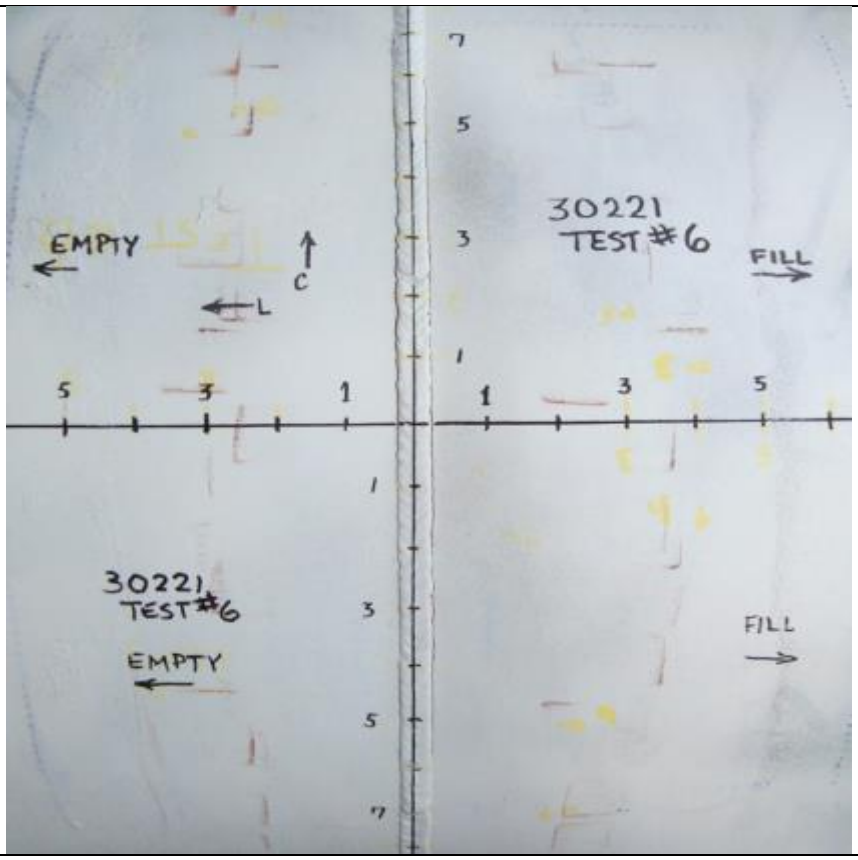


(b)

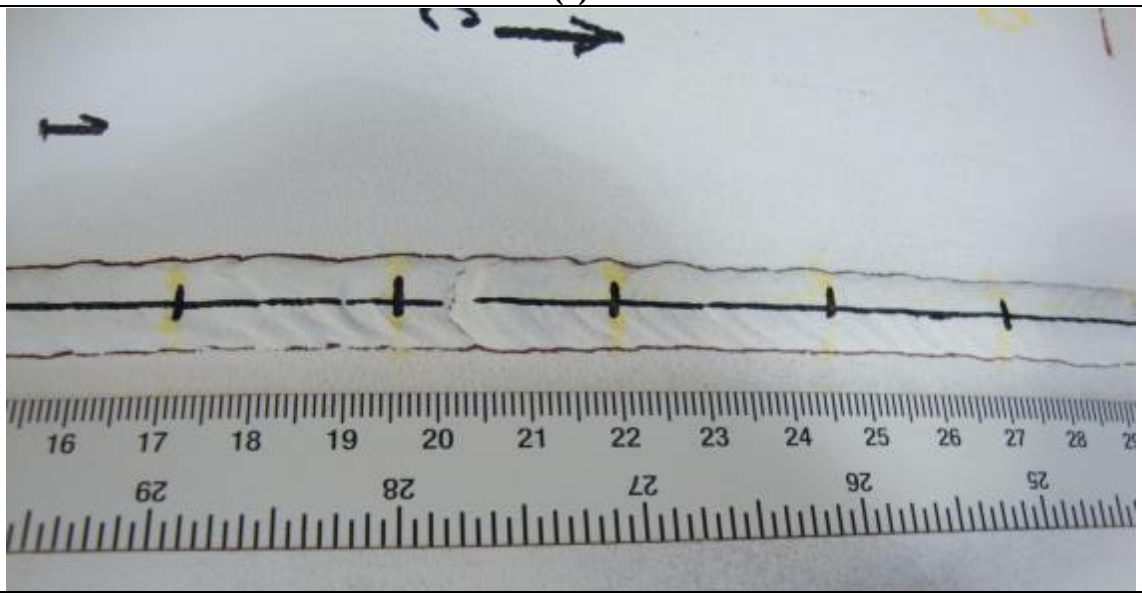


(c)

Figure 21: Test # 5 – Dent interacted with GW - ID MPI – Pipe D
(a) Circumferential OD crack as seen on the ID Surface
(b) ID Surface, Enlarged crack photograph (Girth Weld Crack)
(c)Axial ID crack on the ID Surface, (Enlarged crack photograph)

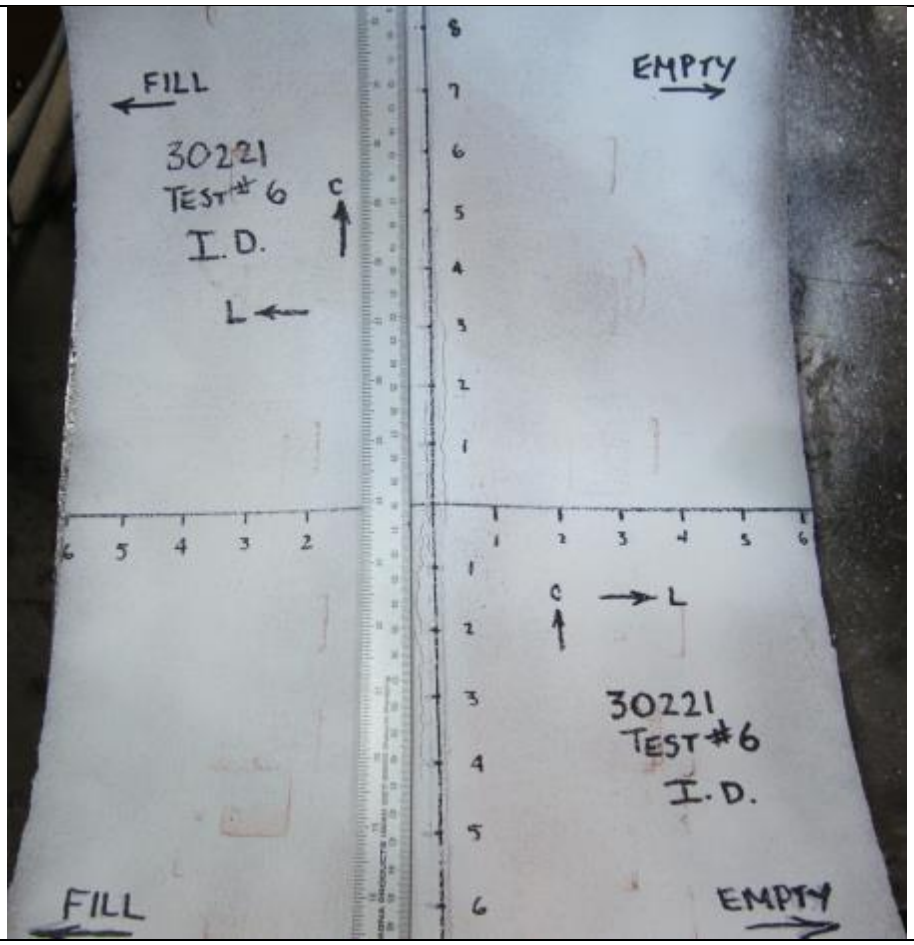


(a)

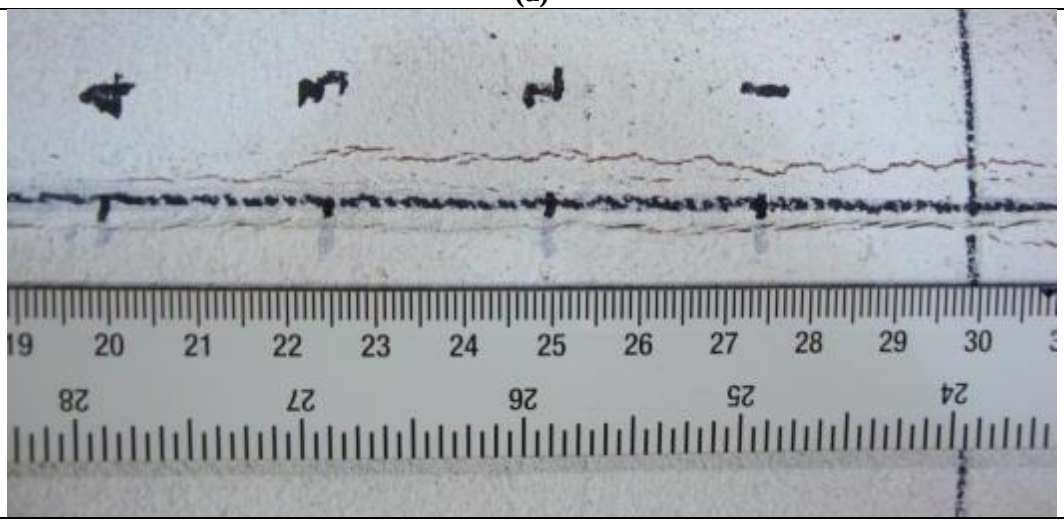


(b)

Figure 22: Test # 6 – Dents interacted with GW – OD MPI – Pipe D
(a) Circumferential OD Crack as seen on the OD Surface (b) OD Surface (Enlarged crack photograph)

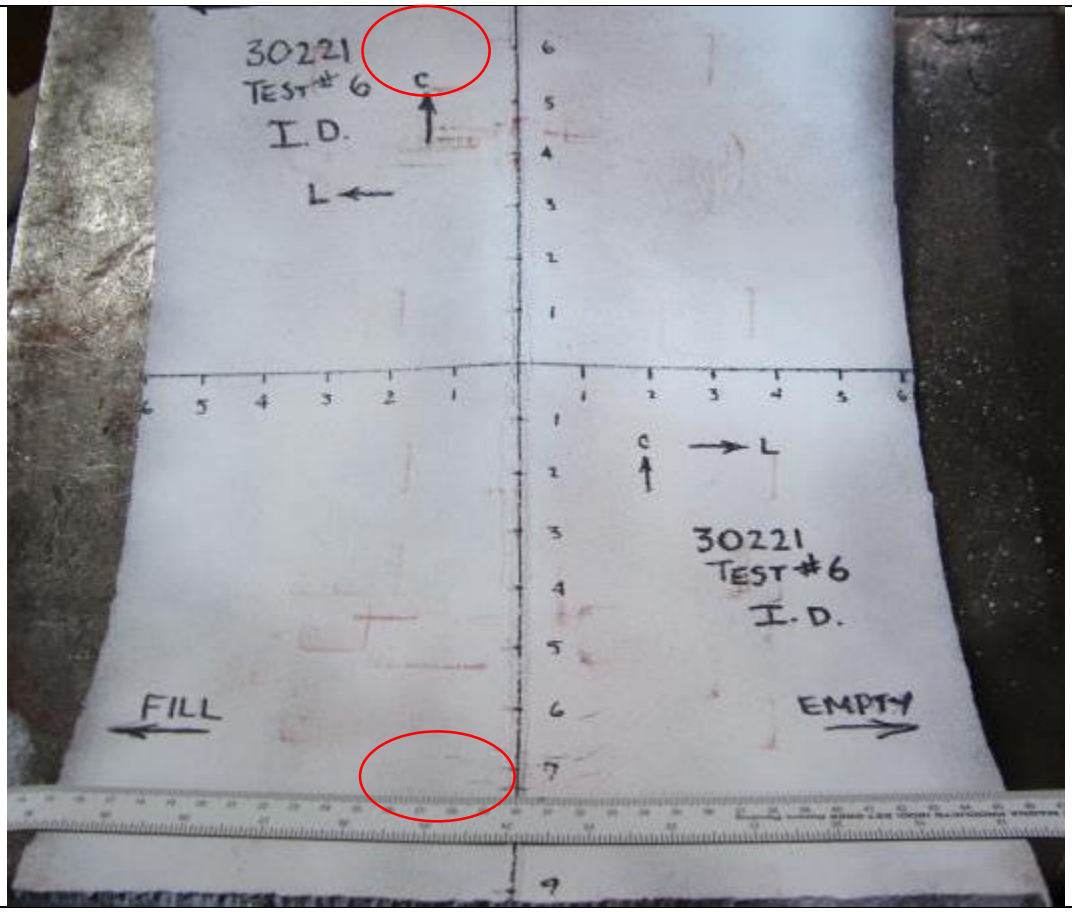


(a)

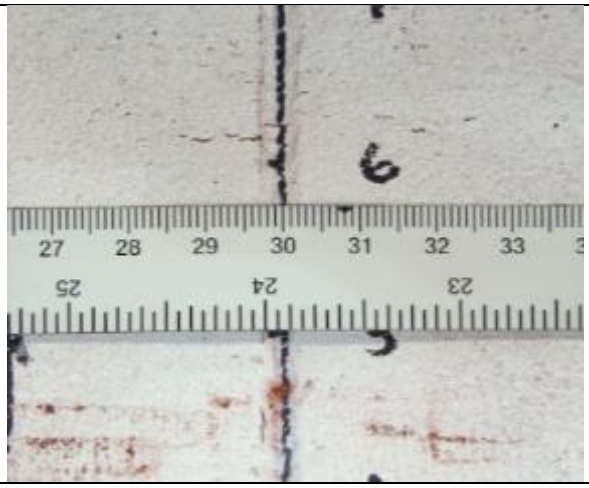


(b)

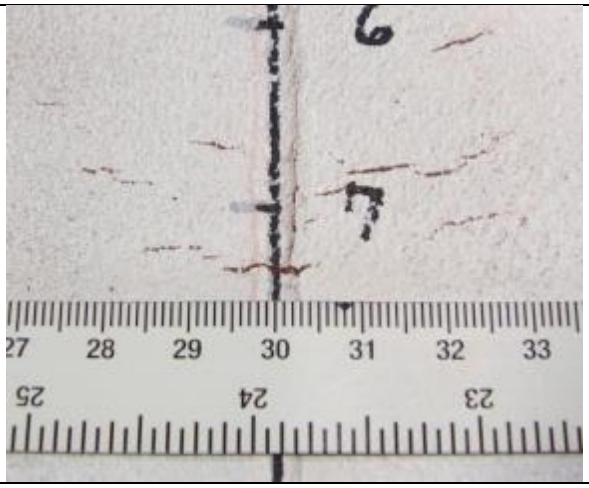
Figure 23: Test # 6 – Dents interacted with GW – Circumferential Crack - ID MPI – Pipe D (a) Circumferential OD Crack as seen on the ID Surface (b) OD Surface (Enlarged crack photograph)



(a)

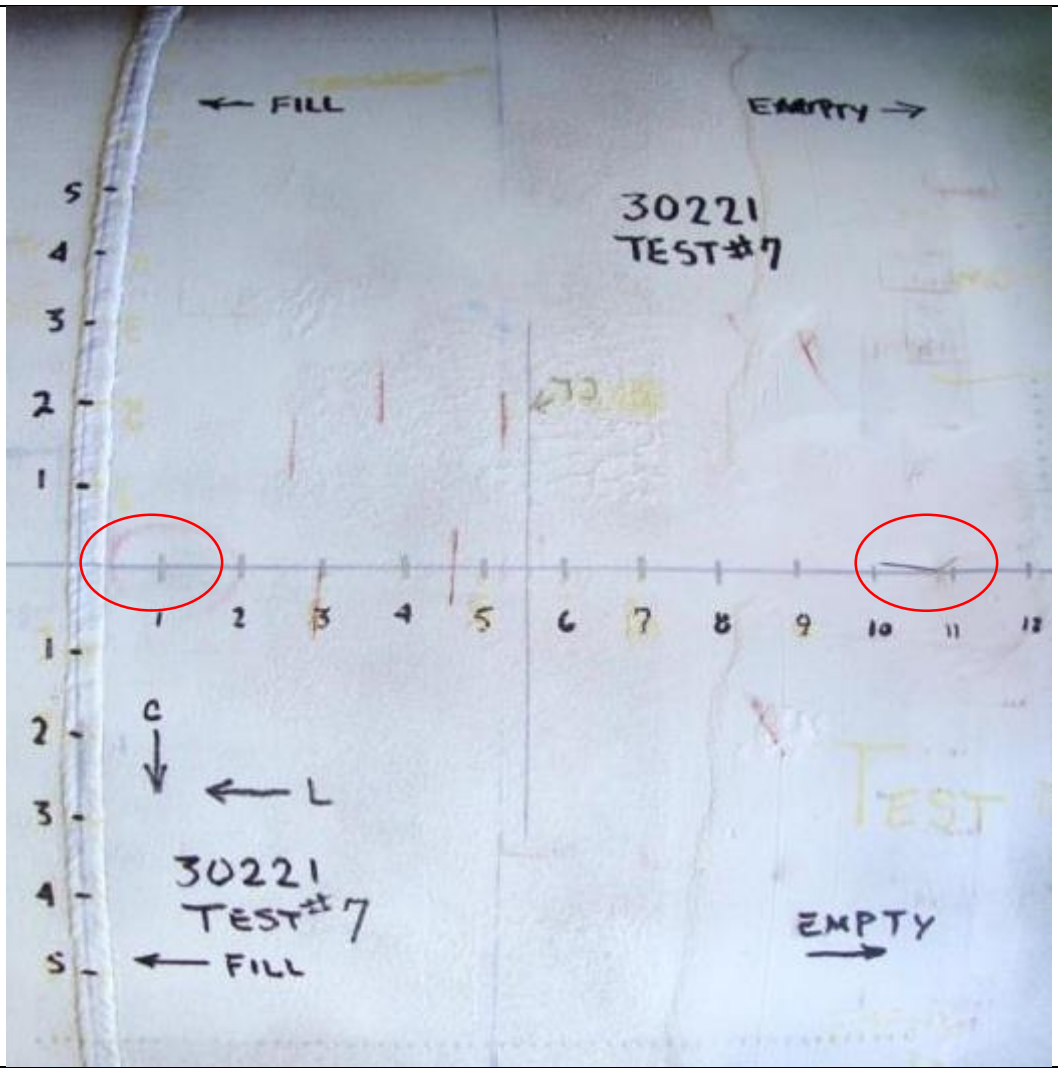


(b)

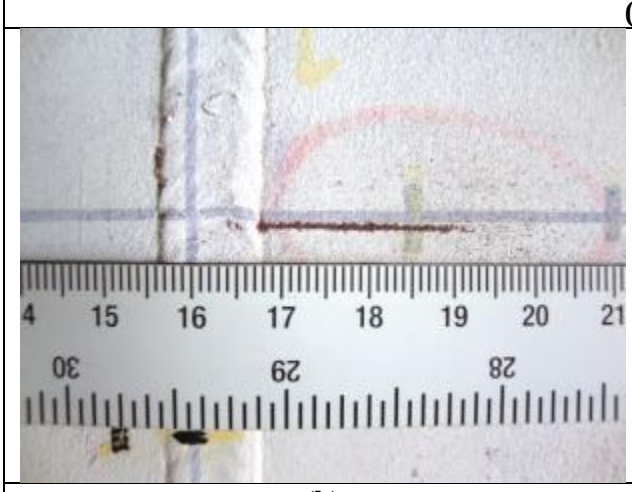


(c)

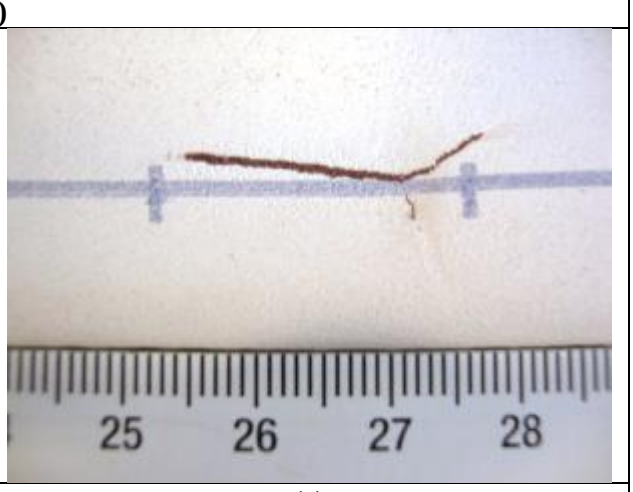
Figure 24: Test # 6 – Dents interacted with GW – Axial Crack - ID MPI – Pipe D
(a) Axial ID Crack as seen on the ID Surface
(b) ID Surface, Enlarged crack photograph (Axial Crack 1)
(c) ID Surface, Enlarged crack photograph (Axial crack 2)



(a)

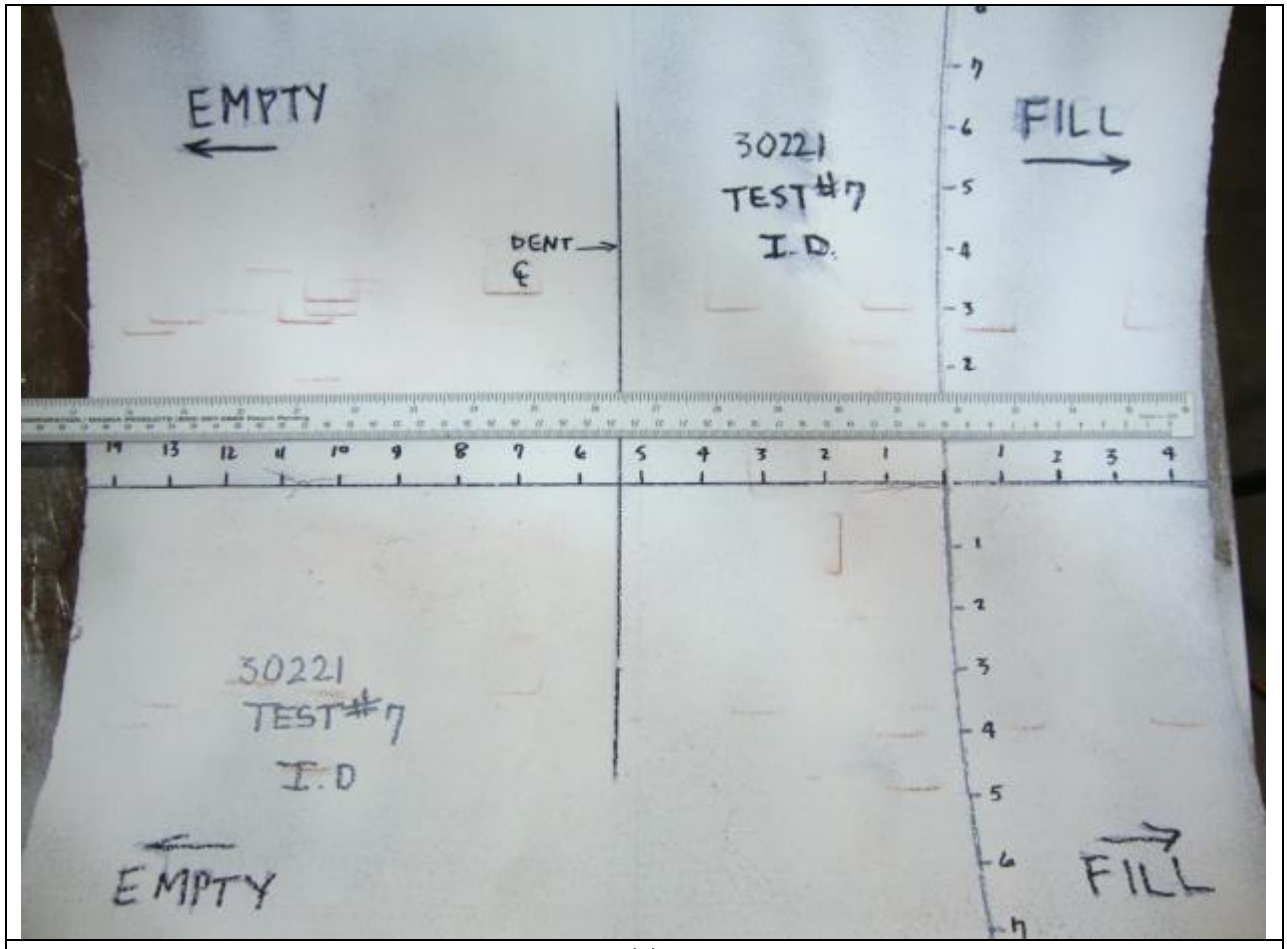


(b)

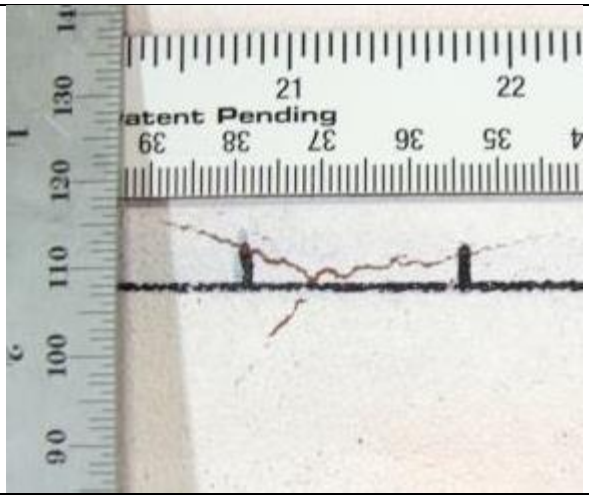


(c)

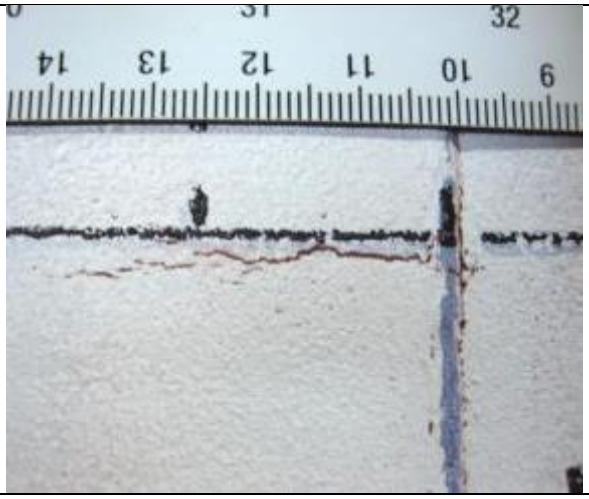
Figure 25: Test # 7 - Dents interacted with GW - OD MPI – Pipe D
(a) Axial ID Crack as seen on the OD Surface
(b) OD Surface, Enlarged crack photograph (Fill Side Crack)
(c) OD Surface, Enlarged crack photograph (Exit Side Crack)



(a)

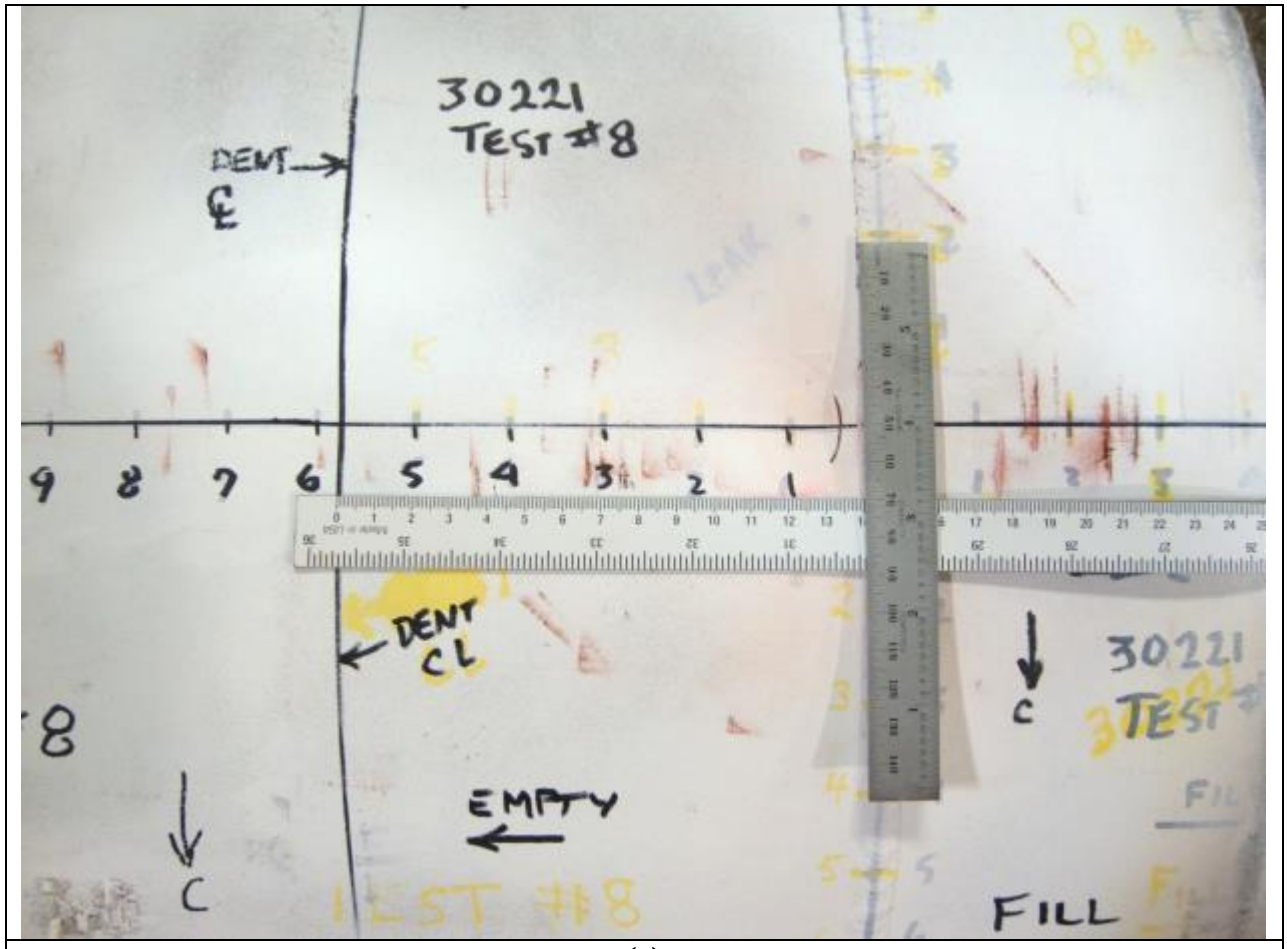


(b)

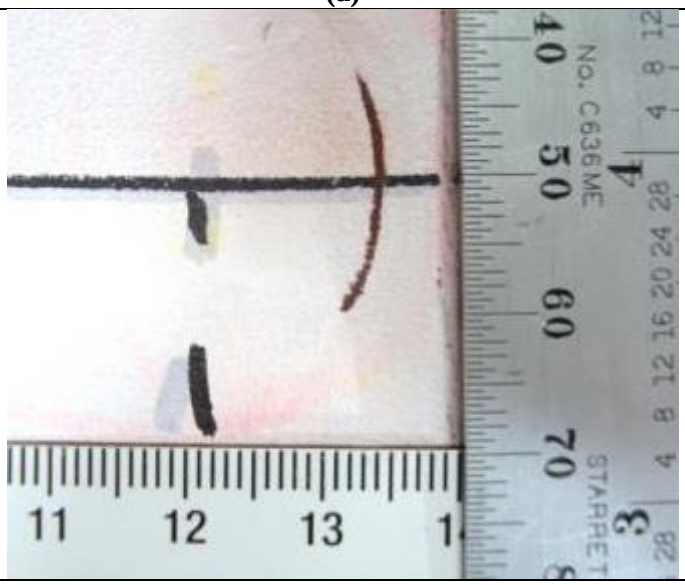


(c)

Figure 26: Test # 7 - Dents interacted with GW - ID MPI - Pipe D
(a) Axial ID crack as seen on the ID Surface
(b) ID Surface, Enlarged crack photograph (Outlet Side Crack)
(c) ID Surface, Enlarged crack photograph (Inlet Side Crack)

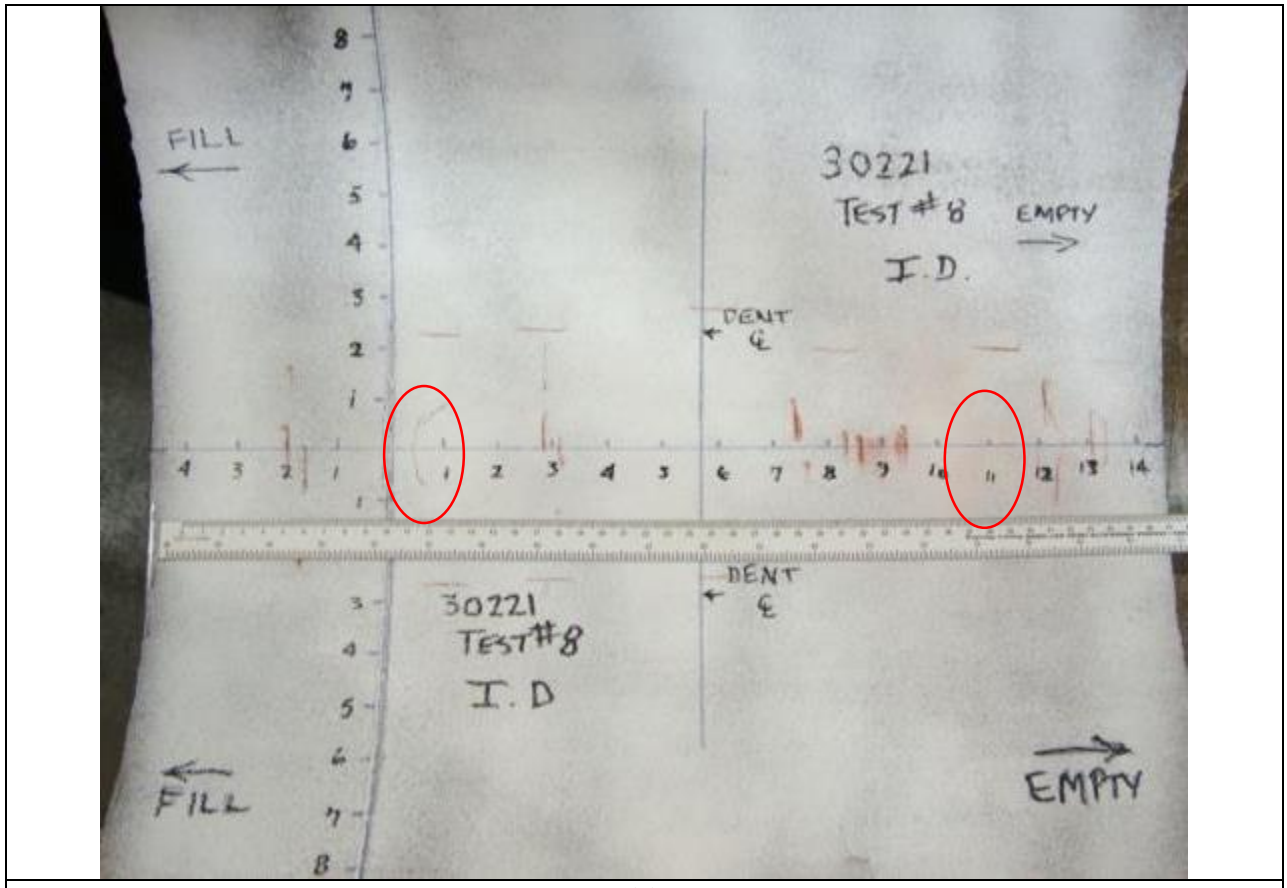


(a)

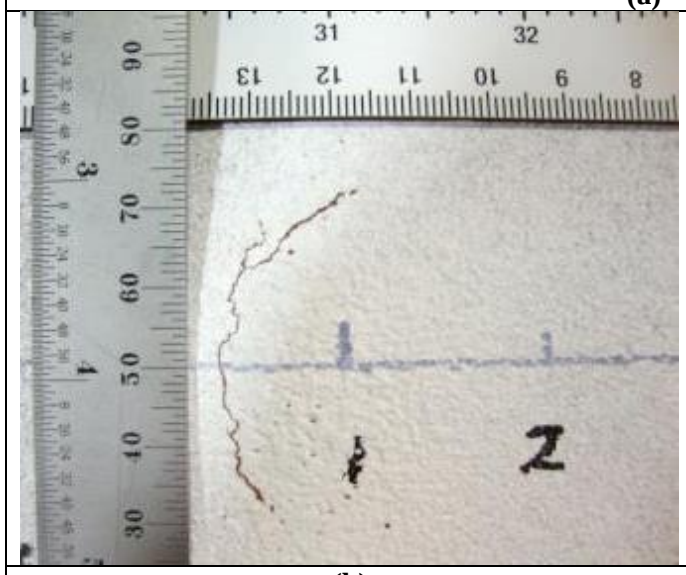


(b)

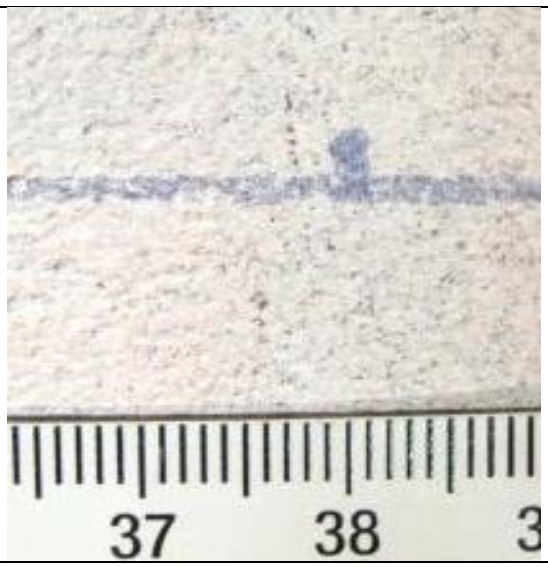
Figure 27: Test # 8 - Dents interacted with GW – OD MPI – Pipe D
(a) Circumferential ID crack as seen on the OD Surface (b) OD Surface, Enlarged crack photograph



(a)

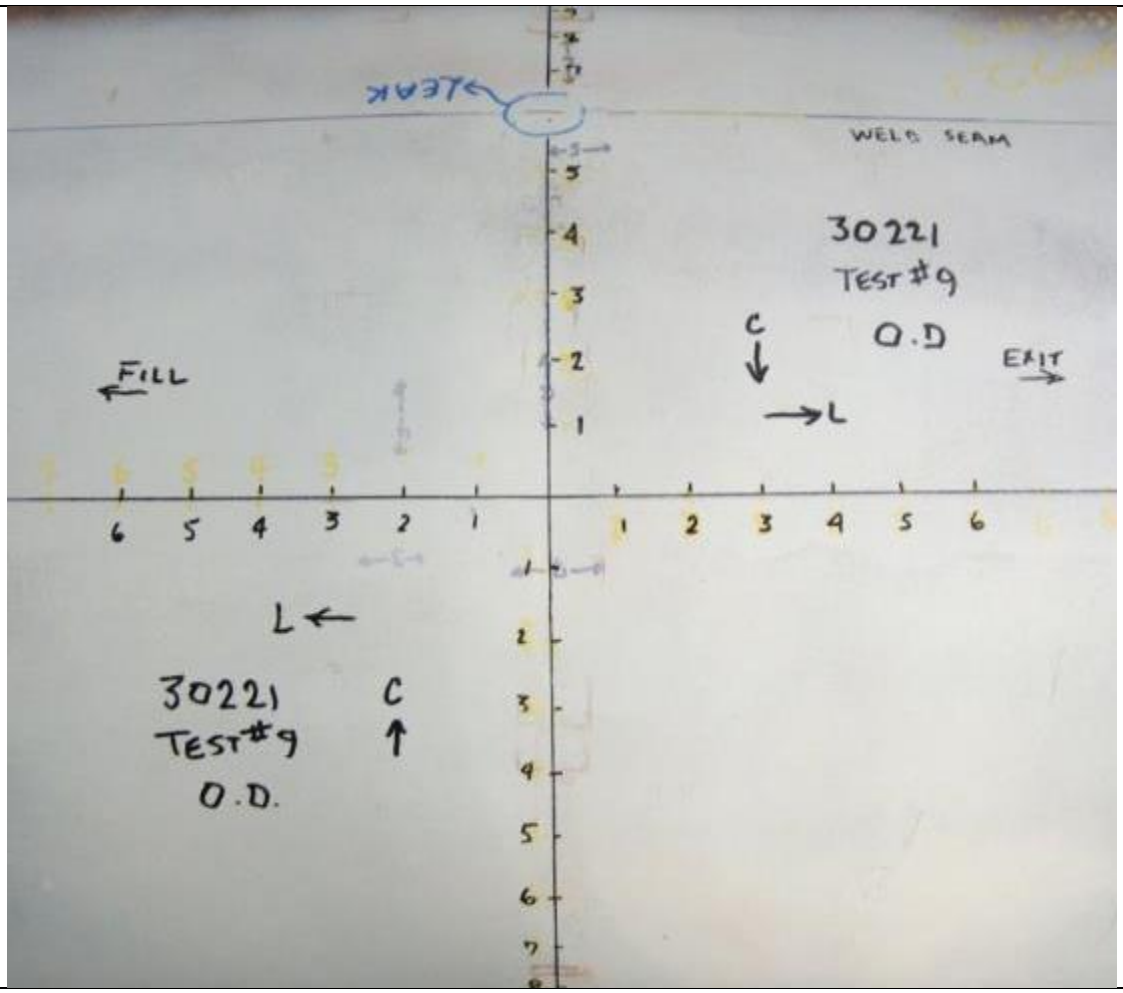


(b)

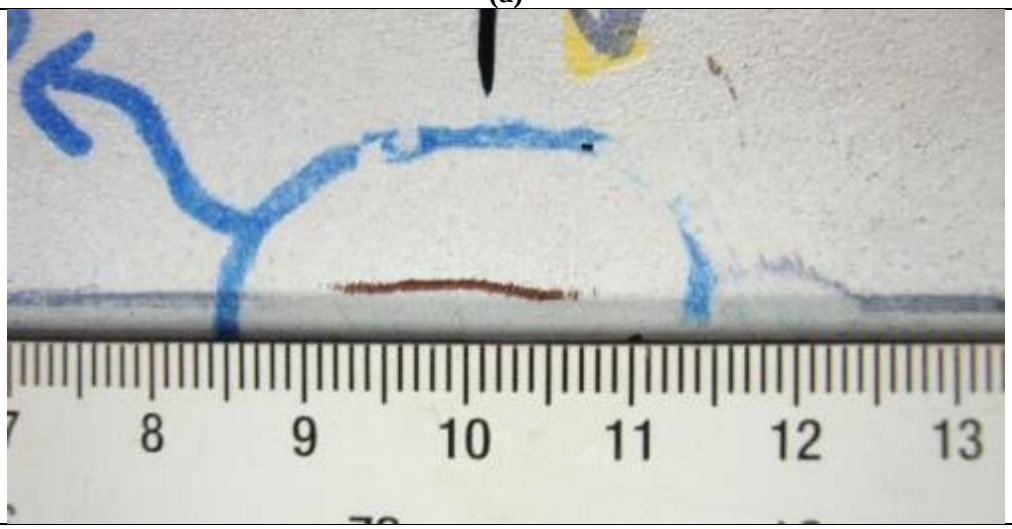


(c)

Figure 28: Test # 8 - Dents interacted with GW – ID MPI – Pipe D
(a) Circumferential ID crack as seen on ID Surface
(b) ID Surface, Enlarged crack photograph (Fill Side Crack)
(c) ID Surface, Enlarged crack photograph (Exit Side Crack)

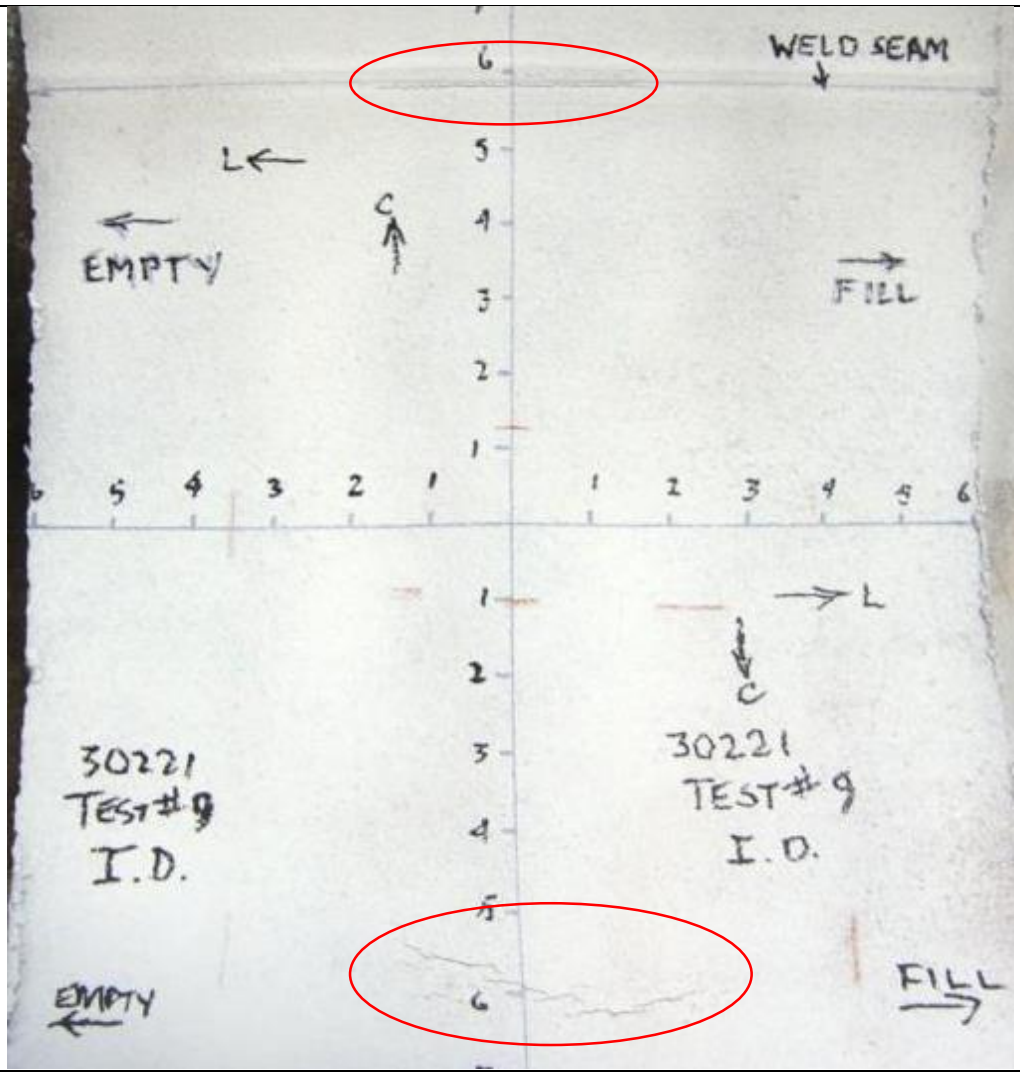


(a)

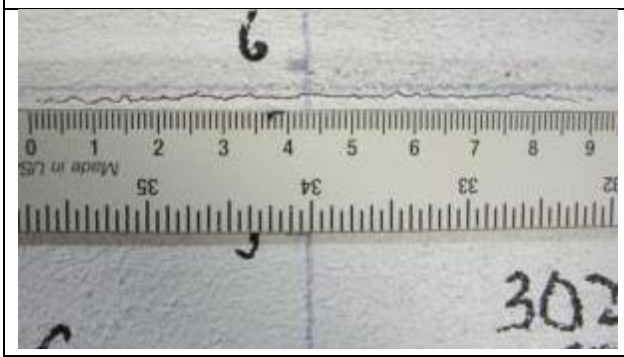


(b)

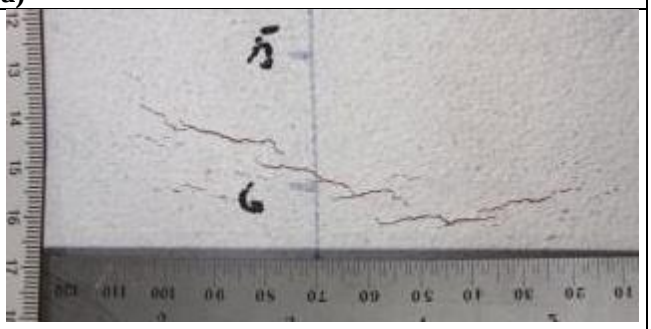
Figure 29: Test # 9 - Dent interacted with LSW – OD MPI – Pipe D
(a) Axial ID crack as seen on the OD Surface (b) OD Surface, Enlarged crack photograph



(a)

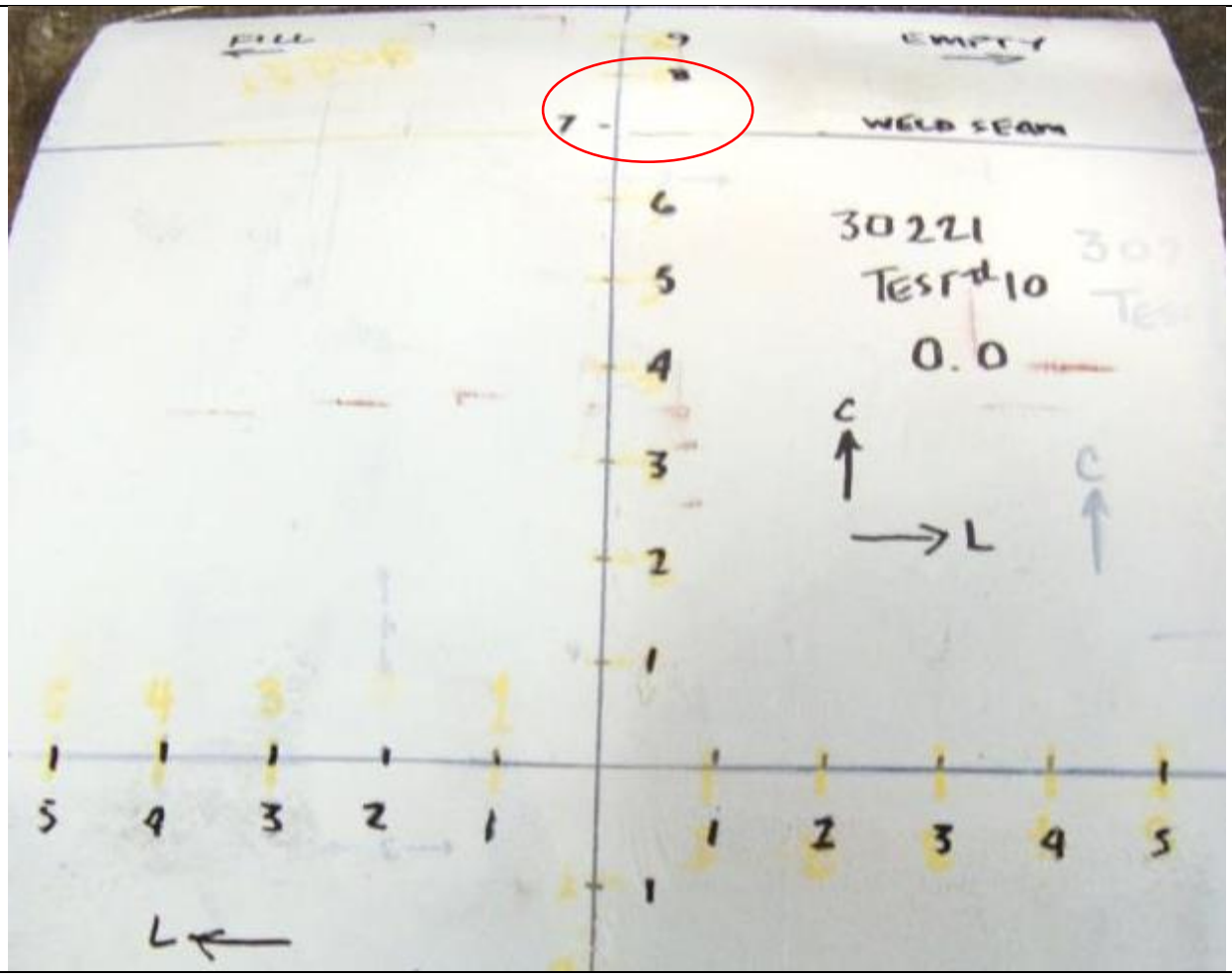


(b)

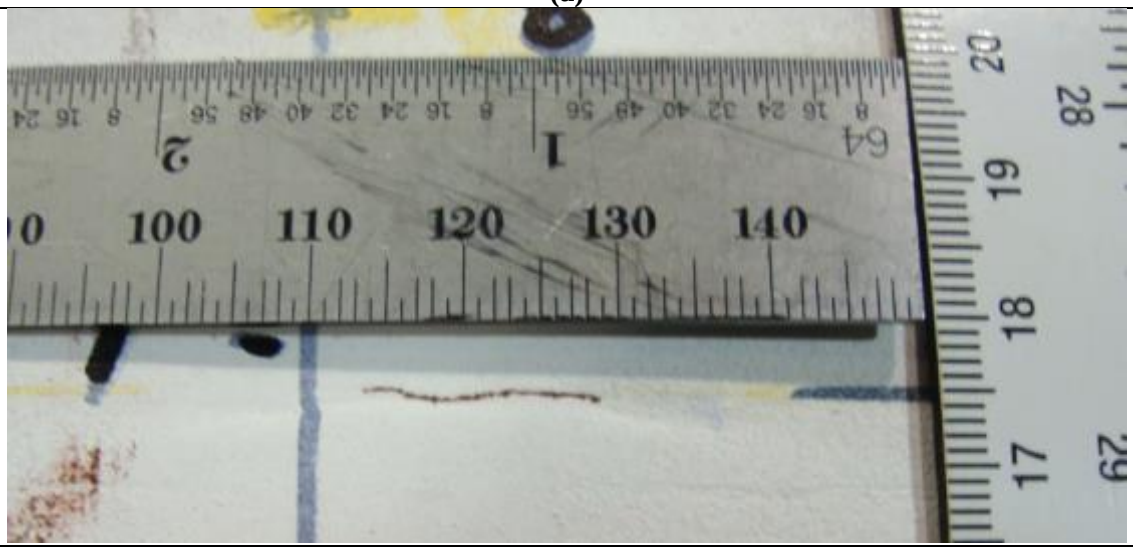


(c)

Figure 30: Test # 9 - Dent interacted with LSW – ID MPI – Pipe D
(a) Axial ID crack as seen on the ID Surface
(b) ID Surface, Enlarged crack photograph (Axial crack 1)
(c) ID Surface, Enlarged crack photograph (Axial crack 2)

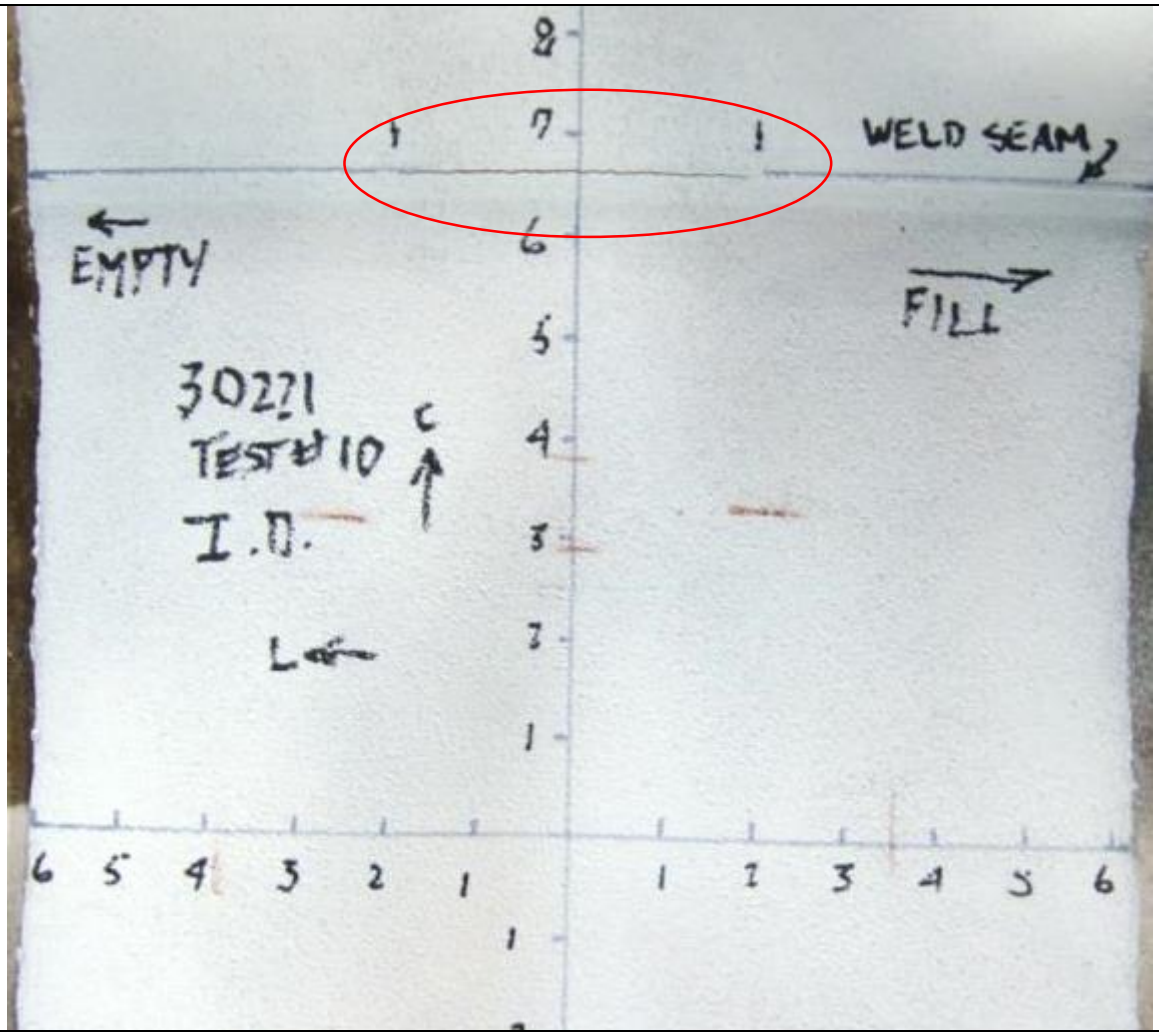


(a)

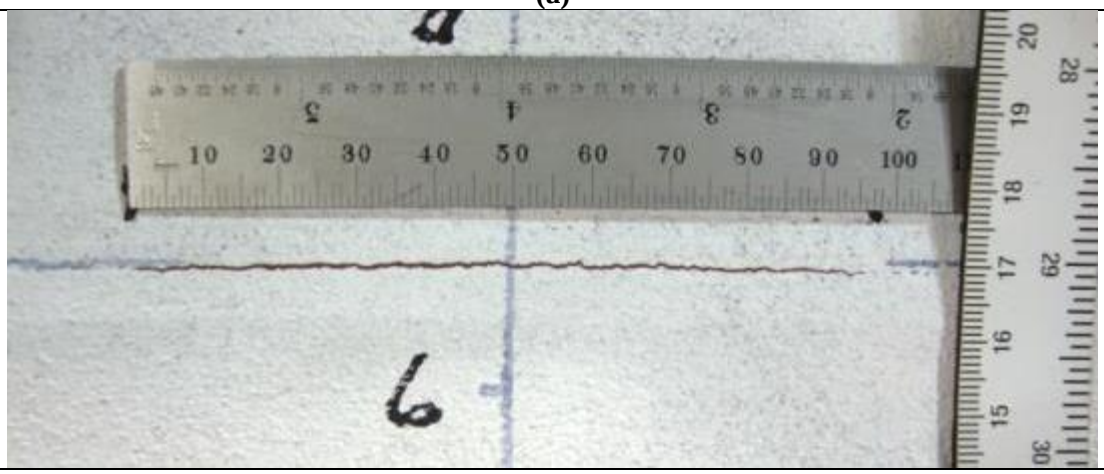


(b)

Figure 31: Test # 10 – Dent interacted with LSW - OD MPI – Pipe D
(a) Axial ID crack as seen on the OD Surface (b) OD Surface, Enlarged crack photograph

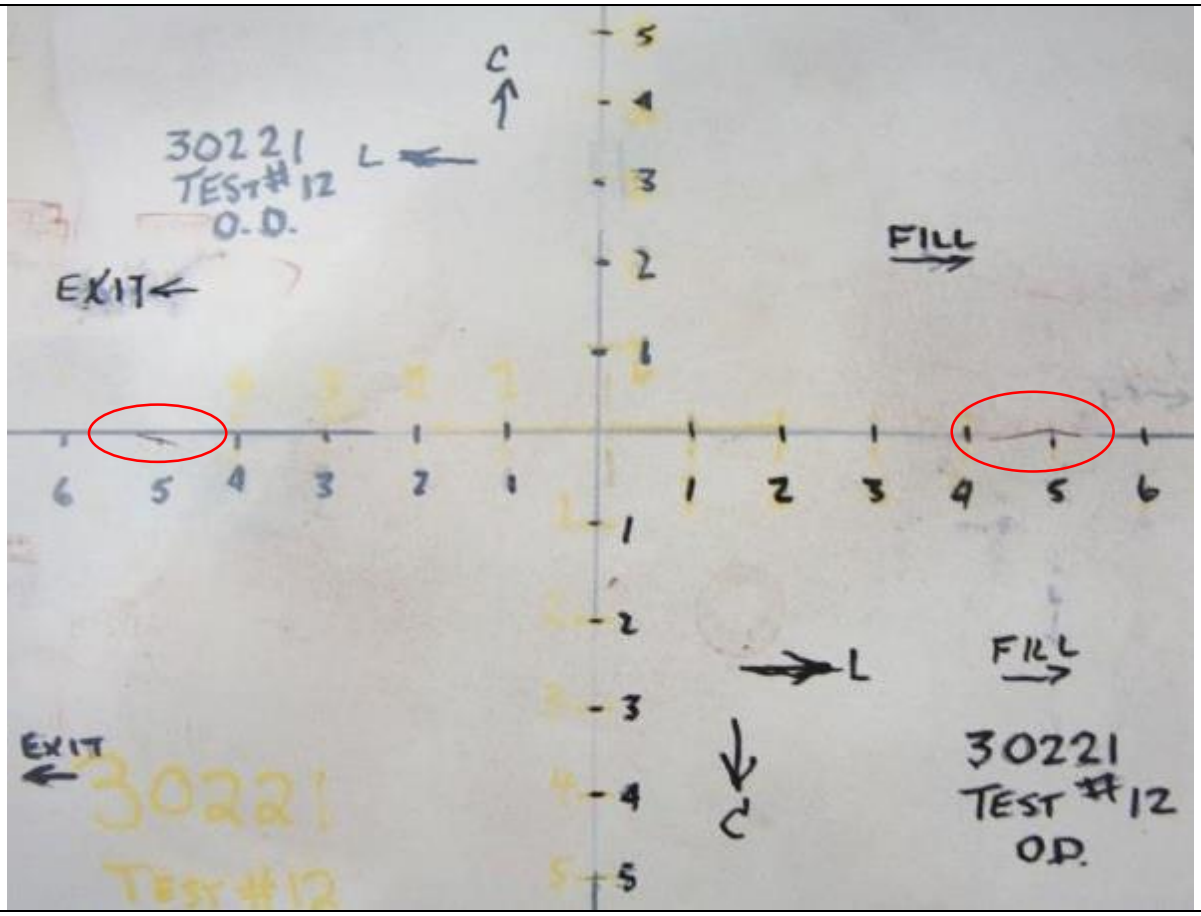


(a)

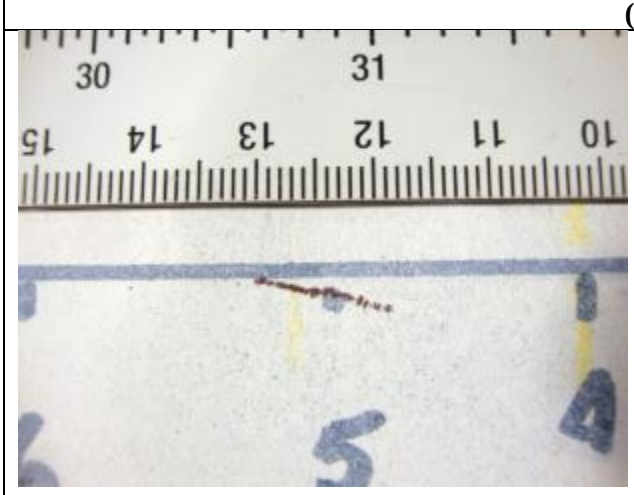


(b)

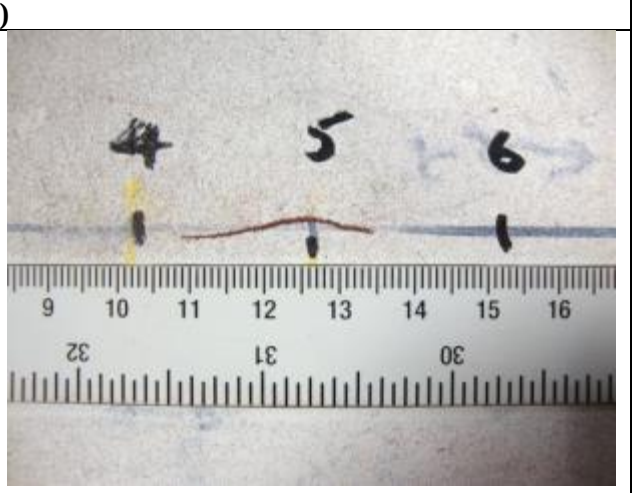
Figure 32: Test # 10 – Dent interacted with LSW - ID MPI – Pipe D
(a) Axial ID crack a seen on the ID Surface (b) ID Surface, Enlarged crack photograph



(a)

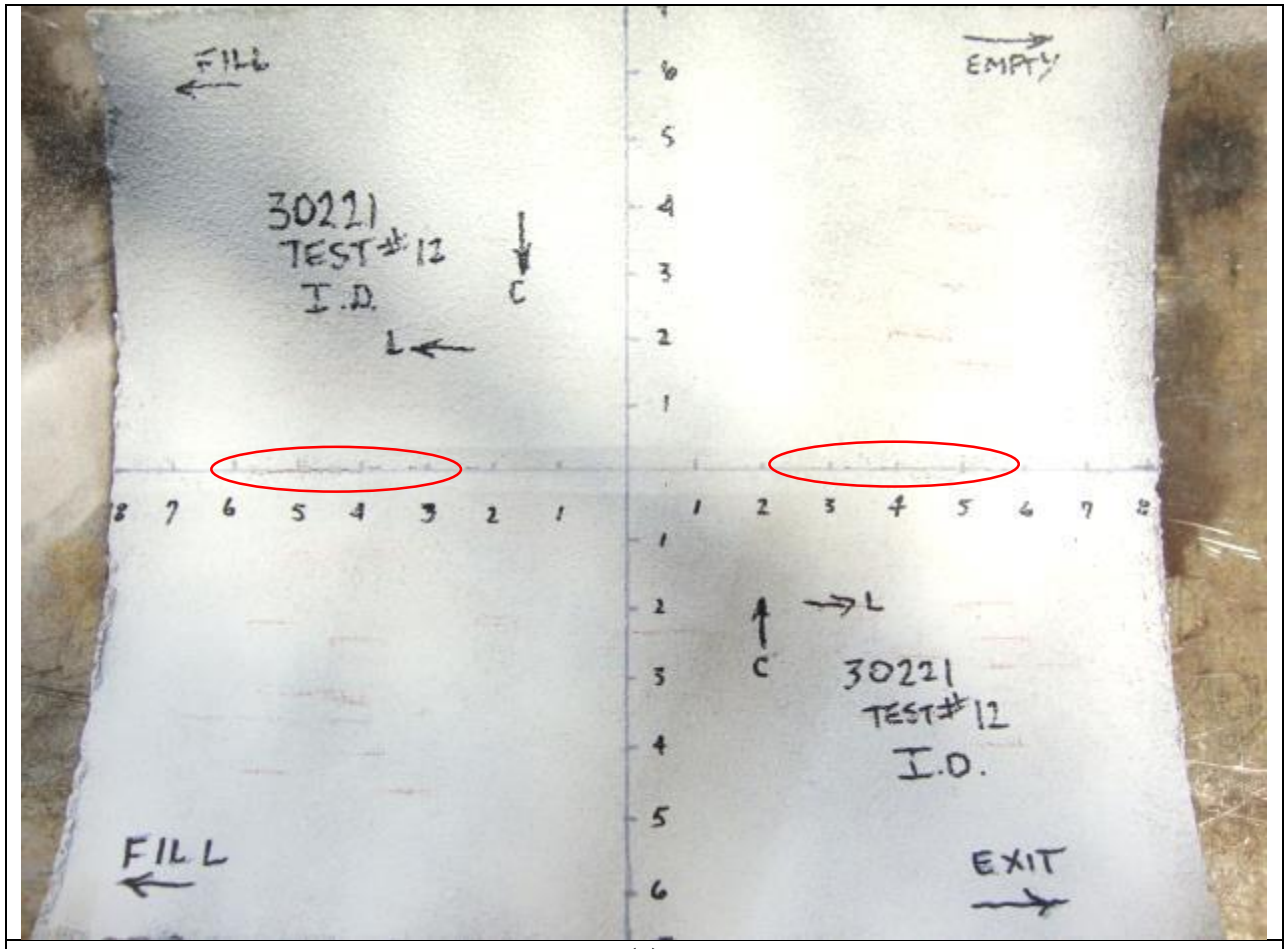


(b)

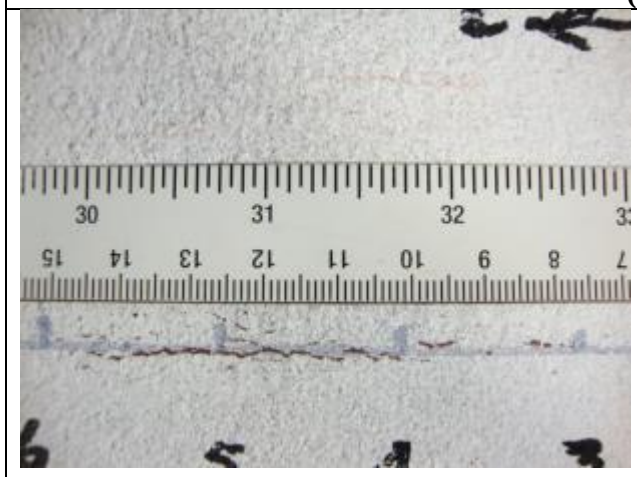


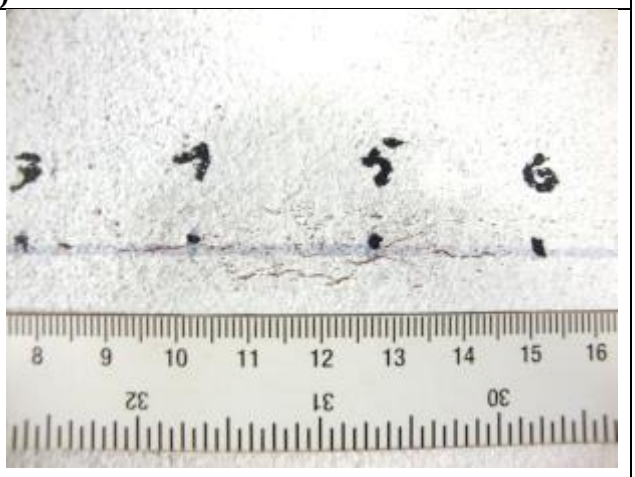
(c)

Figure 33: Test # 12 – Dent interacted with LSW - OD MPI – Pipe D
(a) Axial ID crack as seen on the OD Surface
(b) OD Surface, Enlarged crack photograph (Exit Side)
(c) OD Surface, Enlarged crack photograph (Fill Side)



(a)

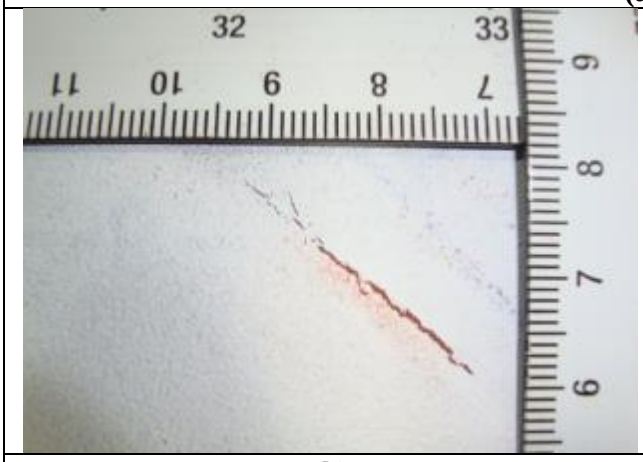




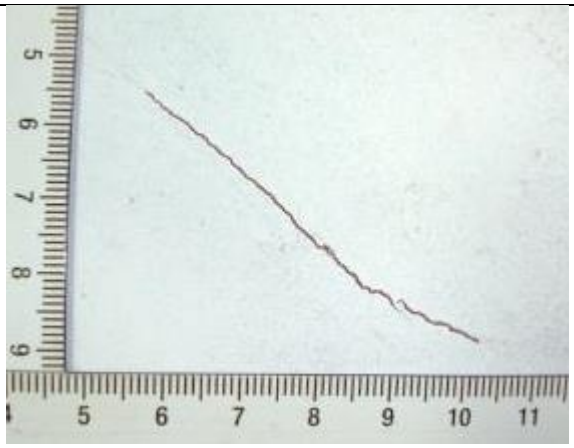
(b)

Figure 34: Test # 12 – Dent interacted with LSW - ID MPI – Pipe D
(a) Axial ID cracks as seen on the ID Surface
(b) ID Surface, Enlarged crack photograph (Fill Side)
(c) ID Surface, Enlarged crack photograph (Exit Side)

(a)

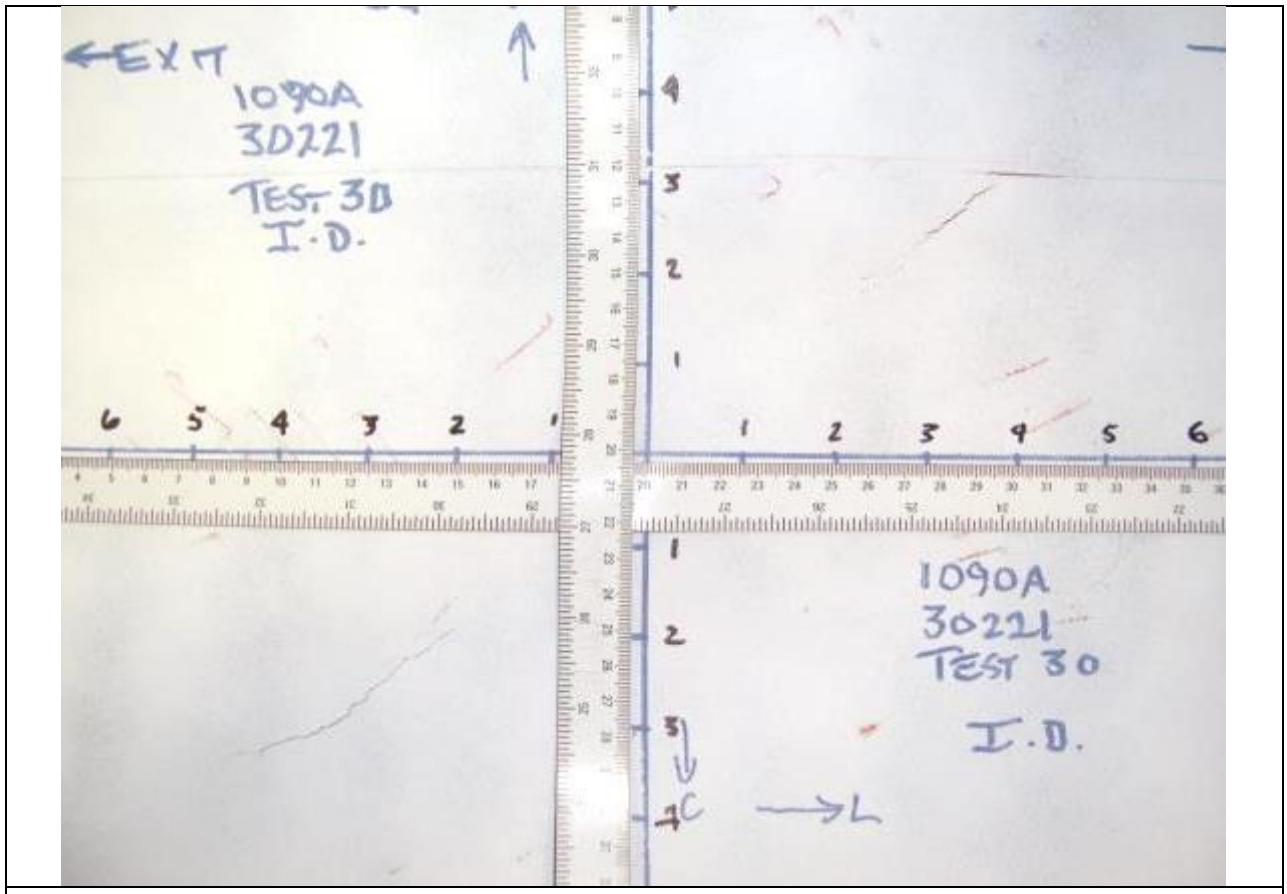


(b)

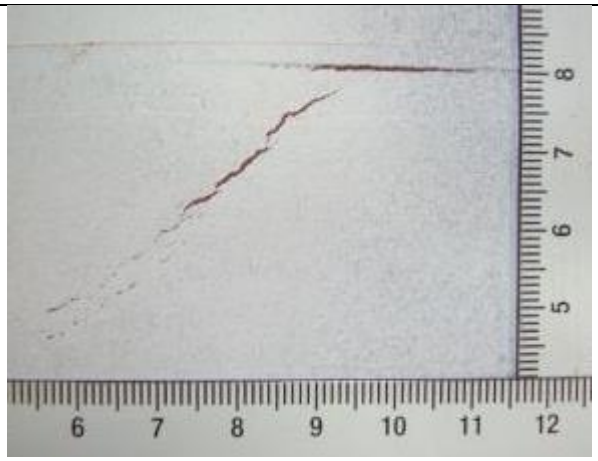


(c)

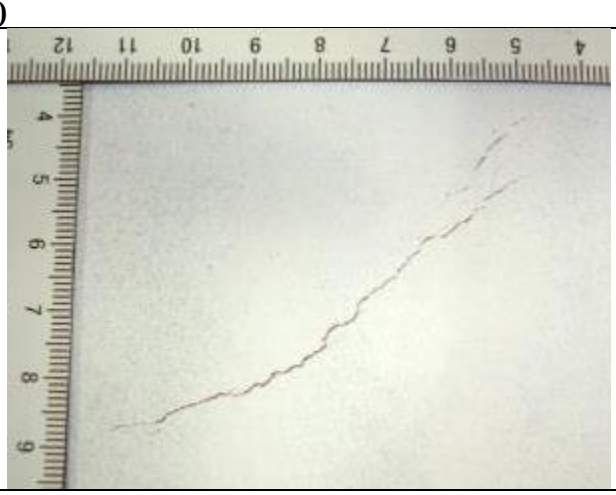
Figure 35: Test # 30 – Dent interacted with LSW - OD MPI – Pipe F
(a) 42 degree ID crack as seen on the OD Surface
(b) OD Surface, Enlarged crack photograph (Fill Side)
(c) OD Surface, Enlarged crack photograph (Exit Side)



(a)



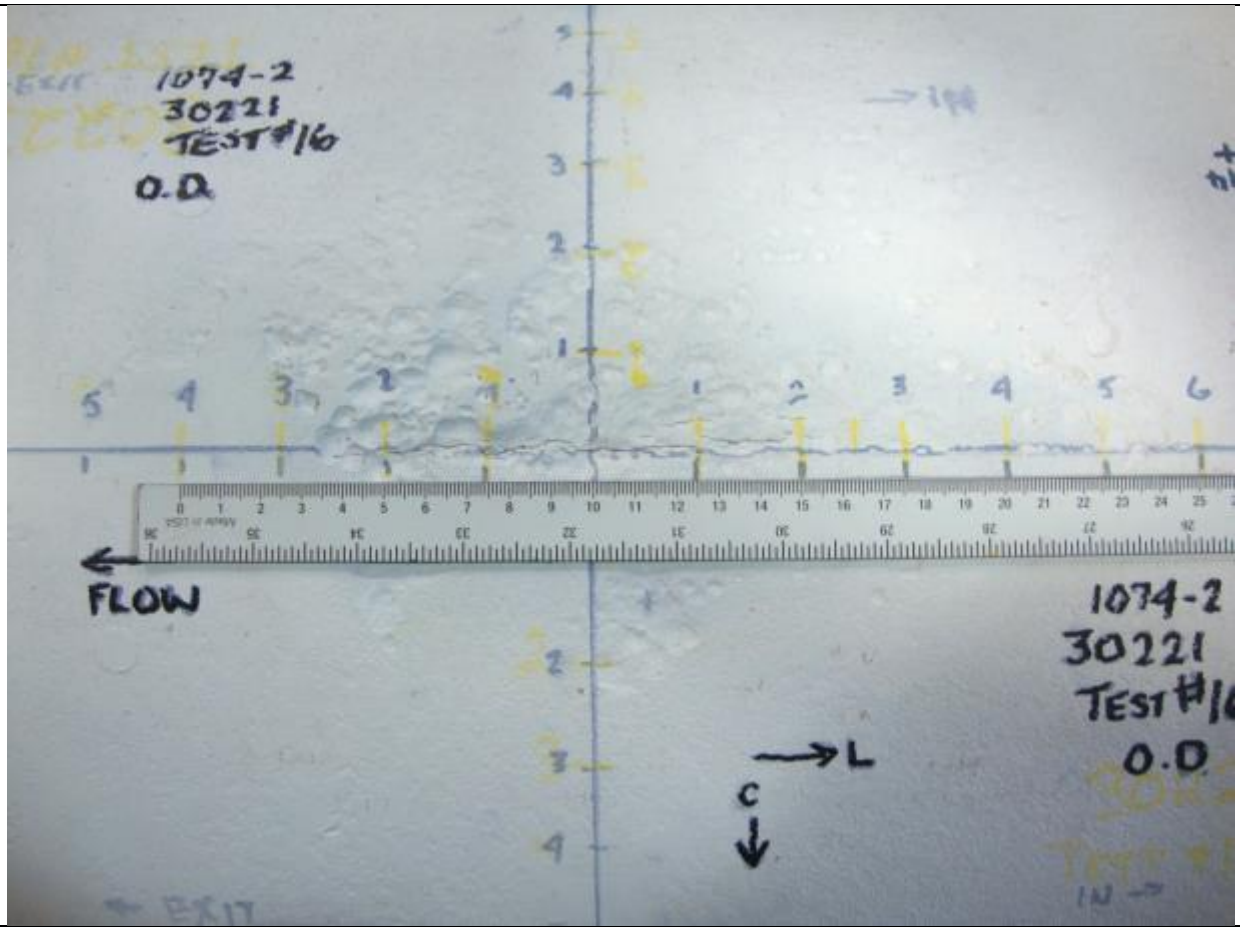
(b)



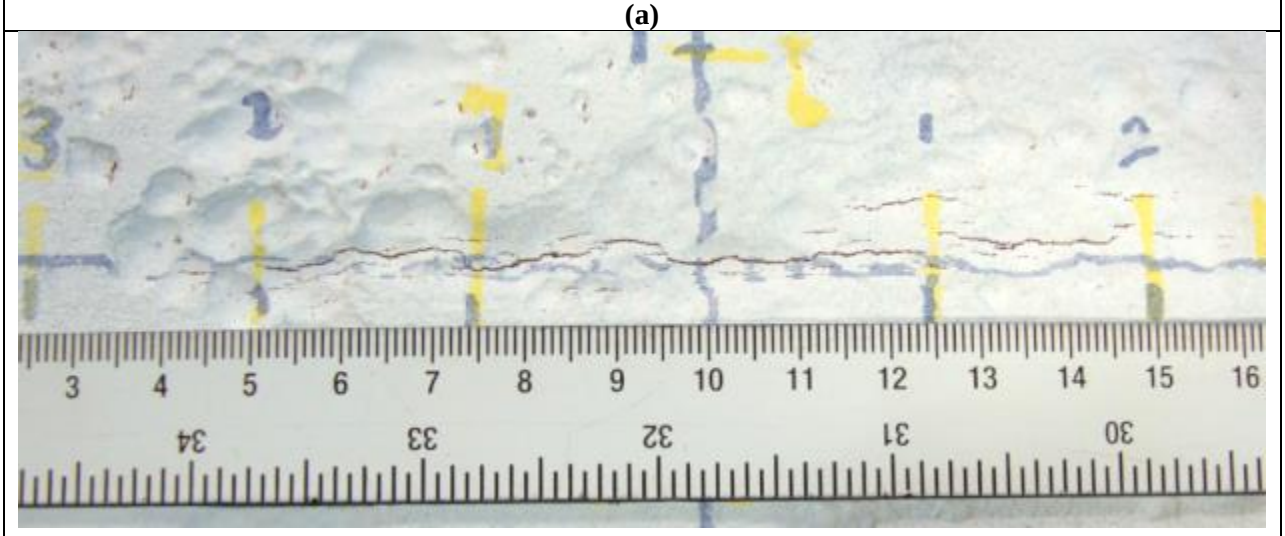
(c)

Figure 36: Test # 30 – Dent interacted with LSW - ID MPI – Pipe F
(a) 42 degree ID crack as seen on the ID Surface
(b) ID Surface, Enlarged crack photograph (Exit Side)
(c) ID Surface, Enlarged crack photograph (Fill Side)

