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Fill Stem Manufacturing Changes and Pinch Weld Qualifications

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Title: Fill Stem Manufacturing Changes and Pinch Weld Qualifications

APPROVALS

P.S. Korinko, Author Materials Compatibility and Welding Technology	Date
D.N Maxwell, Author Materials Compatibility and Welding Technology	Date
E.A. Clark, Technical Reviewer Materials Compatibility and Welding Technology	Date
W.L. West DP Weld Engineer	Date
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Background

In March of 2007 a document was issued, see attachment I, that defined the test protocol and required welding for the Kansas City Plant to change cutting oils from the recently approved 50:50 oil to an oil with similar characteristics but with different chemistry, additives, and possibly a different vendor due to plans by the current vendor to stop preparing the oils that are used in the KCP 50:50 mix.

The KCP manufactured stems with the existing 50:50 oil blend in late FY07 and SRNL welded the stems and evaluated them in agreement with the test plan. This report provides all the data from these set-up and test welds. Set-up welds were shot and low and high voltages (currents) to ensure the window limits were applicable and then additional welds were made to validate the window. The purpose of this report is to ensure that the agreed upon path forward is still applicable.

Results

Set-up Welds

Type 316 Stainless Steel

The set-up welds were made at voltages consistent with the currents used in the plant for Type 316 stainless steel; samples are identified as B###. The target current range was 3300-3700 A. The low current was 3270 and the upper was 3680 which resulted in bond ratings of 3 and 1, respectively. The voltage was increased slightly and another weld was made at 3346 A which resulted in a class 1 bond. Subsequent samples were welded approximately 100 A higher. The weld conditions and response variables are provided in Table 1.

The set-up welds were useful in that the initial conditions did not all meet the weld criteria established for the Type 304L stainless steel stems that were previously studied (Ref. 1). However, a weld window for 316 stainless steel stems machined with 50:50 oil was established. The micrographs showing the weldments are in Appendix A.

21-6-9 Stainless Steel

Set-up welds for 21-6-9 were shot between 345 and 405 volts (3490 and 4150 A); 21-6-9 stems are designated C###. The welds within this voltage (current) range exhibited acceptable cold welds and an unacceptable hot weld, i.e., a weld expulsion (spit). The response variables are listed in Table 2. Even at the low current weld conditions the closure lengths are fairly long. The micrographs of these welds, with the exception of the spit weld are in Appendix B.

Table 1. Set-up Weld Conditions for Type 316 Stainless Steel Stems, PN PRJ706566-102

ID	Volt (V)	Force (lbs)	Press. (psi)	Stat. Res. (mΩ)	Dyn. Res. (mΩ)	Weld Current (A)	Weld Energy (J)	Weld Volt (V)	Displ. (in)	Closure (in)	Extr. (in)	Comments Rad.	BR	Comments Met.
B061	327.8	1252	108.7	0.321	0.244	3276	513.2	0.800	0.0183	0.140	0.002		3	Almost Cont.
B063	363.4	1253	108.8	0.296	0.228	3679	605.2	0.840	0.0221	0.172	0.014		1	Nugget
B062	334.6	1247	108.3	0.314	0.245	3345	535.0	0.820	0.0190	0.155	0.008		1	Nugget

Table 2. Set-up Conditions for 21-6-9 Stainless Steel Stems, PN PRJ706566-102

ID	Volt (V)	Force (lbs)	Press. (psi)	Stat. Res. (mΩ)	Dyn. Res. (mΩ)	Weld Current (A)	Weld Energy (J)	Weld Volt (V)	Displ. (in)	Closure (in)	Extr. (in)	Comments Rad.	BR	Comments Met.
C108	345.9	1506	130.1	0.307	0.228	3490	540.0	0.796	0.0207	0.160	0.009		2	Disc line
C110	381.5	1506	130.1	0.299	0.217	3895	638.1	0.845	0.0253	0.188	0.029		1	Nugget
C099	404.9	1508	130.2	0.296	0.208	4153	696.0	0.866	0.0279	0.185		SPIT		
C098	368.6	1506	130.0	0.293	0.222	3733	602.4	0.830	0.0254	0.184	0.015		1	Nugget

Table 3. Set-up Conditions for Type 304L Stainless Steel Stems, PN PRJ706566-102

ID	Volt (V)	Force (lbs)	Press. (psi)	Stat. Res. (mΩ)	Dyn. Res. (mΩ)	Weld Current (A)	Weld Energy (J)	Weld Volt (V)	Displ. (in)	Closure (in)	Extr. (in)	Comments Rad.	BR	Comments Met.
X0122	345.3	1254	108.9	0.292	0.227	3483	540.4	0.792	0.0197	0.152	0.004		2	Disc line
X0118	381.0	1256	109.1	0.293	0.214	3883	628.2	0.832	0.0237	0.177	0.014		1	With Melting

Type 304L Stainless Steel

Due to the significant amount of work that was completed during a stem manufacturing and pinch weld task, refs 2 and 3, there was higher confidence that Type 304L stems would be readily prepared. Table 3 contains the weld conditions used and the response variables. The weld window was consistent between the previous work and the current welds. The nominal weld window was 345 to 380V (3500 to 3900 A). The welds met all the requirements defined in Ref. 1. Appendix C contains typical micrographs.

Validation Welds

Type 316 Stainless Steel

Three welds were made at the low heat / current condition and three at the high heat condition. These welds were subjected to visual, dimensional, radiographic, pressure, and metallographic testing. The weld data for the six stems are listed in Table 4. Note that three of the cold welds were made about 10 V higher than the set-up welds but the closure and extrusion values are about the same. All of the samples passed the 40 ksi pressure test. After determining that these welds exhibited more melting than desired, two additional welds were made at 335 V. These welds were radiographed and metallographically examined, no pressure testing was done. All of the weldments had class 1 and 2 bonds as desired. The micrographs of the weldments are in Appendix D.

21-6-9 Stainless Steel

As was the case for the 316 stainless steel, the 21-6-9 samples were subjected to the same series of inspections and testing. The data are presented in Table 5. One of the low current samples, C101, exhibited a class 3 bond as rated by a qualified MTF pinch weld inspector. Management review by C. Kestin was not requested and it was decided to not reshoot this condition, since there are four welds at the low value and one that did not pass. The extrusion and bond lengths of the four low current samples are consistent. The micrographs of these six verification welds are shown in Appendix E.

Type 304L Stainless Steel

Two additional low current and two additional high current samples of type 304L SS stems were welded at the current defined previously. These welds were made to minimize stem usage and the confidence level was high that the weld conditions would be acceptable based on the previous extensive efforts (Refs 2, 3). Uniform weld data was achieved. The weld data are presented in Table 6 and the micrographs in Appendix F.

Table 4. Verification weld data Type 316 Stainless Steel Stems

ID	Volt (V)	Force (lbs)	Press. (psi)	Stat. Res. (mΩ)	Dyn. Res. (mΩ)	Weld Current (A)	Weld Energy (J)	Weld Volt (V)	Displ. (in)	Closure (in)	Extr. (in)	Com Rad.	BR	Comments Met.
B050	344.2	1254	108.8	0.307	0.236	3448	549.9	0.814	0.0194	0.154	0.007		2	Disc line with melt
B057	344.4	1252	108.6	0.306	0.237	3447	548.8	0.816	0.0194	0.155	0.008	Split	2	Disc line with melt
B058	344.4	1252	108.6	0.313	0.237	3449	551.8	0.817	0.0191	0.156	0.007	Split	2	Disc line with melt
B055	363.7	1253	108.7	0.314	0.229	3668	602.8	0.840	0.0223	0.170	0.020	.030 B	1	Nugget
B059	363.9	1253	108.7	0.303	0.226	3672	593.8	0.831	0.0221	0.168	0.016		1	Nugget
B060	364.2	1251	108.5	0.305	0.228	3672	598.6	0.838	0.0218	0.170	0.016		1	Nugget
B051	330.3	1252	108.4	0.312	0.245	3315.5	522.3	0.814	0.0851	0.145	0.004		2	Disc line with melt
B053	330.6	1257	108.8	0.308	0.243	3317.9	528.7	0.807	0.0854	0.147	0.006		2	Disc line with melt

Table 5. Verification weld data 21-6-9 Stainless Steel Stems

ID	Volt (V)	Force (lbs)	Press. (psi)	Stat. Res. (mΩ)	Dyn. Res. (mΩ)	Weld Current (A)	Weld Energy (J)	Weld Volt (V)	Displ. (in)	Closure (in)	Extr. (in)	Com. Rad.	BR	Comments Met.
C103	347.1	1505	129.8	0.302	0.228	3495	542.2	0.797	0.0221	0.161	0.007	Split	2	Disc line
C104	347.2	1505	129.8	0.303	0.230	3491	546.2	0.804	0.0214	0.161	0.010		2	Disc line
C101	347.4	1507	129.8	0.292	0.226	3497	540.5	0.790	0.0218	0.158	0.008	Split	3	Almost cont line
C105	369.9	1507	129.9	0.308	0.222	3744	609.2	0.833	0.0246	0.177	0.014	Split	1	Nugget
C102	370.7	1506	129.8	0.299	0.220	3758	604.8	0.828	0.0248	0.180	0.016	Split	1	Nugget
C109	371.0	1507	129.9	0.305	0.221	3760	607.1	0.831	0.0250	0.180	0.016		1	Nugget

Table 6.Verification weld data Type 304L Stainless Steel Stems

ID	Volt (V)	Force (lbs)	Press. (psi)	Stat. Res. (mΩ)	Dyn. Res. (mΩ)	Weld Current (A)	Weld Energy (J)	Weld Volt (V)	Displ. (in)	Closure (in)	Extr. (in)	Com. Rad.	BR	Comments Met.
X0119	345.7	1251	108.5	0.306	0.237	3467	558.2	0.821	0.0186	0.162	0.009		2	Disc line
X0116	345.7	1243	107.9	0.330	0.235	3469	546.2	0.815	0.0188	0.154	0.005	Split	2	Disc line
X0115	381.5	1251	108.5	0.318	0.219	3876	639.1	0.848	0.0215	0.180	0.017	Split	1	Nugget
X0120	381.9	1253	108.7	0.304	0.222	3870	645.1	0.858	0.0239	0.183	0.019	.033 B	1	Nugget

Summary

A series of welds were made on fill stems of Type 316, 21-6-9, and Type 304L stainless steel machined with the Koch's current machining oil termed 50:50. The weld window was established / verified for the alloys and several stems were welded at the low and high currents for the stems. All but one of the welds passed the inspection criteria.

The weld conditions defined in this task will be used to weld a series of ten stems made with the new machining oil that KCP will be implementing at the beginning calendar year 2008.

References

1. WSRC-RP-2005-01589, "Pinch Weld Technical Specification for Screening Design of Experiments (DOEx)", P. Korinko, May 2005.

2. KCP-613-8133, "Nuclear Weapons Complex Screening Experiment to Identify Variables Critical to Stem Closure Welds", K. Arnold (KCP) & P. Korinko, May 2006.

3. WSRC-STI-2006-00158, "Optimization Study for Fill Stem Manufacturing and Pinch Weld Processing", P. Korinko & K Arnold (KCP), Sept. 2006.

4. WSRC-STI-2006-00158, "Validation Study for Fill Stem Manufacturing and Pinch Weld Processing", P. Korinko & K Arnold (KCP), Aug. 2006

Acknowledgements

The authors would like to acknowledge the support and assistance they received from W. West, DP radiographers, MTF staff for reading test welds, T. Curtis and L. Thacker for metallographic sample preparation, G. Crowe, C. Allen, D. Holliday, G. Sides, and W. Good for pressure testing support.

Attachment 1. Original document describing machining oil change weld verification

SRNL-MST-2007-00066
Fill Stem Manufacturing Changes and Pinch Weld Qualifications
To: C. Cadden, B. Meyer, K. Arnold, D. Grote, J. McGrath, W. West, S. Mazurek, J. McCowan, S. West, M. Dupont, D. Maxwell

Based on previous discussions from the Stem Team the following protocol is recommended to ensure that manufacturing changes that are not expected to result in the need for a full qualification in the tritium facility. In order to accomplish this task with the fewest reasonable number of stems, the following plan is tendered:

1. Determine weld conditions on the SRNL prototypic welder for 316 stainless steel fill stems that produce class 1 and 2 bonds. Test stems of the PRJ706566-102 will be used. The stems will be machined with 50/50 cutting oil

A. Preliminary conditions for 316 based on email dated 3-6-07 from B. West
3/16" electrode, 1250 lbs +/- 50 lbs, current from 3300-3700 A for WR weld conditions
Weld in 2 atm of Nitrogen or deuterium
Weld one stem each at 3300 A and 3500A and 3700A
Proof test at 40ksi
X-ray for closure length, extrusion, and geometry
Transverse metallographic examination

B. Based on these conditions either increase or decrease current (voltage) range for welds, weld a new set to if range is changed.
Weld three 50/50 test stems at the low and high conditions, with current at low and force at high and current at high with force low, to ensure suitable weld parameters

2. Determine weld conditions on the SRNL prototypic welder for 21-6-9 stainless steel fill stems that produce class 1 and 2 bonds.

A. Preliminary conditions for 21-6-9 based on email dated 3-6-07 from B. West
3/16" electrode, 1500 lbs, current from 3750 to 4150 A for WR weld conditions (this simulates M conditions).
Weld one stem each at 3750 A, 3950A, and 4150A
Weld in 2 atm of Nitrogen or deuterium
Proof test at 60 ksi
X-ray for closure length, extrusion, and geometry
Transverse metallographic examination

B. Based on these conditions either increase or decrease current (voltage) range for welds.
Weld three 50/50 test stems at the low and high conditions, with current at low and force at high and current at high with force low, to ensure suitable weld parameters

3. Use current range established during fill stem project for 304L (3500-3900) A.

Based on these conditions weld three 50/50 test stems at the low and high conditions, with current at low and force at high and current at high with force low, to ensure suitable weld parameters

Using these conditions, weld a total of ten stems of each material manufactured using modified, i.e., changed cutting oil, process. Weld four stems at "cold" condition, three at midpoint (nominal) condition, and three at "hot" condition, varying force opposite of current. Use standard suite of non-destructive and destructive tests to ensure acceptable quality.

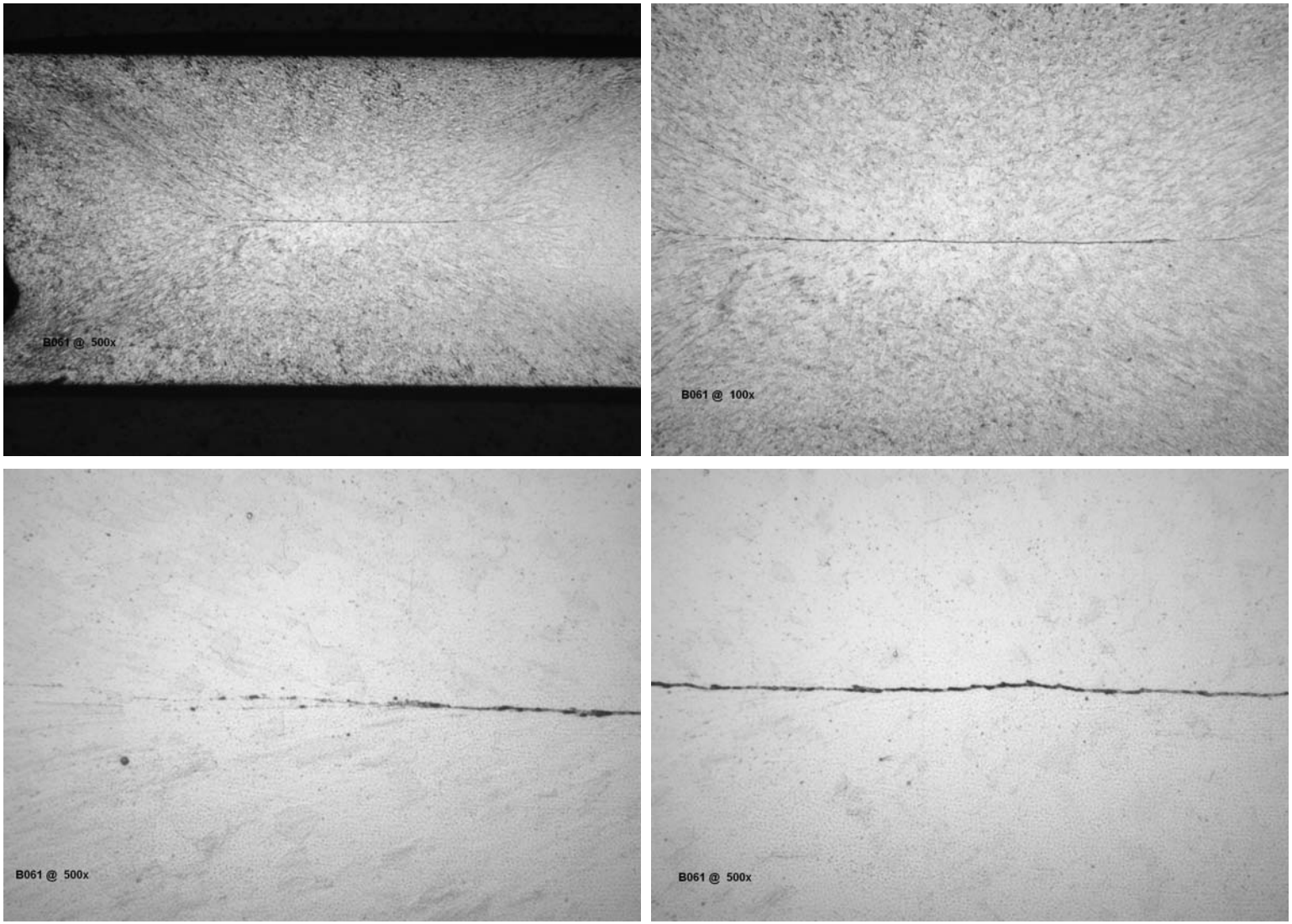
Upon successful completion of these tasks, issue report(s) detailing the work that was completed and circulate to stakeholders. Include recommendation indicating approval of process for WR components.

