THE MATERIALS JOINING EXPERTS

Edison Welding Institute, Inc. 1250 Arthur E. Adams Drive | Columbus, Ohio 43221-3585 | (614) 688-5000 | FAX (614) 688-5001 | www.ewi.org

September 19, 2007

Phil Heitzenroeder
Princeton Plasma Physics Laboratory
P.O. Box 451
Princeton, NJ 08543-0451

EWI Project No. 50862GTH, "NCSX Modular Coil Type A/B Inner Leg Weld Test Evaluation"

Dear Phil:

Enclosed is EWI's report for the above referenced project. One hard copy will follow by mail. Please feel free to contact me at 614-688-5243 if you have any questions or comments regarding this project.

Sincerely,

Kevin Clear
Project Engineer
NDE Technology

Enclosure

EWI Project No. 50862GTH

Date: September 19, 2007

Submitted to: Princeton Plasma Physics Lab

Title: NCSX Modular Coil Type A/B Inner Leg Weld Test Evaluation

Introduction: Princeton Plasma Physics Laboratory (PPPL) is currently winding the modular coils for the National Compact Stellarator Experiment (NCSX). These coils are supported by stainless steel castings. Recently, a design modification was requested to include welds on the inward sections of three types of bolted joints between these castings. These welds will join the castings to stainless steel shims and join casting to casting across the shims. To determine the integrity of these welds, NCSX contracted EWI to perform nondestructive evaluation (NDE) and metallographic cross-sectioning of selected welds.

Objectives: Provide NDE and metallographic evaluation of selected weld sections.

Approach: NCSX provided 10 of the worst-welded shim/flange sections from the welded leg setup based on NCSX's examinations and judgment. Upon receipt of the welded sections, EWI considered the use of radiography testing (RT) and ultrasonic testing (UT) as possible NDE methods for detection of flaws in the welded sections. Based on the geometries of the sections, it was determined that radiography testing (RT) would not provide useful information about the weld integrity. Consequently, UT was the method used for further NDE.

EWI performed immersion C-Scan UT to inspect primarily for lack-of-fusion (LOF) and porosity flaws. The inspection of full-thickness sections was attempted using phased array (PA) UT testing to penetrate through the full material thickness. While PA UT was able to penetrate the thickness, it was decided that thinner material sections less than 1 in. (25 mm) would provide the best results. This was discussed with the Sponsor and approval was given to saw cut the specimens to a thickness that would provide a better inspection. Following approval from the Sponsor, the sections were saw cut and immersion UT testing was performed. Results of the C-Scan UT were evaluated and locations were selected for metallographic cross-sectioning. A total of 20 cross-sections were obtained; 10 transverse sections and 10 longitudinal sections. Macrographs of these cross-sections were taken and are provided in Appendix A, along with C-Scan results of the same locations.

Conclusions: Based on the results of the NDE and metallographic cross-sections, it appears that the welds were sufficiently fused to the base metal flanges and shim.

NDE and metallography revealed some instances of isolated porosity, small inclusions, and an area of LOF (shown as red circles in Appendix A); however, the welds were generally sound with uniform penetration depths as shown in images taken from the longitudinal cross-sections, as well as, the ultrasonic C-Scan images.

C-scan and macro photographs can be seen in Appendix A.

Ultrasonic C-Scan was able to detect the depth of fusion of the flange to shim welds as shown in Figure 1, provided the sound beam could be oriented perpendicular to the flange surfaces.

Ultrasonic C-Scan was able to detect flaws in the weld zone as shown in Figure 2.

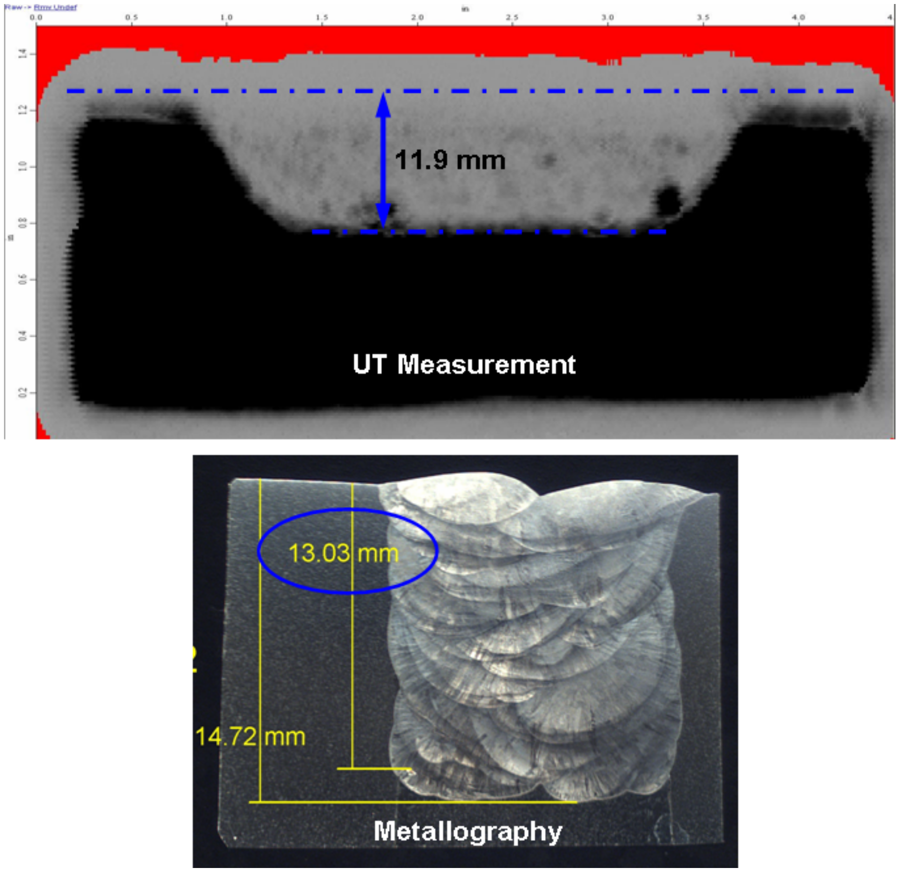


Figure 1. Weld 11 Comparison of Depth of Fusion Measurement Using UT and Metallography

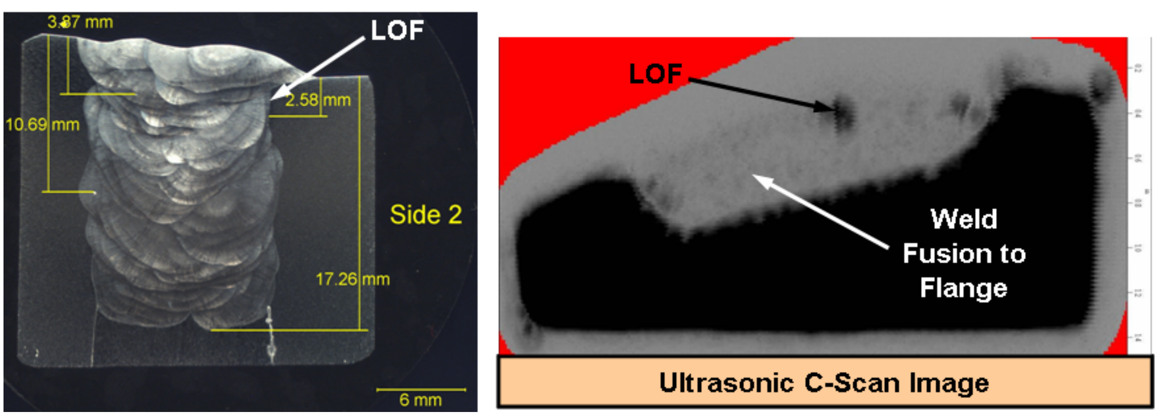
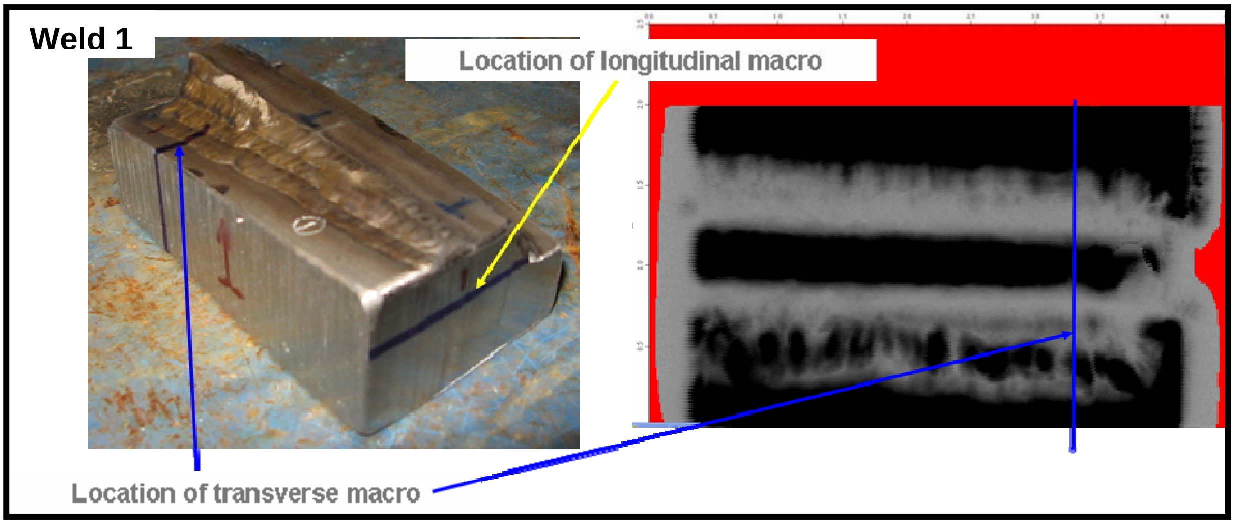