D.3 Dents interacted with Corrosion

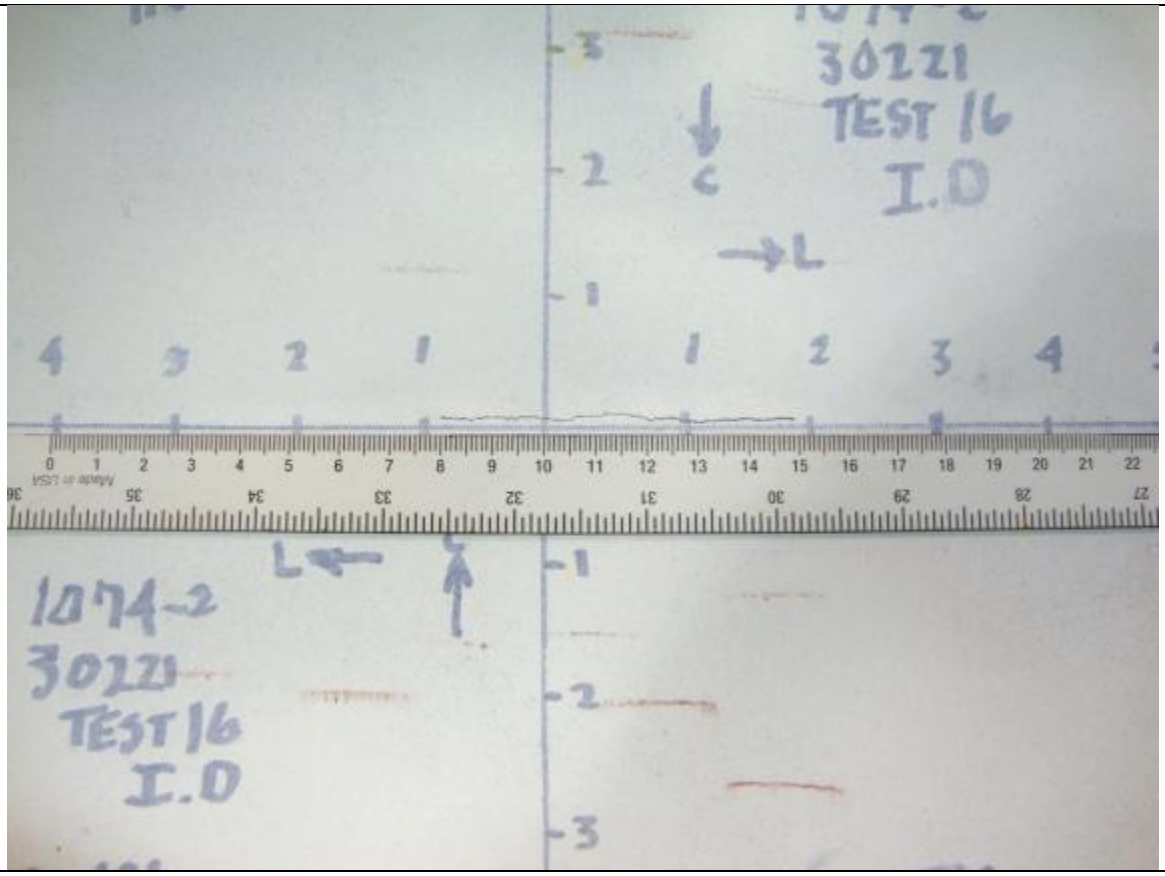


(a)

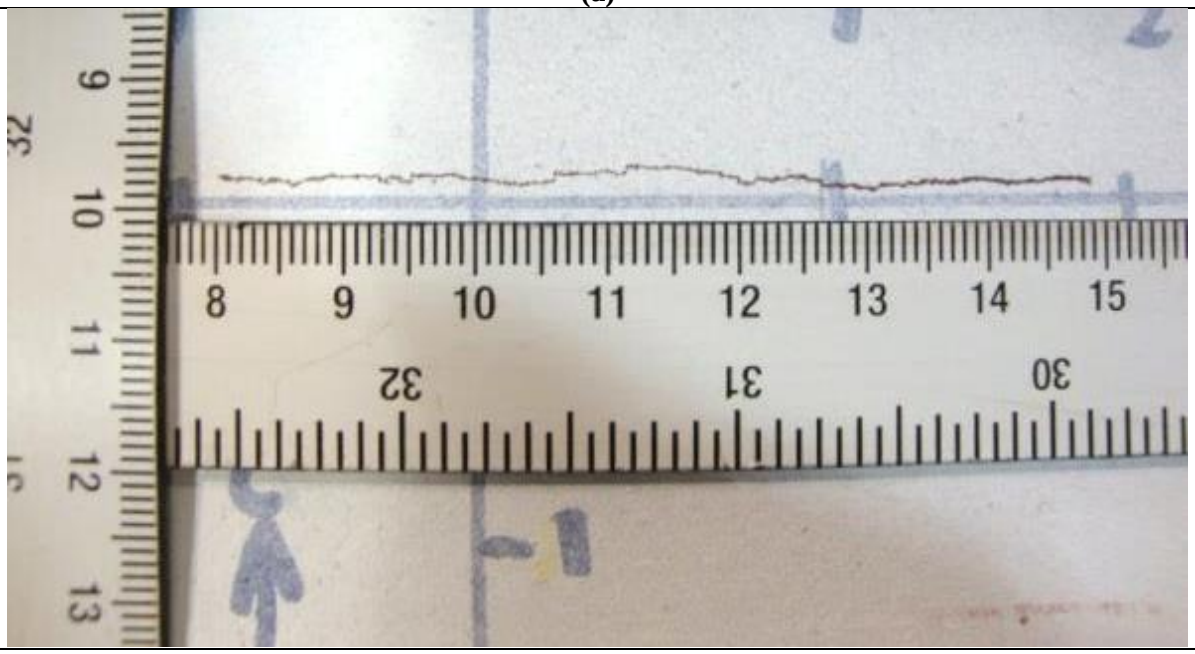


(b)

Figure 37: Test # 16 – Dent interacted with 42% Corrosion – OD MPI – Pipe F
(a) Axial OD crack as seen on the OD Surface (b) OD Surface, Enlarged crack photograph

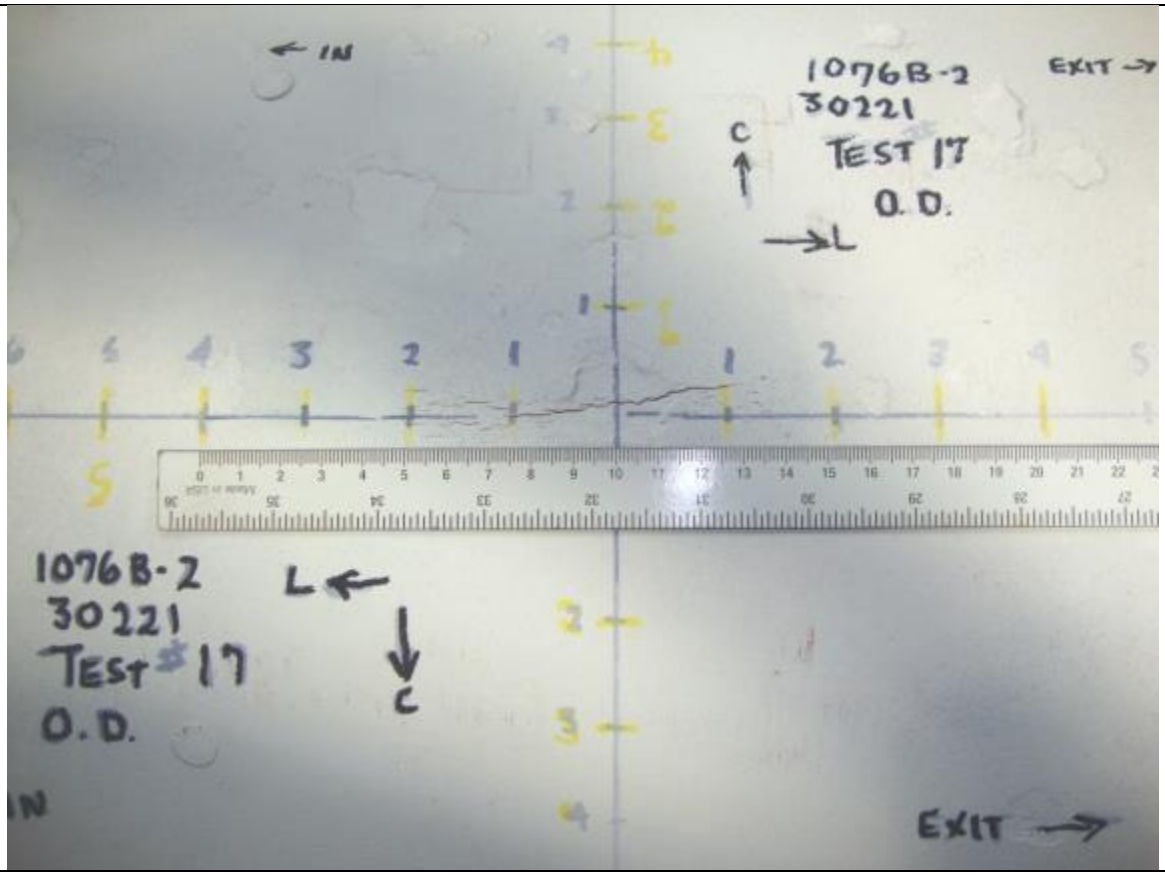


(a)

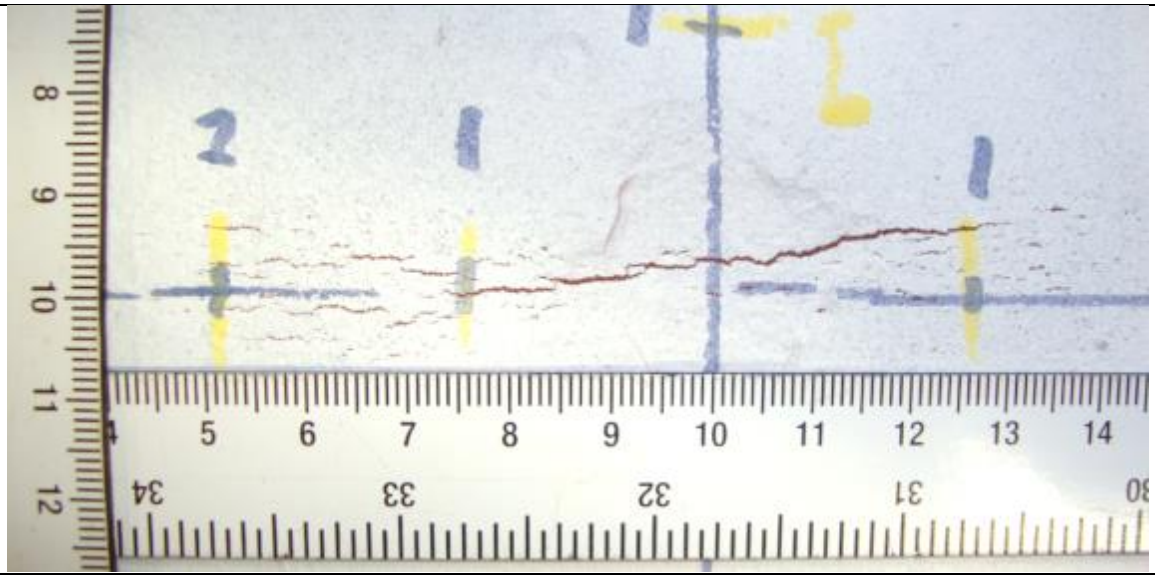


(b)

Figure 38: Test # 16 – Dent interacted with 42% Corrosion – ID MPI – Pipe F
(a) Axial OD crack as seen on the ID Surface (b) ID Surface, Enlarged crack photograph

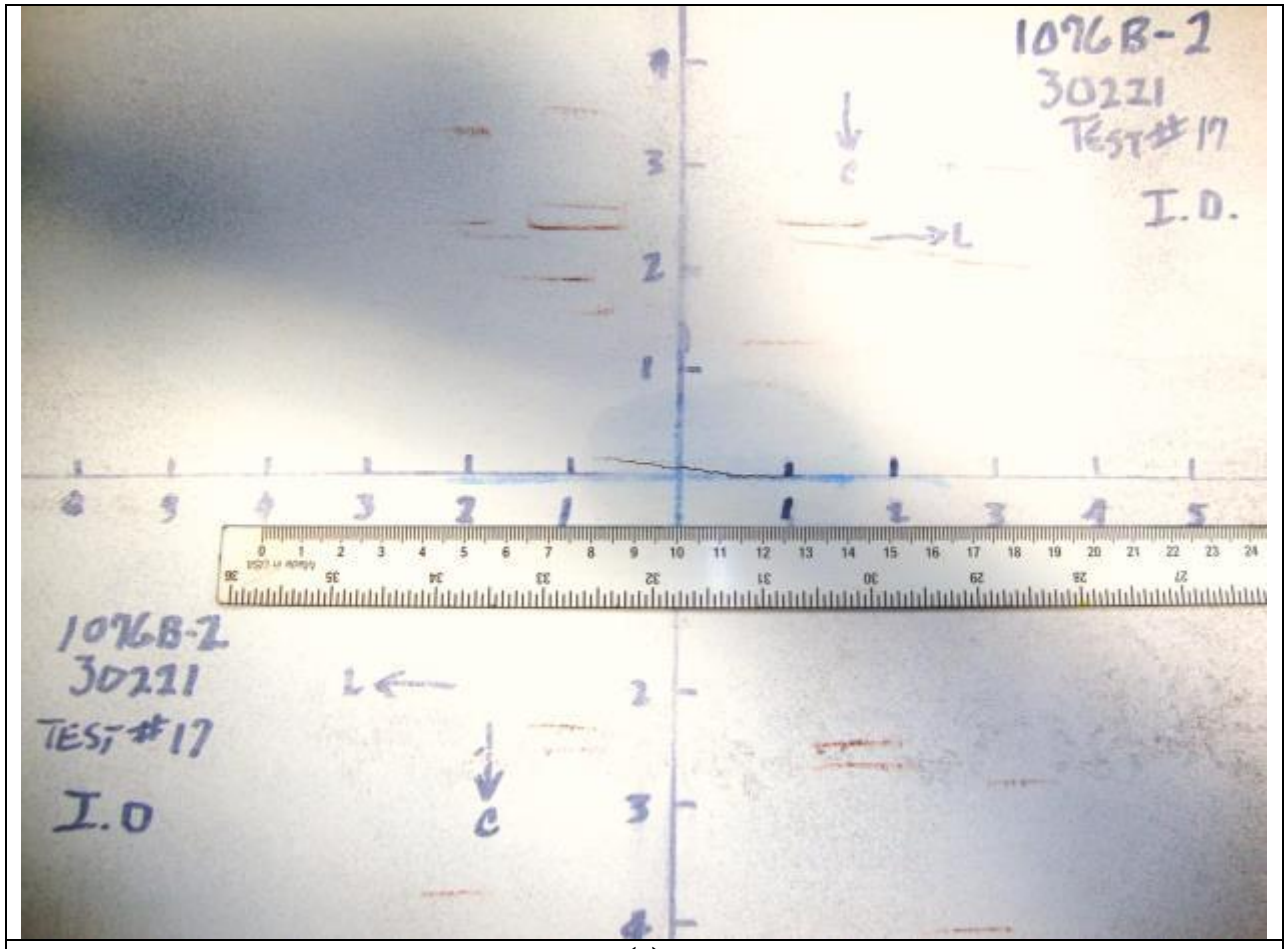


Test # 17:

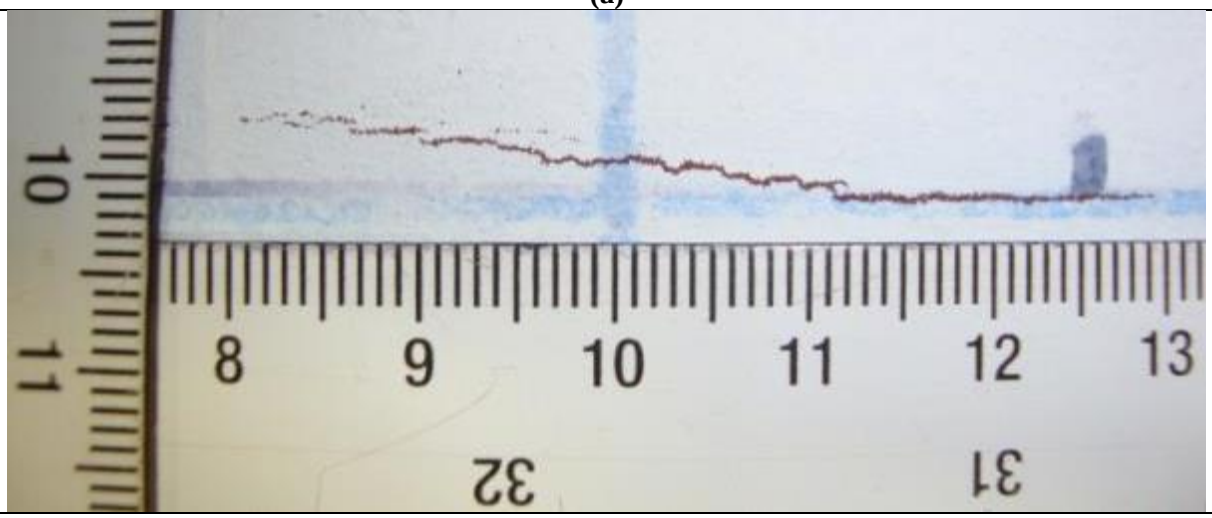


(b)

Figure 39: Test # 17 - Dent interacted with 17% Corrosion – OD MPI – Pipe F
(a) Axial OD crack as seen on the OD Surface (b) OD Surface, Enlarged crack photograph

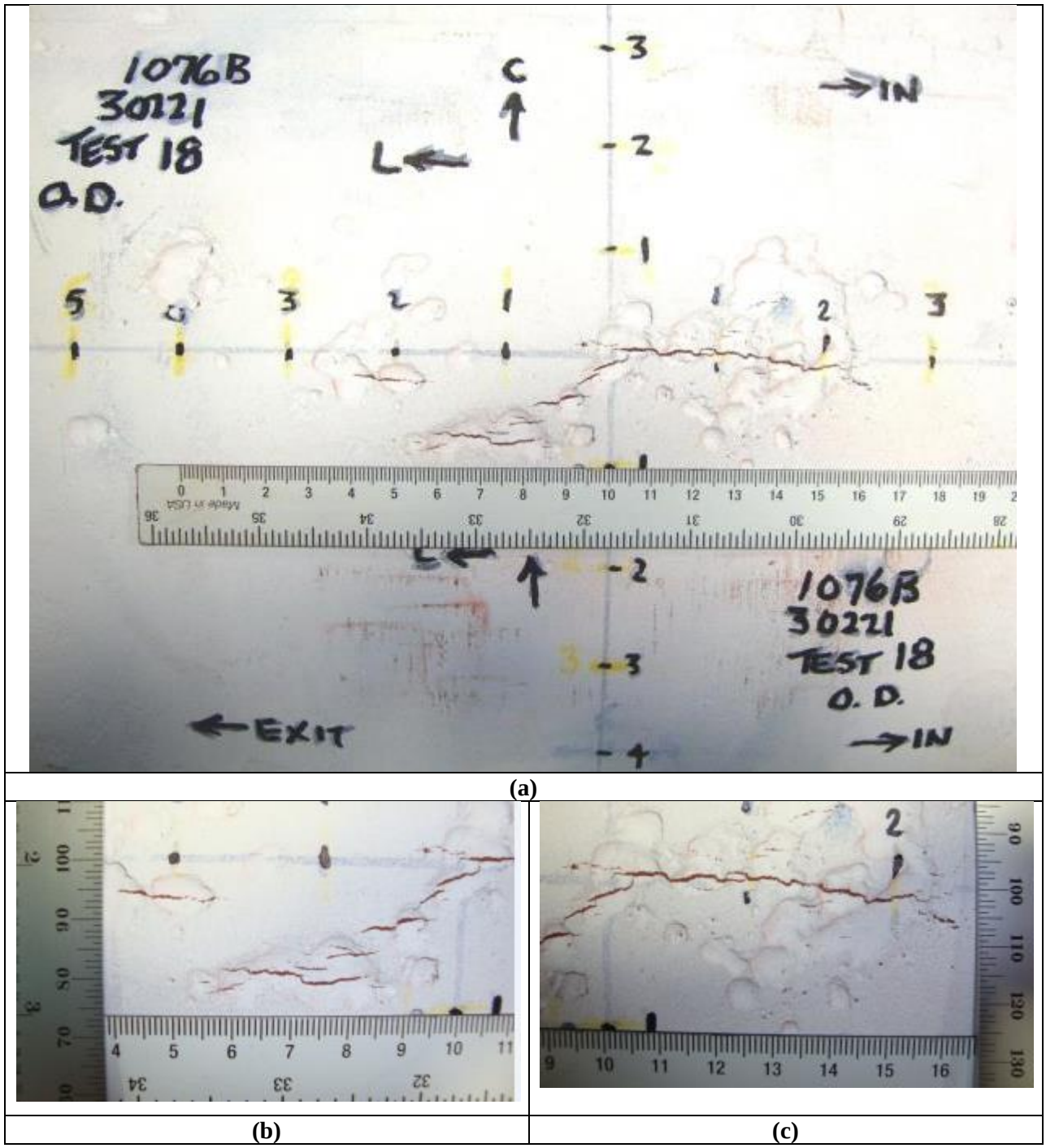


(a)



(b)

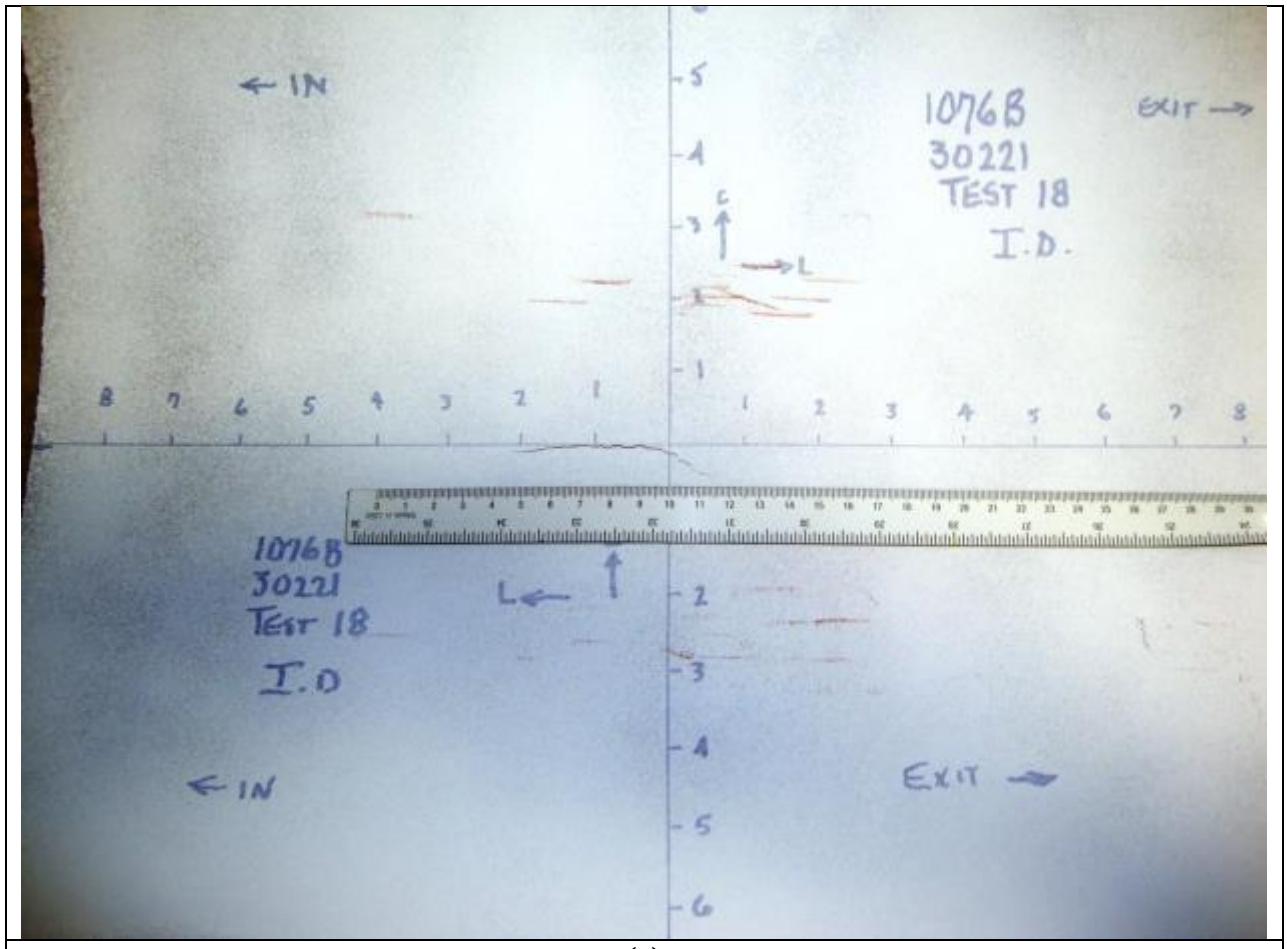
Figure 40: Test # 17 - Dent interacted with 17% Corrosion – ID MPI – Pipe F
(a) Axial OD crack as seen on the ID Surface (b) ID Surface, Enlarged crack photograph



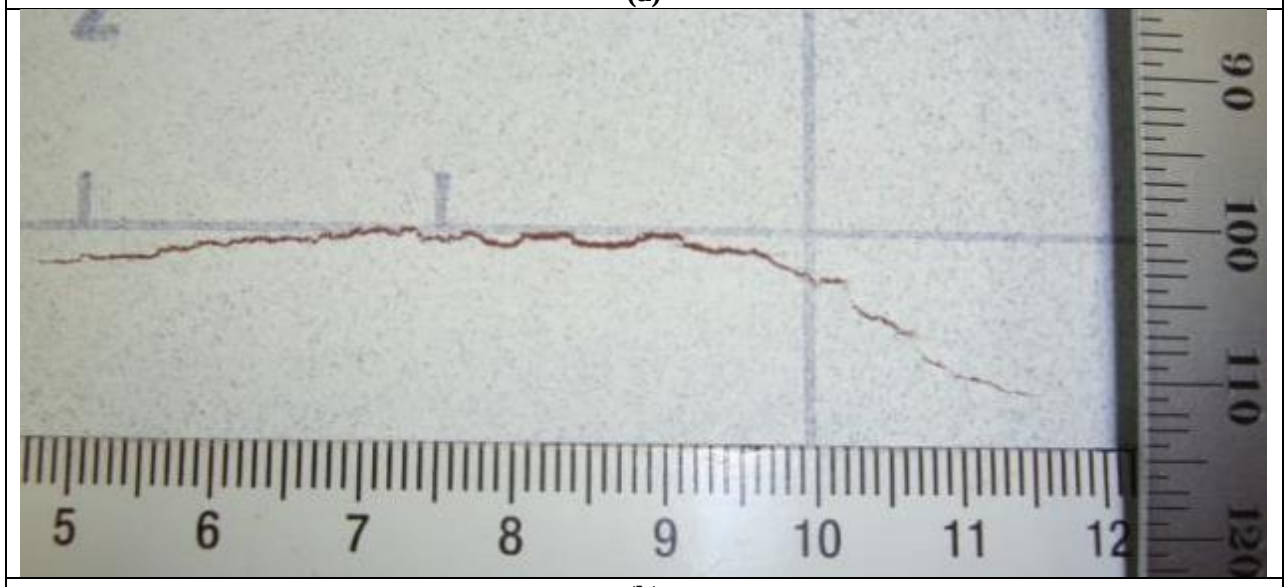
(a)

(b) **(c)**

Figure 41: Test # 18 – Dent interacted with 30% Corrosion – OD MPI – Pipe F
(a) Axial OD crack as seen on the OD Surface
(b) OD Surface, Enlarged crack photograph (Exit Side)
(c) OD Surface, Enlarged crack photograph (Fill Side)

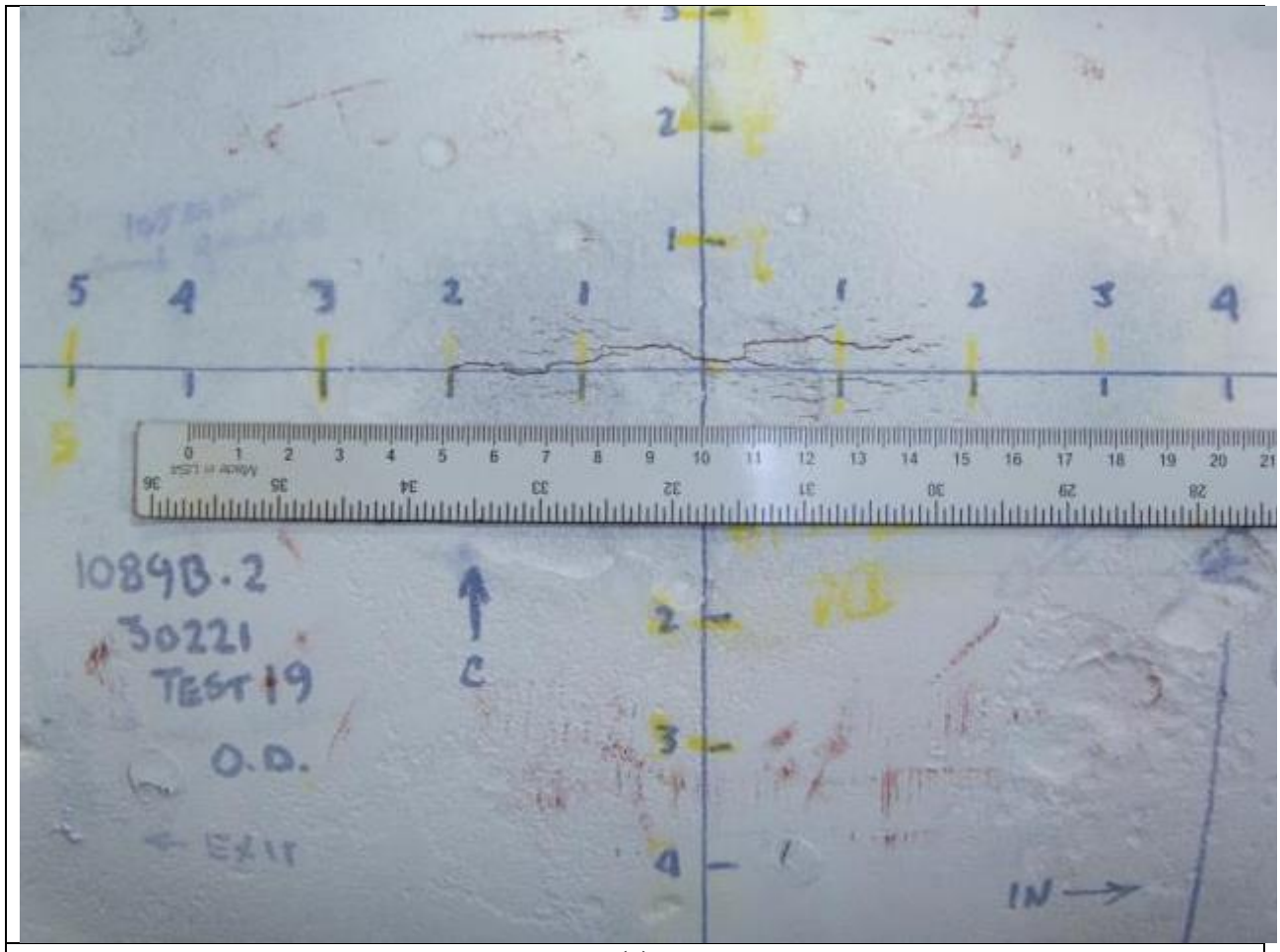


(a)

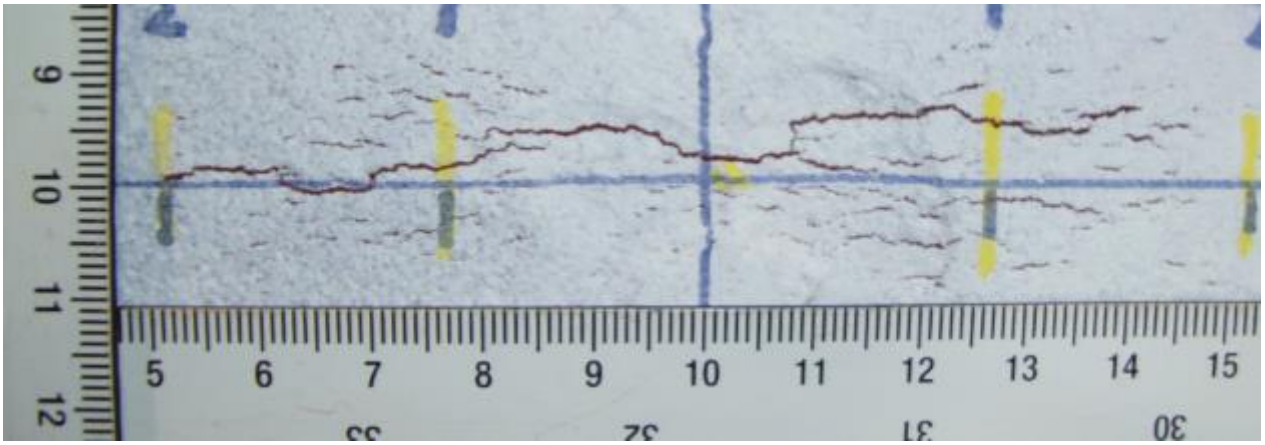


(b)

Figure 42: Test # 18 – Dent interacted with 30% Corrosion – ID MPI – Pipe F
(a) Axial OD crack as seen on the ID Surface (b) ID Surface, Enlarged crack photograph

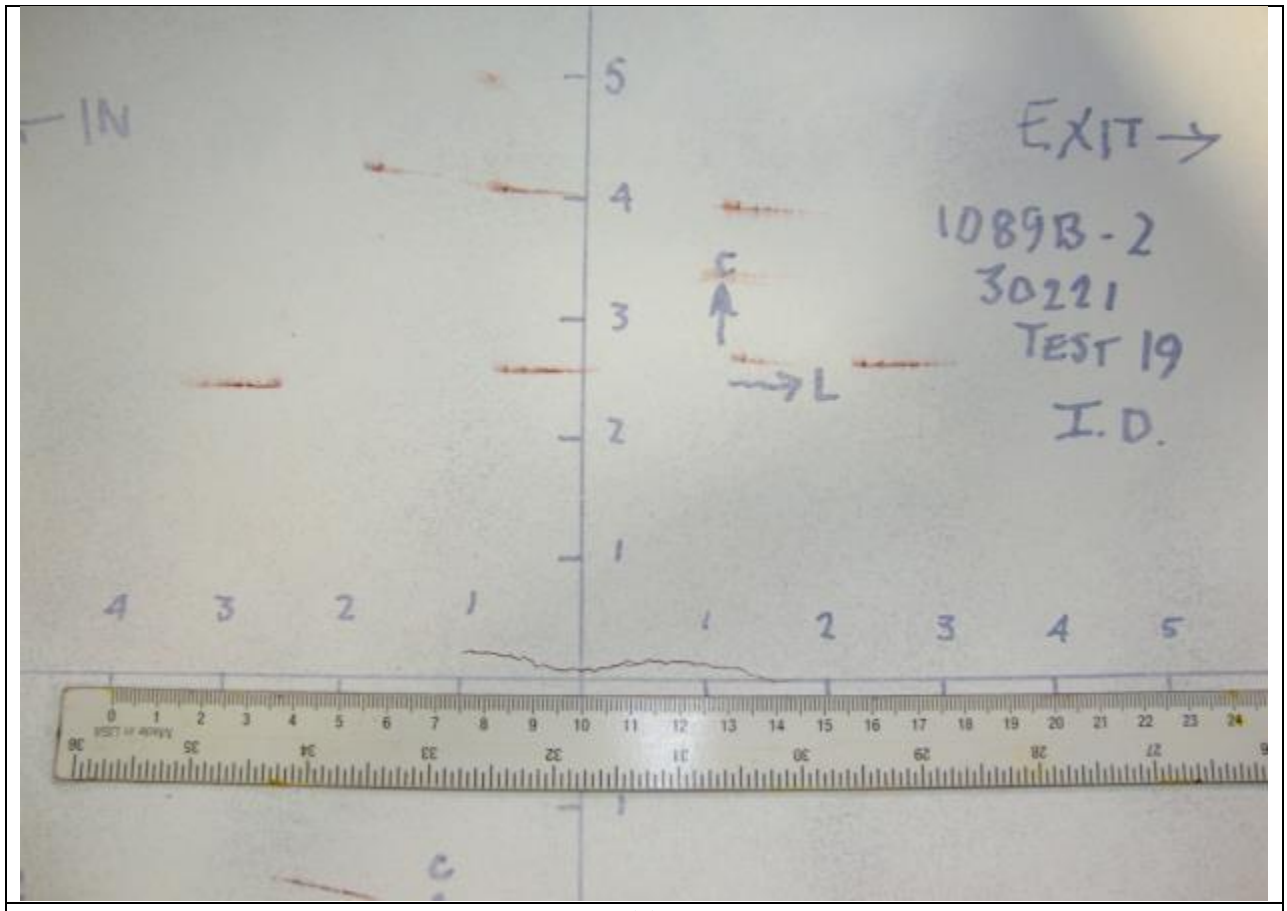


(a)

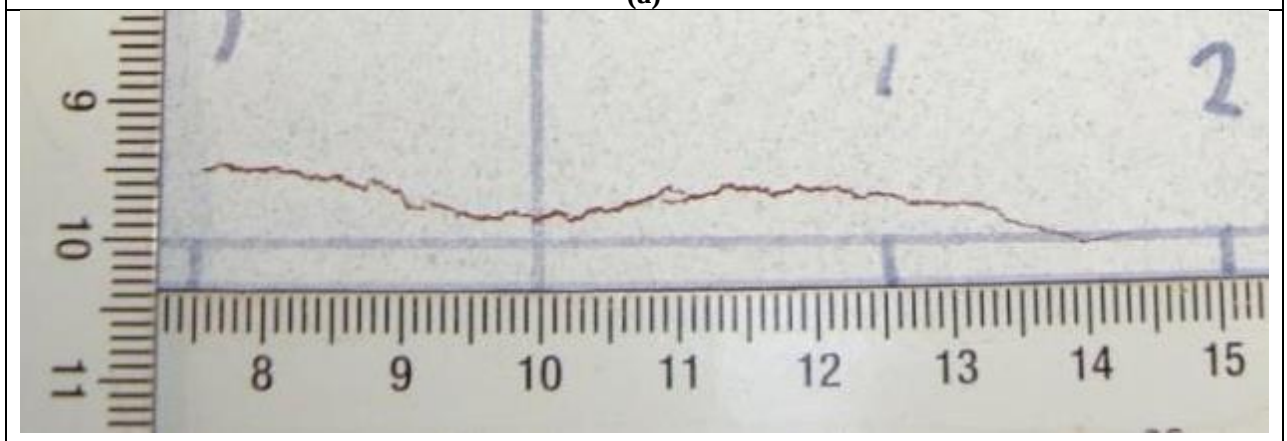


(b)

Figure 43: Test # 19 – Dent interacted with 16% Corrosion - OD MPI – Pipe F
(a) Axial OD crack as seen on the OD Surface (b) OD Surface, Enlarged crack photograph

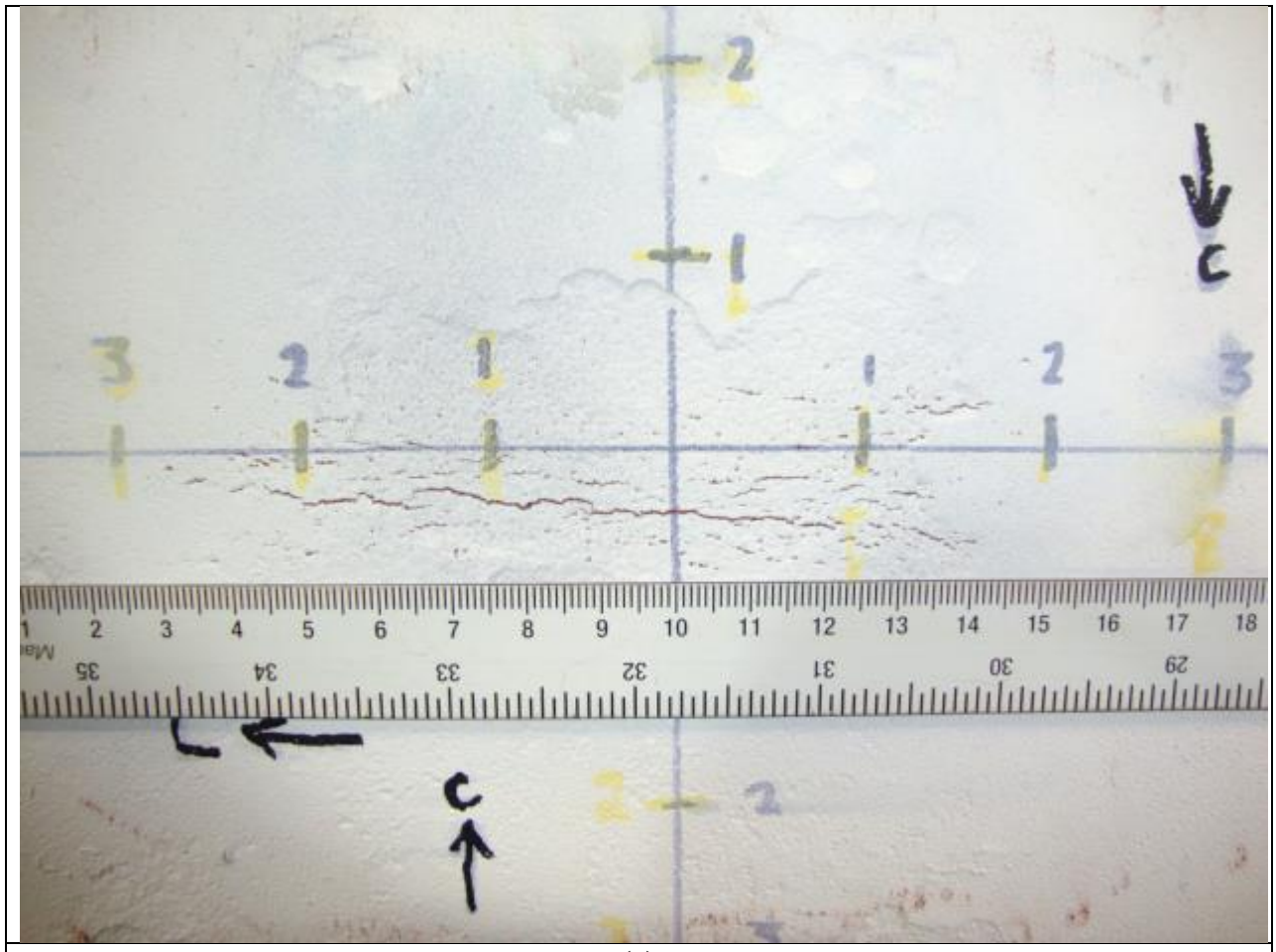


(a)

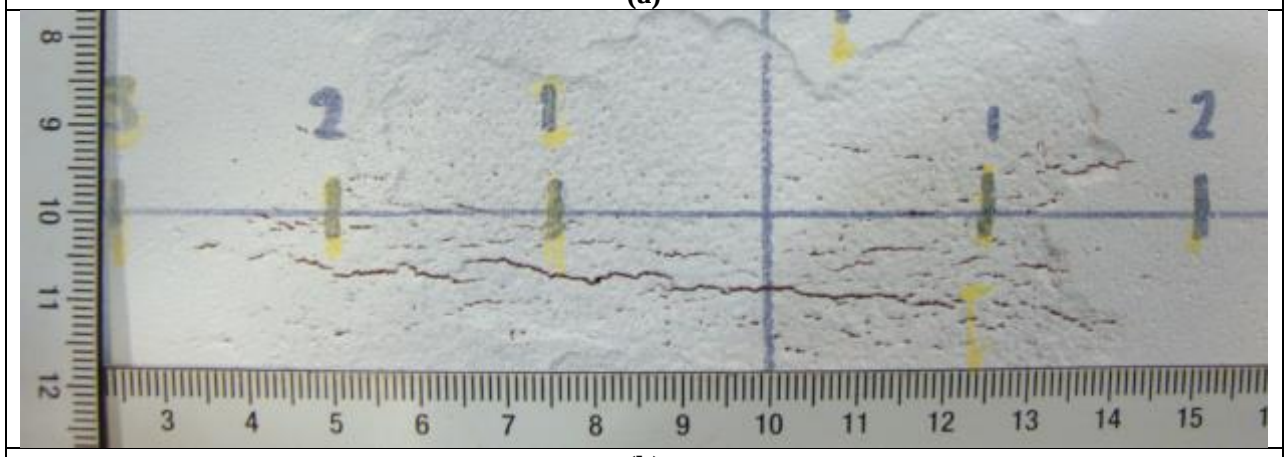


(b)

Figure 44: Test # 19 – Dent interacted with 16% Corrosion - ID MPI – Pipe F
(a) Axial OD crack as seen on the ID Surface (b) ID Surface, Enlarged crack photograph

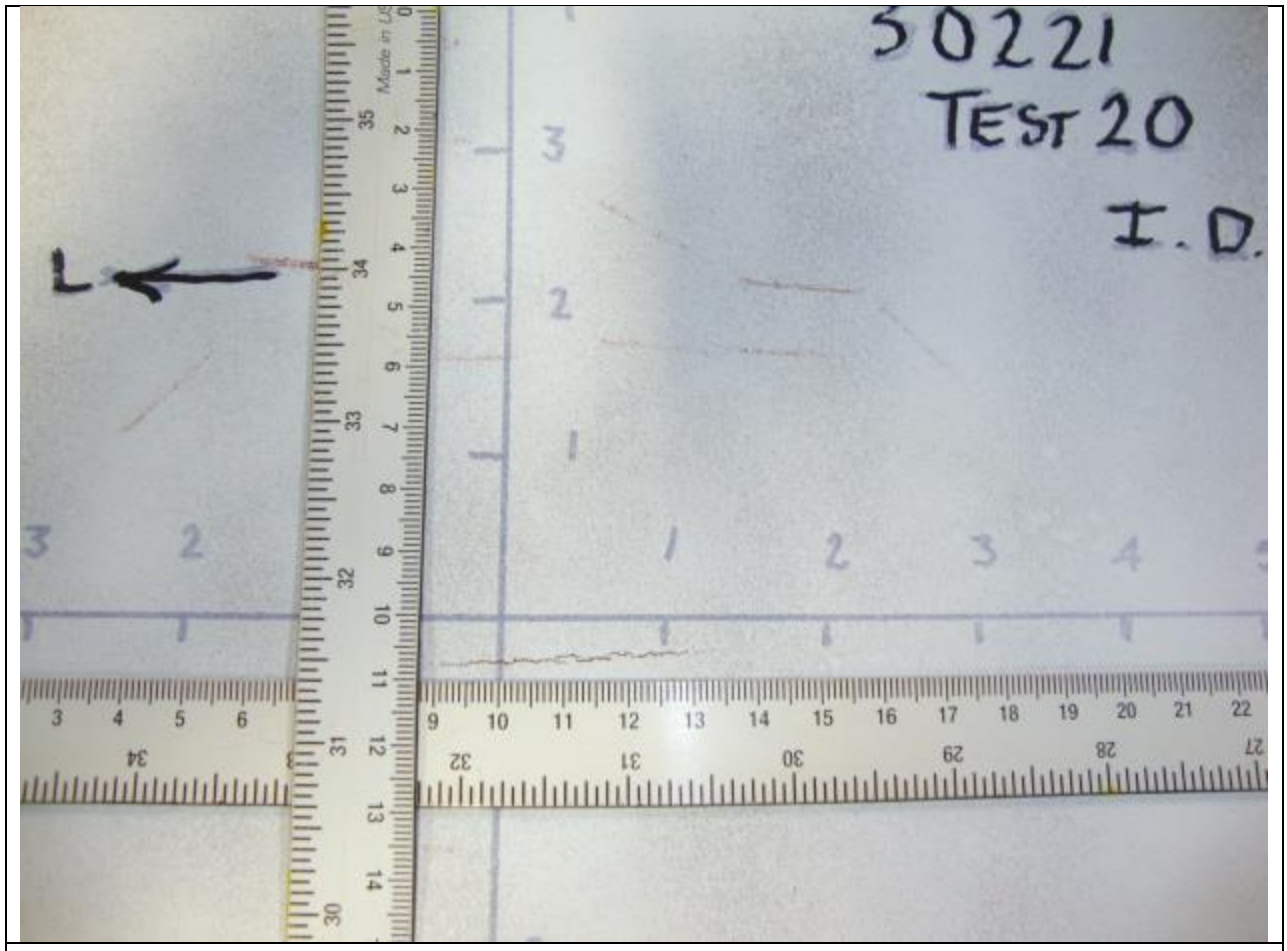


(a)

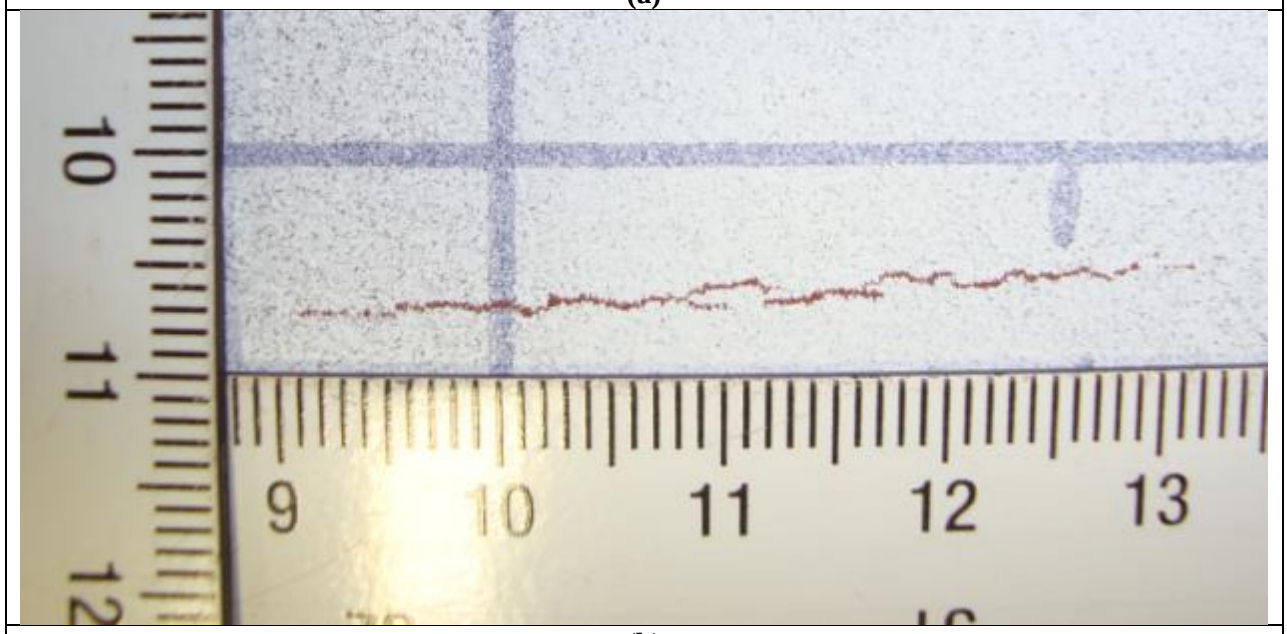


(b)

Figure 45: Test # 20 – Dent interacted with 8% Corrosion – OD MPI – Pipe F
(a) Axial OD crack as seen on the OD Surface (b) OD Surface, Enlarged crack photograph

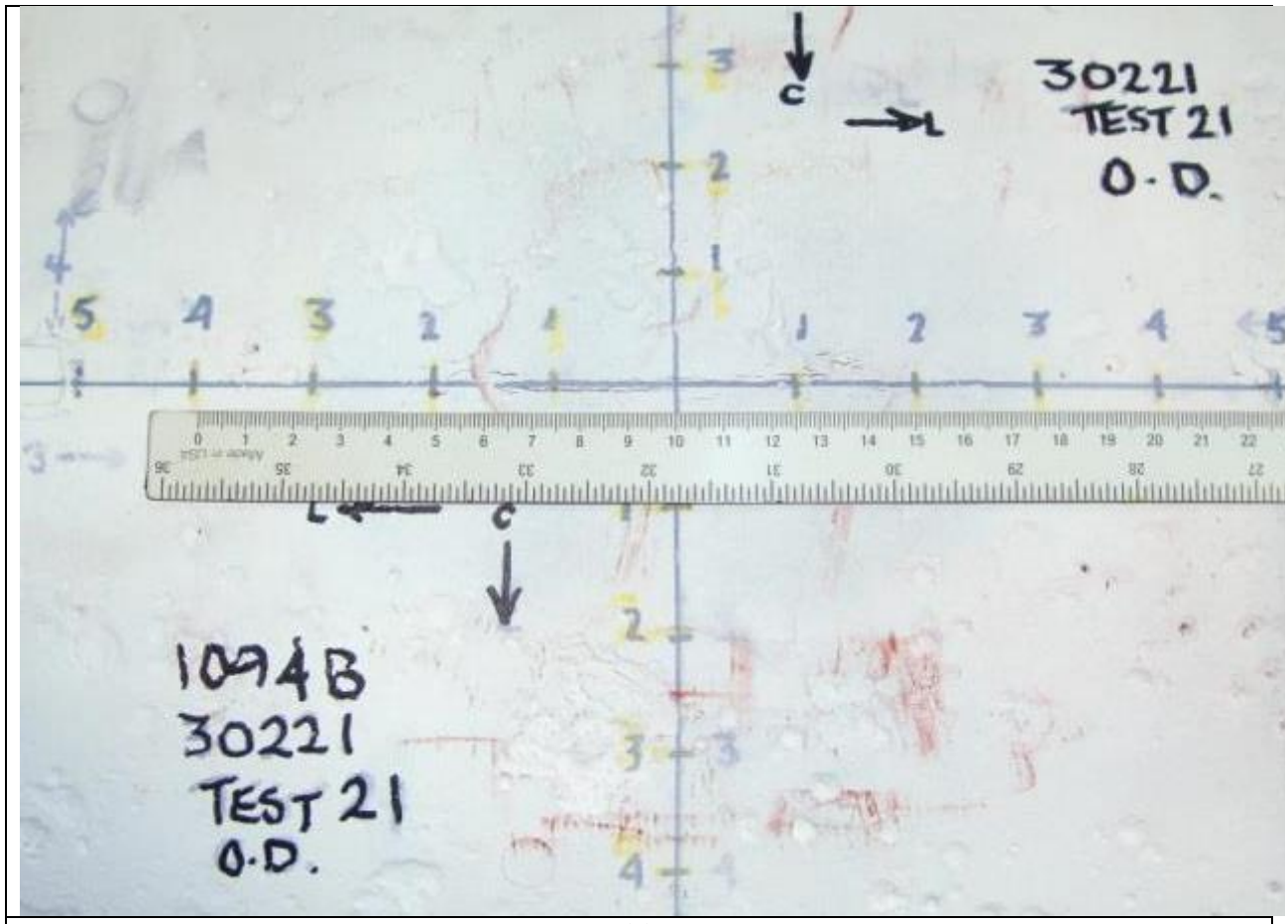


(a)

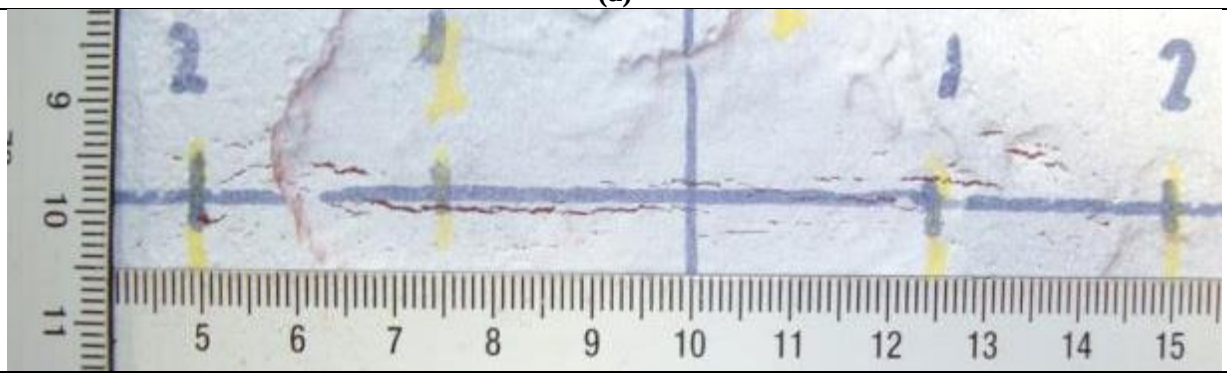


(b)

Figure 46: Test # 20 – Dent interacted with 8% Corrosion – ID MPI – Pipe F
(a) Axial OD crack as seen on the ID Surface (b) ID Surface, Enlarged crack photograph

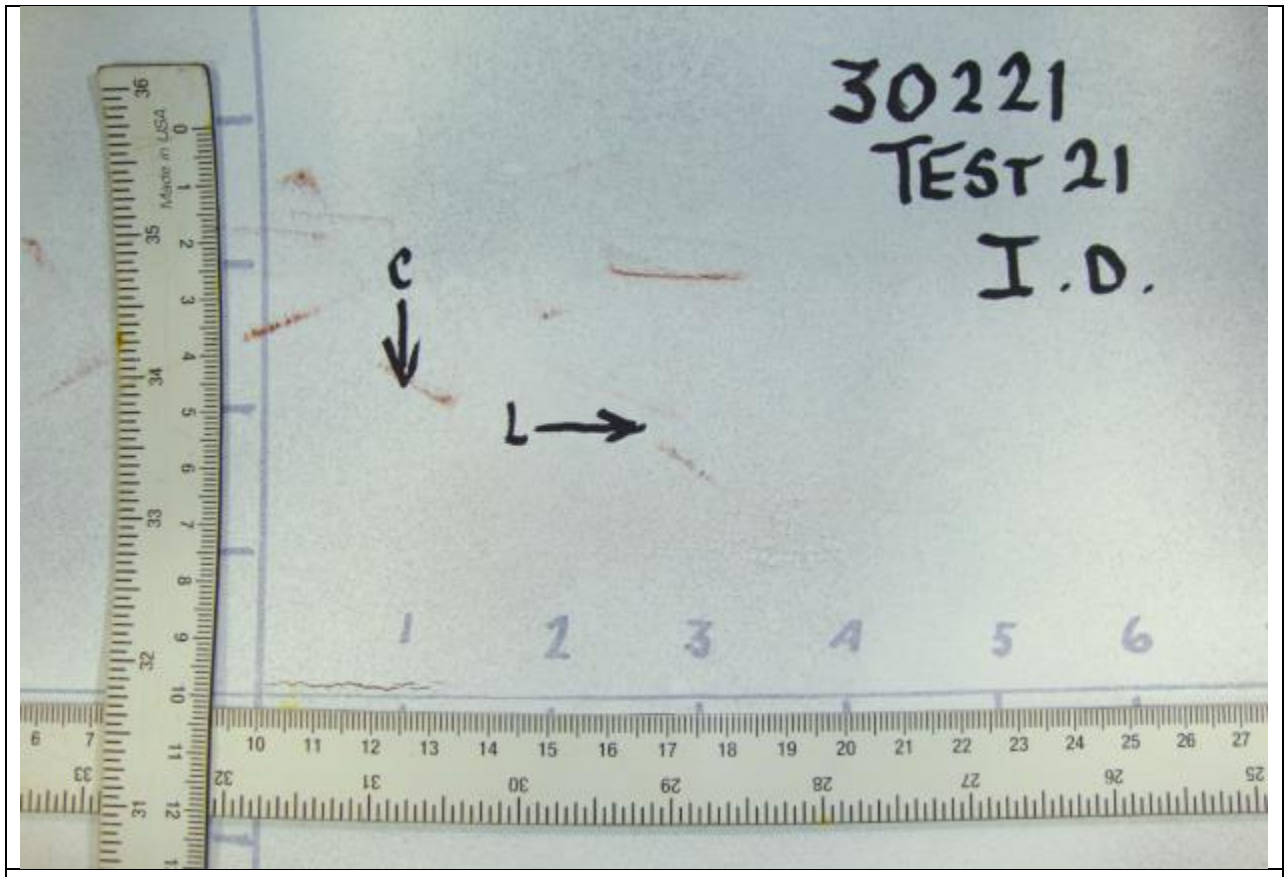


(a)

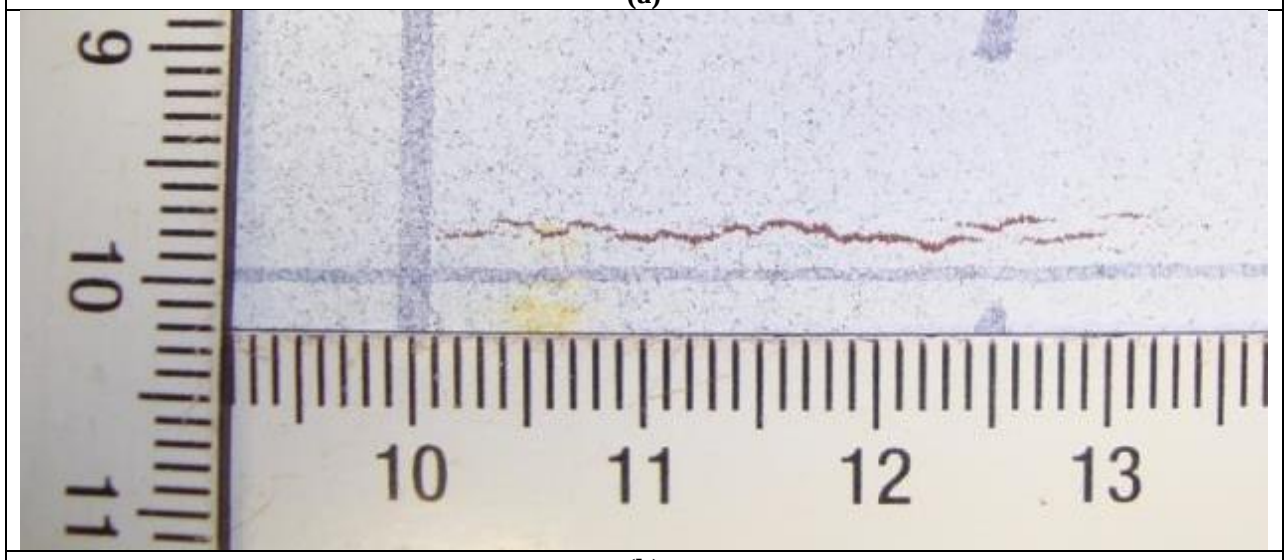


(b)

Figure 47: Test # 21 – Dent interacted with 26% Corrosion – OD MPI – Pipe F
(a) Axial OD crack as seen on the OD Surface (b) OD Surface, Enlarged crack photograph

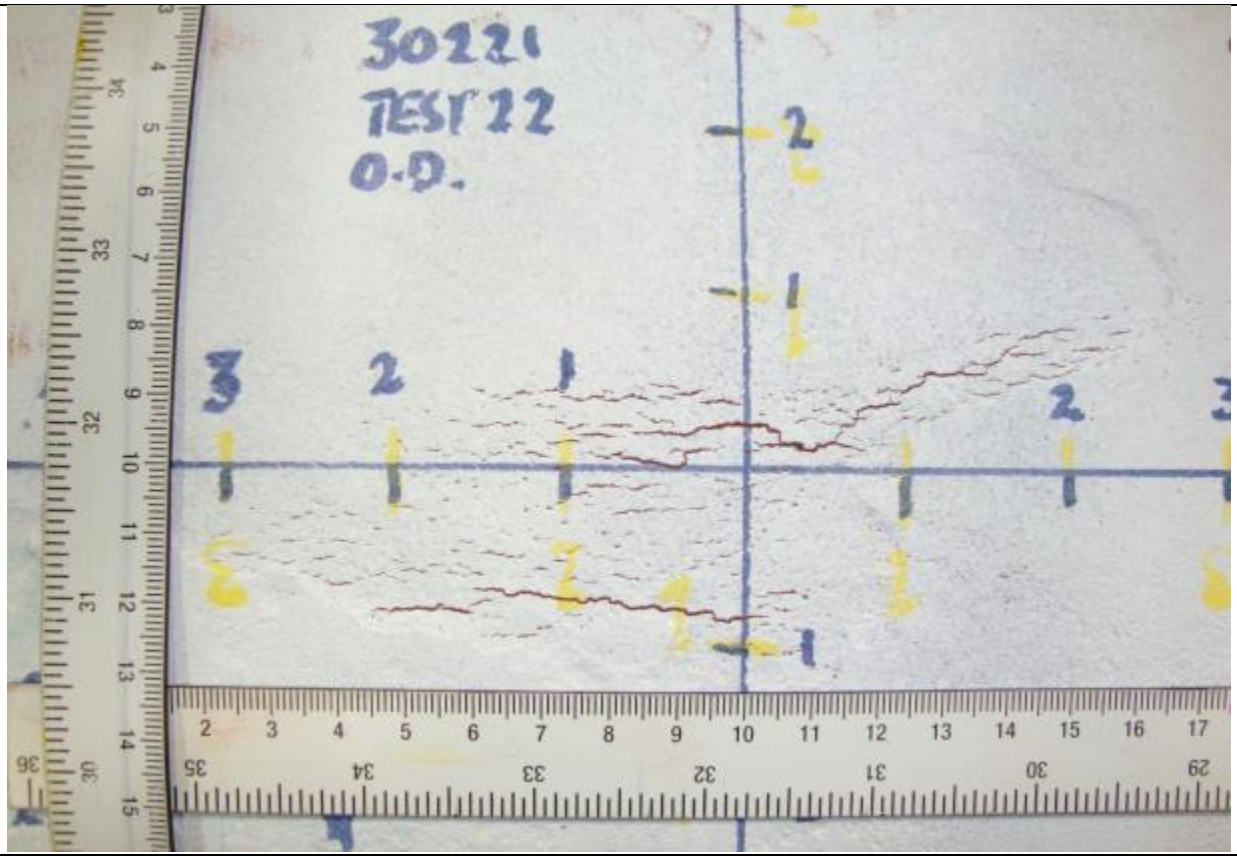


(a)

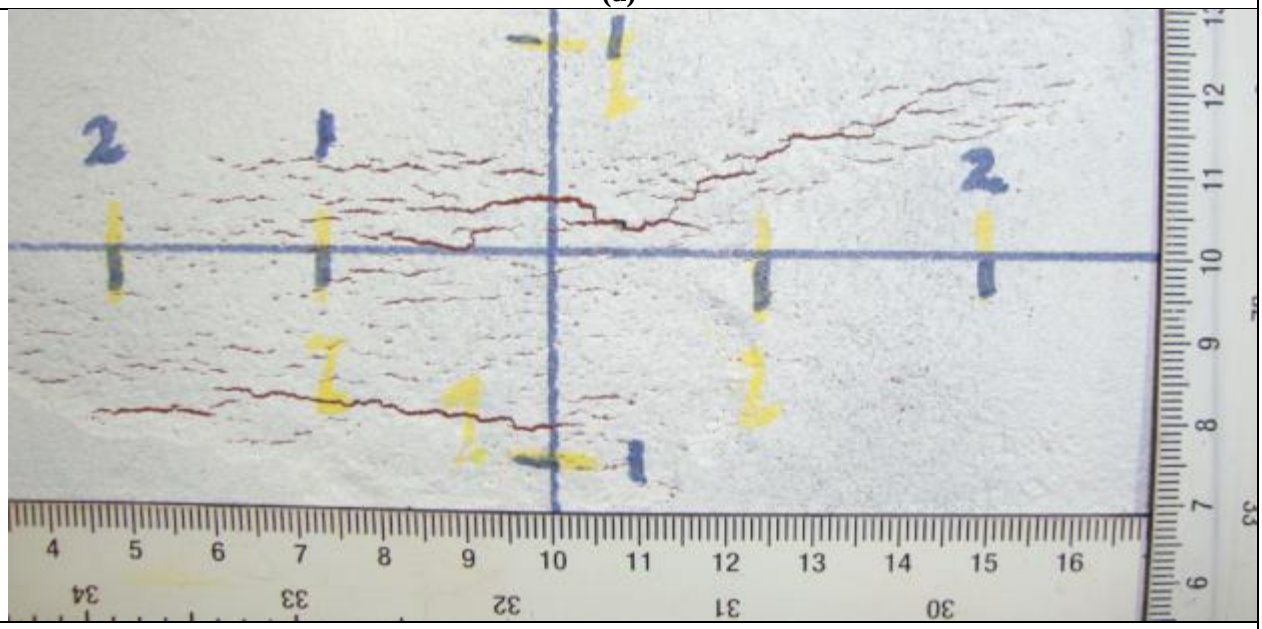


(b)

Figure 48: Test # 21 – Dent interacted with 26% Corrosion – ID MPI – Pipe F
(a) Axial OD crack as seen on the ID Surface (b) ID Surface, Enlarged crack photograph

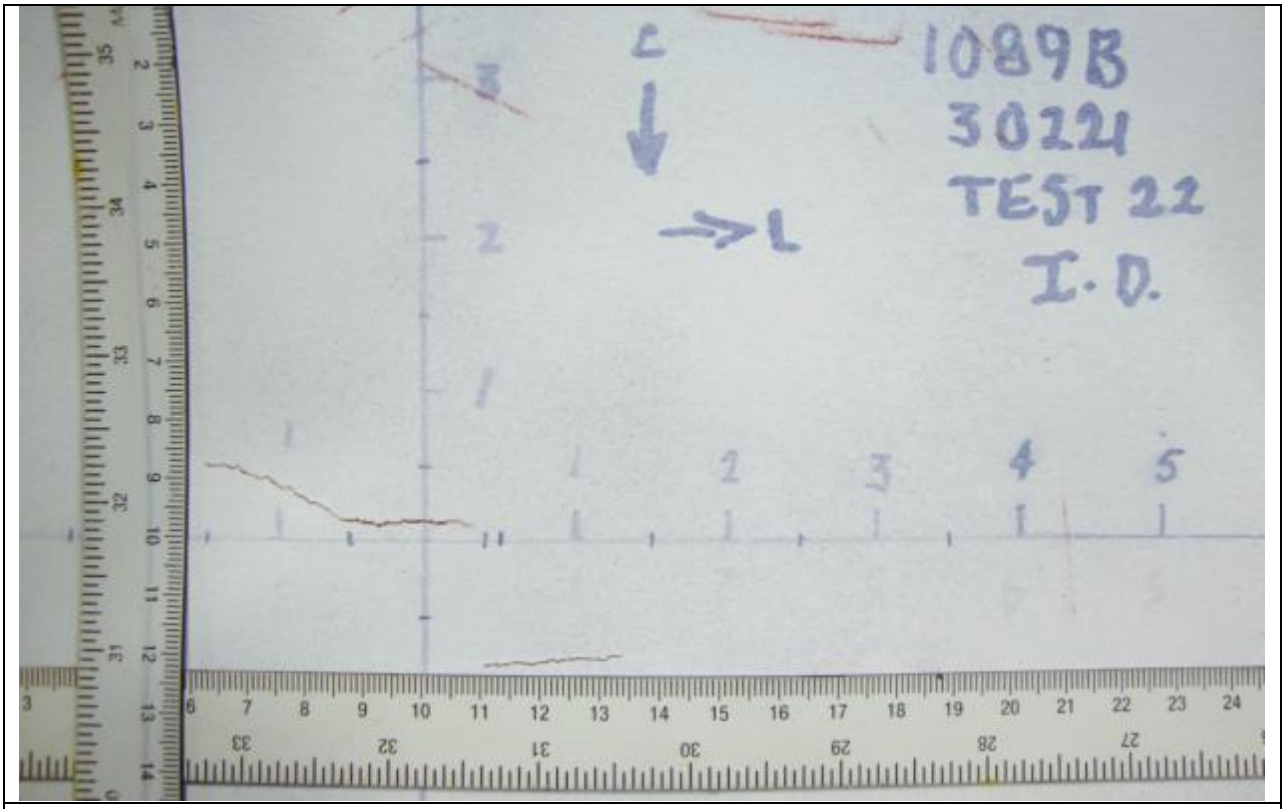


(a)

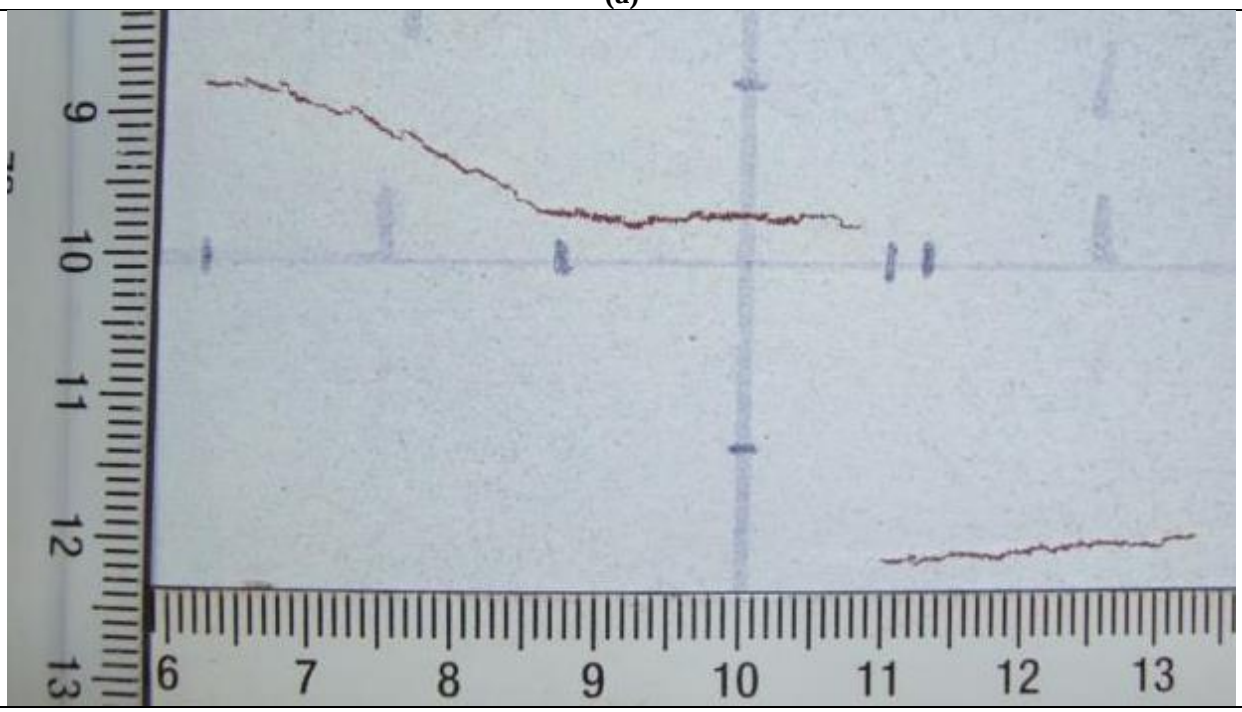


(b)

Figure 49: Test # 22 – Dent interacted with 9% Corrosion – OD MPI – Pipe F
(a) Axial OD crack as seen on the OD Surface (b) OD Surface, Enlarged crack photograph

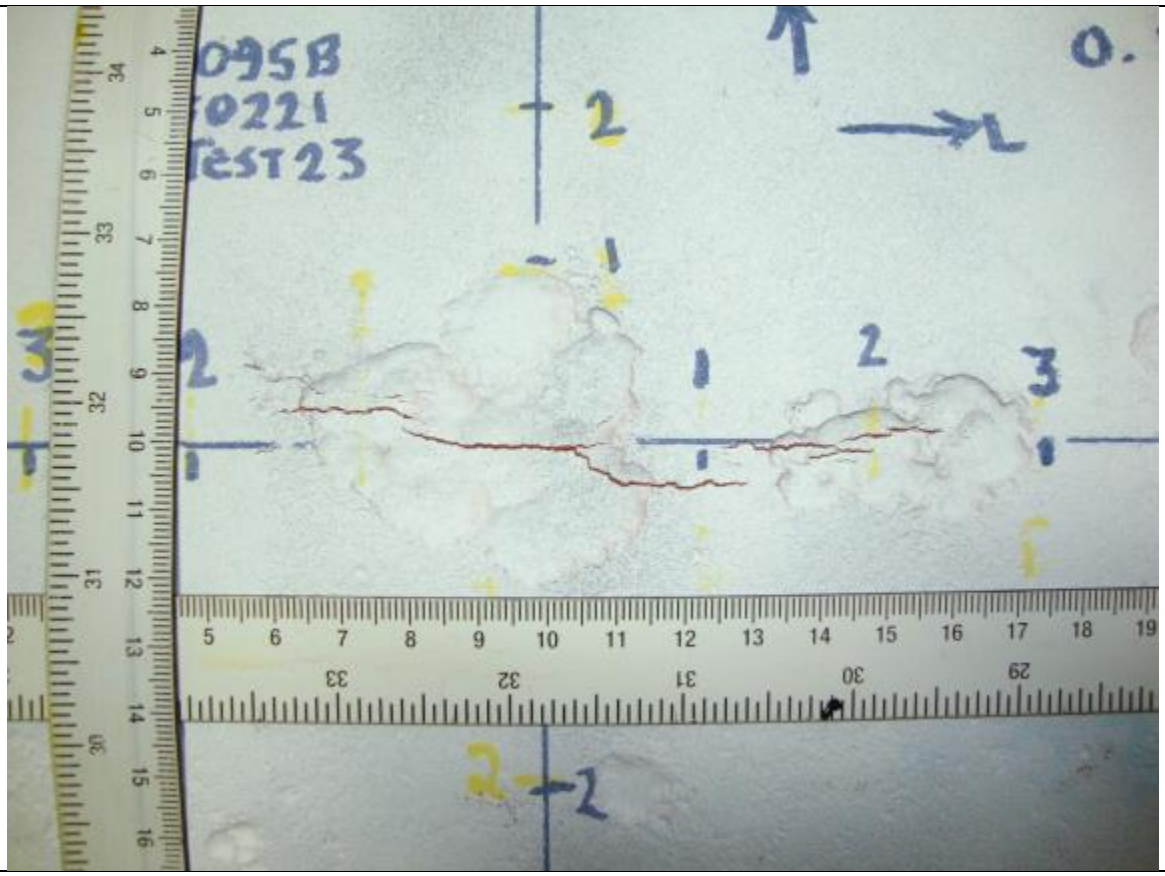


(a)

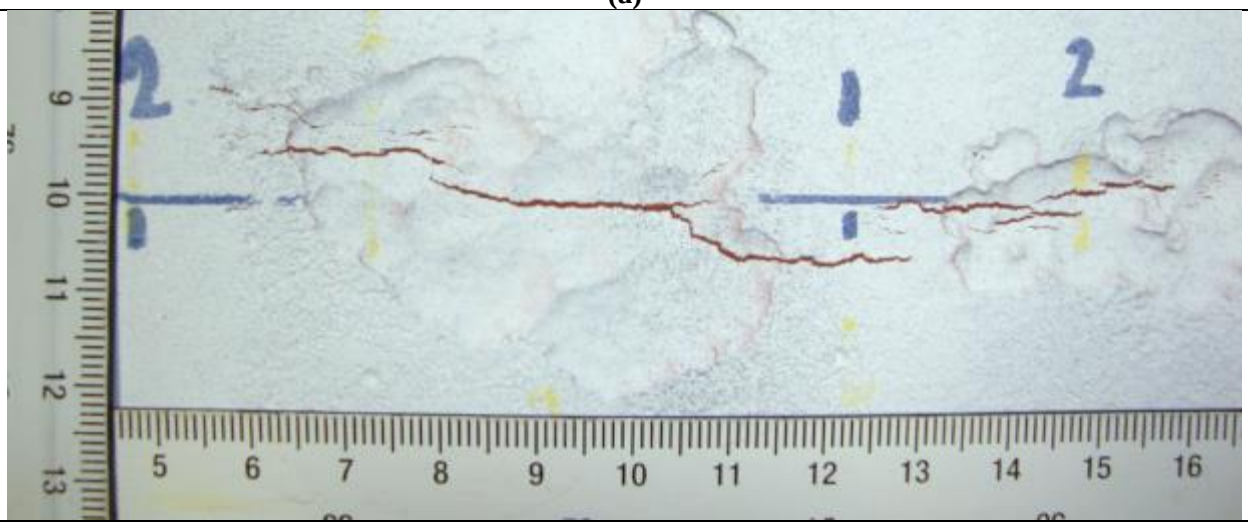


(b)

Figure 50: Test # 22 – Dent interacted with 9% Corrosion – ID MPI – Pipe F
(a) Axial OD cracks as seen on the ID Surface (b) ID Surface, Enlarged cracks photograph

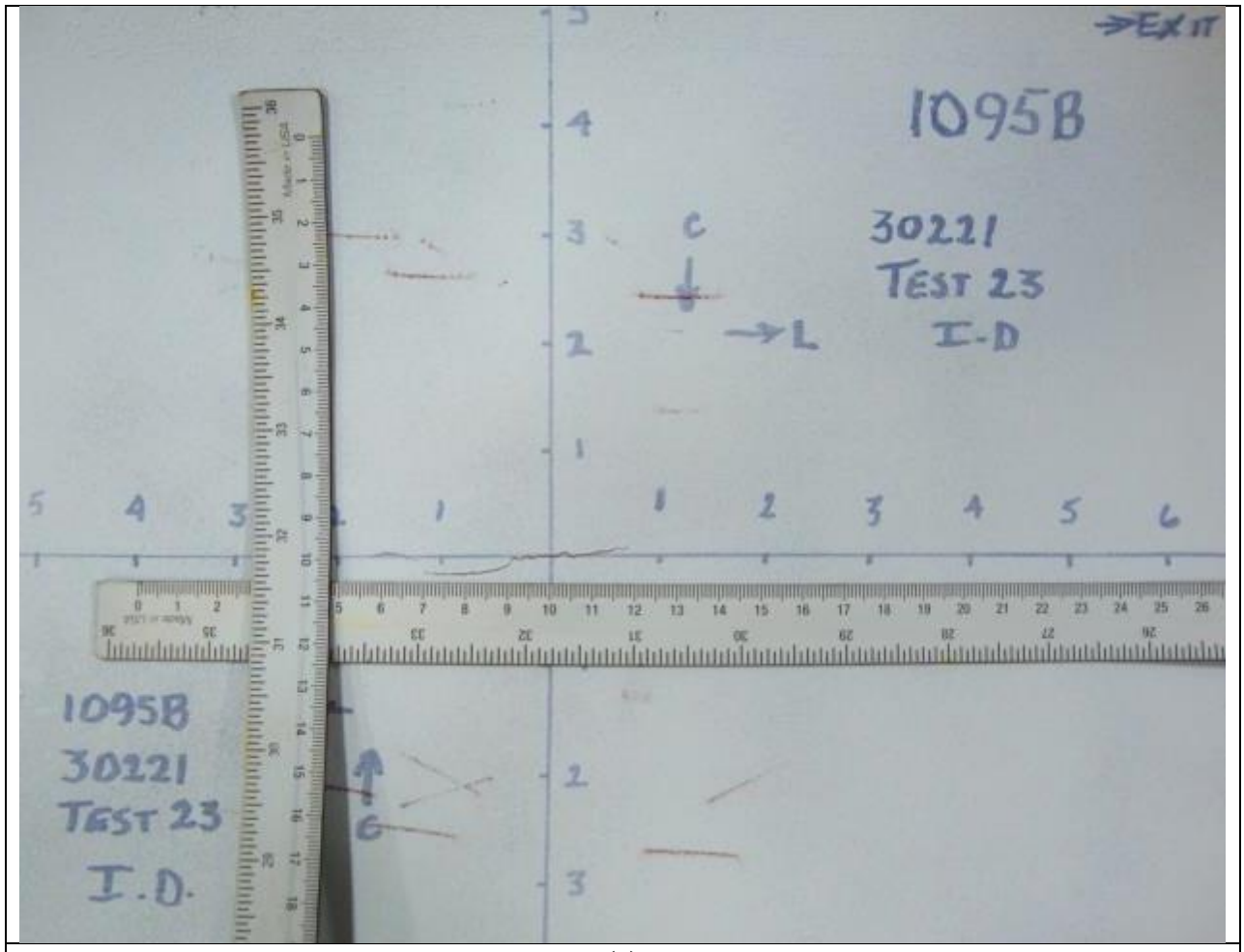


(a)



(b)

Figure 51: Test # 23 – Dent interacted with 39% Corrosion - OD MPI – Pipe F
(a) Axial OD Crack as seen on the OD Surface (b) OD Surface, Enlarged cracks photograph