The Tritium Facility will weld qualification stems as part of their normal quality assurance program for equipment validation prior to loading reservoirs. A full requalification of the process will not be required.

Test stems needed:

Type	Quantity	Cutting Fluid	Purpose
21-6-9	6	50/50	Weld window tuning
21-6-9	6	50/50	Low and high validation
21-6-9	12	New	Process verification (and 2 contingency)
316	6	50/50	Weld window tuning
316	6	50/50	Low and high validation
316	12	New	Process verification (and 2 contingency)
304L	6	50/50	Low and high validation
304L	12	New	Process verification (and 2 contingency)

Appendix A. Micrographs of Type 316 stem pinch welds used for set-up.



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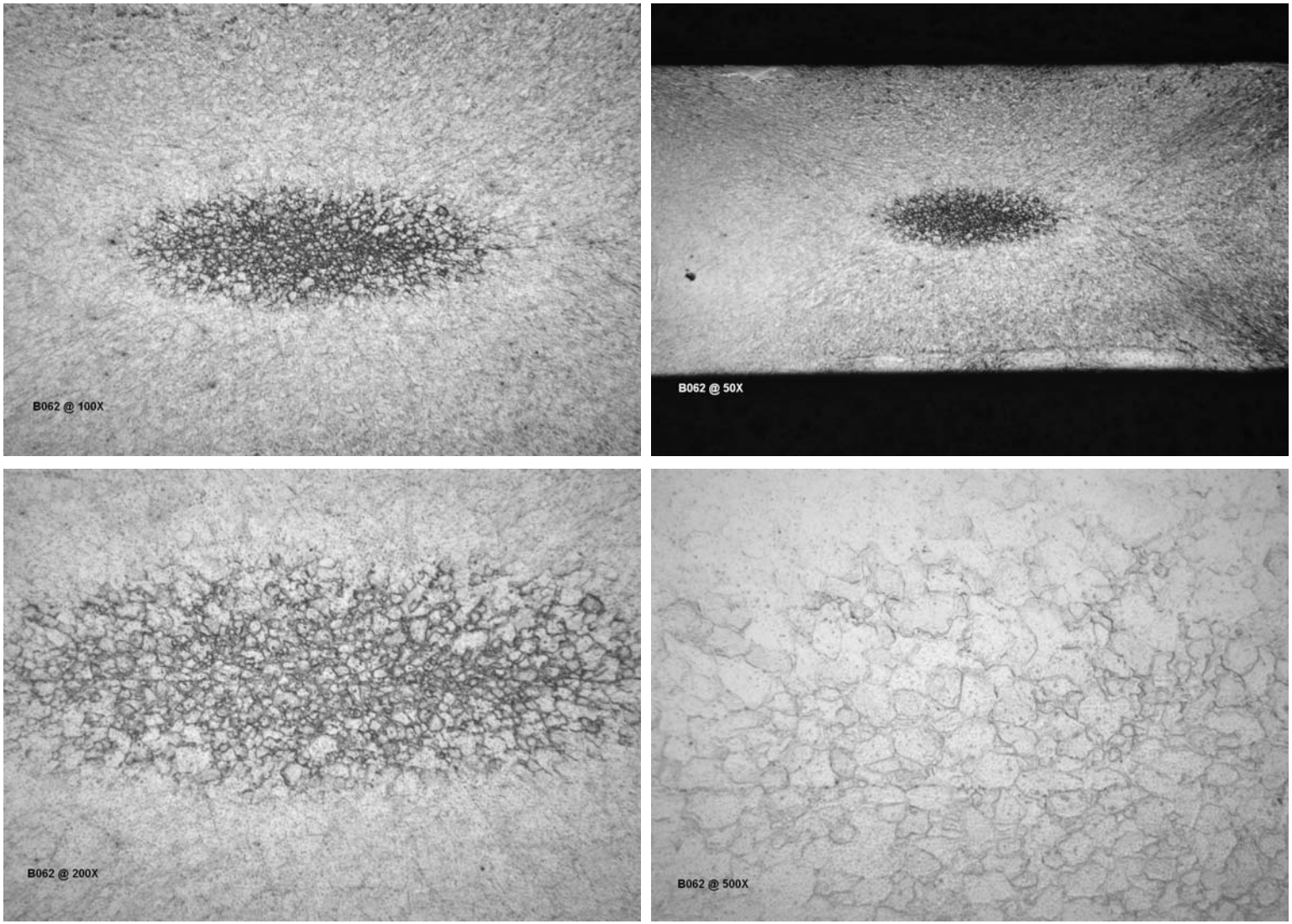

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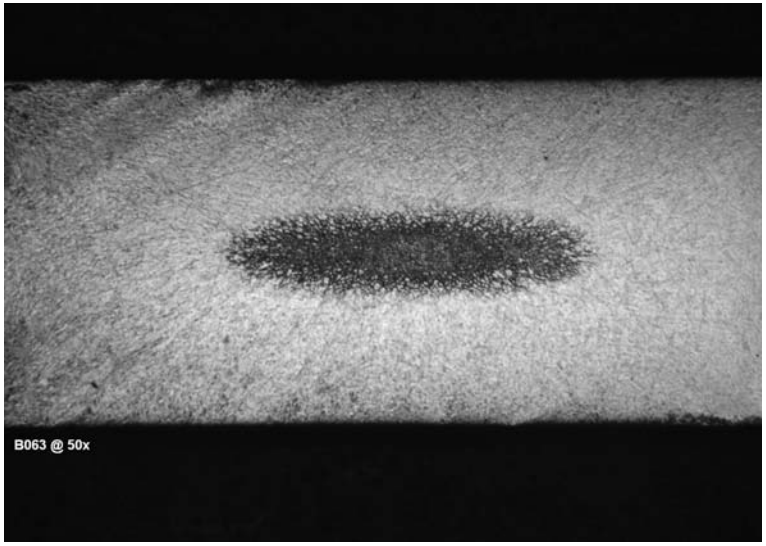

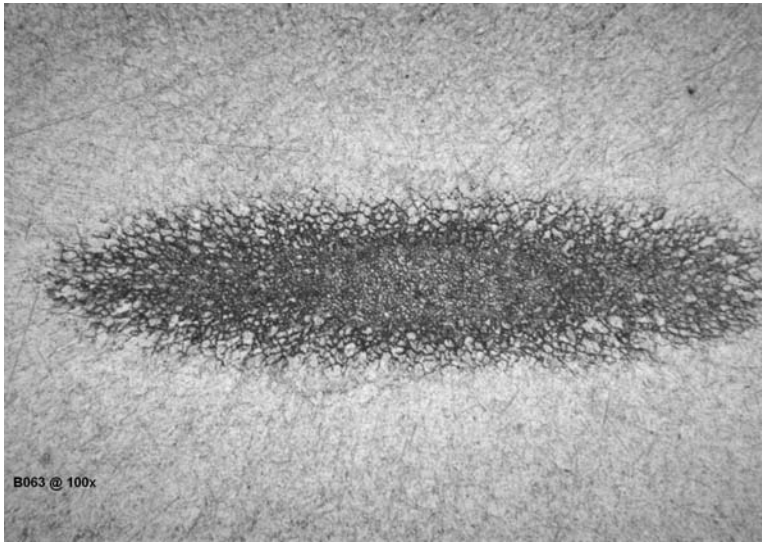

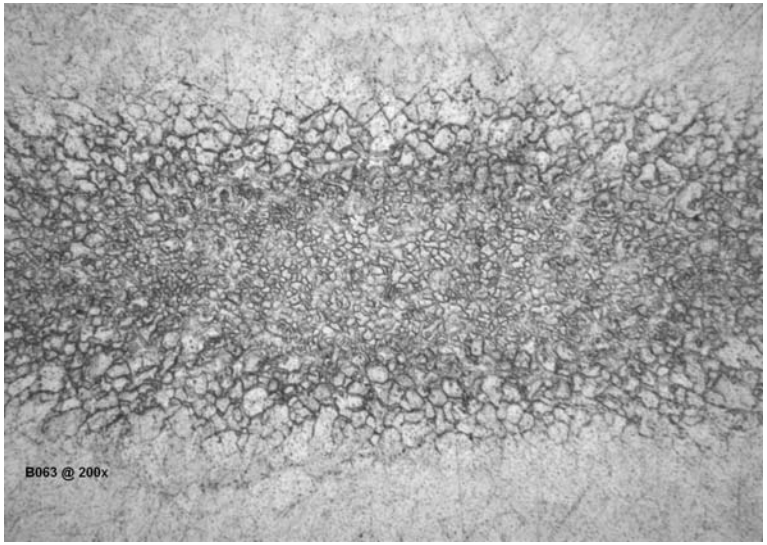

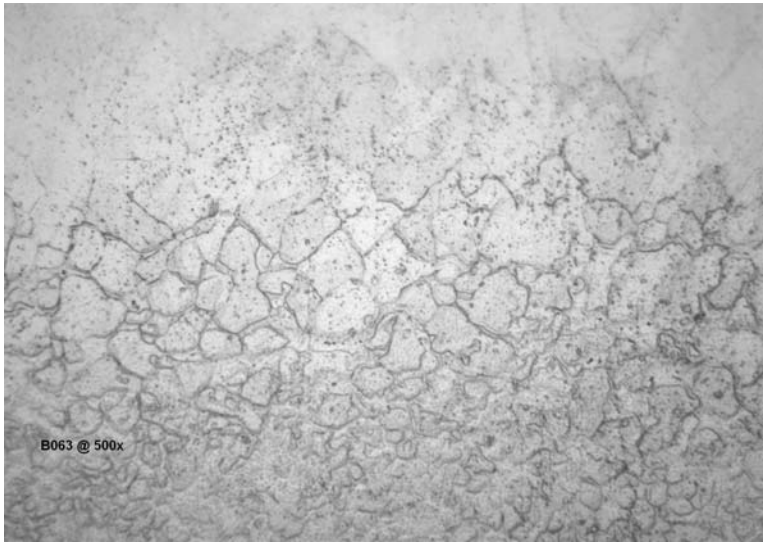

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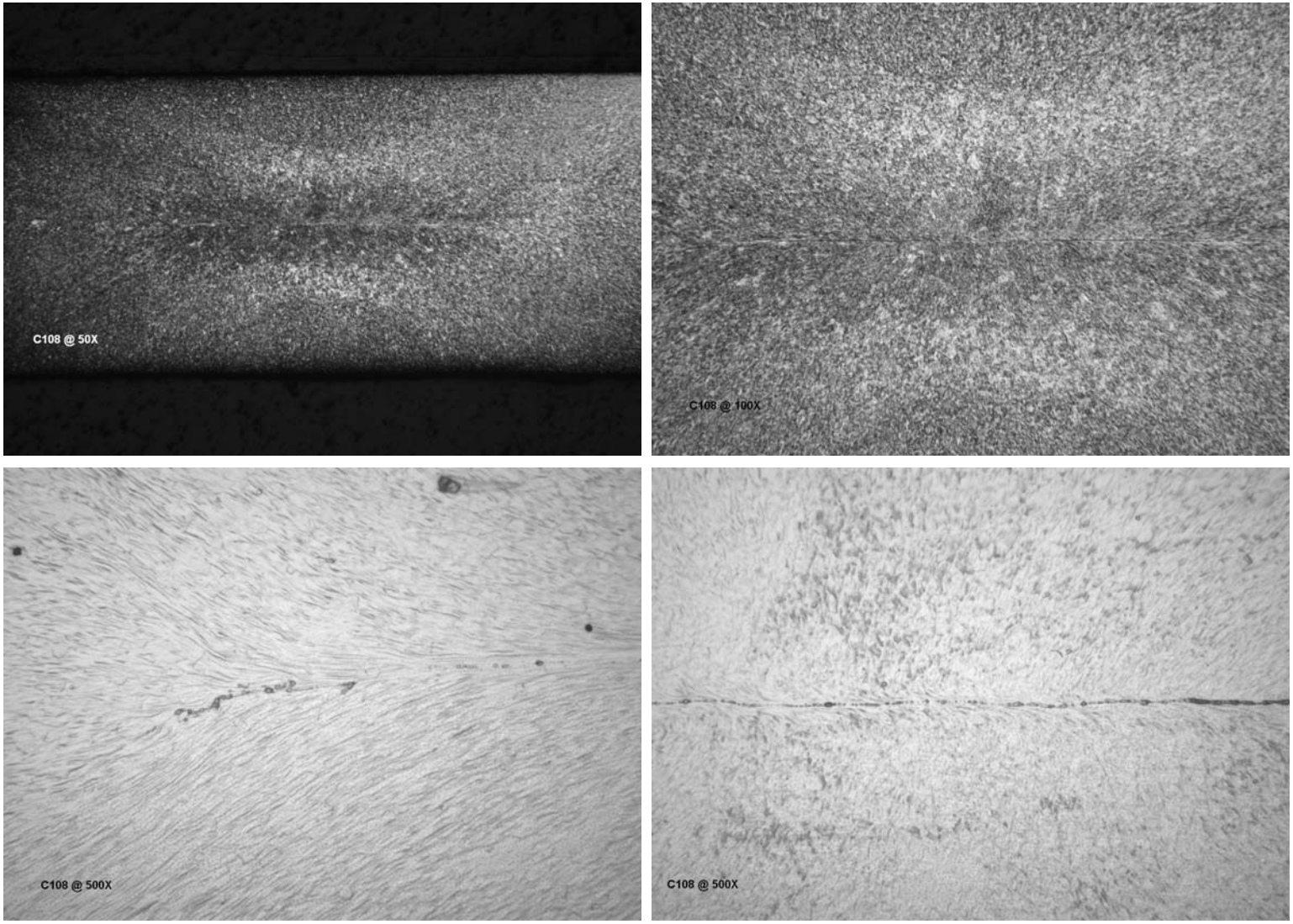
Appendix B. Micrographs of 21-6-9 stem pinch welds used for set-up.