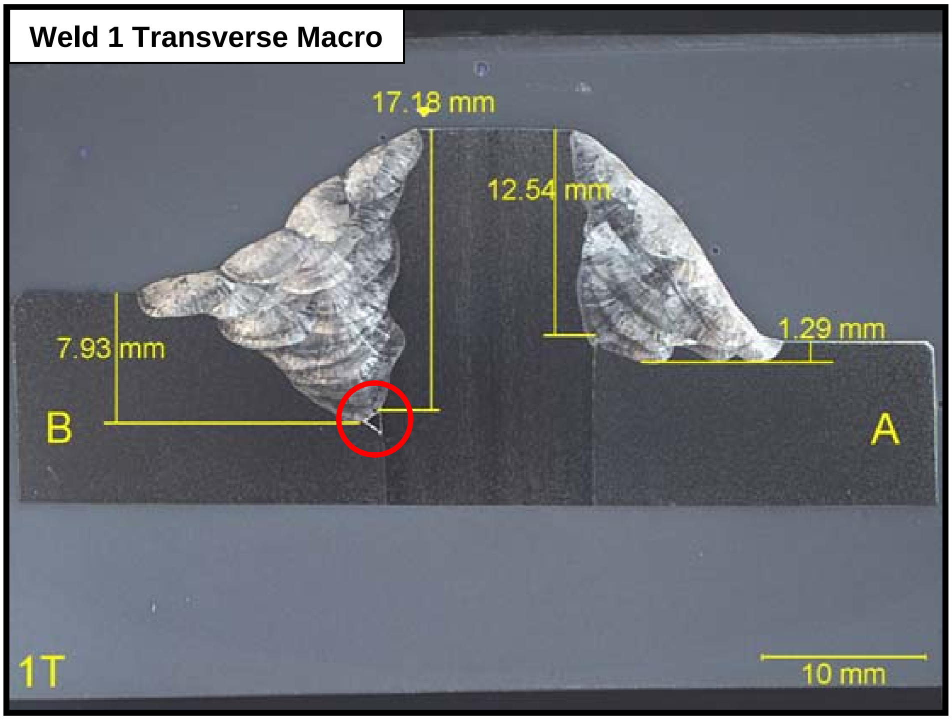
Figure 2. Weld 5 Showing LOF Indication

For more information contact: Kevin Clear at 614-688-5243

Appendix A

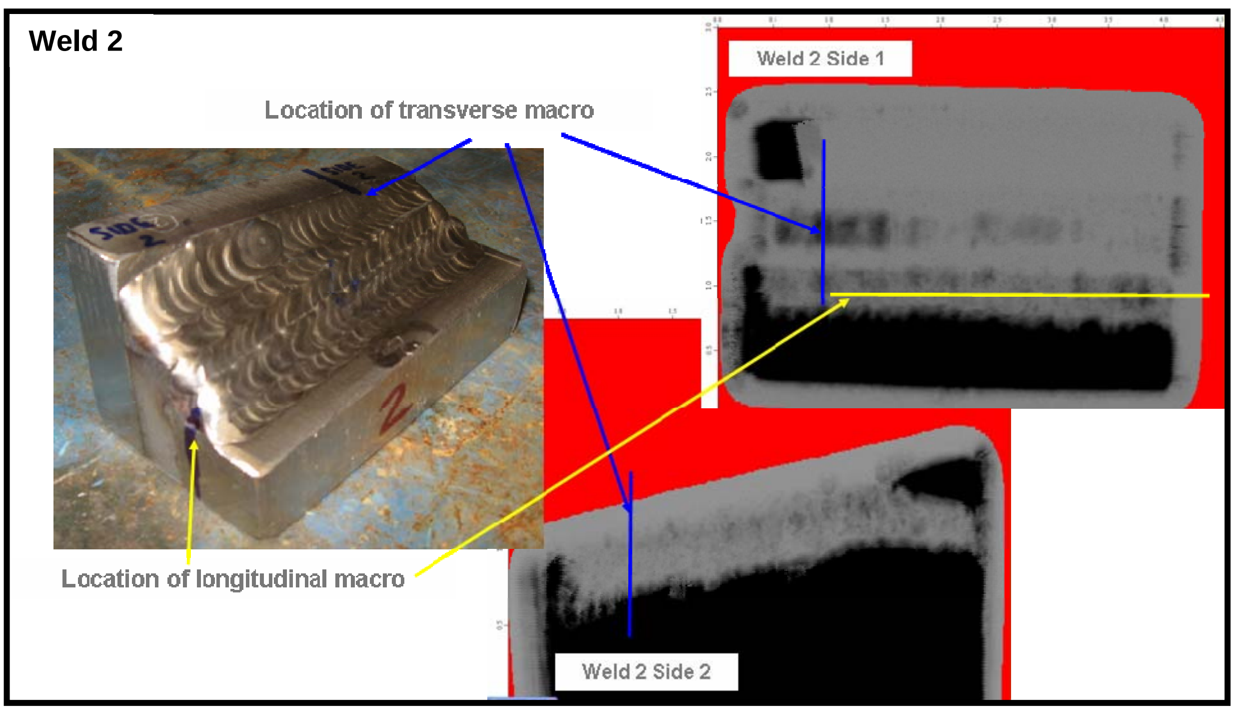


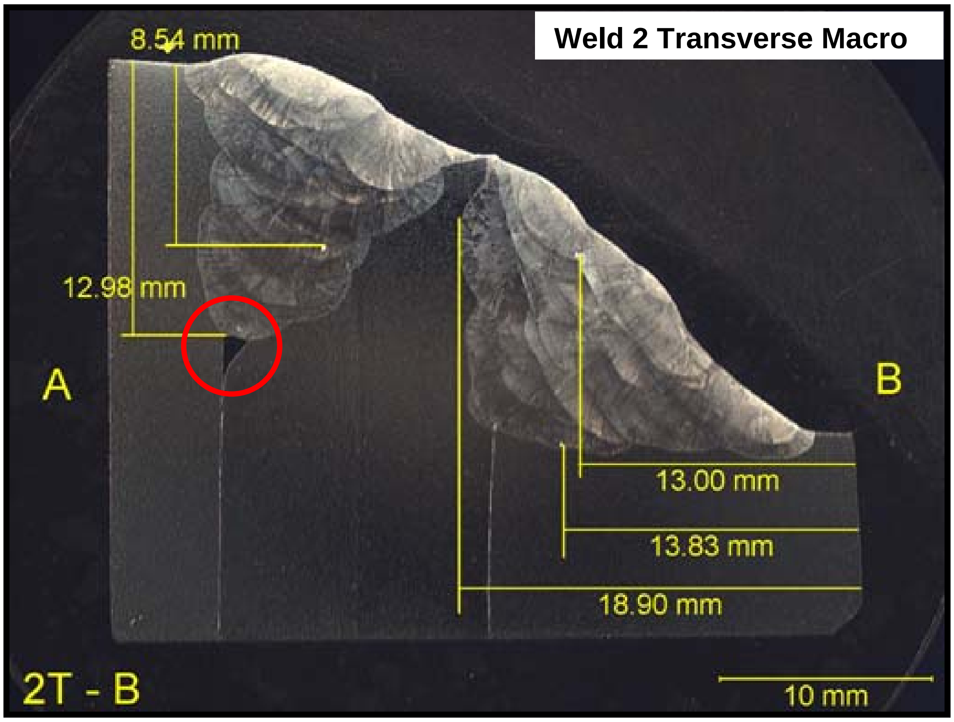
Weld 1
Location of longitudinal macro
Location of transverse macro



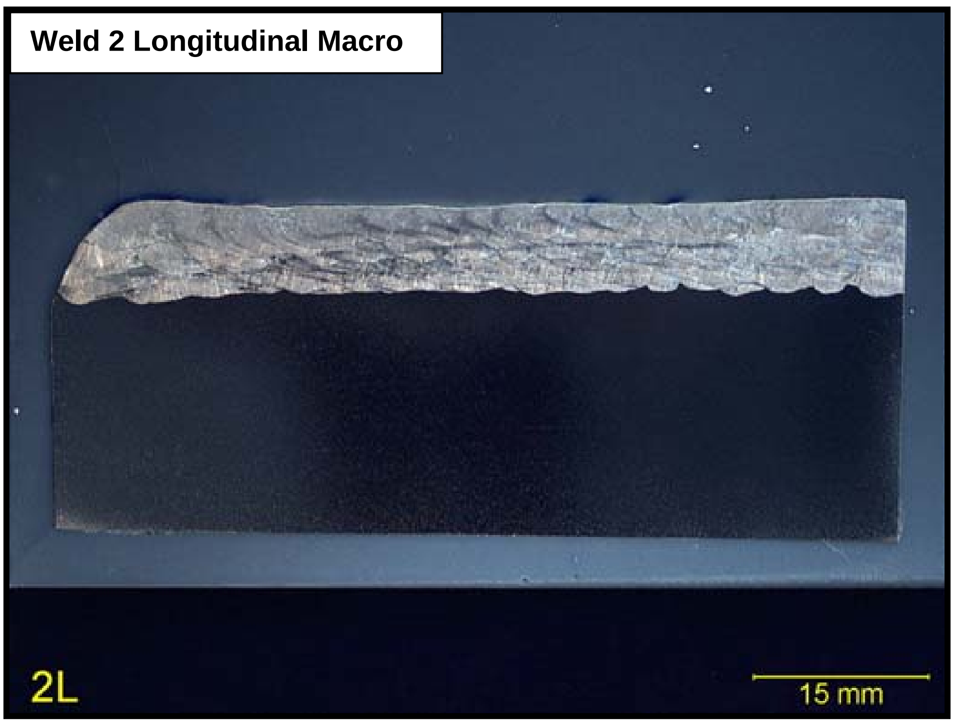
Weld 1 Transverse Macro
17.18 mm
12.54 mm
7.93 mm
1.29 mm
B
A
1T
10 mm