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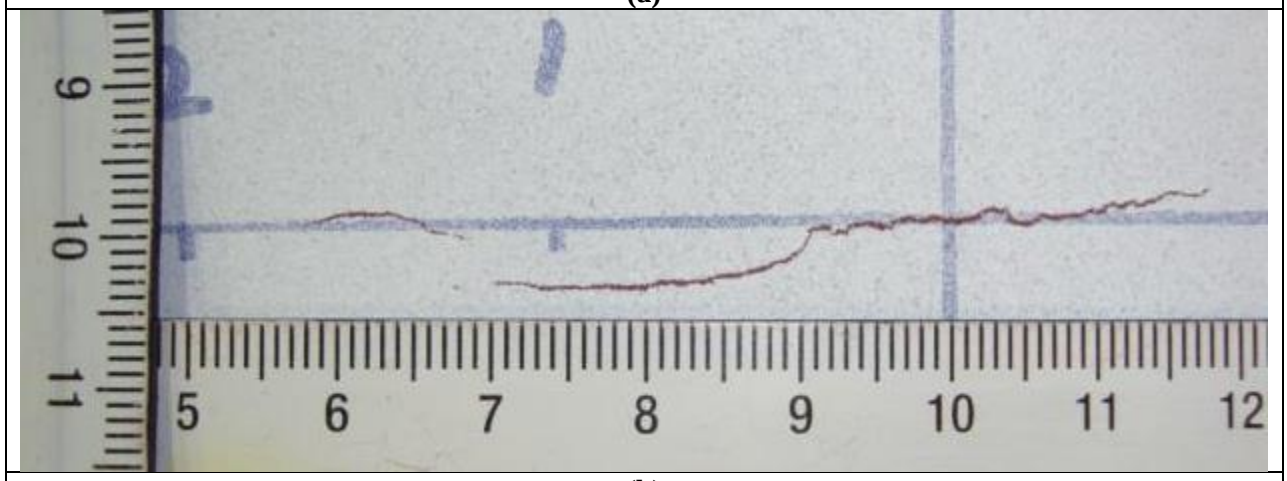
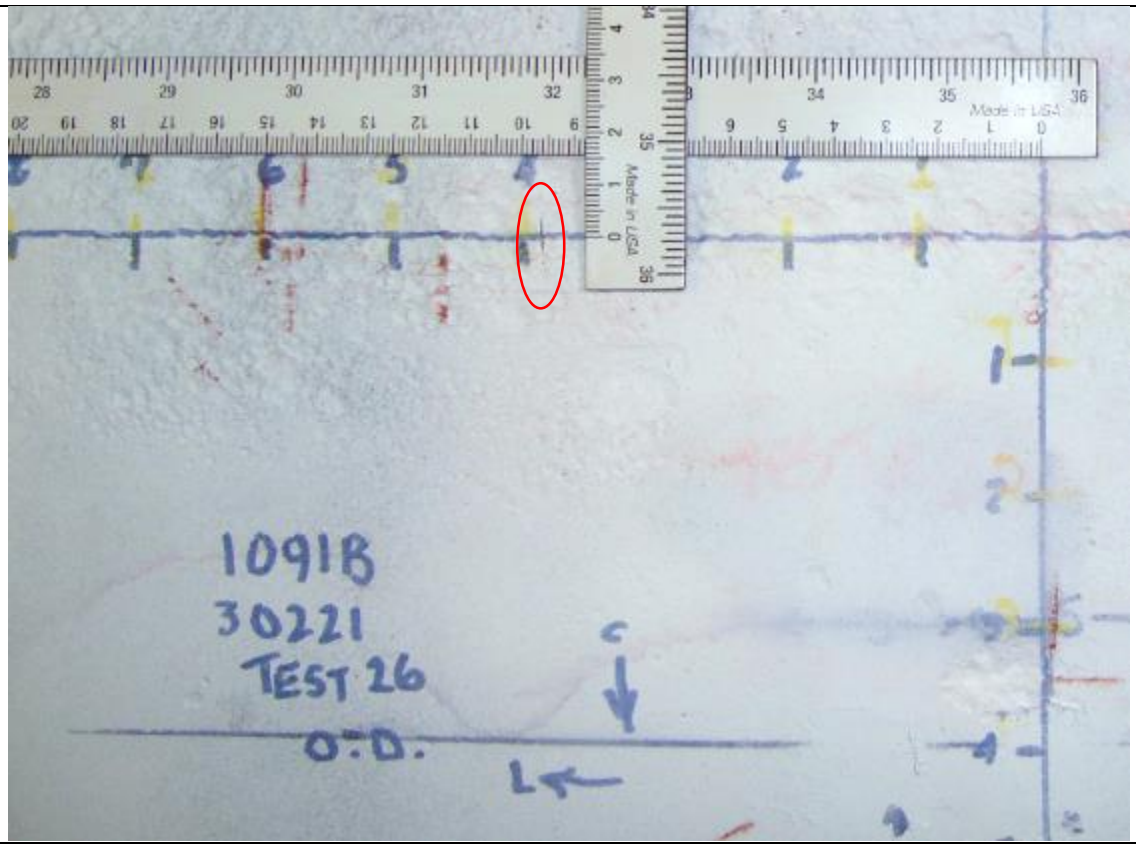


(b)

Figure 52: Test # 23 – Dent interacted with 39% Corrosion - ID MPI – Pipe F
(a) Axial OD crack as seen on the ID Surface (b) ID Surface, Enlarged crack photograph



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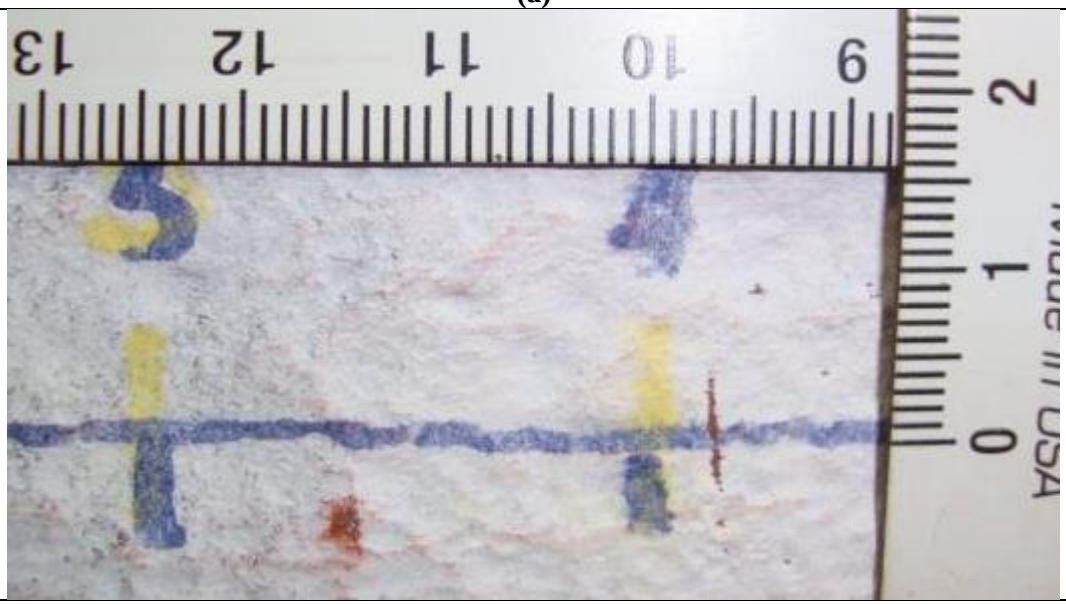
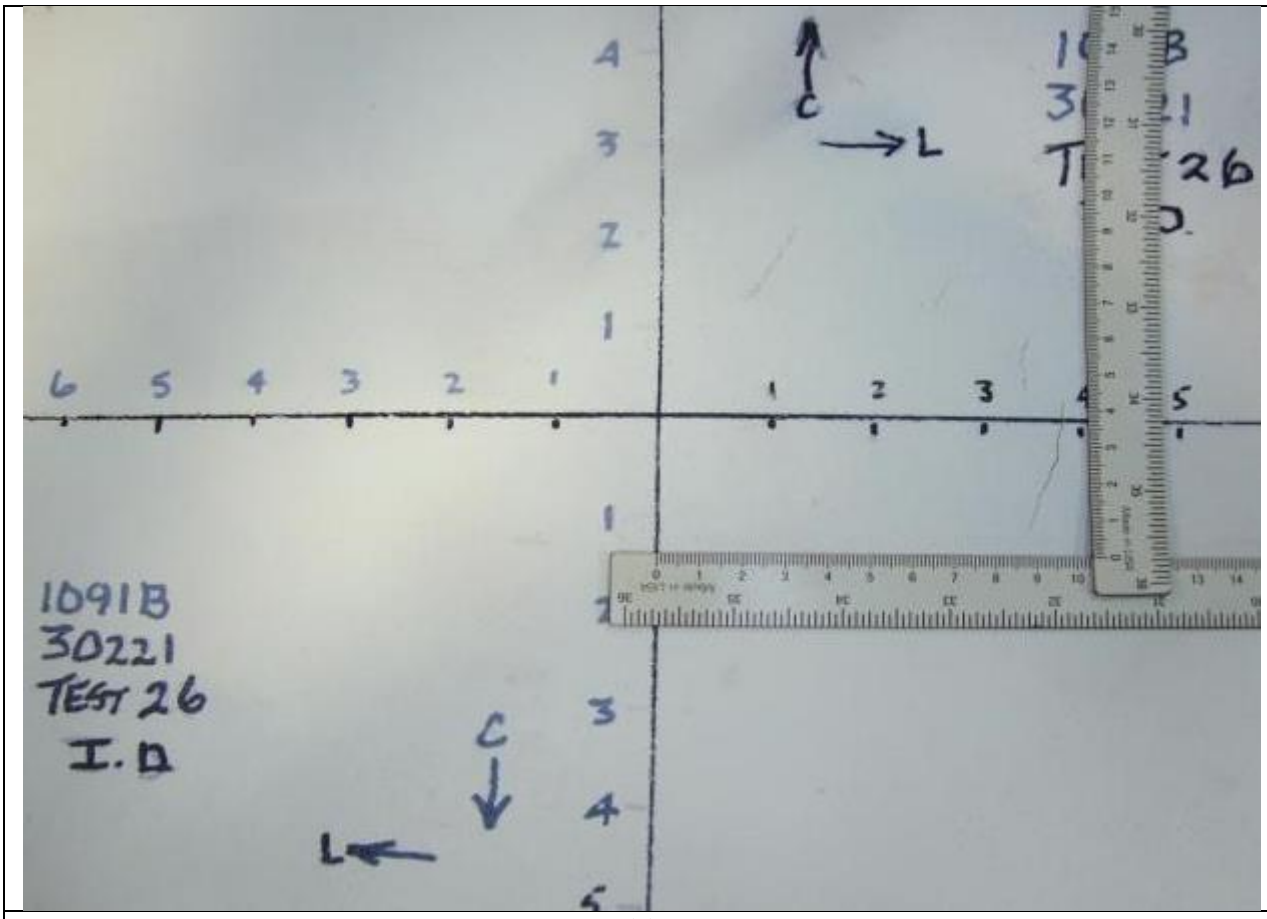


(b)

Figure 53: Test # 26 – Dent interacted with 20% Corrosion - OD MPI – Pipe F
(a) Circumferential ID crack as seen on the OD Surface (b) OD Surface, Enlarged crack photograph



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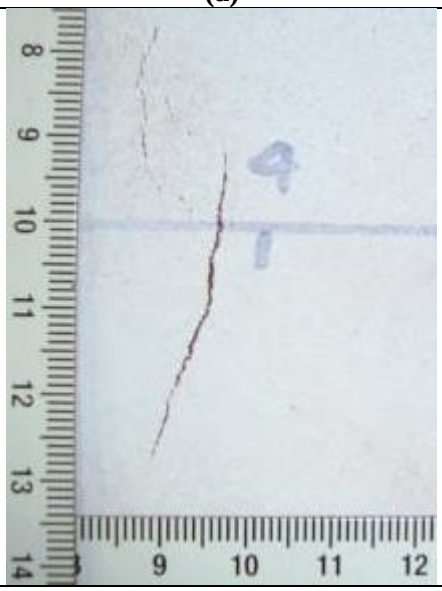
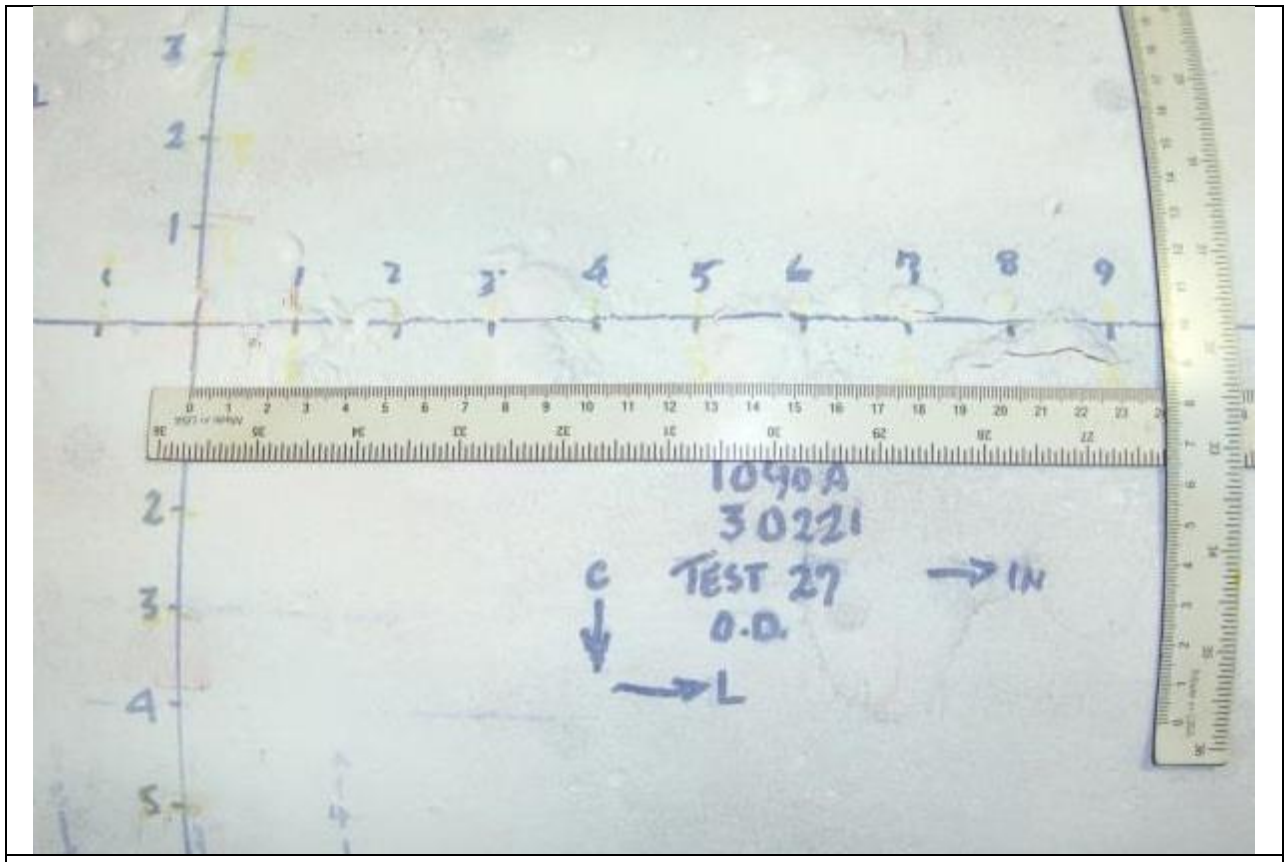


(b)

Figure 54: Test # 26 – Dent interacted with 20% Corrosion - ID MPI – Pipe F
(a) Circumferential ID crack as seen on the ID Surface (b) ID Surface, Enlarged crack photograph



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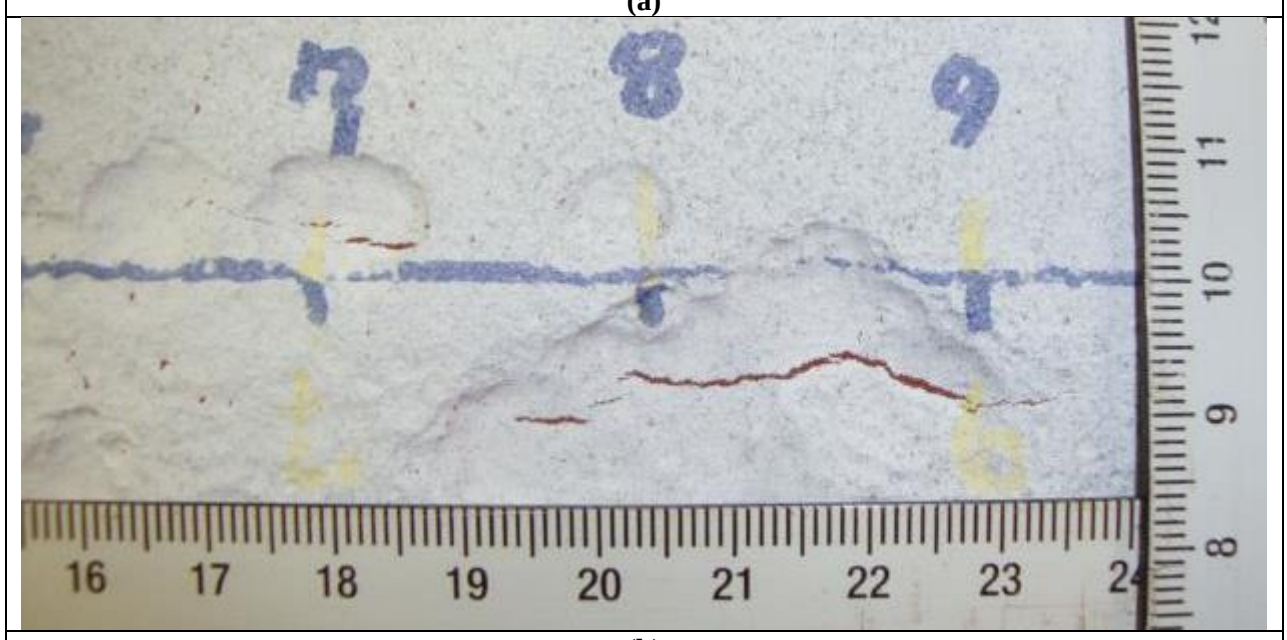
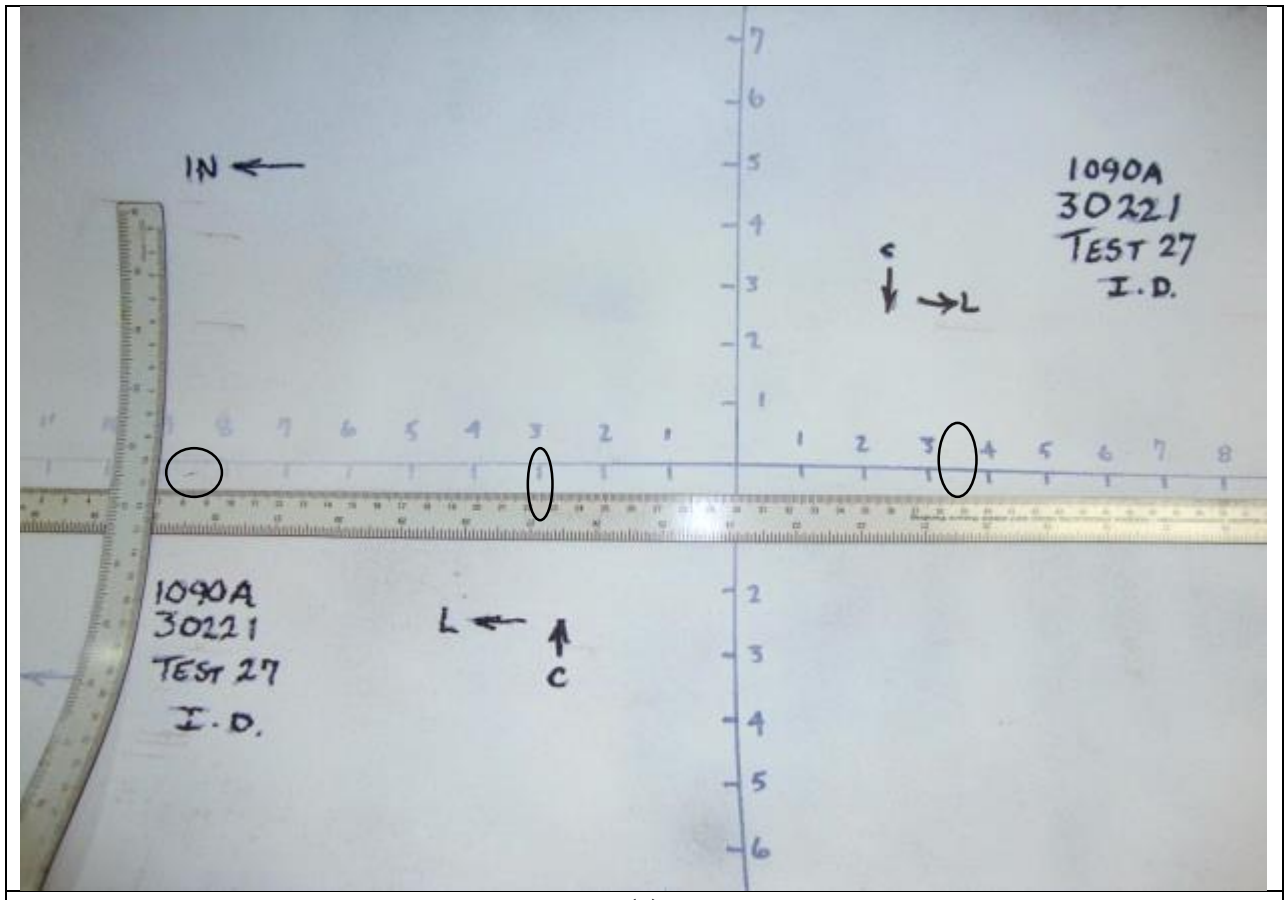


(b)

Figure 55: Test # 27 – Dent interacted with 35% Corrosion - OD MPI – Pipe F
(a) Axial OD crack as seen on the OD Surface (b) OD Surface, Enlarged crack photograph



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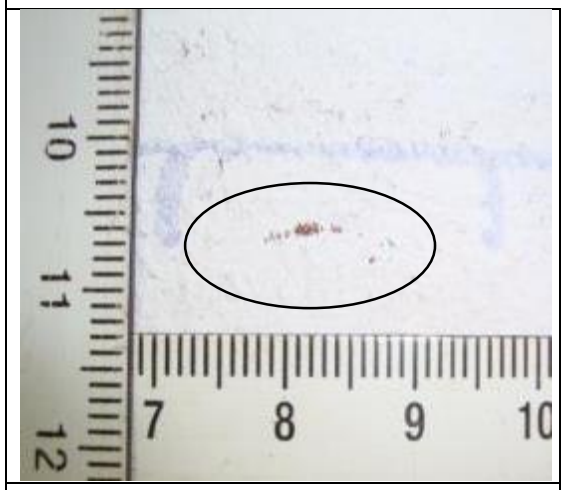

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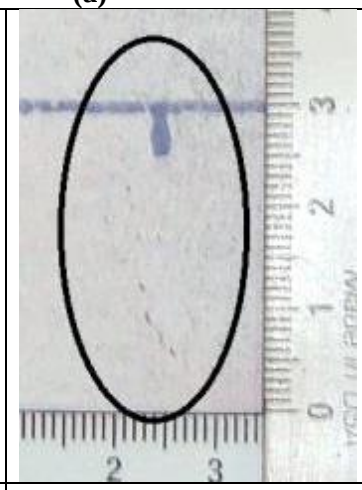

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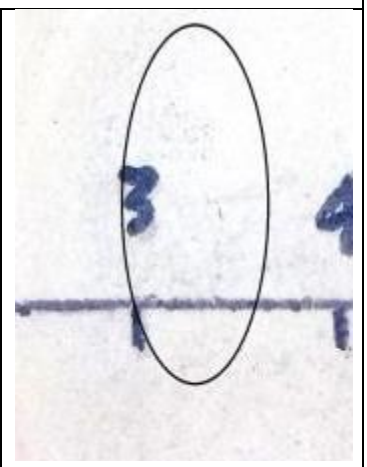
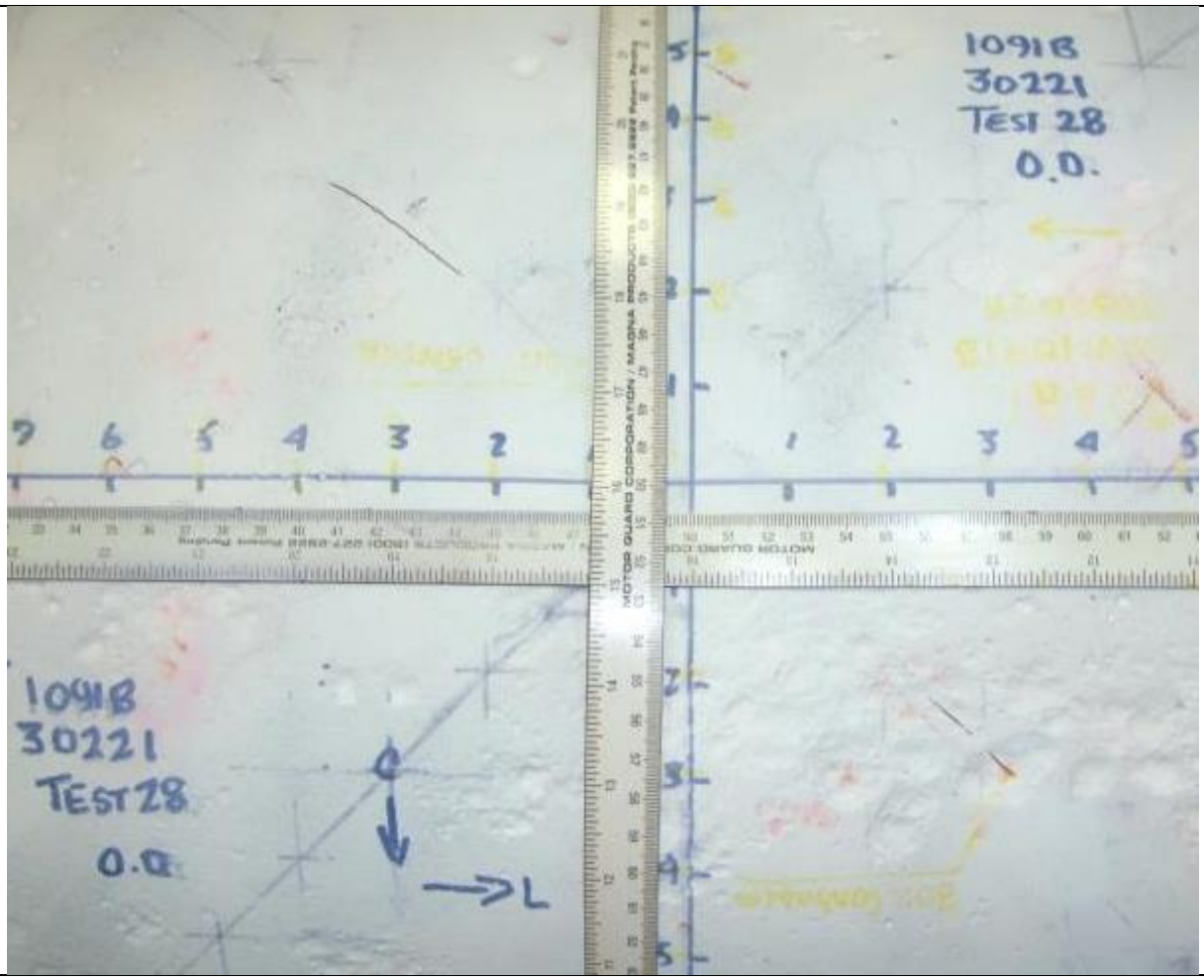


(c)

Figure 56: Test # 27 – Dent interacted with 35% Corrosion - ID MPI – Pipe F
(a) Axial OD crack and circumferetial ID cracks as seen on the ID Surface
(b) ID Surface, Enlarged crack photograph (Axial OD crack – Fill Side)
(c) ID Surface, Enlarged crack photograph (Circumferential ID Crack – Fill Side)
(c) ID Surface, Enlarged crack photograph (Circumferential ID Crack – Exit Side)



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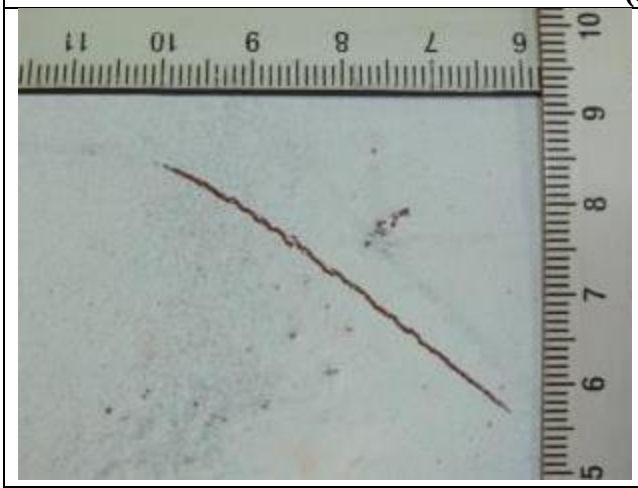

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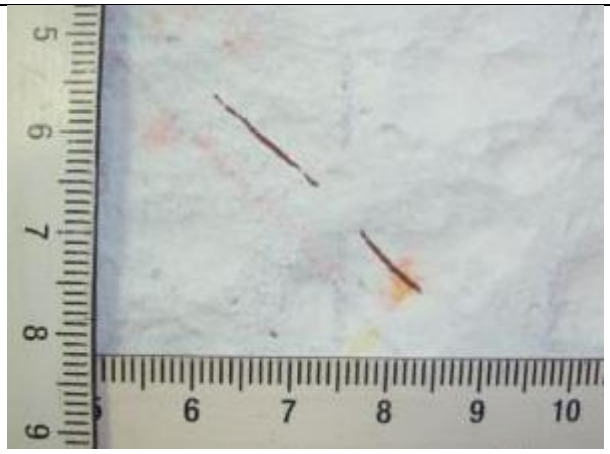
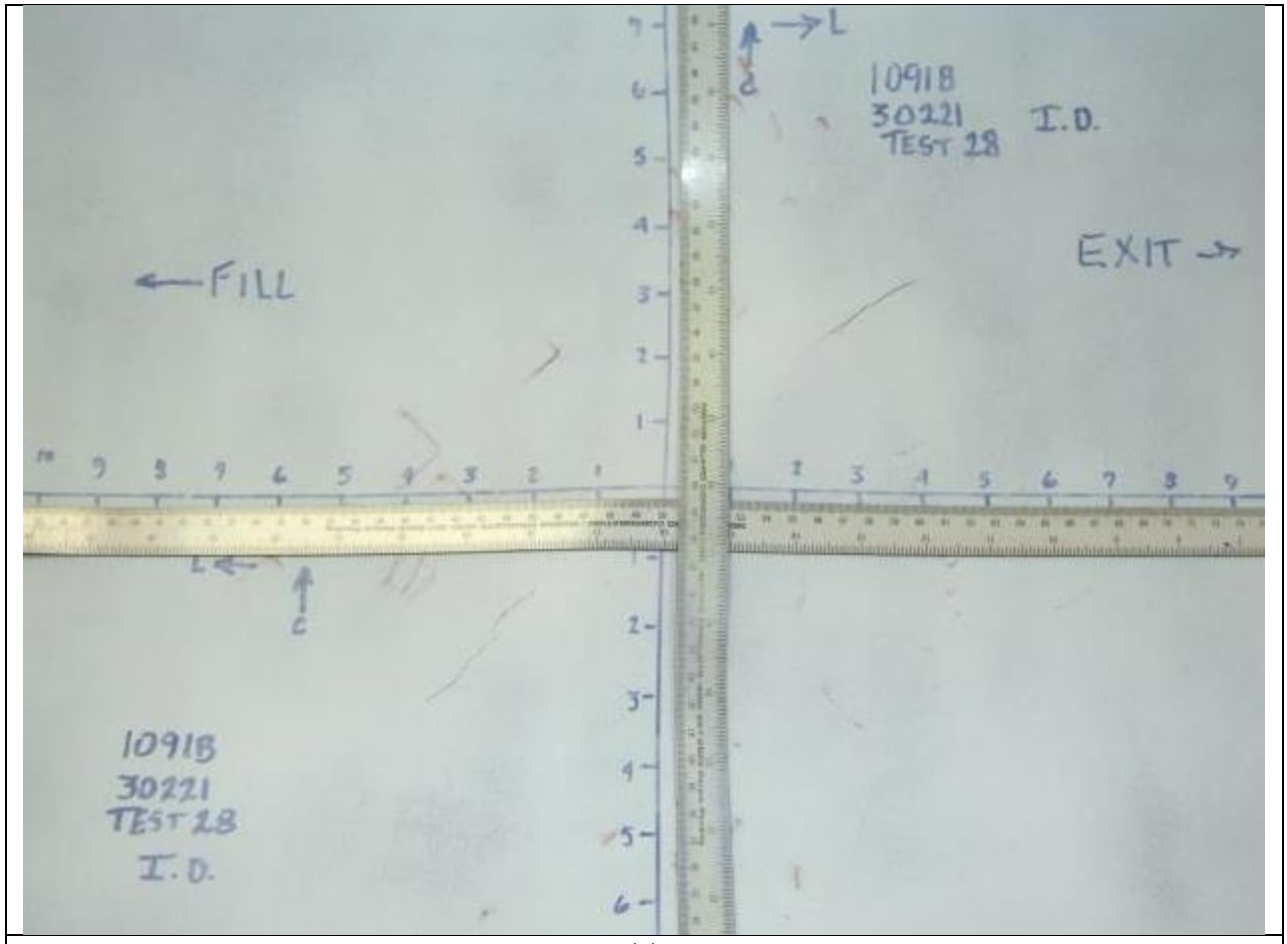
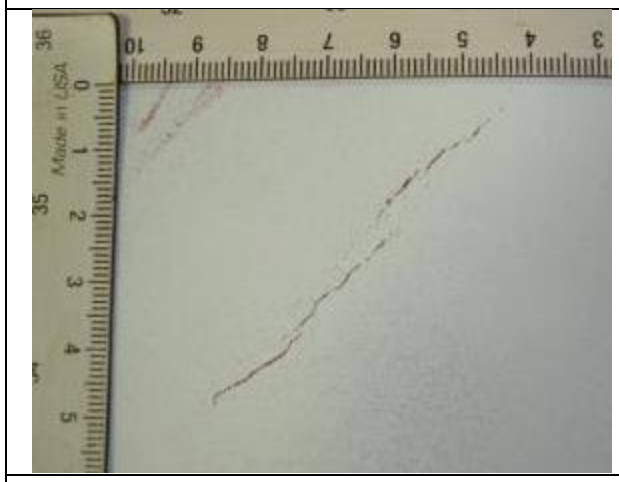


(c)

Figure 57: Test # 28 – Dent interacted with 28% Corrosion – OD MPI – Pipe F
(a) 32 degree Angle ID crack as seen on the OD Surface
(b) OD Surface, Enlarged crack photograph (Exit Side)
(c) OD Surface, Enlarged crack photograph (Fill Side)



(a)



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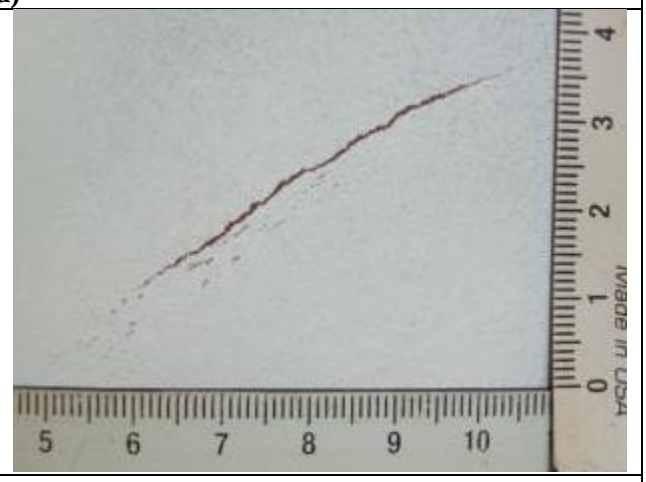
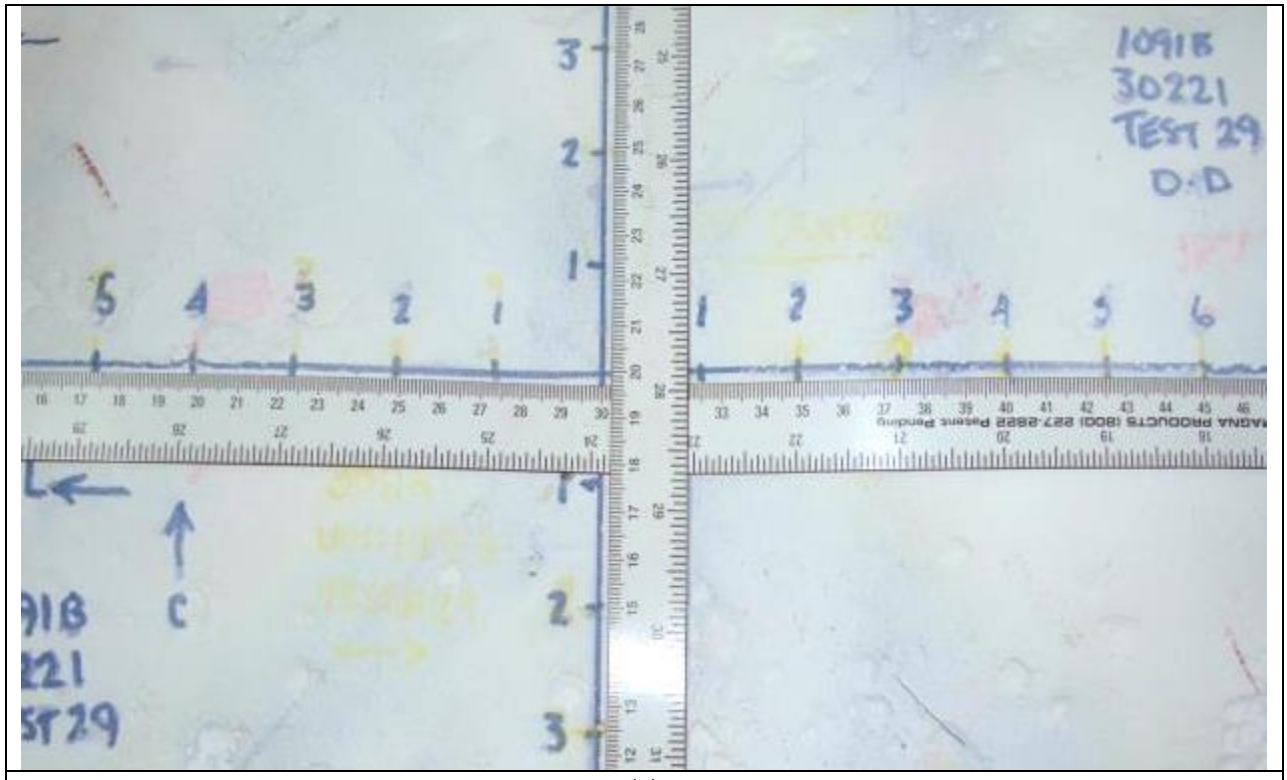
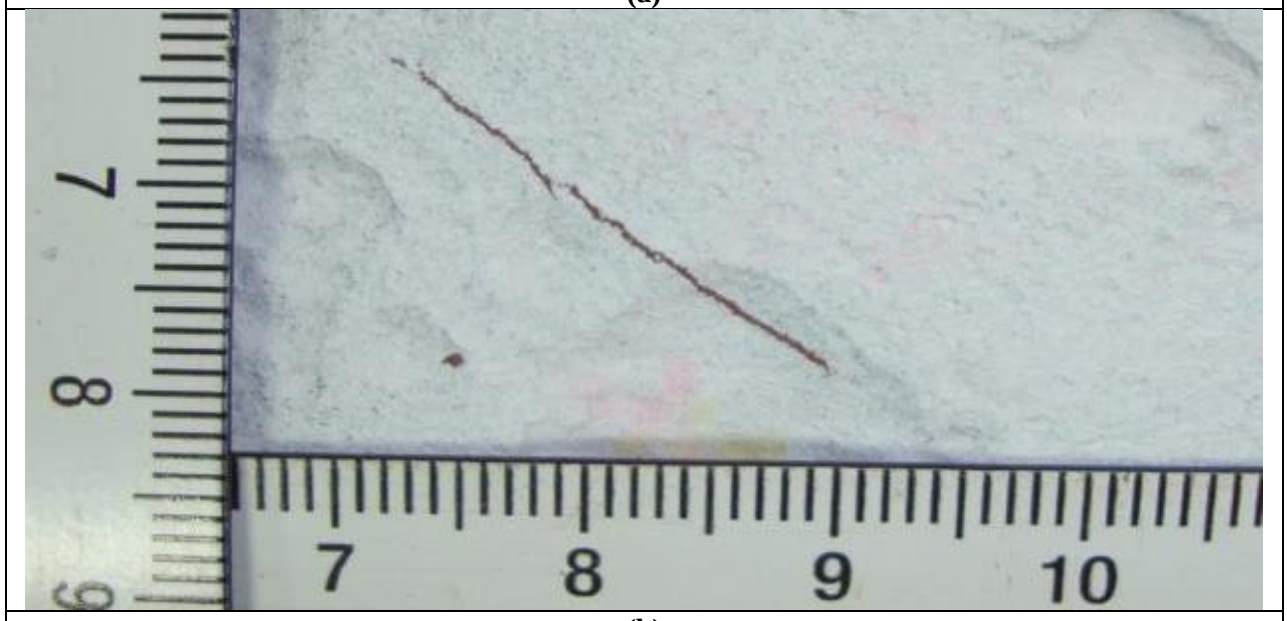


(c)

Figure 58: Test # 28 – Dent interacted with 28% Corrosion – ID MPI – Pipe F
(a) 32 degree Angle ID crack as seen on the ID Surface
(b) ID Surface, Enlarged crack photograph (Fill Side)
(c) ID Surface, Enlarged crack photograph (Exit Side)

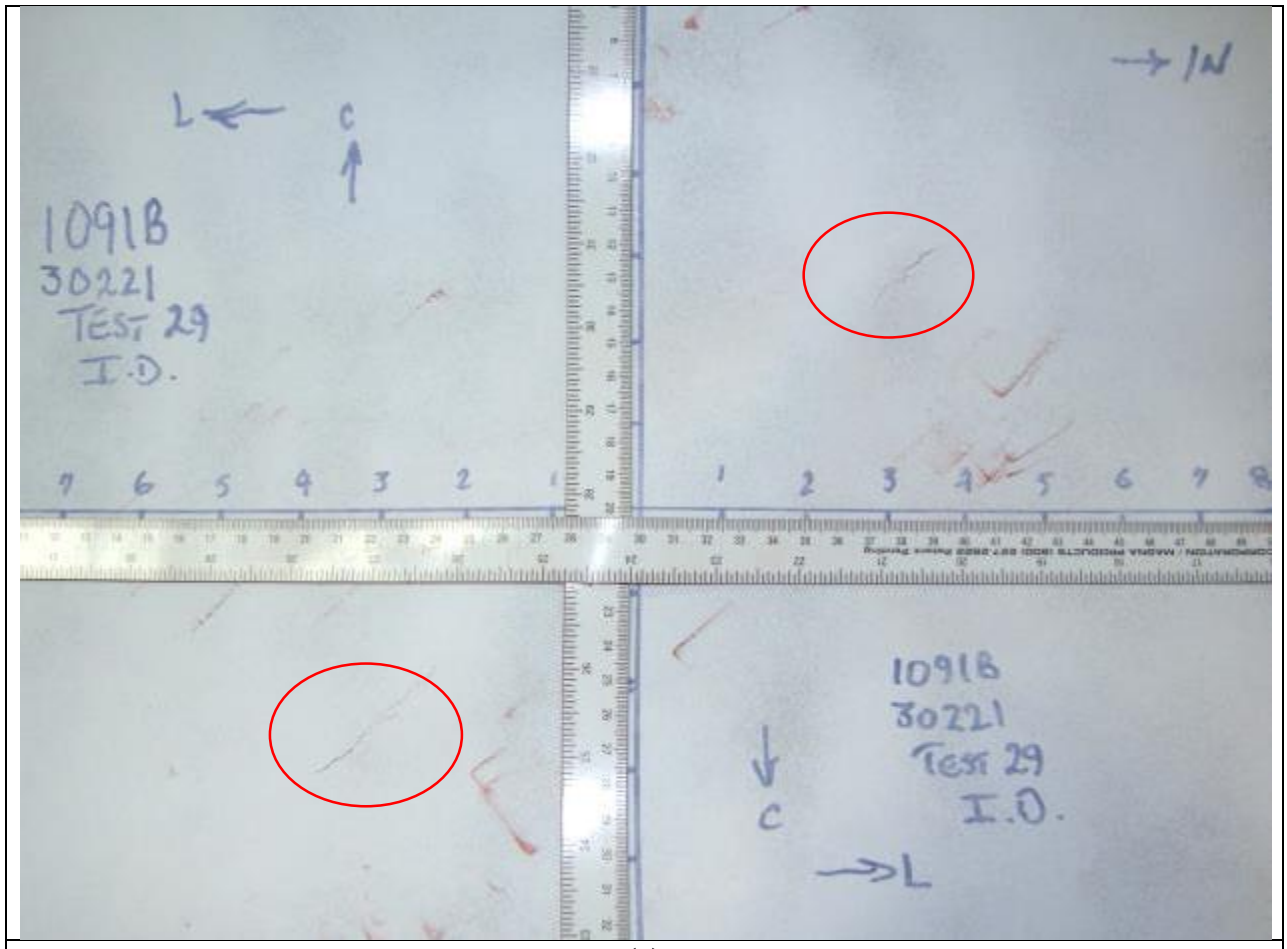


(a)

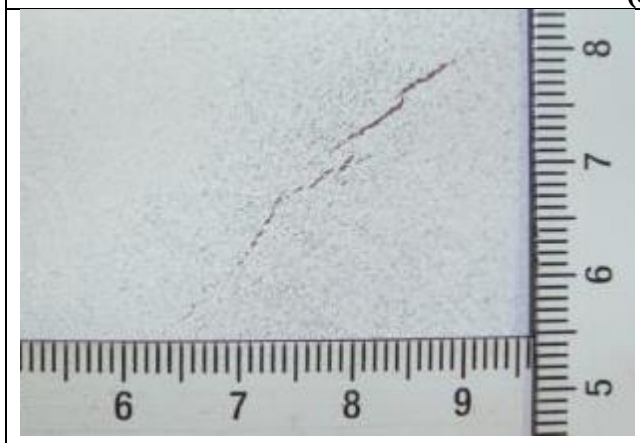


(b)

Figure 59: Test # 29 – Dent interacted with 23% Corrosion – OD MPI – Pipe F
(a) 42 degree angle ID crack as seen on the OD Surface
(b) OD Surface, Enlarged crack photograph (Exit Side)



(a)



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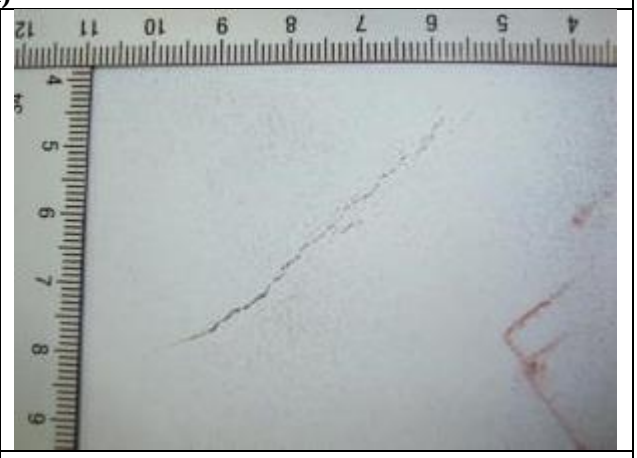

(c)

Figure 60: Test # 29 – Dent interacted with 23% Corrosion – ID MPI – Pipe F
(a) 42 degree angle ID crack as seen on the ID Surface
(b) ID Surface, Enlarged crack photograph (Fill Side)
(c) ID Surface, Enlarged crack photograph (Exit Side)

ANNEX E

CROSS-SECTION METALLOGRAPHY

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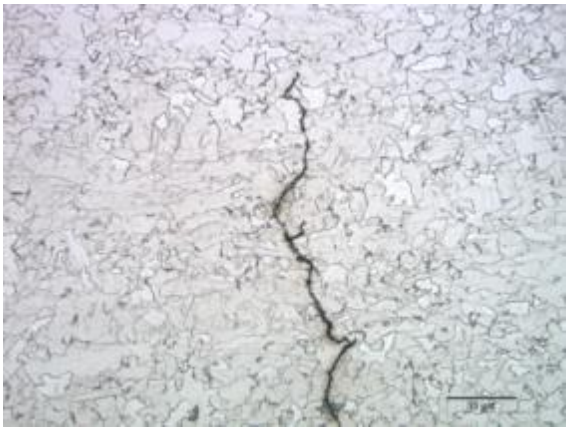
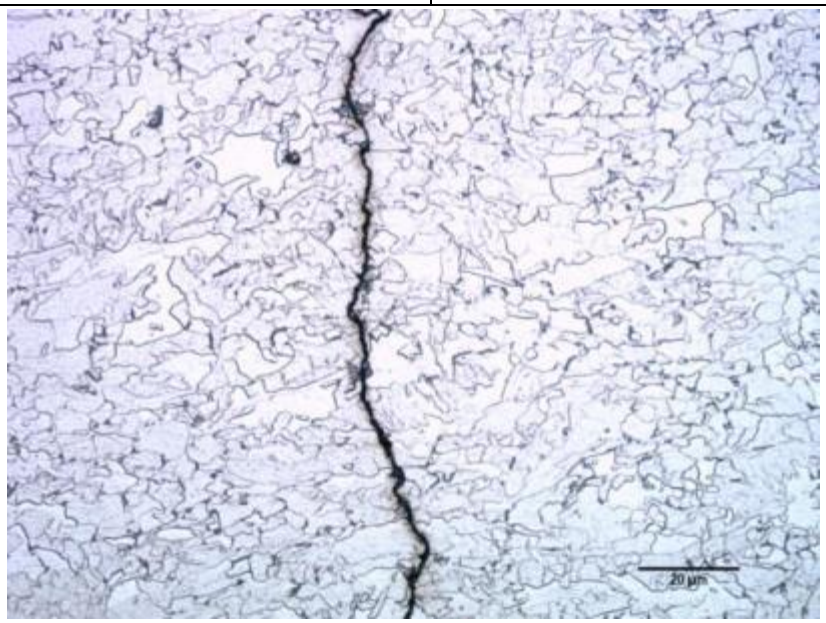
E. Cross-section Metallography

E.1 Dents interacted with Plain Dents

Crack at ID Location -50X

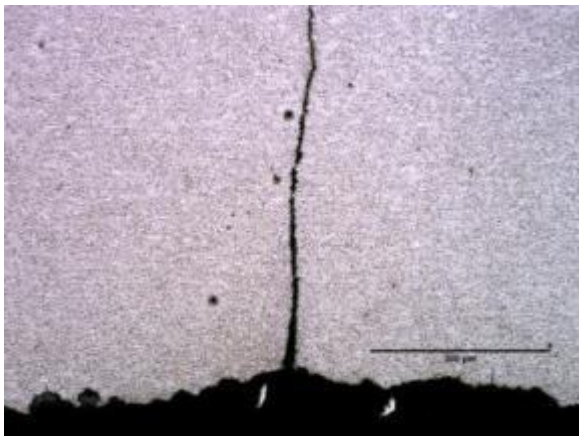


Crack Root -500X



Crack Path Detail -500X

Figure 1: Test # 1 – Plain Dent – Axial Crack Cross-section Photographs – Pipe D



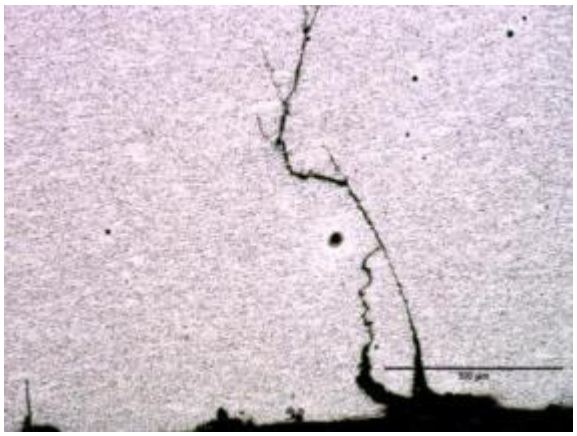
Crack at ID location -50X

Crack root (2mm from ID) -100X

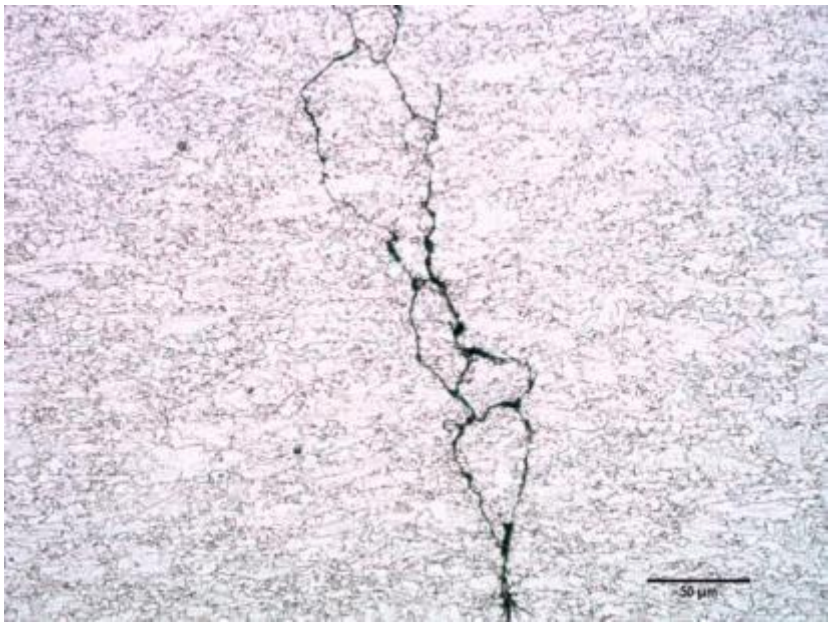
Crack path branching detail (1mm from ID) -500X

Figure 2: Test # 2 – Plain Dent – Axial Crack Cross-section Photographs – Pipe D

Crack at ID location -50X

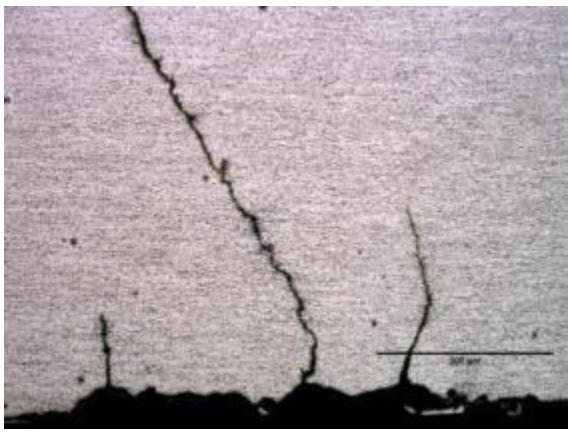


Secondary crack path -50X

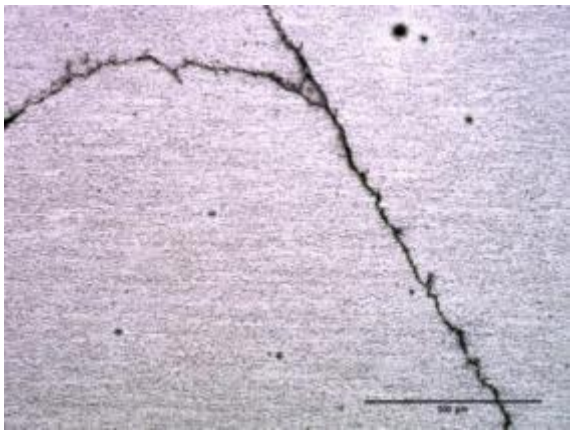


Crack path branching detail mid wall -200X

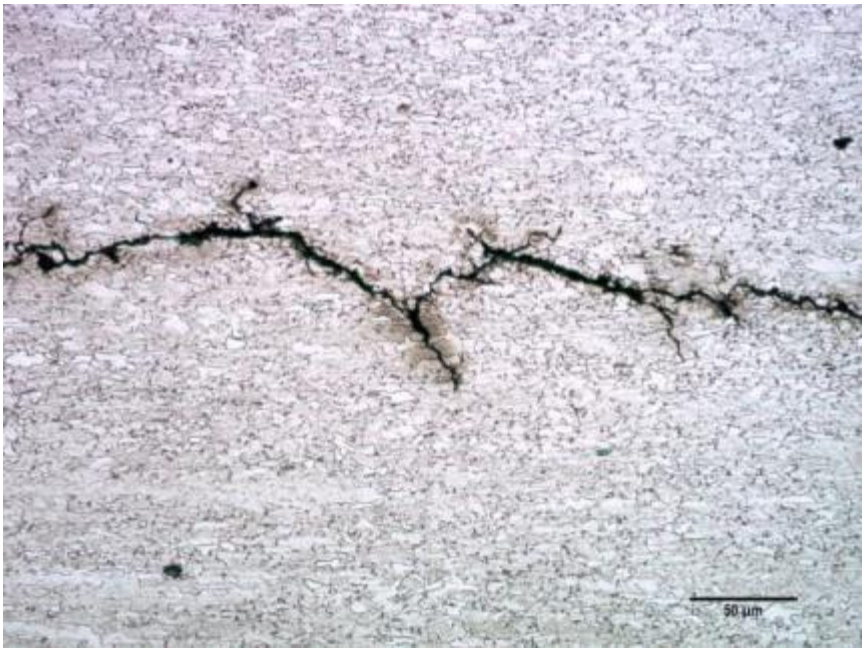
Figure 3: Test # 3 – Plain Dent – Axial Crack Cross-section Photographs – Pipe D



Crack at ID location -50X



Crack path & branching -50X



Crack branching detail mid wall -200X

Figure 4: Test # 4 – Plain Dent – Circumferential Crack Cross-section Photographs – Pipe D

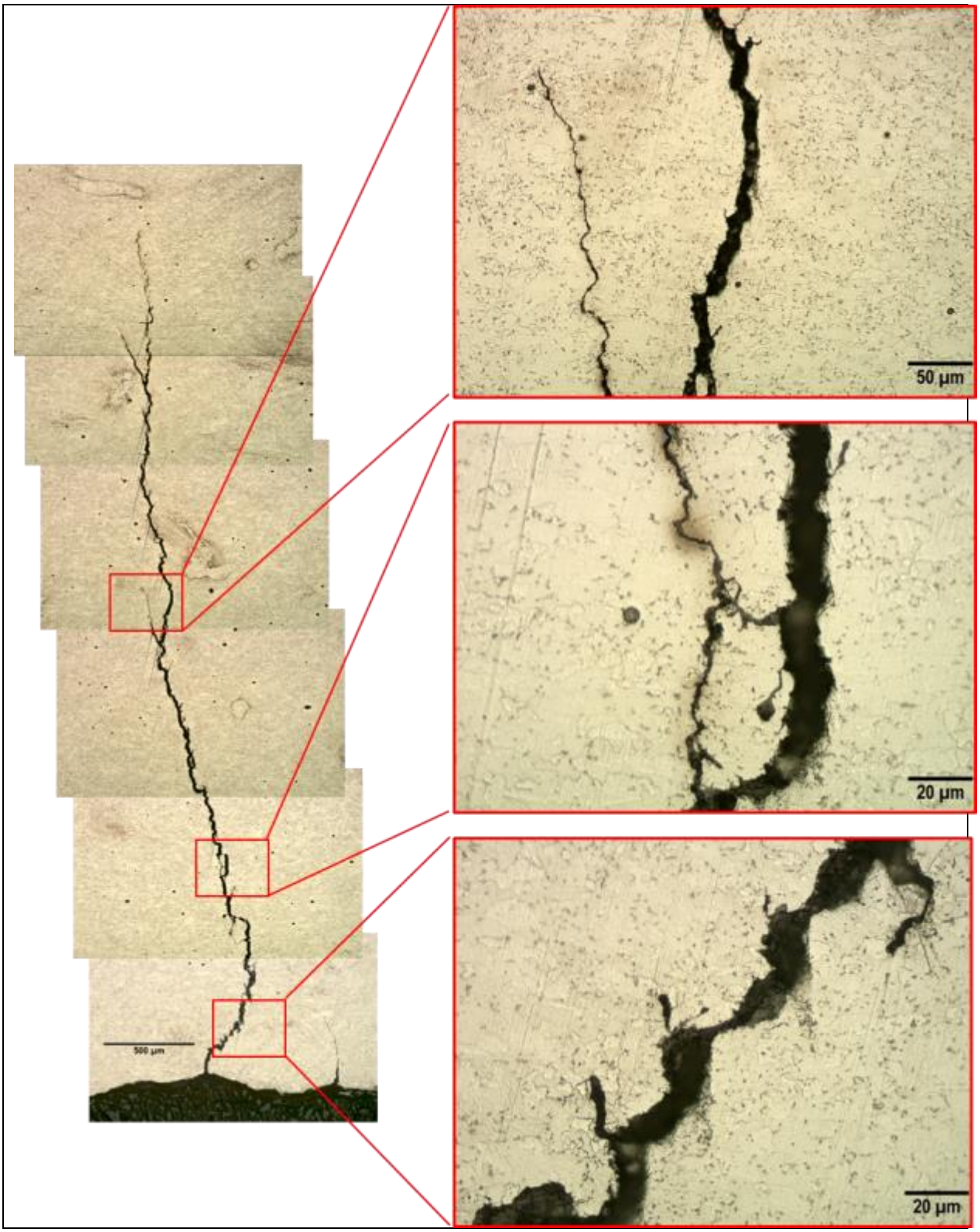


Figure 5: Test # 11 – Plain Dent – Axial Crack Cross-section Photographs – Pipe D

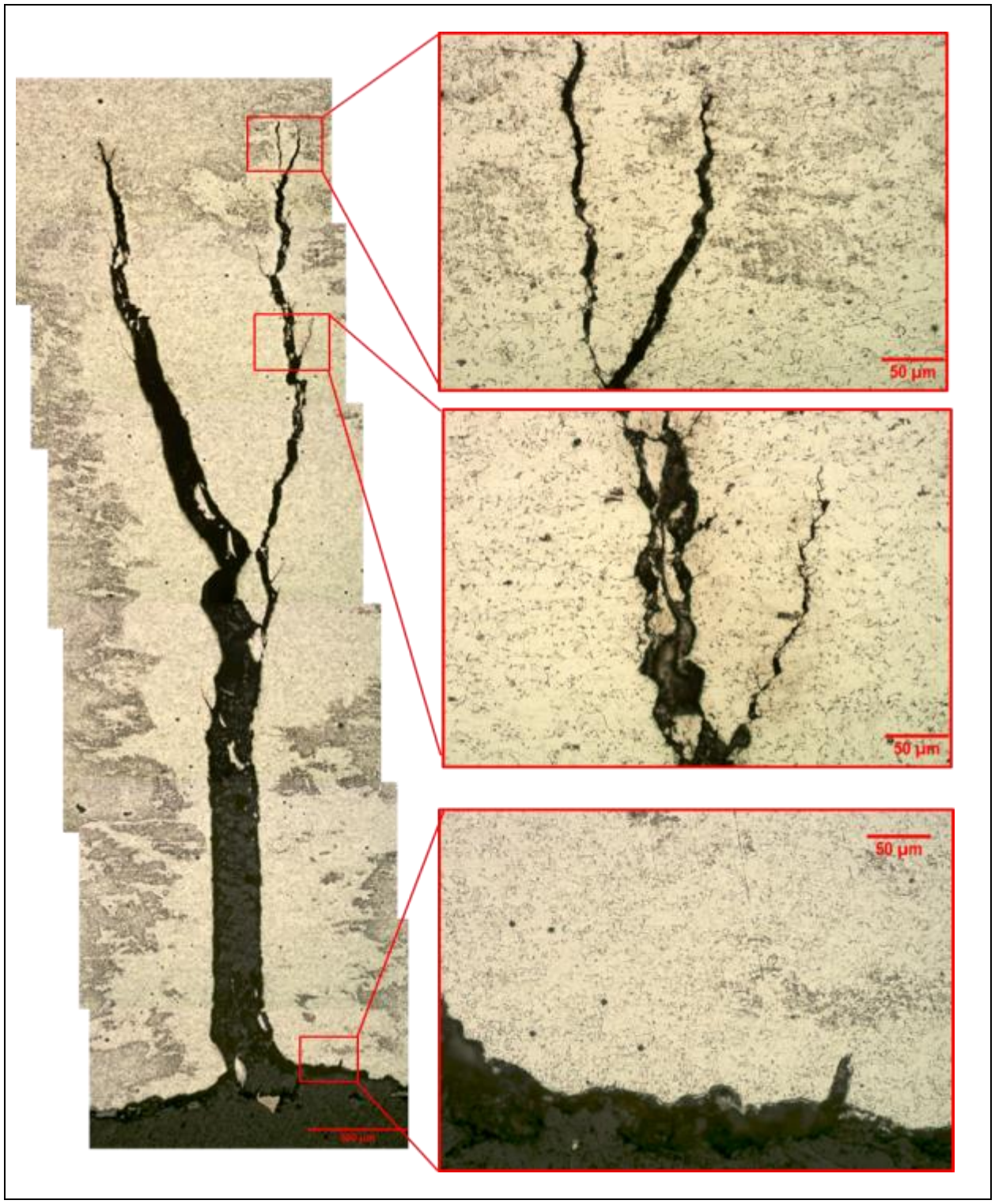
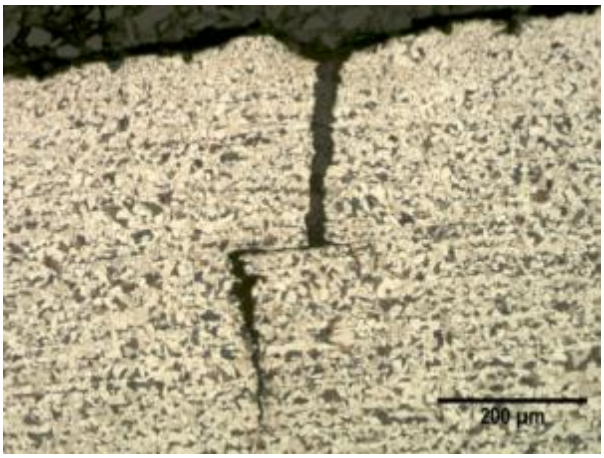
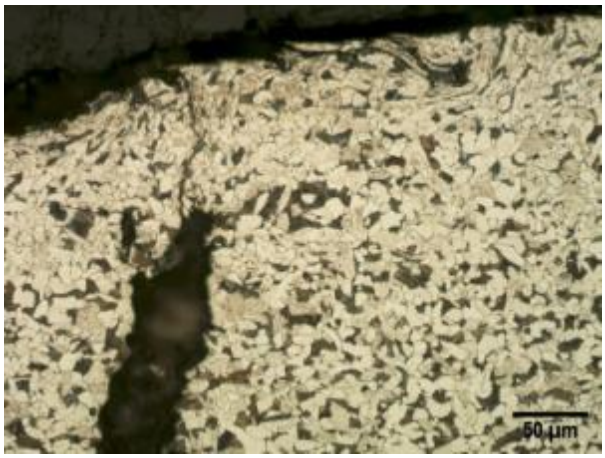


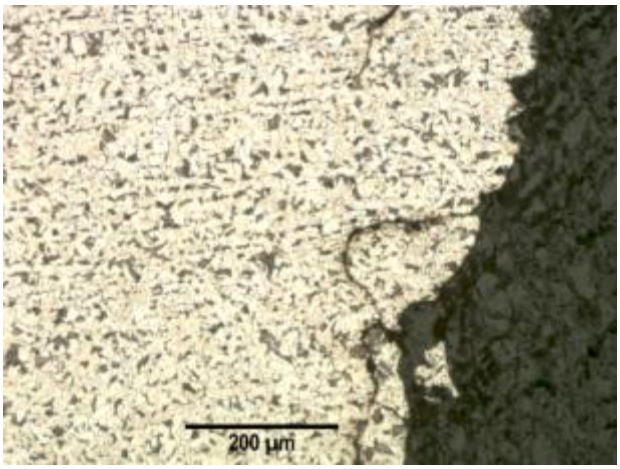
Figure 6: Test # 13 – Plain Dent – Axial Crack Cross-section Photographs – Pipe D



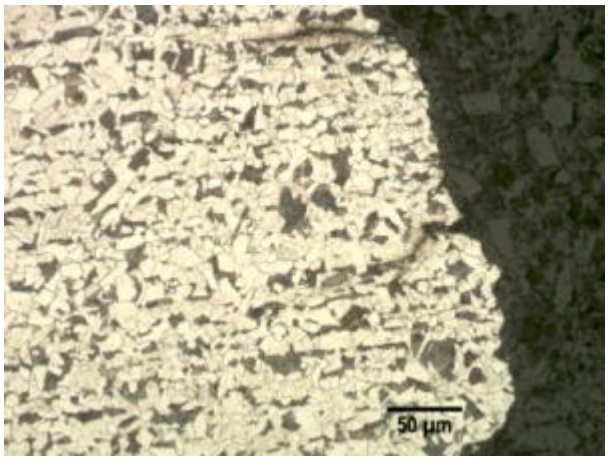
OD secondary crack / lamination -100X



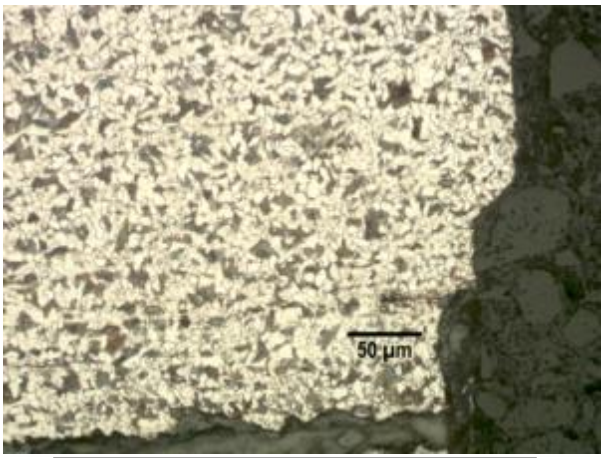
At the OD -200X



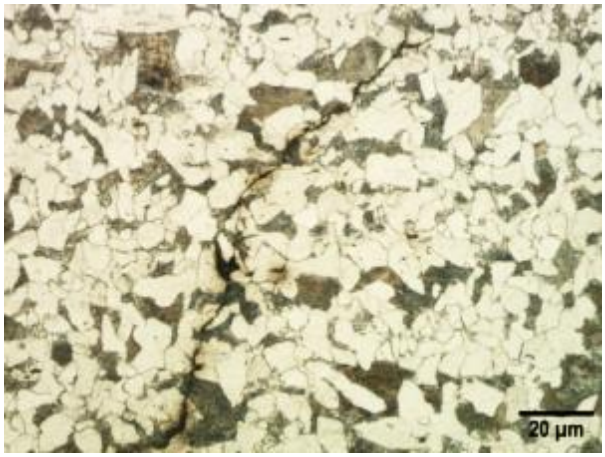
Subsidiary cracks mid-wall -100X



Subsidiary cracks ¼ wall OD side -200X

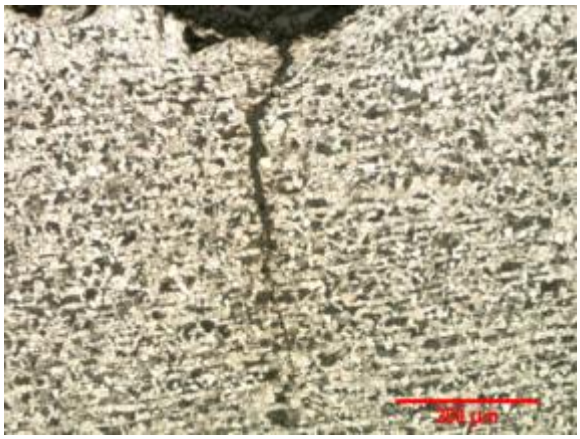


Subsidiary cracks ID side -200X

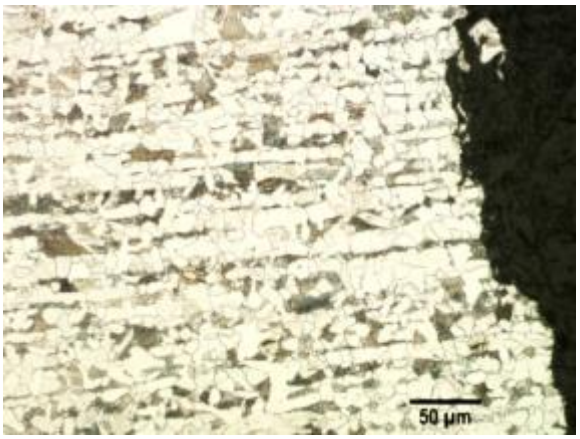


Crack root ID side -500X

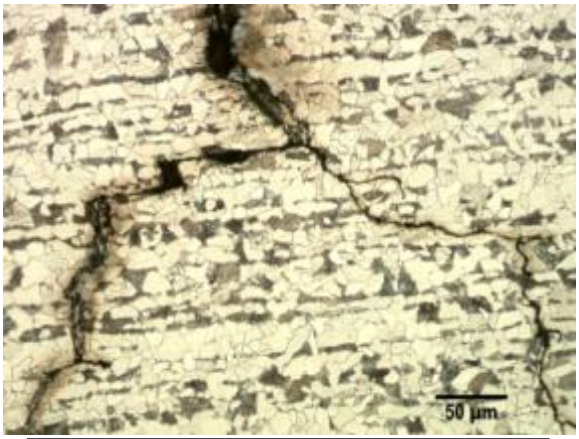
Figure 7: Test # 14 – Plain Dent – Axial Crack Cross-section Photographs – Pipe F



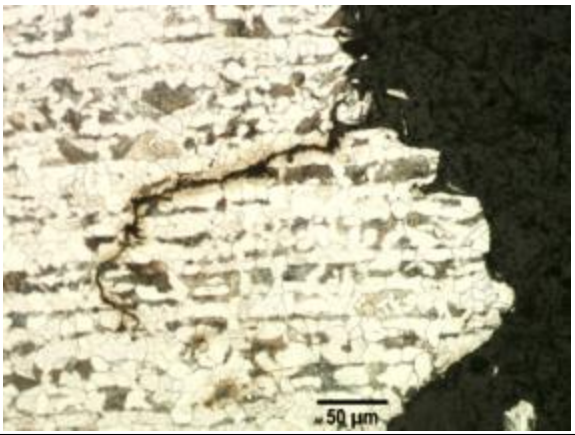
Crack originated at an OD Pit -100X



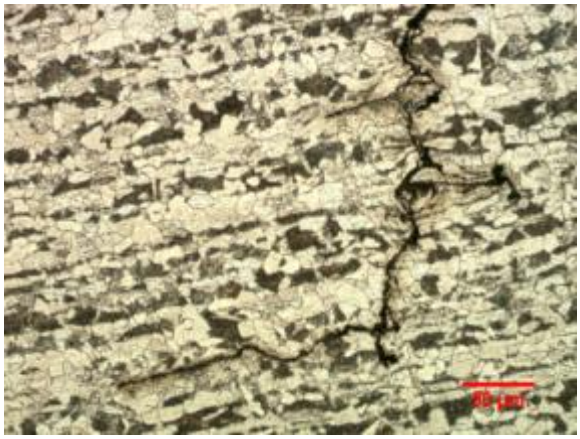
Through pipe wall crack (OD side) -200X



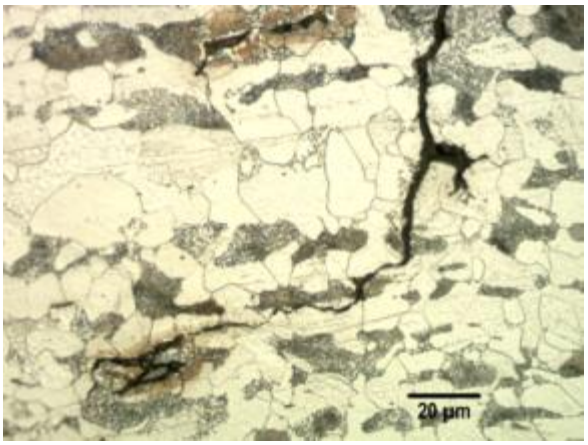
Crack branches mid wall -200X



Branch formed at through crack (near OD) -200X

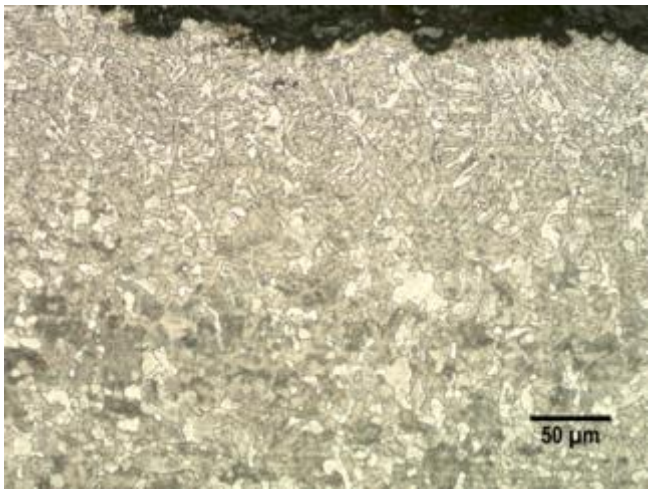


Subsidiary crack ¼ wall OD side -200X



Crack root (through wall crack) mid wall -500X

Figure 8: Test # 15 – Plain Dent – Axial Crack Cross-section Photographs – Pipe F



Detail microstructure OD side- 200X

Detail microstructure mid wall- 200X

Detail microstructure ID side- 200X

Figure 9: Test # 24 – Plain Dent – 32 degree Angle Crack Cross-section Photographs – Pipe F

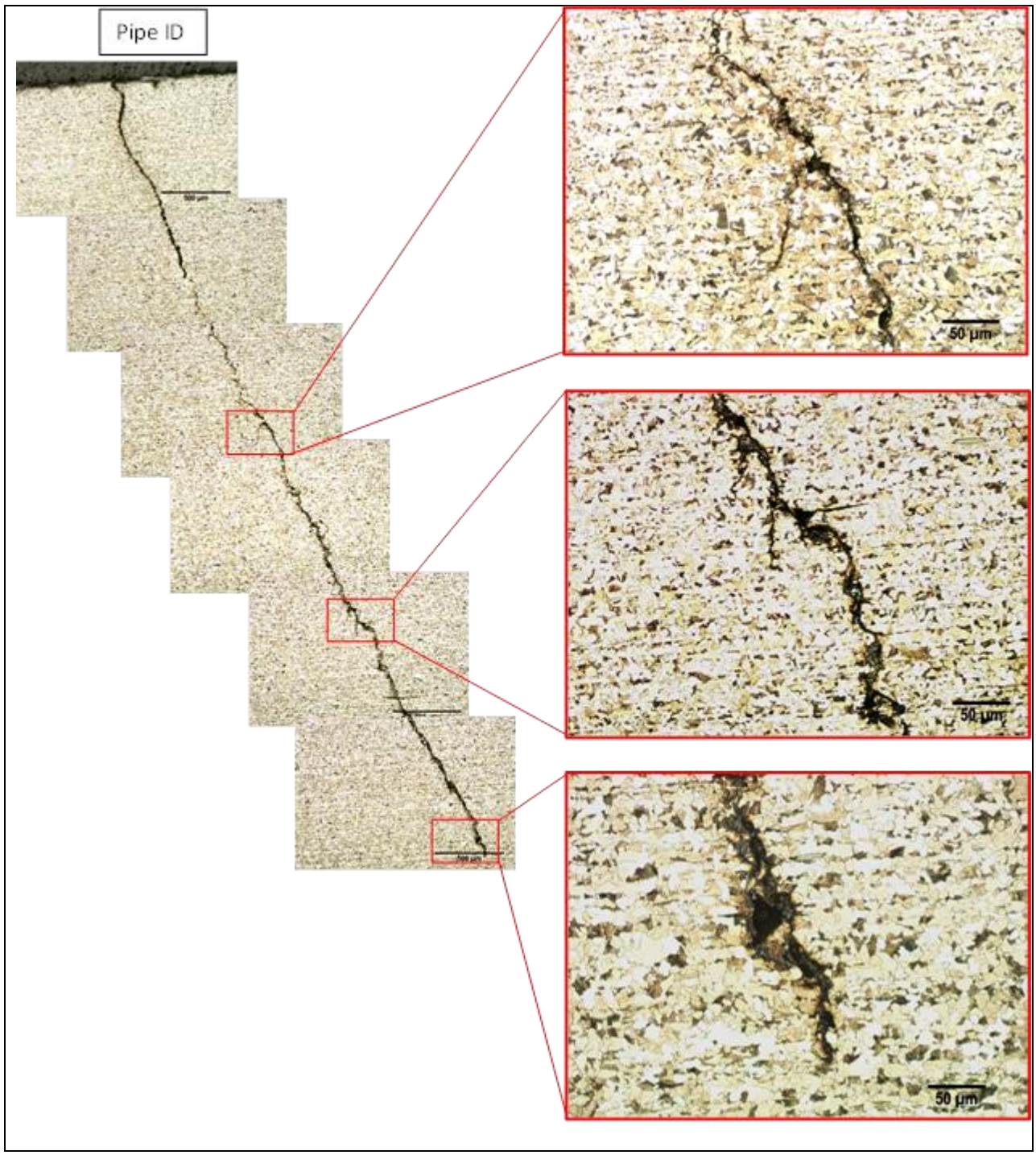


Figure 10: Test # 25 – Plain Dent – Circumferential Crack Cross-section Photographs – Pipe F

E.2 Dents interacted with Welds

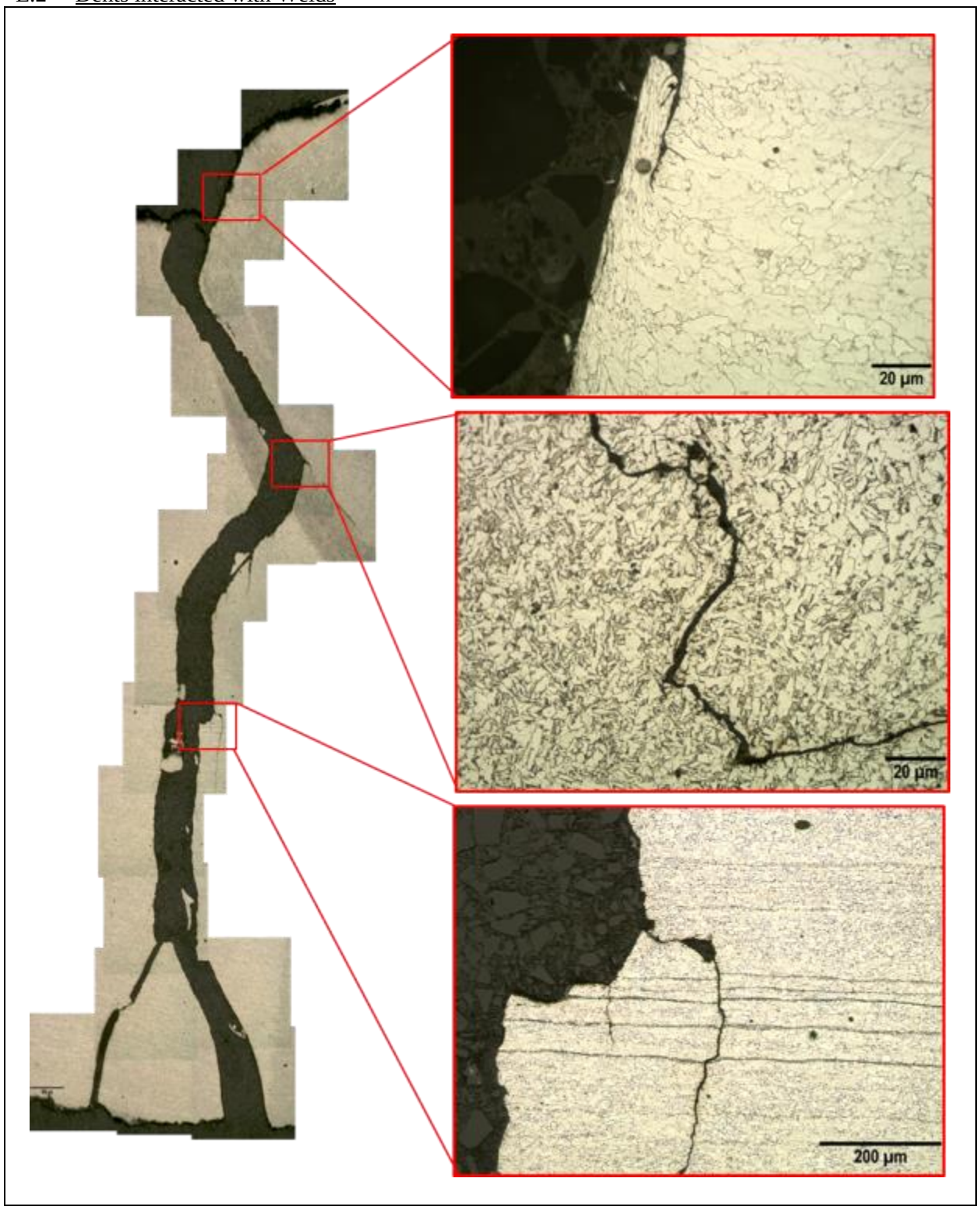


Figure 11: Test # 5 – Dent interacted with GW – Circumferential Crack Cross-section Photographs – Pipe D