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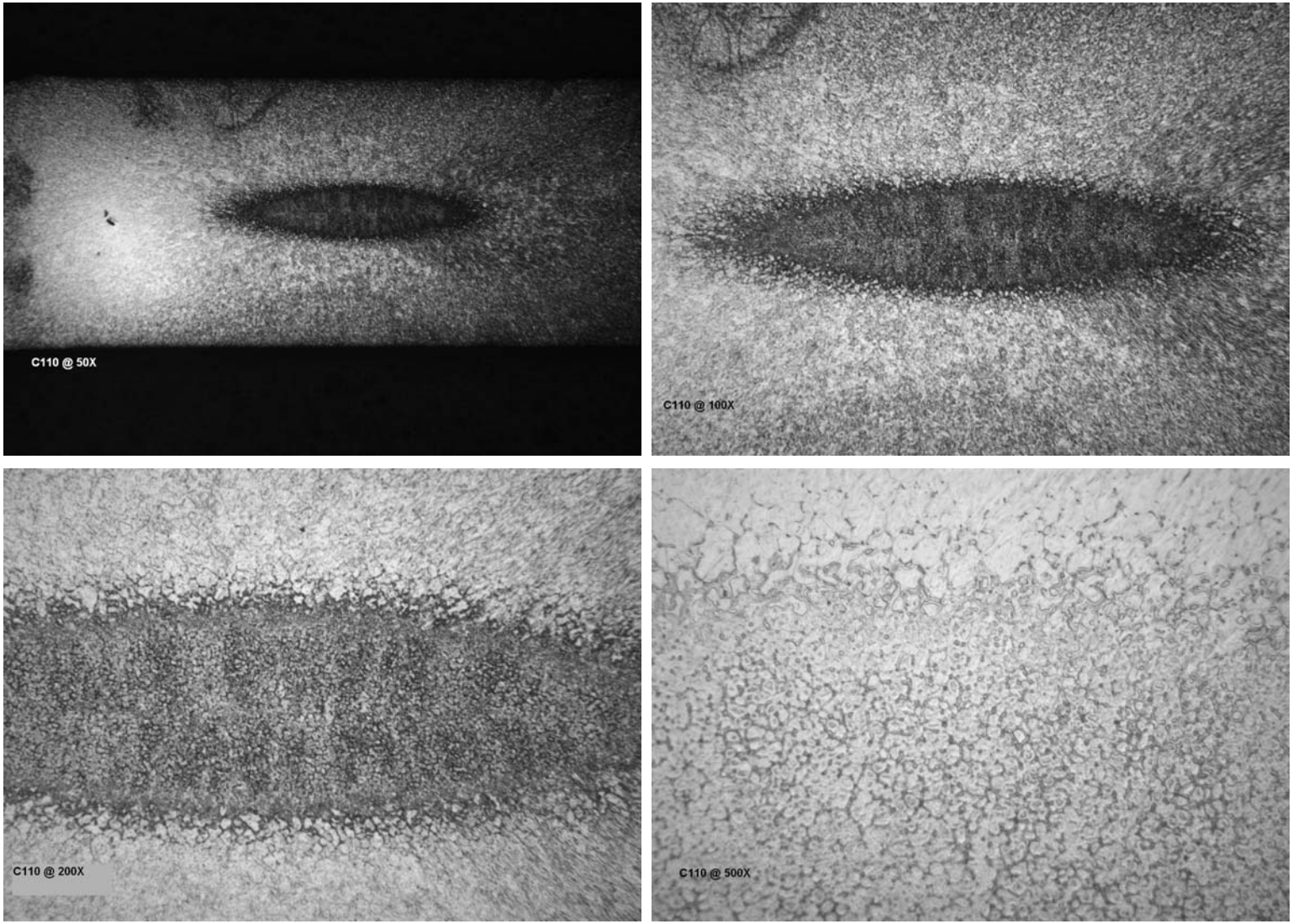

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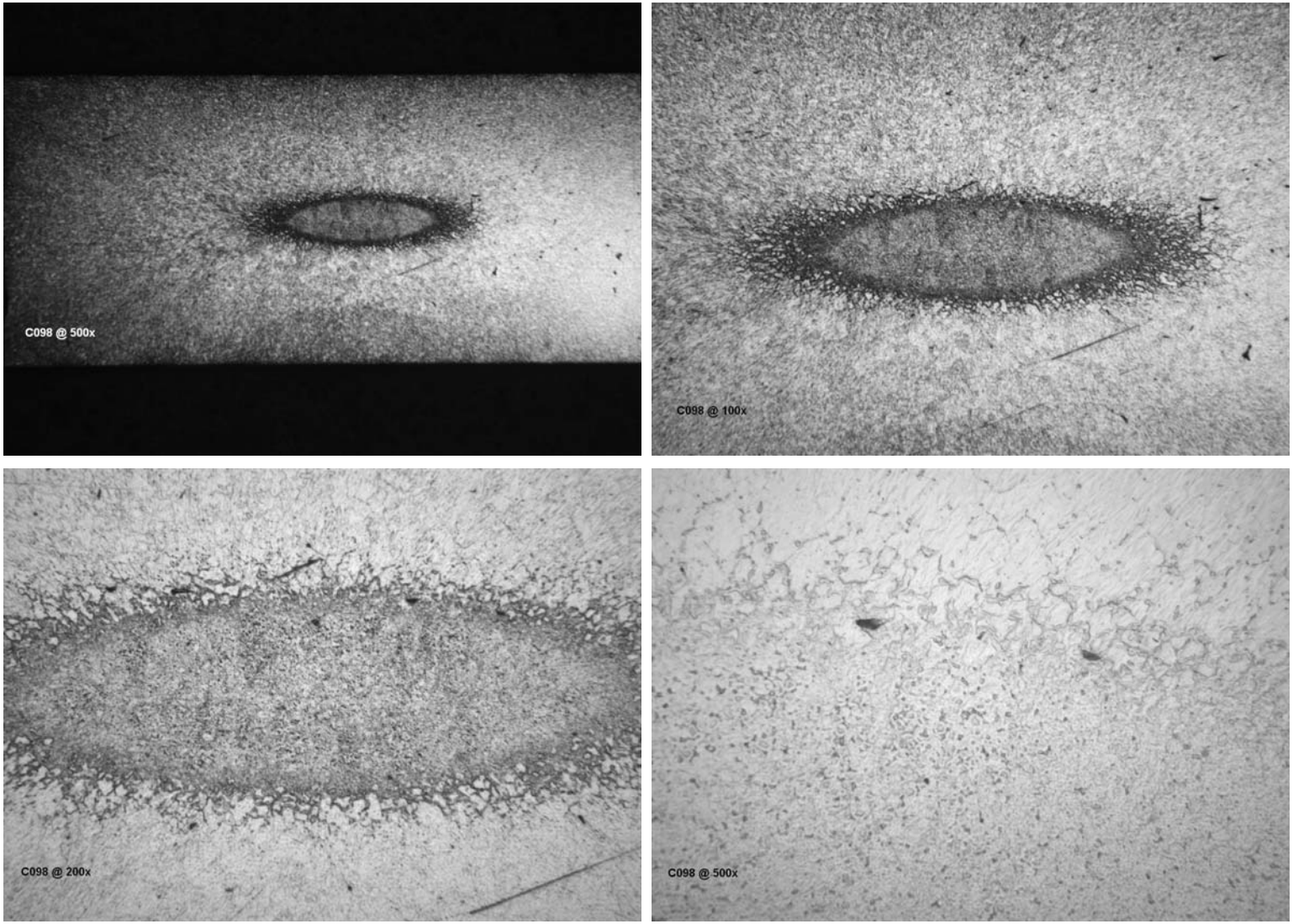

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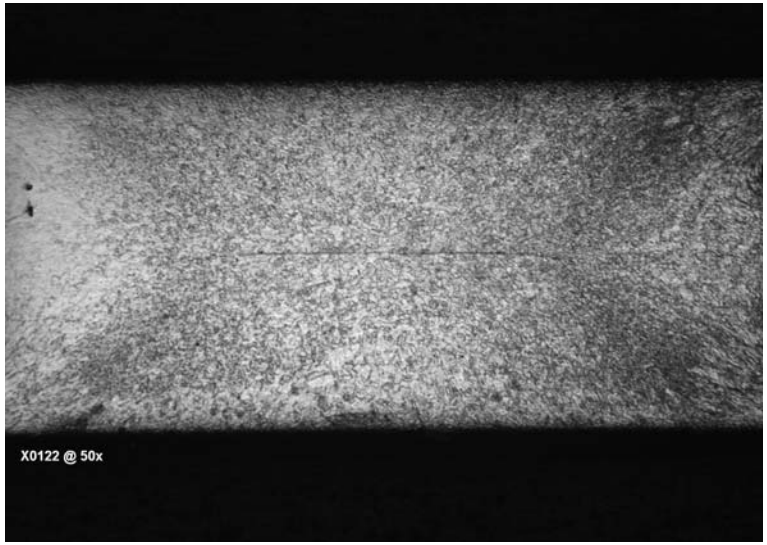
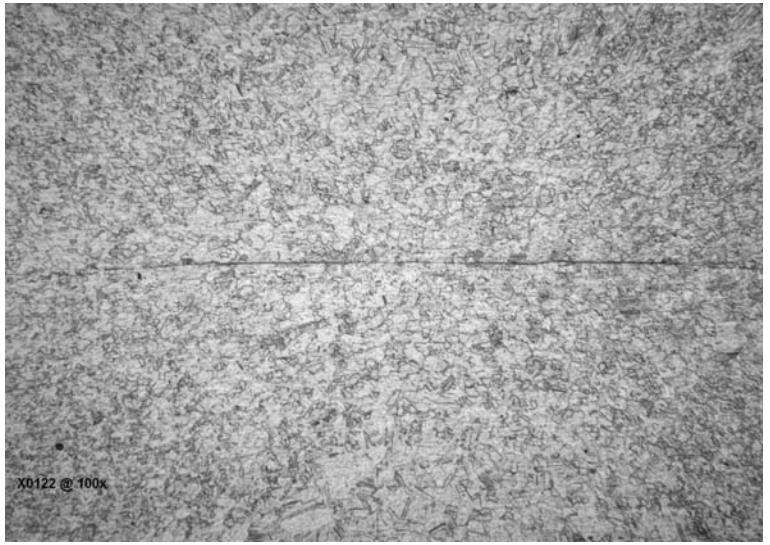
Appendix C. Micrographs of Type 304L stem pinch welds used for set-up





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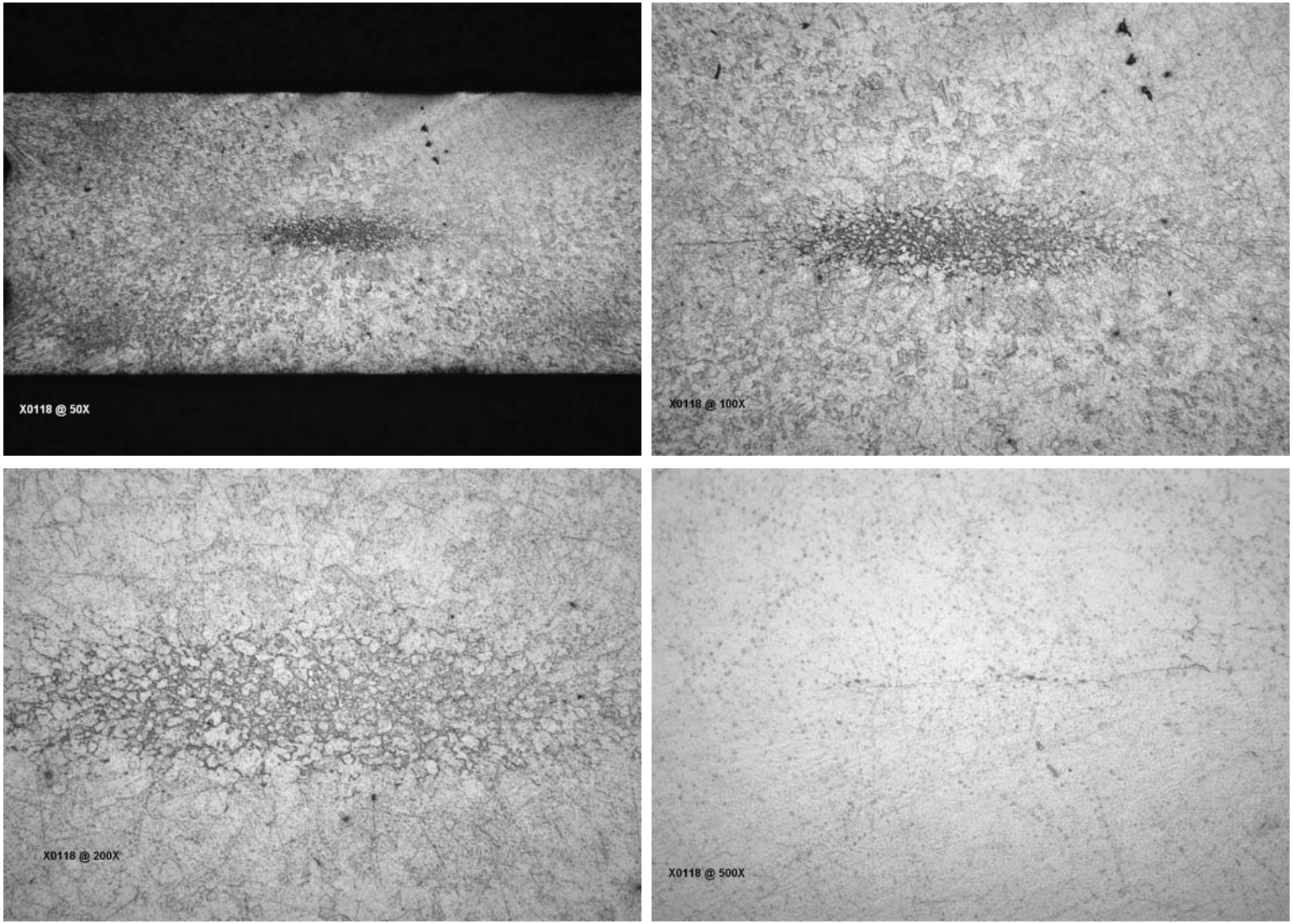