Weld 1 Longitudinal Macro
1L
15 mm

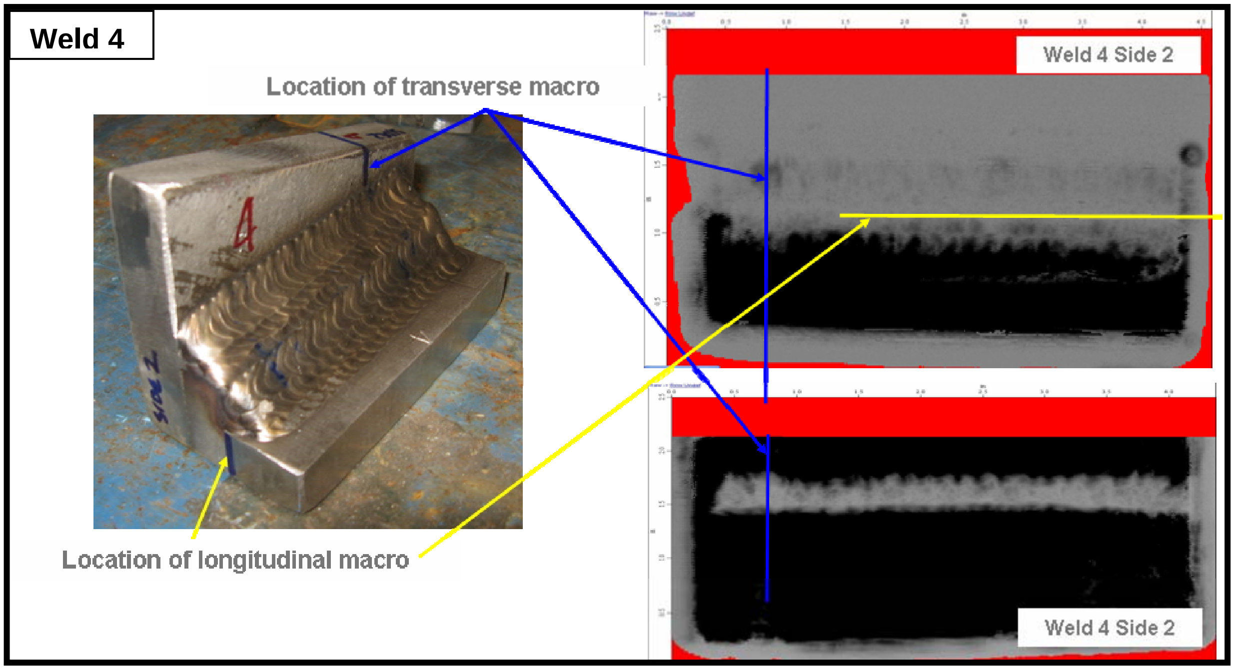

Weld 2
Location of transverse macro
Weld 2 Side 1
Location of longitudinal macro
Weld 2 Side 2



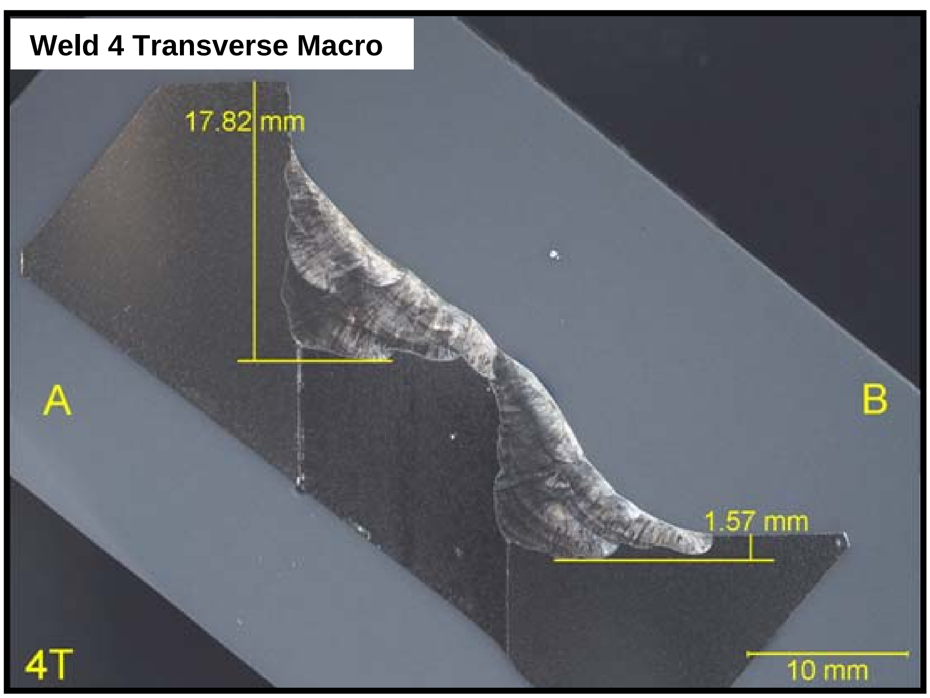
Weld 2 Transverse Macro
8.54 mm
12.98 mm
A
B
13.00 mm
13.83 mm
18.90 mm
2T - B
10 mm