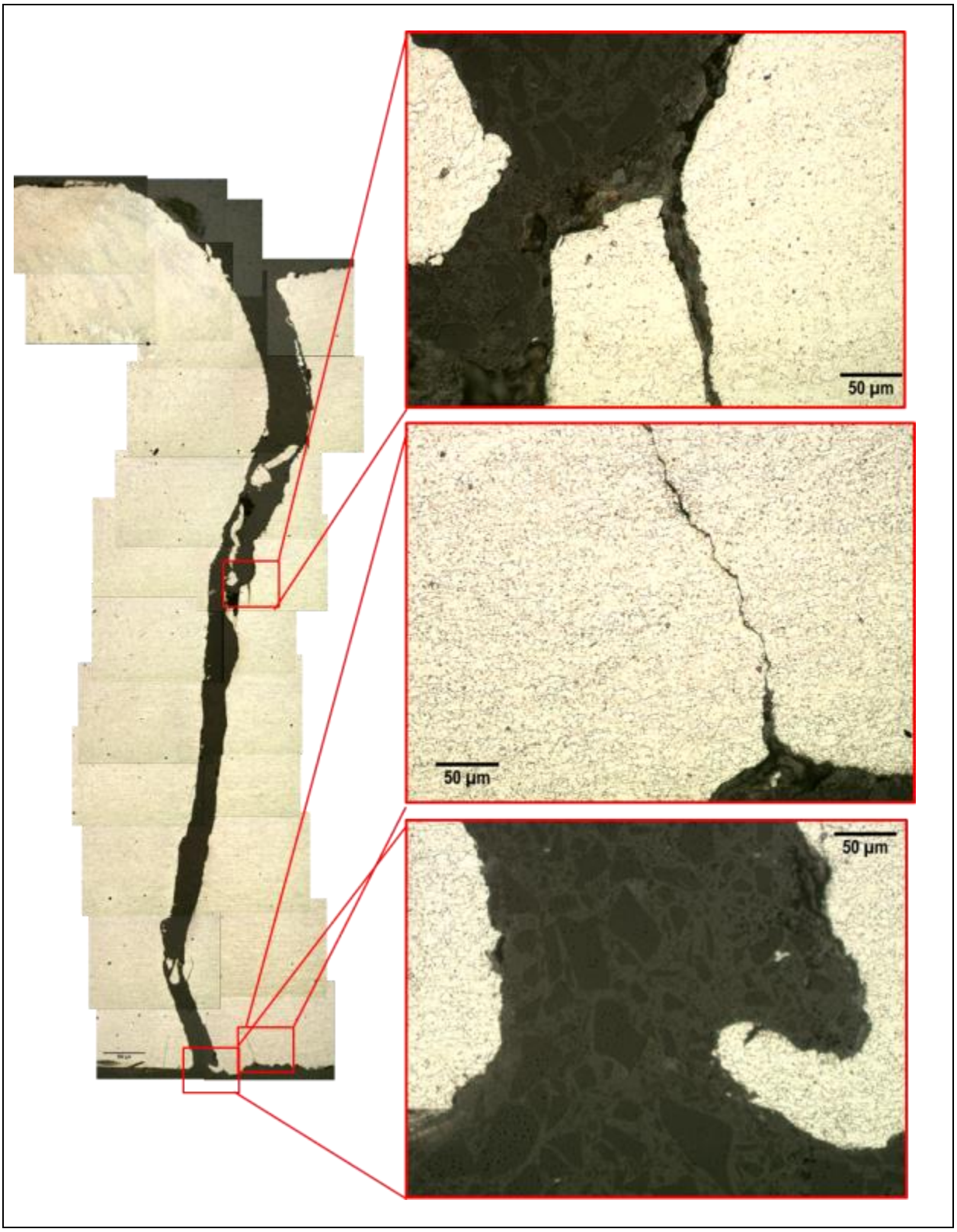


Figure 12: Test # 6 – Dent interacted with GW – Circumferential Crack Cross-section Photographs – Pipe D

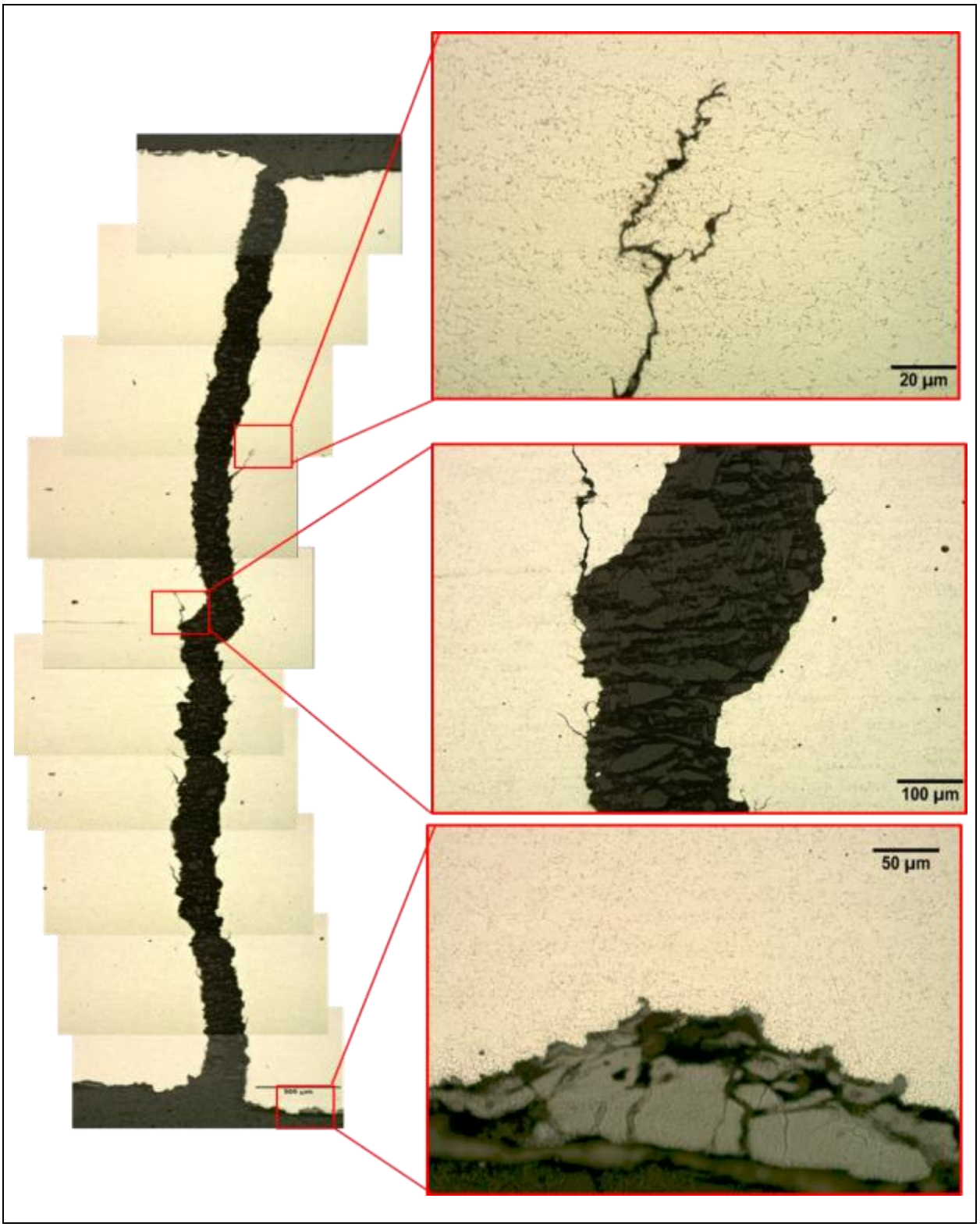
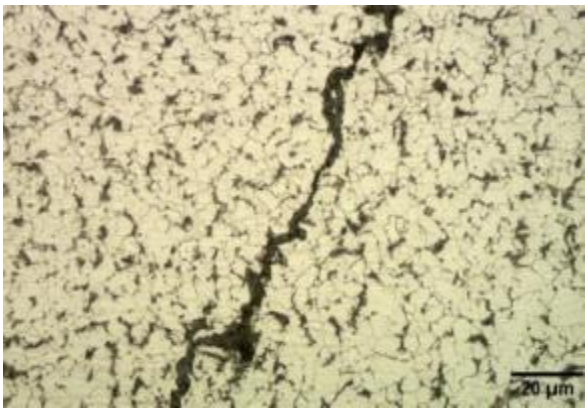


Figure 13: Test # 7 – Dent interacted with GW – Axial Crack Cross-section Photographs – Pipe D

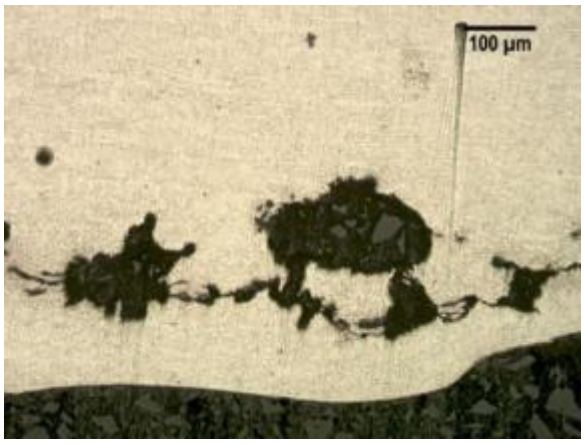
Crack Root Mid Wall -500x

Separate Branch Crack Root -500X

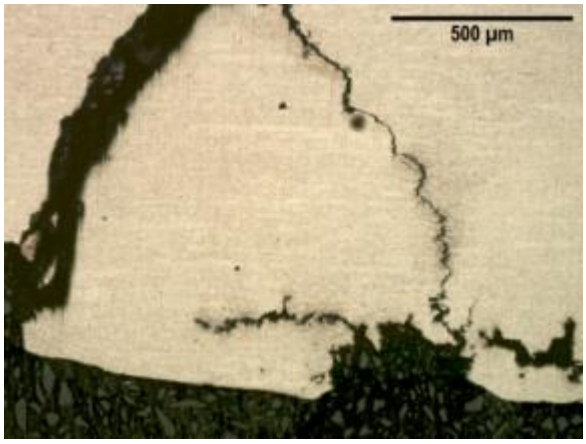
Close to ID Pore -500X



Crack Path ¼ Wall ID Side -500X



Under-surface Fissures ID Side -100X



Crack Morphology ID Side -50X

Figure 14: Test # 8 – Dent interacted with GW – Circumferential Crack Cross-section Photographs – Pipe D

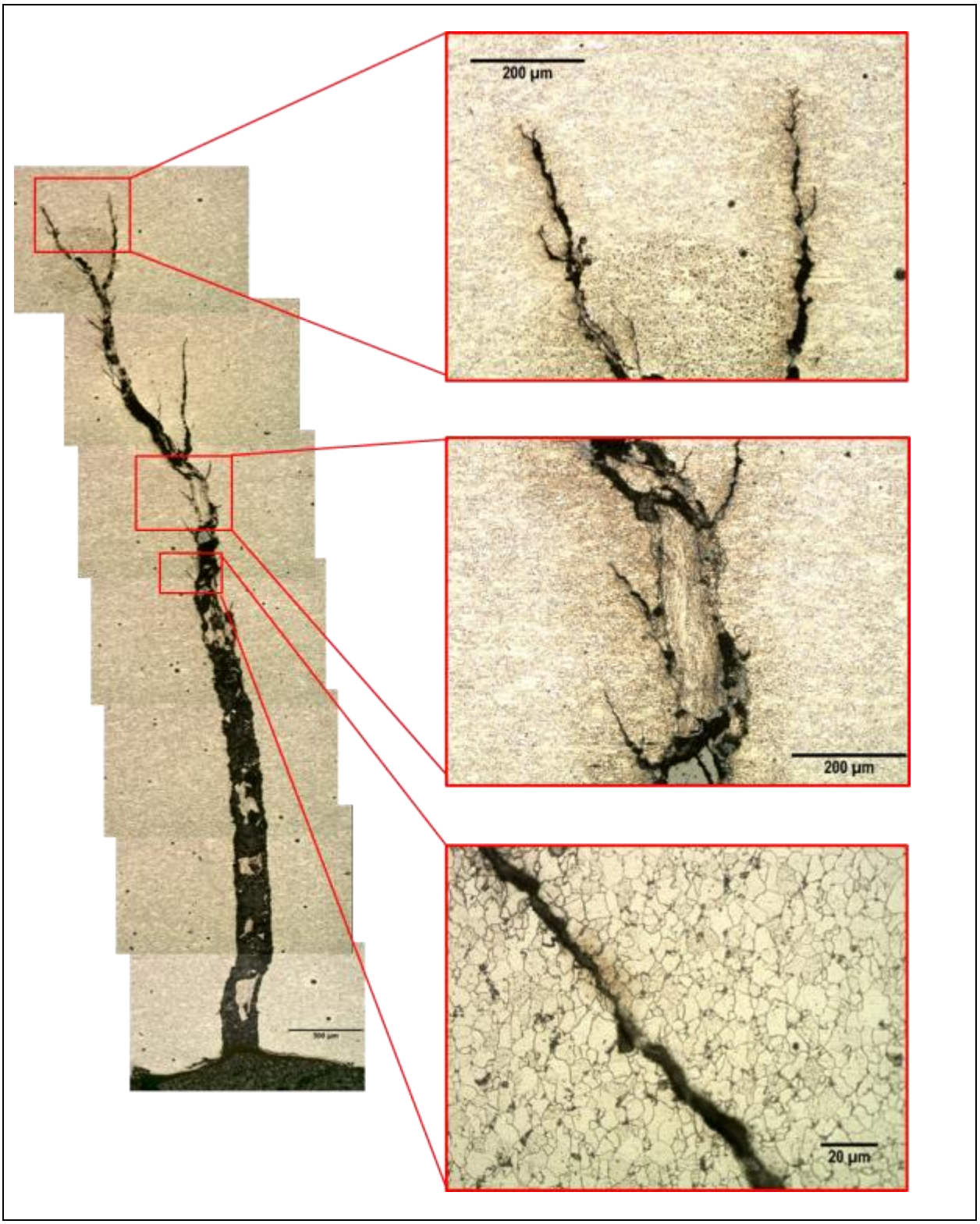


Figure 15: Test # 9 – Dent interacted with LSW – Axial Crack Cross-section Photographs – Pipe D

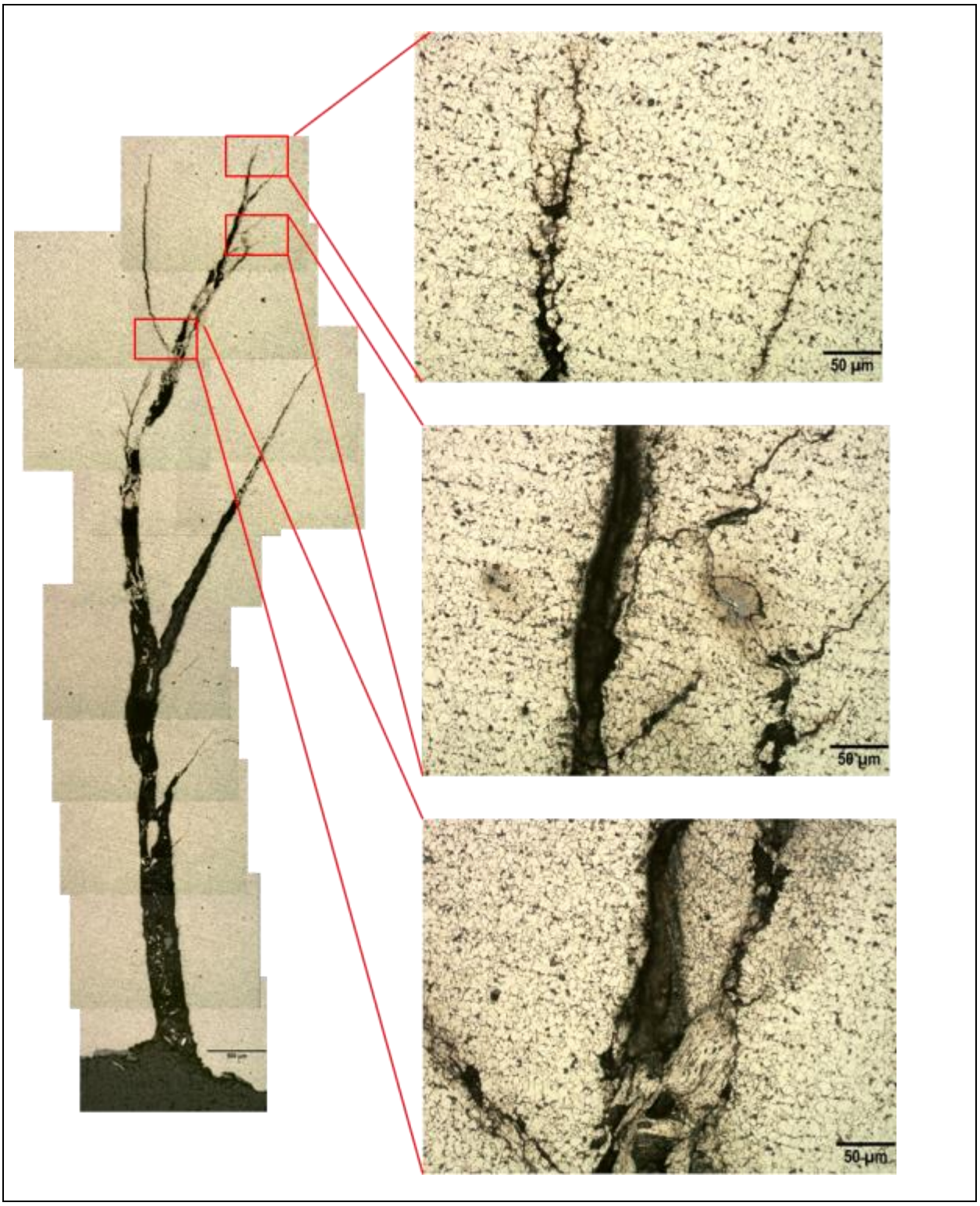


Figure 16: Test # 10 – Dent interacted with LSW – Axial Crack Cross-section Photographs – Pipe D

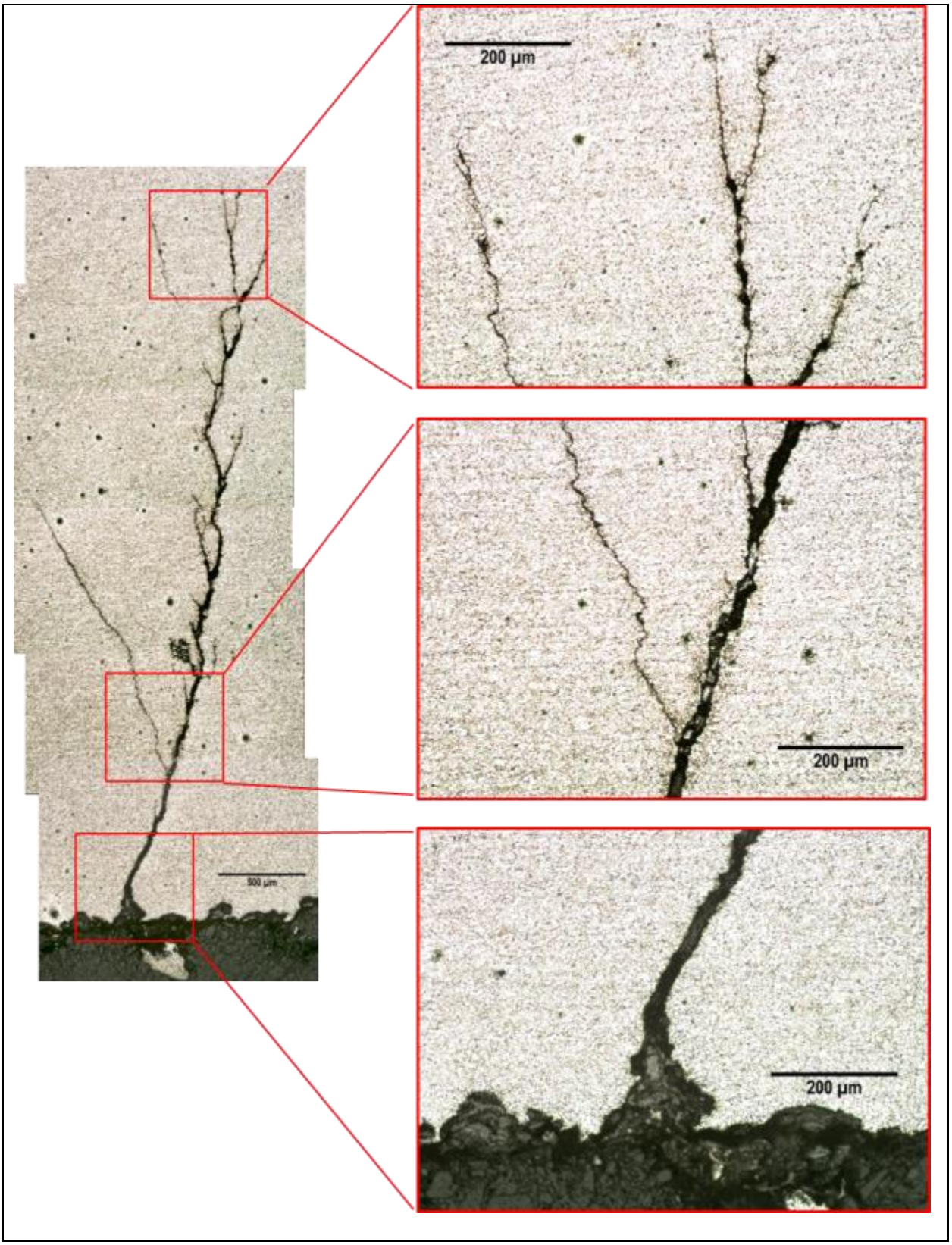


Figure 17: Test # 12 – Dent interacted with LSW – Axial Crack Cross-section Photographs – Pipe D

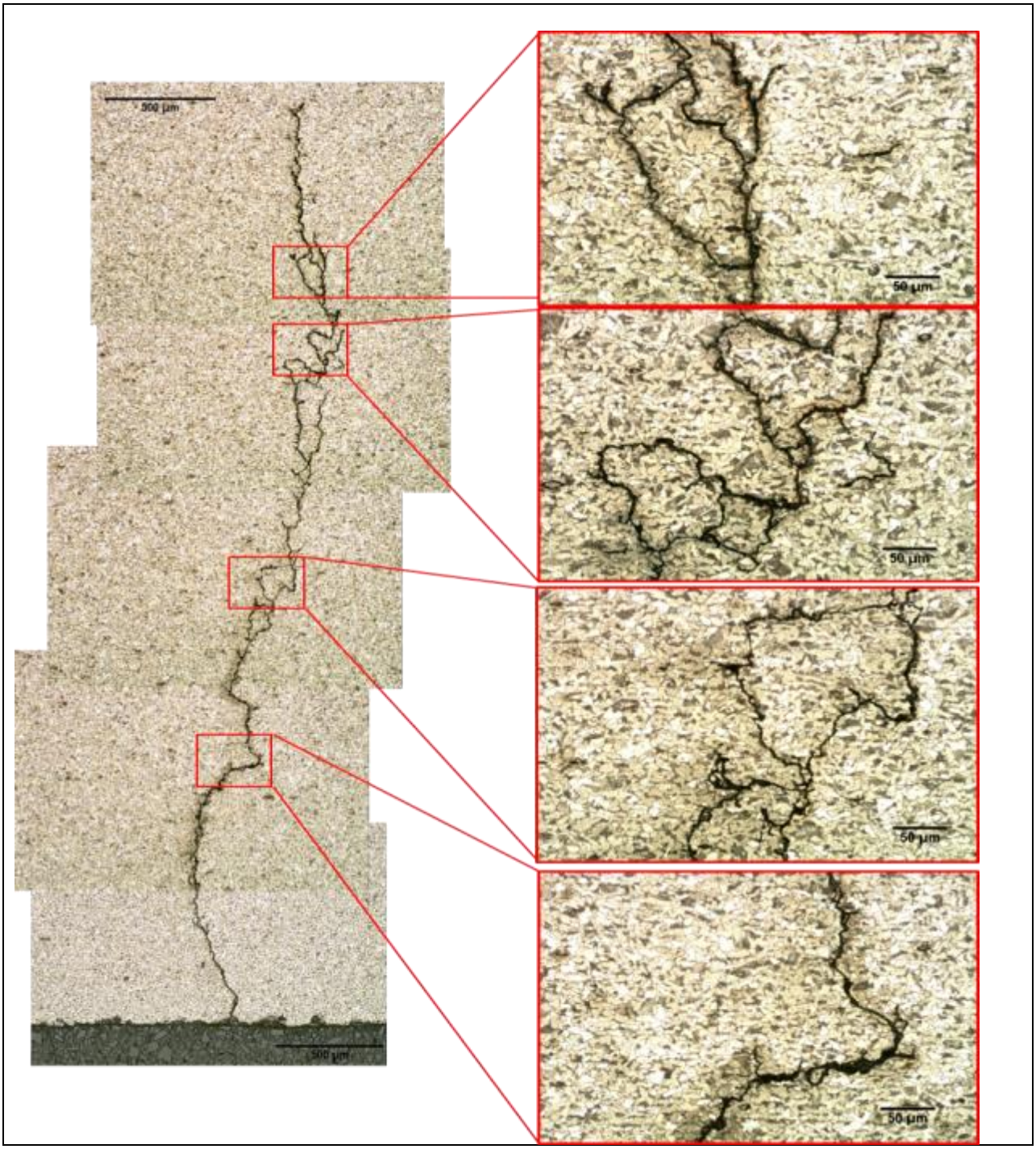


Figure 18: Test # 30- Dent interacted with LSW – Base Metal side of Axial Crack Photographs – Pipe F

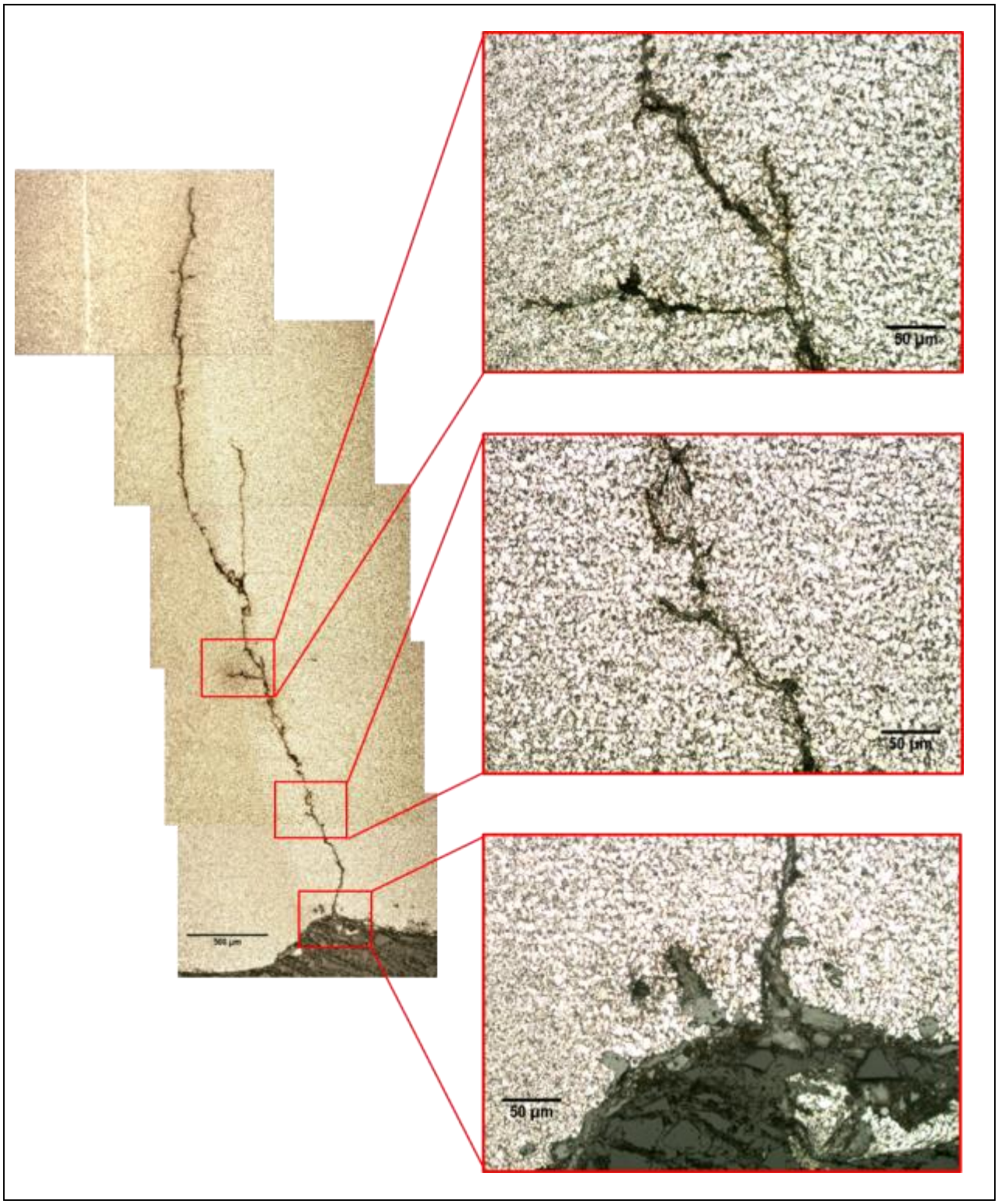
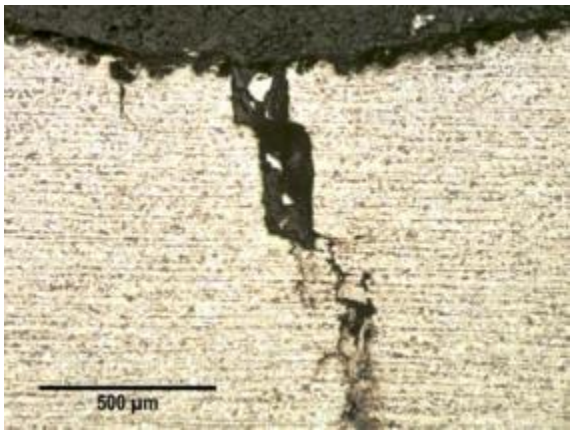


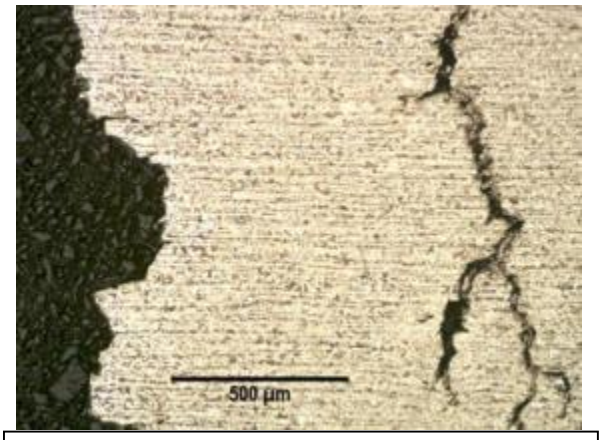
Figure 19: Test # 30 – Dent interacted with LSW – Seam Weld side of Axial Crack Photographs– Pipe F

E.3 Dents interacted with Corrosion



Crack at OD location -50X

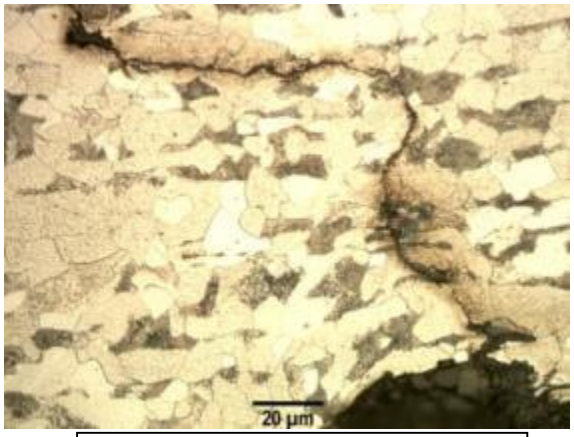
Crack branches mid wall -200X



Secondary crack branches ¼ wall -50X

Crack root-200X

Detail crack branching -200X



Crack root detail -500X

Figure 20: Test # 16 – Dent interacted with Corrosion (42%) – Axial Crack Cross-section Photographs – Pipe F

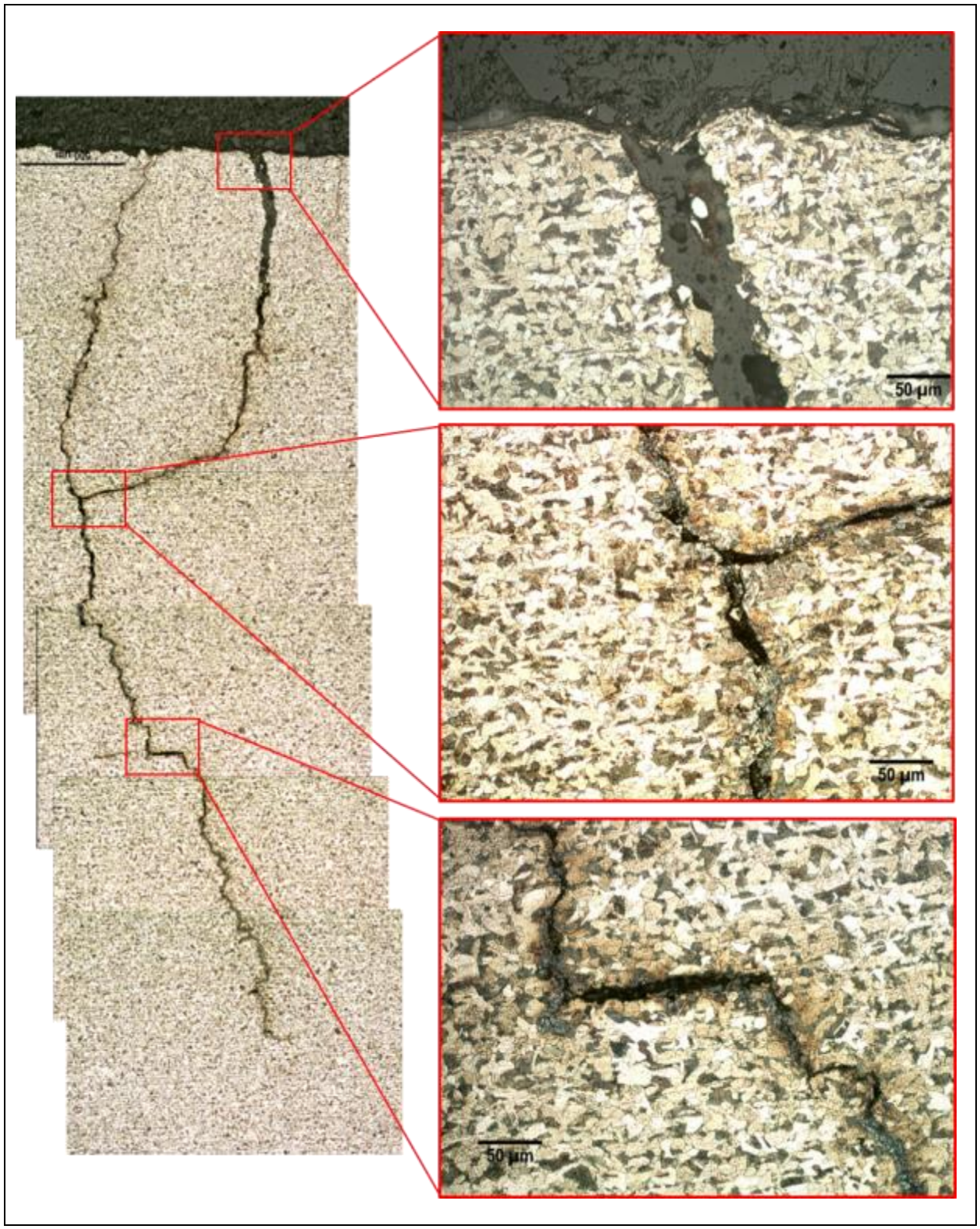
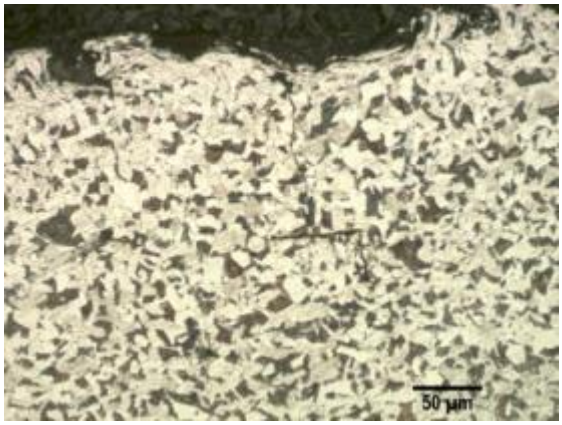
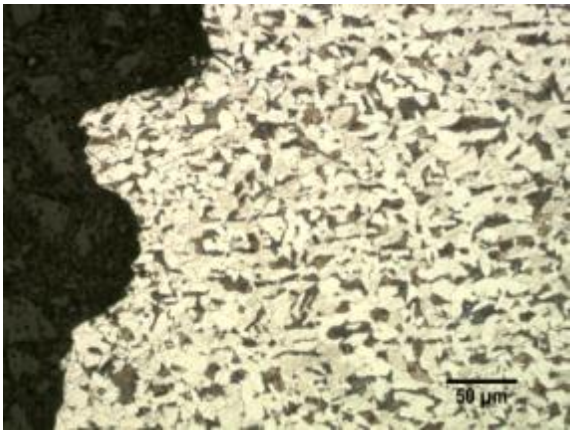


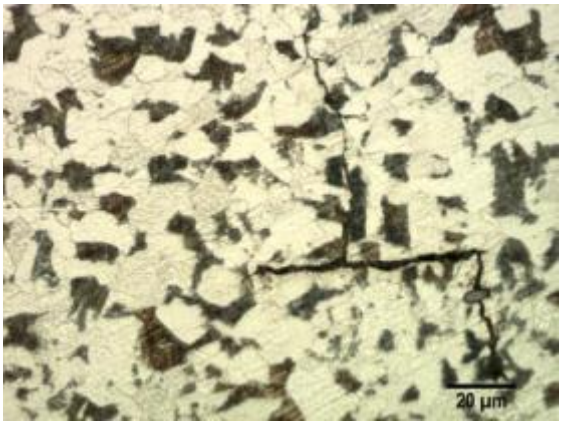
Figure 21: Test # 17 – Dent interacted with Corrosion (17%) – Axial Crack Cross-section Photographs – Pipe F



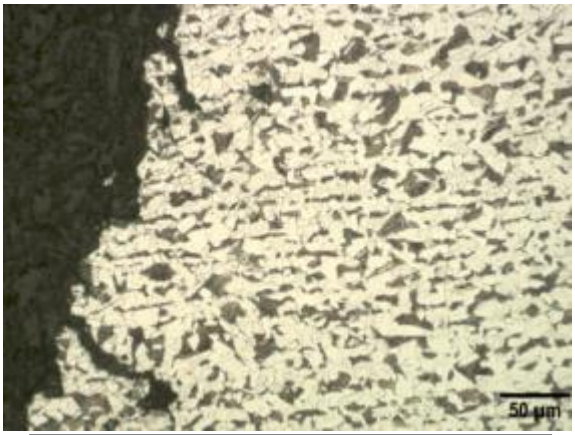
Shallow crack OD side -200X



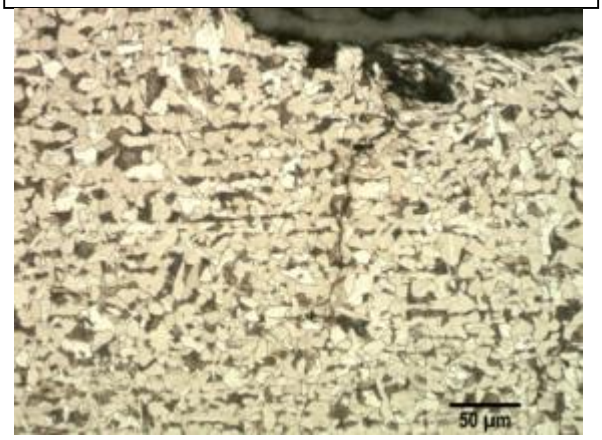
Through wall crack close to OD -



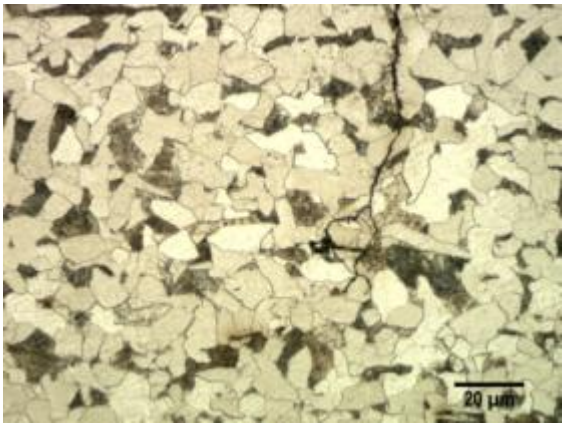
Shallow crack OD side (detail) -500X



Through wall crack mid wall -200X



Crack originated at an OD pit -200X



Root of the crack -500X

Figure 22: Test # 18 – Dent interacted with Corrosion (30%) – Axial Crack Cross-section Photographs – Pipe F

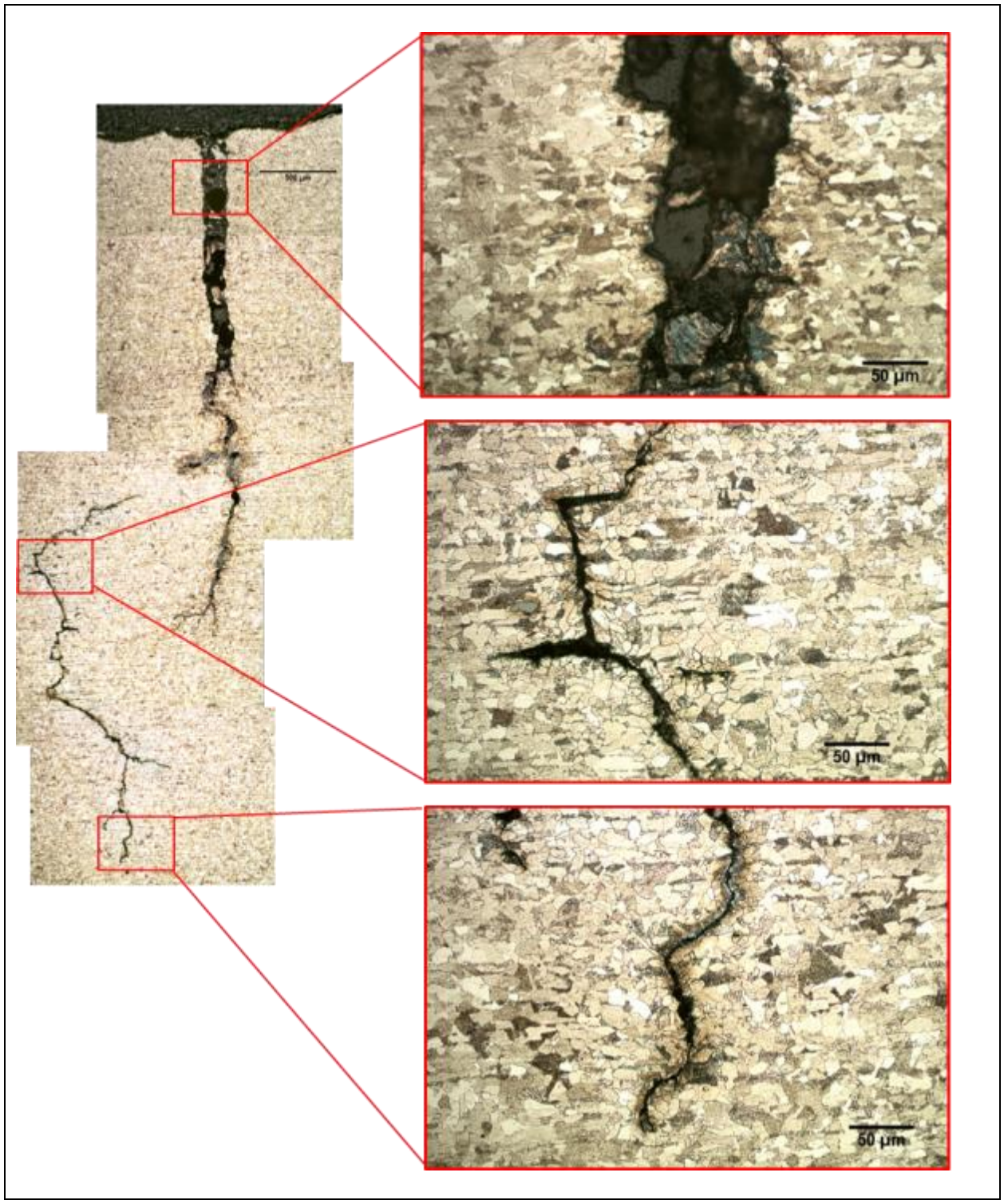
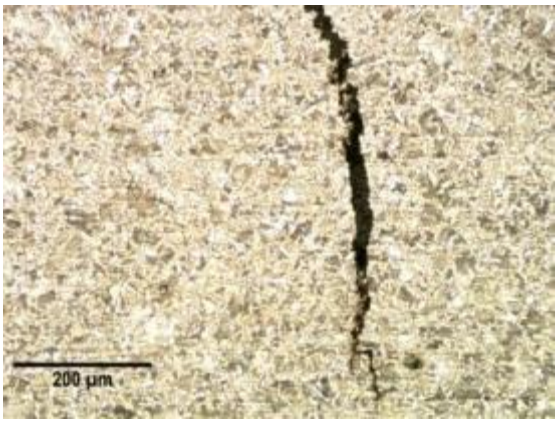
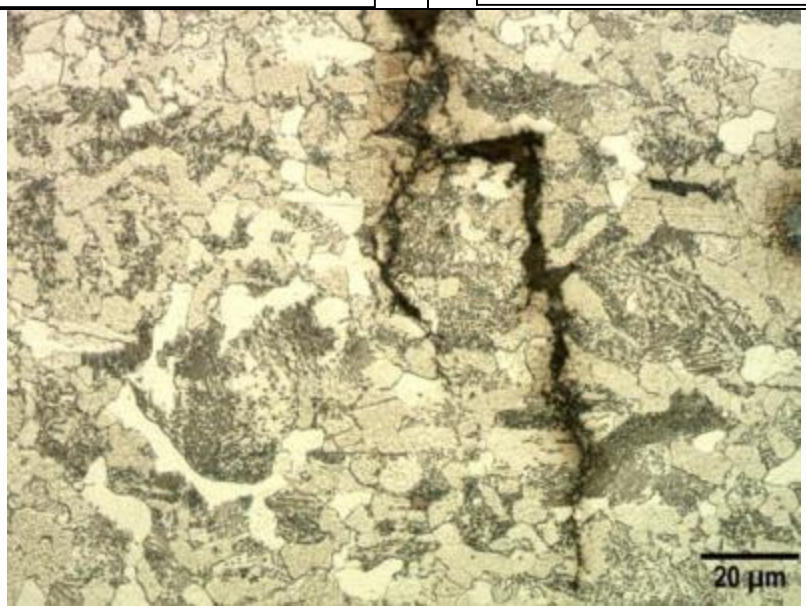


Figure 23: Test # 19 – Dent interacted with Corrosion (16%) – Axial Crack Cross-section Photographs – Pipe F

Crack path at OD -100X

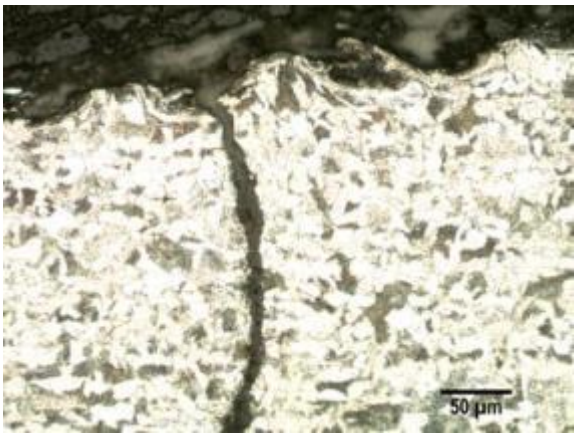


Crack path near OD location -100X

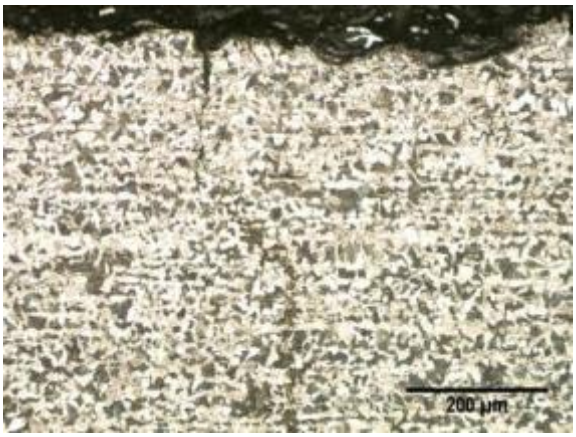


Crack root detail (0.8mm from OD) -500X

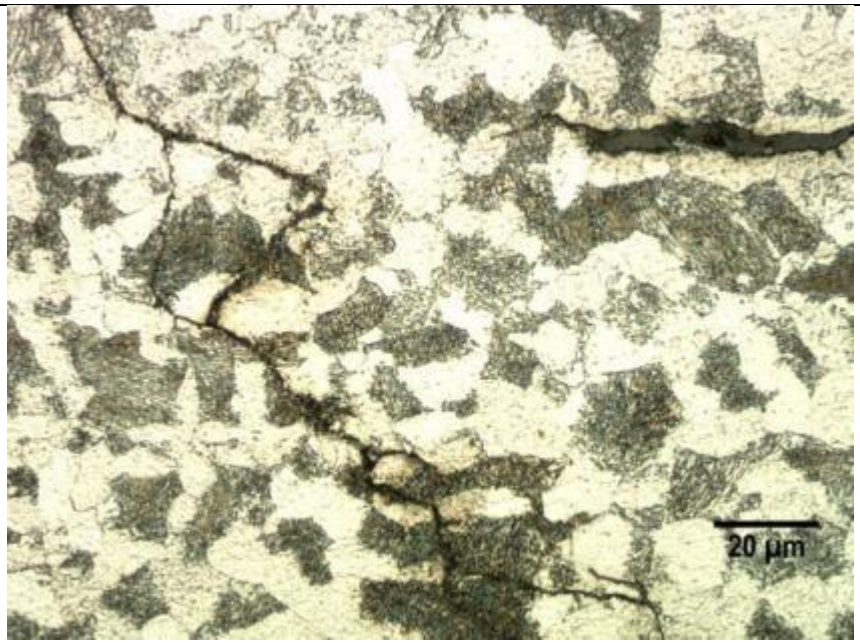
Figure 24: Test #20 – Dent interacted with Corrosion (8%) – Axial Crack Cross-section Photographs – Pipe F



Crack path at OD -200X



Crack path near OD location -100X



Crack root detail (0.2mm from OD) -500X

Figure 25: Test # 21 – Dent interacted with Corrosion (26%) – Axial Crack Cross-section Photographs – Pipe F

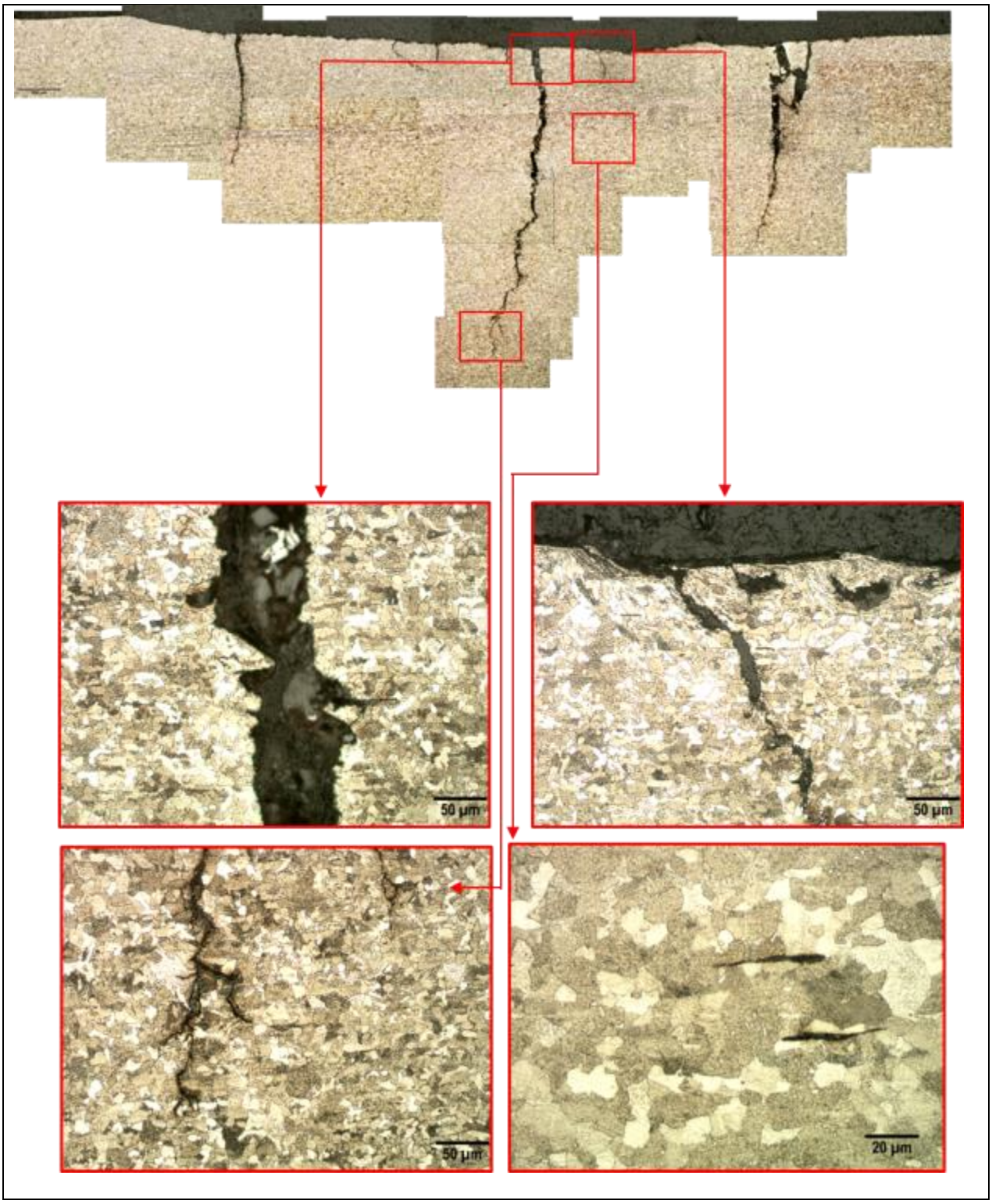


Figure 26: Test # 22 – Dent interacted with Corrosion (9%) – Axial Crack Cross-section Photographs – Pipe F

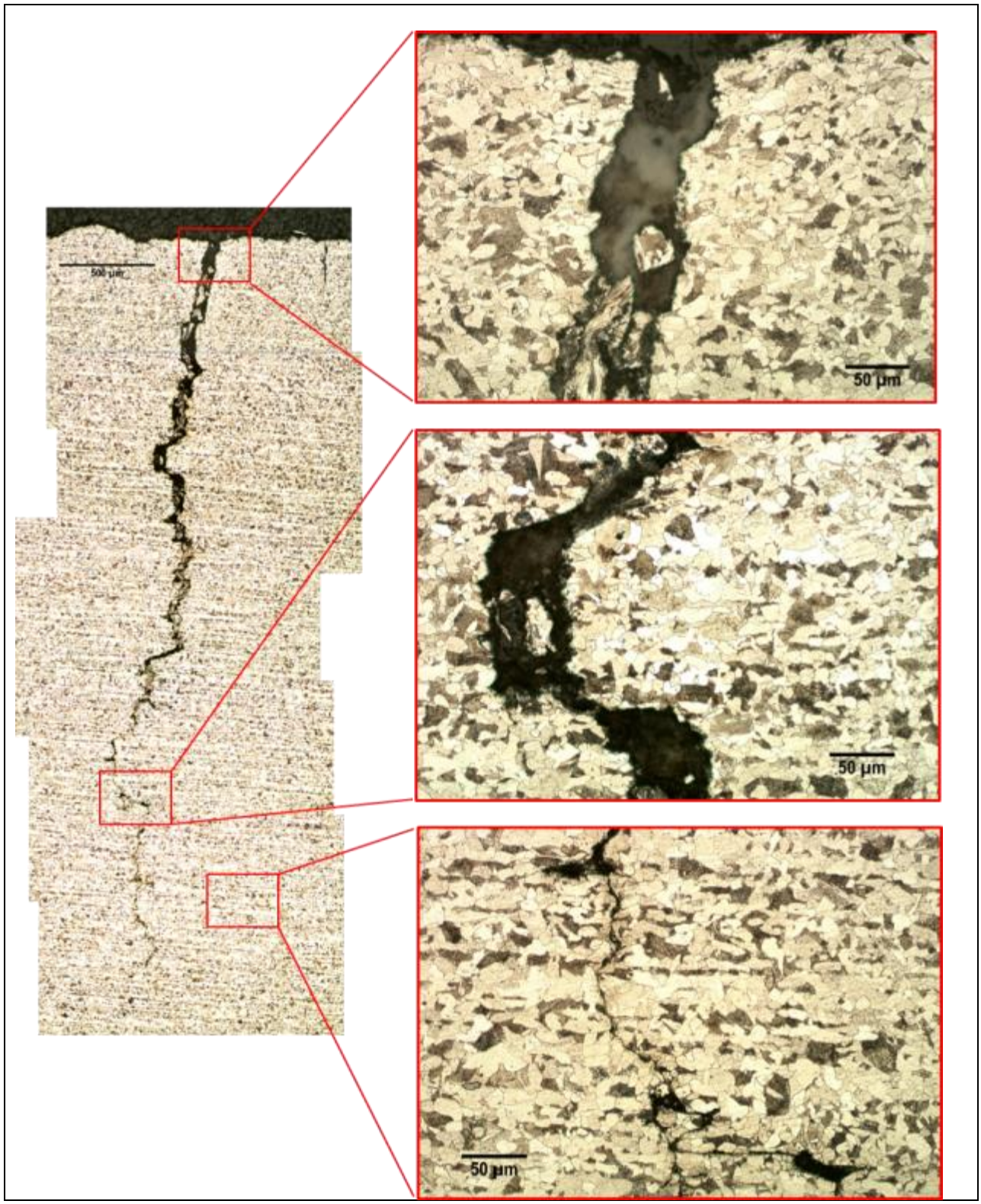


Figure 27: Test # 23 – Dent interacted with Corrosion (39%) – Axial Crack Cross-section Photographs – Pipe F

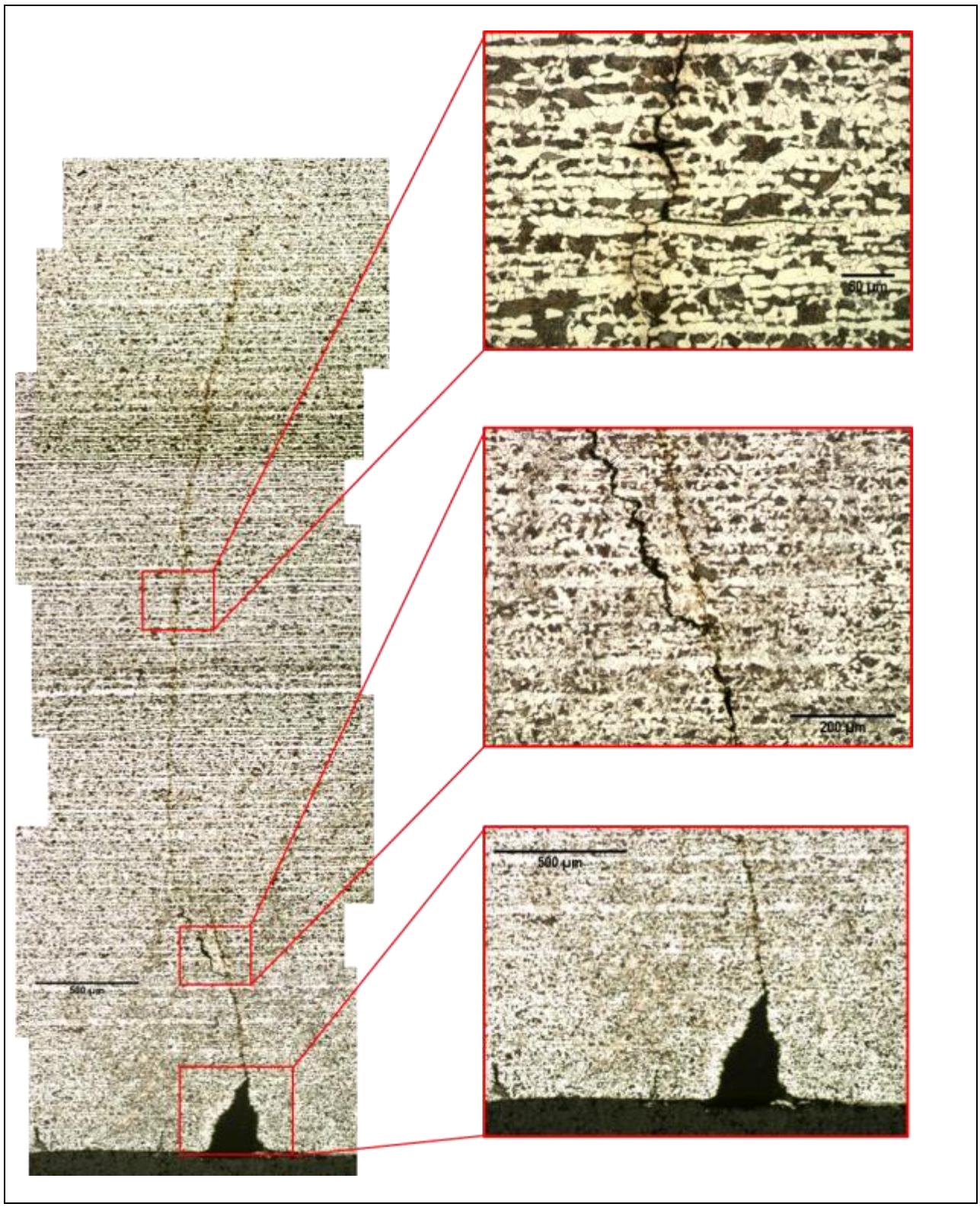


Figure 28: Test # 26 – Dent interacted with Corrosion (20%) – Circumferential Crack Cross-section Photographs – Pipe F

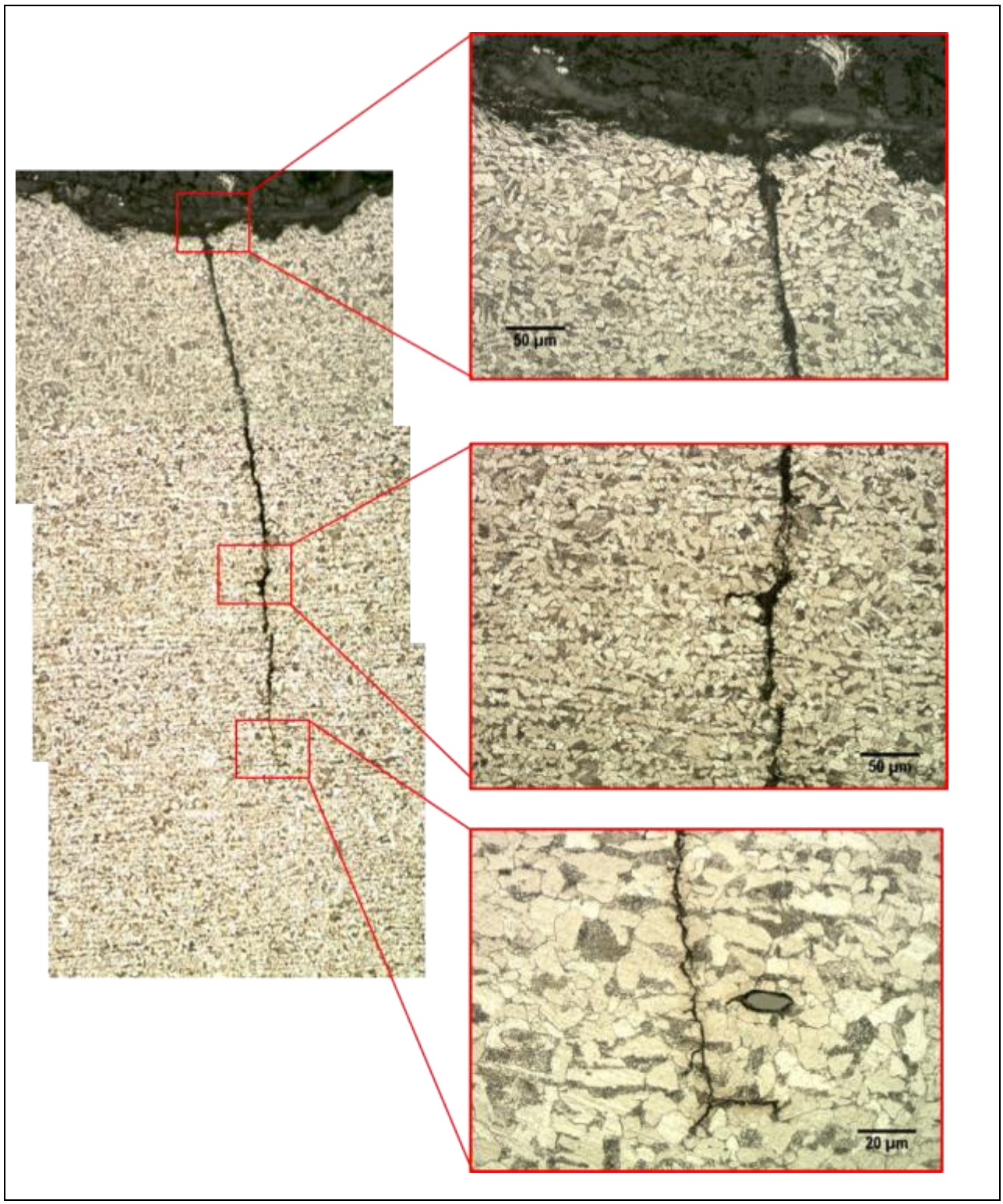
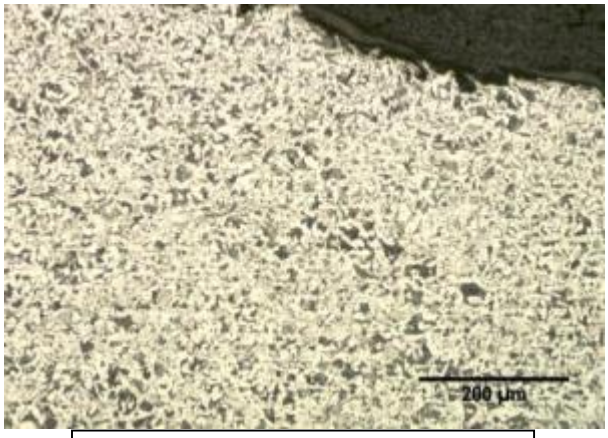
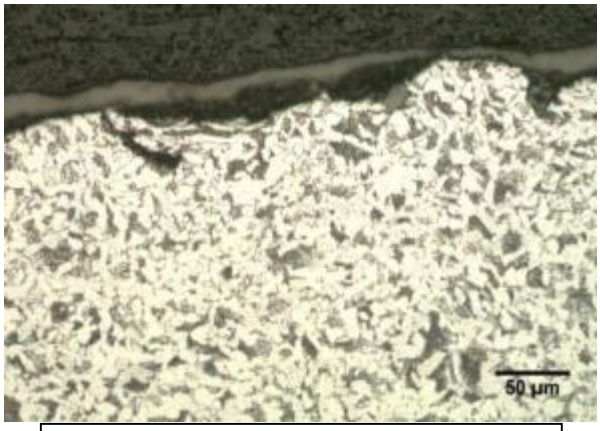


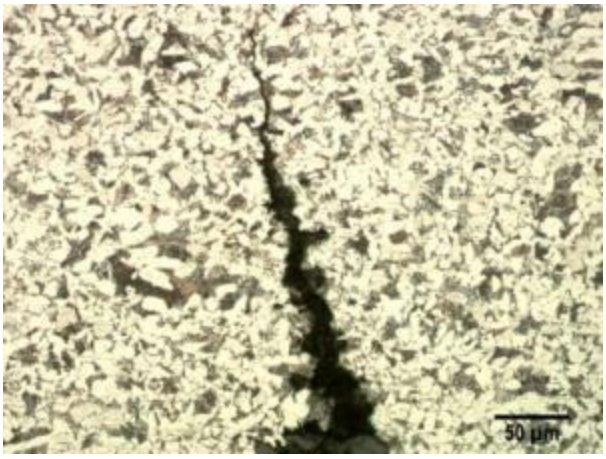
Figure 29: Test # 27 – Dent interacted with Corrosion (35%) – Axial Crack Cross-section photographs – Pipe F



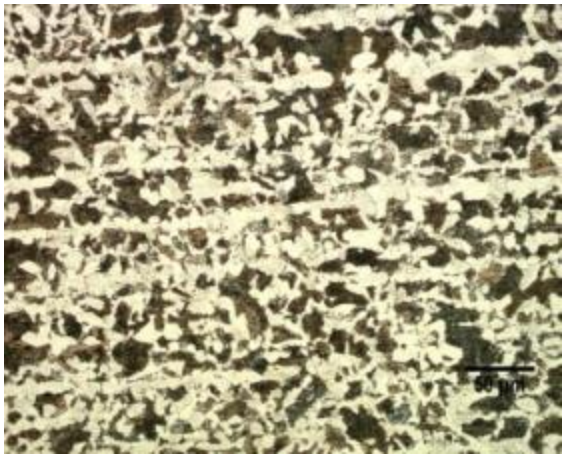
Microstructure OD side -100X



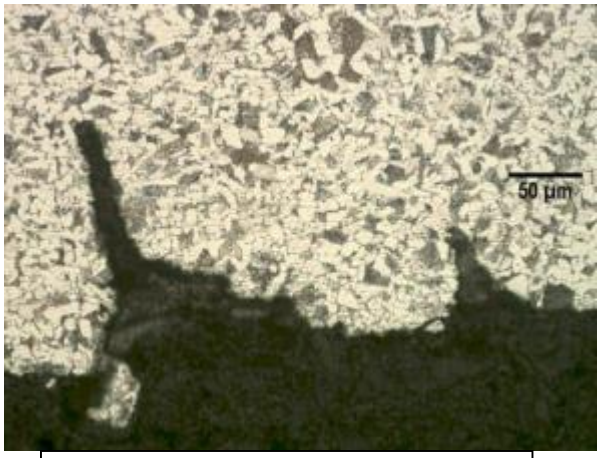
Detail microstructure OD side- 200X



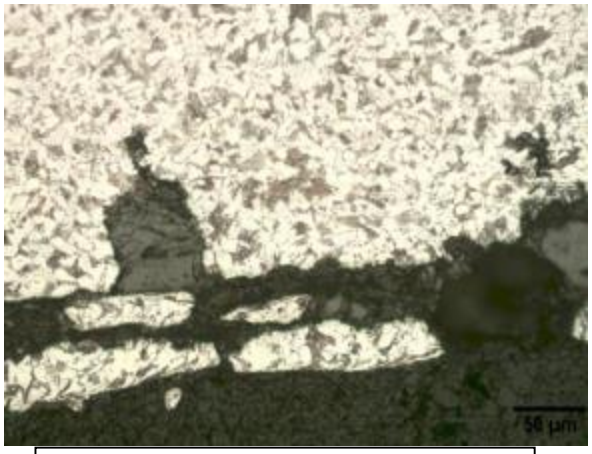
Detail crack path ID side -200X



Banded microstructure mid wall- 200X

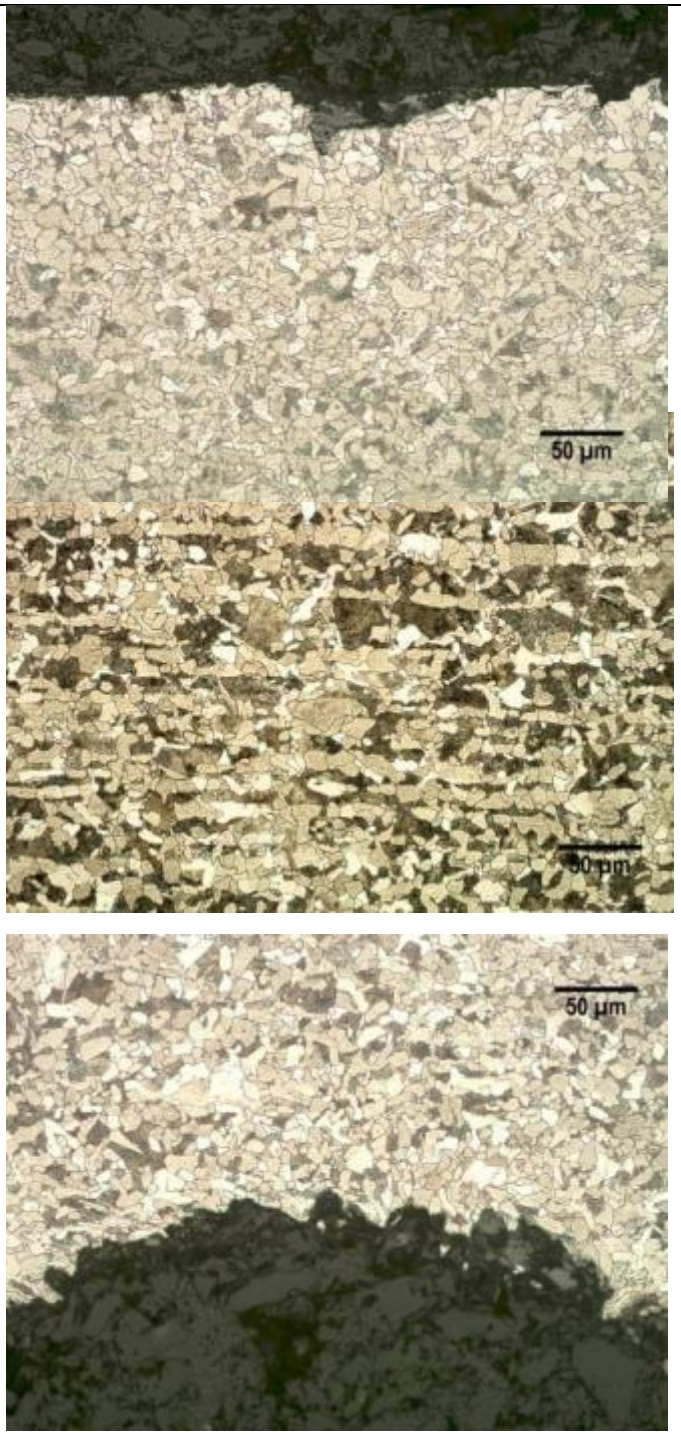


Tears at corrosion ID pits -200X



Tears at corrosion ID pits- 200X

Figure 30: Test # 28 – Dent interacted with Corrosion (28%) – 32 degree Angle Crack Cross-section Photographs – Pipe F



Detail microstructure OD side- 200X

Detail microstructure mid wall- 200X

Detail microstructure ID side- 200X

Figure 31: Test # 29 – Dent interacted with Corrosion (23%) – 42 degree Angle Crack Cross-section Photographs – Pipe F

ANNEX F

FRACTURE SURFACE FOR EACH TEST SPECIMEN

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F. Fracture Surface for each test specimen

F.1 Plain Dents

Figure 1: Test # 1 - Plain Dent – Sample 1 - Axial Crack - Fracture photograph – Pipe D

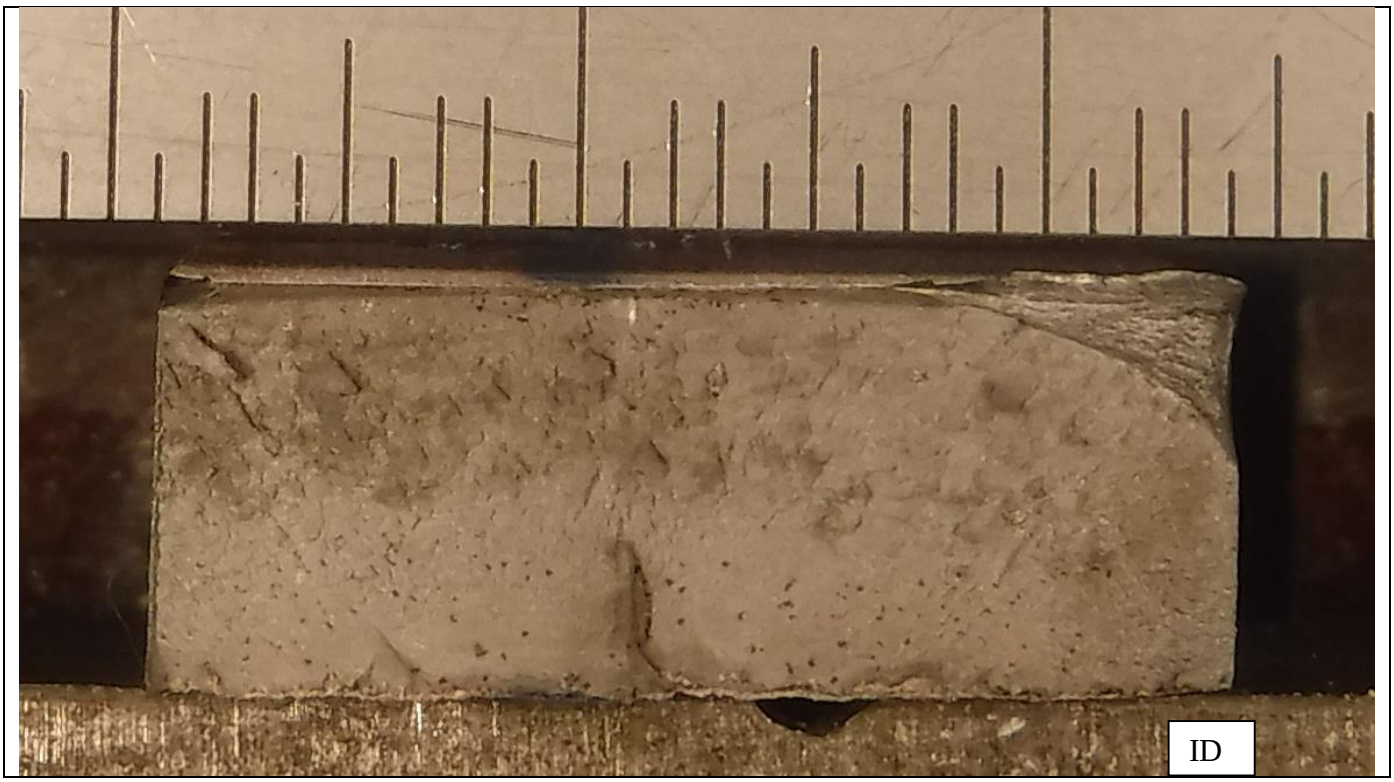


Figure 2: Test # 2 - Plain Dent – Sample 1 - Axial Crack - Fracture photograph – Pipe D

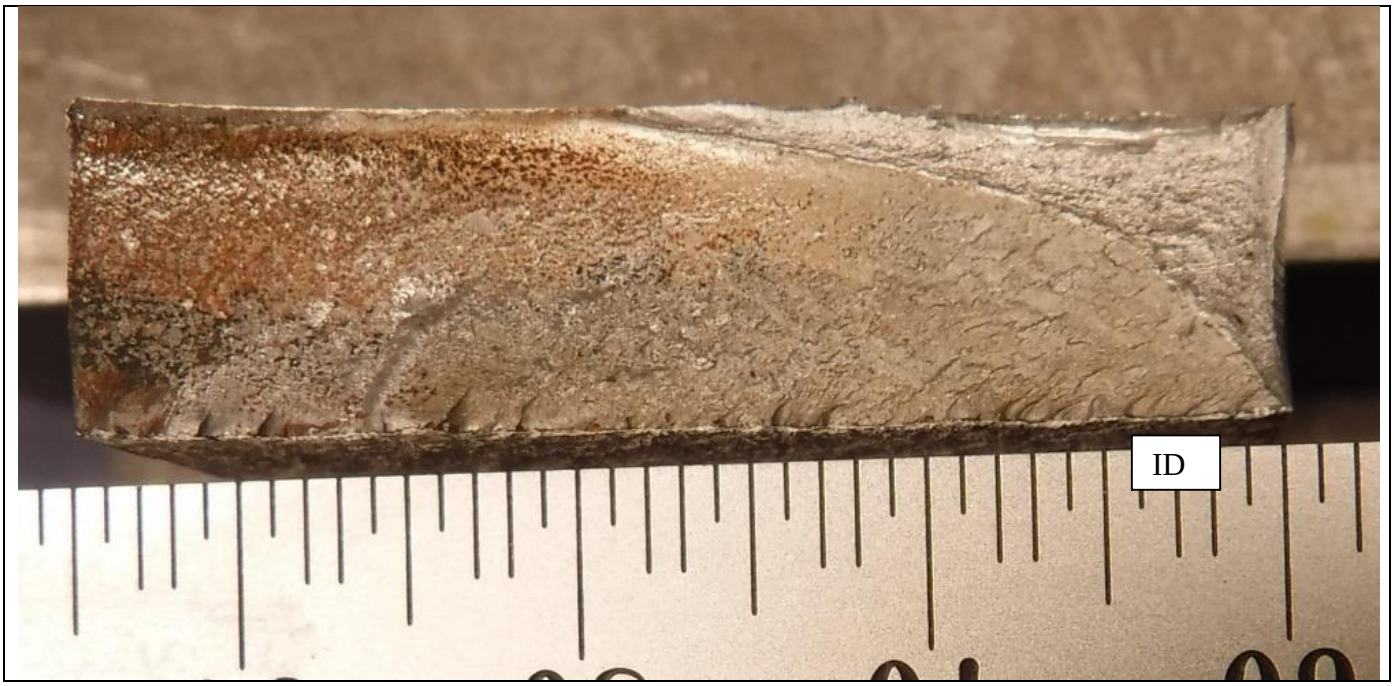


Figure 3: Test # 3 - Plain Dent – Sample 1 – Axial Crack - Fracture photograph – Pipe D

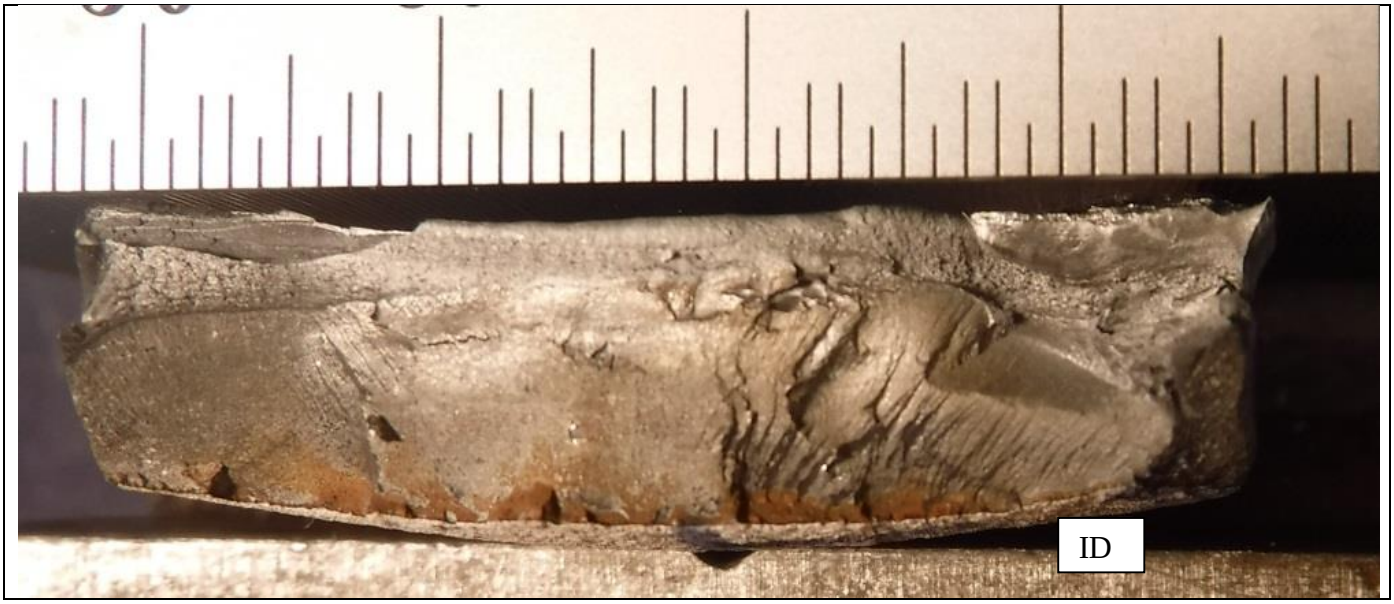


Figure 4: Test # 4 - Plain Dent – Sample 1 – Circumferential Crack - Fracture photograph – Pipe D

Figure 5: Test # 11 - Plain Dent – Sample 1 – Axial Crack - Fracture photograph – Pipe D

Figure 6: Test # 13 - Plain Dent – Sample 1 – Axial Crack - Fracture photograph – Pipe D

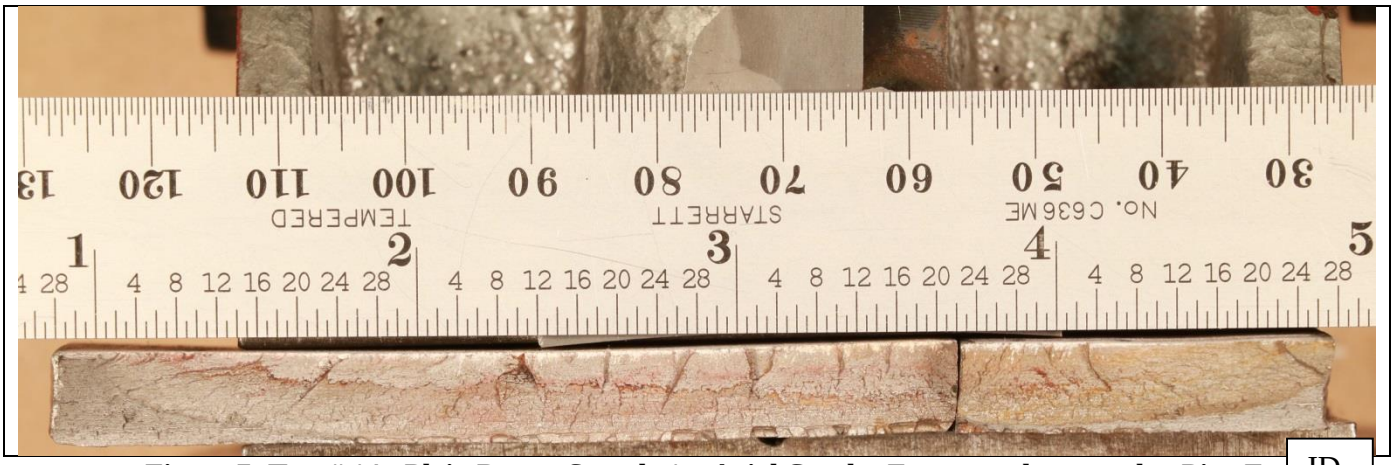


Figure 7: Test # 14 - Plain Dent – Sample 1 – Axial Crack - Fracture photograph – Pipe F