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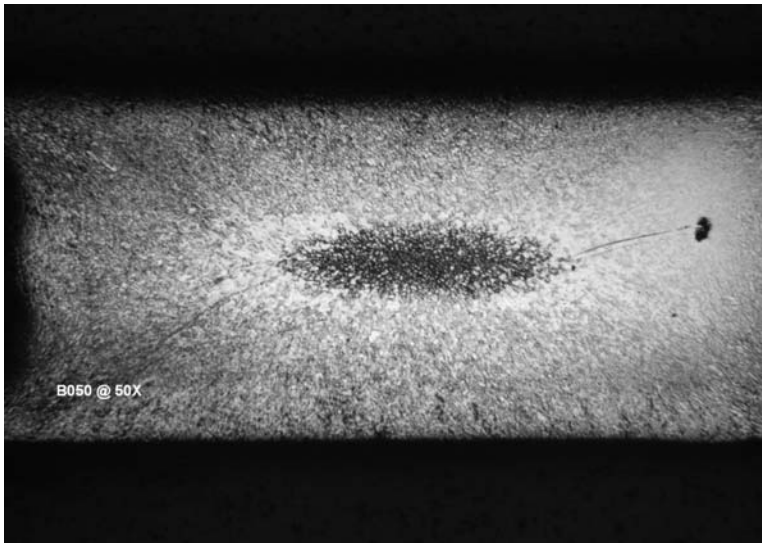
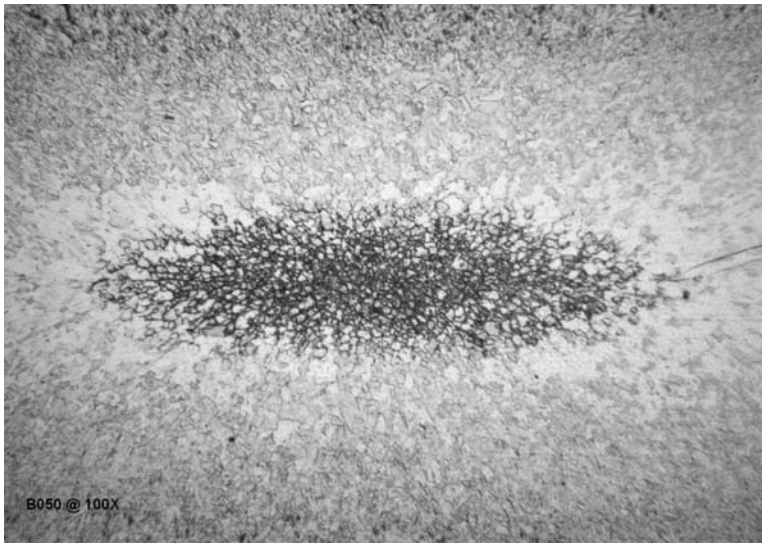
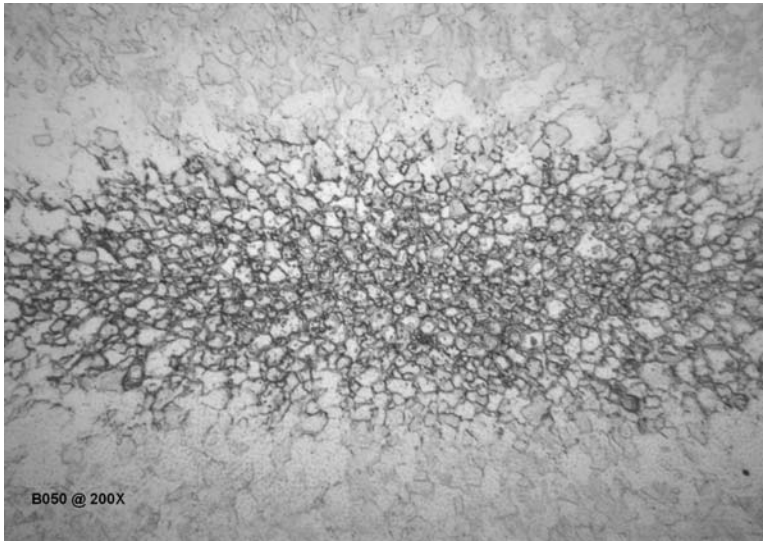
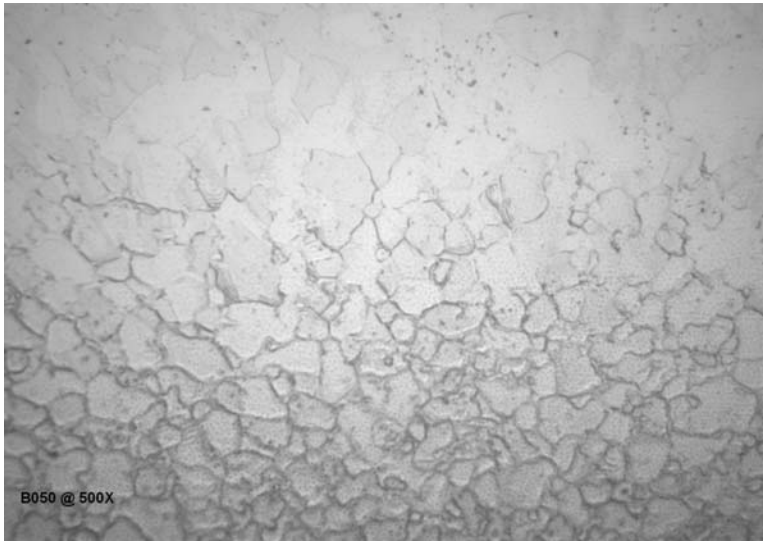
Appendix D. Micrographs of Type 316 stainless steel stems used for weld window verification.









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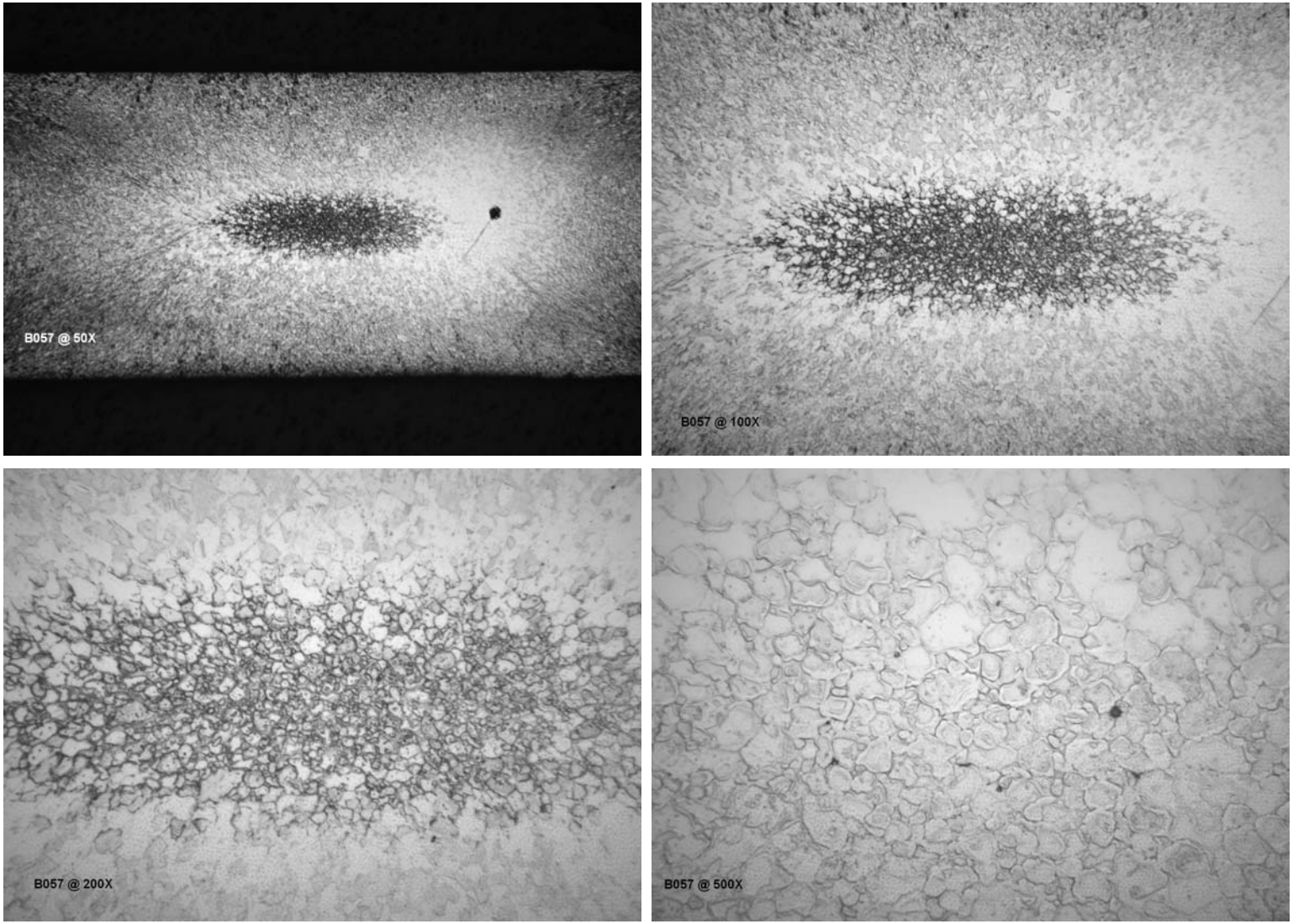

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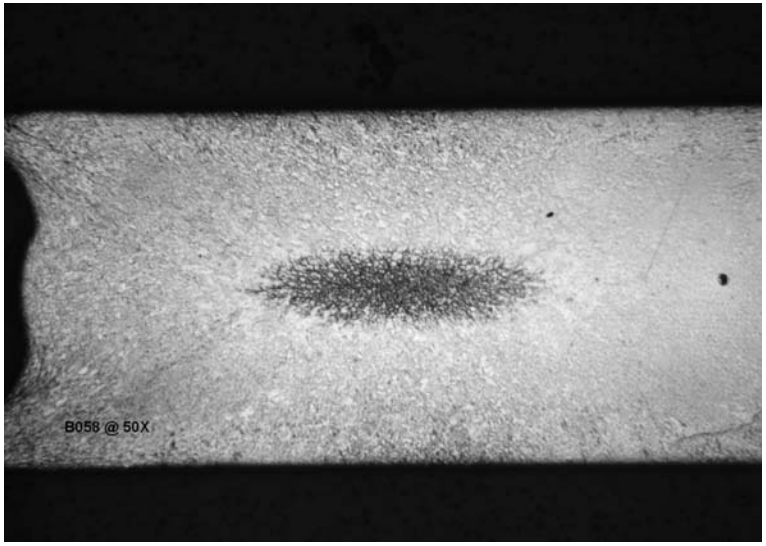

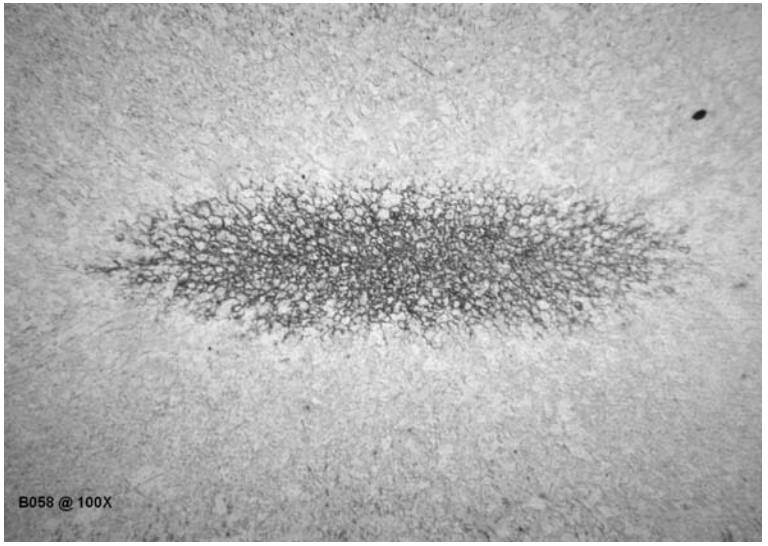

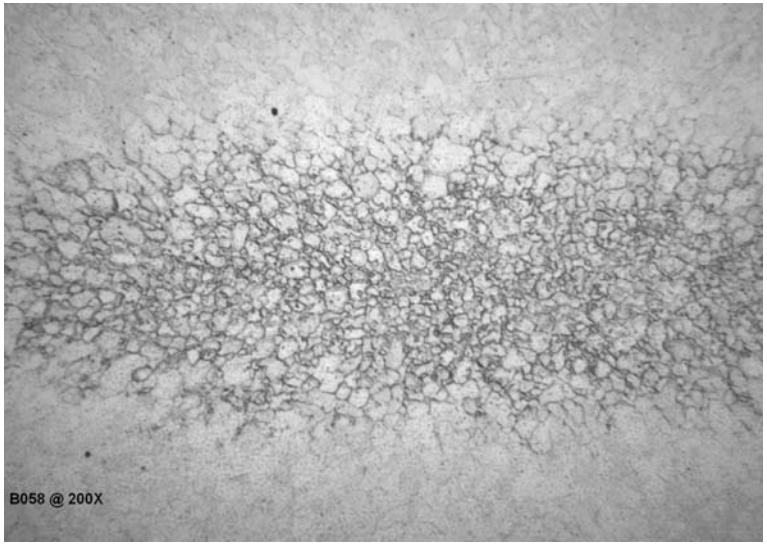

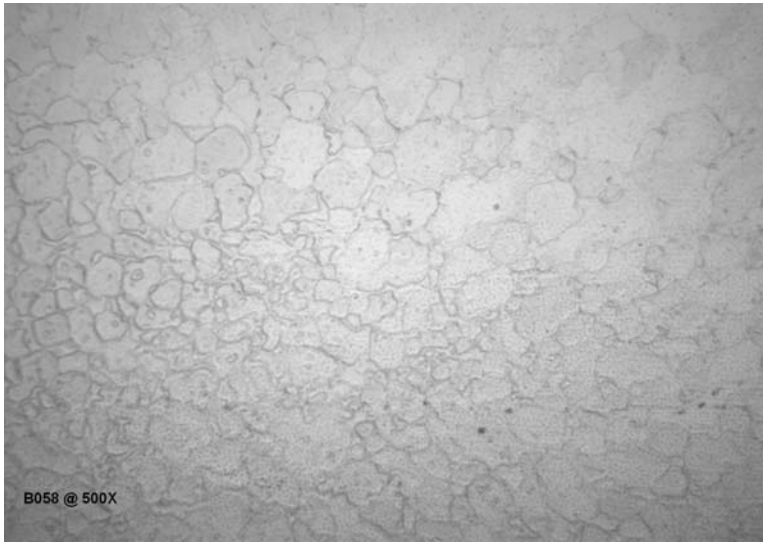

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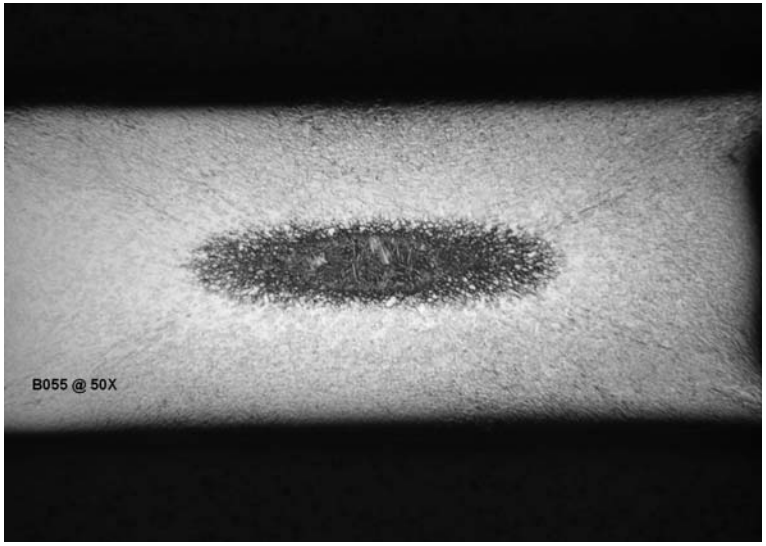
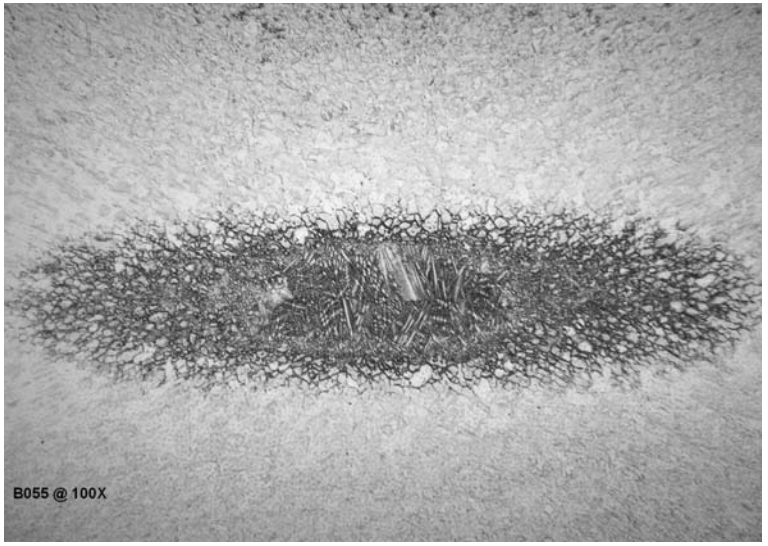
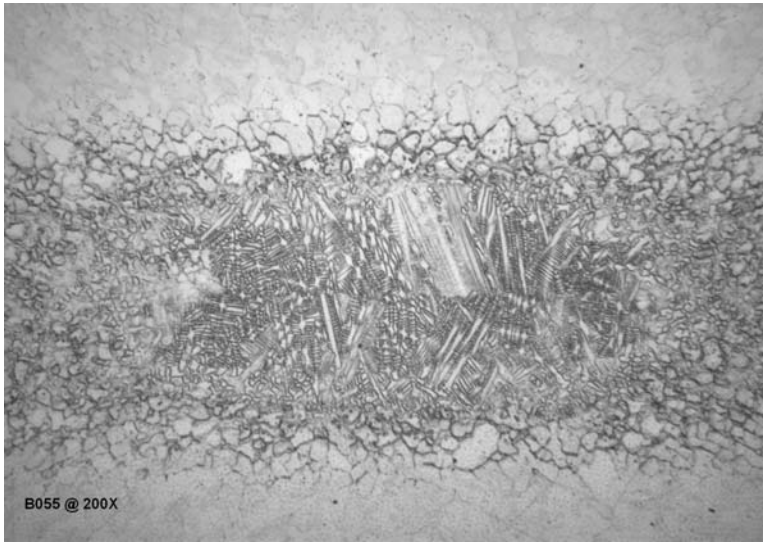
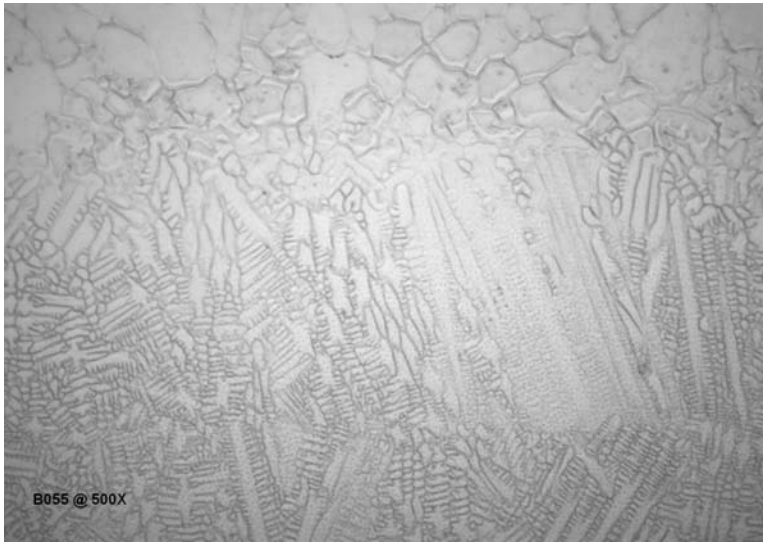
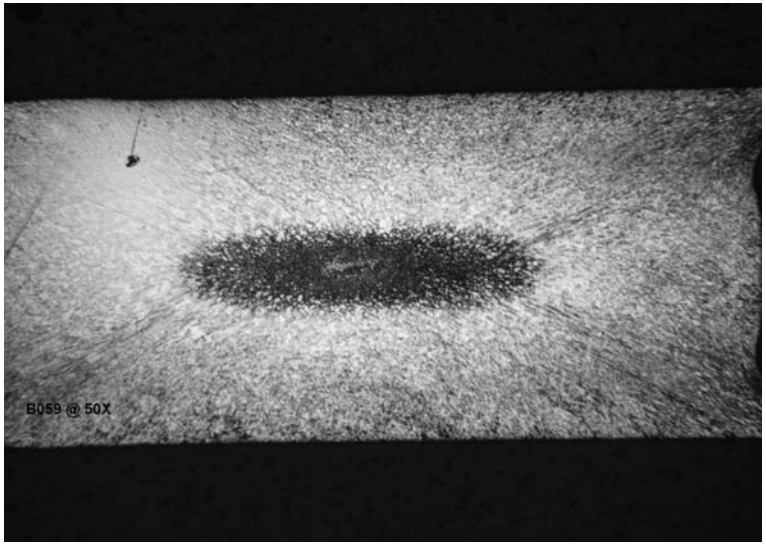