Weld 2 Longitudinal Macro
2L
15 mm

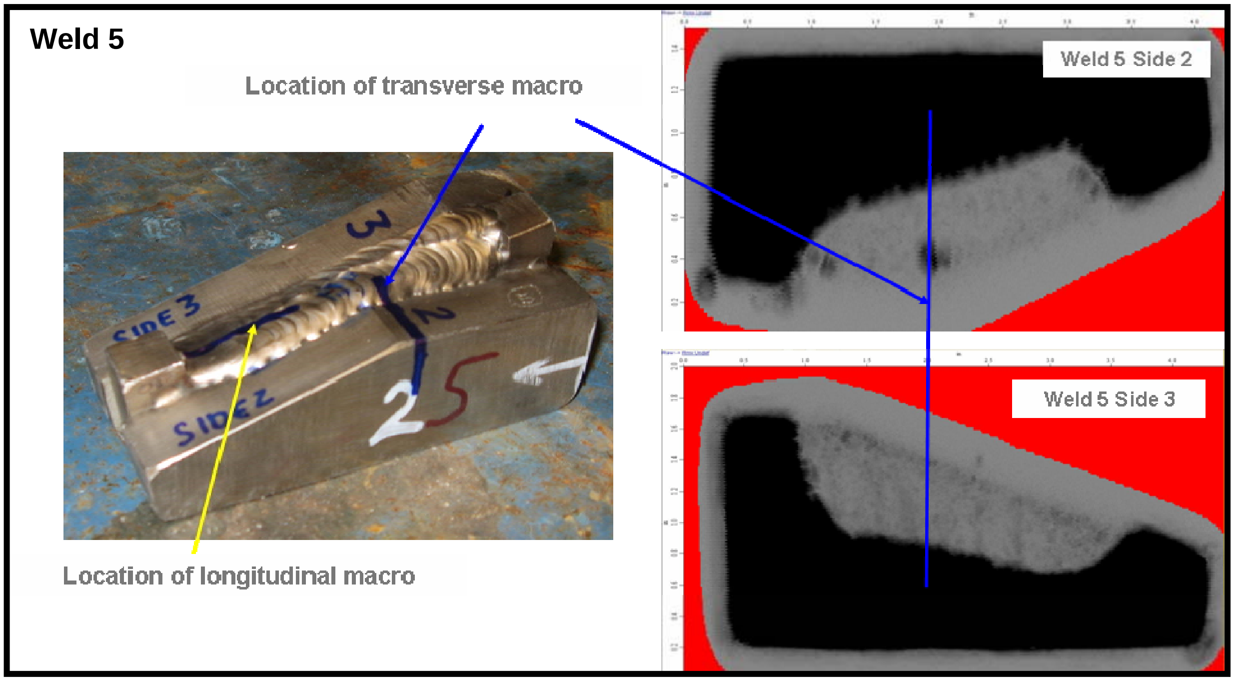


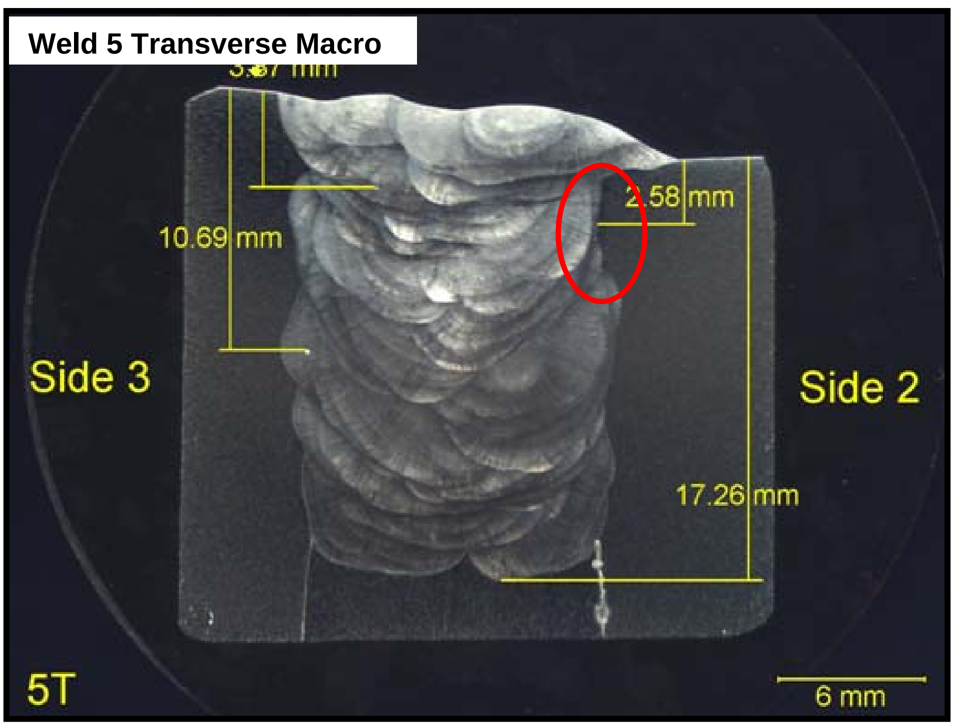
Weld 4
Location of transverse macro
Weld 4 Side 2
Location of longitudinal macro
Weld 4 Side 2



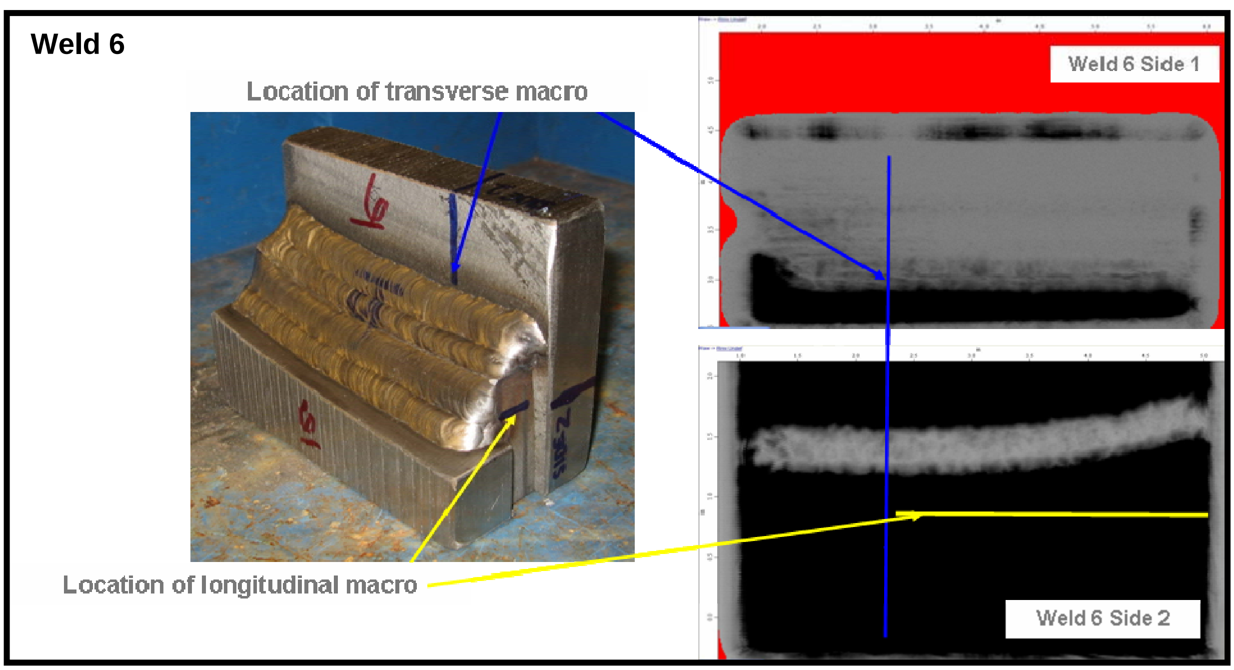
Weld 4 Transverse Macro
17.82 mm
A
B
1.57 mm
4T
10 mm

Weld 4 Longitudinal Macro
4L
15 mm

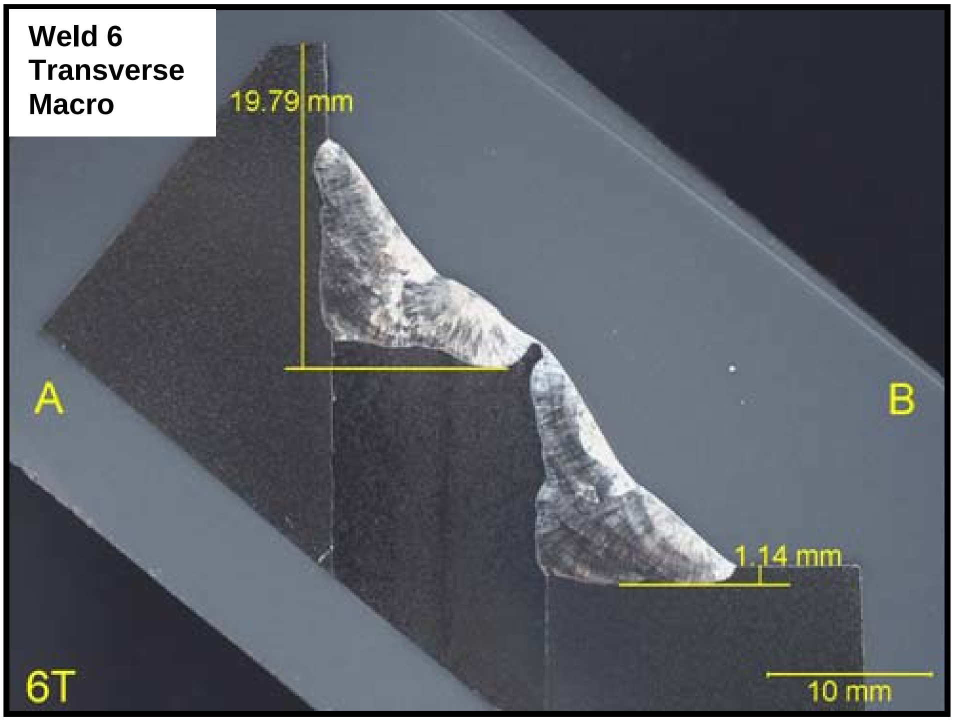

Weld 5
Location of transverse macro
Weld 5 Side 2
Weld 5 Side 3
Location of longitudinal macro