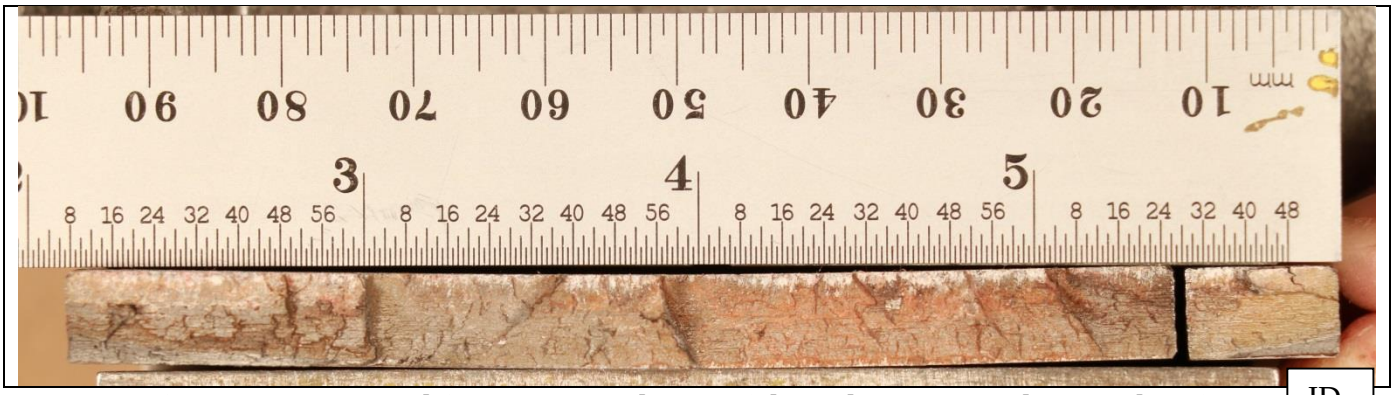


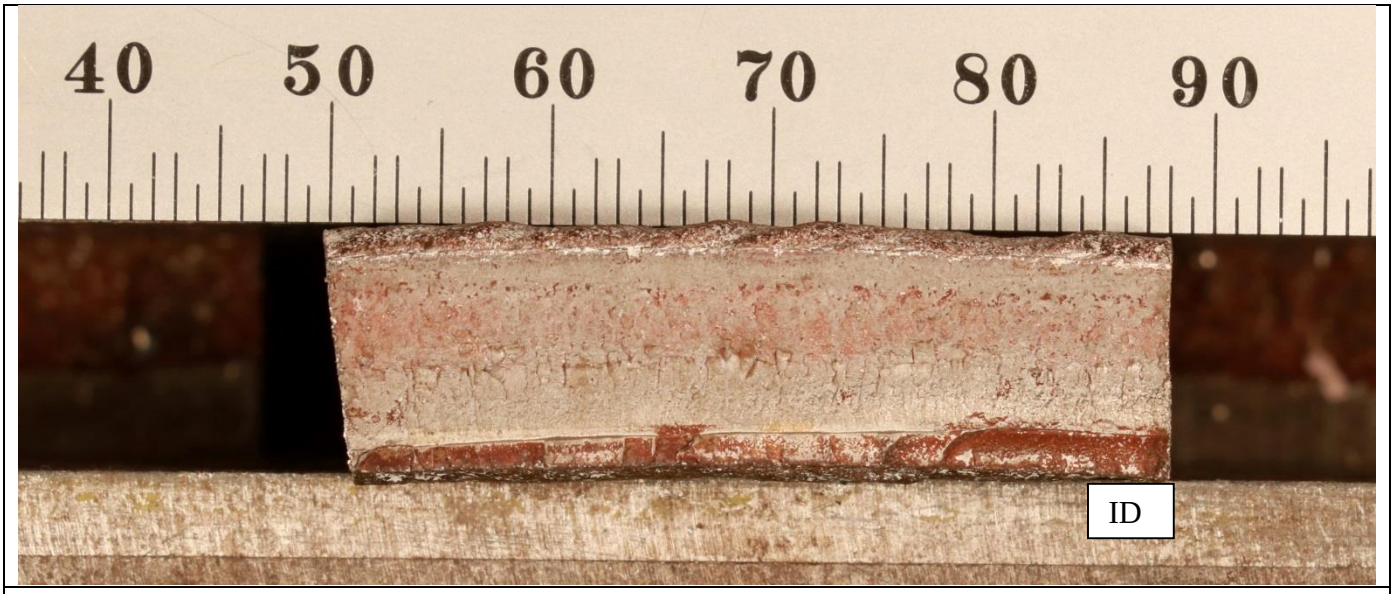
Figure 8: Test # 15 - Plain Dent – Sample 1 – Axial Crack - Fracture photograph – Pipe F

Figure 9: Test # 24 - Plain Dent – Sample 1 – 32 degree Angle Crack - Fracture photograph – Pipe F

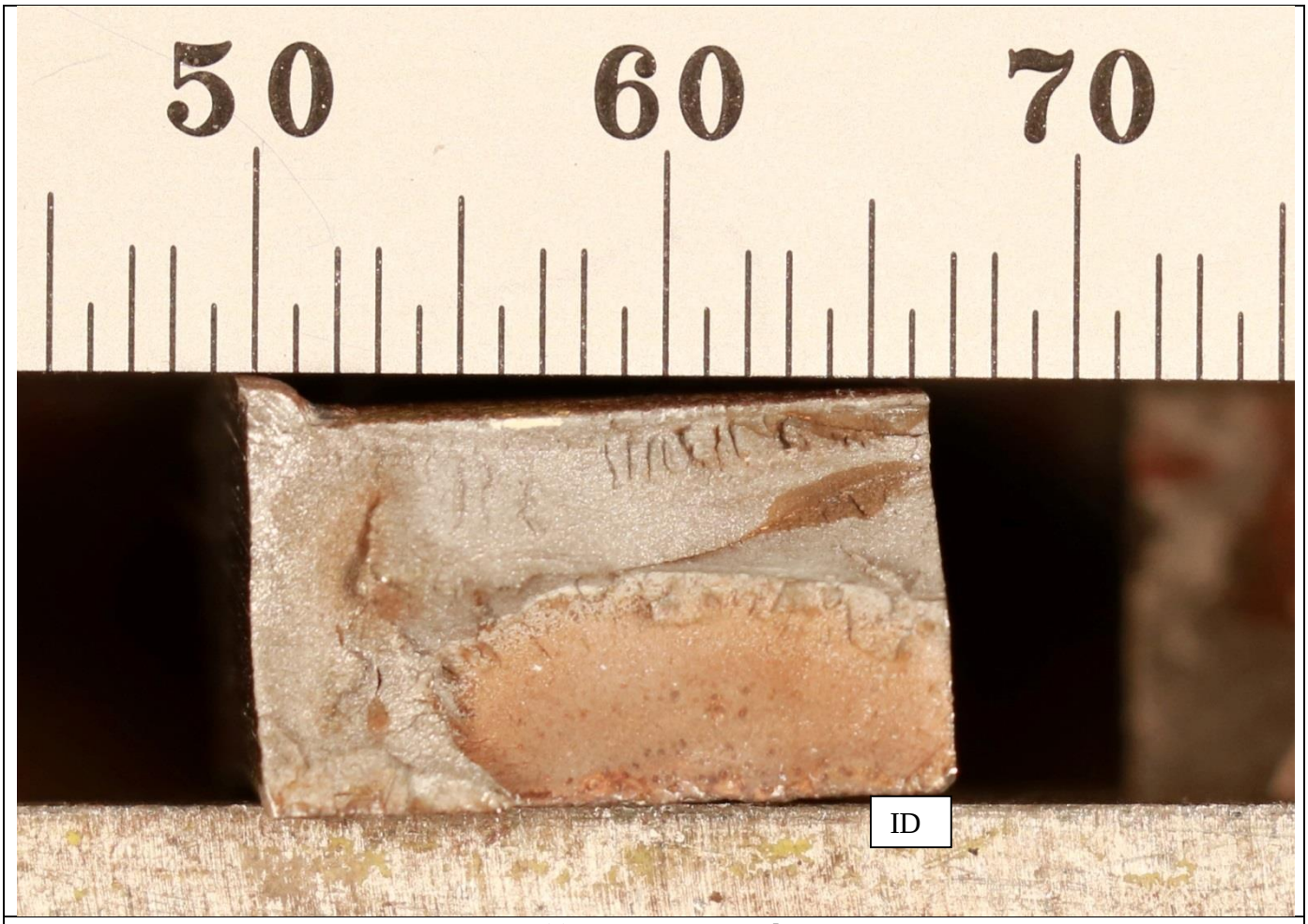
Figure 10: Test # 25 - Plain Dent – Sample 1 – Circumferential Crack - Fracture photograph – Pipe F

F.2 Dents interacted with Welds

(a) Test # 5 – Sample 1

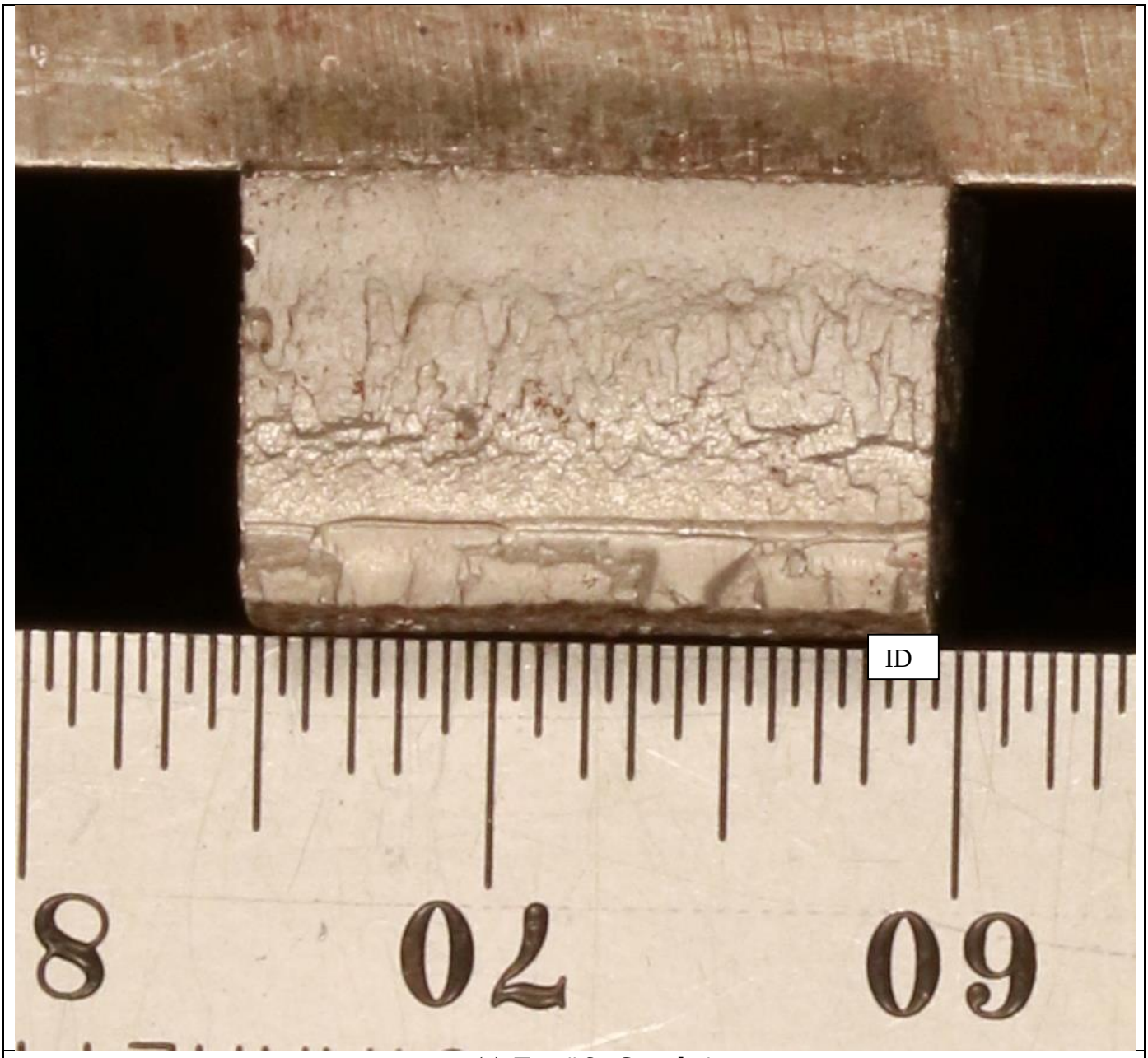


(b) Test # 5 – Sample 2

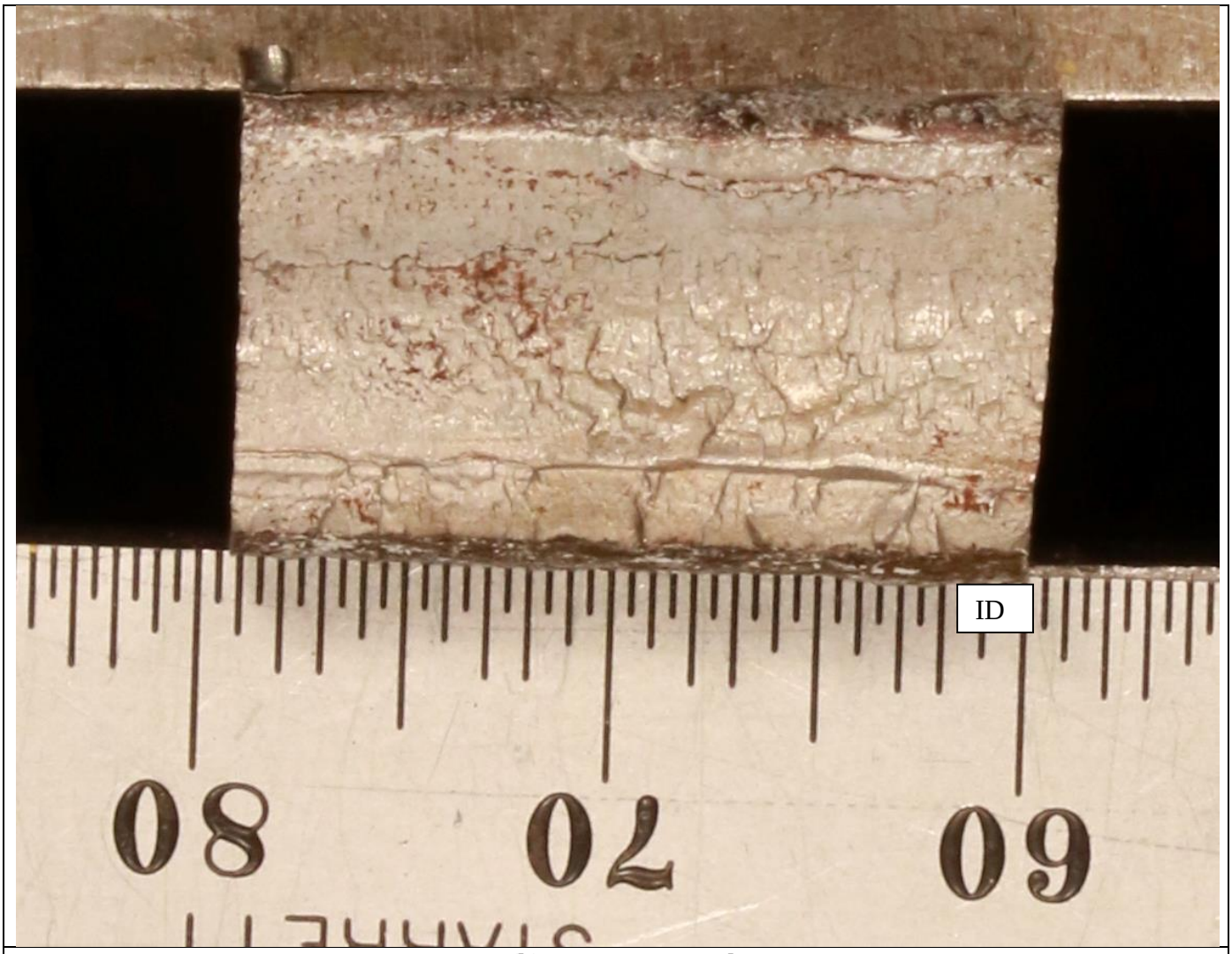


(c) Test # 5 – Sample 3

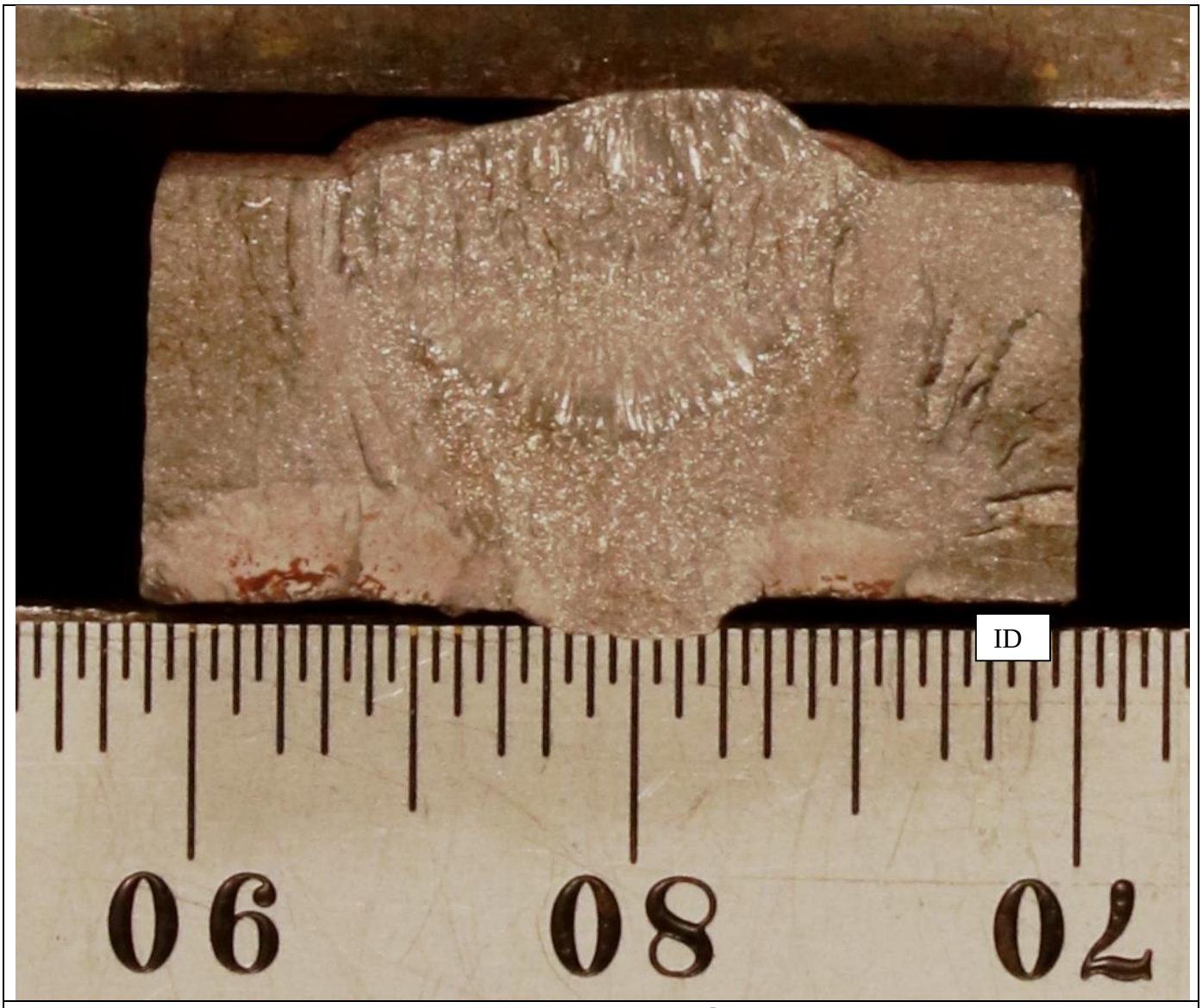
Figure 11: Test # 5 – Dent interacted with GW – Circumferential Crack - Fracture photograph – Pipe D
(a) Sample 1 (b) Sample 2 (c) Sample 3



(a) Test # 6 – Sample 1

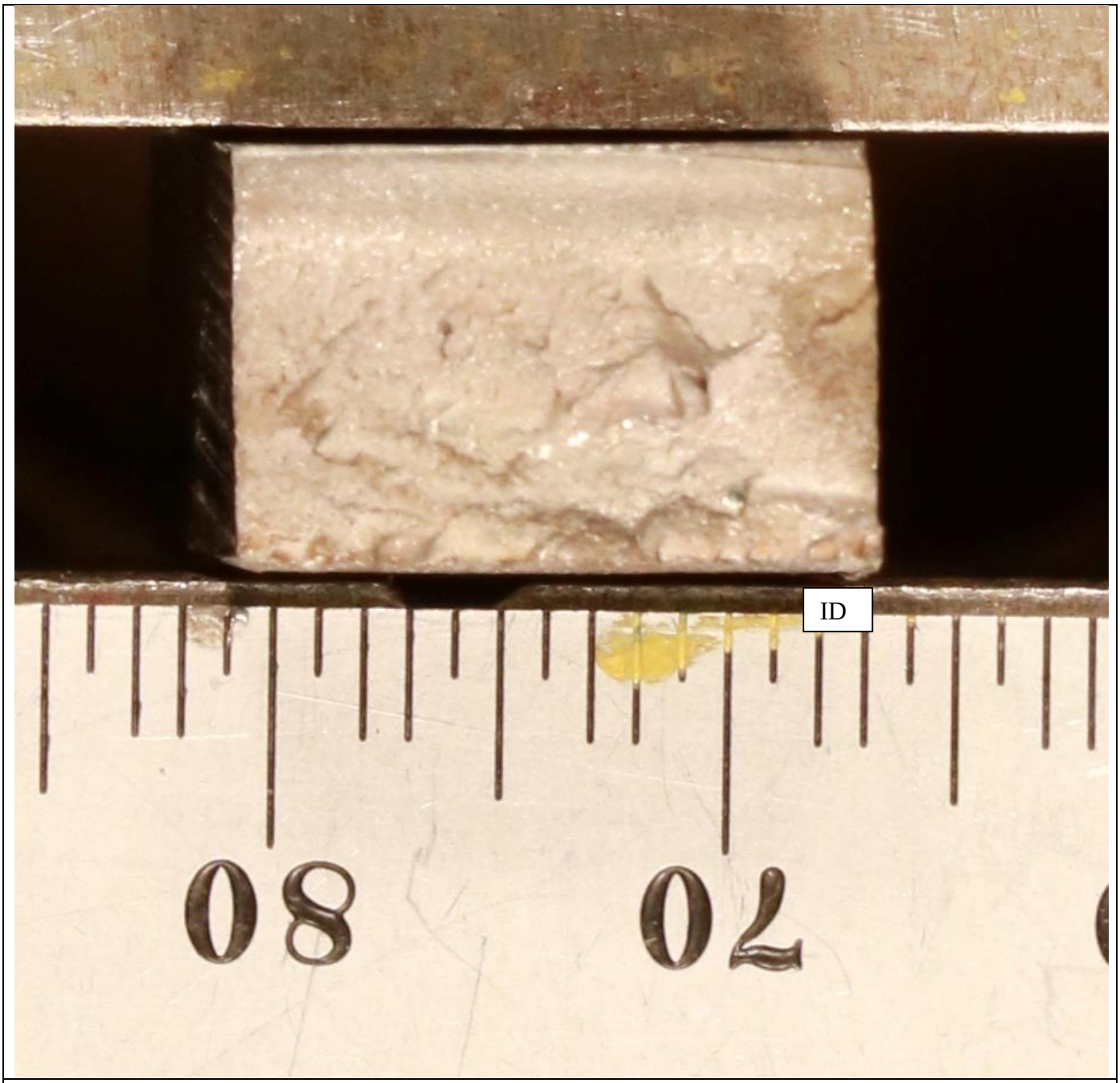


(b) Test # 6 – Sample 2



(c) Test # 6 – Sample 3

Figure 12: Test # 6 - Dent interacted with GW – Circumferential Crack - Fracture photograph – Pipe D
(a) Sample 1 (b) Sample 2 (c) Sample



(a) Test #7 Sample 1

(b) Test #7 Sample 2

Figure 13: Test # 7 - Dent interacted with GW – Axial Crack - Fracture photograph – Pipe D (a) Sample 1 (b) Sample 2 (c) Sample

Figure 14: Test # 8 - Dent interacted with GW – Sample 1 - Circumferential Crack - Fracture photograph – Pipe D

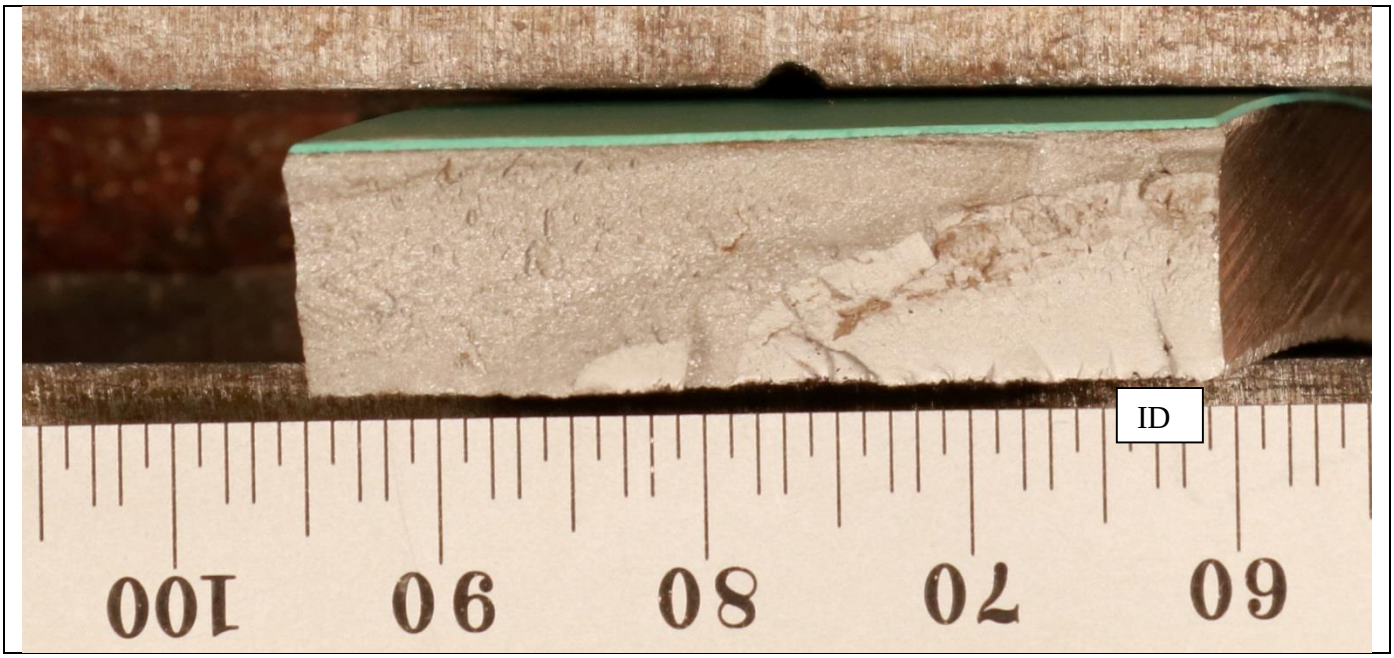


Figure 15: Test # 9 - Dent interacted with LSW – Sample 1 - Axial Crack - Fracture photograph – Pipe D

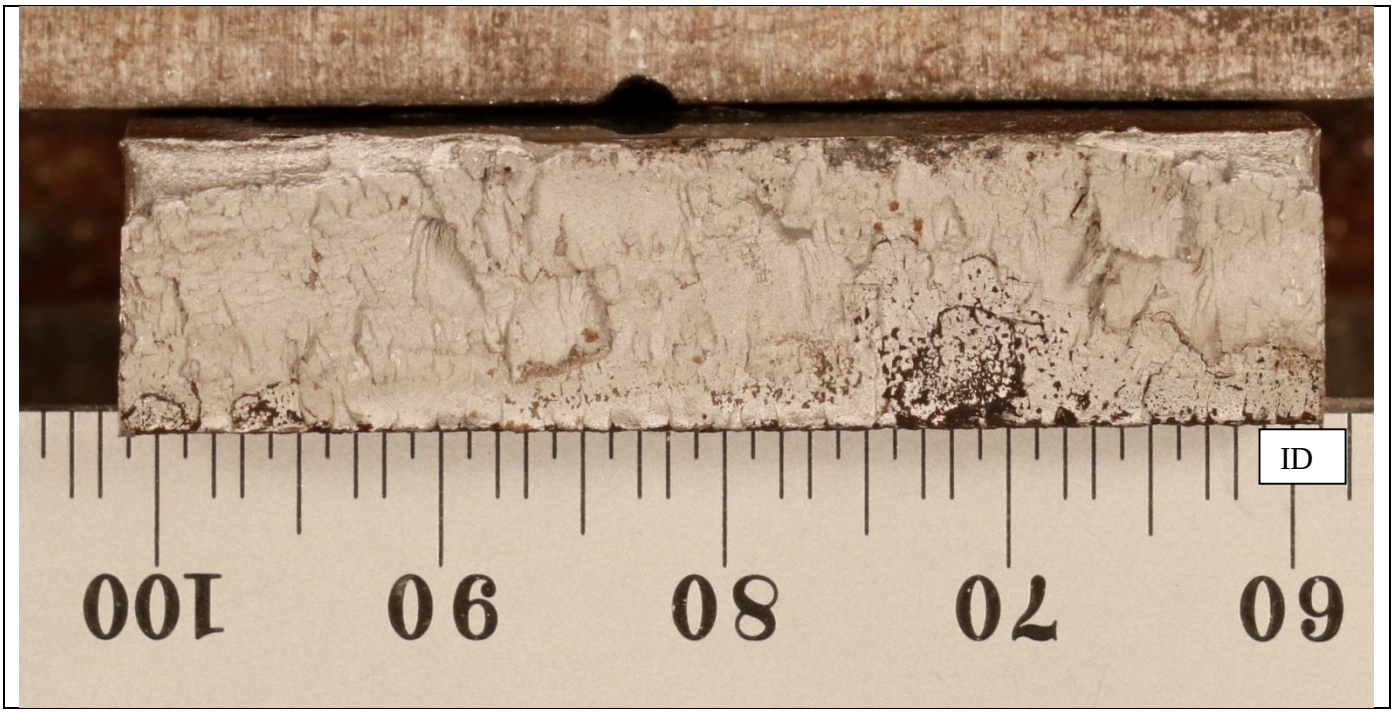
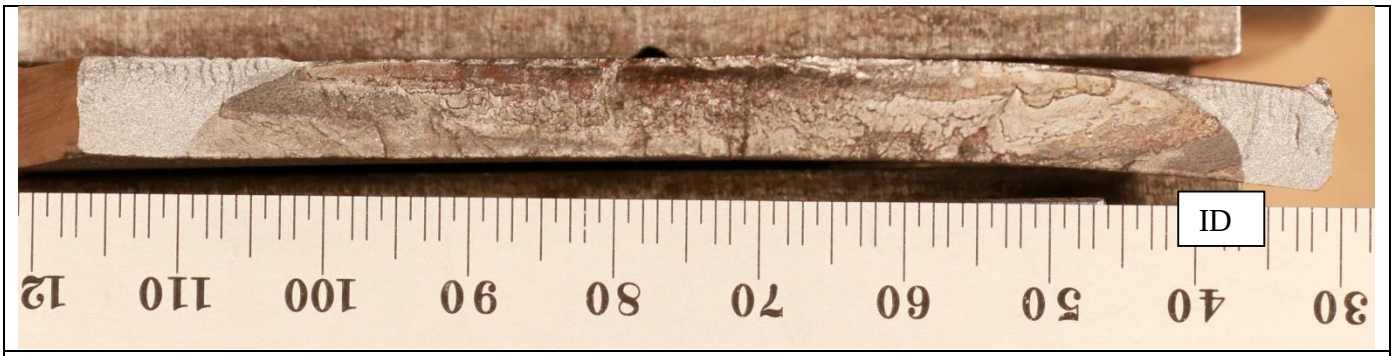


Figure 16: Test # 10 – Dent interacted with LSW - Sample 1 – Axial Crack - Fracture photograph – Pipe D

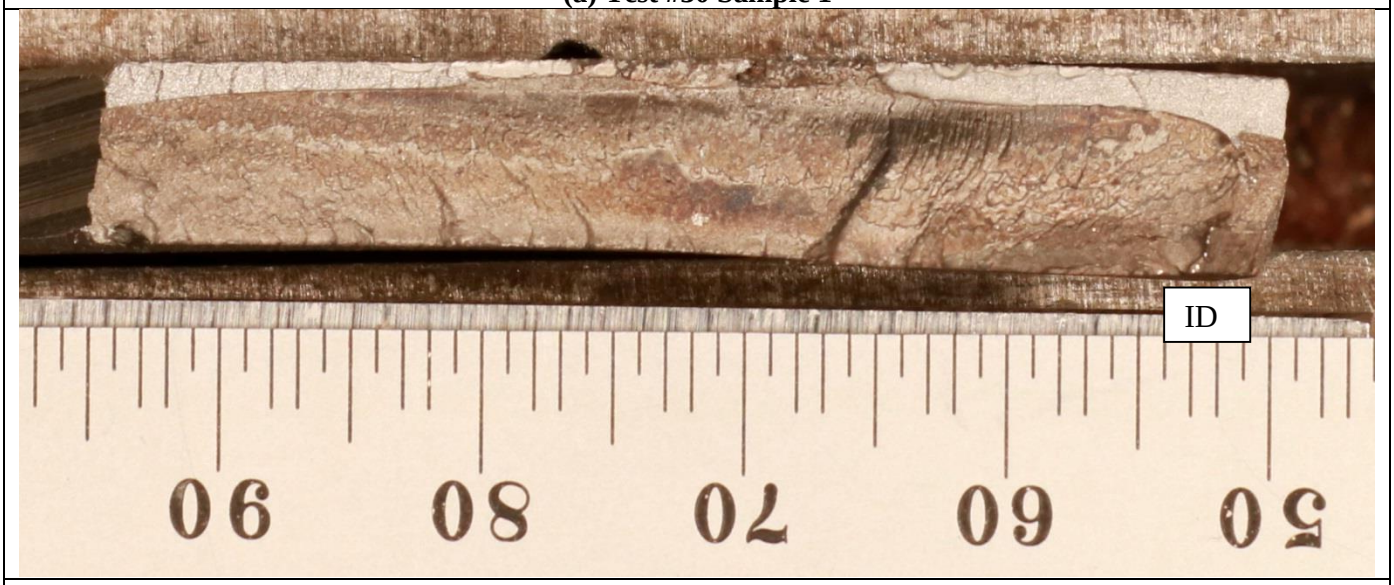
(a) Test #12 Sample 1

(b) Test #12 Sample 2

Figure 17: Test # 12 – Dent interacted with LSW - Sample 1 – Axial Crack - Fracture photograph – Pipe D
(a) Sample 1 (b) Sample 2



(a) Test #30 Sample 1



(b) Test #30 Sample 2

Figure 18: Test # 30 – Dent interacted with LSW - Axial Crack - Fracture photograph – Pipe D
(a) Sample 1 (b) Sample 2

F.3 Dents interacted with Corrosion

Figure 19: Test # 16 – Dent interacted with 42% Corrosion – Axial Crack - Sample 1 - Fracture photograph – Pipe F

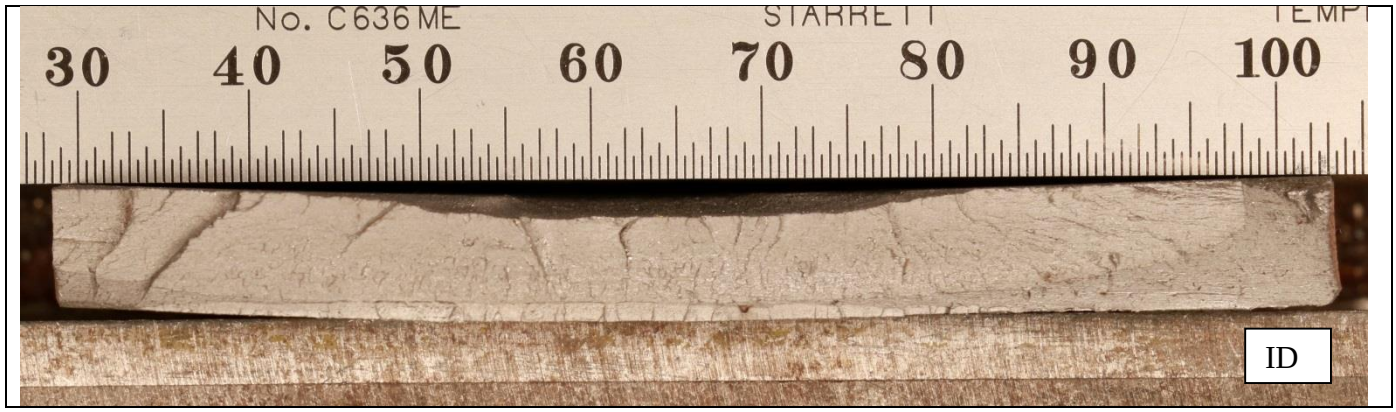


Figure 20: Test # 17 – Dent interacted with 17% Corrosion – Axial Crack - Sample 1 - Fracture photograph – Pipe F

Figure 21: Test # 18 – Dent interacted with 30% Corrosion – Axial Crack - Sample 1 - Fracture photograph – Pipe F

Figure 22: Test # 19 – Dent interacted with 16% Corrosion – Axial Crack - Sample 1 - Fracture photograph – Pipe F

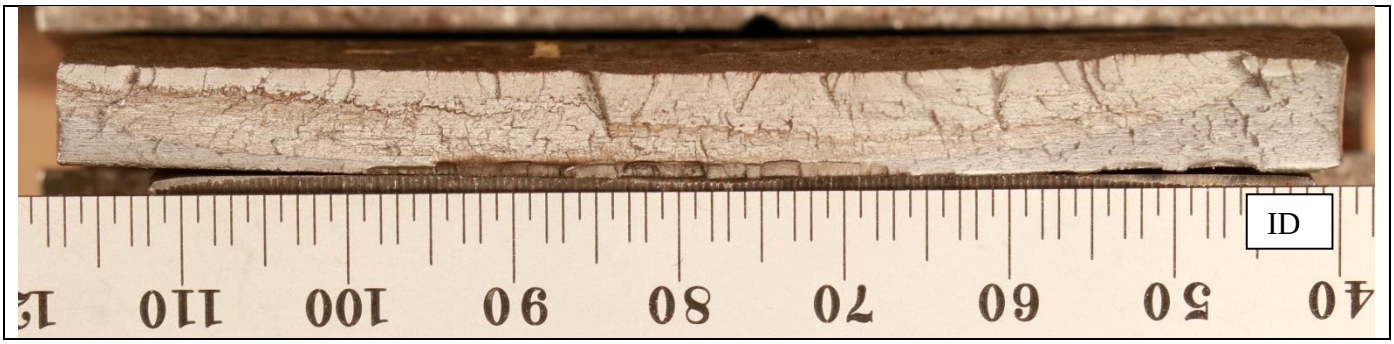
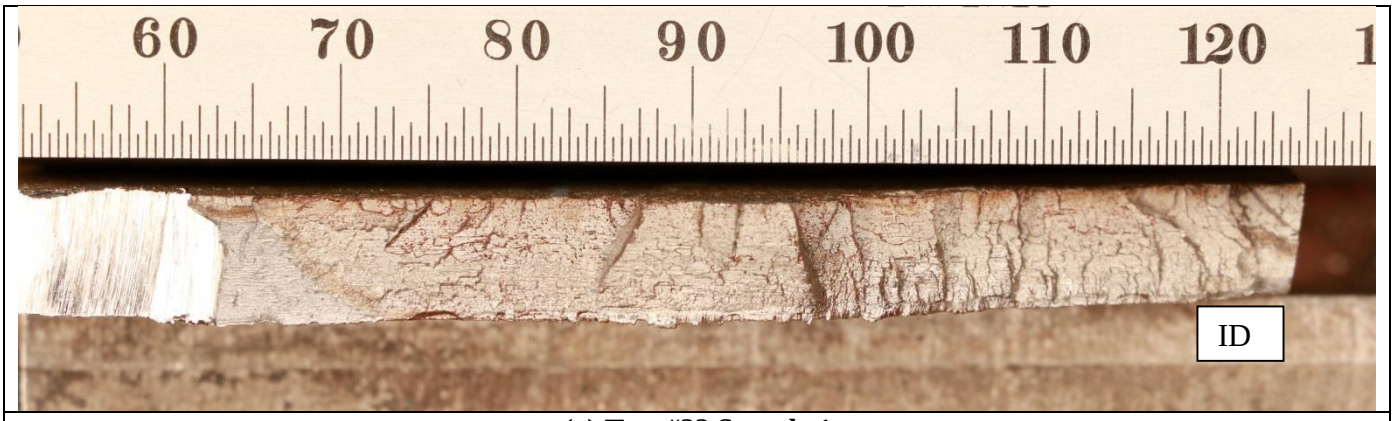
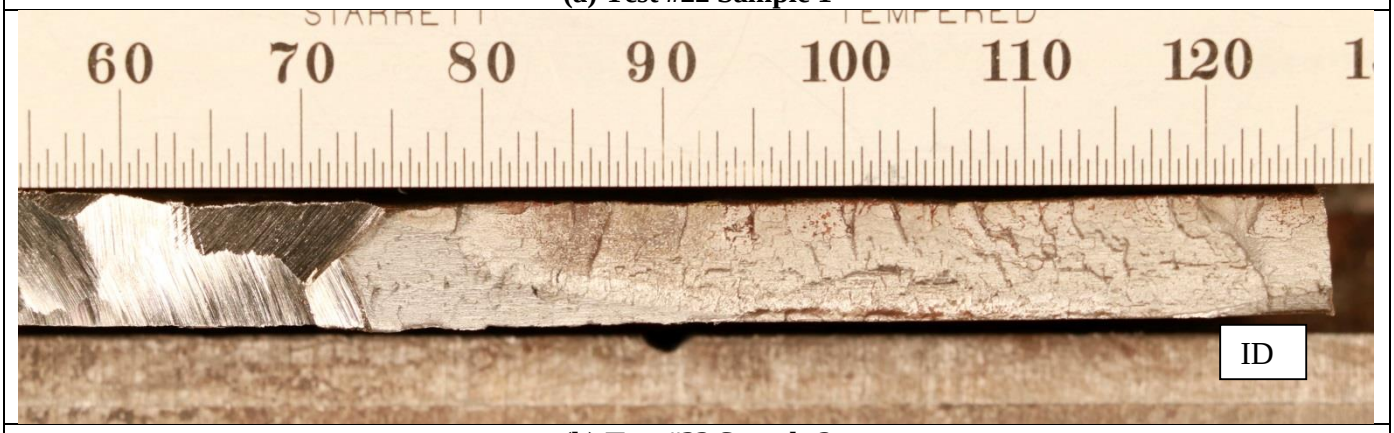


Figure 23: Test # 20 – Dent interacted with 8% Corrosion – Axial Crack - Sample 1 - Fracture photograph – Pipe F

Figure 24: Test # 21 – Dent interacted with 26% Corrosion – Axial Crack - Sample 1 - Fracture photograph – Pipe F



(a) Test #22 Sample 1



(b) Test #22 Sample 2

Figure 25: Test # 22 – Dent interacted with 9% Corrosion – Axial Crack - Fracture photograph – Pipe F
(a) Sample 1 (b) Sample 2

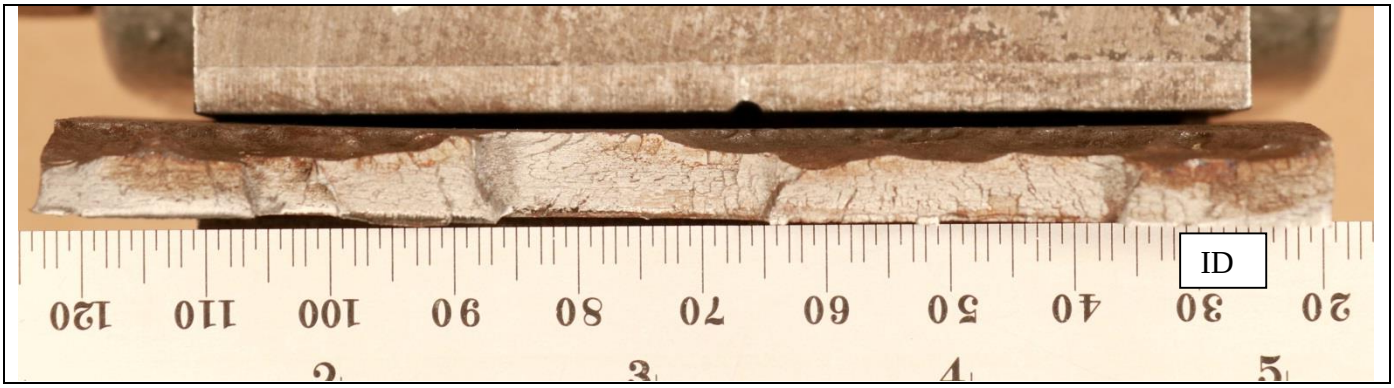


Figure 26: Test # 23 – Dent interacted with 39% Corrosion – Axial Crack - Sample 1 - Fracture photograph – Pipe F

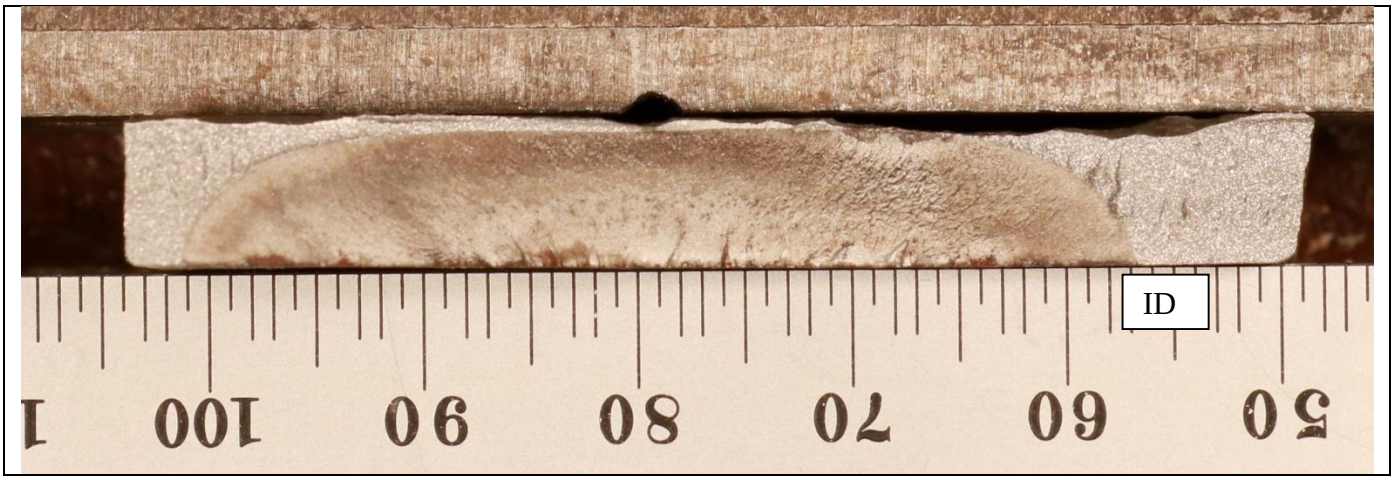
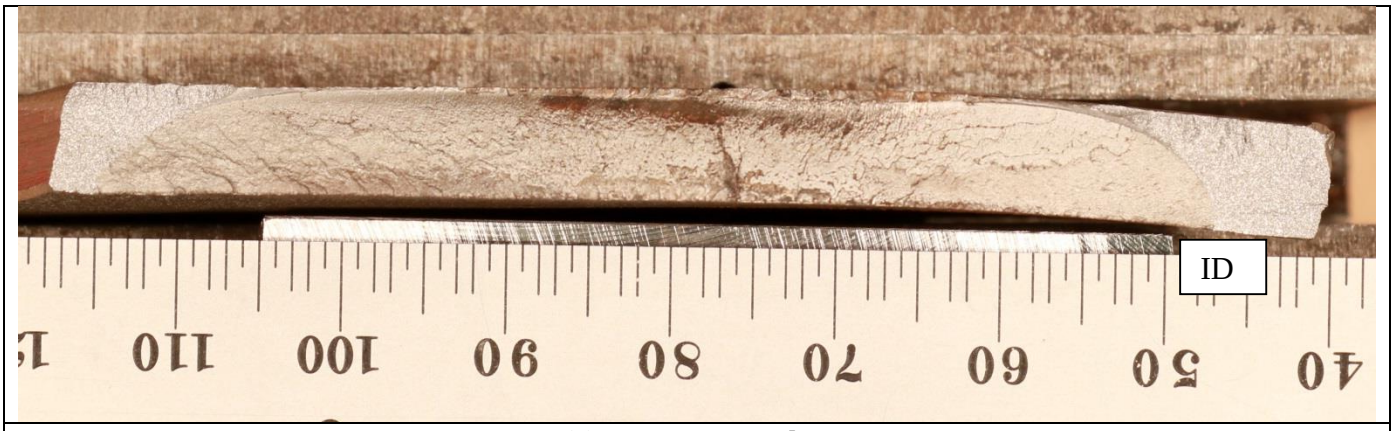


Figure 27: Test # 26 – Dent interacted with 20% Corrosion – Circumferential Crack - Sample 1 - Fracture photograph – Pipe F

Figure 28: Test # 27 – Dent interacted with 35% Corrosion – Axial Crack - Sample 1 - Fracture photograph – Pipe F



(a) Test #28 Sample 1

(b) Test #28 Sample 2

Figure 29: Test # 28 – Dent interacted with 28% Corrosion – 32 degree Angle Crack - Fracture photograph – Pipe F
(a) Sample 1 (b) Sample 2

(a) Test #29 Sample 1

(b) Test #29 Sample 2

Figure 30: Test # 29 – Dent interacted with 23% Corrosion – 42 degree Angle Crack - Fracture photograph – Pipe F
(a) Sample 1 (b) Sample 2

ANNEX G

TYPICAL SCANNING ELECTRON MICROSCOPE FRACTOGRAPHS

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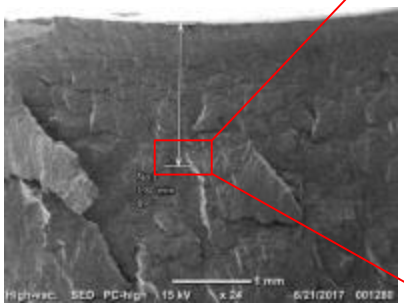
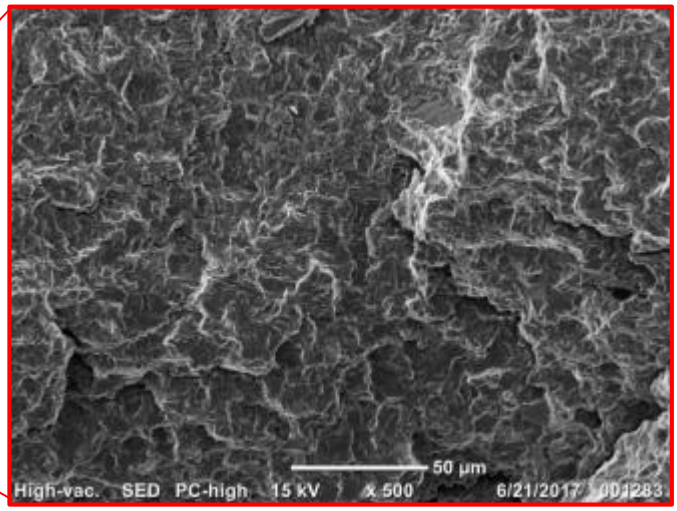
Figure 20: Test # 26 - Dent Interacted with Corrosion - SEM – Pipe F 21
Figure 21: Test # 27 - Dent Interacted with Corrosion - SEM – Pipe F 22
Figure 22: Test # 29 - Dent Interacted with Corrosion - SEM – Pipe F 23

G. Typical Scanning Electron Microscope (SEM) Fractographs

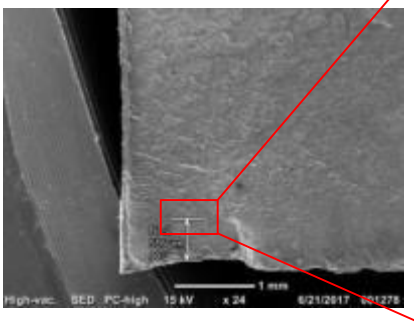
G.1 Plain Dents



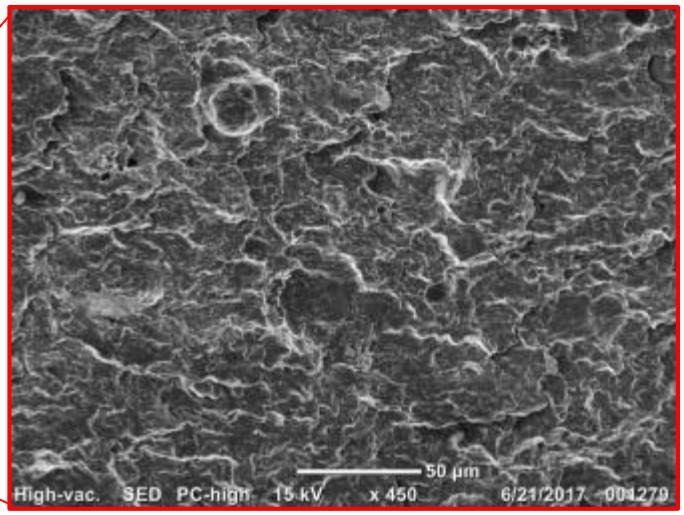
SEM image near OD-24X



Fracture facets @1.8mm from OD -500X

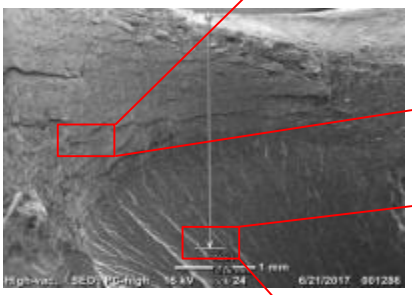


SEM image near ID side -24X

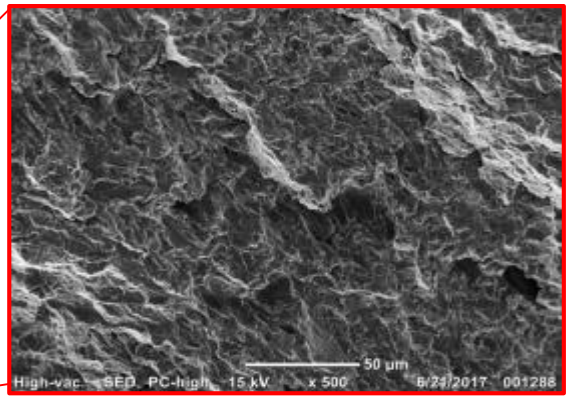


Fracture facets @ 0.5 mm from ID -450X

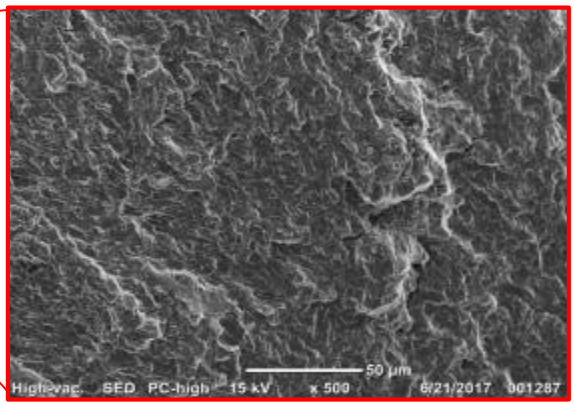
Figure 1: Test # 2 – Plain Dent - SEM – Pipe D



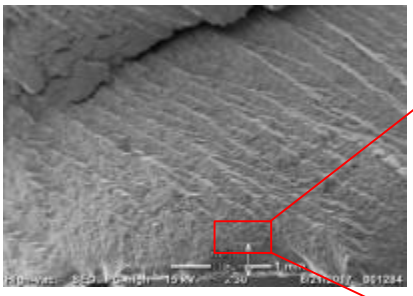
SEM image near mid wall /OD side -24X



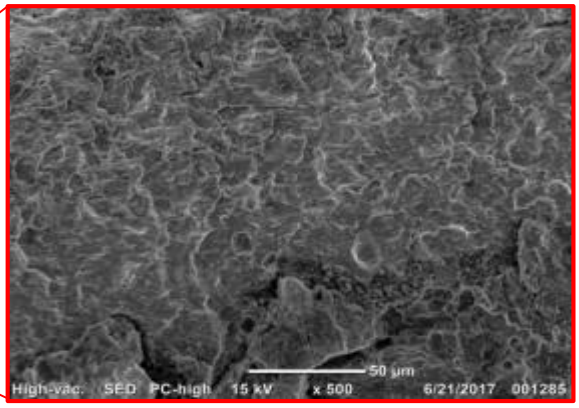
Fracture facets @1.5mm from ID surface -500X



Fracture facets @3.2mm from OD surface -500X

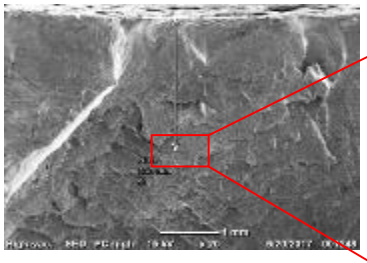


SEM image near ID side -30X

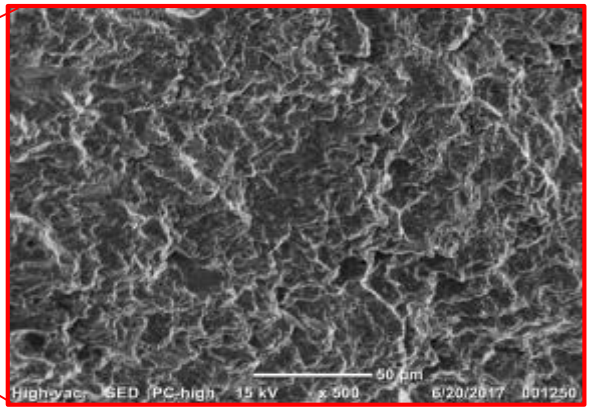


Fracture facets @ 0.35mm above ID surface-500X

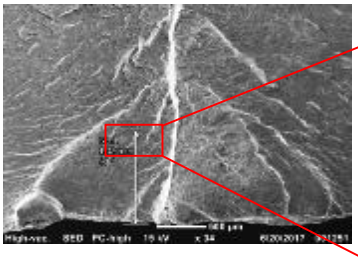
Figure 2: Test # 4 - Plain Dent - SEM – Pipe D



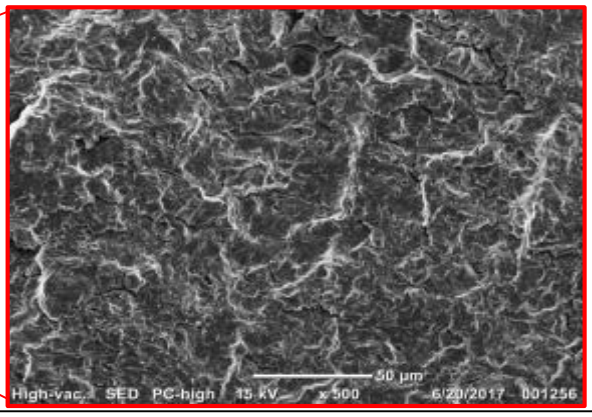
SEM image near OD - 20X



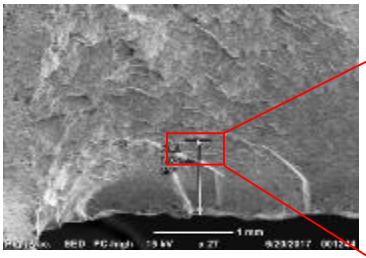
Fracture facets @2.43mm from OD surface -500X



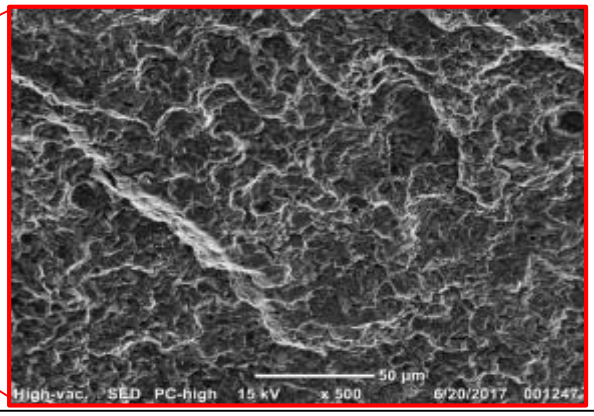
SEM image near ID side - 34X



Fracture facets @ 1mm above ID surface -500X

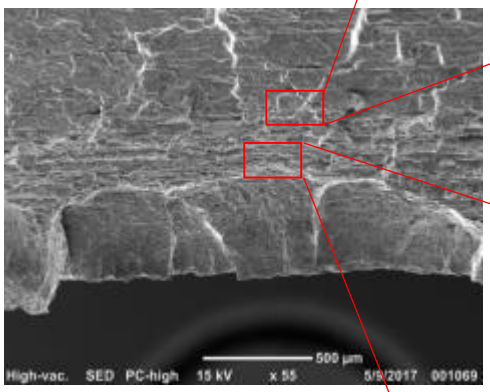


SEM image near ID side - 27X

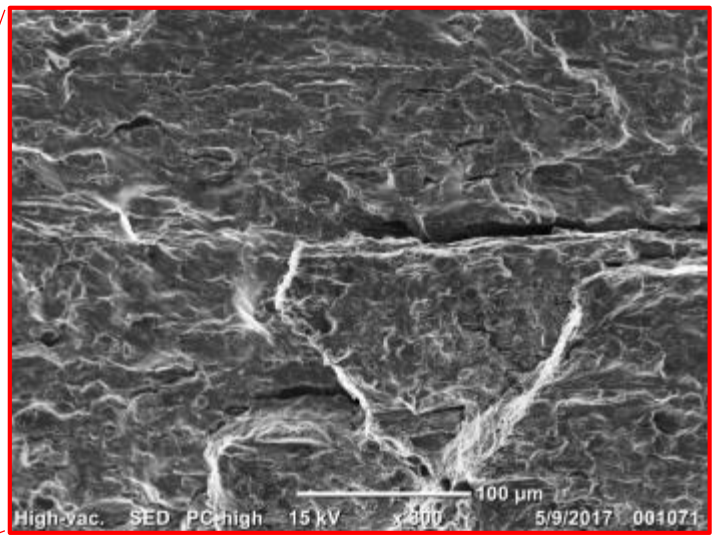


Fracture facets @ 1mm above ID surface -500X

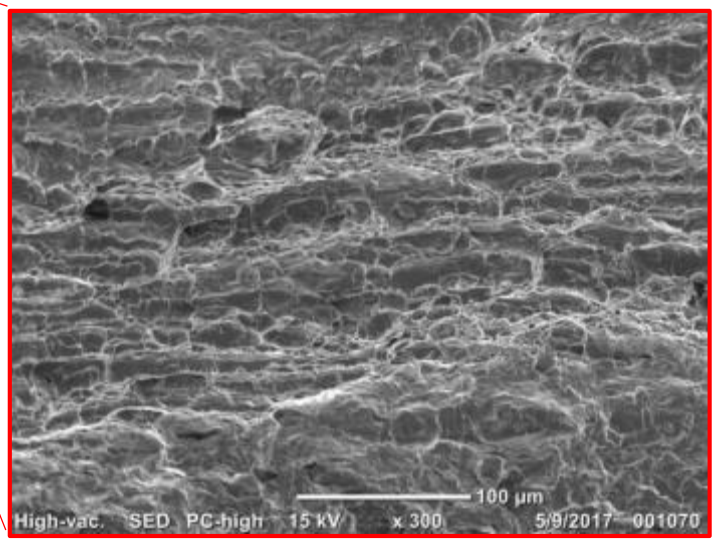
Figure 3: Test # 13 - Plain Dent - SEM – Pipe D



SEM image ID side - 55X



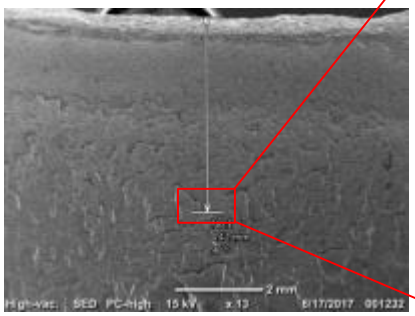
Tear ridges -800X



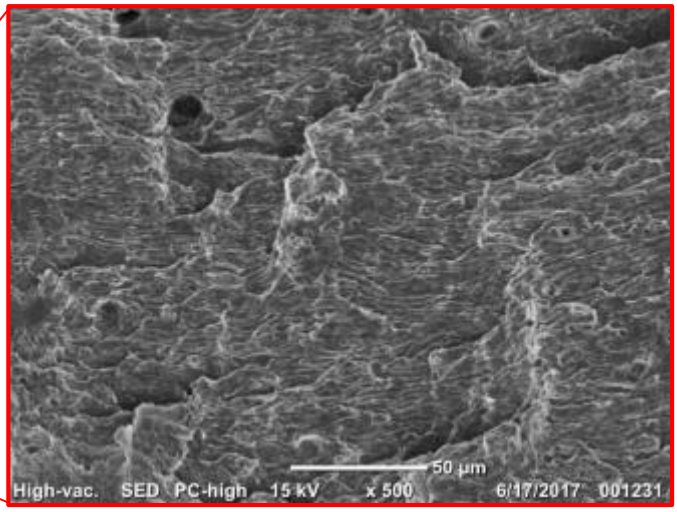
Ductile tear fracture facets -300X

Figure 4: Test # 14 - Plain Dent - SEM – Pipe F

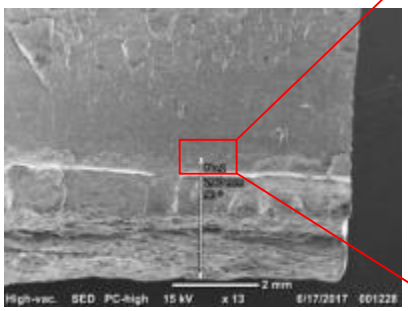
G.2 Dents interacted with Welds



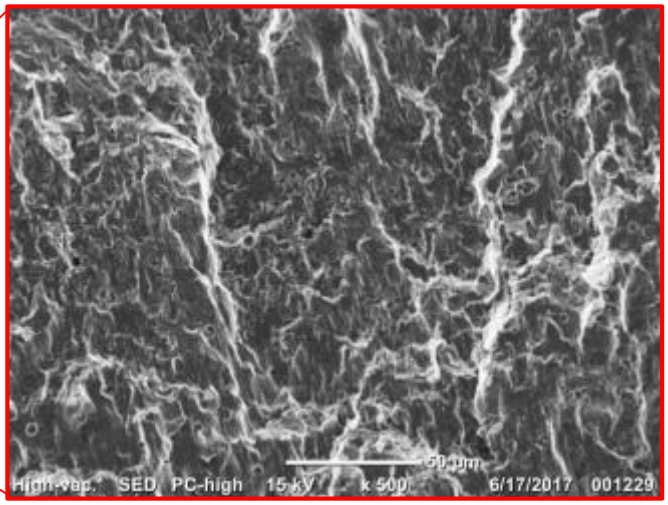
SEM image near mid wall - 13X



Fatigue striations -500X

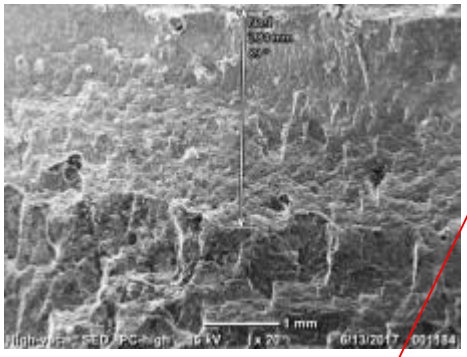


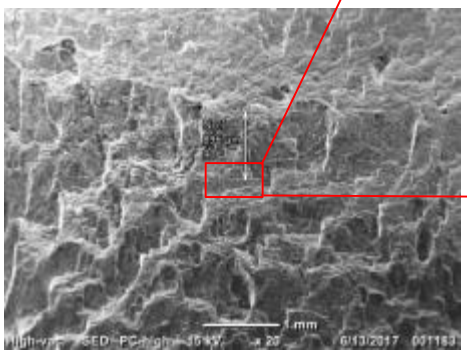
SEM image near ID side - 13X



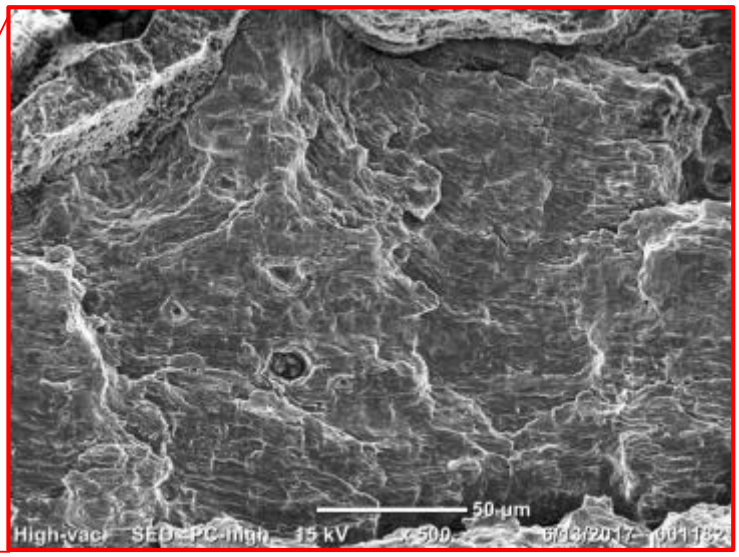
Fracture facets @ 2.8 mm from ID -500X

Figure 5: Test # 5 – Dent Interacted with GW - SEM – Pipe D



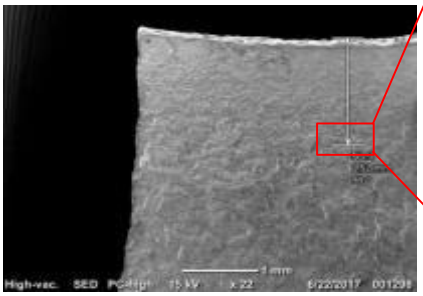


SEM image mid wall -20X

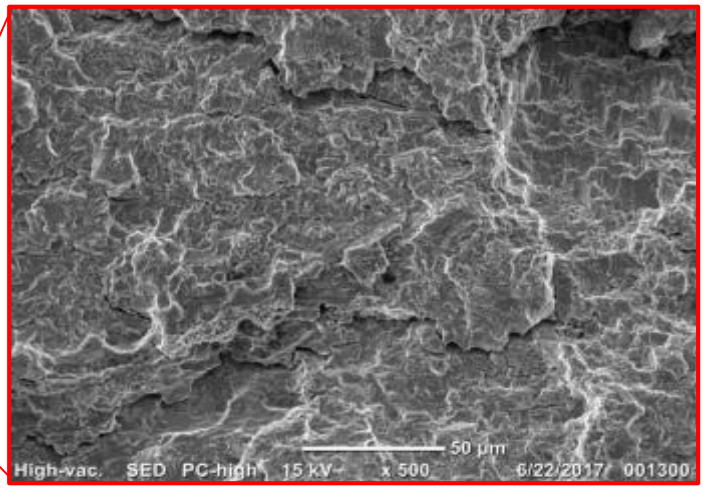


Fracture surface morphology
@3.74mm from OD- 500X

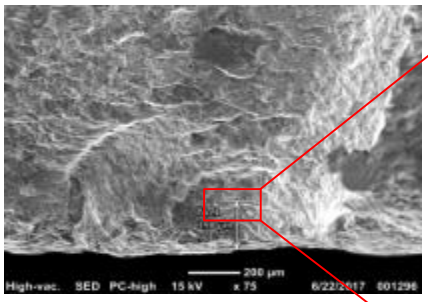
Figure 6: Test # 6 - Dent Interacted with GW - SEM – Pipe D



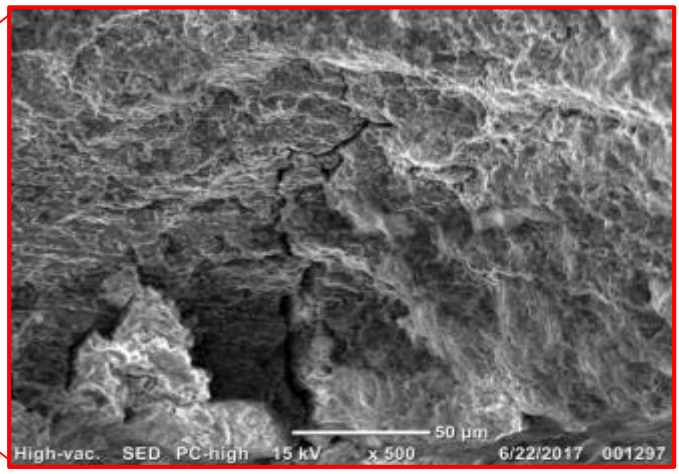
SEM image near OD side - 22X



Fracture facets @1.5mm from OD surface - 500X

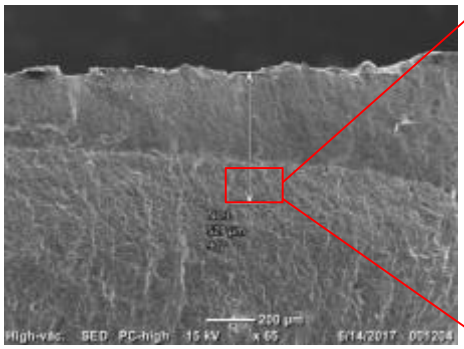


SEM image near ID side - 75X

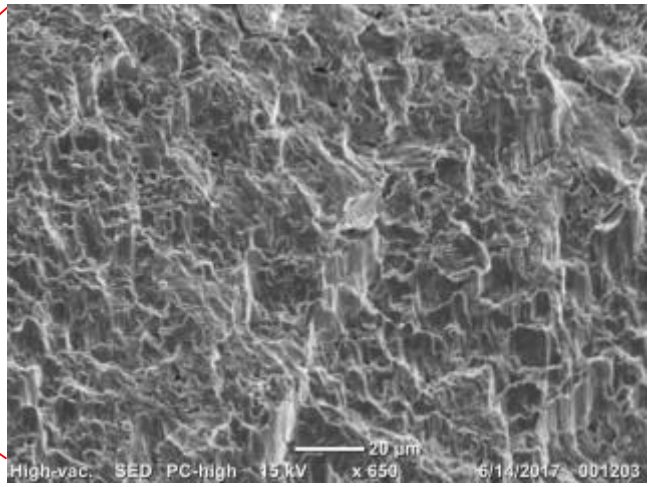


Fracture facets @ 0.2mm above ID surface-500X

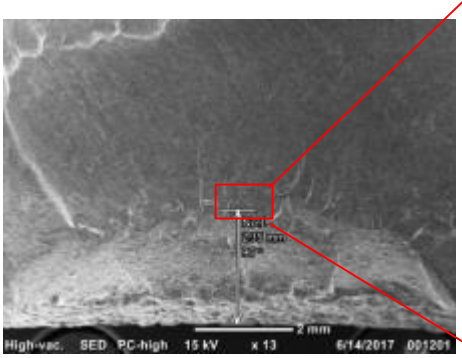
Figure 7: Test # 7 - Dent Interacted with GW - SEM – Pipe D



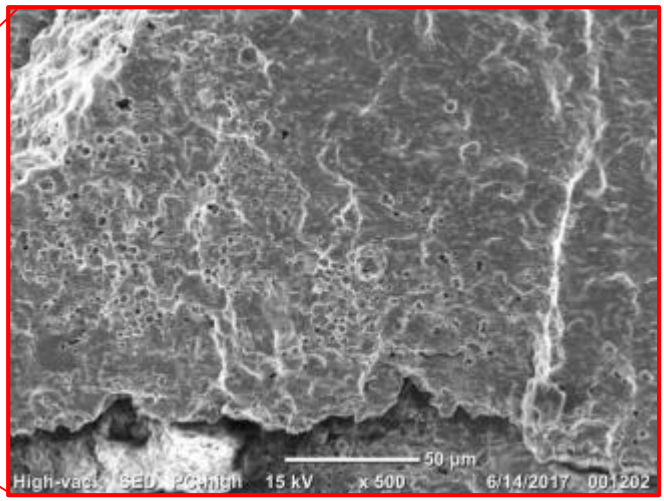
SEM image near OD side - 65X



Fracture facets @ 0.5mm from OD -650X

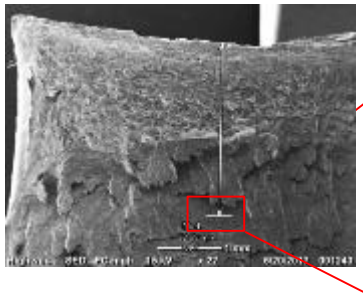


SEM image near ID side -13X

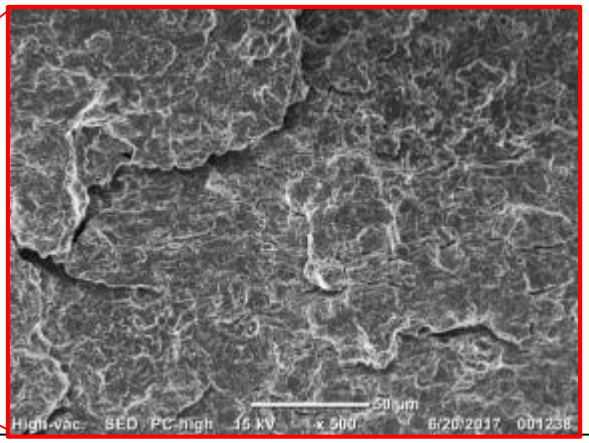


Fracture facets @ 2.35mm from ID -500X

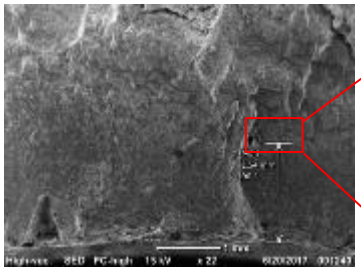
Figure 8: Test # 8 - Dent Interacted with GW - SEM – Pipe D



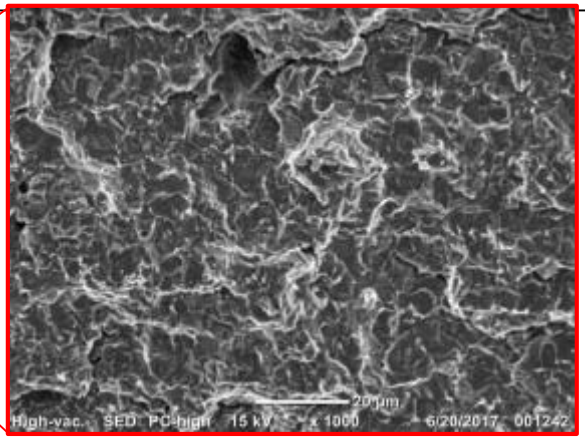
SEM image near OD - 22X



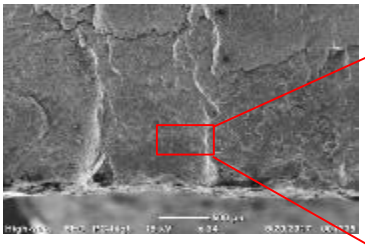
Fracture facets @2.7mm from OD surface -500X



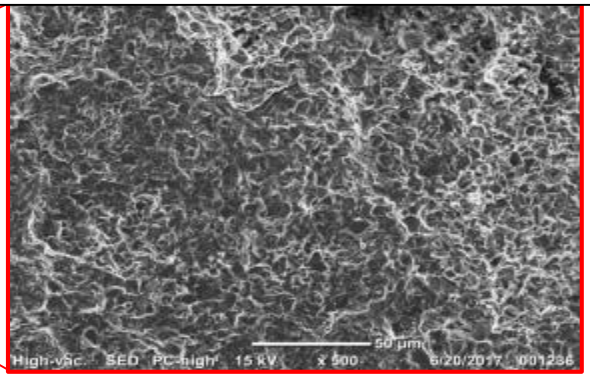
SEM image near ID side - 22X



Fracture facets @1.5mm above ID surface -1000X

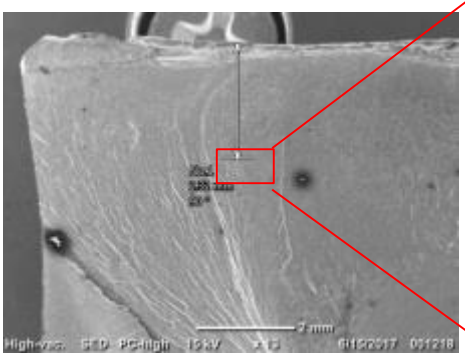


SEM image near ID side - 34X

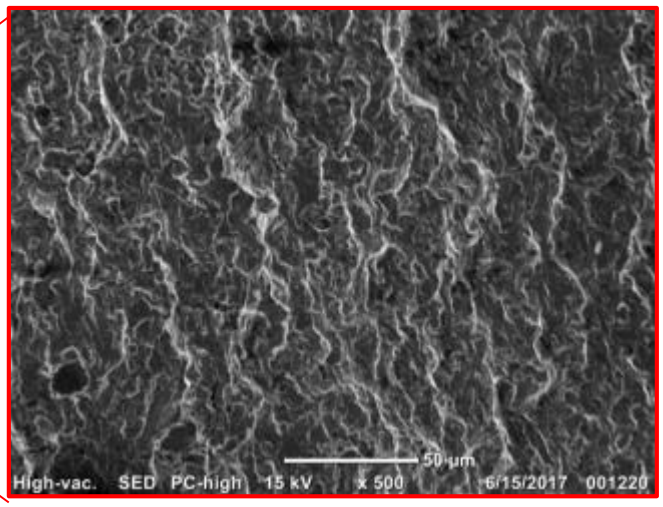


Fracture facets @ 0.5mm above ID surface -500X

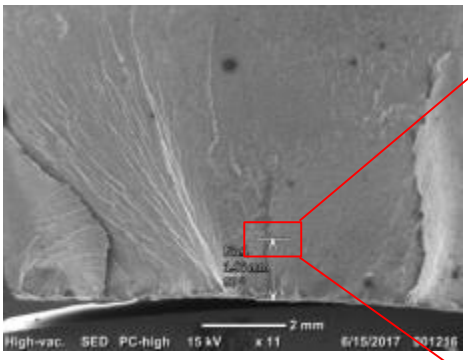
Figure 9: Test # 10 - Dent Interacted with LSW - SEM – Pipe D



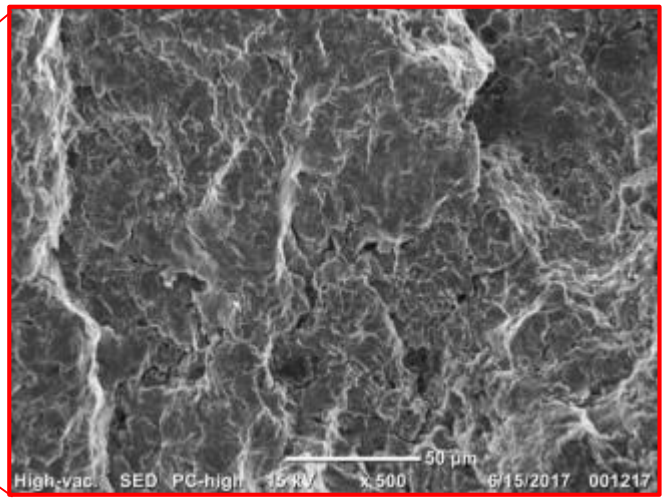
SEM image near OD side - 13X



Fracture facets @ 2.3mm from OD -500X



SEM image near ID side - 11X



Fracture facets @ 1.46mm from ID -500X

Figure 10: Test # 12 - Dent Interacted with LSW - SEM – Pipe D

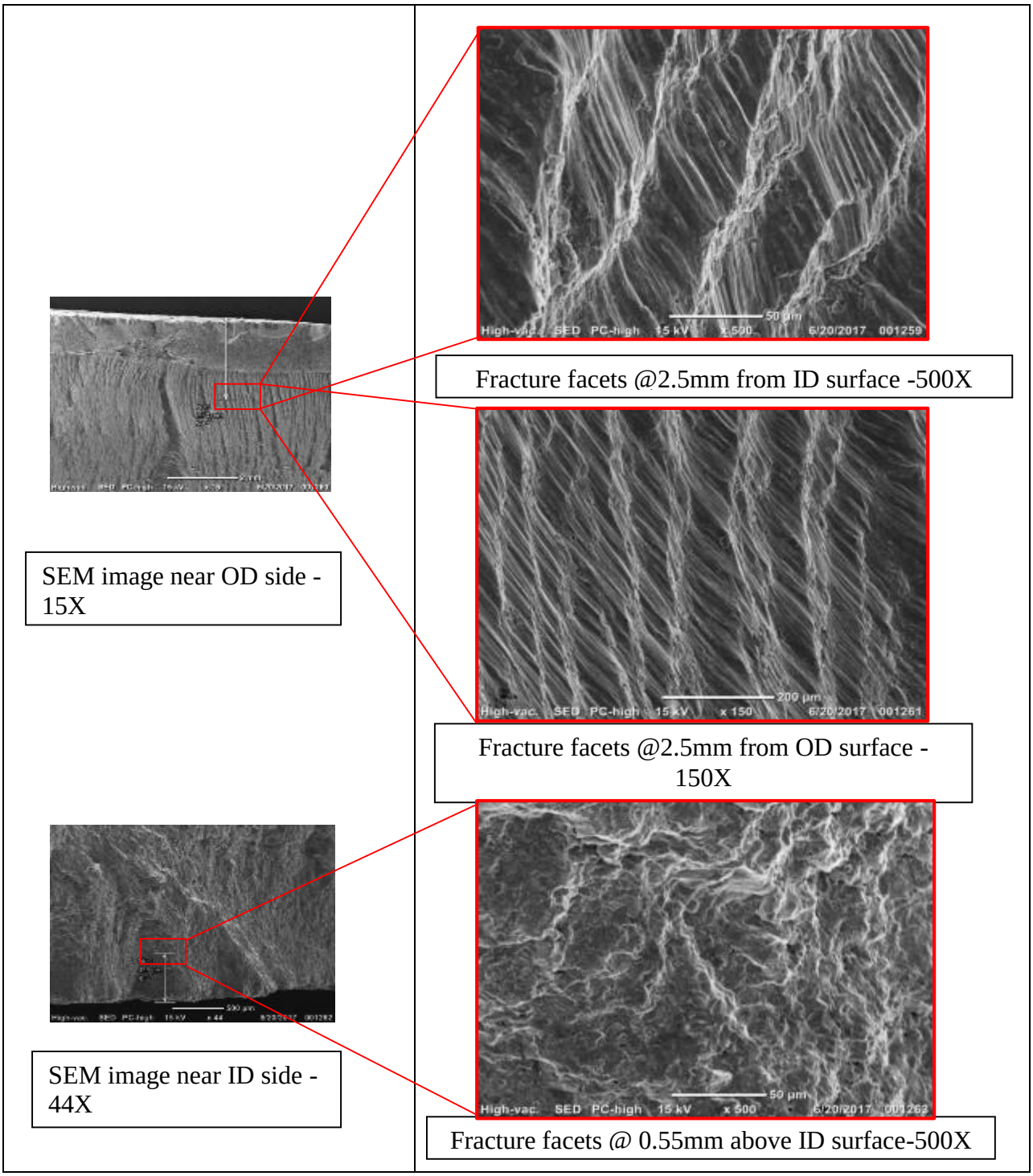


Figure 11: Test # 30 - Dent Interacted with LSW - SEM – Pipe F - Right Side Fracture Surface