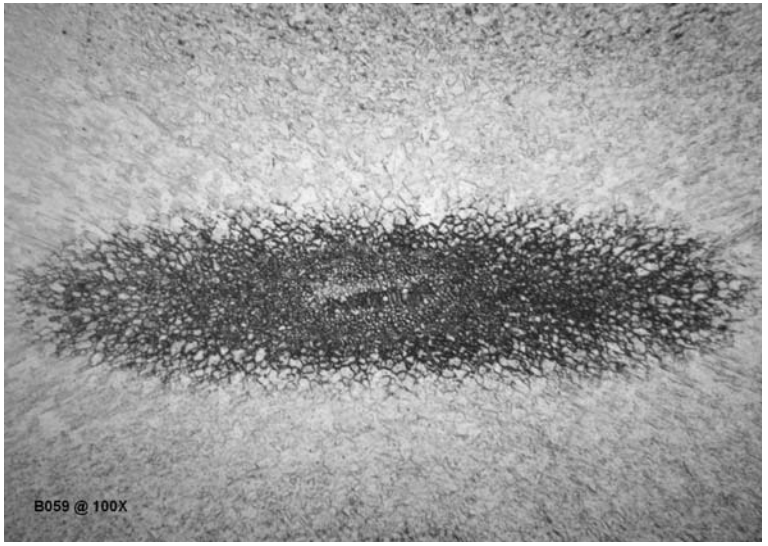


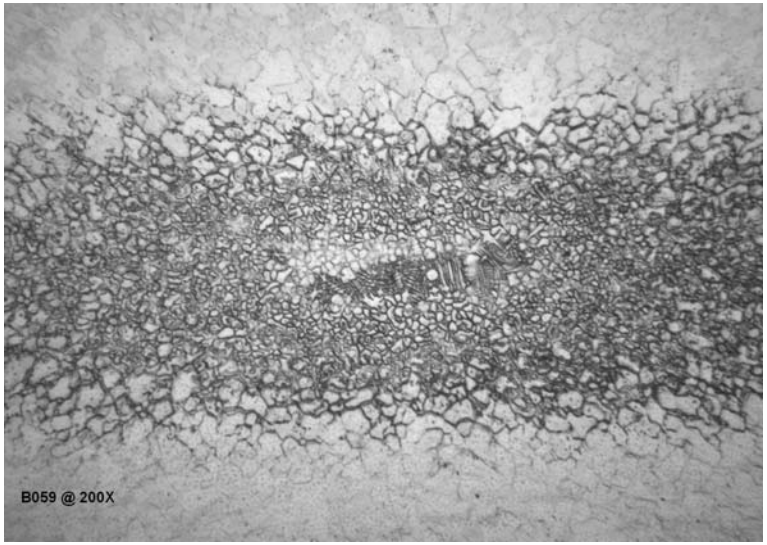


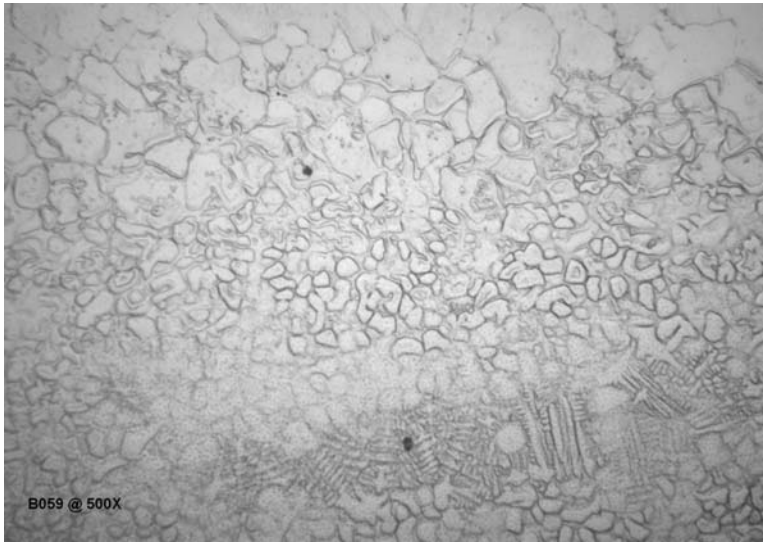


B055 High

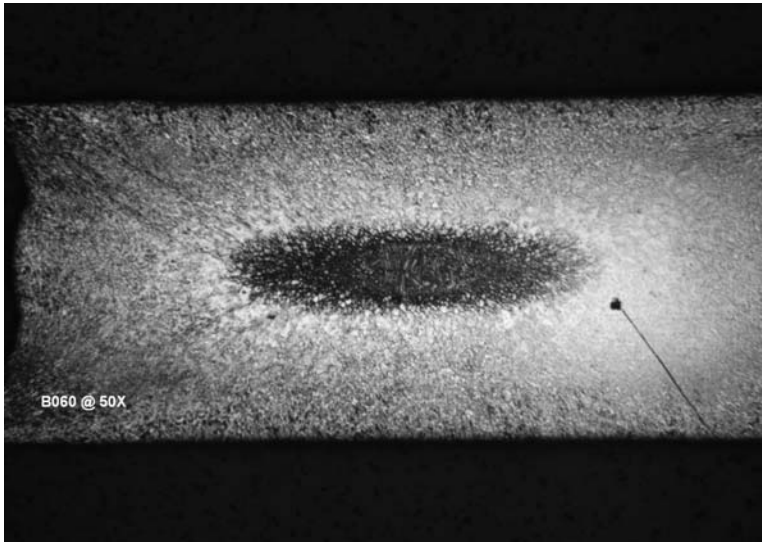


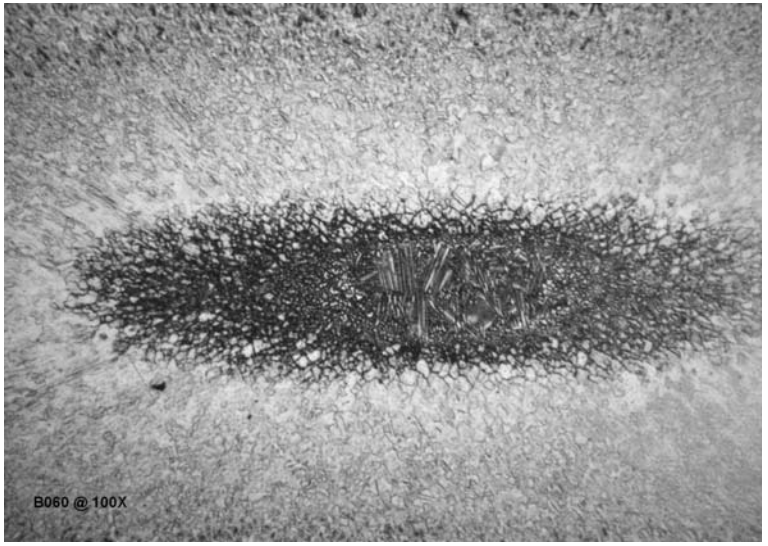


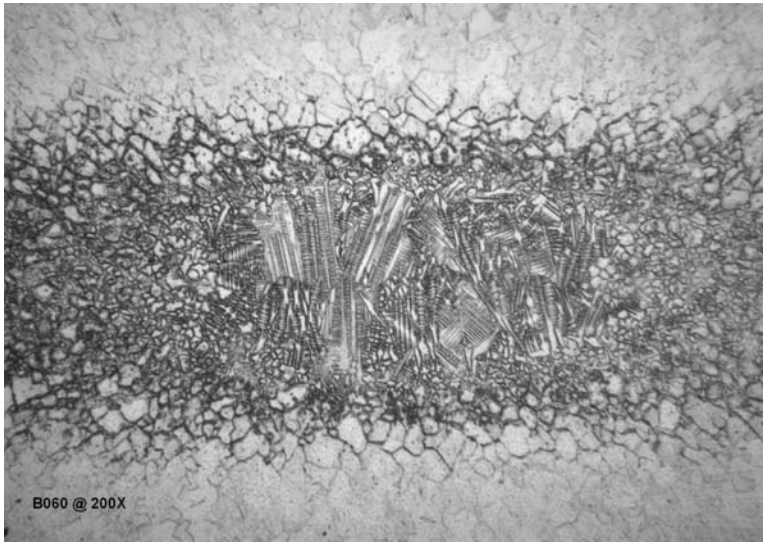


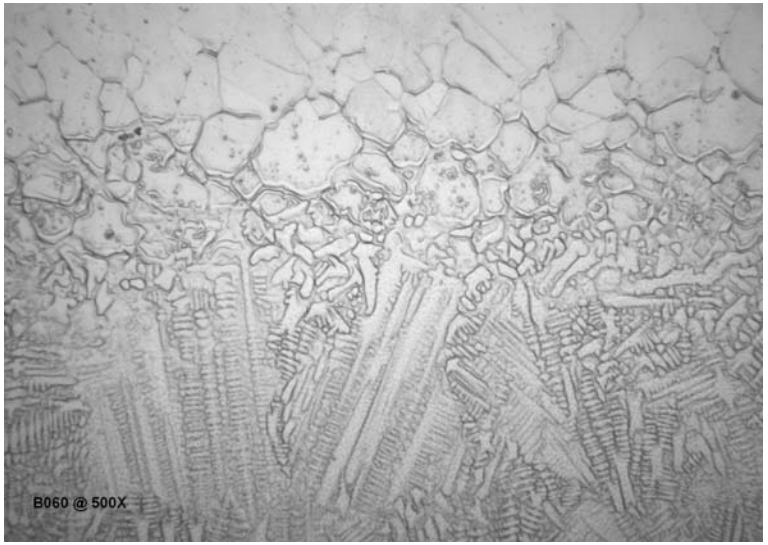


B059 High

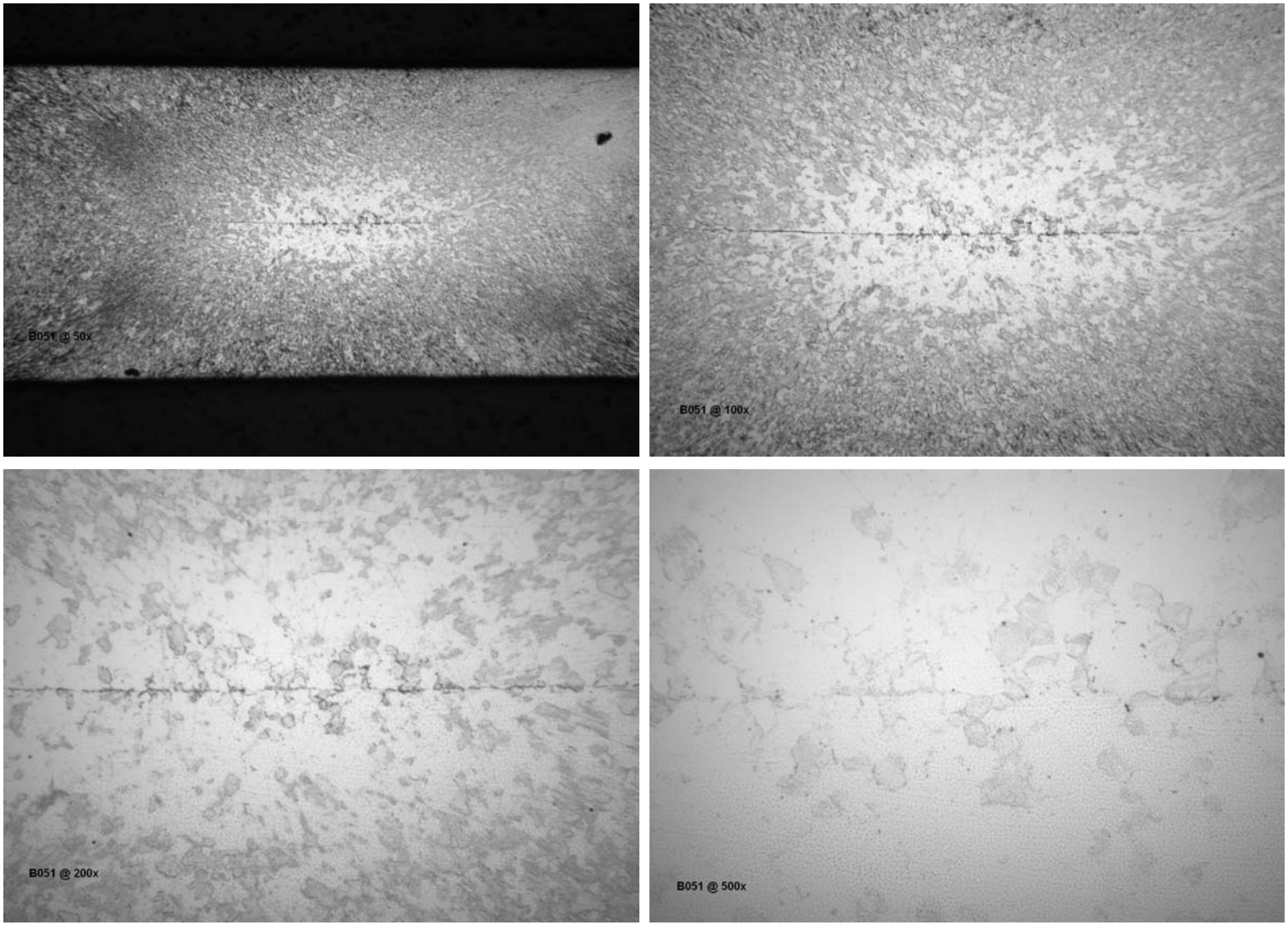