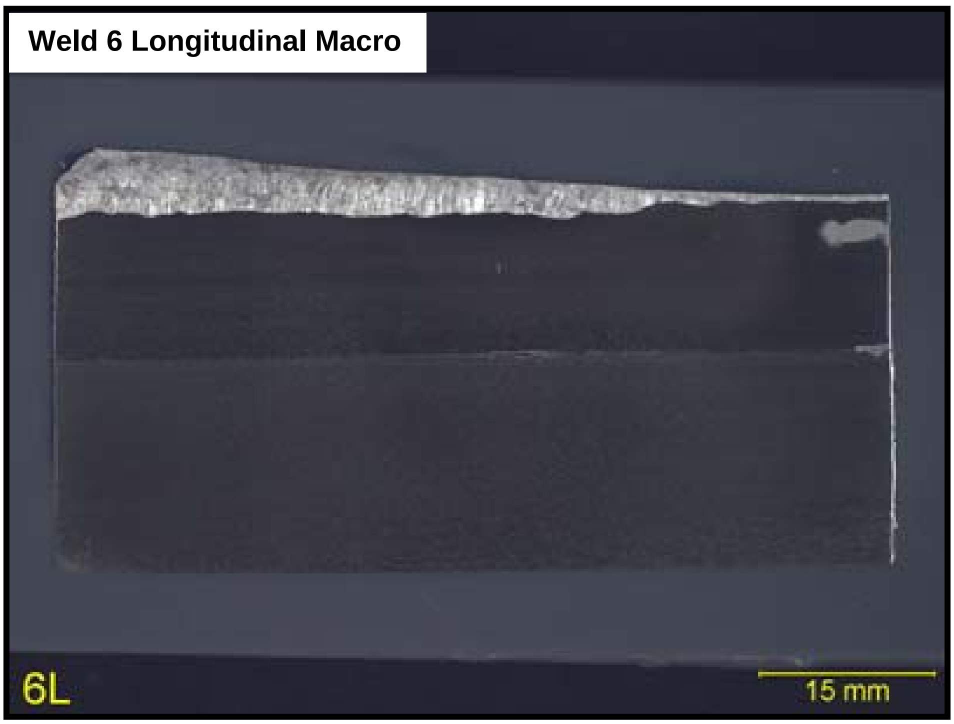

Weld 5 Transverse Macro
2.58 mm
10.69 mm
Side 3
Side 2
17.26 mm
5T
6 mm

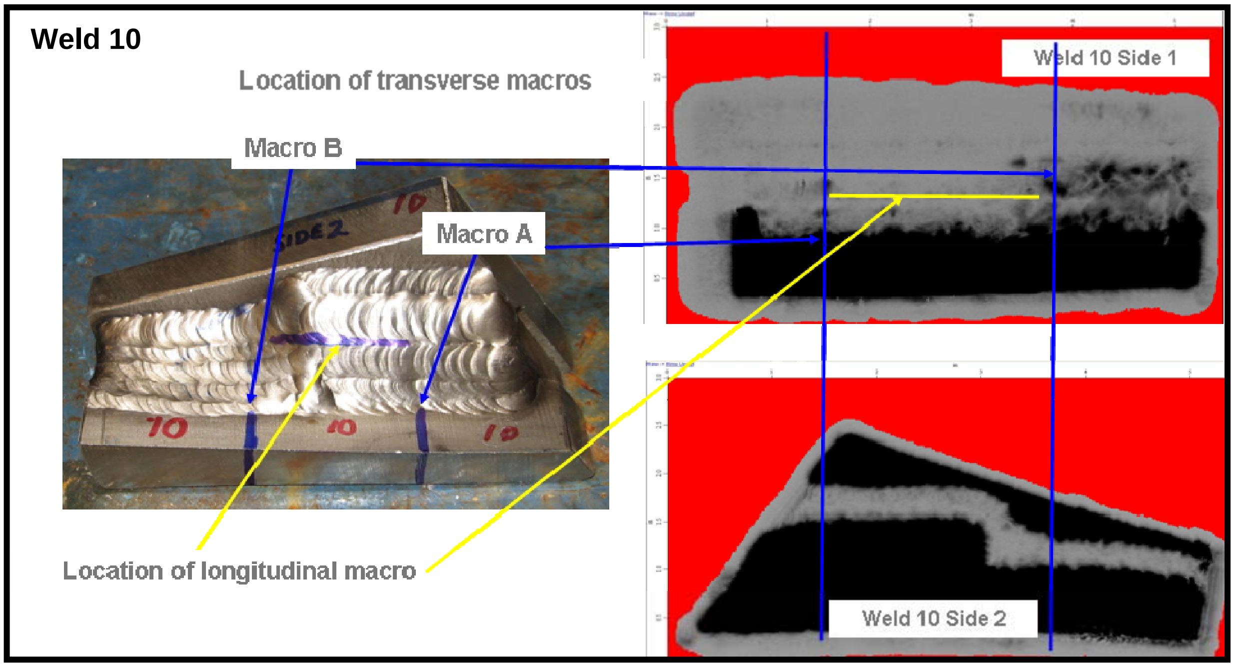
Weld 5 Longitudinal Macro

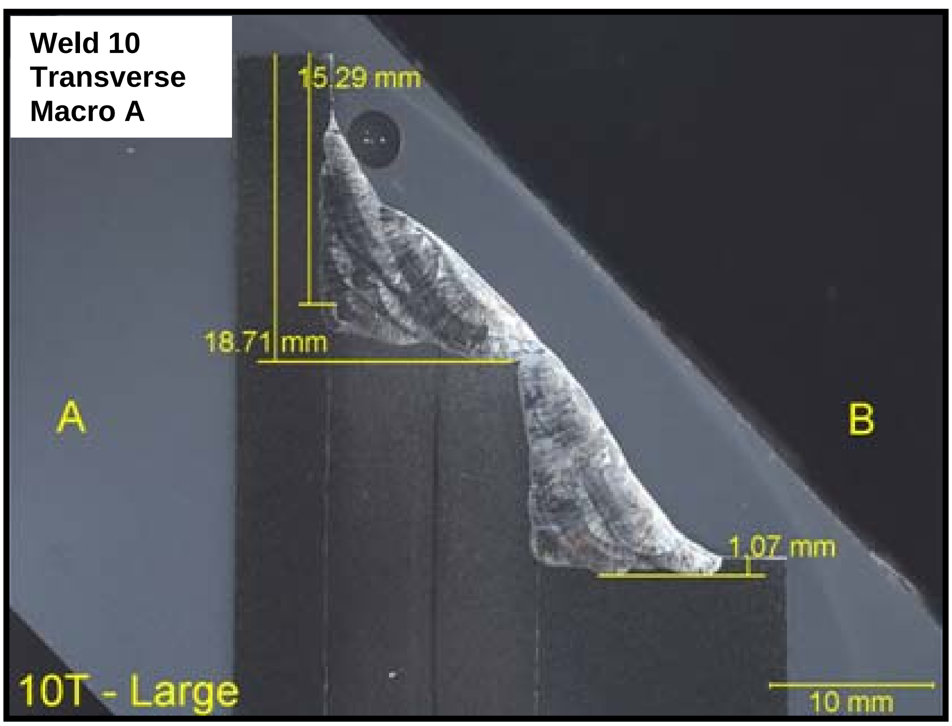


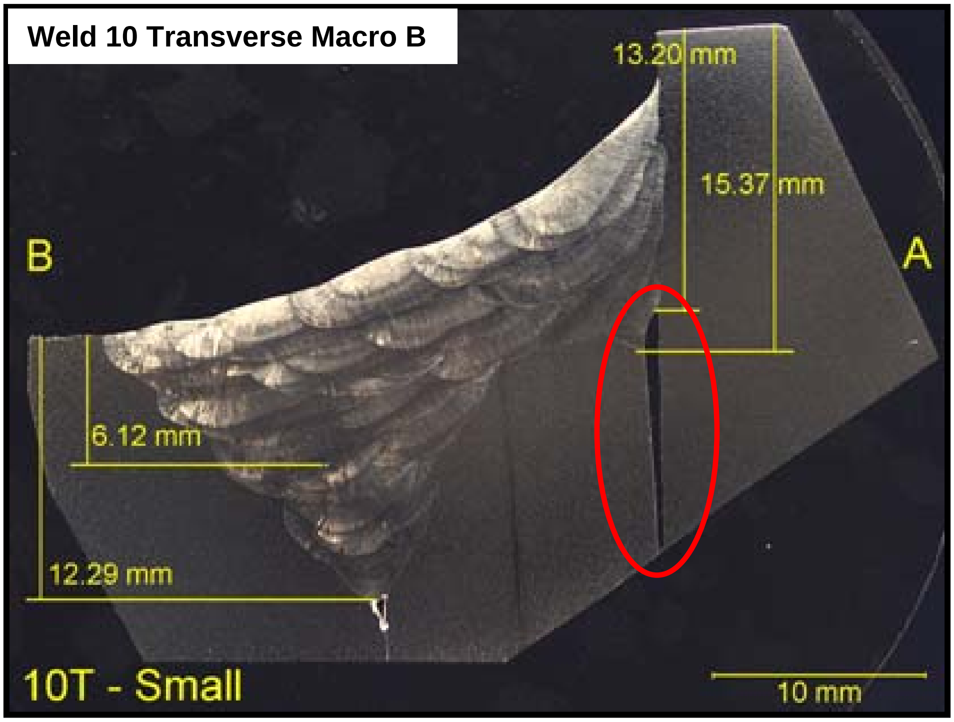
Weld 6

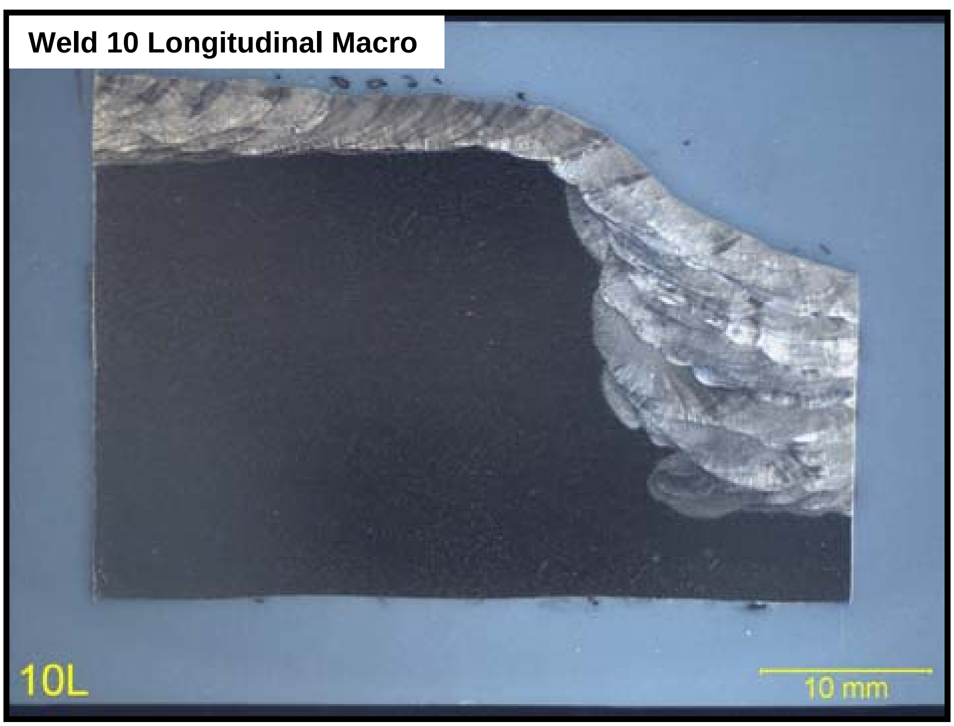

Weld 6
Transverse
Macro
19.79 mm
A
B
1.14 mm
6T
10 mm

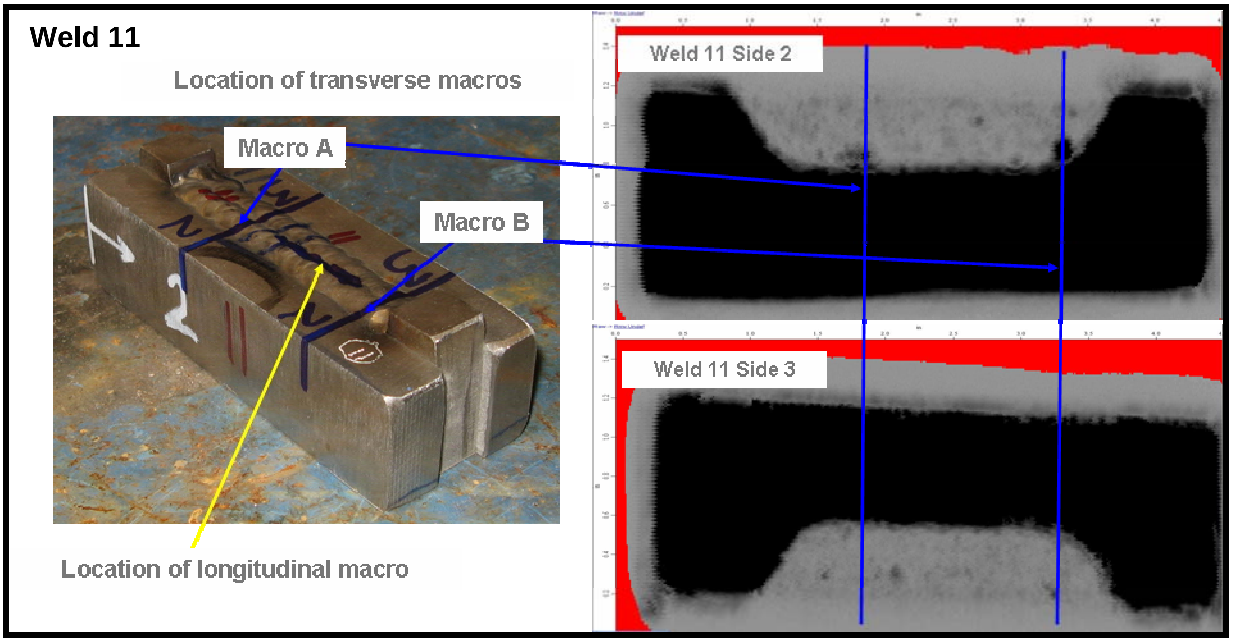