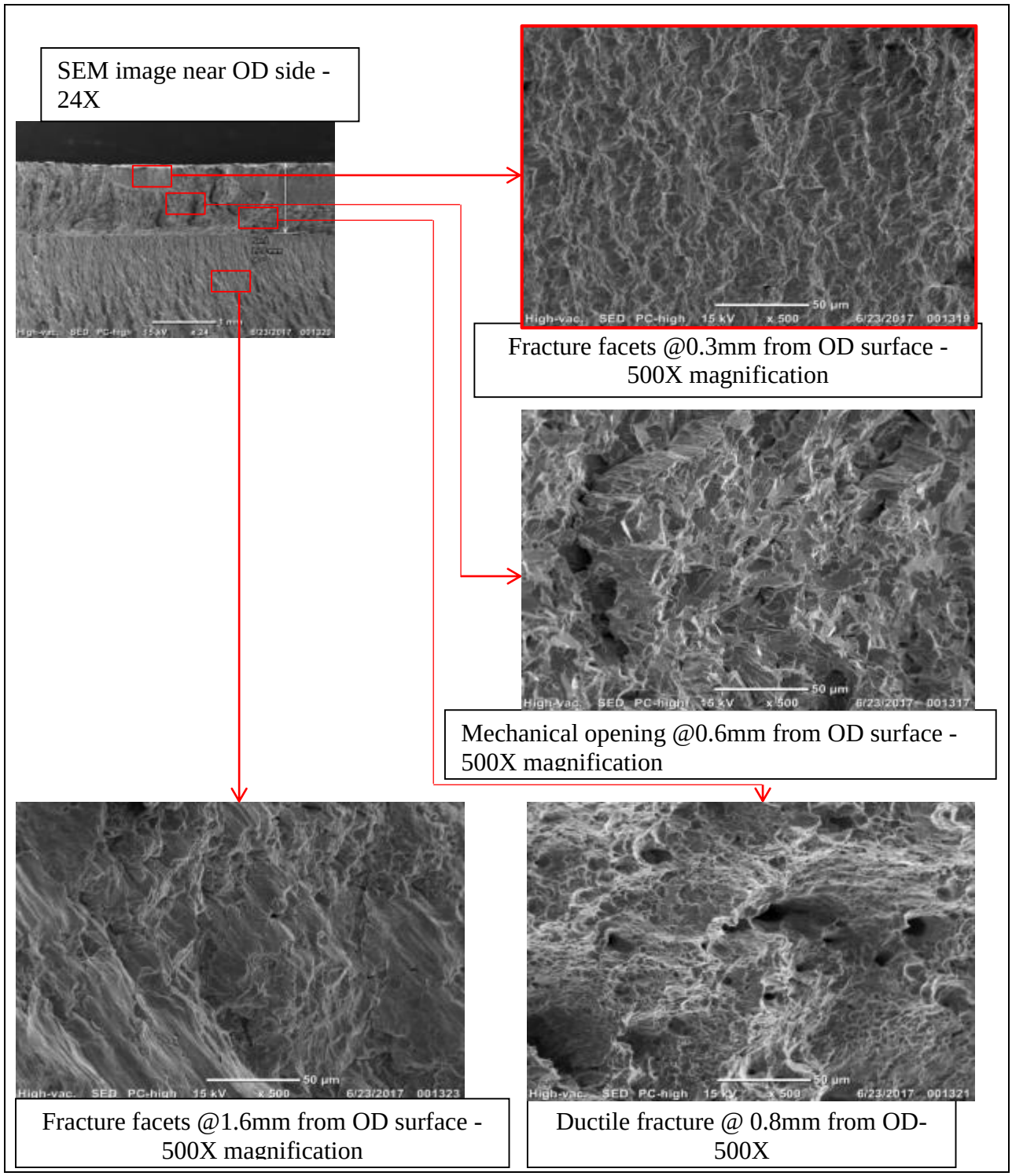
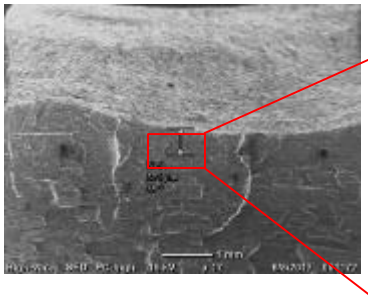
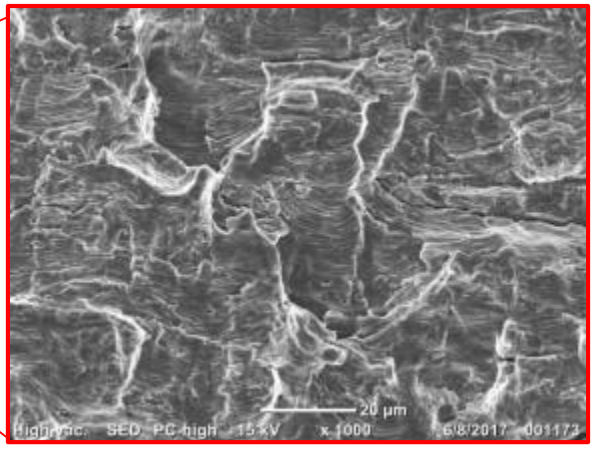


Figure 12: Test # 30 - Dent Interacted with LSW - SEM – Pipe F- Left Side Fracture Surface

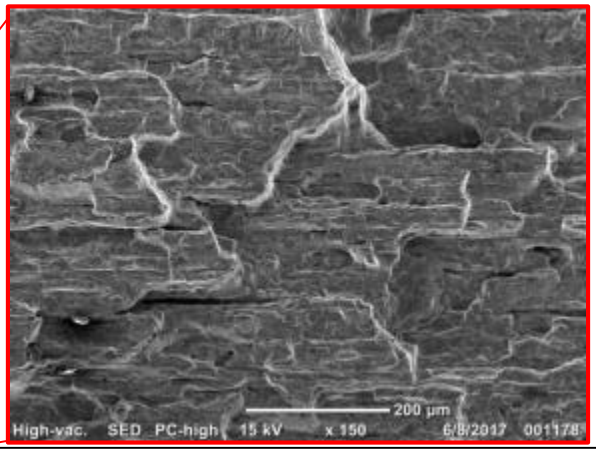
G.3 Dents interacted with Corrosion



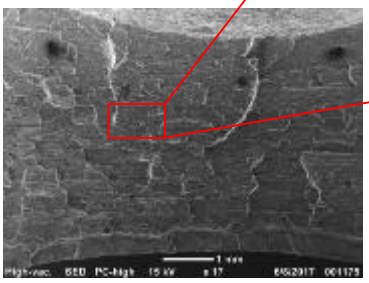
SEM image at OD side -17X



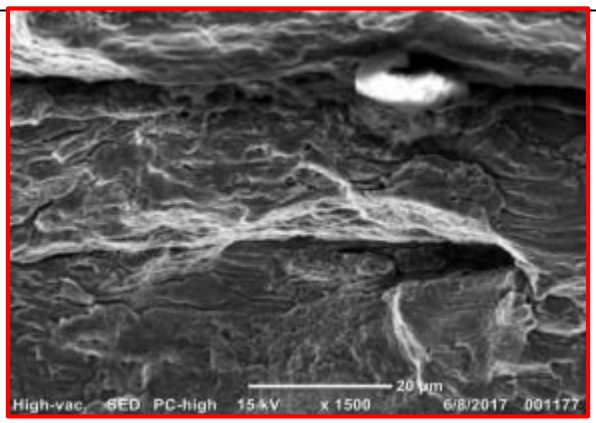
Fatigue striations @0.5mm from OD surface-1000X



Fracture facets @1.5mm below OD surface -150X

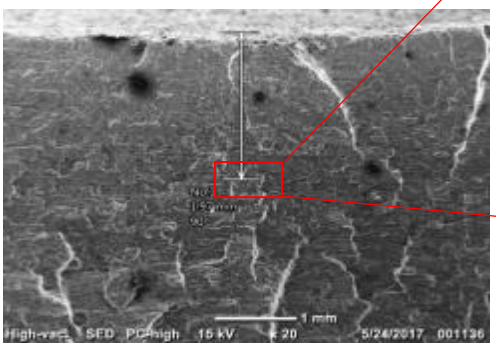


SEM image near OD side -17X

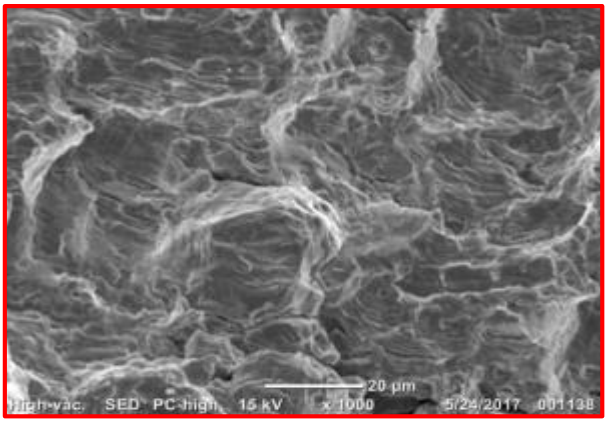


Detail fracture facets @ 1.5mm below OD surface -1500X

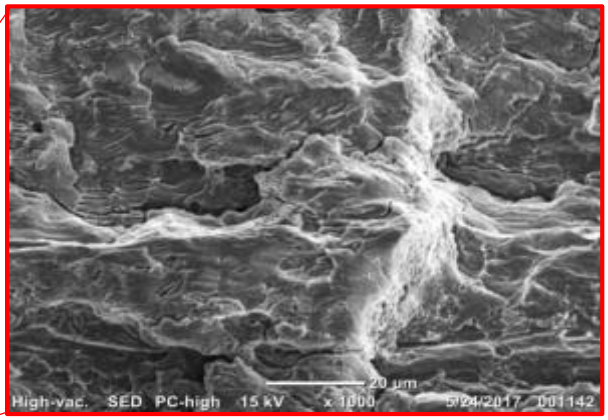
Figure 13: Test # 16 - Dent Interacted with Corrosion - SEM – Pipe F



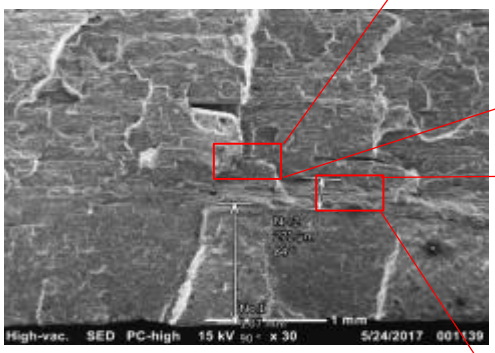
SEM image OD side -20X



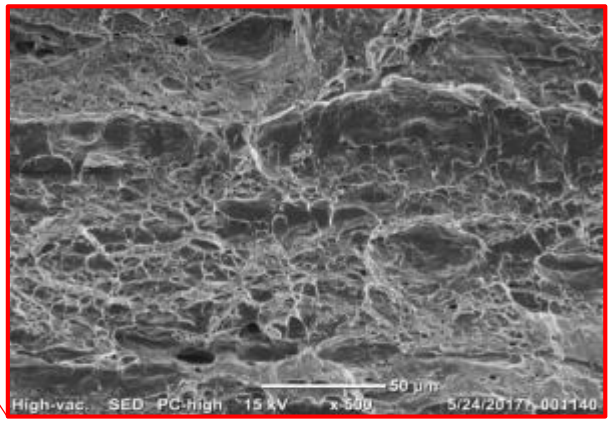
Fatigue striation-1000X



Fatigue striation and tear ridges -1000X

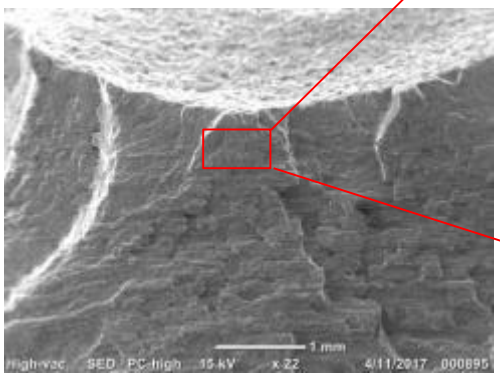


SEM image ID side -30X

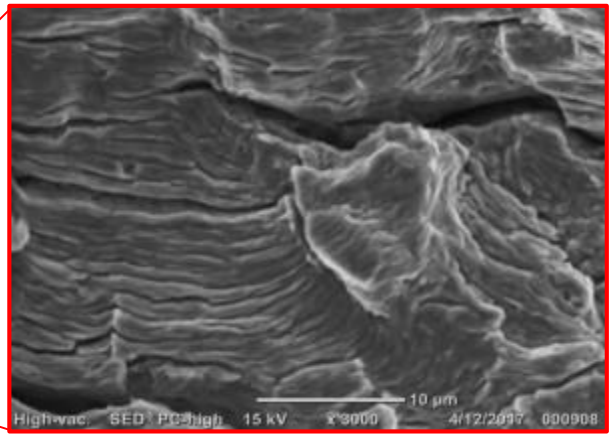


Ductile tear fracture facets -500X

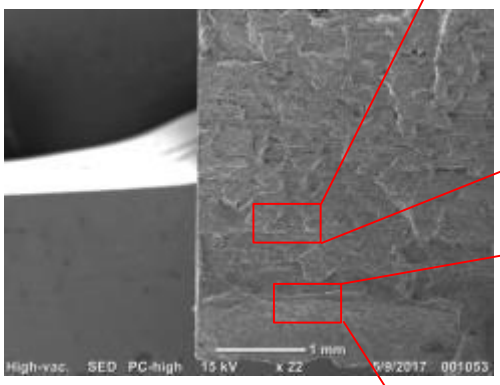
Figure 14: Test # 17 - Dent Interacted with Corrosion - SEM – Pipe F



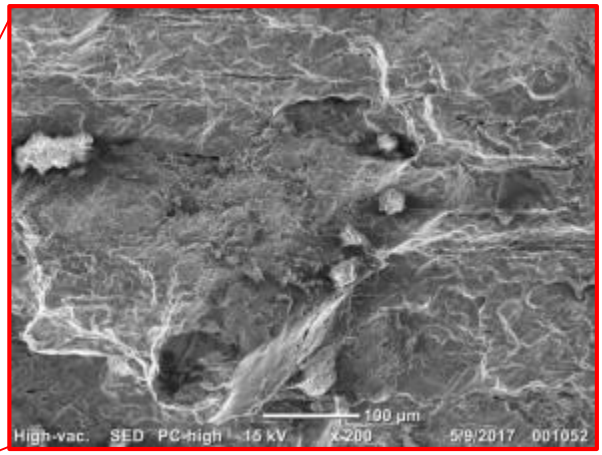
SEM image OD side -22X



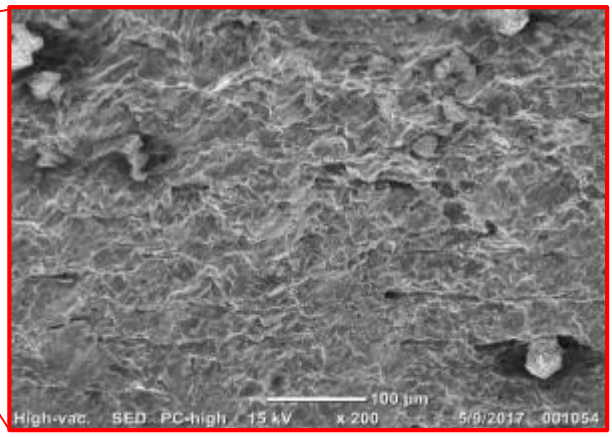
Fatigue striation-3000X



SEM image ID side -22X

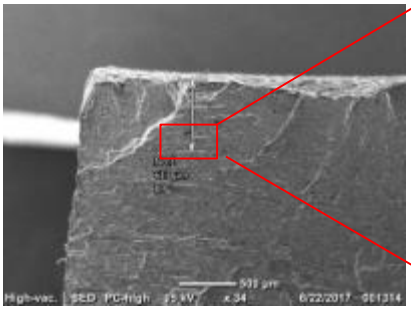


Fracture morphology ID side-200X

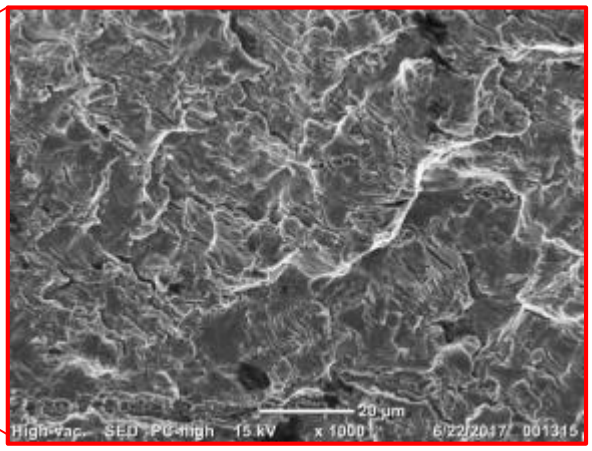


Fracture morphology with limited ductility ID side-200X

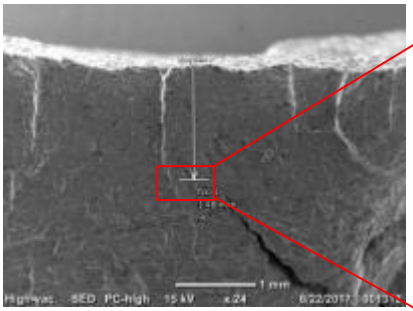
Figure 15: Test # 18 - Dent Interacted with Corrosion - SEM – Pipe F



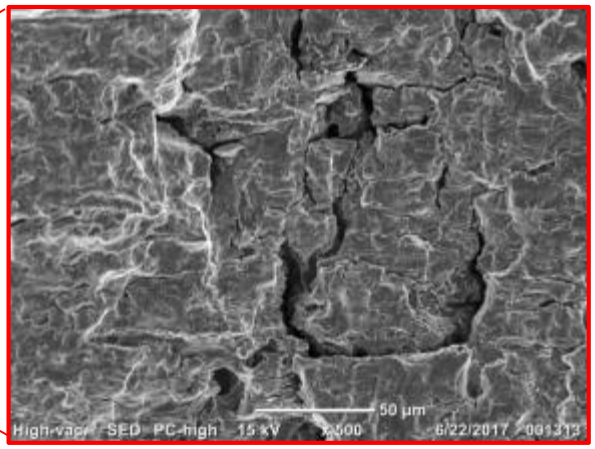
SEM image near OD side -34X



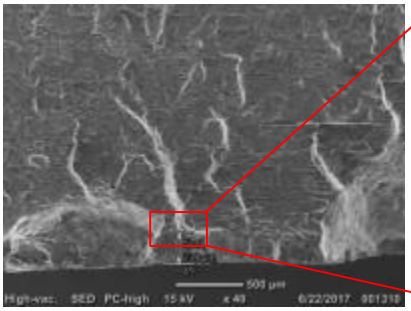
Fracture facets @ 0.6mm below OD surface -1000X



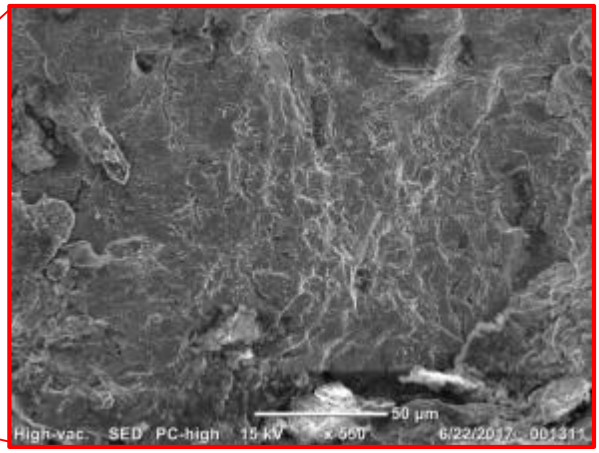
SEM image near OD side -24X



Fracture facets @ 1.5mm below OD surface -500X

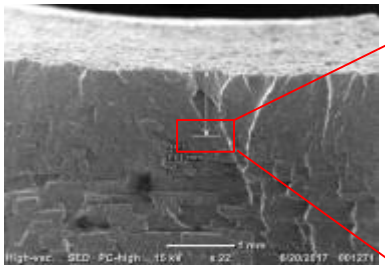


SEM image near ID side - 40X

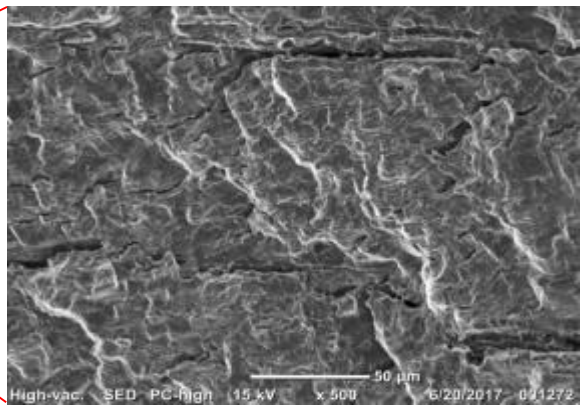


Fracture facets @ 0.3mm above ID surface -550X

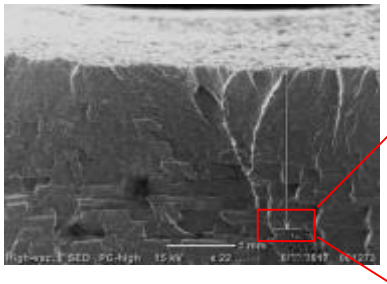
Figure 16: Test # 19 - Dent Interacted with Corrosion - SEM – Pipe F



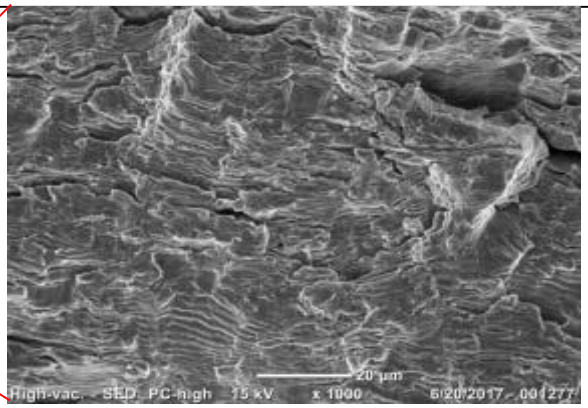
SEM image near OD - 22X



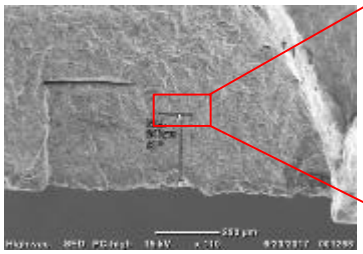
Fracture facets @1.0mm from OD surface -500X



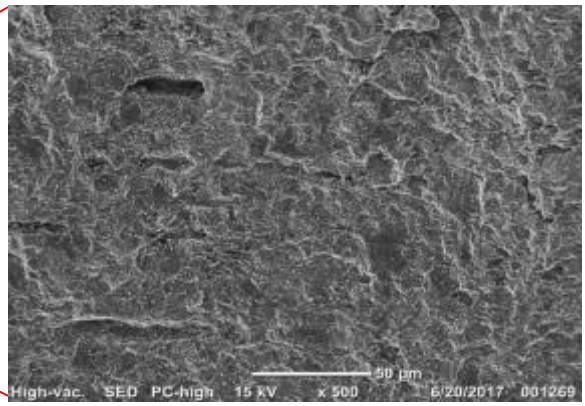
SEM image mid wall - 22X



Fracture facets @ 2.5 mm from OD surface -1000X

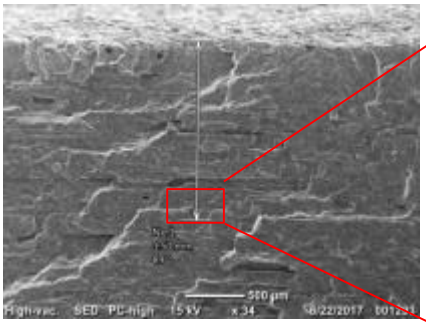


SEM image near ID side -110X

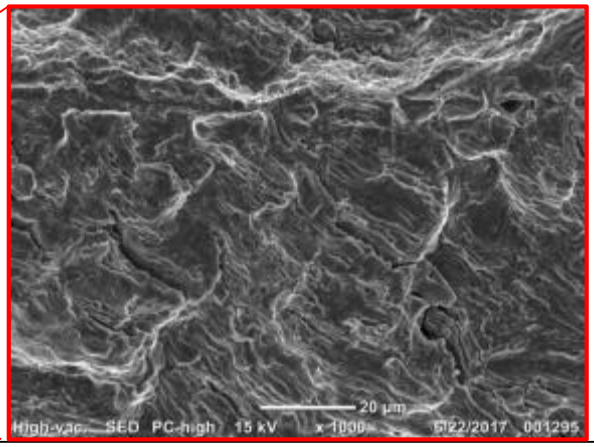


Fracture facets @ 0.3mm above ID surface -500X

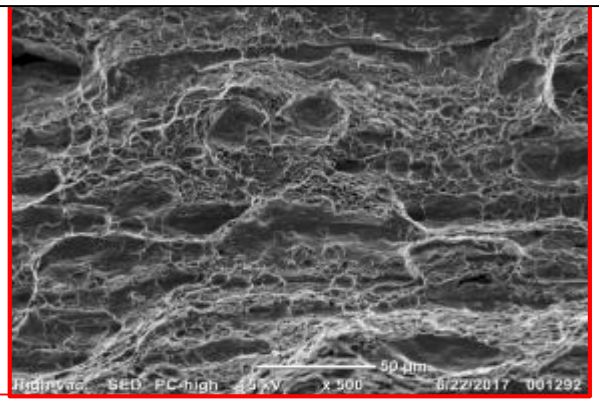
Figure 17: Test # 20 - Dent Interacted with Corrosion - SEM – Pipe F



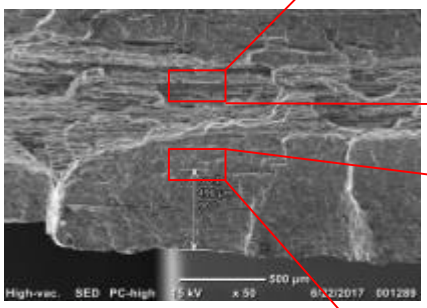
SEM image near OD side -34X



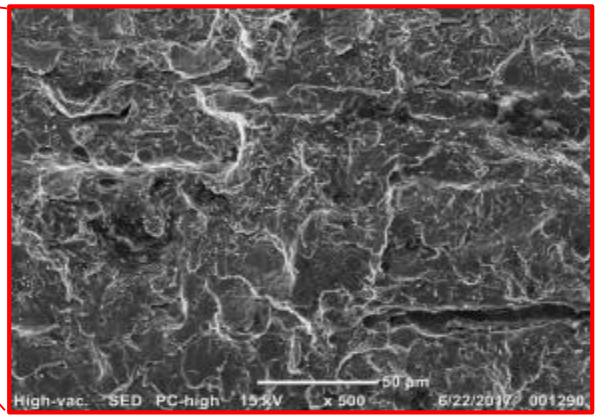
Fracture facets @ 1.5mm below OD surface -1000X



Fracture facets @ 1mm above ID surface -500X

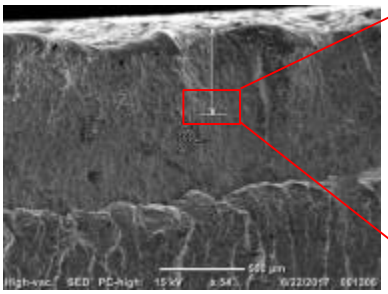


SEM image ID side -50X

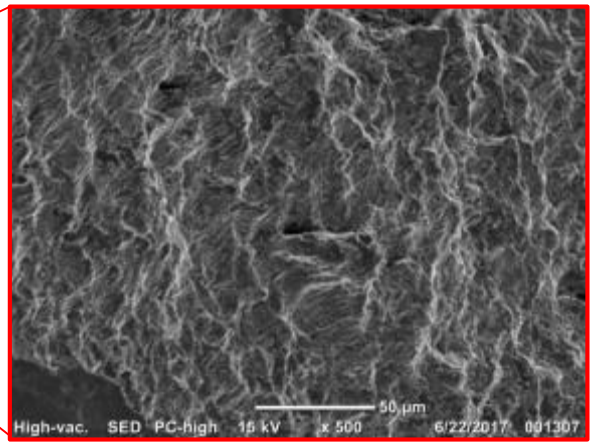


Fracture facets @ 0.5mm above ID surface -500X

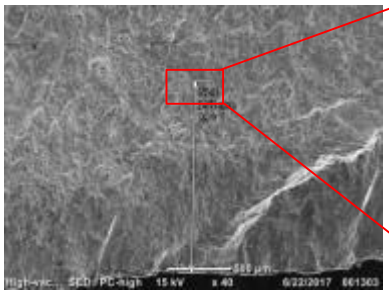
Figure 18: Test # 21 - Dent Interacted with Corrosion - SEM – Pipe F



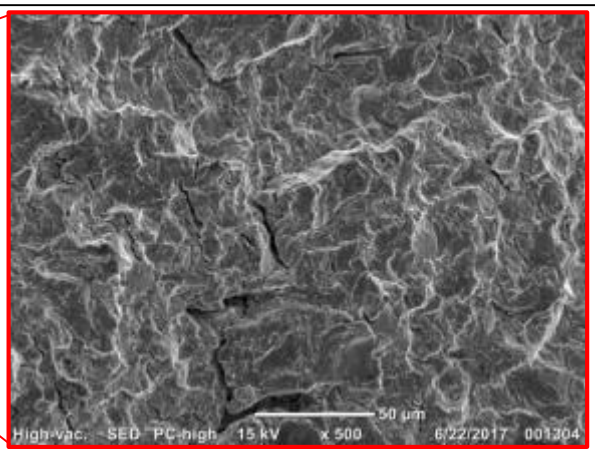
SEM image near OD -54X



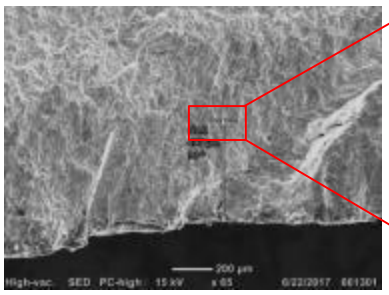
Fracture facets @0.5mm from OD surface -500X



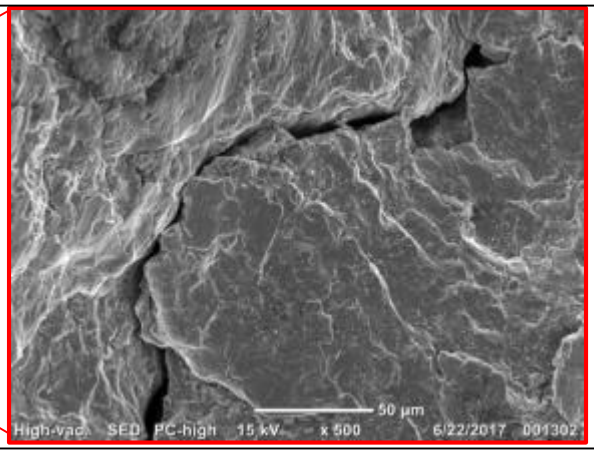
SEM image near ID -40X



Fracture facets @ 1.5 mm above ID surface -500X



SEM image near ID side -65X



Fracture facets @ 0.5mm above ID surface -500X

Figure 19: Test # 24 - Dent Interacted with Corrosion - SEM – Pipe F

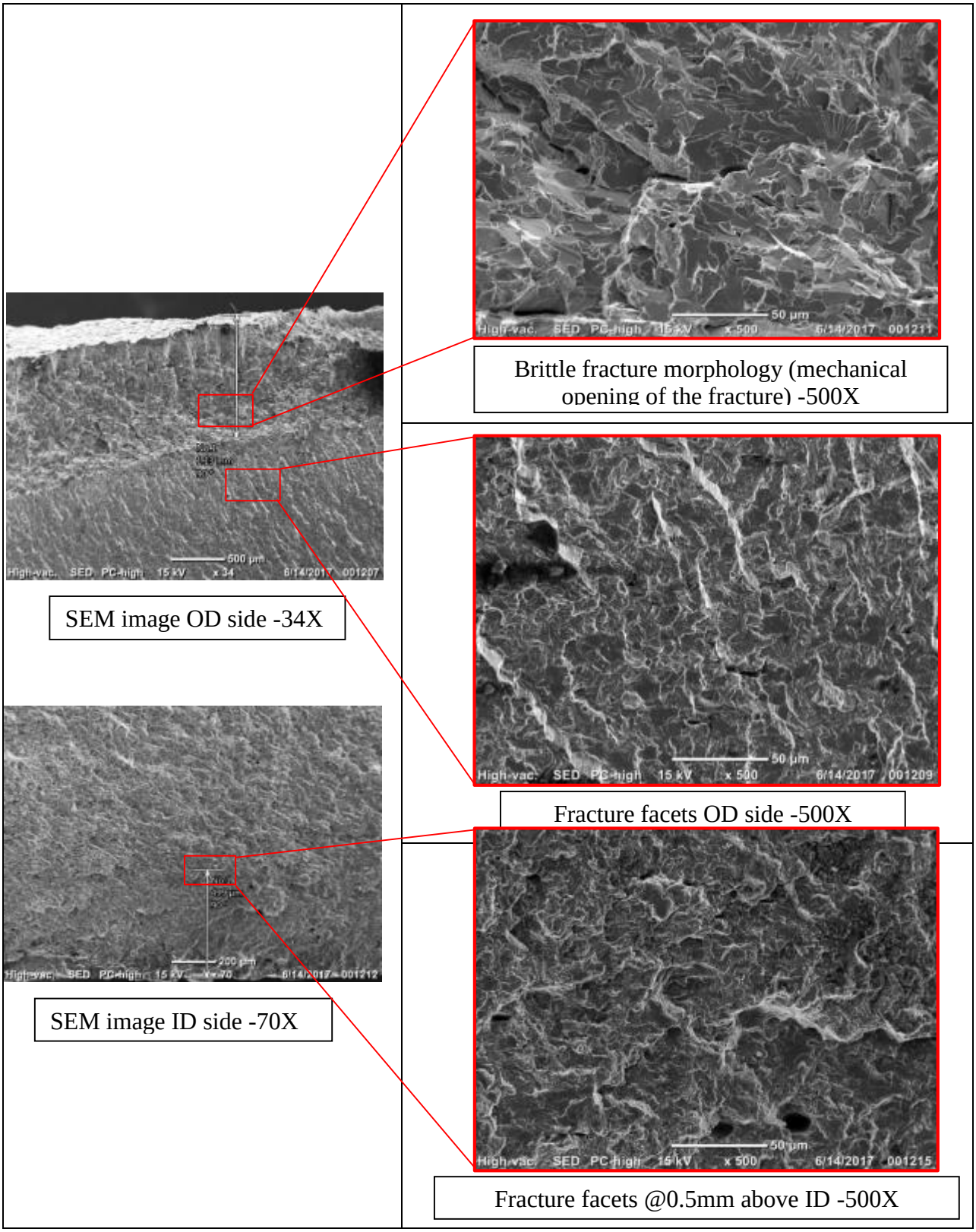
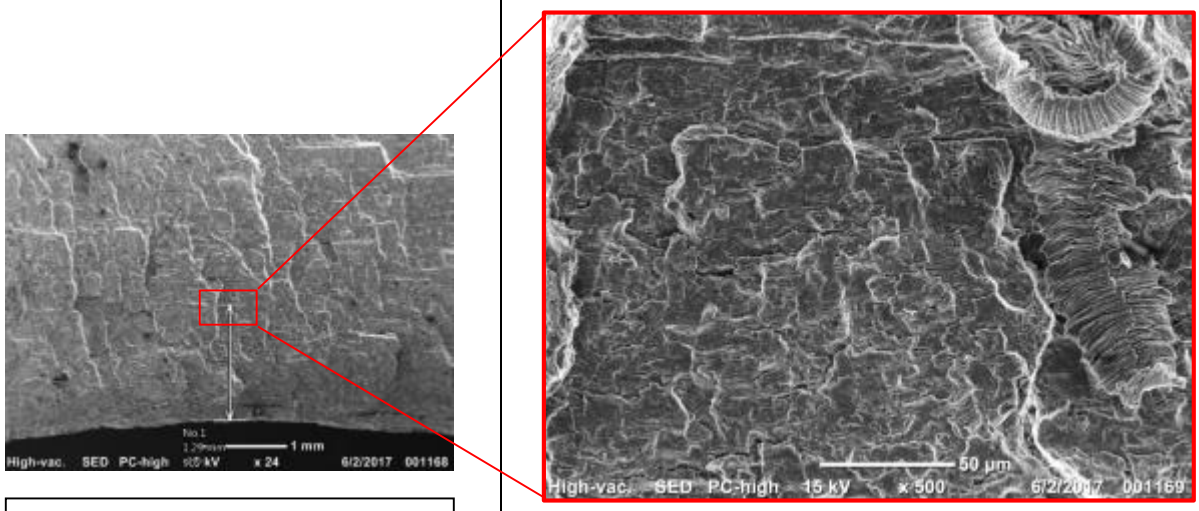


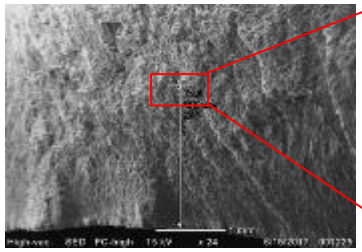
Figure 20: Test # 26 - Dent Interacted with Corrosion - SEM – Pipe F



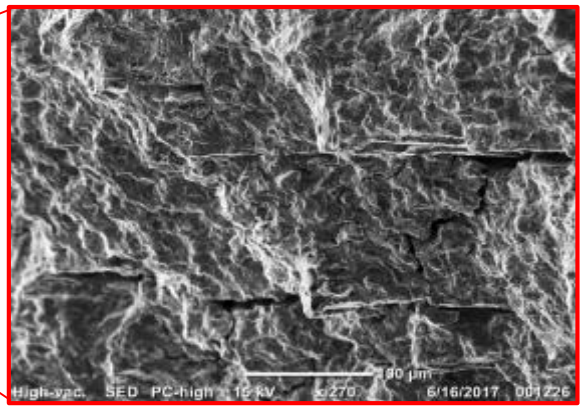
SEM image near ID side -24X

Fatigue striations @ 1.3mm above ID surface -500X

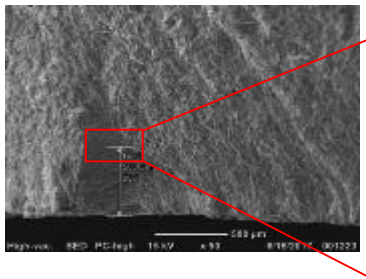
Figure 21: Test # 27 - Dent Interacted with Corrosion - SEM – Pipe F



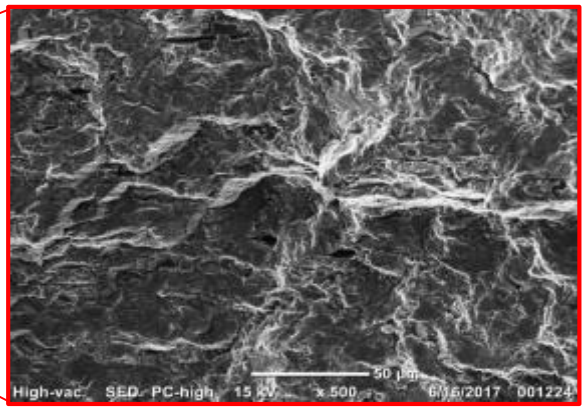
SEM image at close to ID -24X



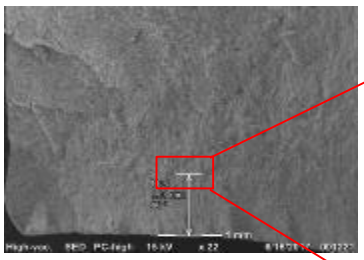
Fracture facets @2.2mm from ID surface -270X



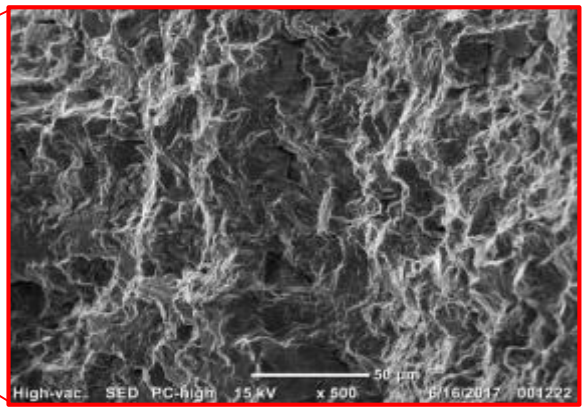
SEM image near ID side -50X



Fracture facets @0.5mm above ID surface -500X



SEM image near ID side -22X



Fracture facets @ 1mm above ID surface -500X

Figure 22: Test # 29 - Dent Interacted with Corrosion - SEM – Pipe F

ANNEX H

DENT STRESS MAGNIFICATION FACTOR

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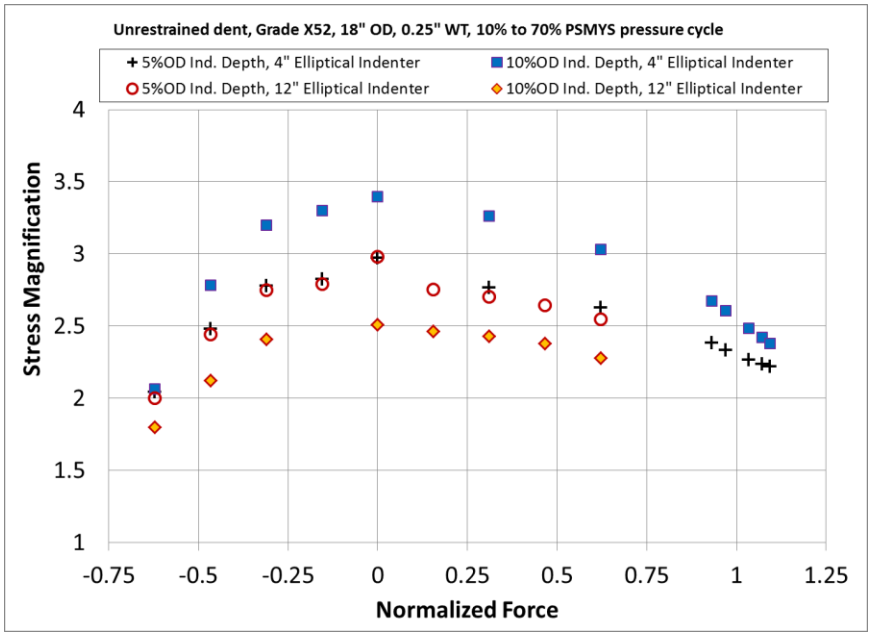
H.1 Detailed Results of Effect of Axial Load on Dent Stress Magnification Factor

H.1.1 Case 1 – 18" OD, 0.25" WT, X52 Grade pipe



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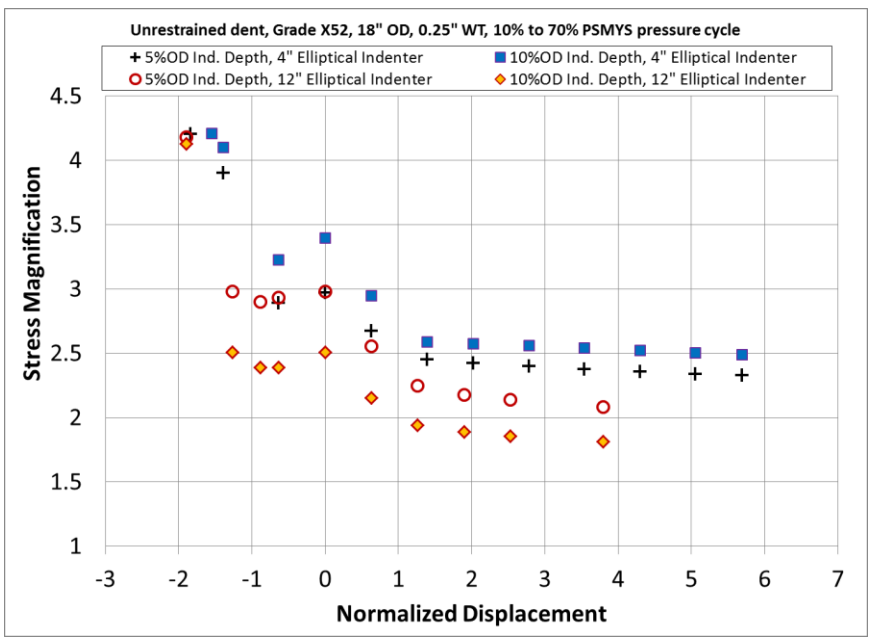
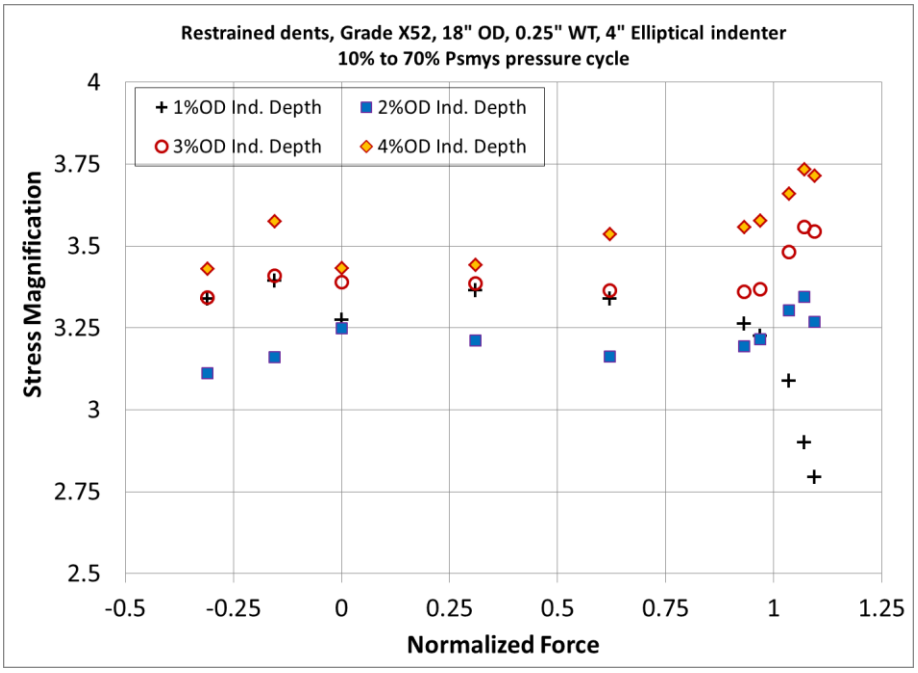


(b)

Figure 1: Stress Magnification of Unrestrained Dents under (a) Axial Force (b) Axial Displacement



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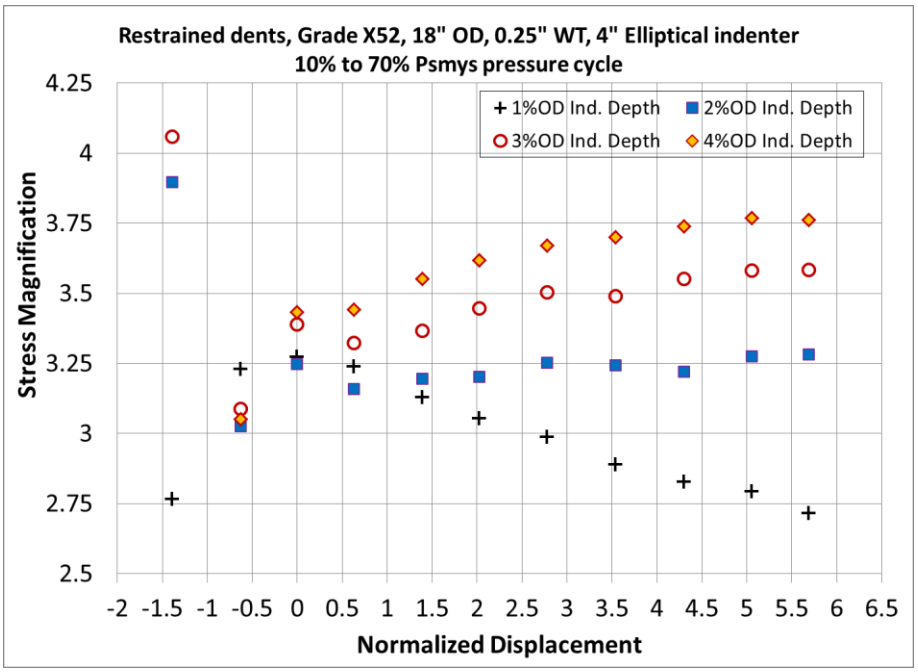
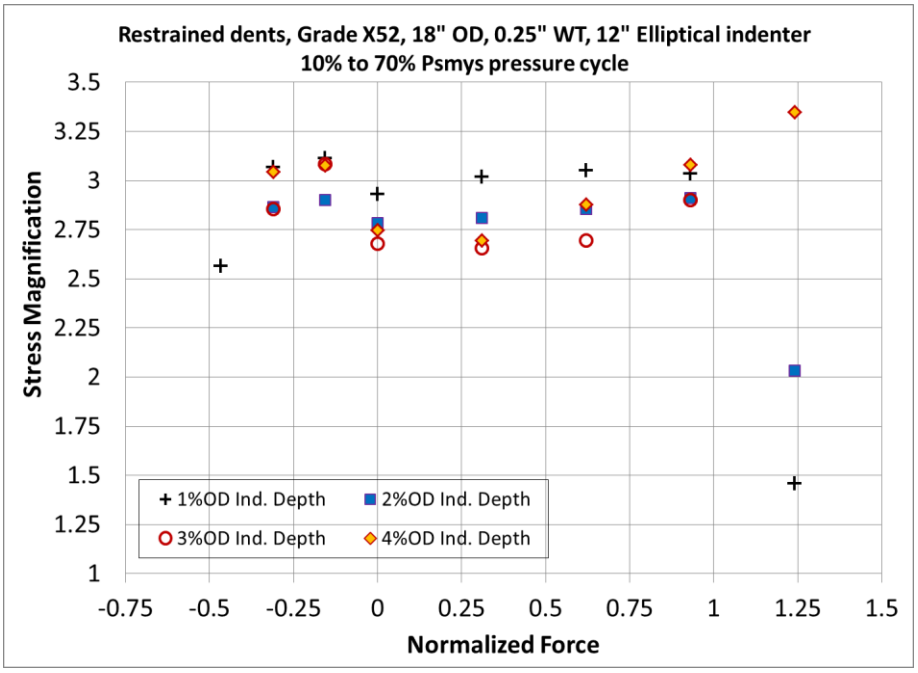


(b)

Figure 2: Stress Magnification of Restrained Dents under (a) Axial Force (b) Axial Displacement



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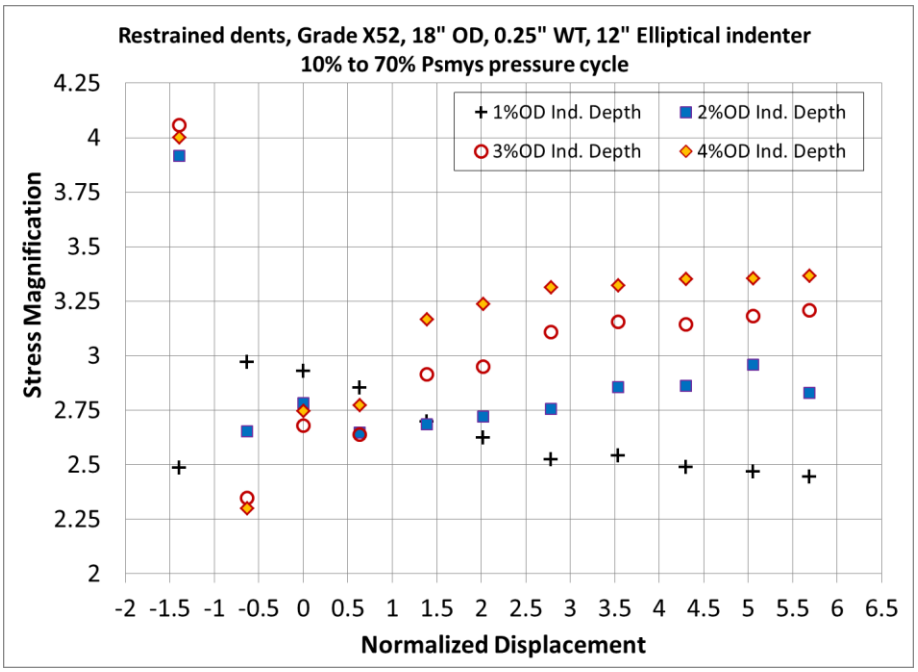
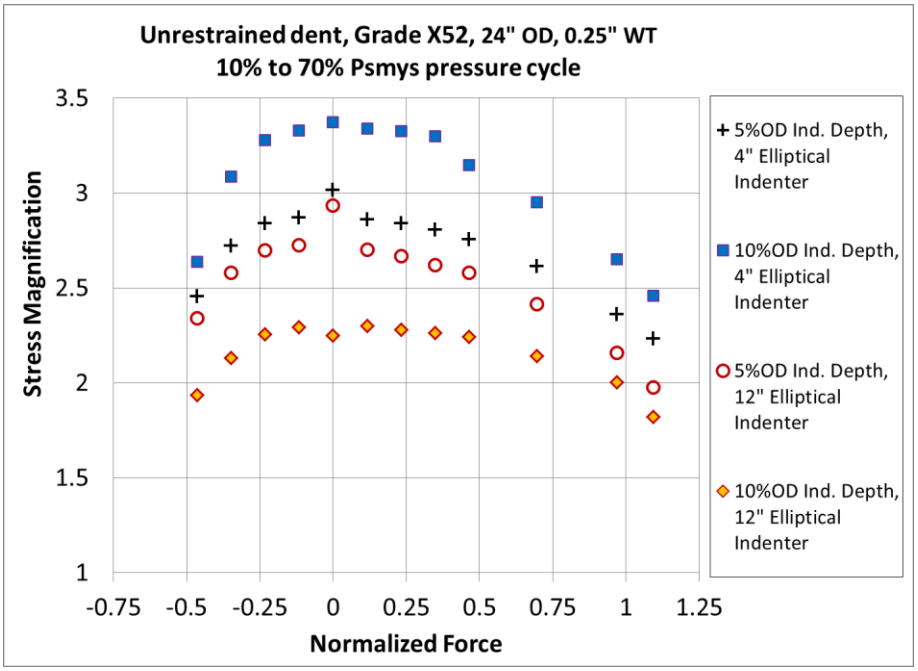


(b)

Figure 3: Stress Magnification of Restrained Dents with 12 in Elliptical Indenter Shape under (a) Axial Force (b) Axial Displacement

H.1.2 Case 2- 24" OD, 0.25" WT, X52 Grade pipe



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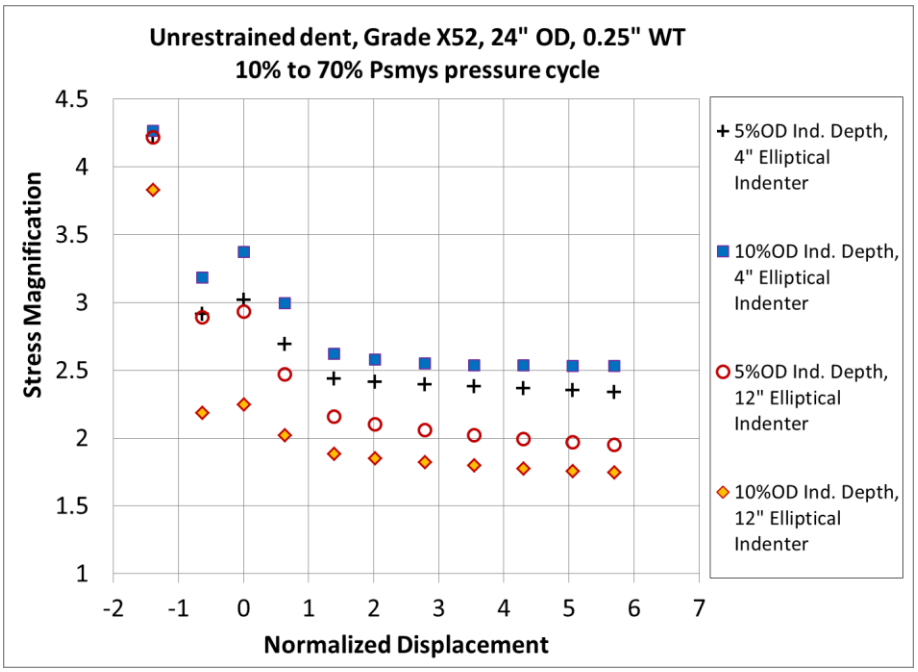

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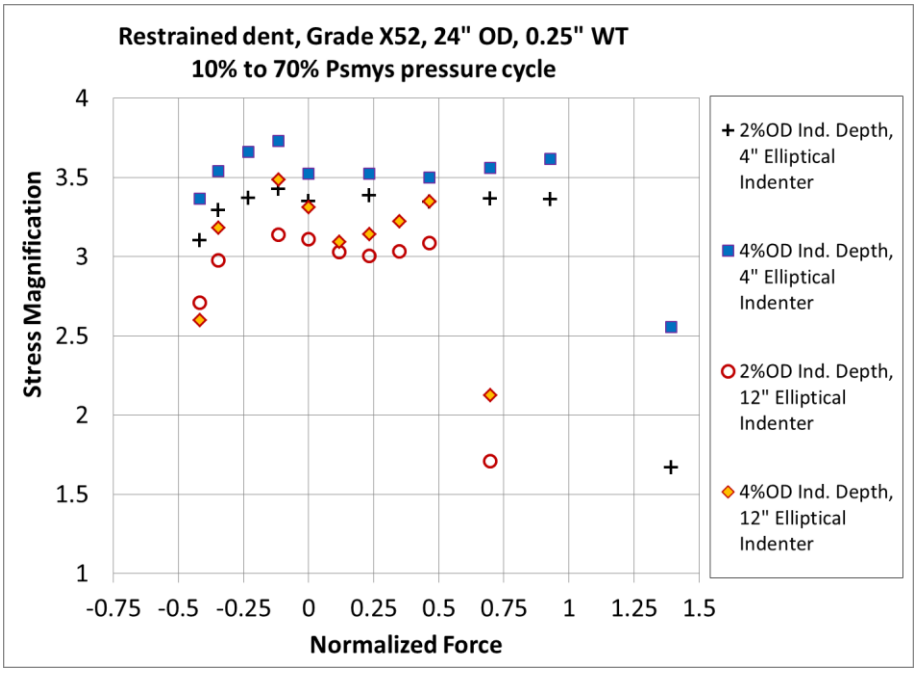
Figure 4: Stress Magnification of Unrestrained Dents in a 24" OD Grade X52 pipe under (a) Axial Force (b) Axial Displacement



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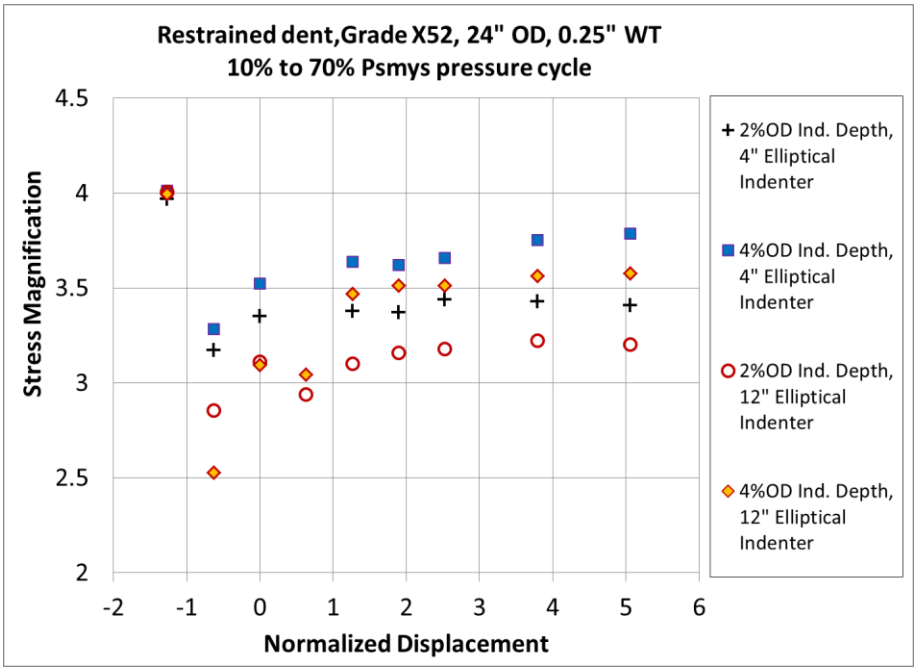
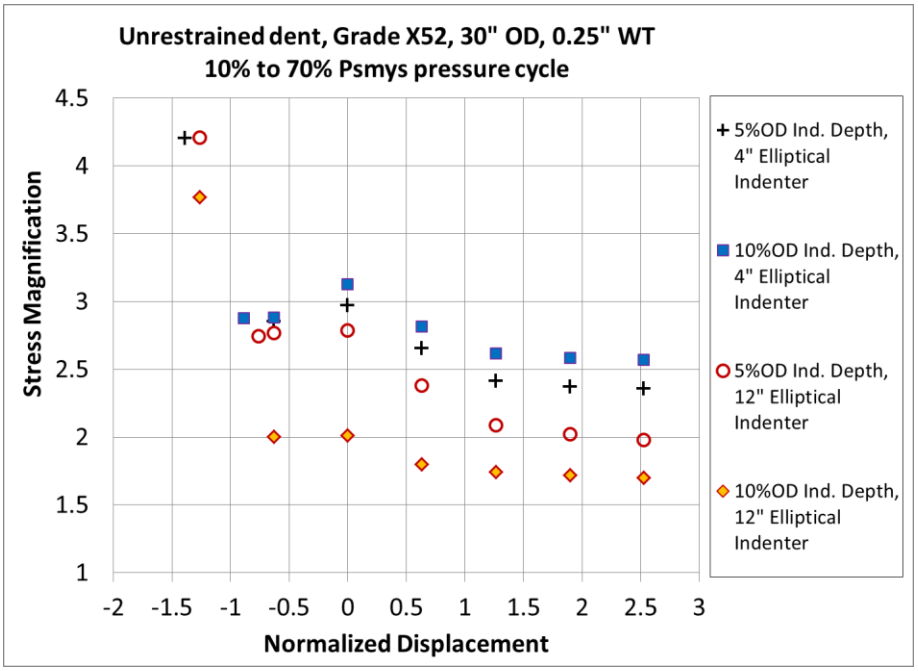


(b)

Figure 5: Stress Magnification of Restrained Dents in an 24" OD Grade X52 pipe under (a) Axial Force (b) Axial Displacement

H.1.3 Case 3- 30" OD, 0.25" WT, X52 Grade pipe



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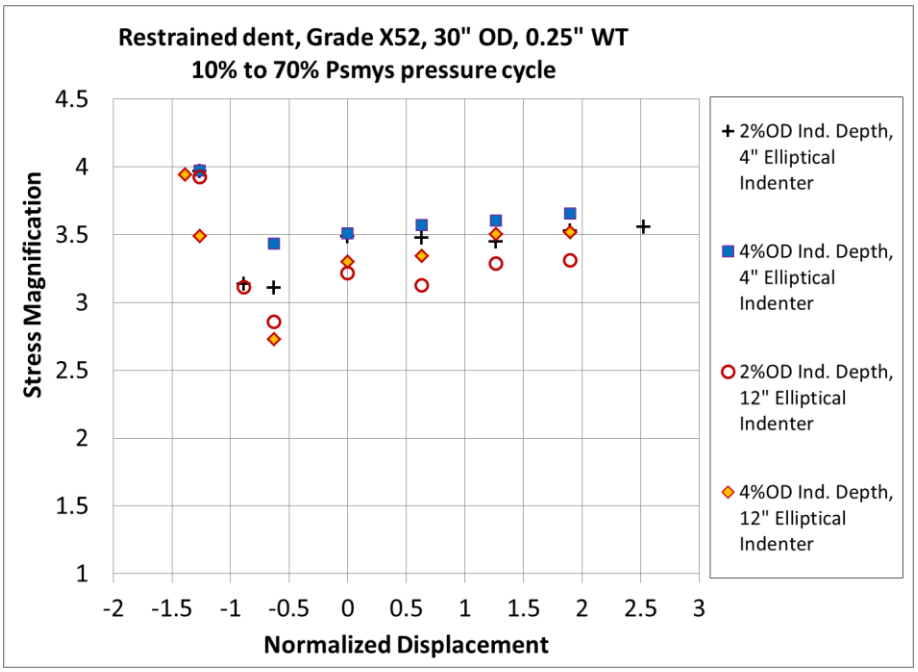
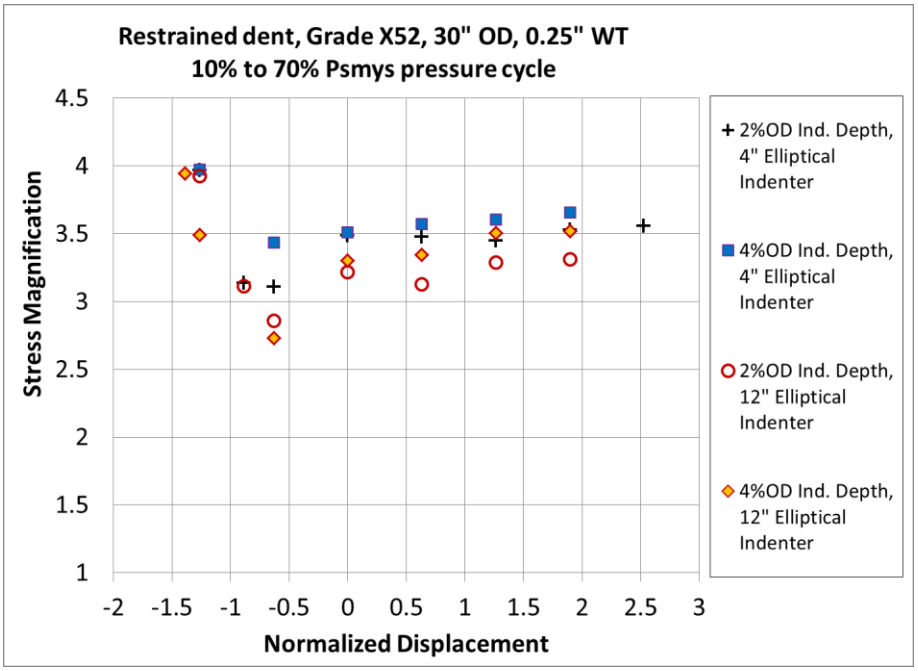


(b)

Figure 6: Stress Magnification of 30" OD Grade X52 pipe under Axial Displacement with (a) Unrestrained Dent (b) Restrained Dent

H.1.4 Case 4- 18" OD, 0.25" WT, X70 Grade pipe



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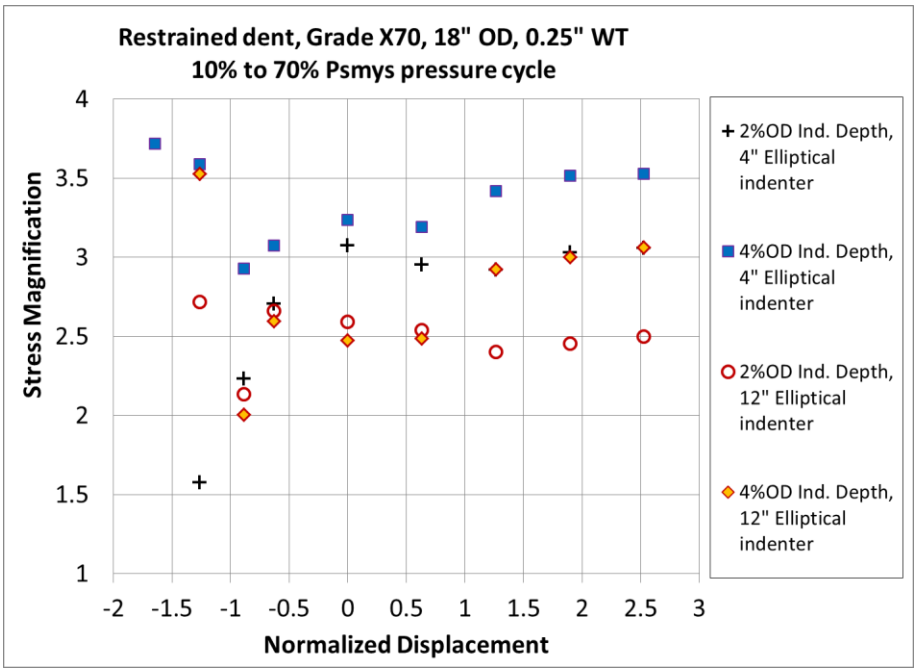
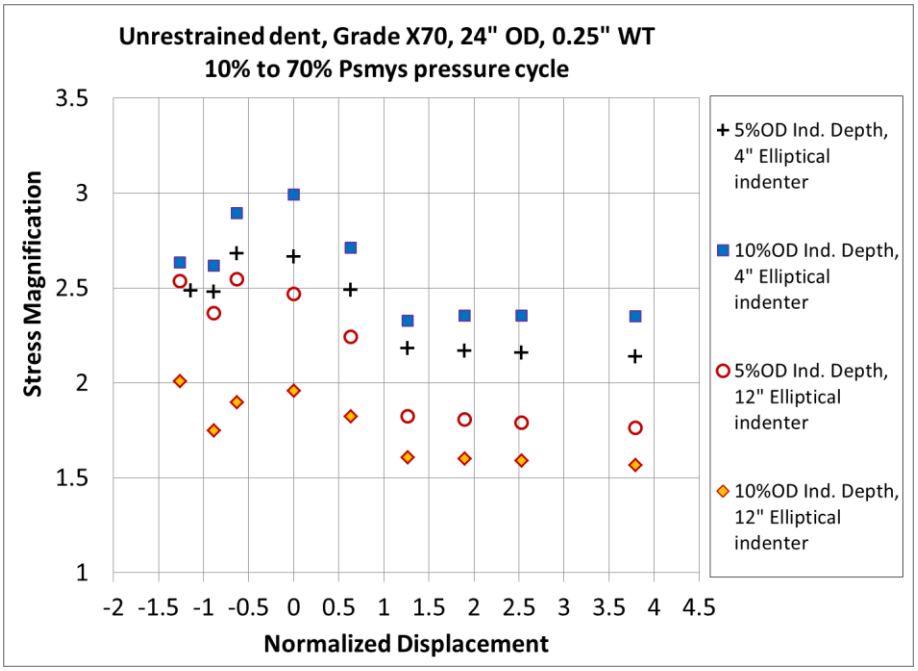


(b)

Figure 7: Stress Magnification of 18" OD Grade X70 pipe under Axial Displacement with (a) Unrestrained Dent (b) Restrained Dent

H.1.5 Case 5- 24" OD, 0.25" WT, X70 Grade pipe



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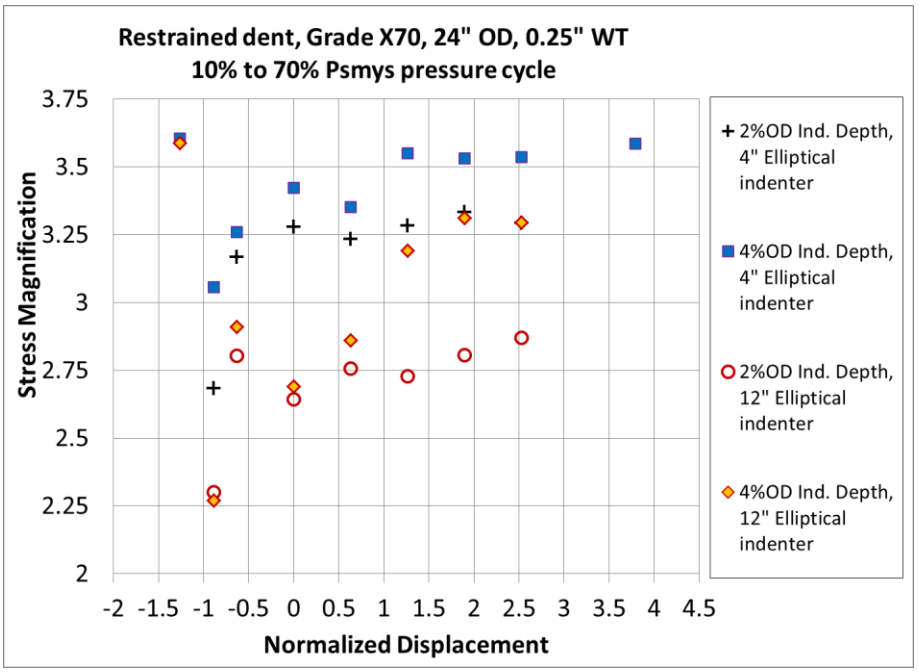
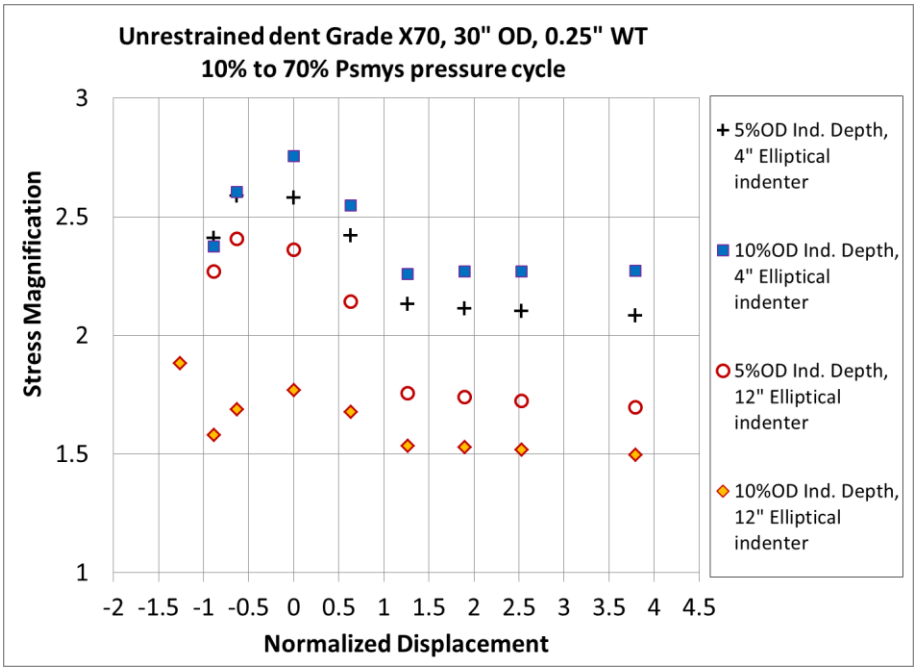


(b)

Figure 8: Stress Magnification of 24" OD Grade X70 pipe under Axial Displacement with (a) Unrestrained Dent (b) Restrained Dent

H.1.6 Case 6- 30" OD, 0.25" WT, X70 Grade pipe



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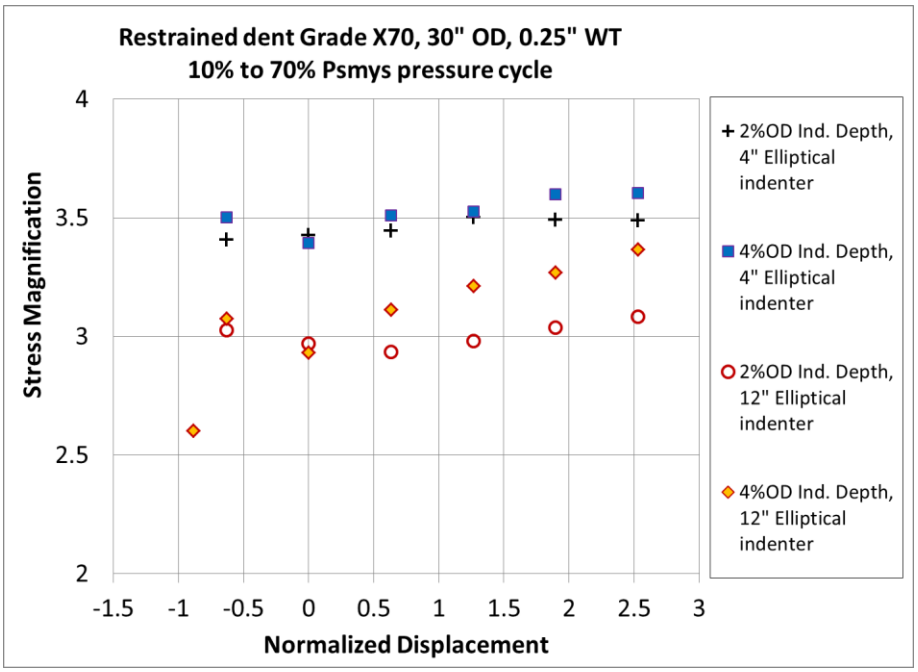
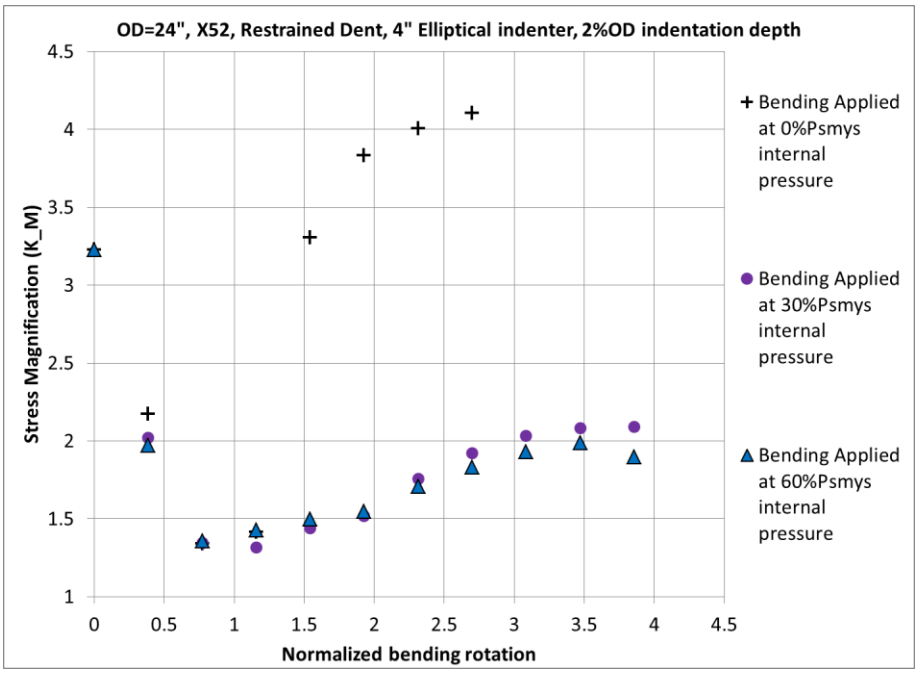


(b)

Figure 9: Stress Magnification of 30" OD Grade X70 pipe under Axial Displacement with (a) Unrestrained Dent (b) Restrained Dent

H.2 Detailed Results of the Effect of Bending Load on dent Stress Magnification Factor



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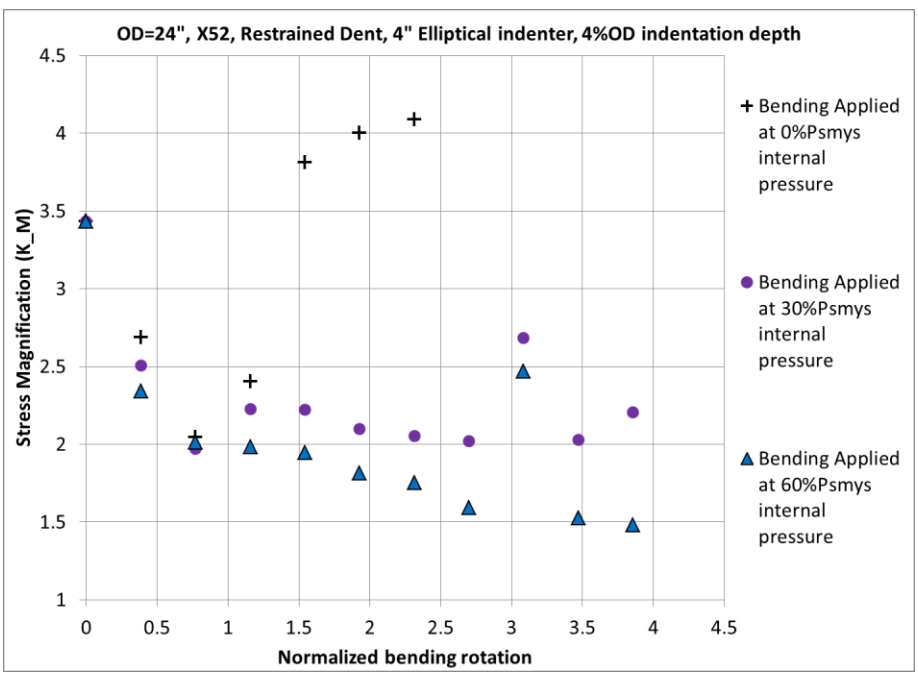
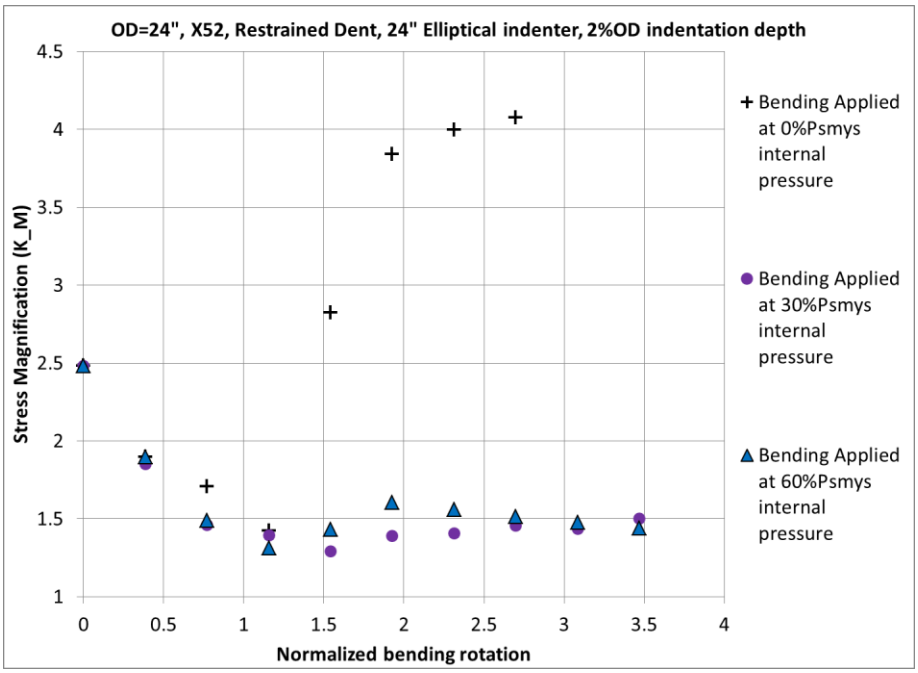


(b)

Figure 10: Stress Magnification Factor under Bending Load with a 4 in Elliptical Indenter Shape and Restrained Dent of depth (a) 2%OD (b) 4%OD