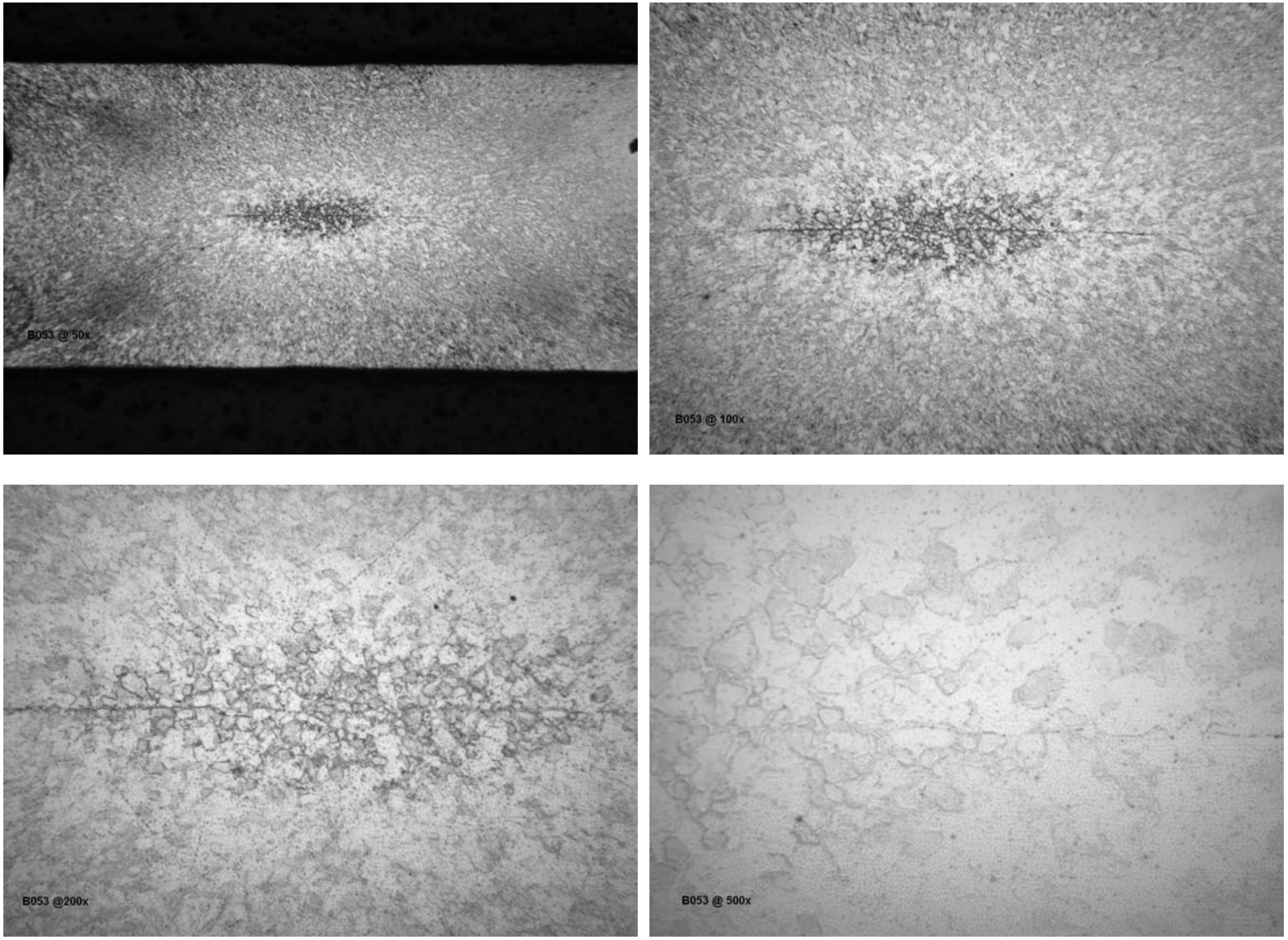




B060 High

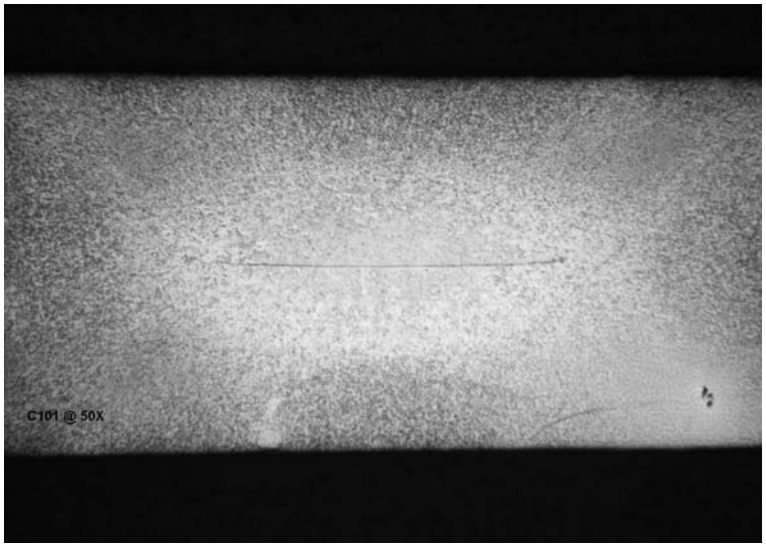


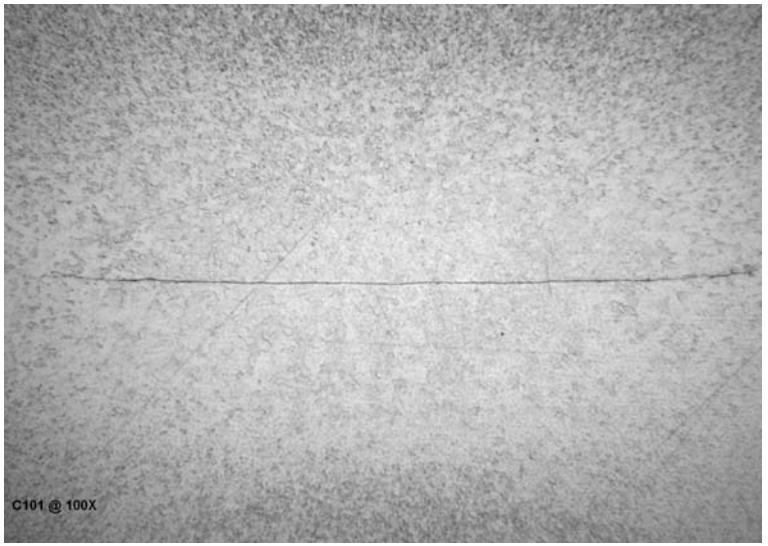
B051 New Cold Weld Condition

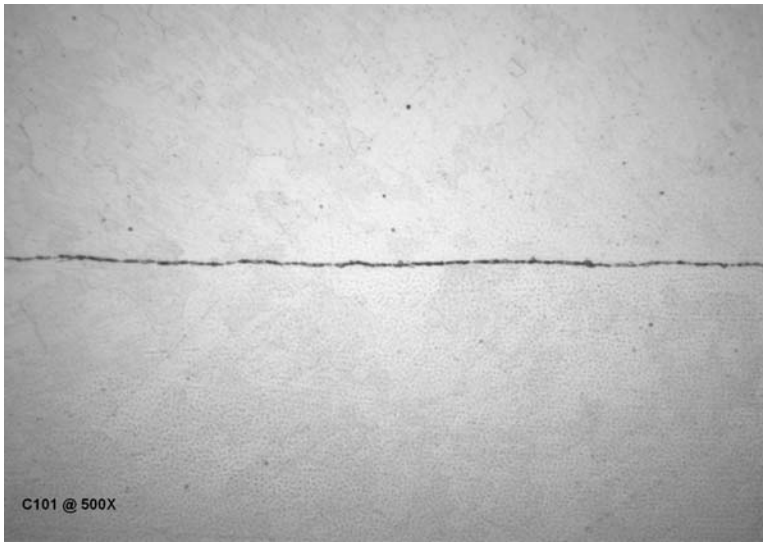


B053 New Cold Weld Condition

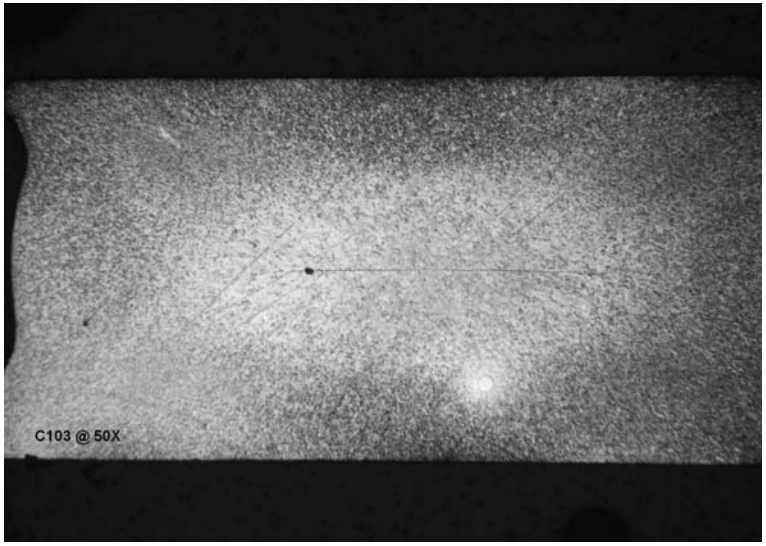
Appendix E. Micrographs of 21-6-9 stainless steel stems used for weld window verification.