Weld 6 Longitudinal Macro
6L
15 mm

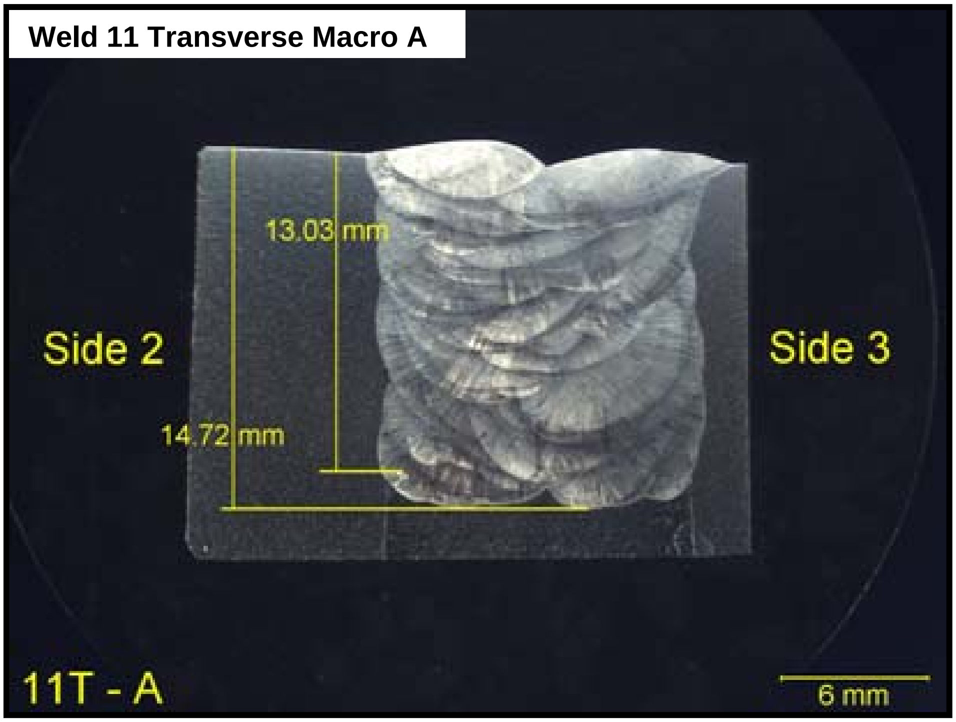

Weld 10
Location of transverse macros
Macro B
Macro A
Weld 10 Side 1
Weld 10 Side 2
Location of longitudinal macro

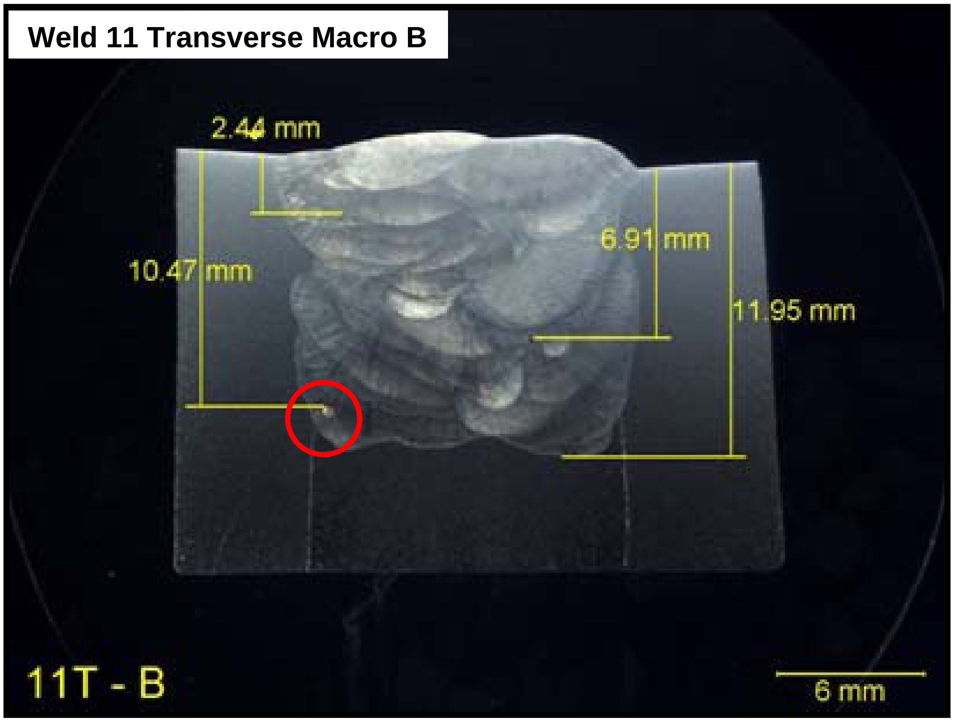

Weld 10
Transverse
Macro A
15.29 mm
18.71 mm
A
B
1.07 mm
10T - Large
10 mm

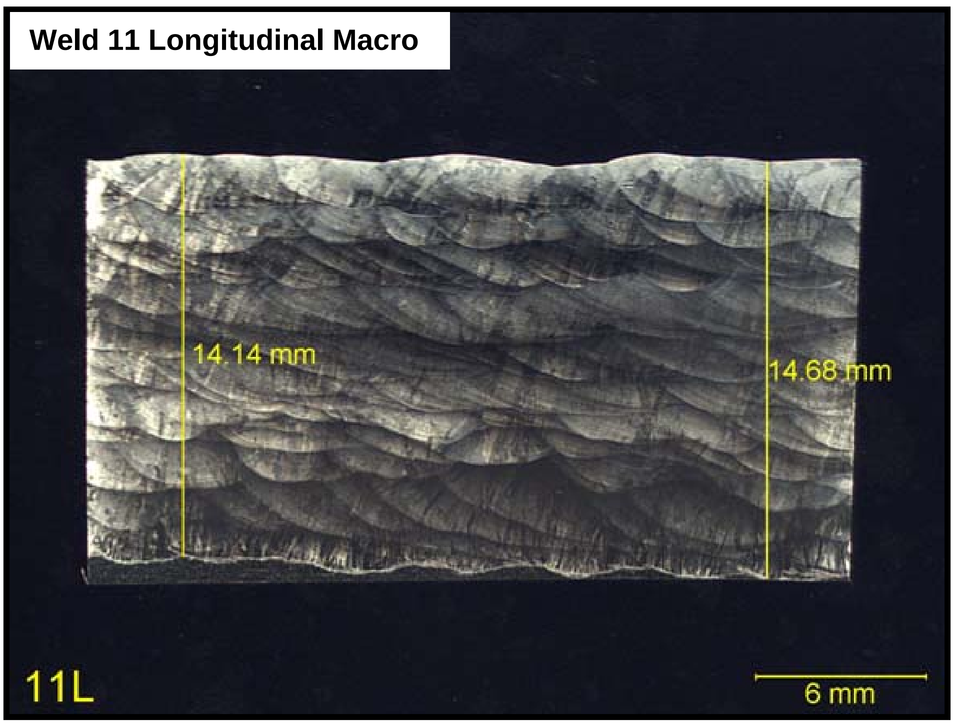

Weld 10 Transverse Macro B
13.20 mm
15.37 mm
B
A
6.12 mm
12.29 mm
10T - Small
10 mm