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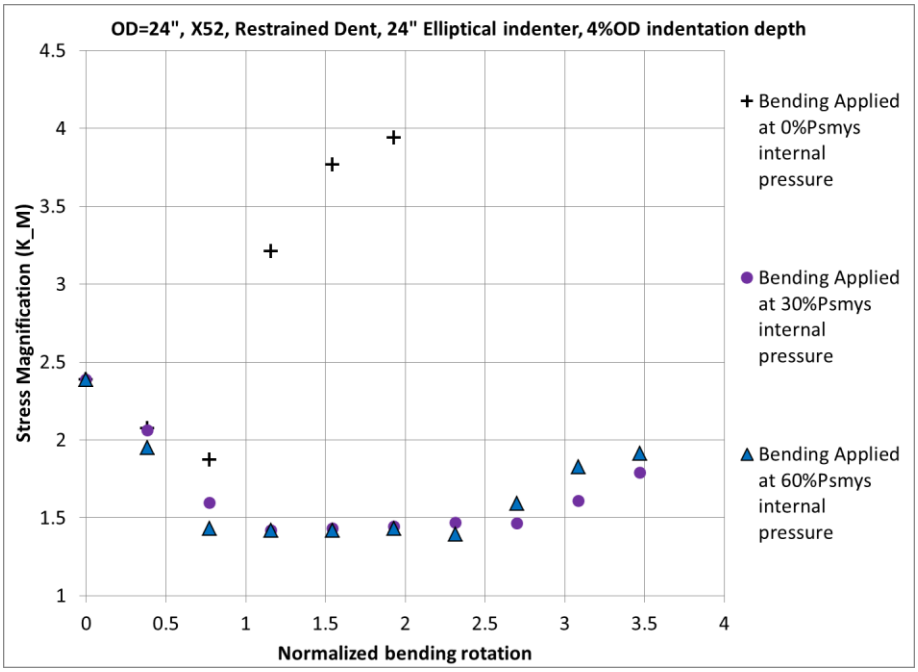
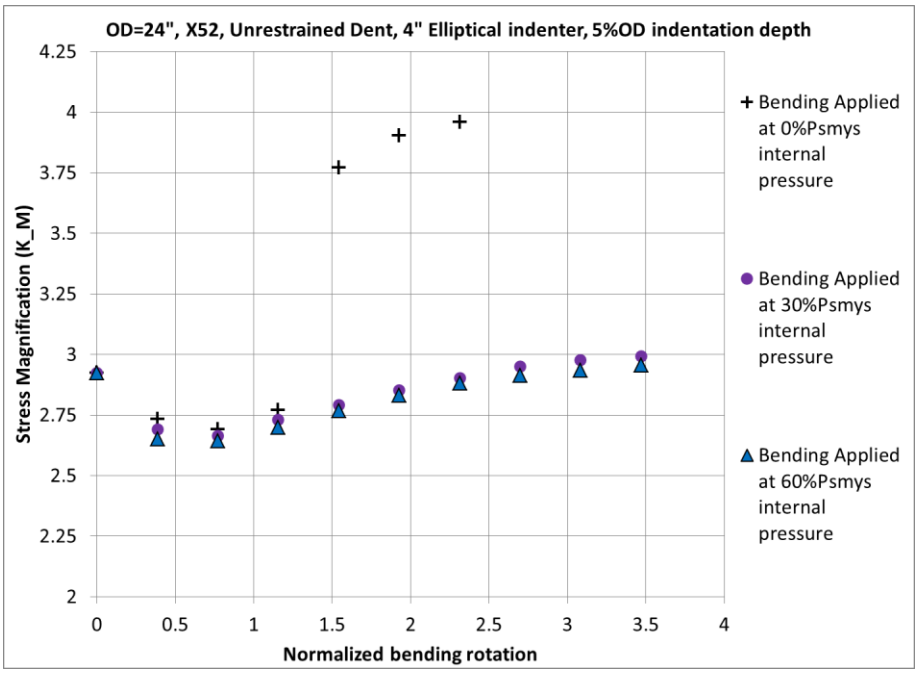


(b)

Figure 11: Stress Magnification Factor under Bending Load with a 4 in Elliptical Indenter Shape and Restrained Dent of depth (a) 2%OD (b) 4%OD



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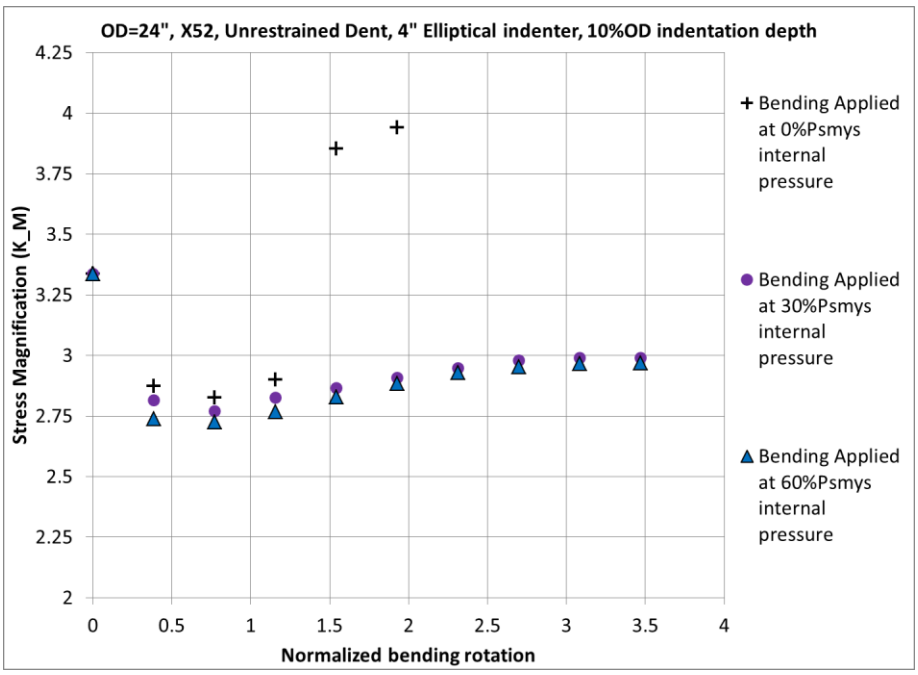
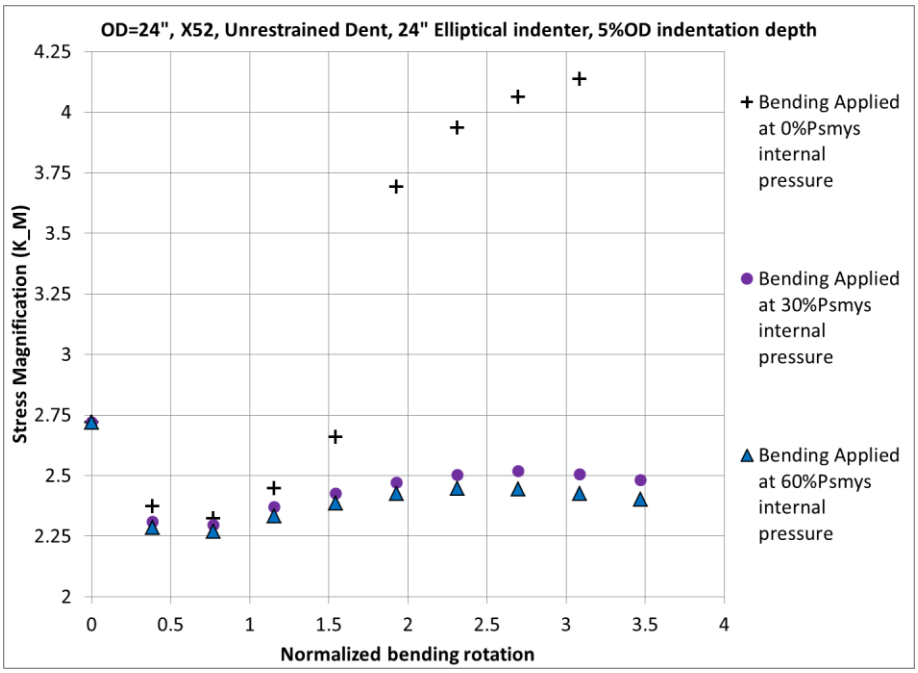


(b)

Figure 12: Stress Magnification Factor under Bending Load with a 4 in elliptical indenter shape and Unrestrained Dent of depth (b) 5%OD (b) 10%OD



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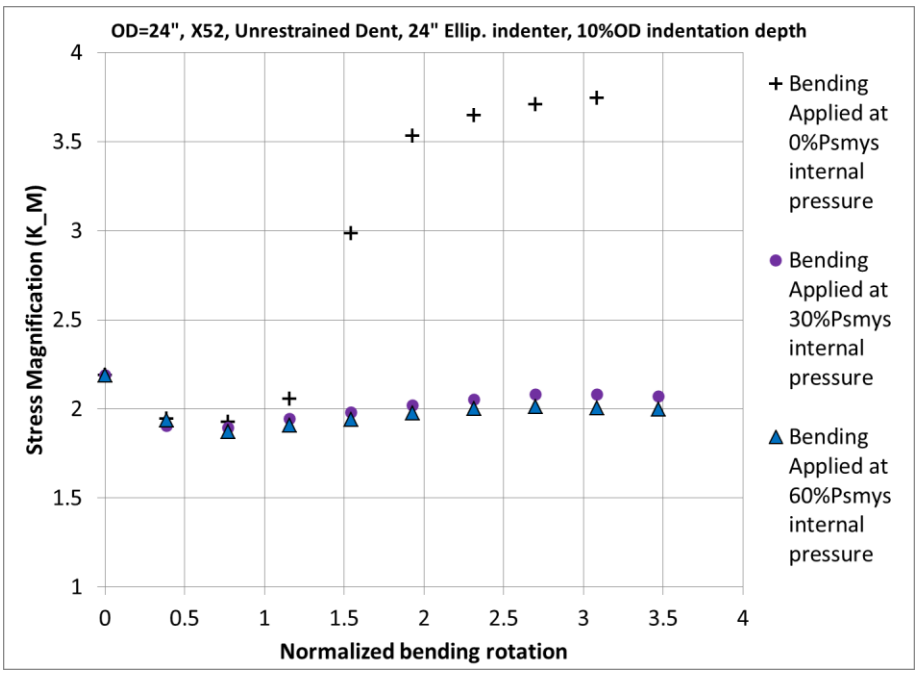

(b)

Figure 13: Stress Magnification Factor under Bending Load with a 24" elliptical indenter shape and Unrestrained Dent of Depth (a) 5%OD and (b) 10%OD

ANNEX I

SCC COLONIES

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1 Material characterization

1.1 Chemical composition

Table 1: Task 6 pipe materials chemical composition

Pipe#	C %	Mn %	Si %	P %	S %	NI %	Cr %	Cu %	Mo %	V %	Al %	Nb %	Ti %	C %
HP20	0.18	1.37	0.27	0.02	0.017	0.04	0.02	0.05	0.01	<0.01	0.03	0.04	<0.01	0.18
R156	0.15	1.3	0.27	0.021	0.015	0.04	0.02	0.07	<0.01	<0.01	0.05	0.02	<0.01	0.15

1.2 Percentage of perlite

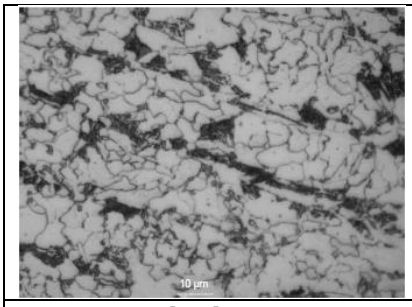
Table 2: Percentage of perlite for pipe R156

	Circumferential orientation	Longitudinal orientation
R156	24% +/- 2.6%	25.6% +/- 2.2%

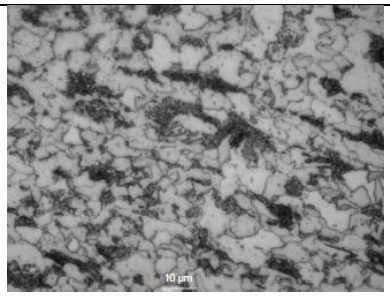
1.3 Grain index

Table 3: Grain index for pipe R156, R157-2 and R157-3

	Circumferential orientation	Longitudinal orientation
R156	11.5	11



Longitudinal orientation



Circumferential orientation

Figure 1: Micro-examination of pipe R156 sample in the longitudinal and circumferential directions (Reagent: NITAL 5%)

1.4 Charpy impact tests

Table 4: Task 6 pipe materials transverse Charpy impact properties

Pipe# TL direction	Test Temperature		Impact Energy	
	(°C)	(°F)	(J) (ft-lb)	($J.cm^{-2}$)
HP20	22	68	14.06	35
R156	27	80.6	10	50

Table 5: Task 6 pipe materials longitudinal Charpy impact properties

Pipe# LT direction	Test Temperature		Impact Energy	
	(°C)	(°F)	(J) (ft-lb)	($J.cm^{-2}$)
HP20	22	68	38.88	97
R156	27	80.6	20	100

1.5 Tensile tests

Table 6: Task 6 pipe materials transverse tensile properties

Pipe# transverse direction	Measured Values					
	0.2% Yield Strength		Ultimate Tensile Strength		Elongation	Area Reduction
	(MPa)	(ksi)	(MPa)	(ksi)	(%)	(%)
HP20	476	69.1	593	86	23.5	44.1
R156	433.7	62.9	581.7	84.4	26.5	41.7

Table 7: Task 6 pipe materials longitudinal tensile properties

Pipe# longitudinal direction	Measured Values					
	0.2% Yield Strength		Ultimate Tensile Strength		Elongation	Area Reduction
	(MPa)	(ksi)	(MPa)	(ksi)	(%)	(%)
HP20	436	63.3	571	82.9	26.2	61.2
R156	435.7	63.2	587.7	85.2	27.2	59.7

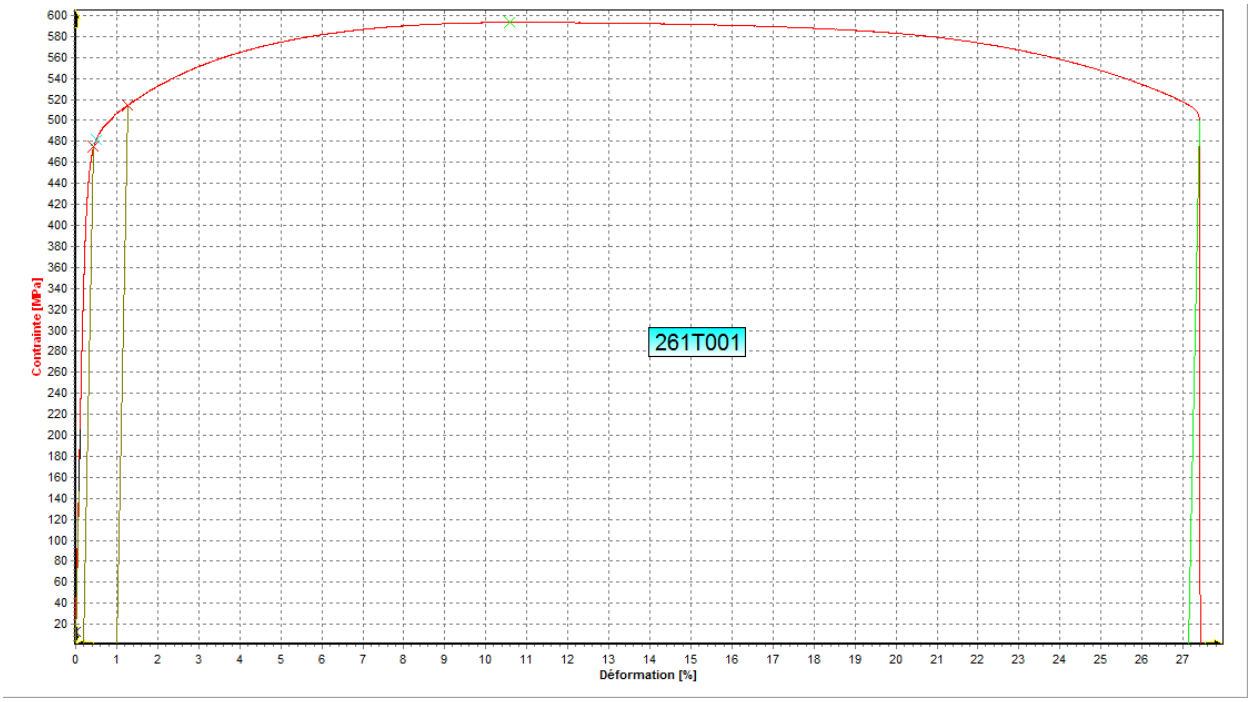


Figure 2: HP20 tensile test in transverse orientation - Stress vs. Strain curve #1

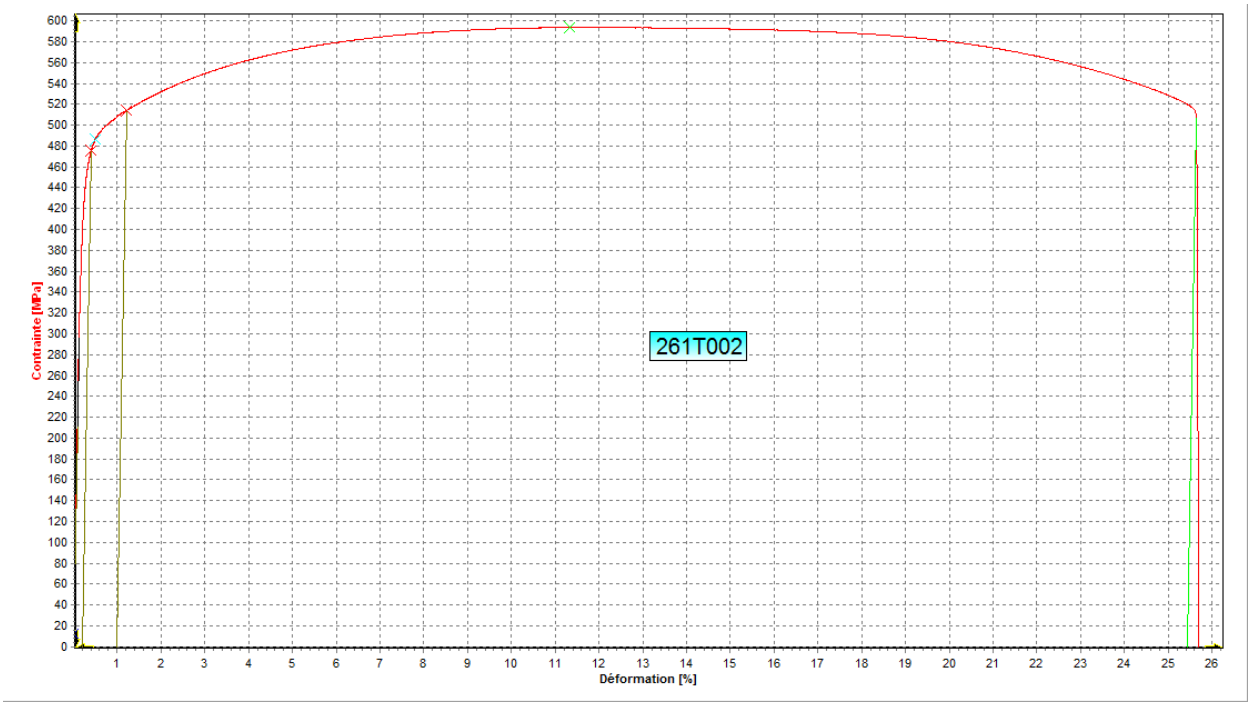


Figure 3: HP20 tensile test in transverse orientation - Stress vs. Strain curve #2

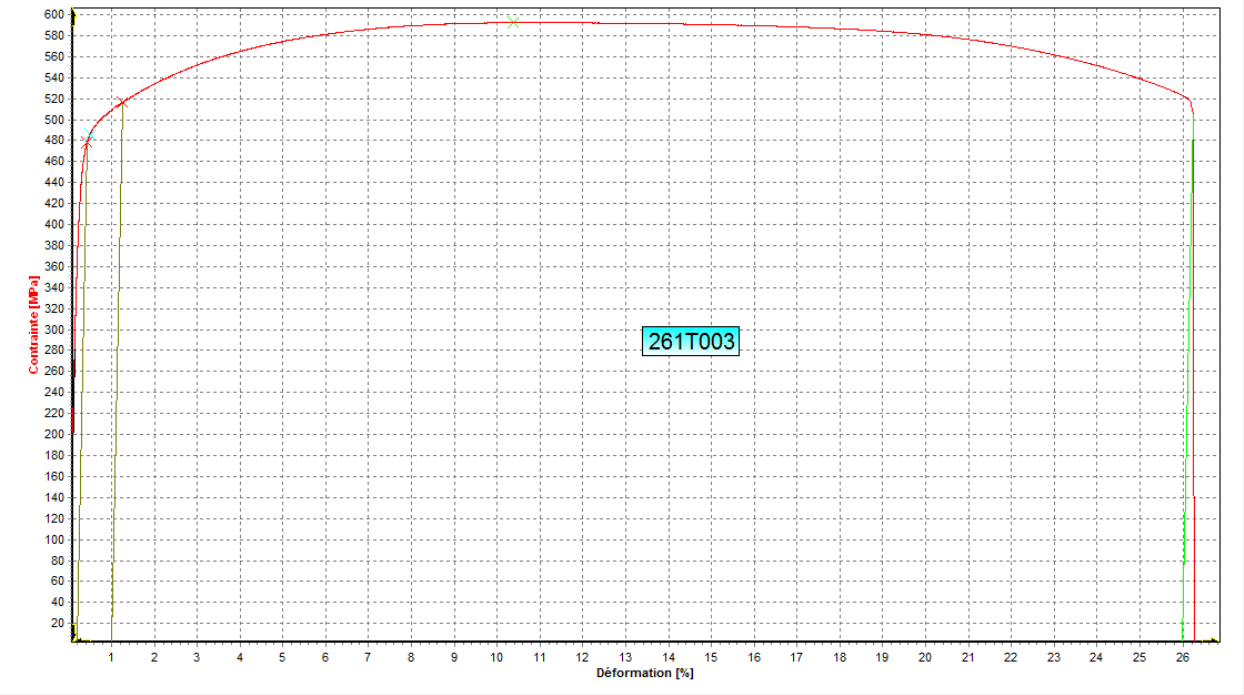


Figure 4: HP20 tensile test in transverse orientation - Stress vs. Strain curve #3

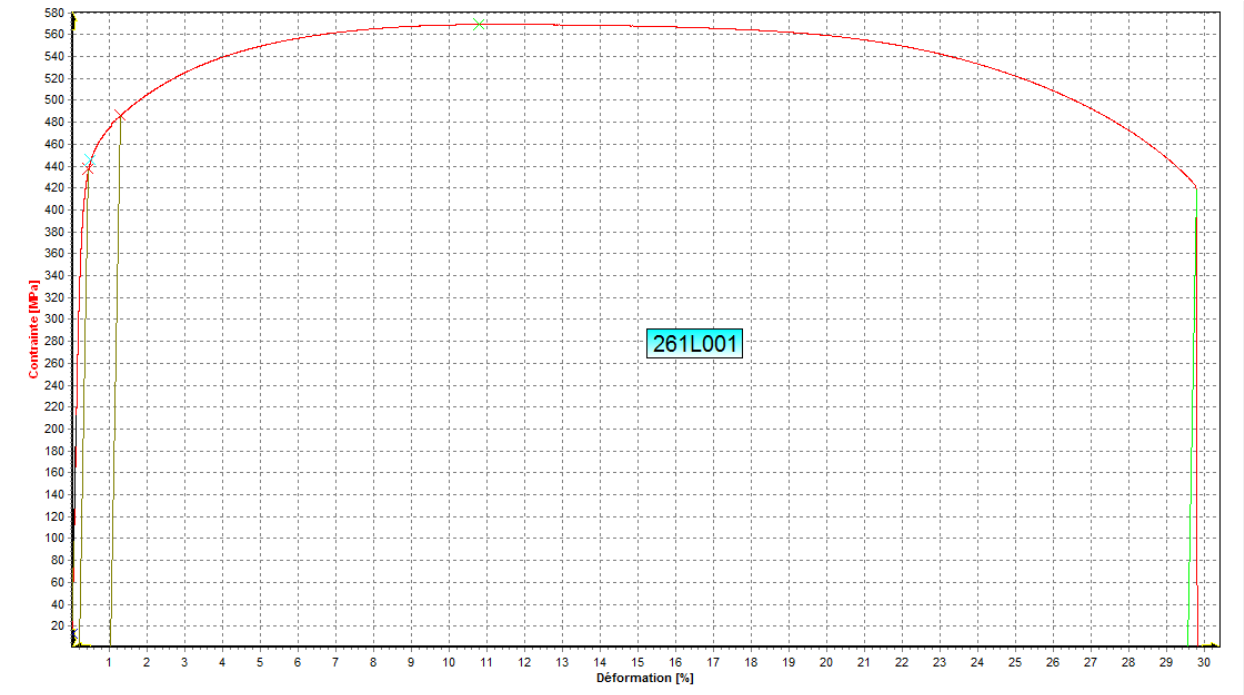


Figure 5: HP20 tensile test in longitudinal orientation - Stress vs. Strain curve #1

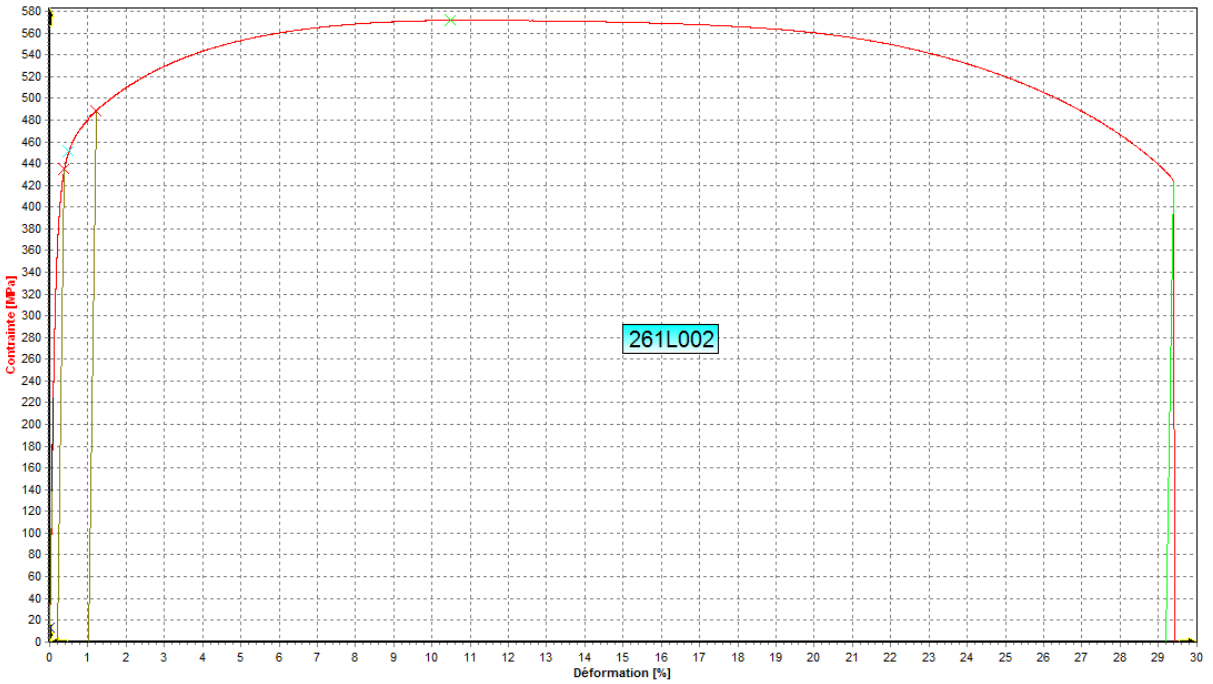


Figure 6: HP20 tensile test in longitudinal orientation - Stress vs. Strain curve #2

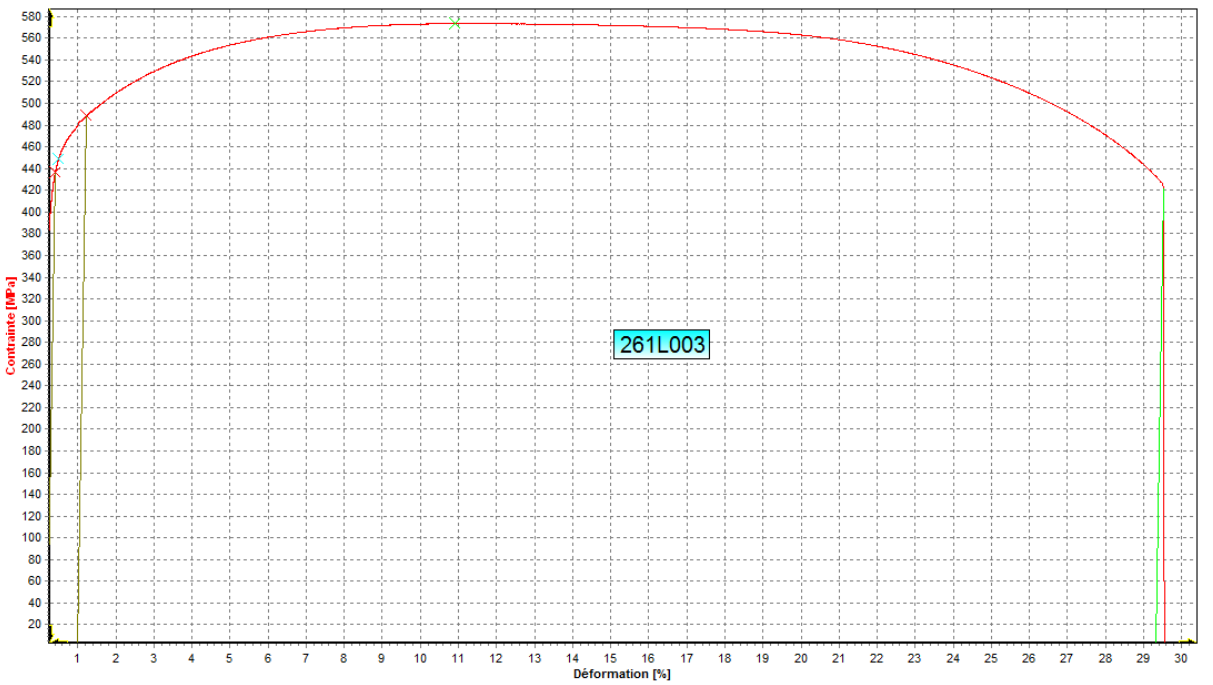


Figure 7: HP20 tensile test in longitudinal orientation - Stress vs. Strain curve #3

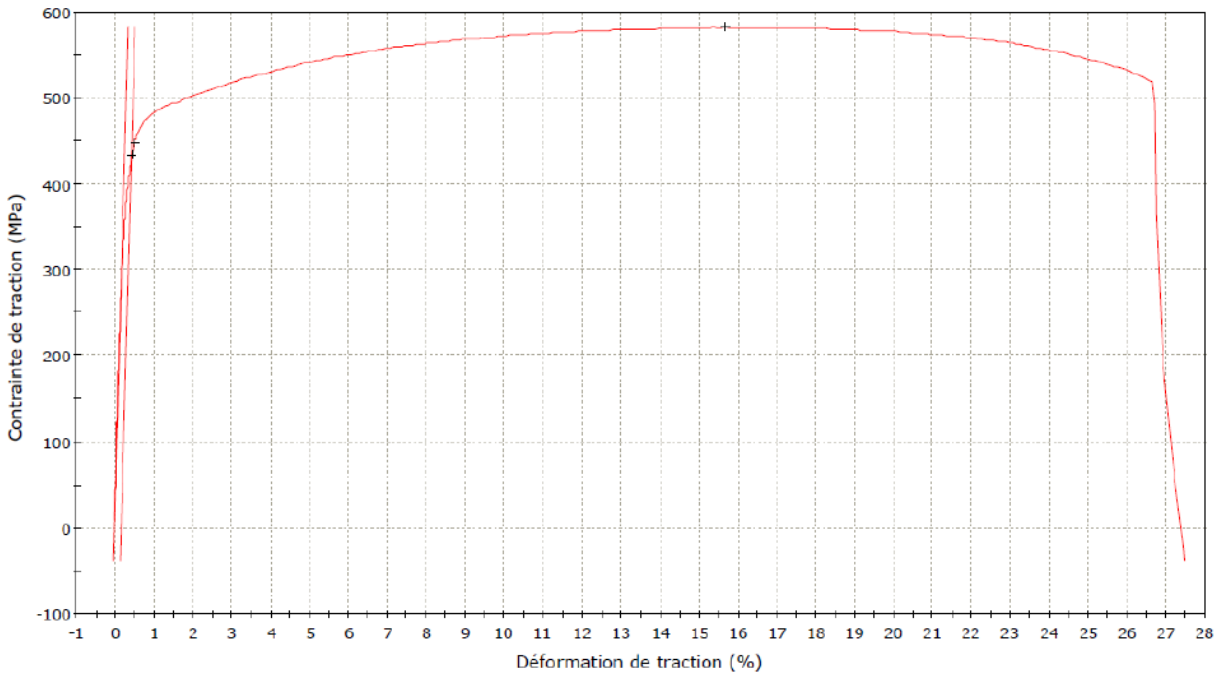


Figure 8: R156 tensile test in transverse orientation - Stress vs. Strain curve #1

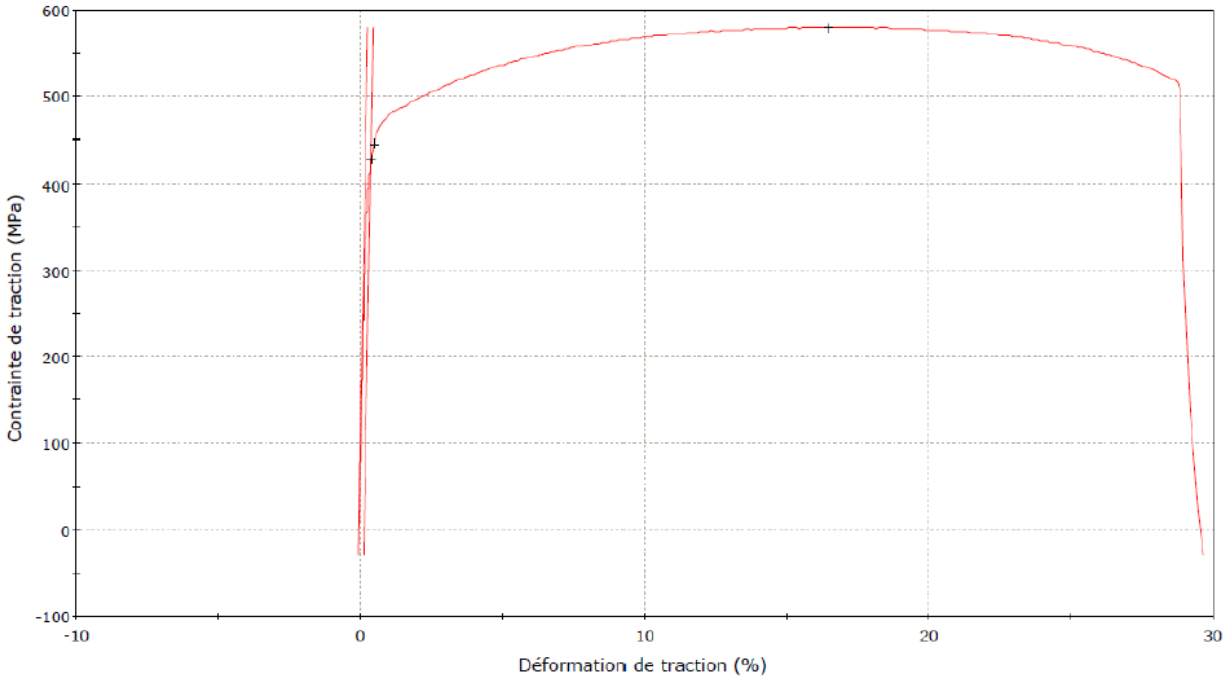


Figure 9: R156 tensile test in transverse orientation - Stress vs. Strain curve #2

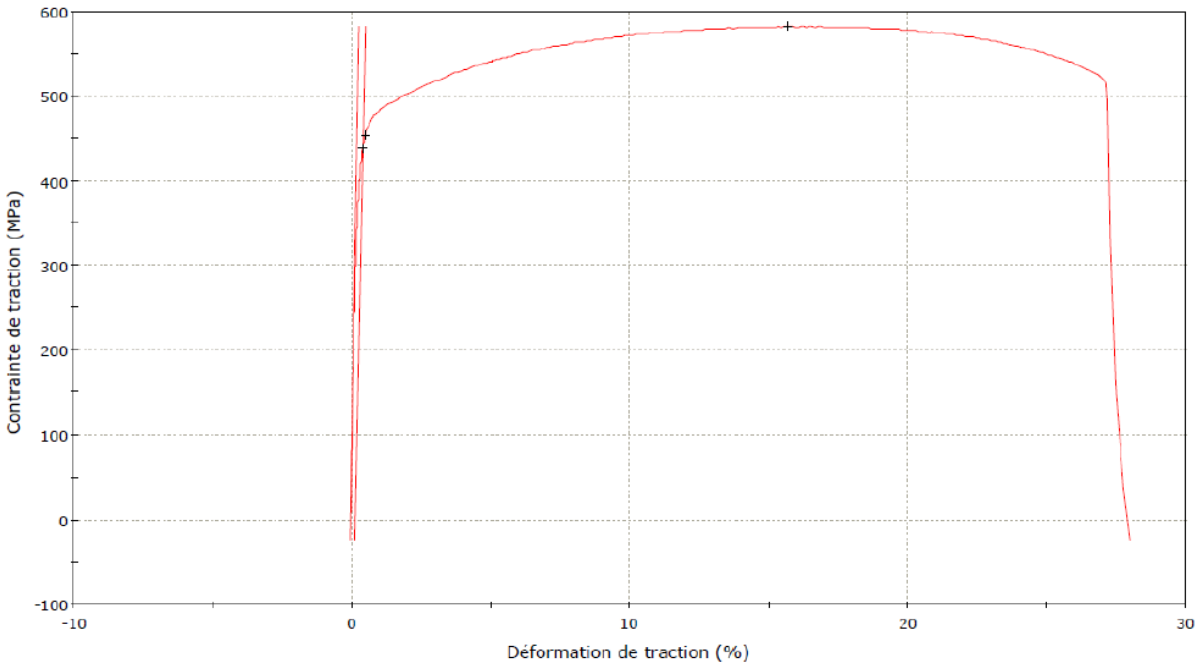


Figure 10: R156 tensile test in transverse orientation - Stress vs. Strain curve #3

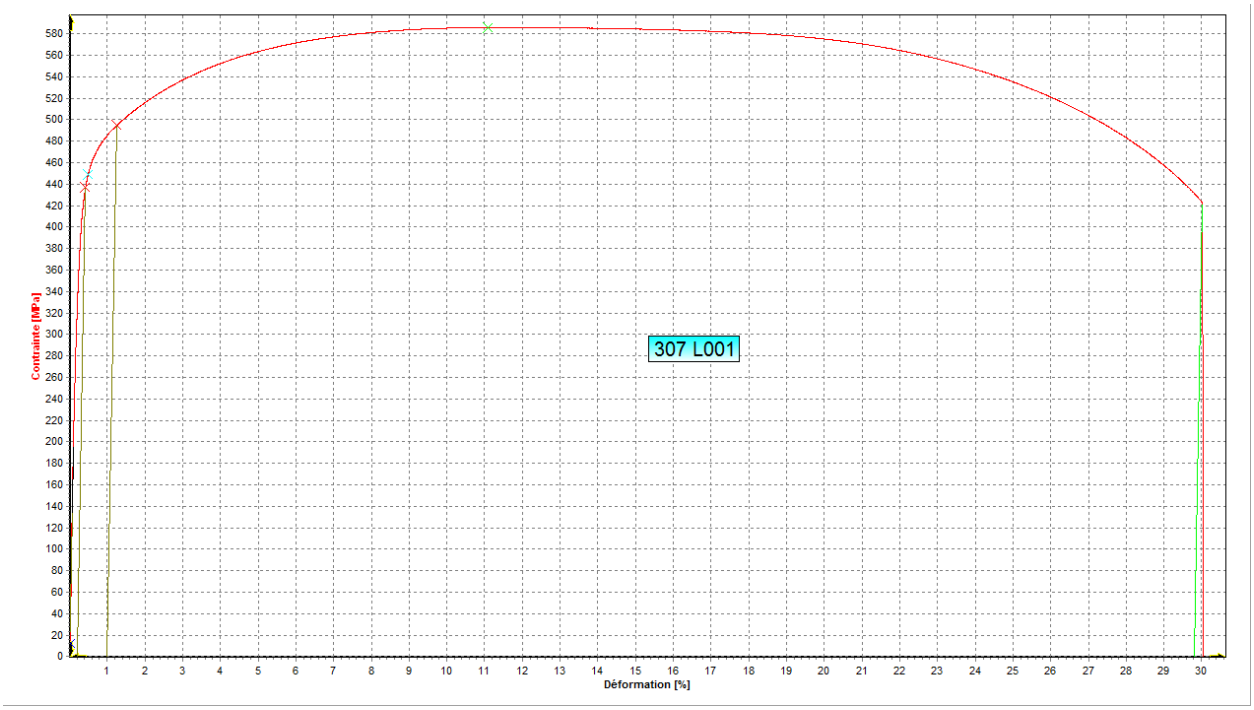


Figure 11: R156 tensile test in longitudinal orientation - Stress vs. Strain curve #1

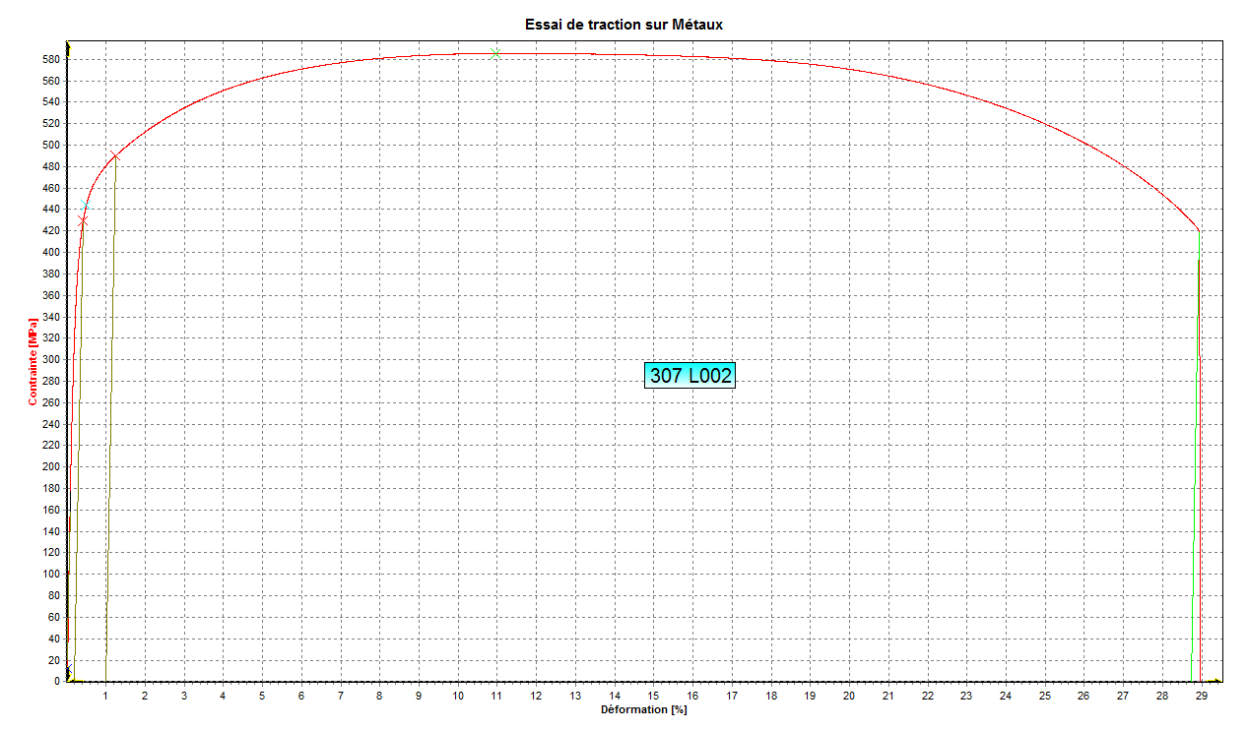


Figure 12: R156 tensile test in longitudinal orientation - Stress vs. Strain curve #2

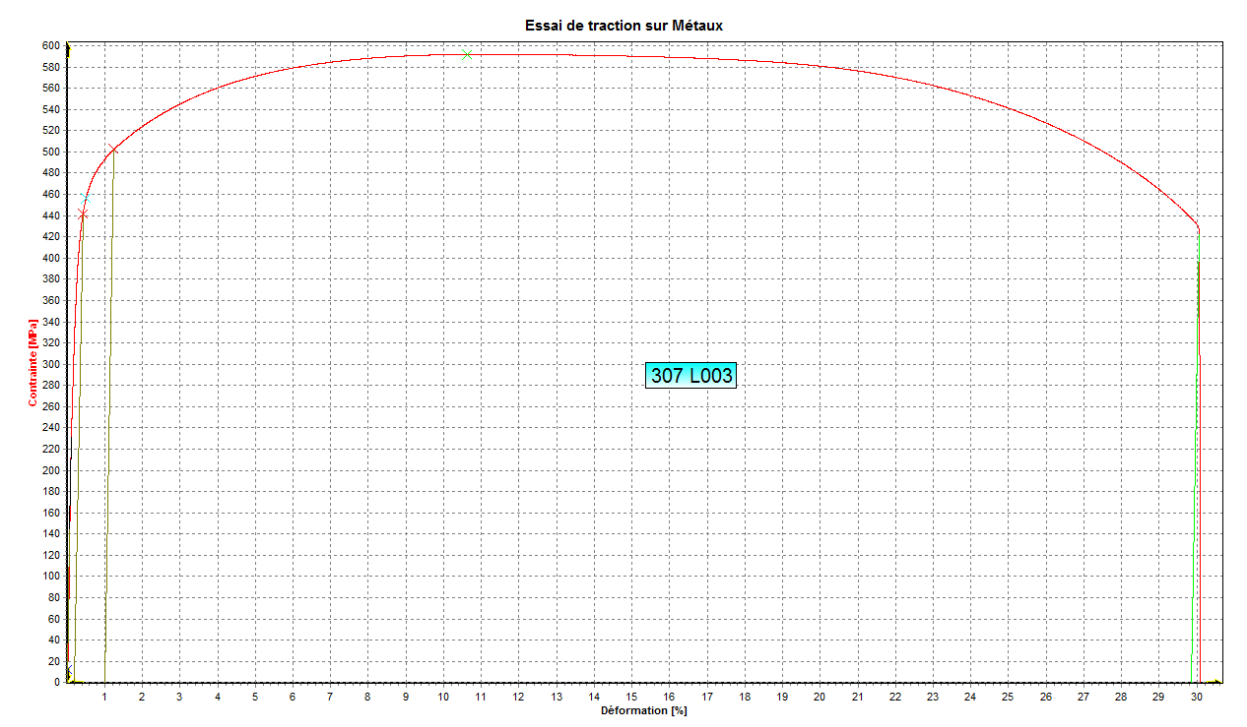


Figure 13: R156 tensile test in longitudinal orientation - Stress vs. Strain curve #3

2 SCC colonies characterization

Table 8: Main characteristics of SCC colonies on pipe SCC-1 according to sizing by MWM FA214 Jentek Sensor.

Colony ID	Colony Max Length (mm)	Max. crack depth (mm)	Max length of the deepest single crack in colony (mm)
B30	217.2	1.1	40
B31	60.6	1.2	7
C9	49.7	1.	31
C8	31.4	1.5	6
N2	26.4	0.8	10
R156-im1	86	1.7	6

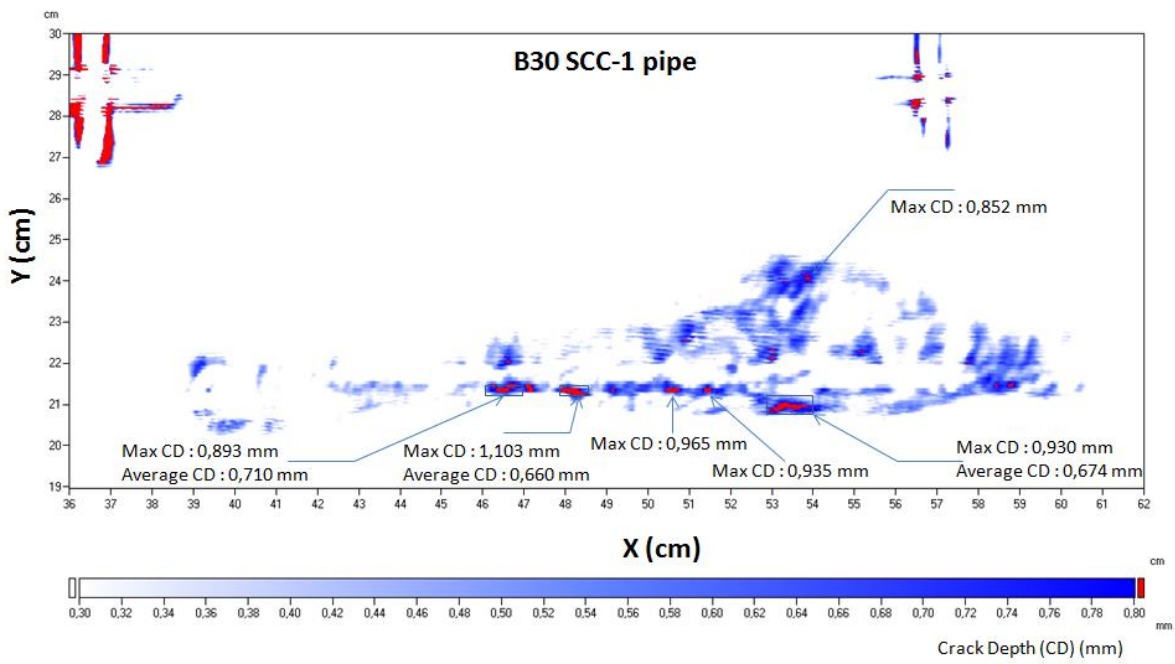


Figure 14: C-SCAN of crack depth in colony B30 as measured by MWM FA214 Jentek Sensor.

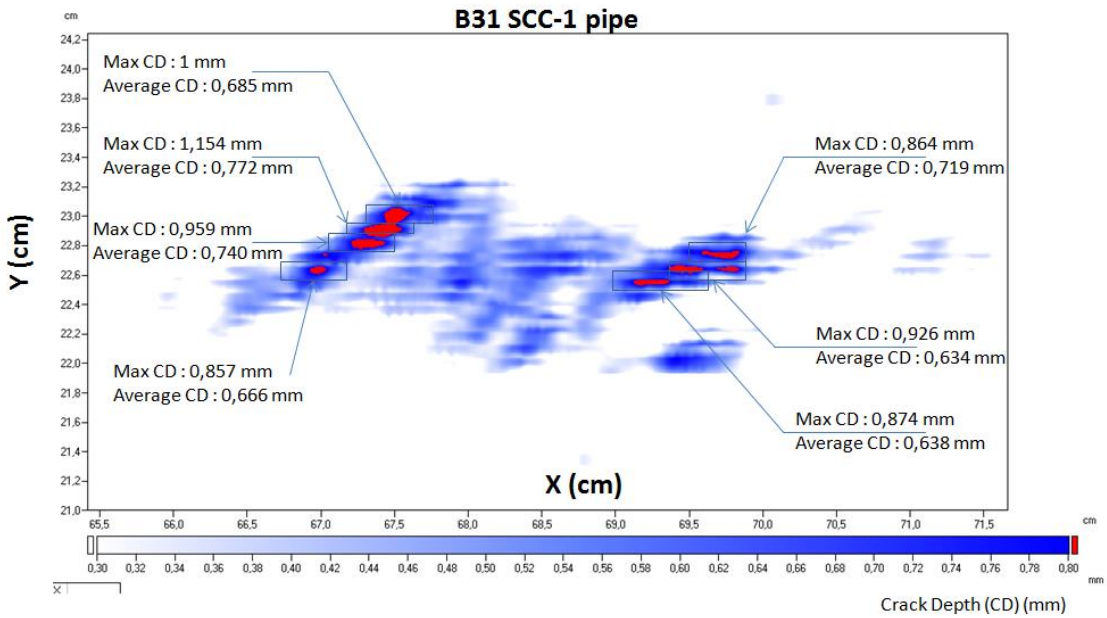


Figure 15: C-SCAN of crack depth in colony B31 as measured by MWM FA214 Jentek Sensor.

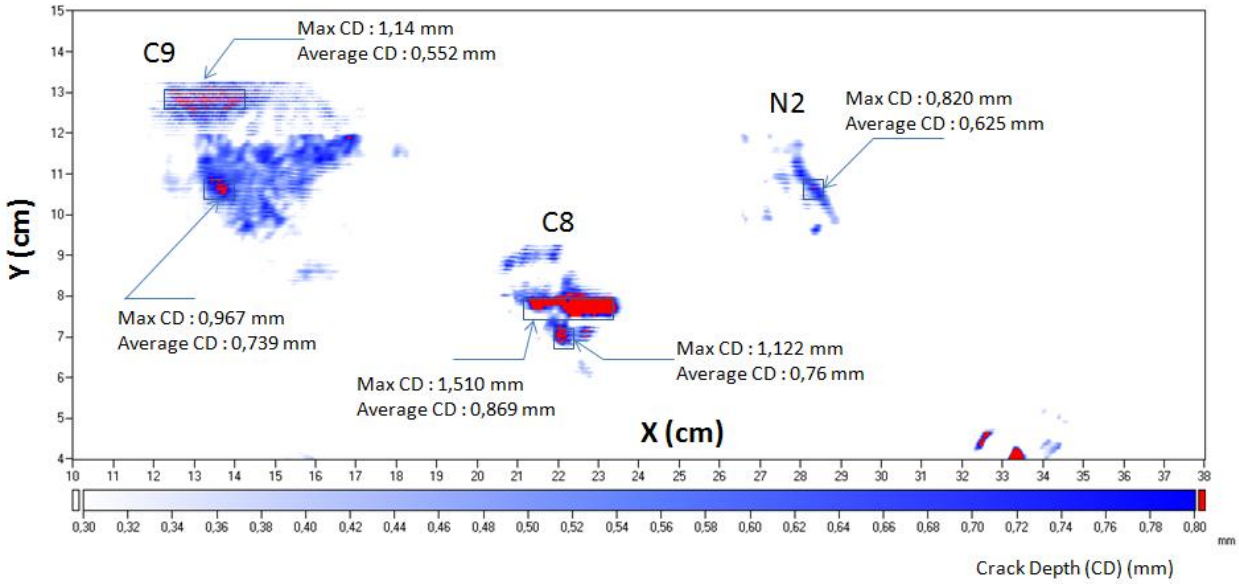


Figure 16: C-SCAN of crack depths in colonies C9-C8-N2 as measured with MWM FA214 Jentek Sensor.

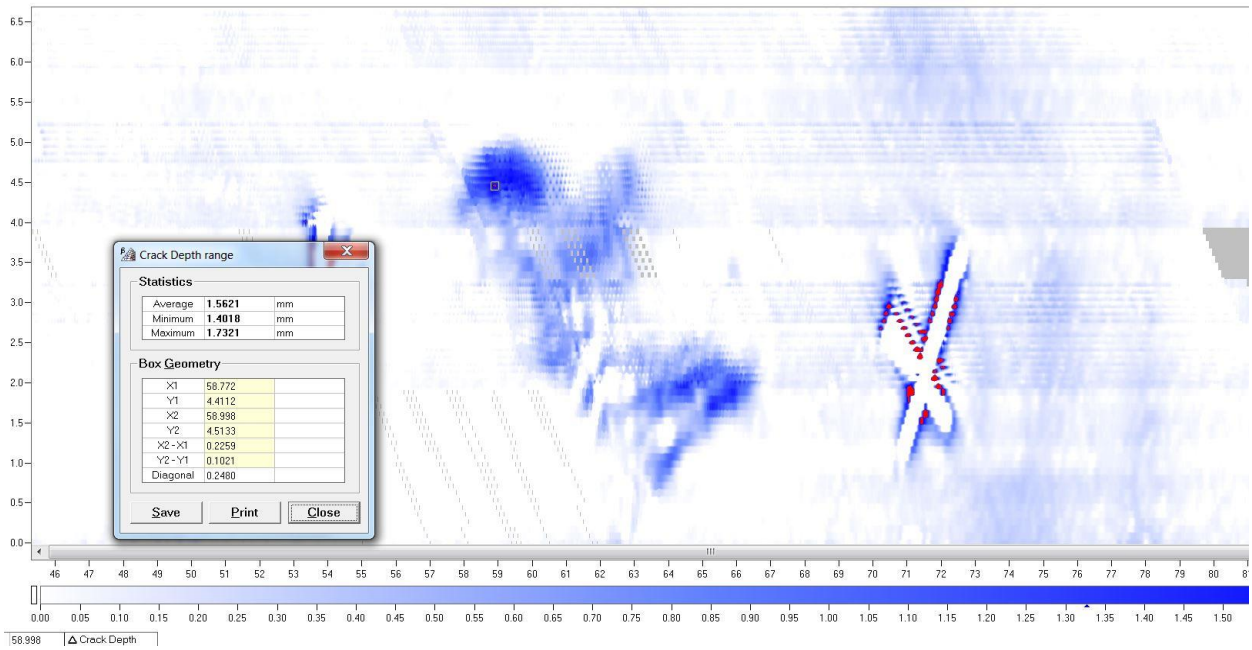


Figure 17: C-SCAN of crack depths in R156-im1 colony as measured with MWM FA214 Jentek Sensor.

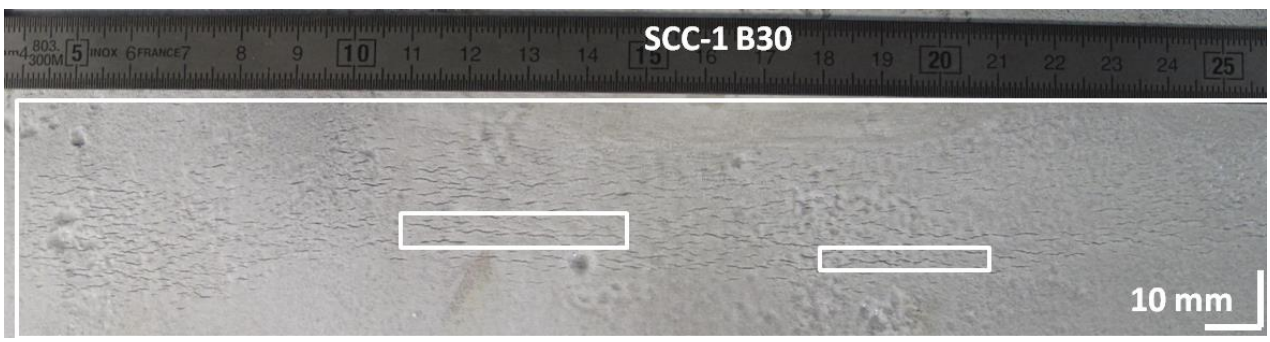


Figure 18: View of defect B30 after Magnetic Particle Inspection in which the location of the deepest cracks according to sizing with MWM FA214 Jentek Sensor is highlighted.

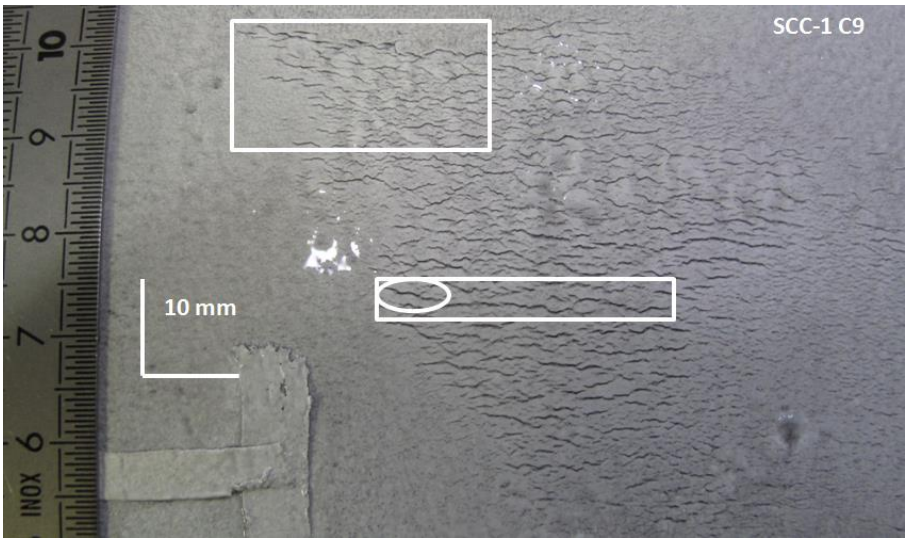


Figure 19: View of the defect C9 after Magnetic Particle Inspection in which the location of the deepest cracks according to sizing with MWM FA214 Jentek Sensor is highlighted.

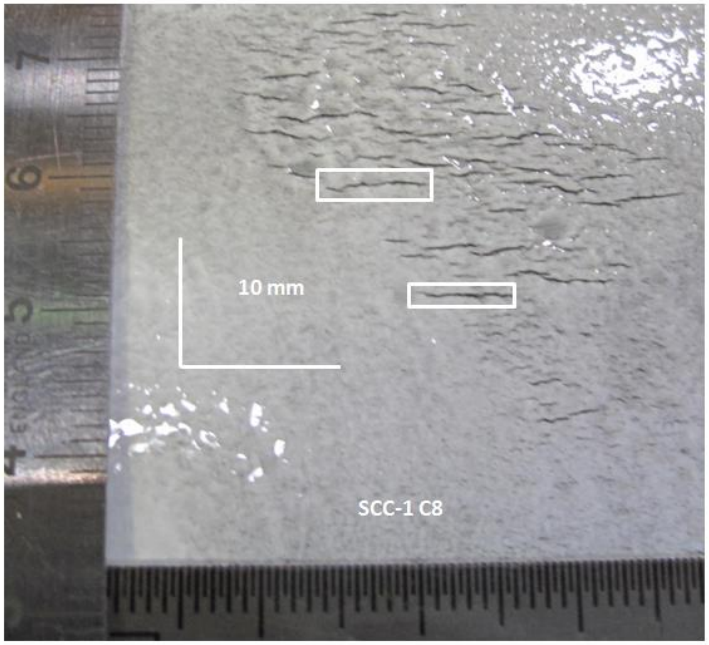


Figure 20: View of the defect C8 after Magnetic Particle Inspection in which the location of the deepest cracks according to sizing with MWM FA214 Jentek Sensor is highlighted.

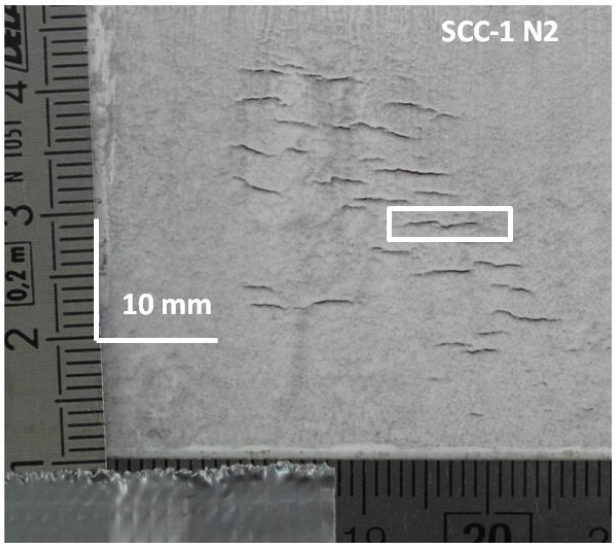


Figure 21: View of the defect N2 after Magnetic Particle Inspection in which the location of the deepest cracks according to sizing with MWM FA214 Jentek Sensor is highlighted.

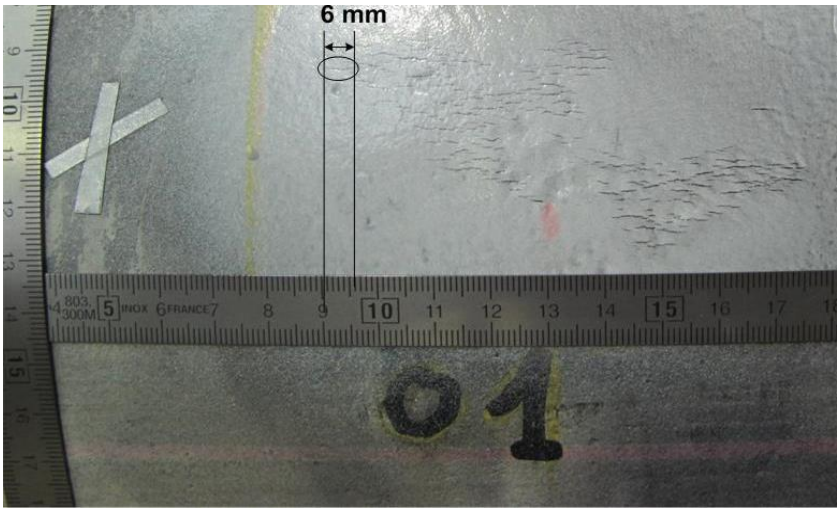


Figure 22: View of the defect R156-im1 after Magnetic Particle Inspection in which the location of the deepest cracks according to sizing with MWM FA214 Jentek Sensor is highlighted.

3 Machined notch sizes

Table 9: Real notch sizes on pipe SCC1a

	Expected notch sizes			Real notch sizes		
Reference	Length (mm)	depth (mm)	width (mm)	Length (mm)	depth (mm)	width (mm)
SCC-1a-10-13	10	1.3	0.2	10.02	1.28	0.18
SCC-1a-10-15	10	1.5	0.2	10.02	1.5	0.2
SCC-1a-11-13	11	1.3	0.2	10.97	1.29	0.19
SCC-1a-12-13	12	1.3	0.2	12.02	1.31	0.2
SCC-1a-5-15	5	1.5	0.2	5.01	1.47	0.19
SCC-1a-5-20	5	2	0.2	5.02	2.04	0.21
SCC-1a-6-15	6	1.5	0.2	6.04	1.48	0.21
SCC-1a-6-17	6	1.7	0.2	6.02	1.7	0.2
SCC-1a-7-15	7	1.5	0.2	7.01	1.53	0.2
SCC-1a-7-17	7	1.7	0.2	7.04	1.72	0.21
SCC-1a-8-15	8	1.5	0.2	8.02	1.51	0.21
SCC-1a-8-17	8	1.7	0.2	8.05	1.69	0.22
SCC-1a-9-15	9	1.5	0.2	9.02	1.52	0.21
SCC-1a-9-17	9	1.7	0.2	9.02	1.72	0.21

Table 10: Real notch sizes on pipe SCC1b

	Expected notch sizes			Real notch sizes		
Reference	Length (mm)	depth (mm)	width (mm)	Length (mm)	depth (mm)	width (mm)
SCC-1b-11-15	11	1.5	0.2	11.009	1.508	0.193
SCC-1b-12-15	12	1.5	0.2	12.049	1.56	0.177
SCC-1b-13-13a	13	1.3	0.2	13.021	1.328	0.202
SCC-1b-13-13b	13	1.3	0.2	13.017	1.28	0.188
SCC-1b-13-13bis	13	1.3	0.2	13.02	1.23	0.193
SCC-1b-13-15a	13	1.5	0.2	13.029	1.529	0.197
SCC-1b-13-15b	13	1.5	0.2	13.027	1.464	0.184
SCC-1b-13-15bis	13	1.5	0.2	13.015	1.534	0.197
SCC-1b-14-13	14	1.3	0.2	13.995	1.253	0.197
SCC-1b-14-13bis	14	1.3	0.2	13.99	1.288	0.197
SCC-1b-15-12	15	1.2	0.2	15.019	1.205	0.206
SCC-1b-16-12a	16	1.2	0.2	16.029	1.218	0.215
SCC-1b-16-12b	16	1.2	0.2	16.018	1.245	0.21
SCC-1b-17-12	17	1.2	0.2	17.024	1.157	0.193
SCC-1b-18-12	18	1.2	0.2	18.042	1.144	0.197
SCC-1b-19-12a	19	1.2	0.2	19.037	1.236	0.206
SCC-1b-19-12b	19	1.2	0.2	19.025	1.223	0.192
SCC-1b-20-12	20	1.2	0.2	19.863	1.16	0.215
SCC-1b-21-12	21	1.2	0.2	21.037	1.16	0.18
SCC-1b-22-12a	22	1.2	0.2	21.966	1.196	0.21
SCC-1b-22-12b	22	1.2	0.2	21.95	1.122	0.219

Table 11: Real notch sizes on pipe SCC1c

	Expected notch sizes			Real notch sizes		
Reference	Length (mm)	depth (mm)	width (mm)	Length (mm)	depth (mm)	width (mm)
SCC-1c-14-15	14	1.5	0.2	14.007	1.499	0.21
SCC-1c-14-15bis	14	1.5	0.2	13.966	1.477	0.193
SCC-1c-15-15	15	1.5	0.2	14.978	1.49	0.206
SCC-1c-16-15a	16	1.5	0.2	16.032	1.516	0.201
SCC-1c-16-15b	16	1.5	0.2	16.029	1.455	0.202
SCC-1c-17-15	17	1.5	0.2	16.977	1.49	0.21
SCC-1c-18-15	18	1.5	0.2	18.009	1.416	0.21
SCC-1c-19-15a	19	1.5	0.2	19.027	1.424	0.188
SCC-1c-19-15b	19	1.5	0.2	19.017	1.486	0.193
SCC-1c-20-13	20	1.3	0.2	19.987	1.284	0.21
SCC-1c-21-13	21	1.3	0.2	21.995	1.332	0.206
SCC-1c-22-13a	22	1.3	0.2	21.98	1.236	0.2
SCC-1c-22-13b	22	1.3	0.2	21.982	1.249	0.215
SCC-1c-23-12	23	1.2	0.2	22.98	1.214	0.197
SCC-1c-23-13	23	1.3	0.2	23.004	1.223	0.193
SCC-1c-24-12	24	1.2	0.2	23.98	1.118	0.201
SCC-1c-24-12bis	24	1.2	0.2	23.94	1.188	0.188
SCC-1c-24-13	24	1.3	0.2	23.954	1.245	0.199
SCC-1c-24-13bis	24	1.3	0.2	23.949	1.284	0.183
SCC-1c-25-12	25	1.2	0.2	24.998	1.17	0.21
SCC-1c-25-12bis	25	1.2	0.2	24.99	1.16	0.21
SCC-1c-25-13	25	1.3	0.2	25.08	1.275	0.223
SCC-1c-25-13bis	25	1.3	0.2	24.99	1.249	0.192