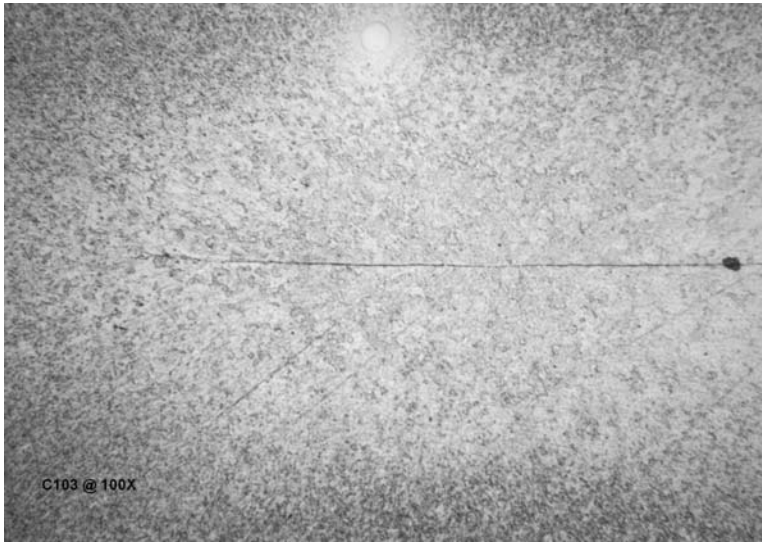


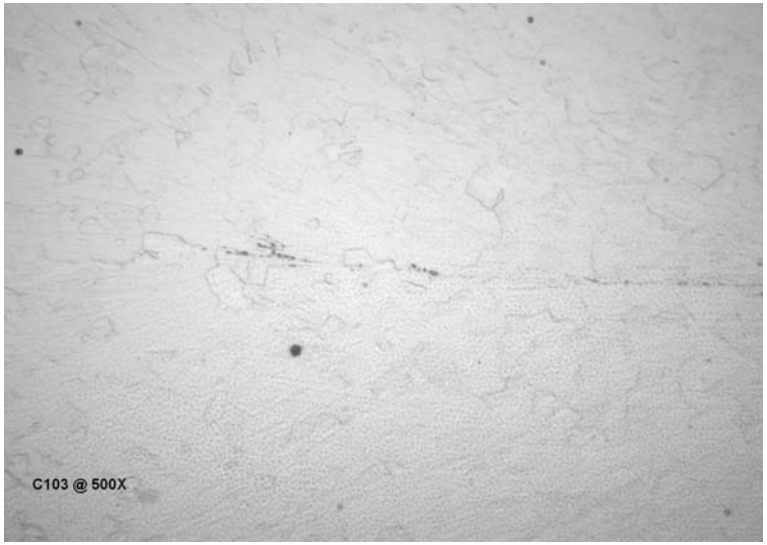


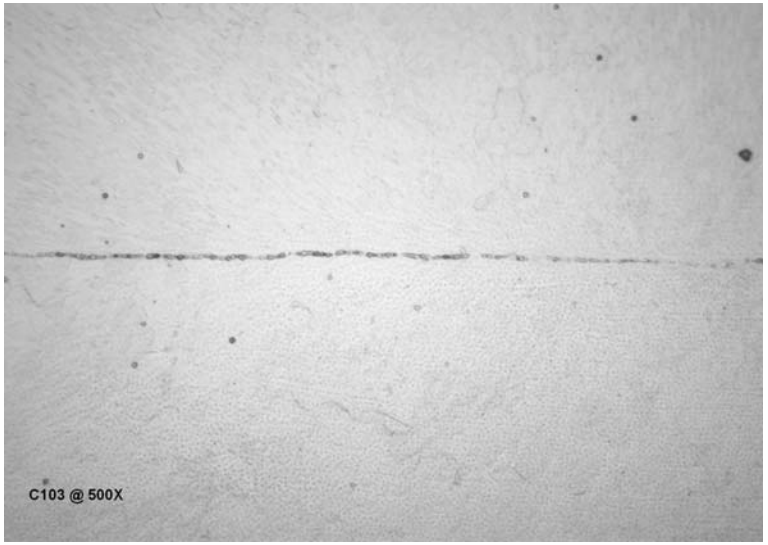


C101 Low

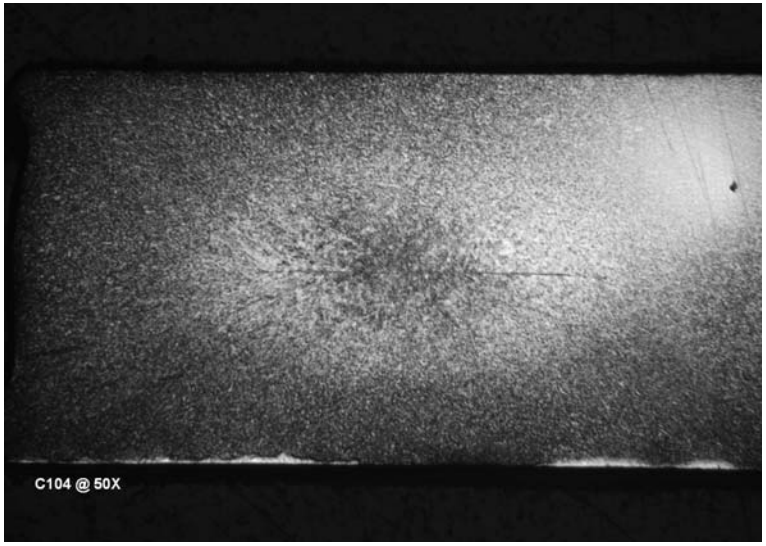


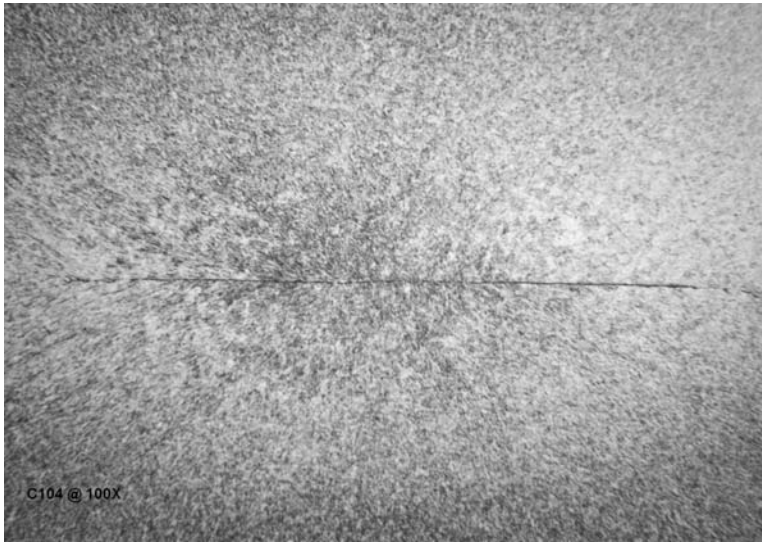




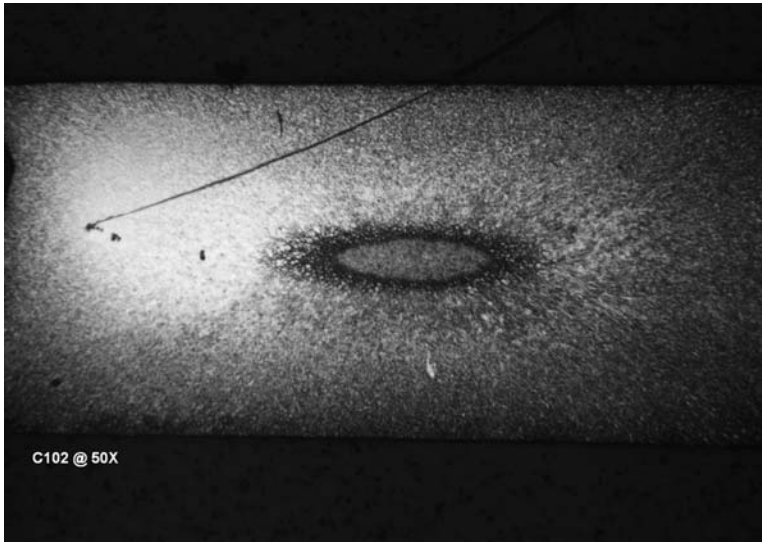


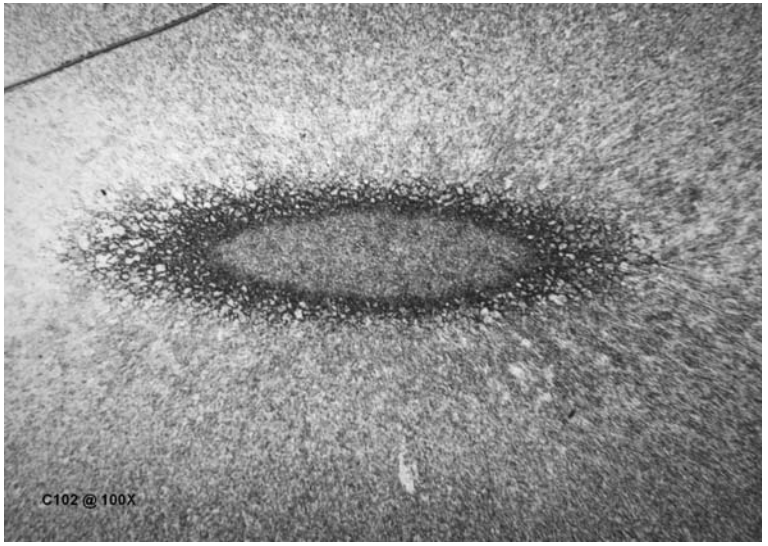
C103 Low

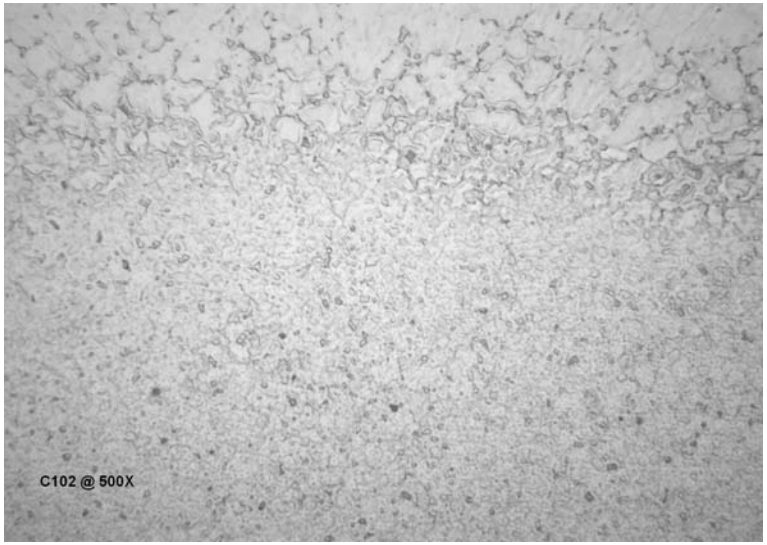


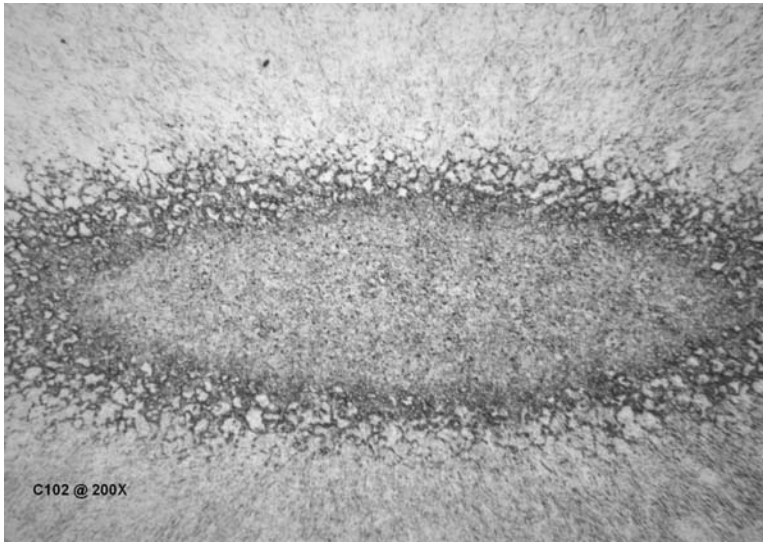


C104 Low

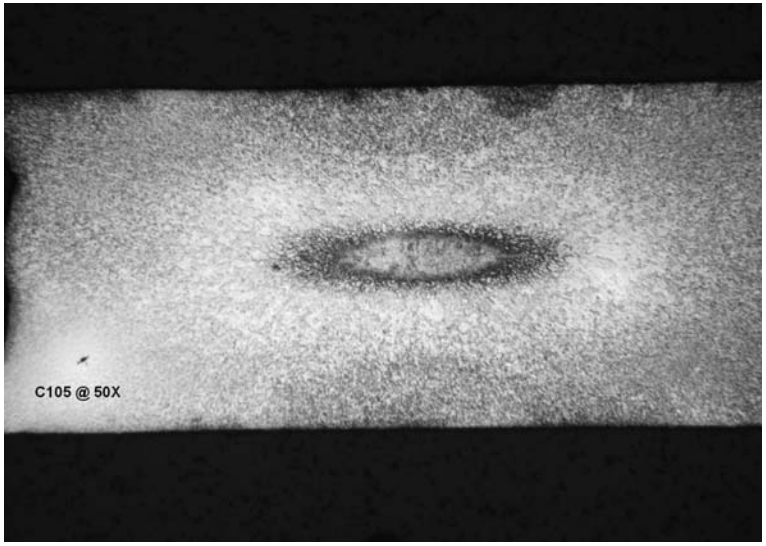


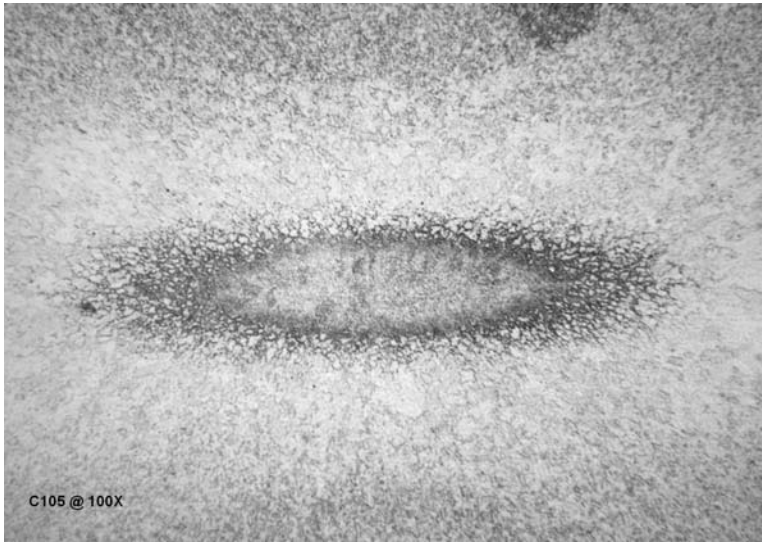


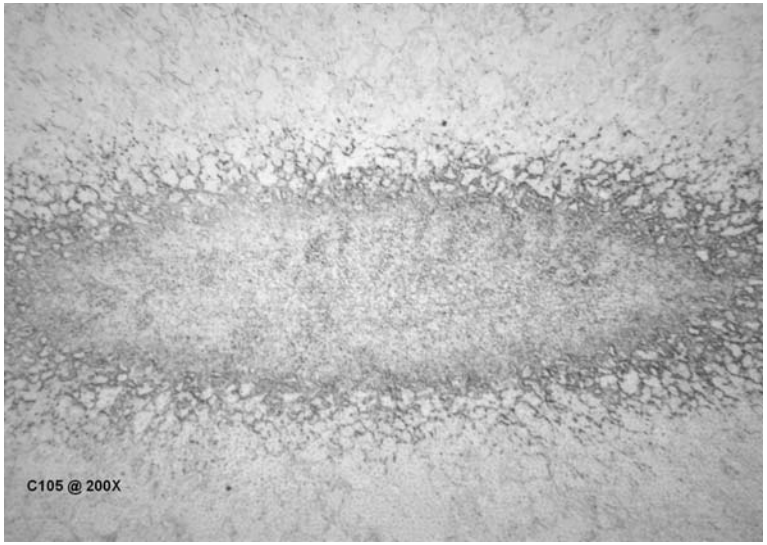