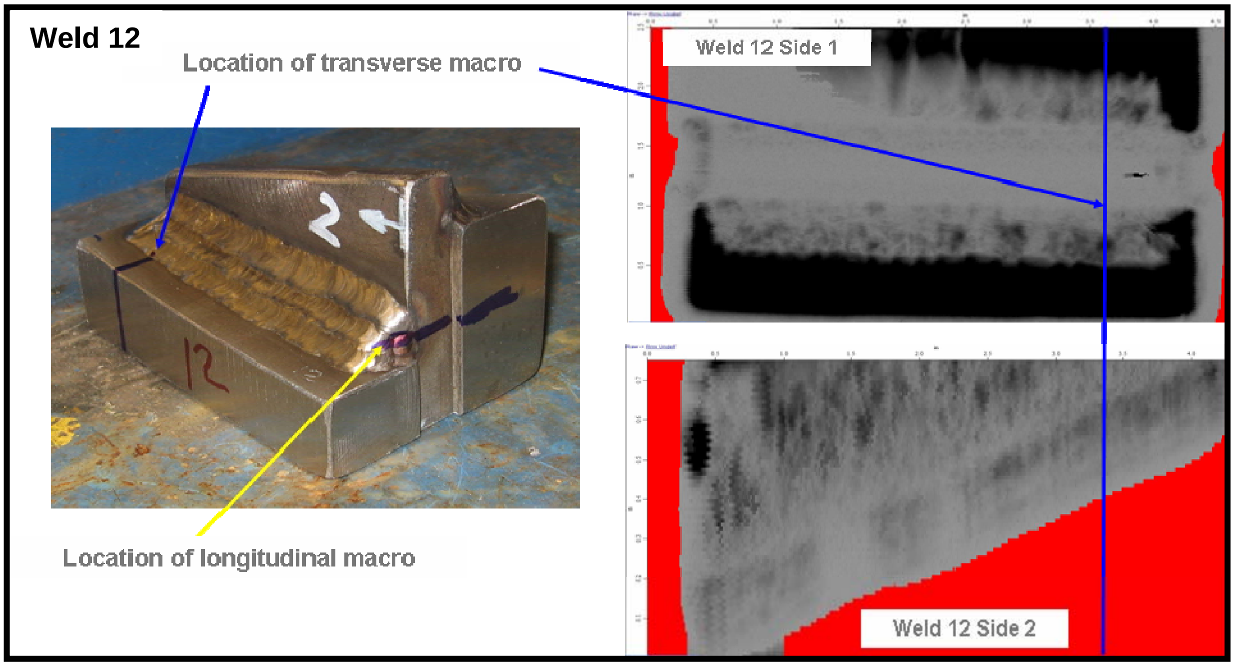

Weld 10 Longitudinal Macro
10L
10 mm

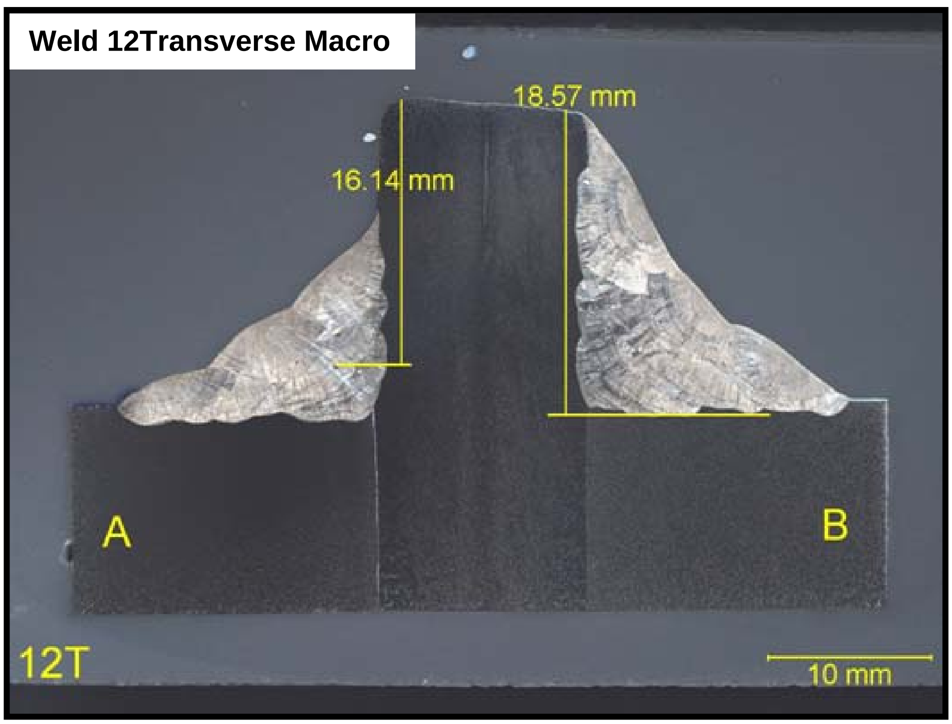

Weld 11
Location of transverse macros
Macro A
Macro B
Location of longitudinal macro
Weld 11 Side 2
Weld 11 Side 3