4 Destructive observations

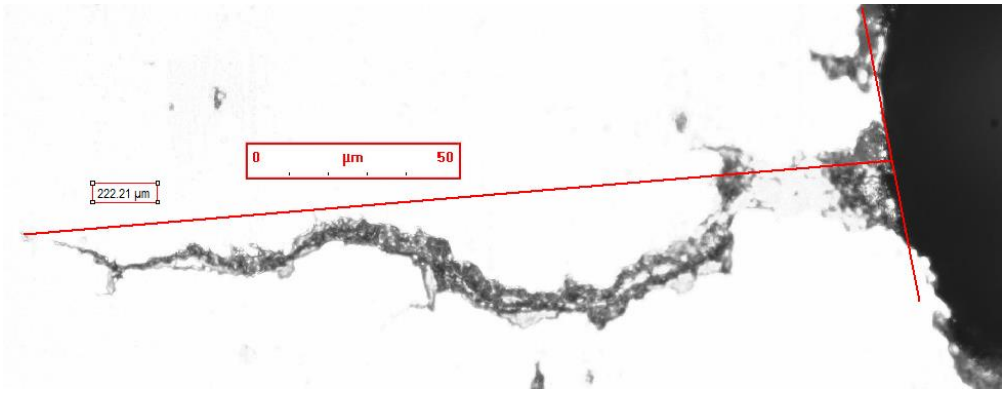


Figure 23: SCC1b-12-15 after oil pipeline condition test

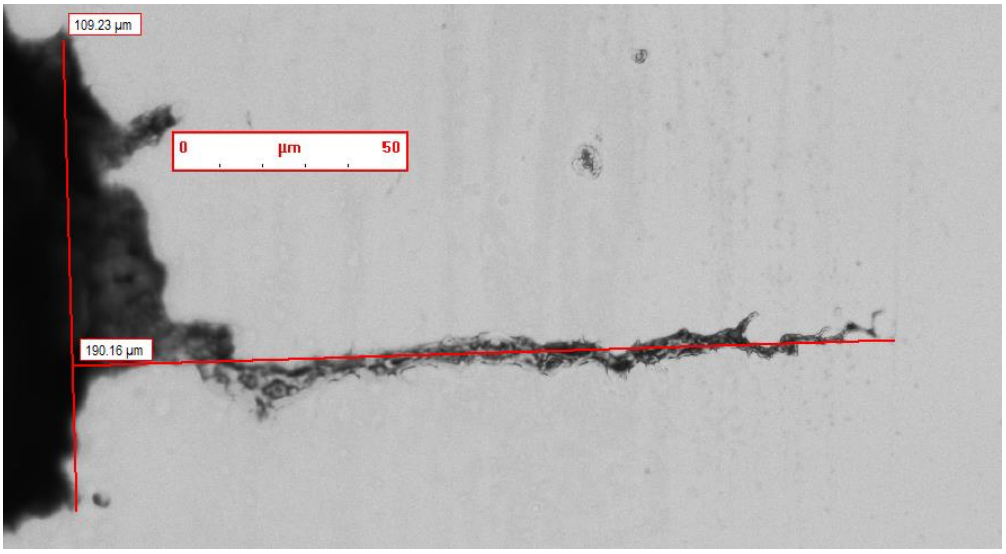


Figure 24: SCC1b-22-12b after oil pipeline condition test

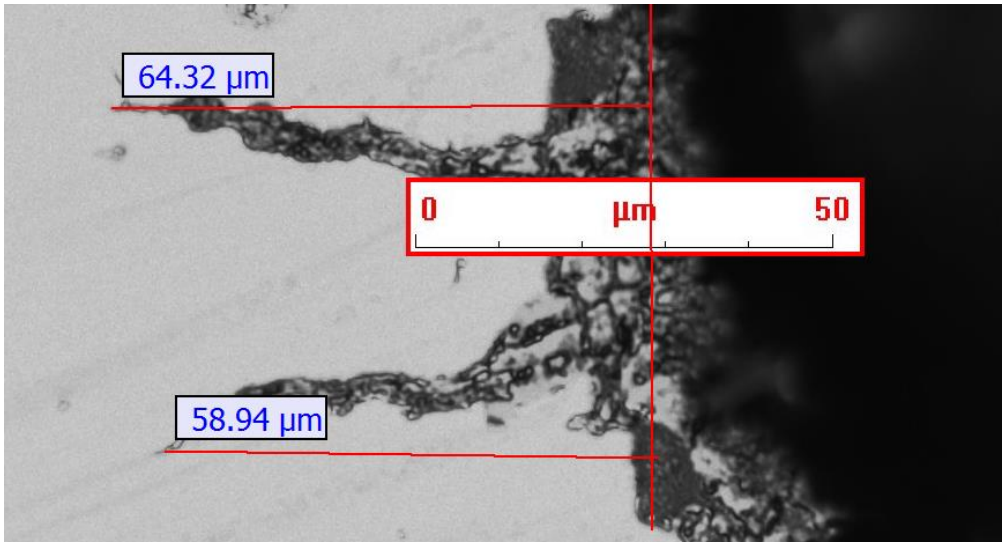


Figure 25: SCC1b-18-12 after oil pipeline condition test

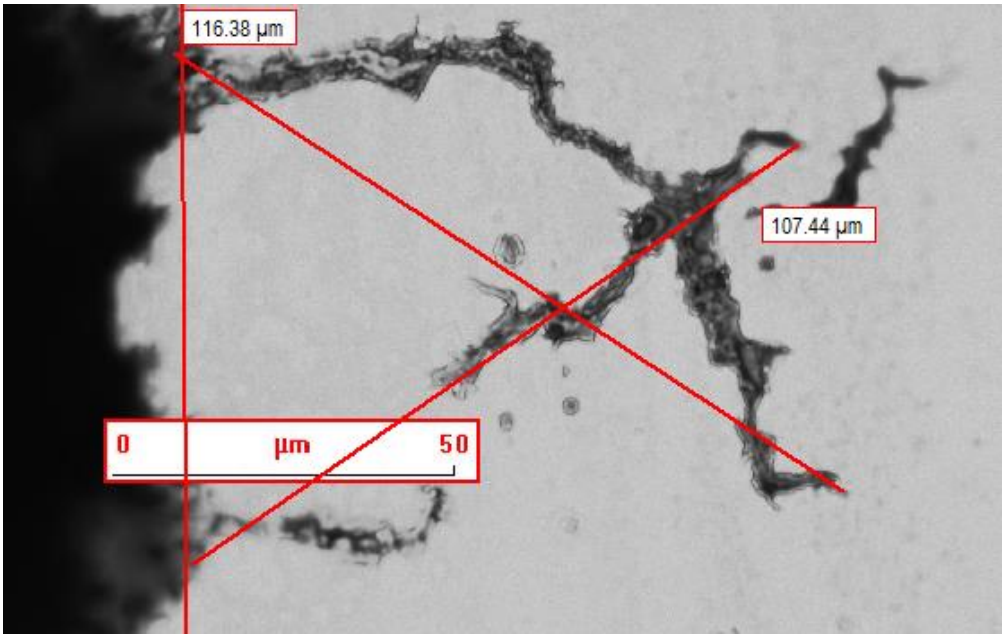


Figure 26: SCC1b-14-13 after oil pipeline condition test

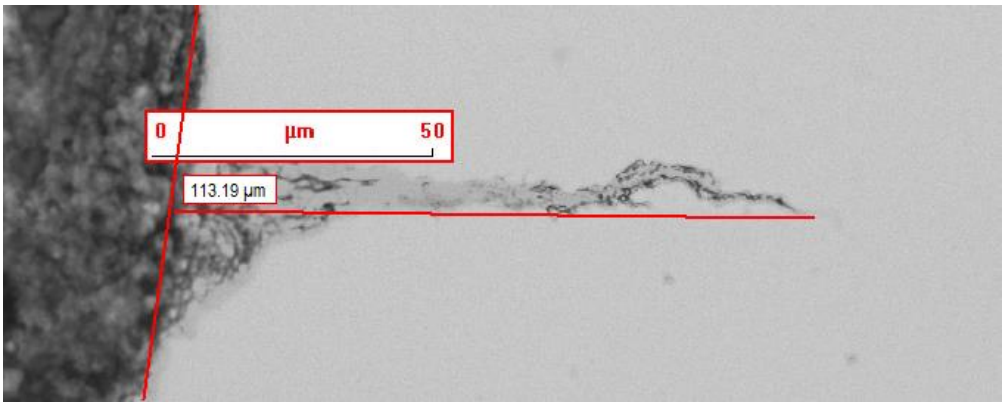


Figure 27: SCC1b-15-12 after oil pipeline condition test

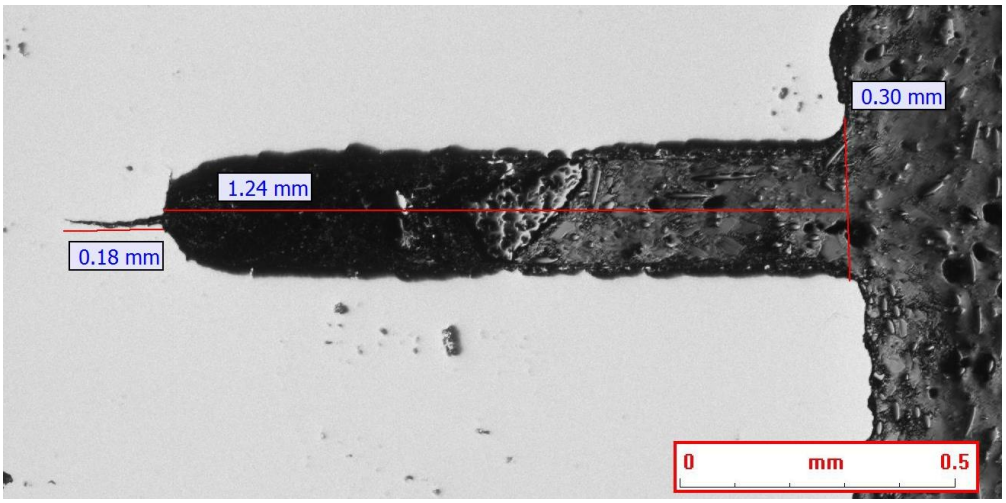


Figure 28: SCC1b-13-13b after oil pipeline condition test

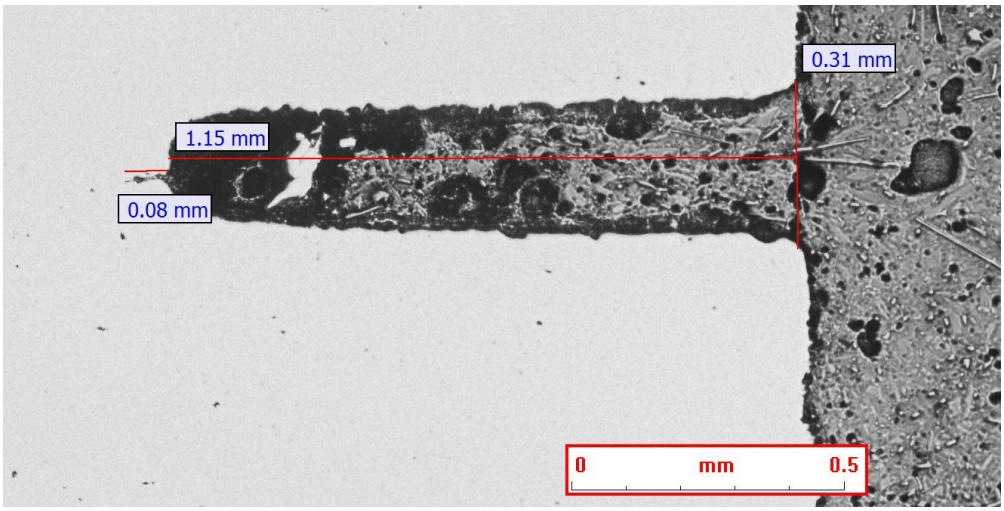


Figure 29: SCC1b-21-12 after oil pipeline condition test

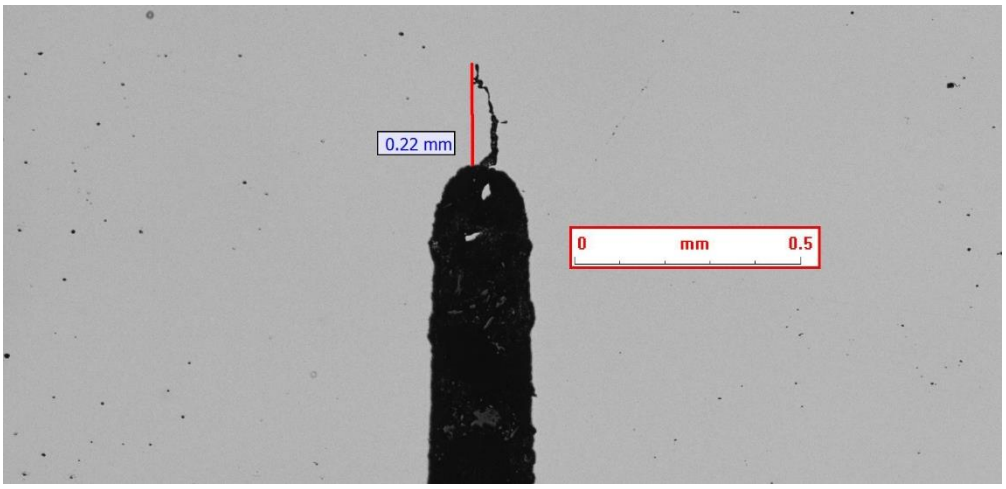


Figure 30: SCC1c-14-15bis after gas pipeline condition test

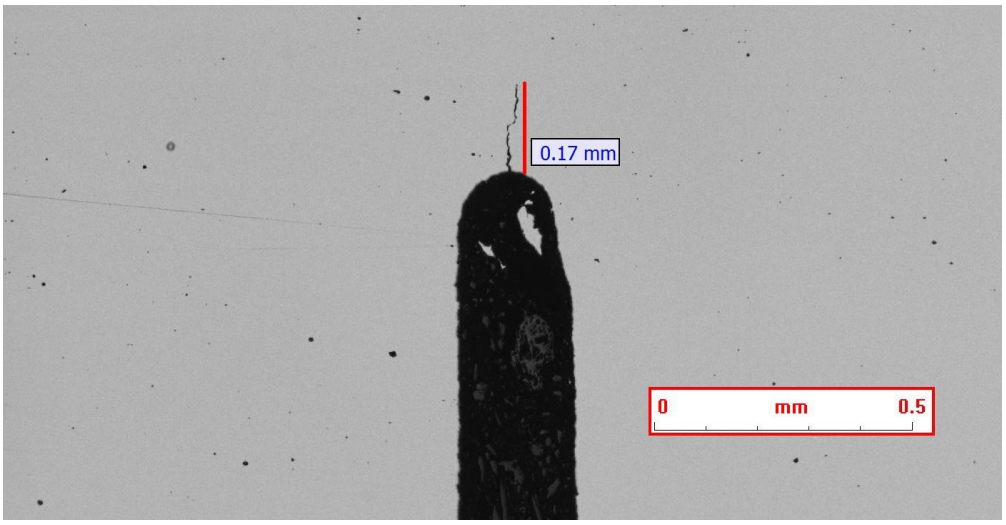


Figure 31: SCC1c-24-13bis after gas pipeline condition test

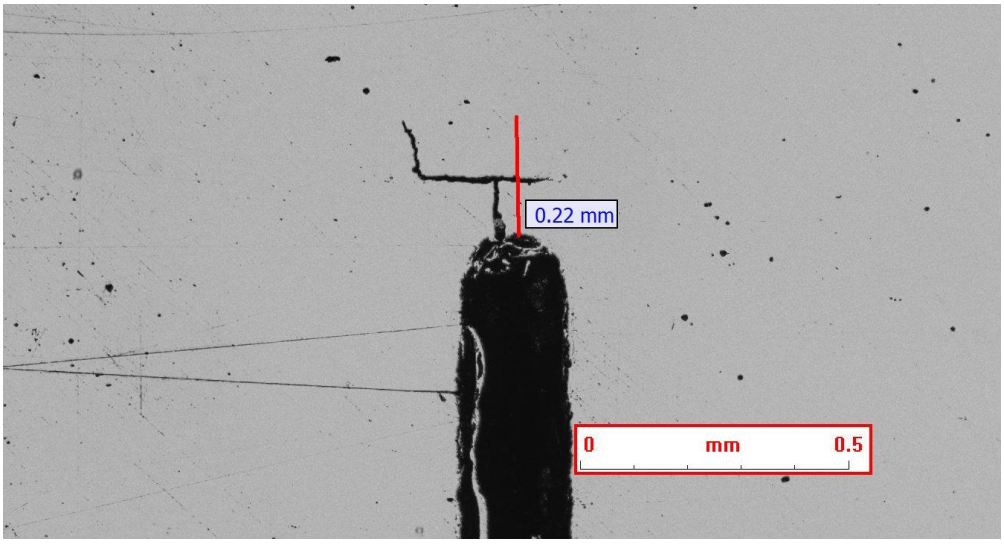


Figure 32: SCC1c-24-12bis after gas pipeline condition test

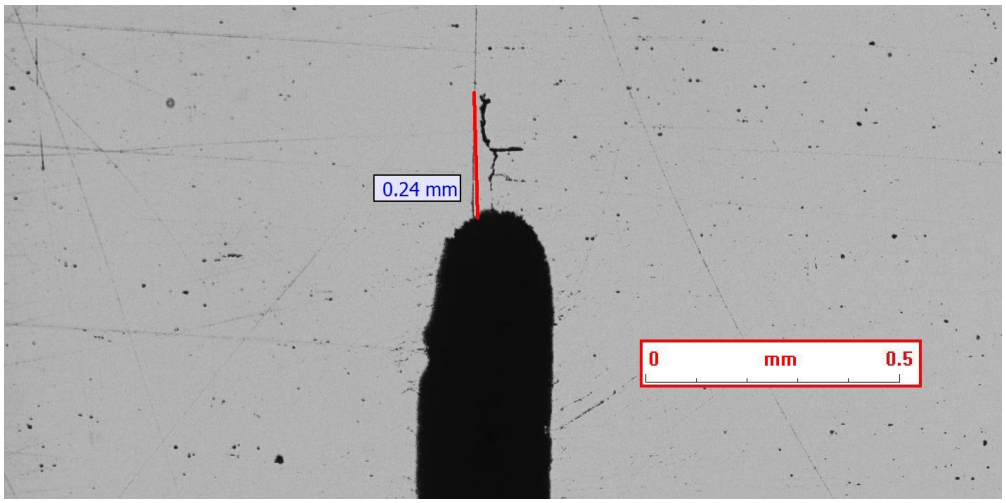


Figure 33: SCC1c-25-13bis after gas pipeline condition test

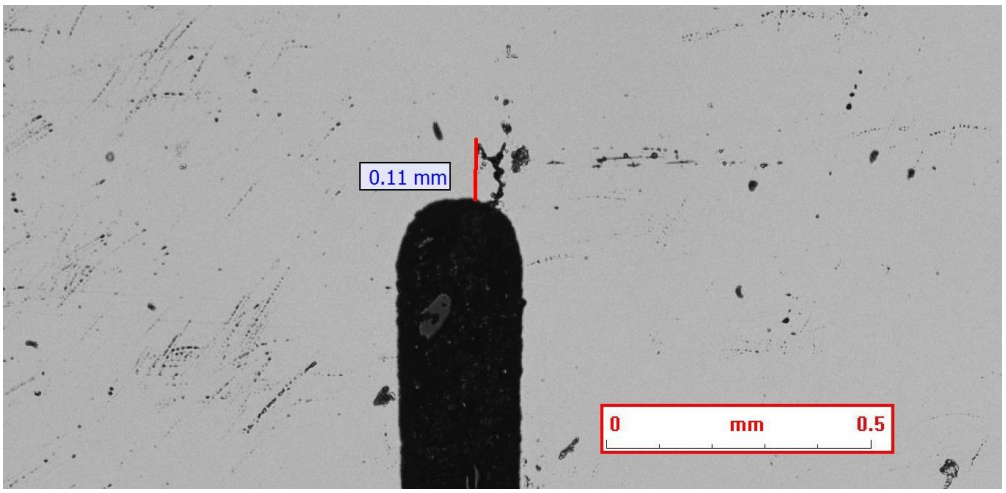


Figure 34: SCC1c-25-12bis after gas pipeline condition test

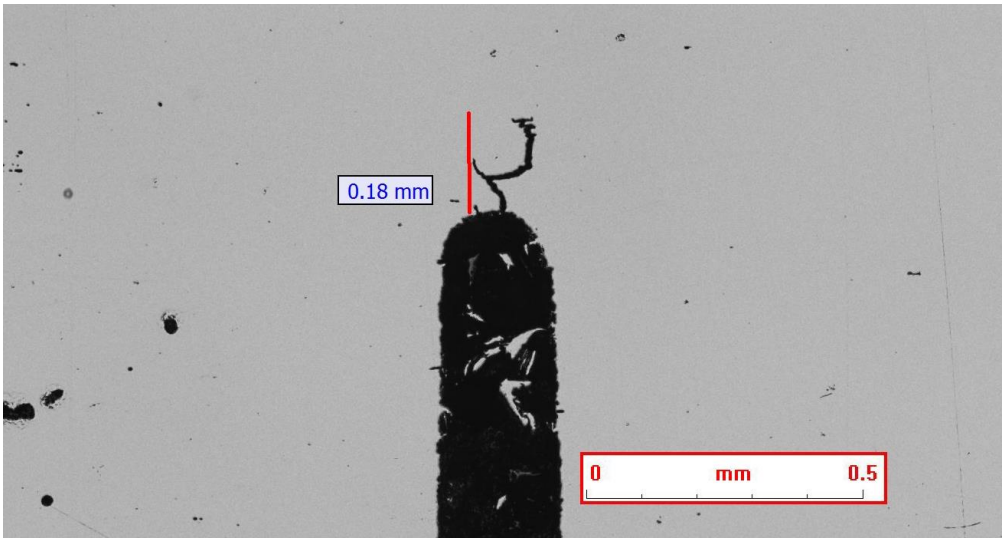


Figure 35: SCC1b-13-15bis after gas pipeline condition test

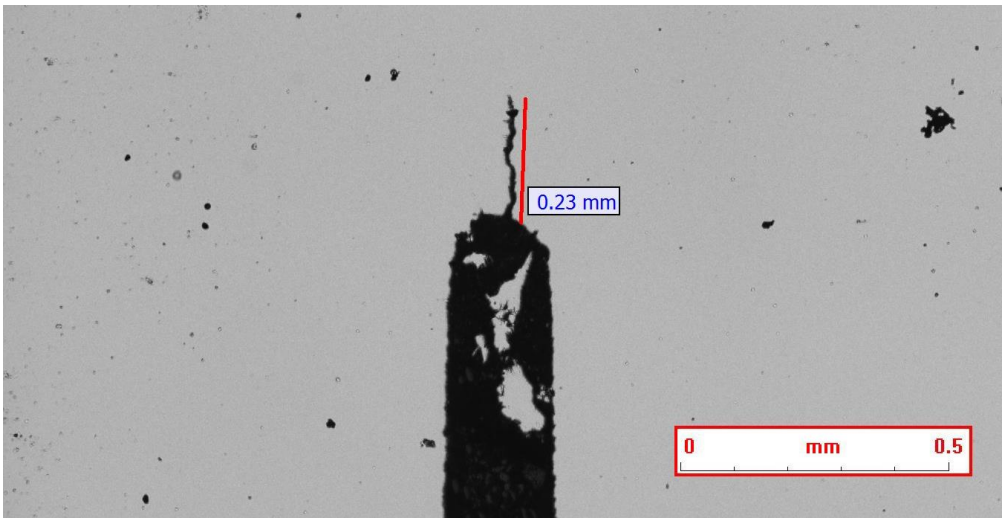


Figure 36: SCC1b-13-13bis after gas pipeline condition test

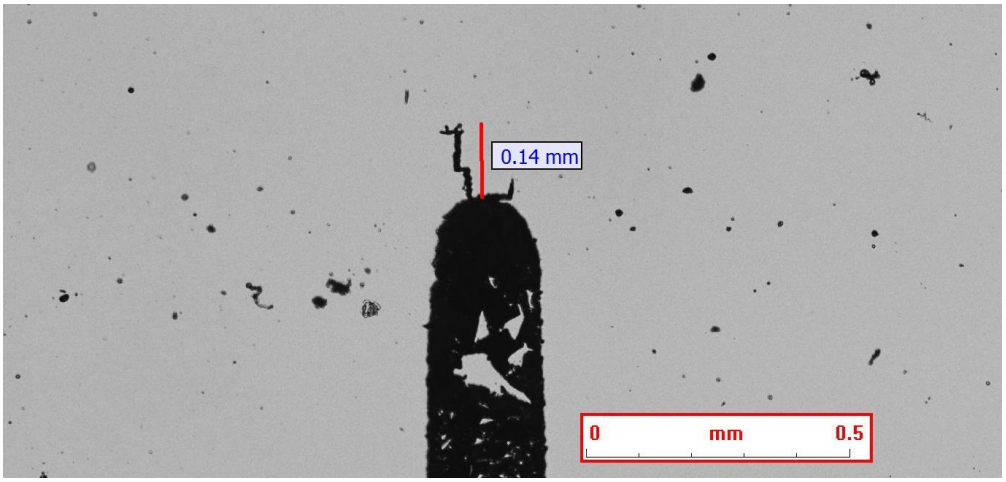


Figure 37: SCC1b-14-13bis after gas pipeline condition test

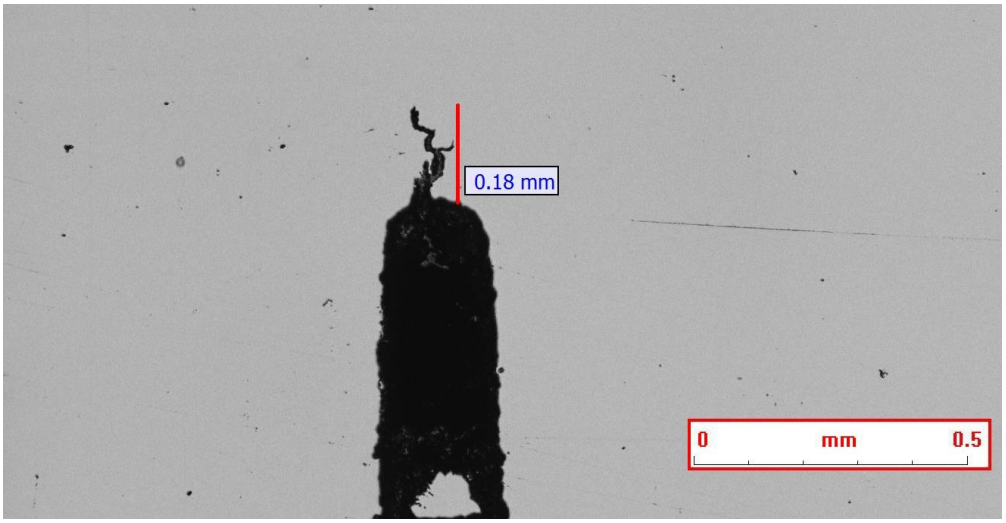


Figure 38: SCC1b-13-13a after gas pipeline condition test

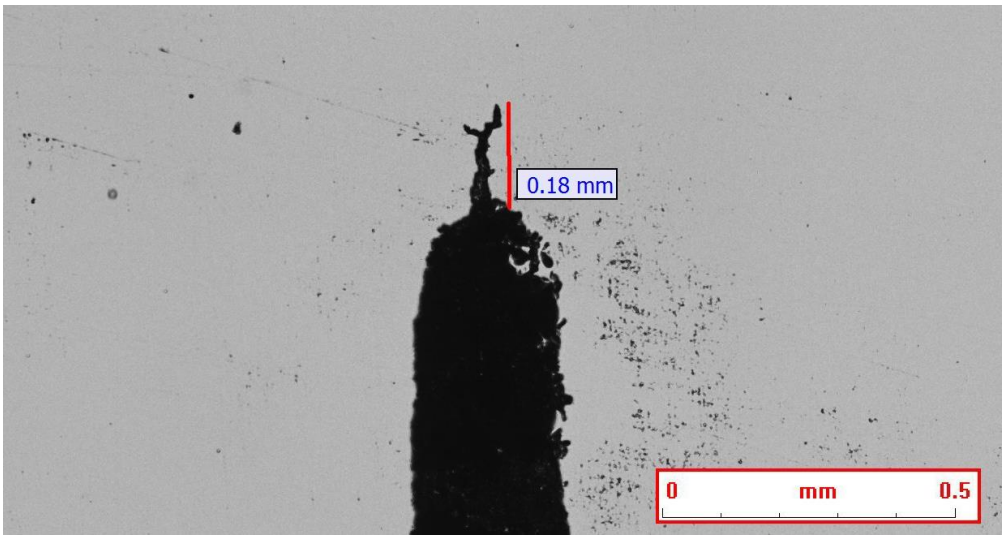


Figure 39: SCC1b-22-12a after gas pipeline condition test

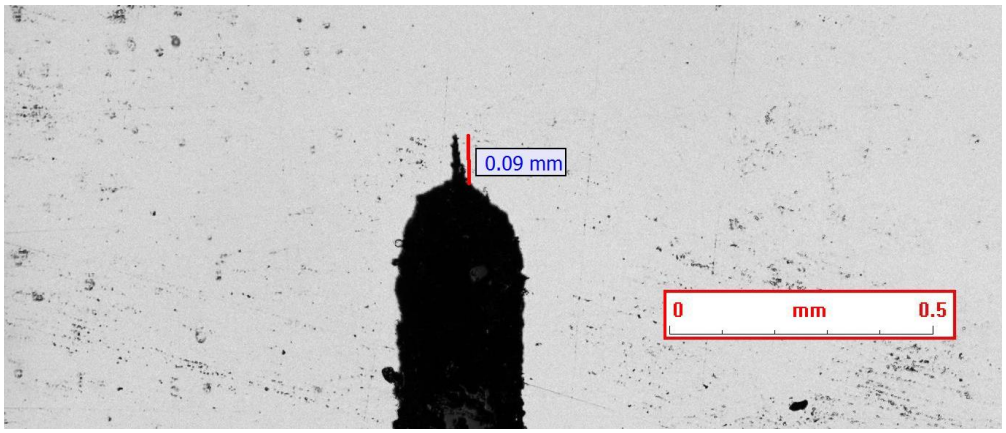


Figure 40: SCC1b-16-12a after gas pipeline condition test

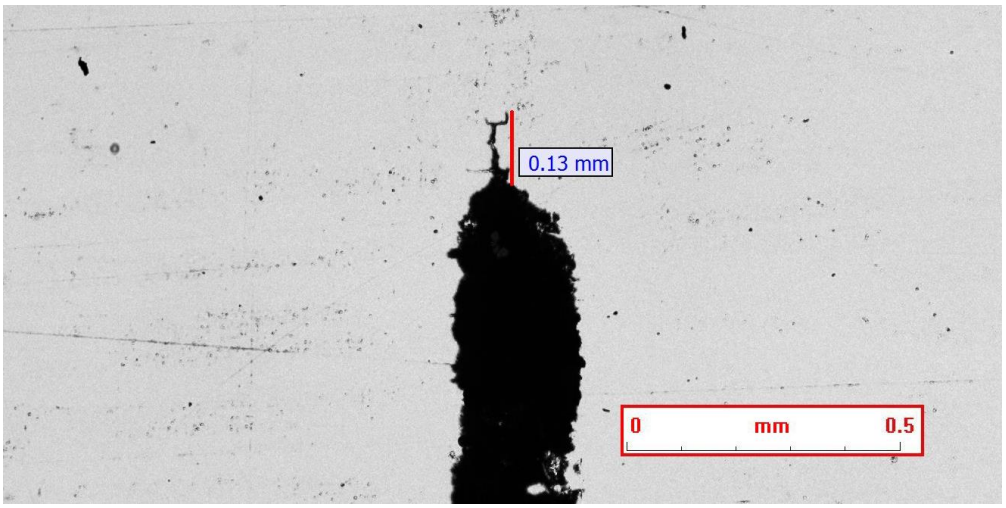


Figure 41: SCC1b-16-12b after gas pipeline condition test

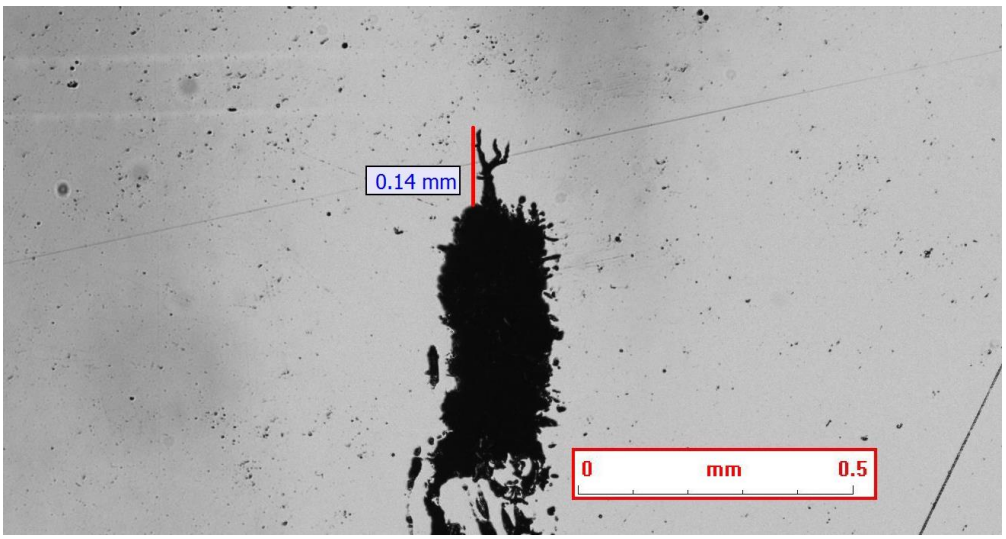


Figure 42: SCC1c-25-13 after gas pipeline condition test – view #1

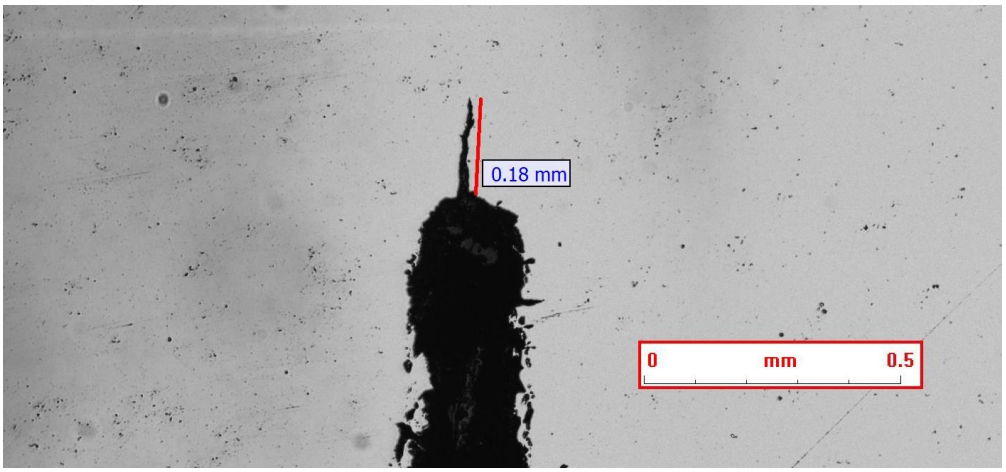


Figure 43: SCC1c-25-13 after gas pipeline condition test – view #2

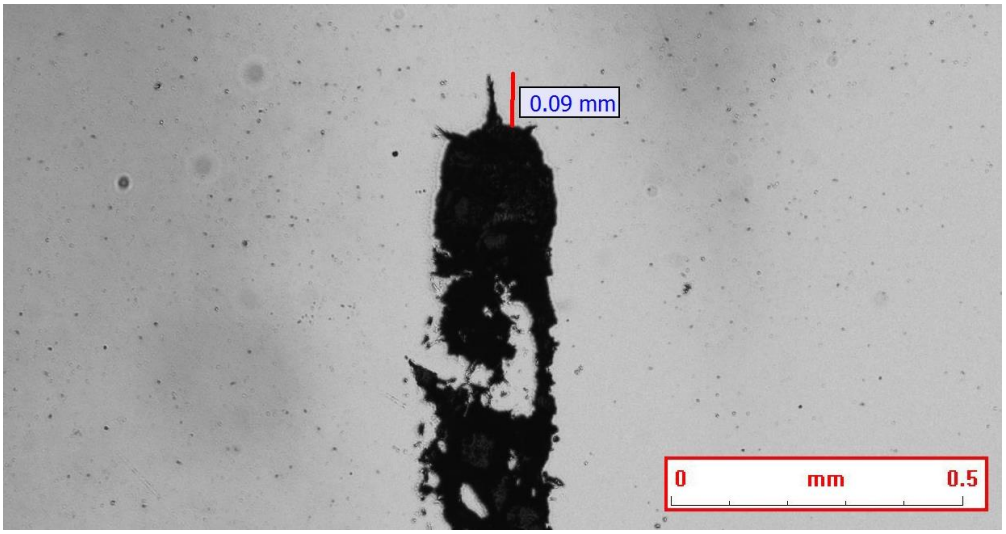


Figure 44: SCC1c-24-13 after gas pipeline condition test - view #1

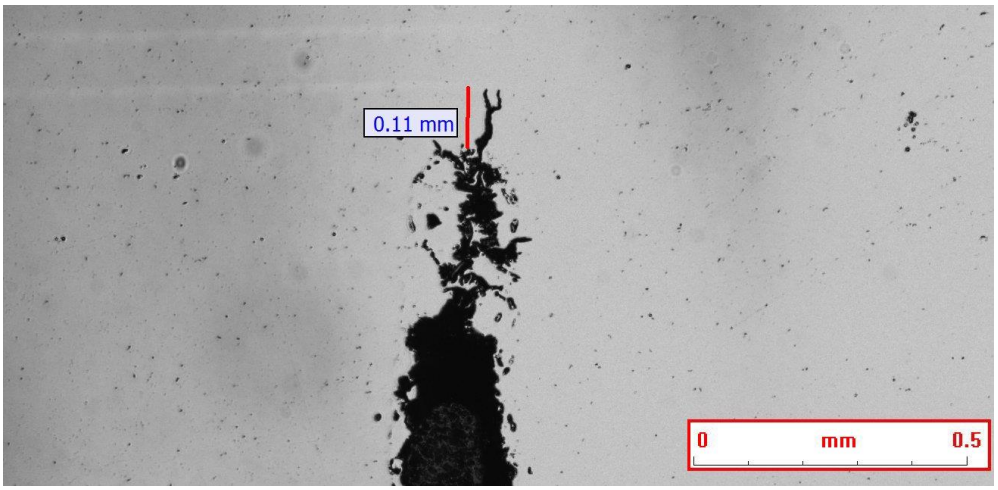


Figure 45: SCC1c-24-13 after gas pipeline condition test - view #2

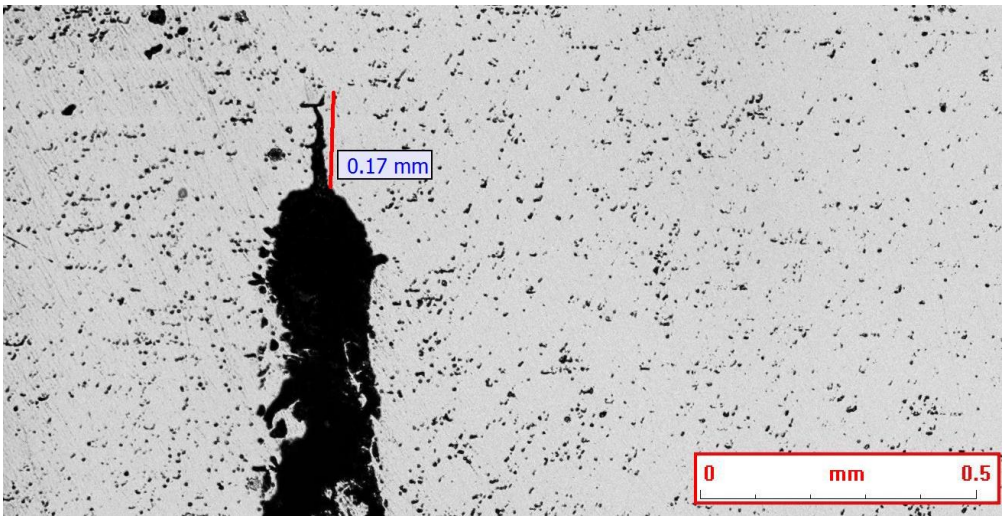


Figure 46: SCC-19-15a after gas pipeline condition test

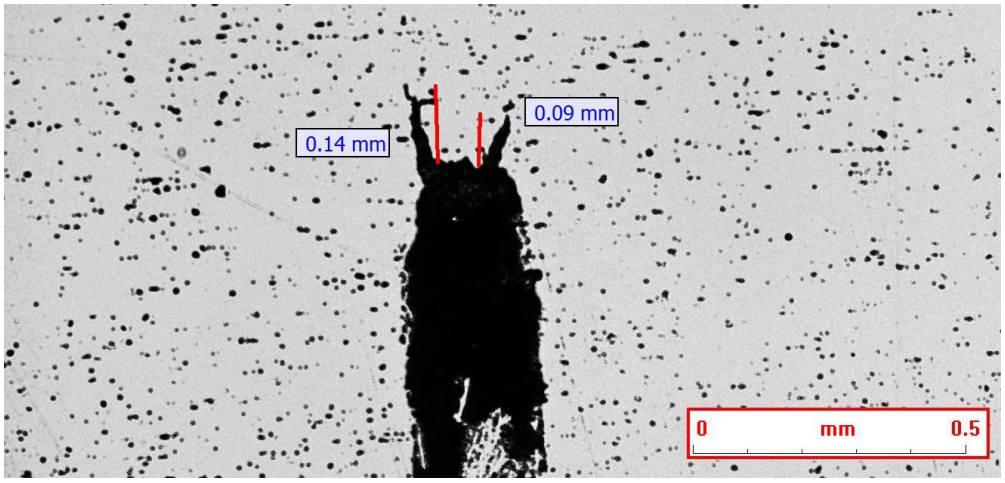


Figure 47: SCC1c-23-13 after gas pipeline condition test

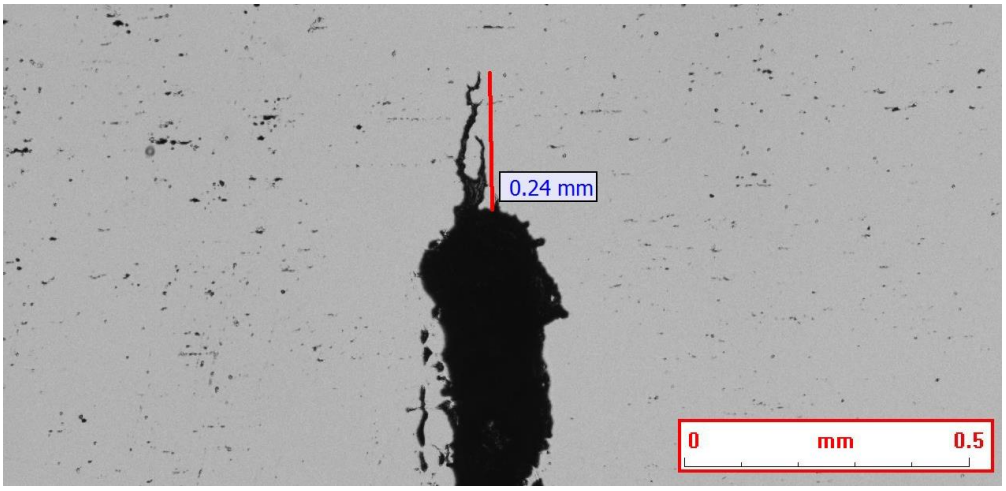


Figure 48: SCC1c-18-15 after gas pipeline condition test

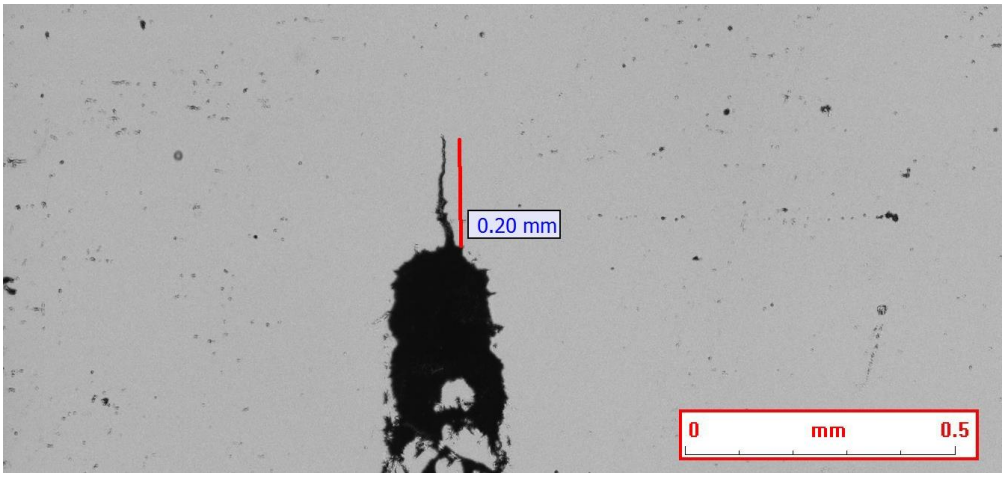


Figure 49: SCC1c-22-13a after gas pipeline condition test

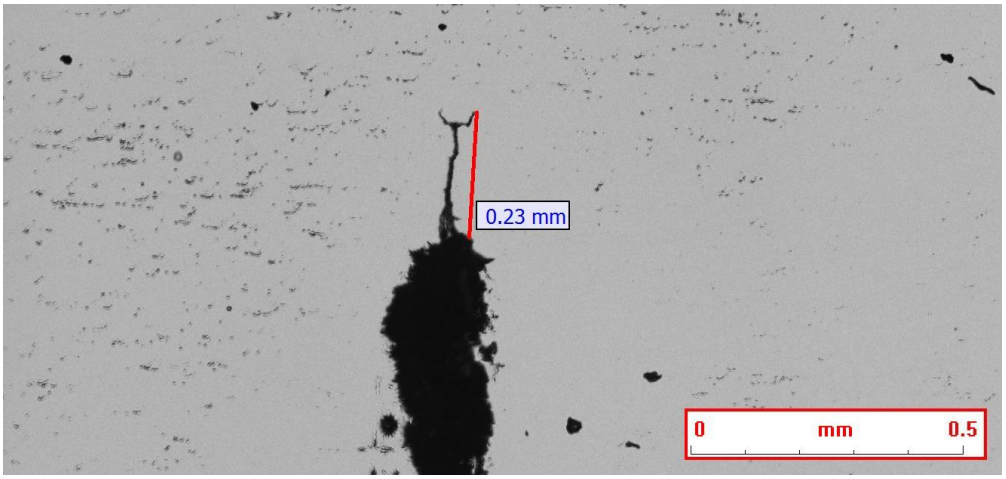


Figure 50: SCC1c-16-15a after gas pipeline condition test

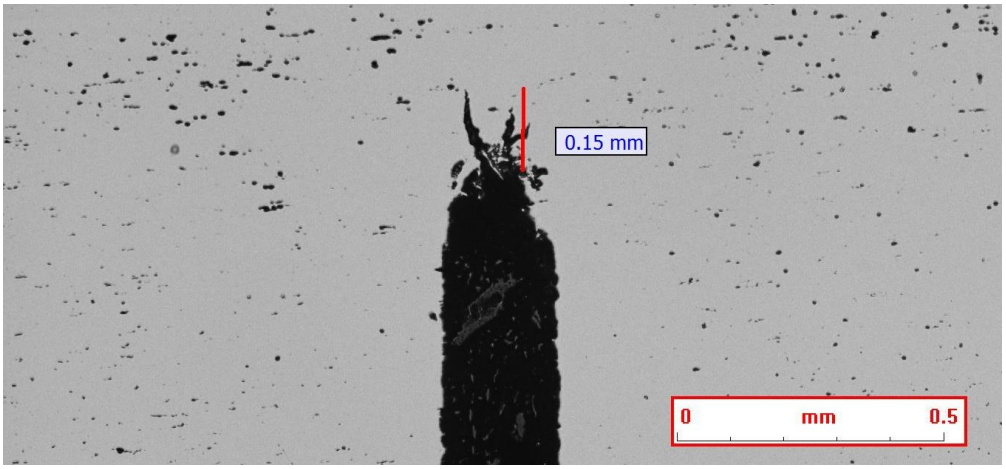


Figure 51: SCC1b-13-15a after gas pipeline condition test

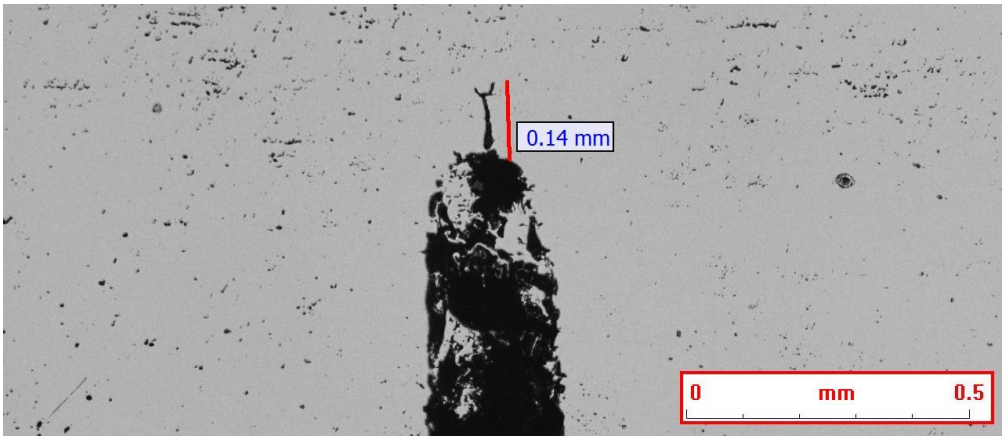


Figure 52: SCC1b-19-12a after gas pipeline condition test

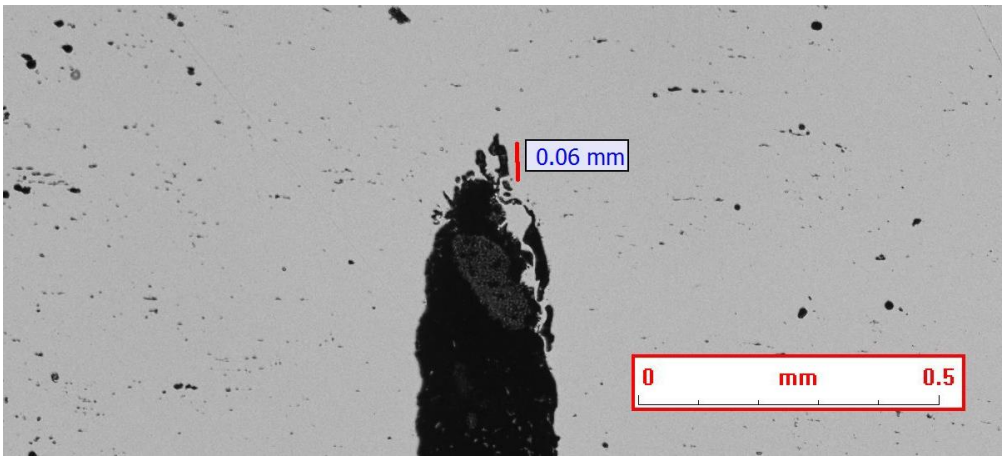


Figure 53: SCC1a-5-20 after gas pipeline condition test

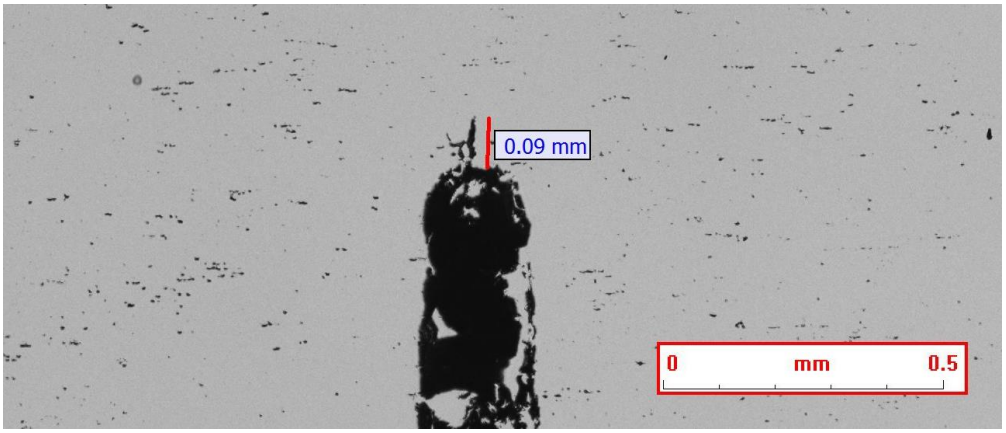


Figure 54: SCC1a-6-17 after gas pipeline condition test

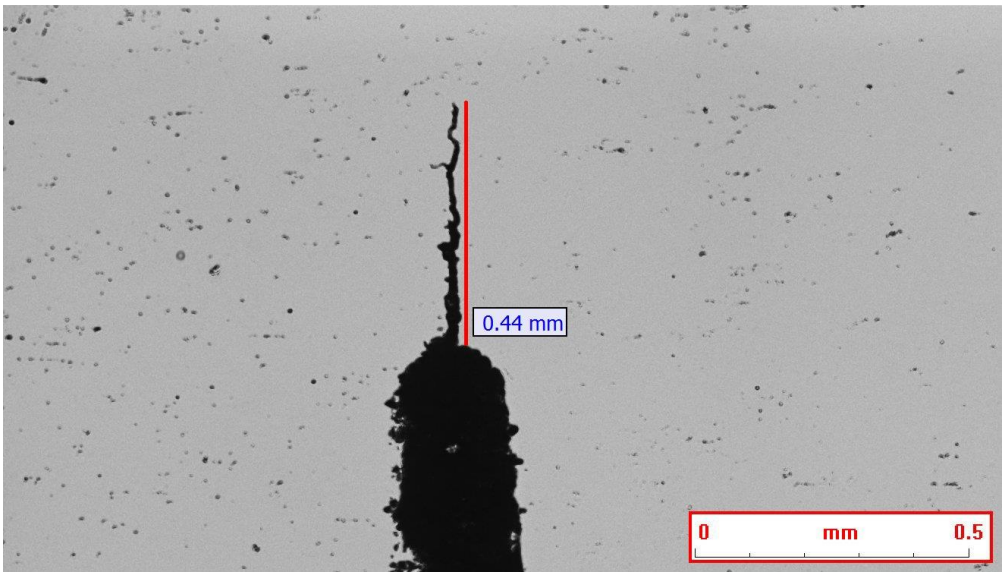


Figure 55: SCC1a-7-17 after gas pipeline condition test

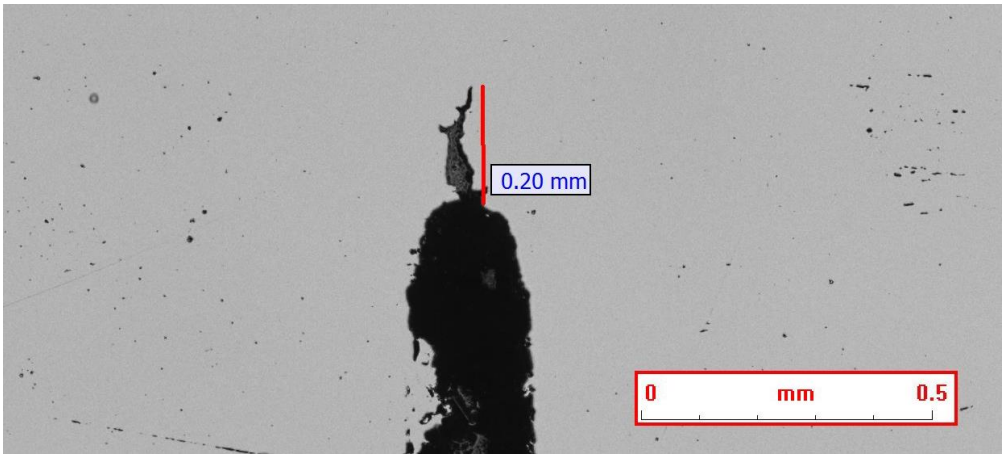


Figure 56: SCC1a-8-17 after gas pipeline condition test

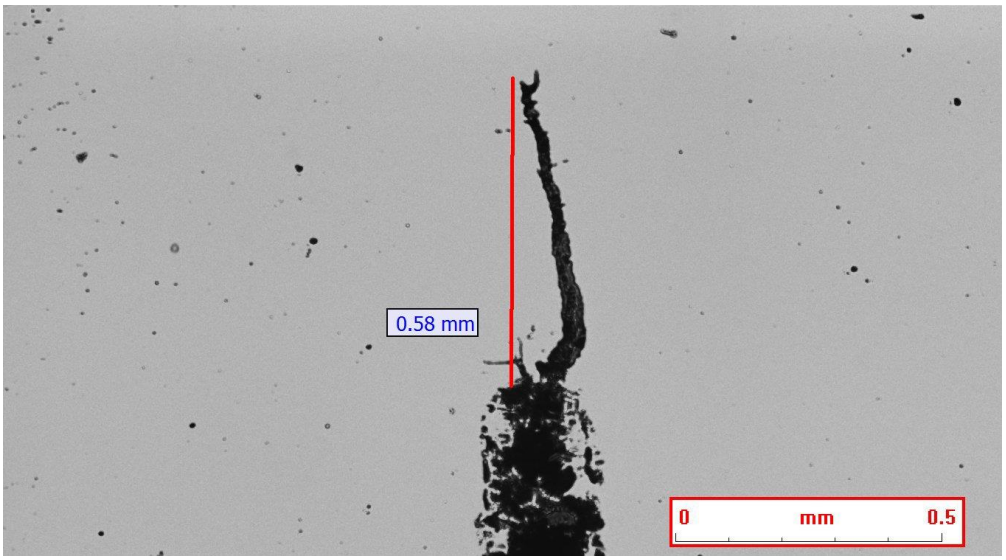


Figure 57: SCC1a-9-17 after gas pipeline condition test

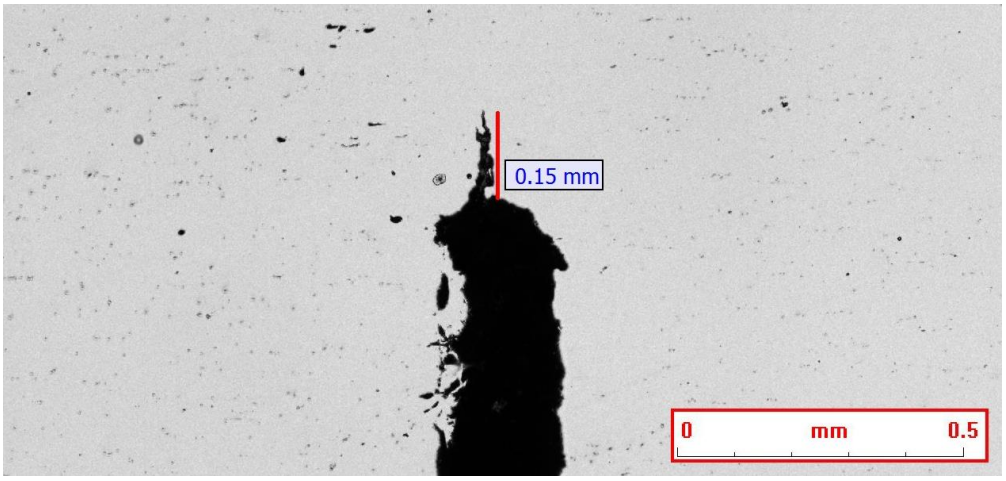


Figure 58: SCC1a-10-15 after gas pipeline condition test

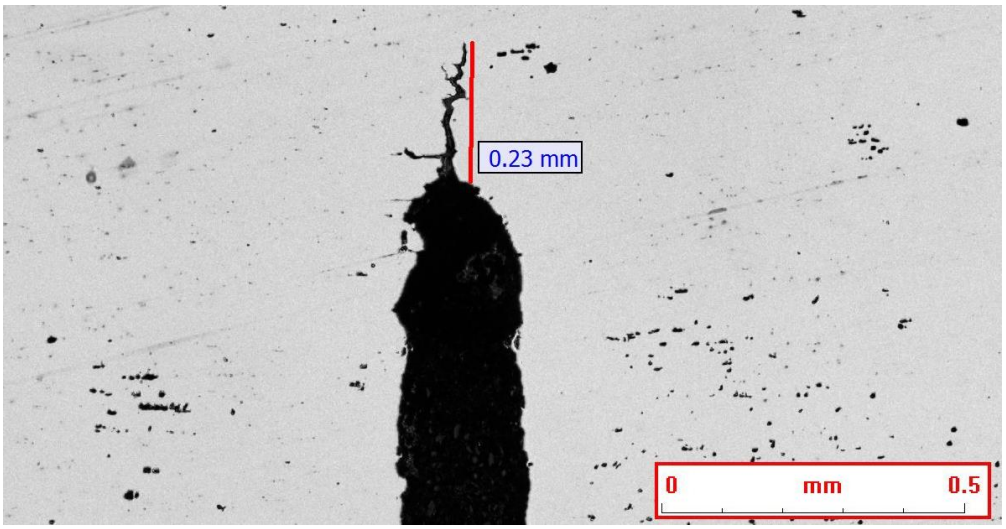


Figure 59: SCC1b-11-15 after gas pipeline condition test

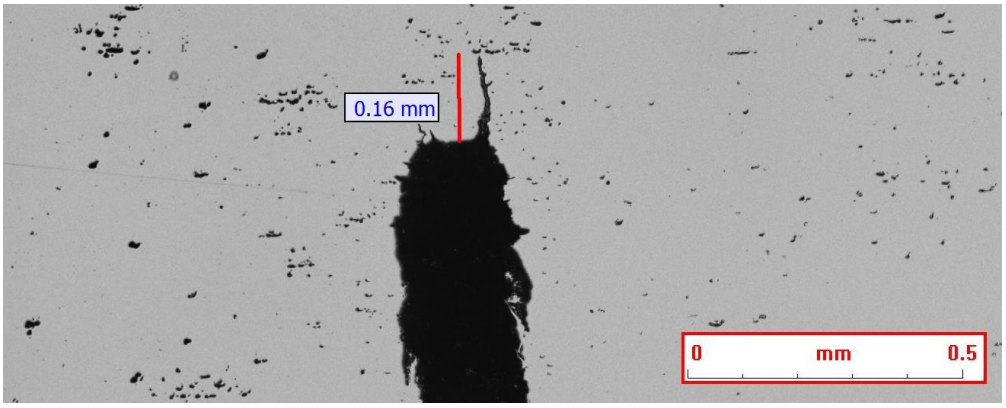


Figure 60: SCC1b-20-12 after gas pipeline condition test

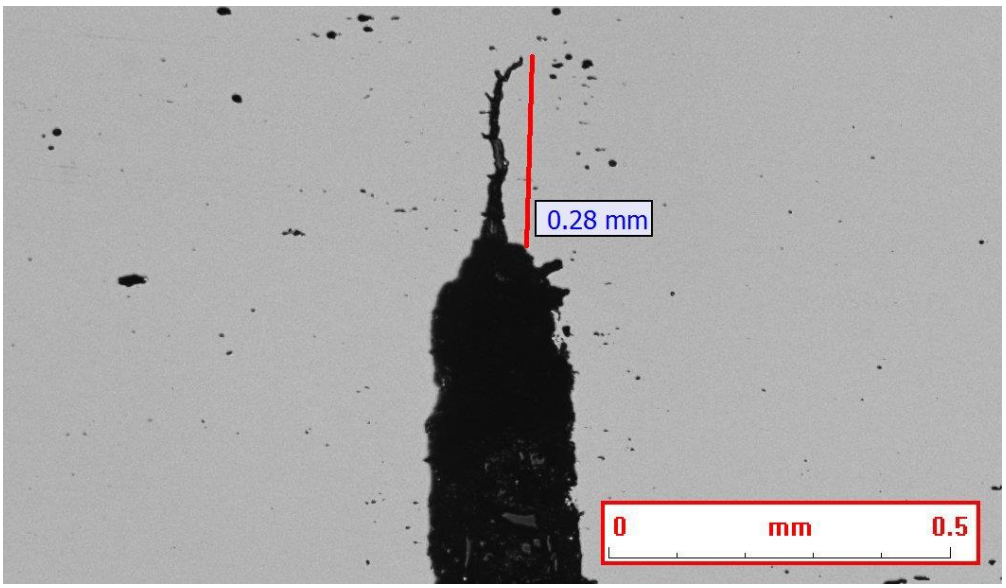


Figure 61: SCC1c-14-15 after gas pipeline condition test

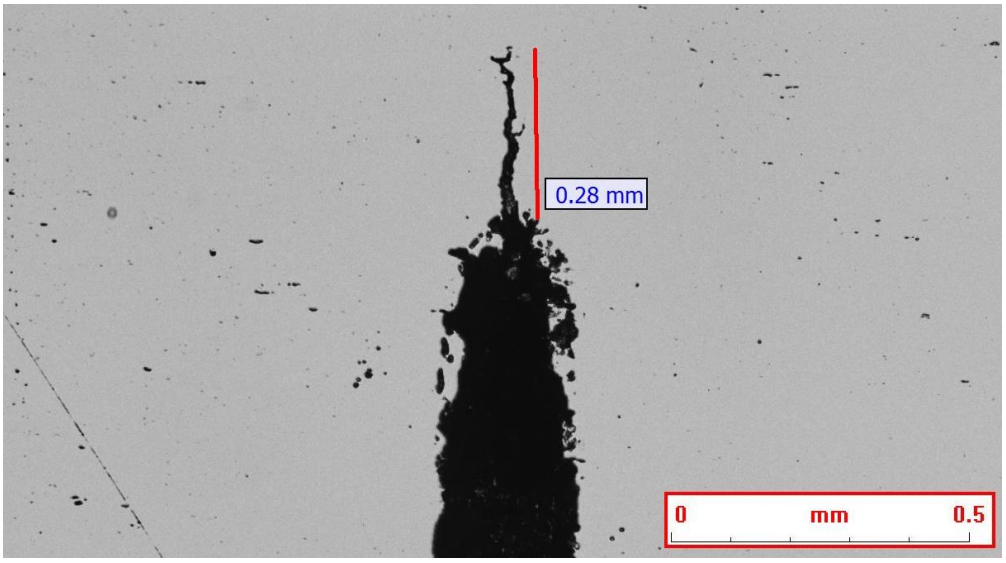


Figure 62: SCC1c-15-15 after gas pipeline condition test

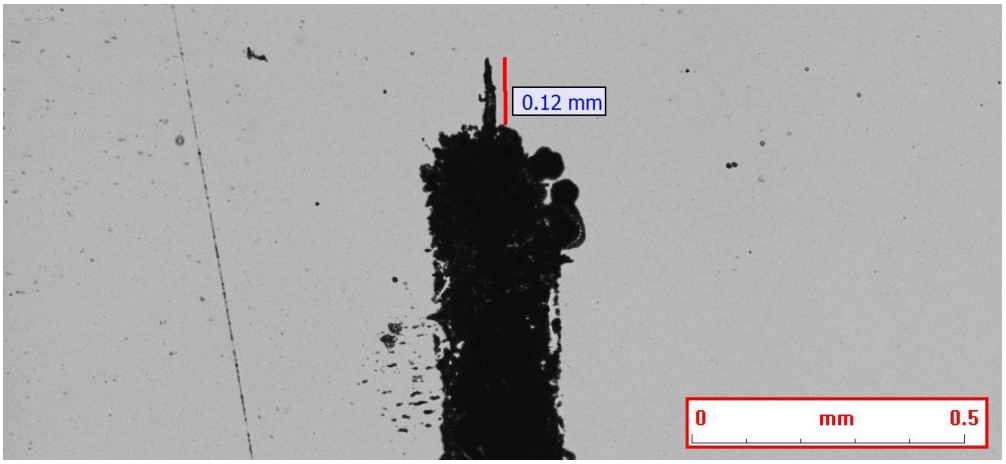


Figure 63: SCC1c-23-12 after gas pipeline condition test - view #1

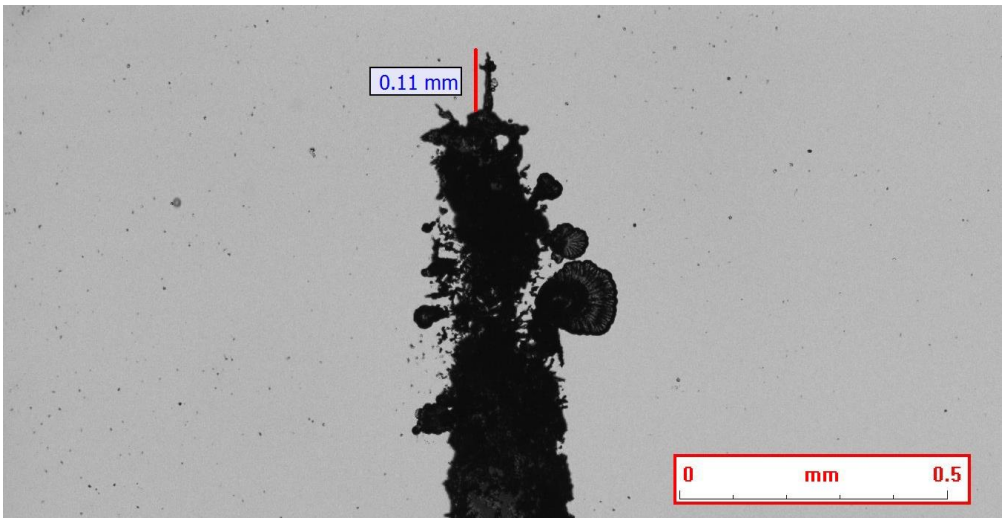


Figure 64: SCC1c-23-12 after gas pipeline condition test - view #2

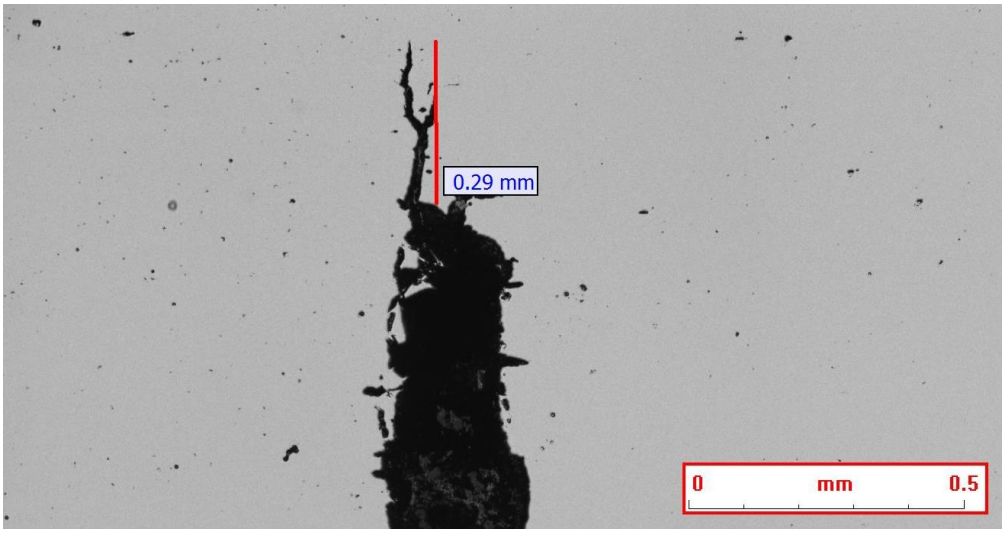


Figure 65: SCC1c-17-15 after gas pipeline condition test

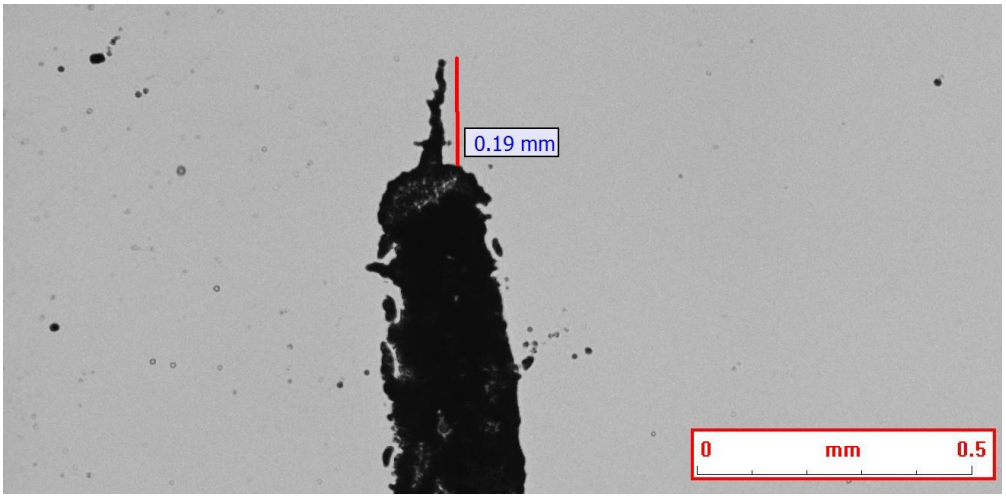


Figure 66: SCC1c-24-12 after gas pipeline condition test - view #1

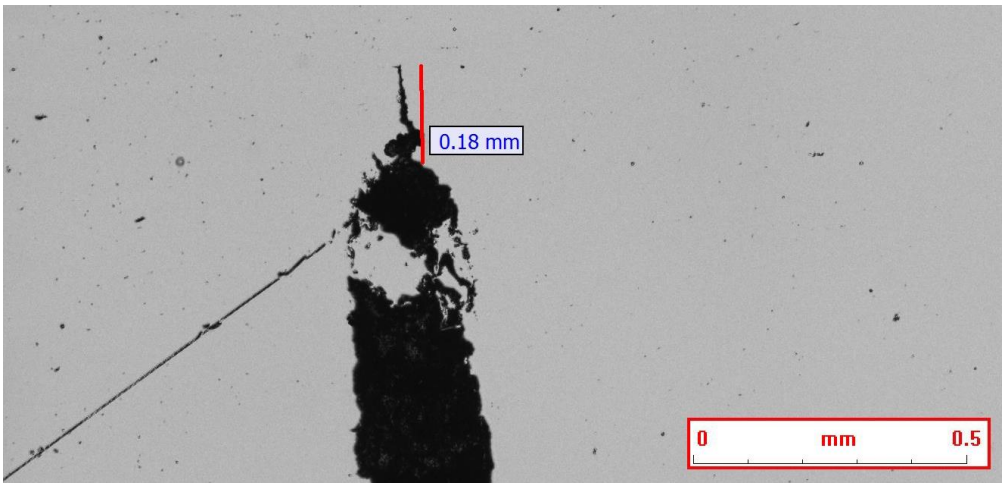


Figure 67: SCC1c-24-12 after gas pipeline condition test - view #2

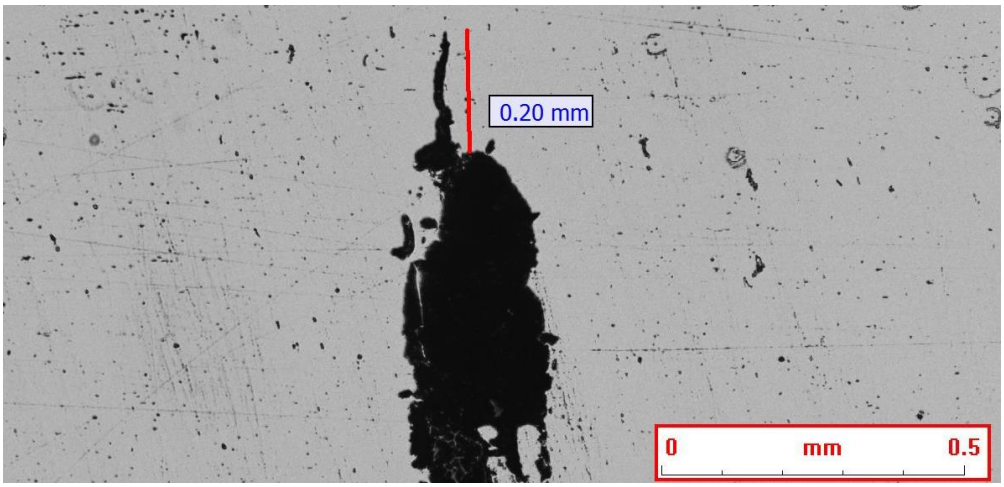


Figure 68: SCC1c-25-12 after gas pipeline condition test

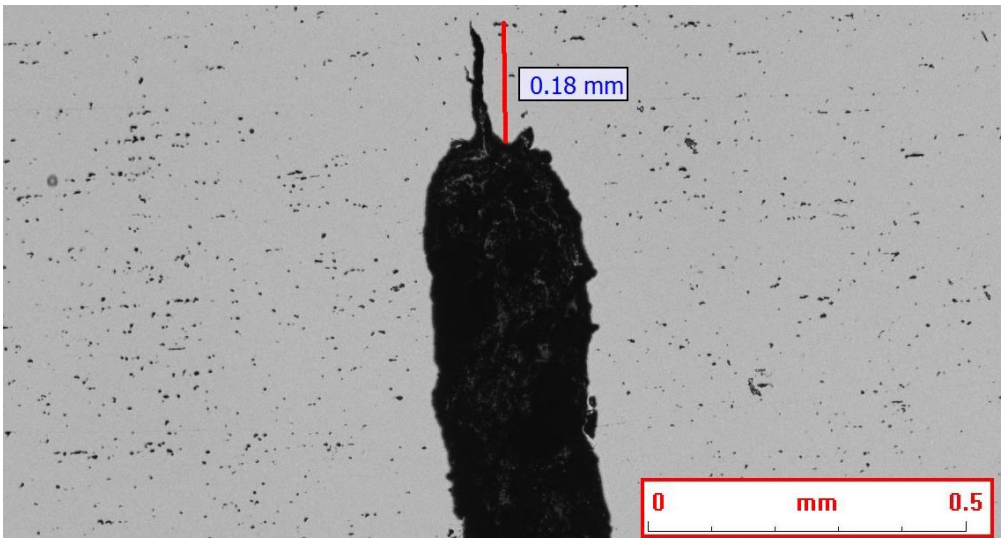


Figure 69: SCC1c-20-13 after gas pipeline condition test

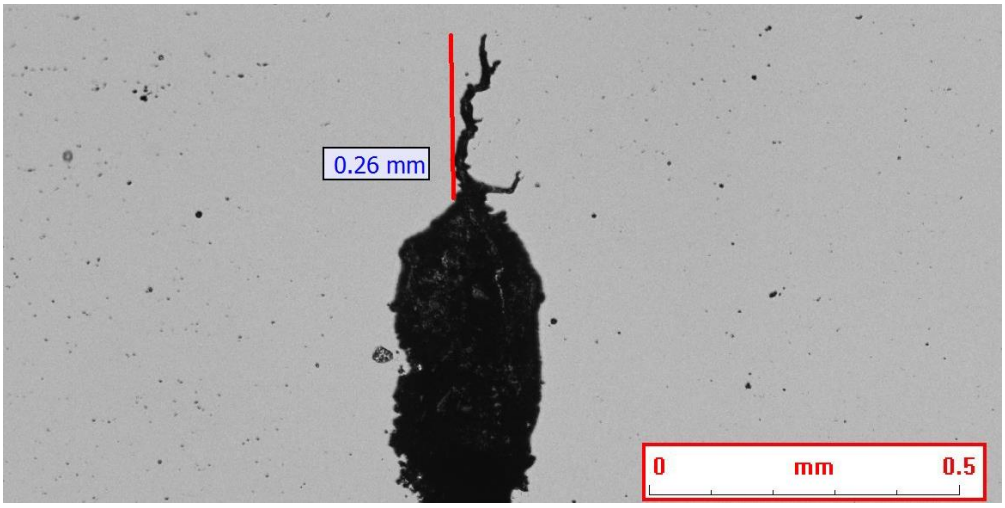


Figure 70: SCC1c-19-15b after gas pipeline condition test

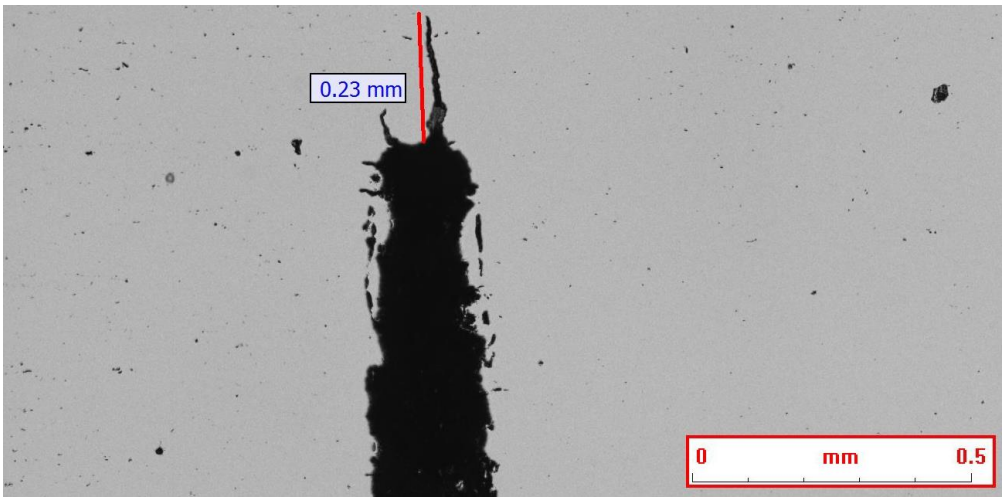


Figure 71: SCC1c-16-15b after gas pipeline condition test

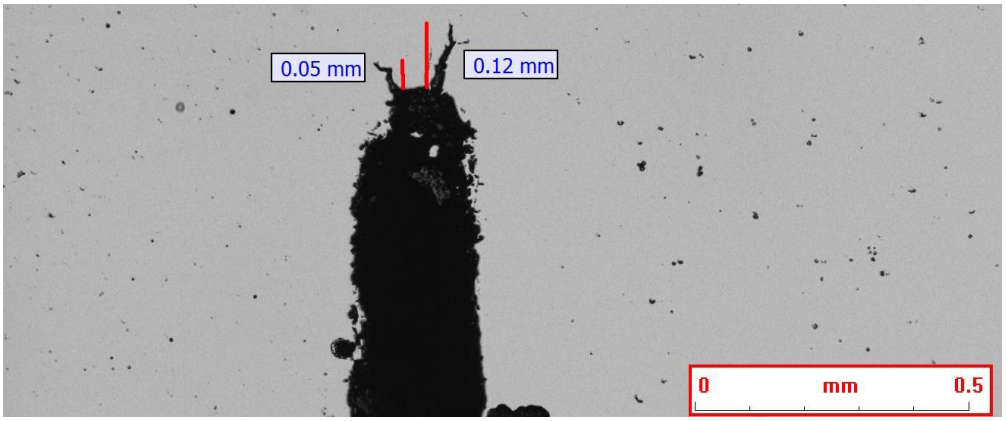


Figure 72: SCC1c-22-13b after gas pipeline condition test - view #1

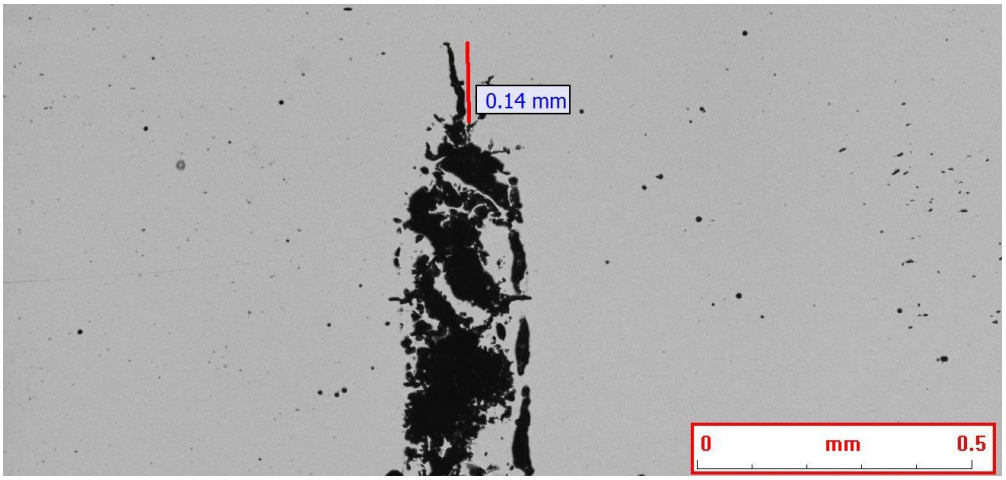


Figure 73: SCC1c-22-13b after gas pipeline condition test - view #2

Figure 74: SCC1c-21-13 after gas pipeline condition test

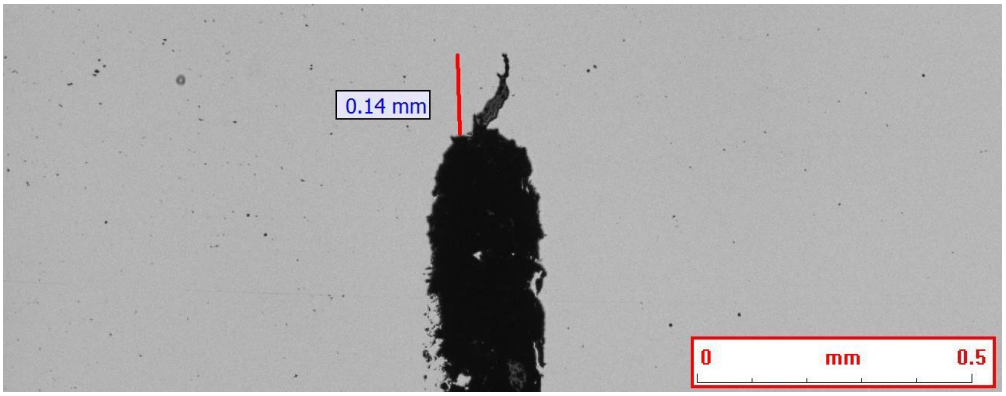


Figure 75: SCC1a-10-13 after gas pipeline condition test

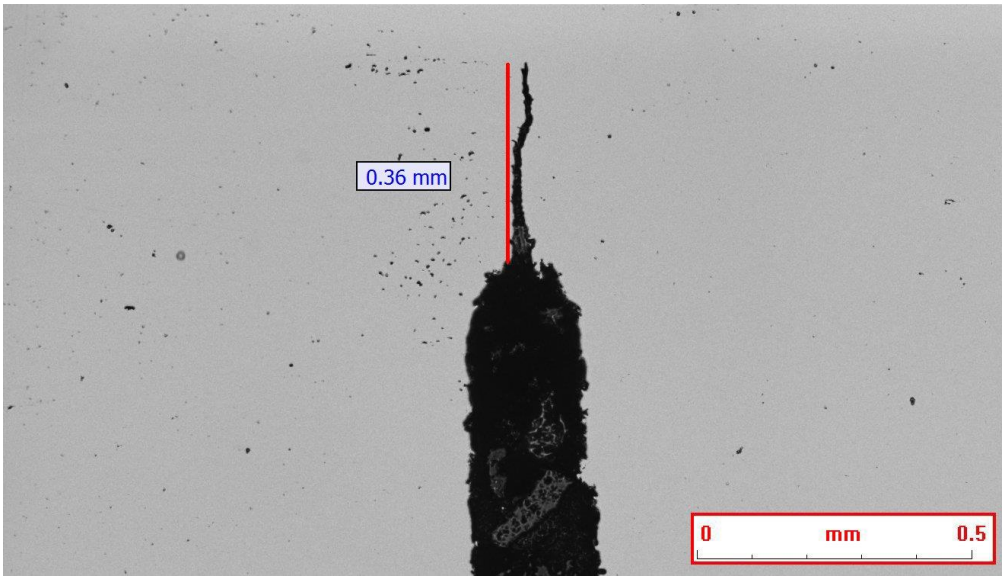


Figure 76: SCC1a-9-15 after gas pipeline condition test

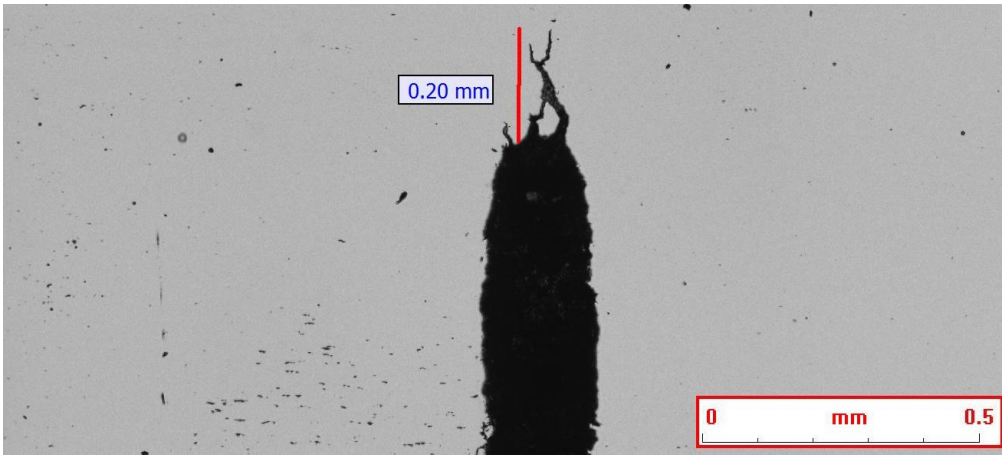


Figure 77: SCC1b-17-12 after gas pipeline condition test

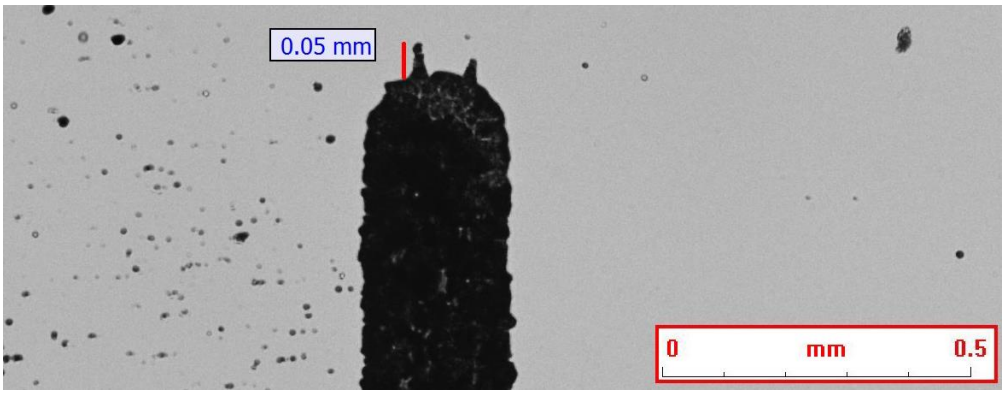


Figure 78: SCC1b-19-12b after gas pipeline condition test

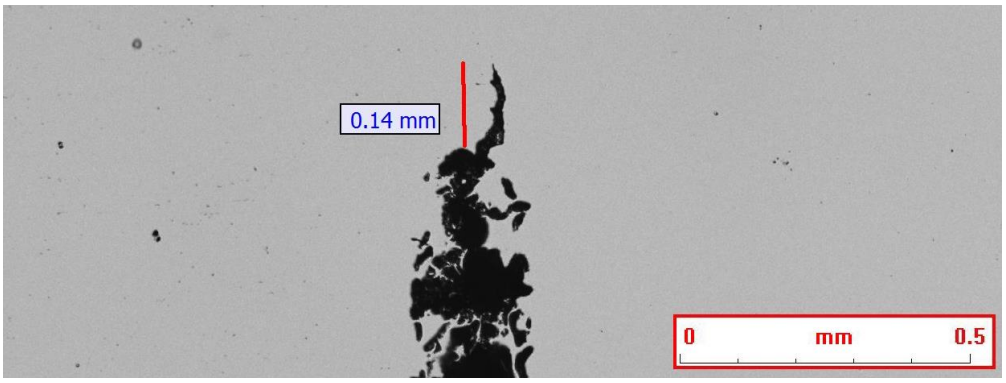


Figure 79: SCC1b-13-15b after gas pipeline condition test

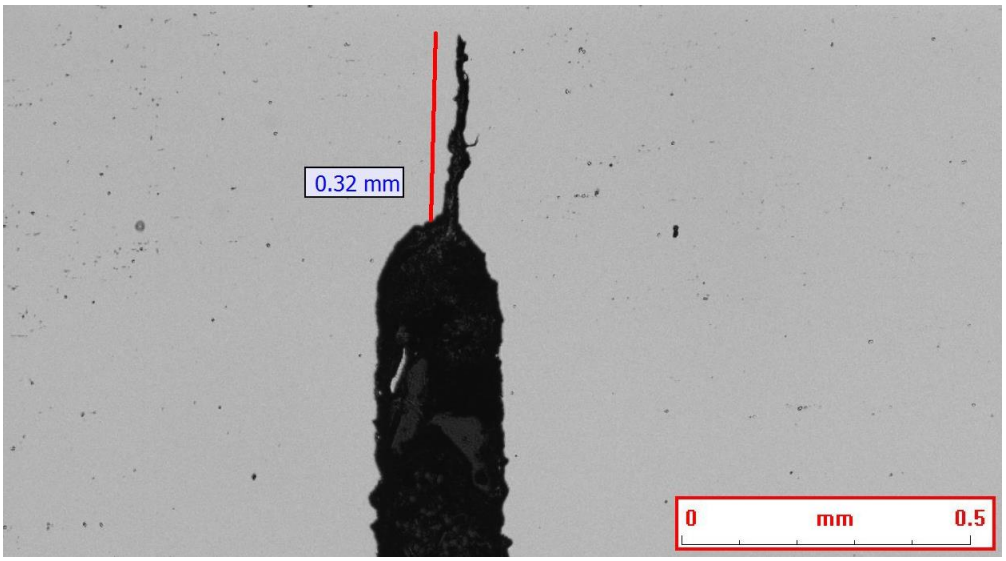


Figure 80: SCC1a-5-15 after gas pipeline condition test

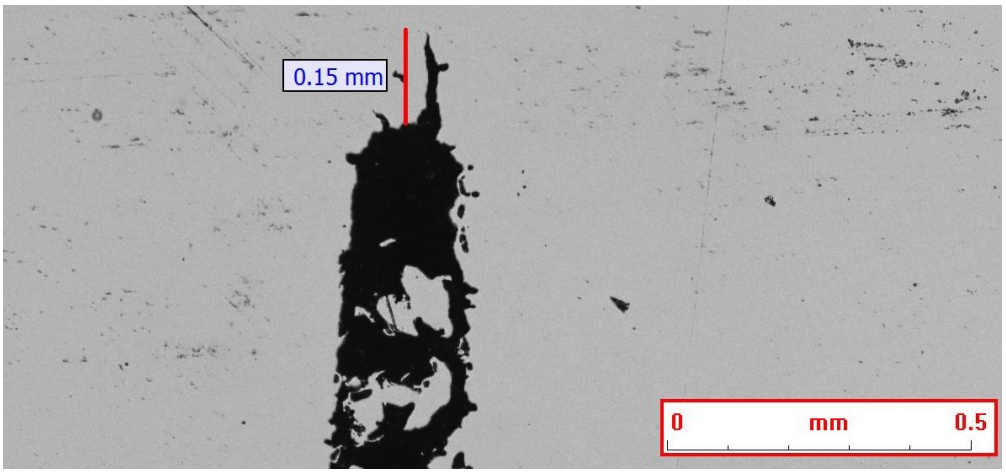


Figure 81: SCC1a-6-15 after gas pipeline condition test

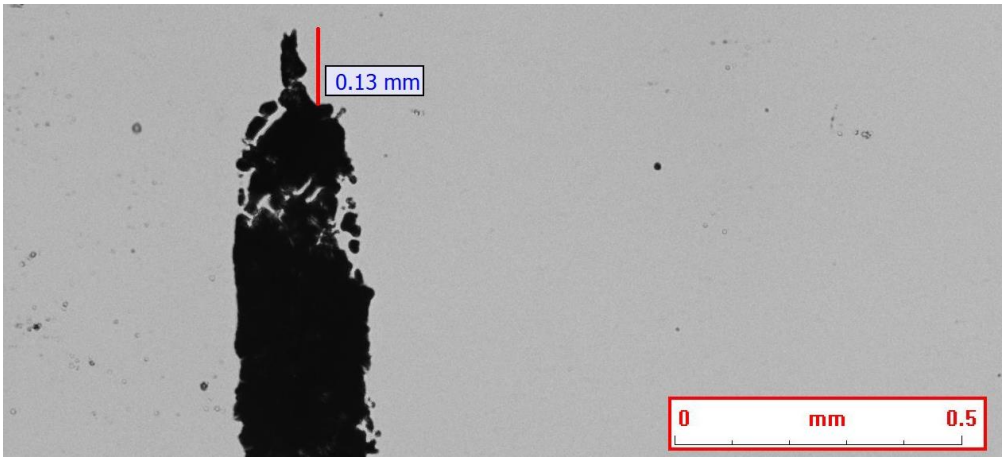


Figure 82: SCC1a-7-15 after gas pipeline condition test

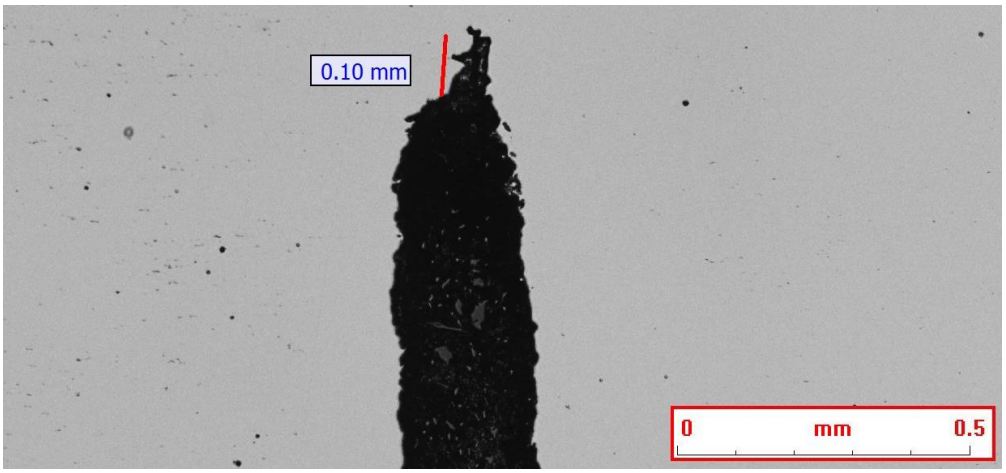


Figure 83: SCC1a-8-15 after gas pipeline condition test

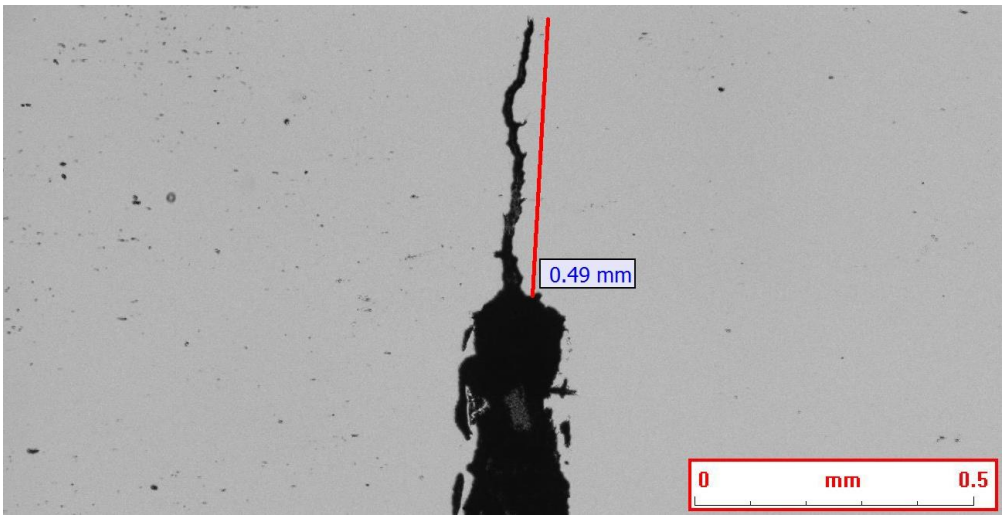


Figure 84: SCC1a-11-13 after gas pipeline condition test

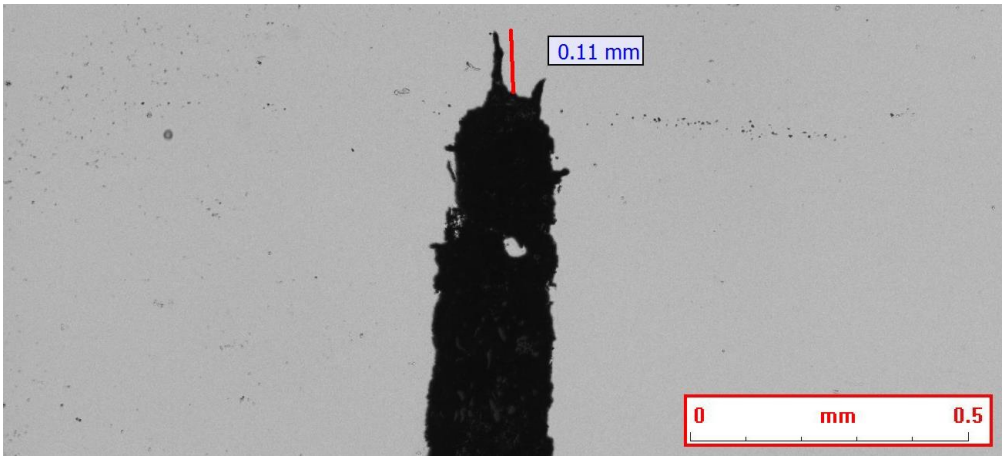


Figure 85: SCC1a-12-13 after gas pipeline condition test