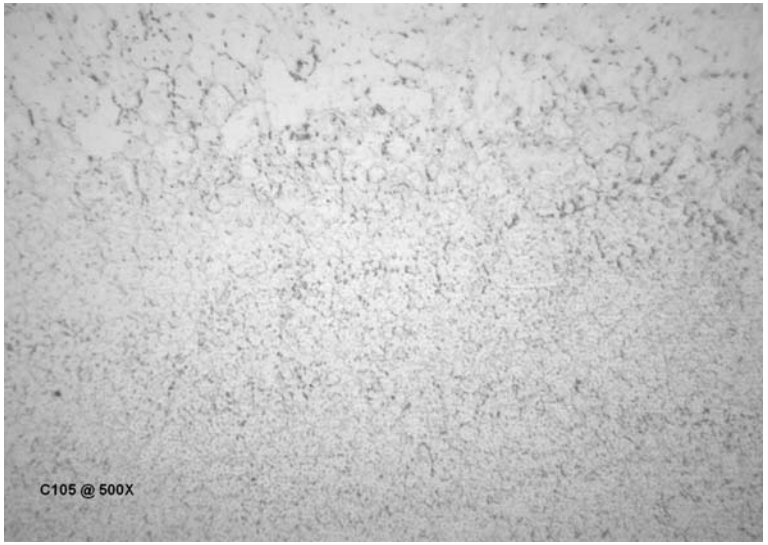


C102 High

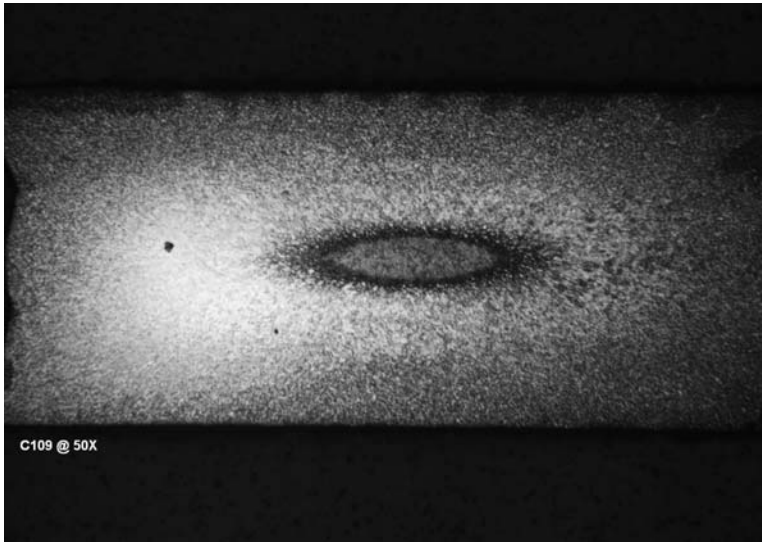


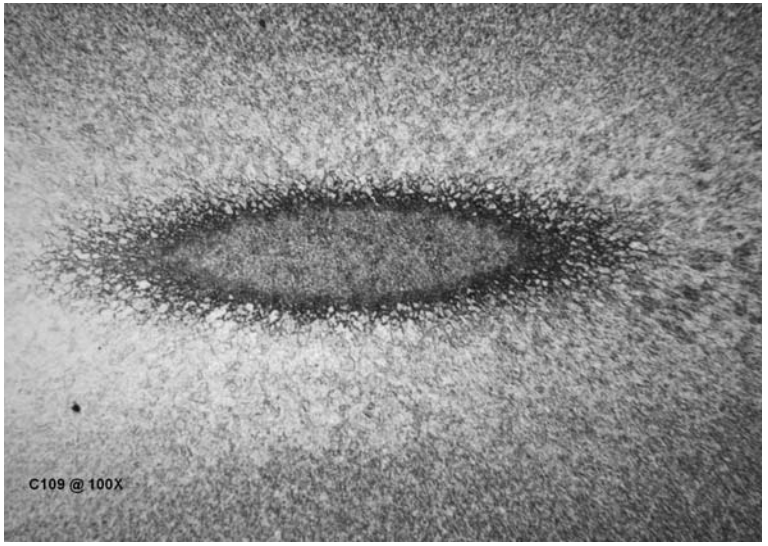


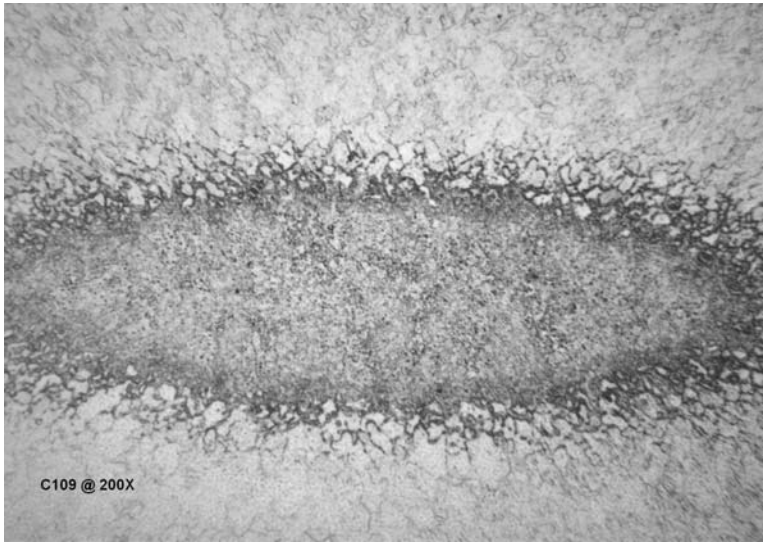


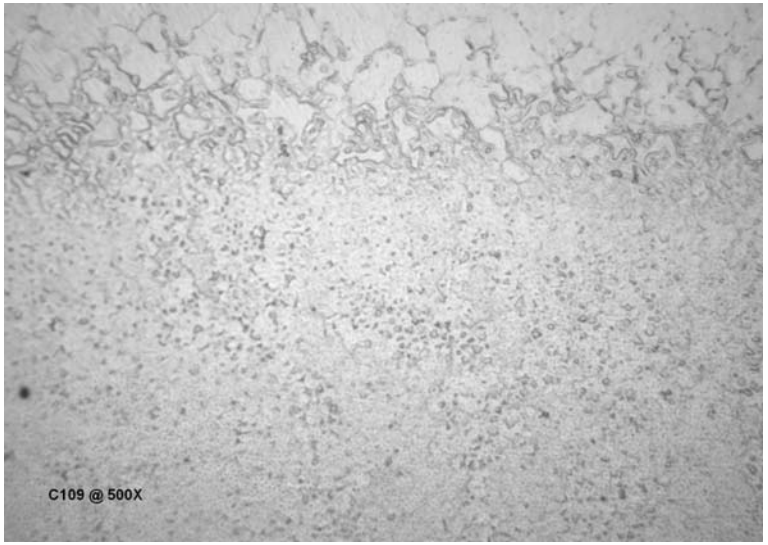


C105 High



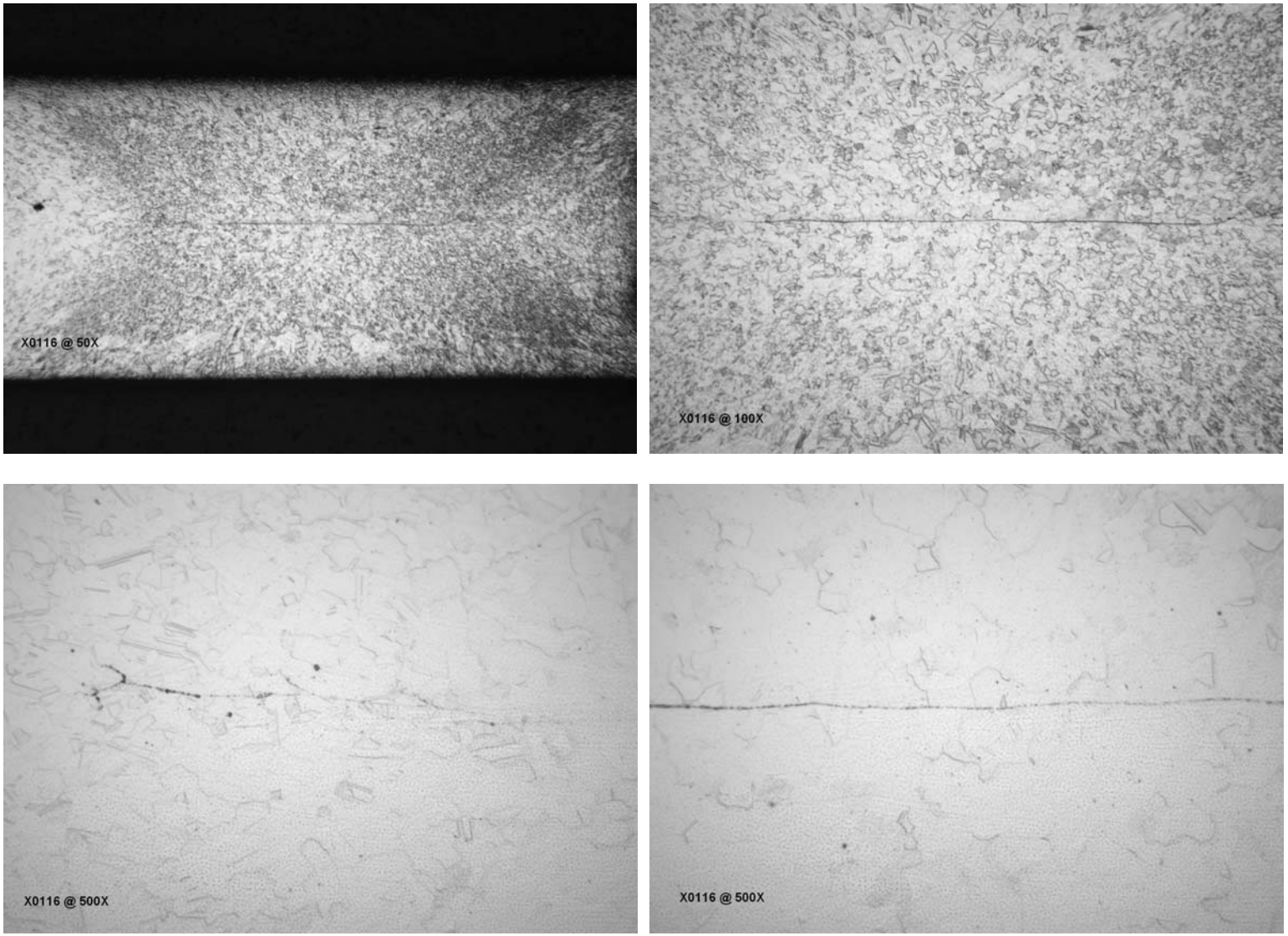




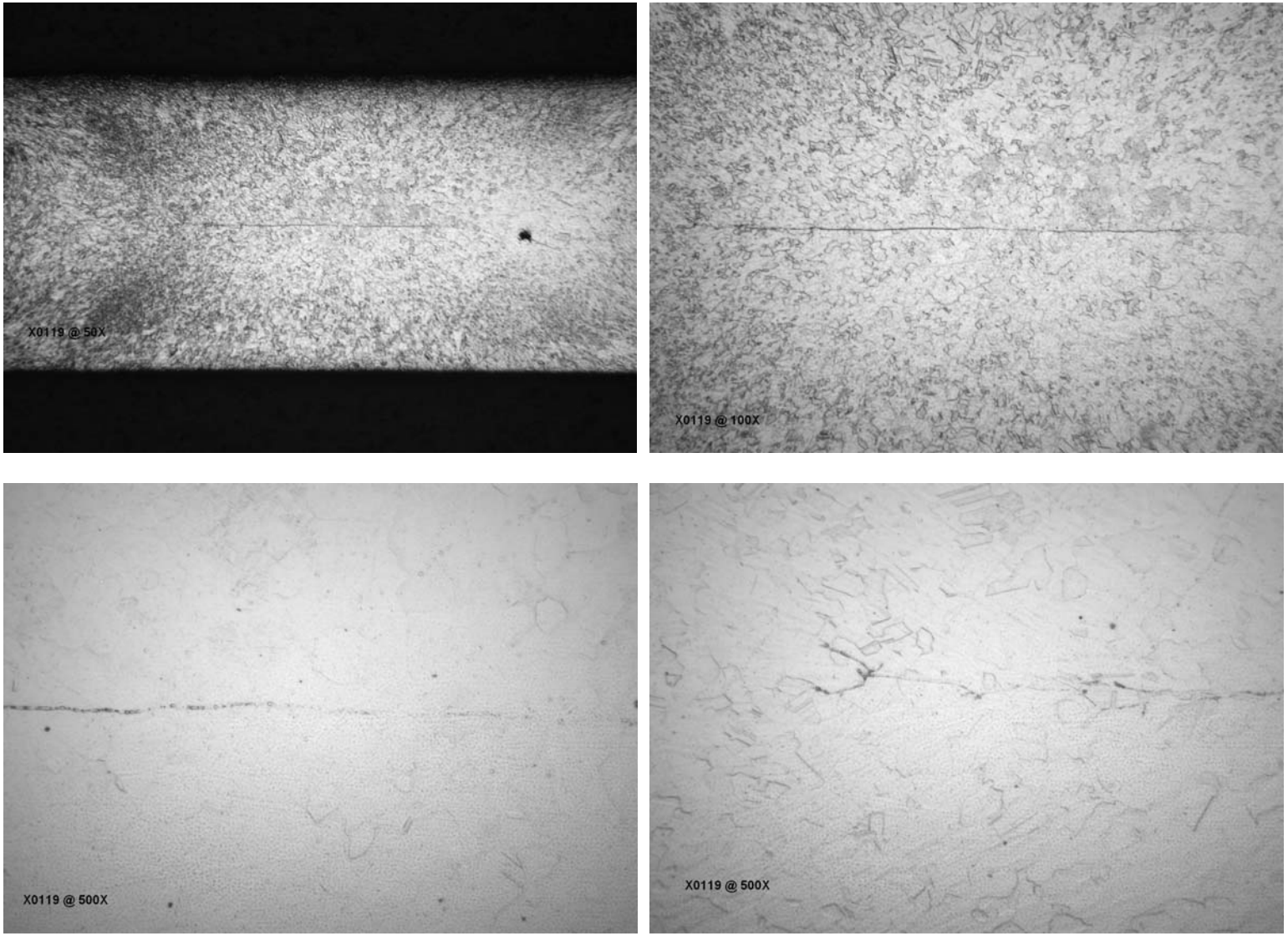


C109 High

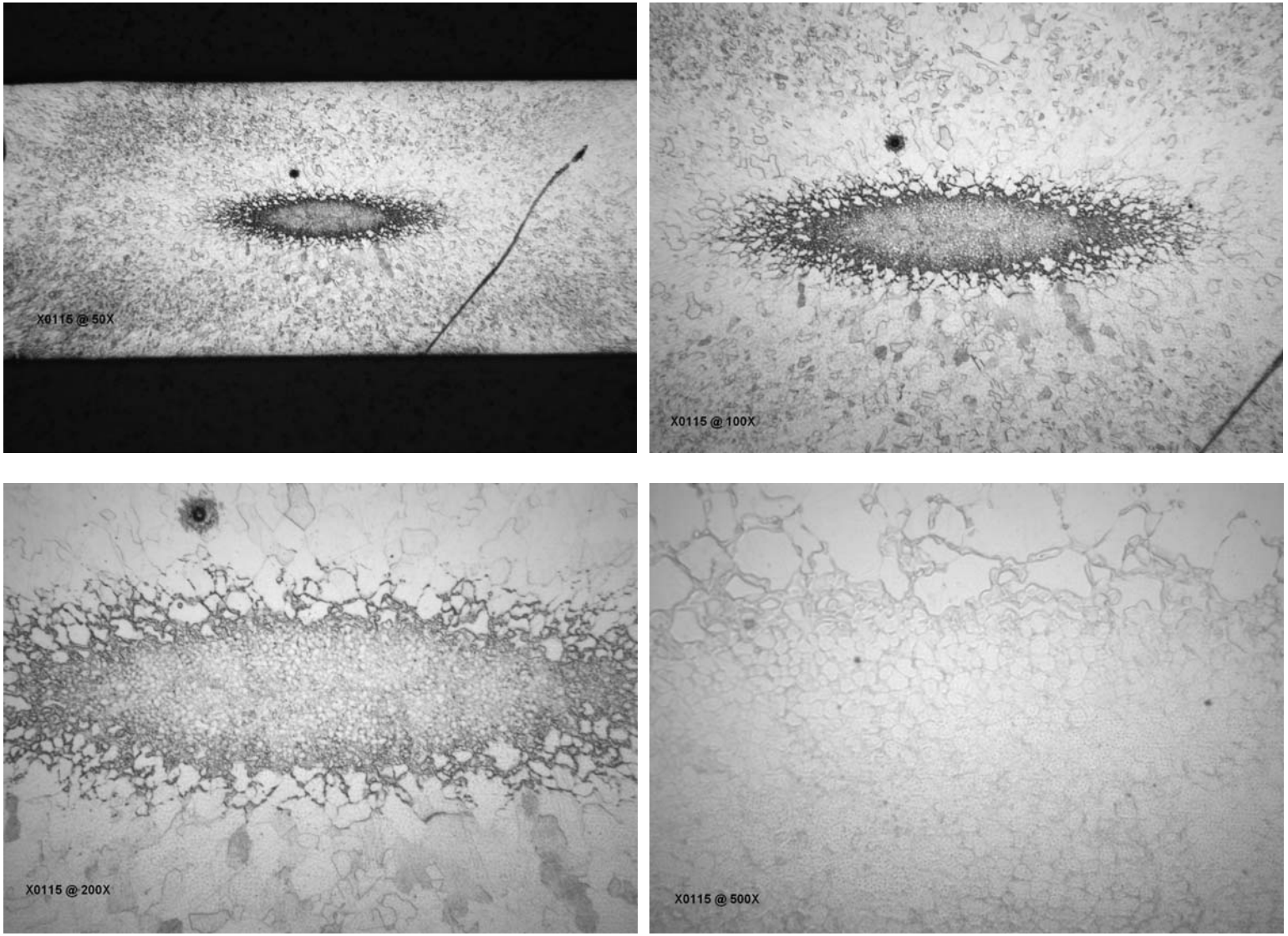
Appendix F. Micrographs of Type 304L stainless steel stems used for weld window verification.



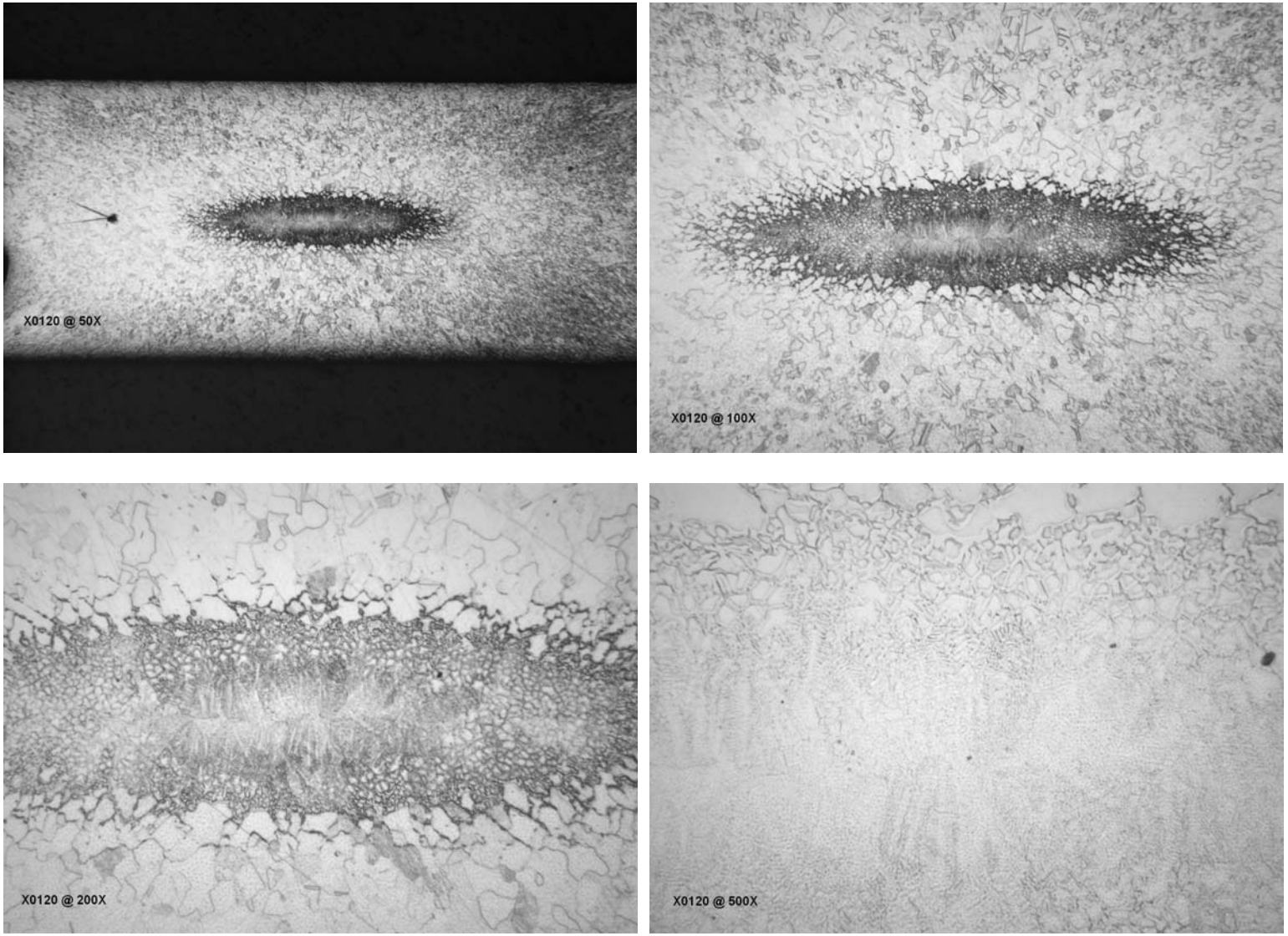
X0116 Low



X0119 Low



X0115 High



X0120 High