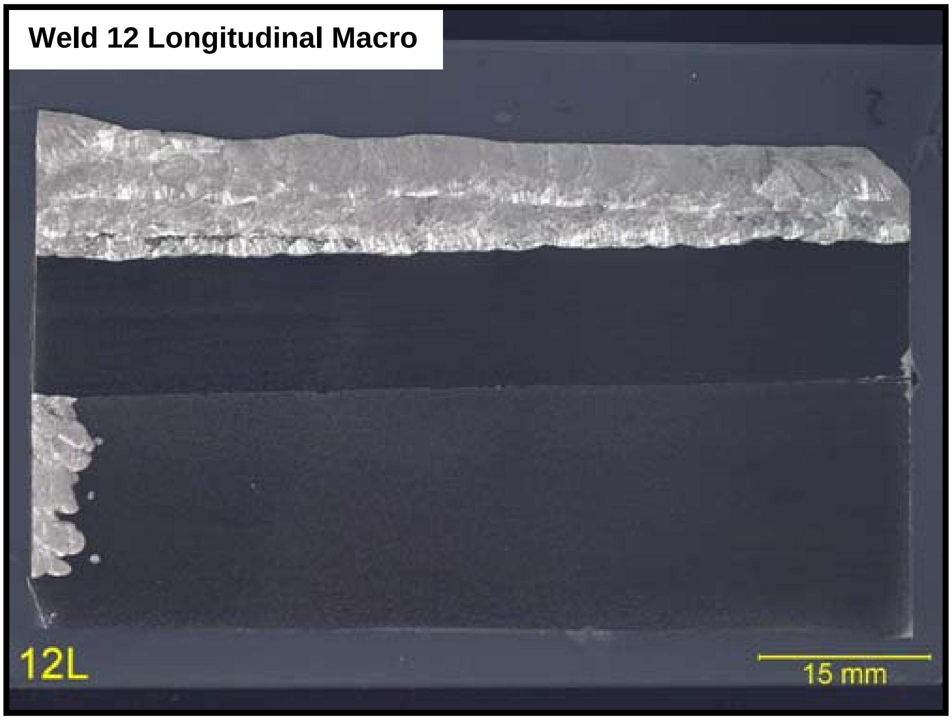

Weld 11 Transverse Macro A
13.03 mm
14.72 mm
Side 2
Side 3
11T - A
6 mm


Weld 11 Transverse Macro B
2.44 mm
10.47 mm
6.91 mm
11.95 mm
11T - B
6 mm

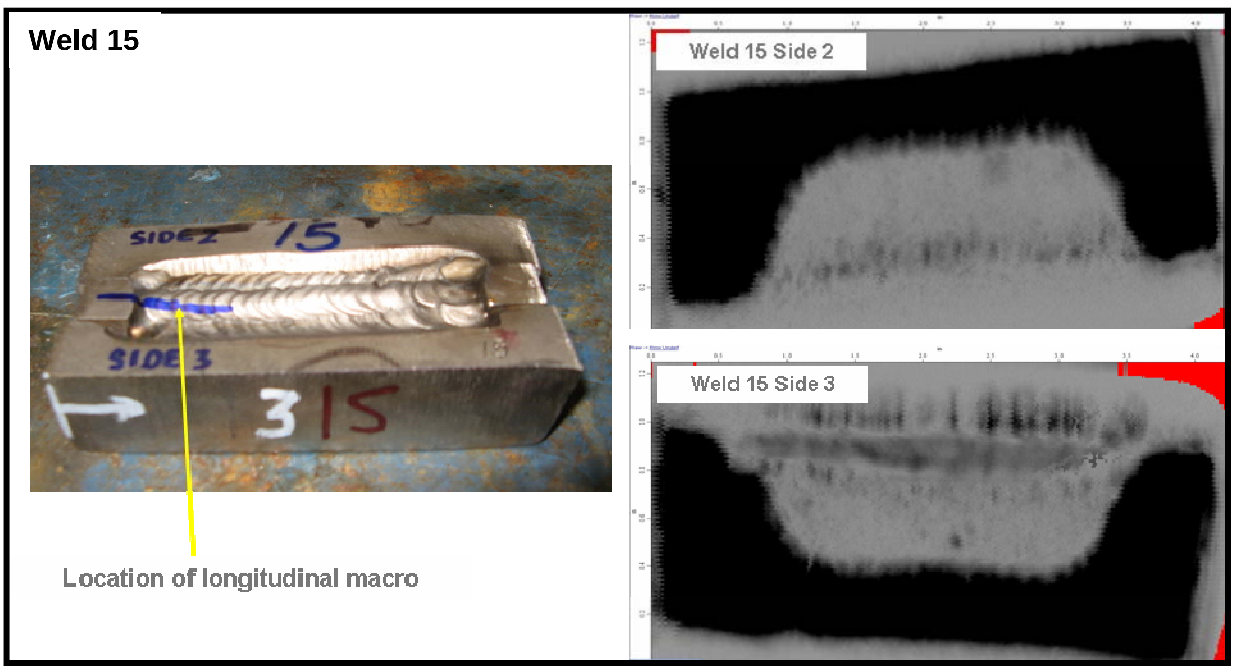

Weld 11 Longitudinal Macro
14.14 mm
14.68 mm
11L
6 mm


Weld 12
Location of transverse macro
Location of longitudinal macro
Weld 12 Side 1
Weld 12 Side 2


Weld 12Transverse Macro
18.57 mm
16.14 mm
A
B
12T
10 mm

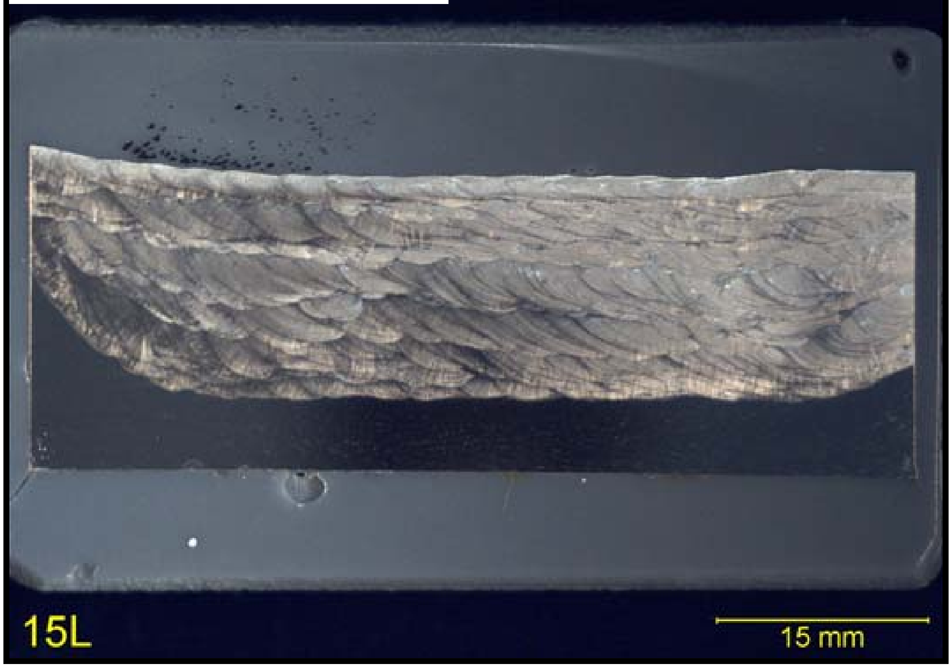


Weld 12 Longitudinal Macro

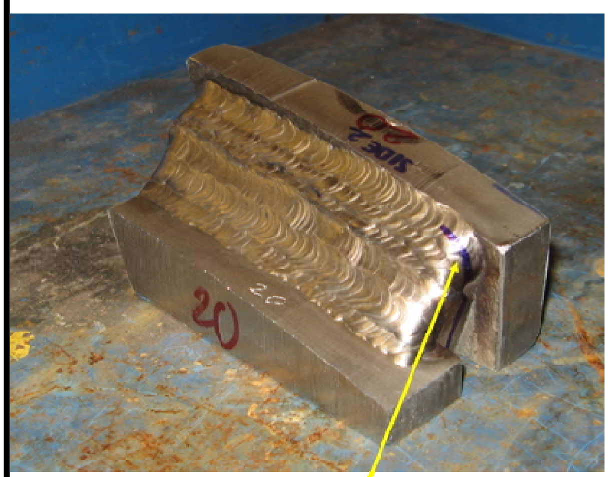


Weld 15

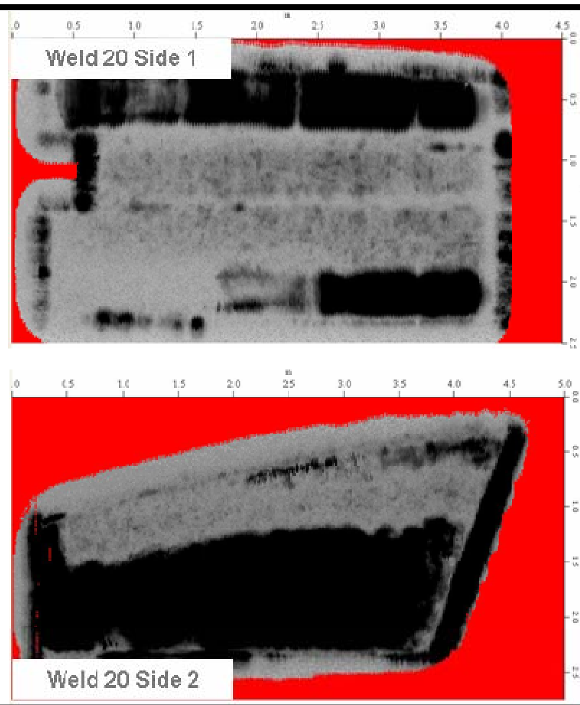
Weld 15 Longitudinal Macro

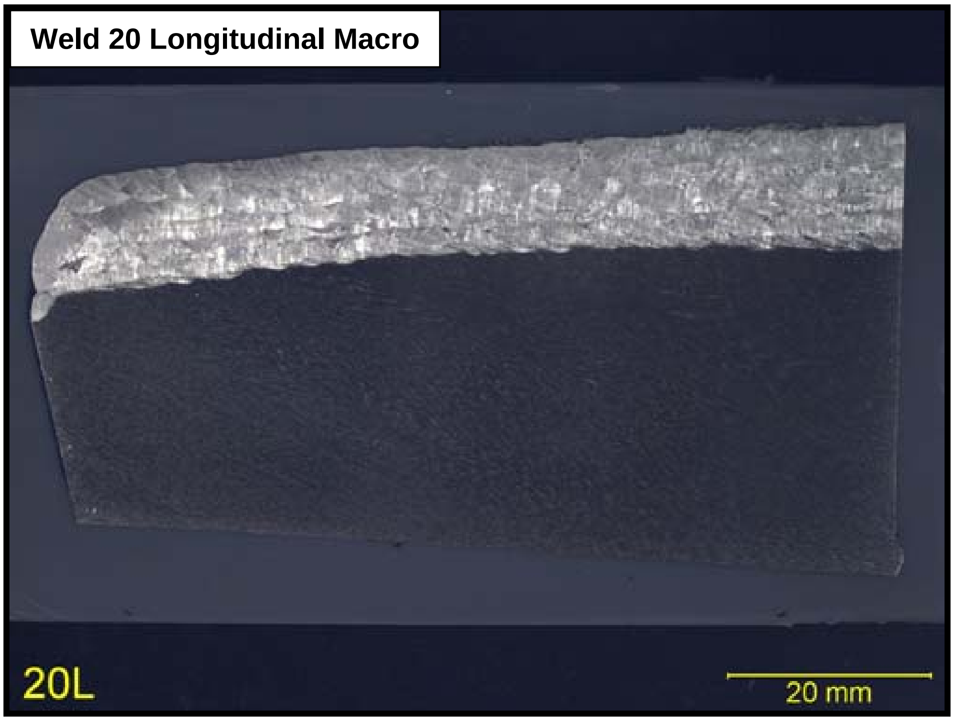


Weld 20



Location of longitudinal macro




Weld 20 Longitudinal Macro
20L
20 mm