Simon Forensic, LLC

Providing material testing and failure analysis for the industrial, transportation, energy, maritime, and manufacturing sectors

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January 14, 2021

Alaska Marine Surveyors, Inc.
P.O. Box 2342
Kodiak, AK 99615

Attn: **Jack McFarland**

Re: Moorage System Failure
Barge SM3
Your File No. DV 3148
S.F. Report No. 4132

Dear Mr. McFarland,

Per your request, the submitted failed section (see Fig. 1) that had reportedly been removed from the buoy (see Attachment 2-3) utilized in the moorage arrangement of barge SM3 (see Attachment 1) was examined, tested and the findings documented.

The following is a short summary of my findings and observations:

1. Historical Background

A discussion and email exchange with Mr. McFarland (President at Alaska Marine Surveyors, Inc., phone no. [redacted] with regards to the subject barge/mooring system revealed the following historical background:

- The barge SM3 (official No. 505535) was built by the Zidell Corp. (Portland, OR) in 1966.
- During a routine offshore moorage of the barge at the village of Ekuk (Alaska) on August 30, 2020 the barge separated from the moorage system and eventually stranded on the nearby beach.
- A subsequent examination of the moorage system revealed that the topside padeye with shackles had liberated from the buoy, see also Attachment 3.
- At the time of the buoy failure, heavy winds and sea conditions developed.
- The subject buoy had been purchased by the current barge owner in March of 2019 from Blue Ocean Tackle Inc. (Coral Springs, Florida).
- No further details as to the operation/service/inspection history of the subject buoy was available at the time this report was generated.

2. Visual Examination

The visual examination of the submitted buoy section revealed the following findings:

- The topside of the buoy consists of a padeye (1¼” thick plate) that had been fillet welded to the shell (5/16” thick curved sheet metal) of the buoy.

- The **buoy has functionally failed**, i.e. a **separating crack** had formed at the **fillet weld** of the **topside padeye** thus **allowing the uncontrolled separation of the padeye**, see Fig. 1-4.

- Three (3) shackles used in the mooring operation were found to be marked as follows:

  1) **Campbell 1 WLL 8’/2T**, measurements confirmed a shackle diameter of 1” (25mm), see Fig. 4-6 and 8.

  2) **Campbell 1 WLL 8’/2T**, measurements confirmed a shackle diameter of 1” (25mm), see Fig. 4-6 and 8.

  3) **Crosby WLL 1.5T**, 1 1/8 1251, Fig. 4-7.

  None of the shackles had failed, i.e. **no plastic deformation or cracking** was observed.

- For further details as the submitted items, please see Fig. 1-11.

3. Fractographic Examination

The fractographic examination of the failure by means of the naked eye and optical stereo microscope (up to 40x) revealed the following:

- A light layer of corrosion products was found to cover the fracture face thus masking the finer fractographic details, see Fig. 12-13.

- The **fracture initiated at the fillet weld** (plate side) at the **end face of the padeye**, see Fig. 17-18.

- A section containing the crack origin was removed (see Fig. 19-23) and ultrasonically cleaned, see Fig. 30.

  A closer examination revealed a **small fatigue zone** (approximately 5mm deep and extending over the width of the padeye), i.e. beach marks (witness marks of stage II fatigue) were observed, see Fig. 30-37.

- Multiple fatigue crack origins were observed (separated by ratchet marks), see Fig. 38.

- No gross metallurgical (non-metallic inclusions) or weld related (lack of weld fusion for example) defects were observed at the crack origins, see Fig. 35-37.

4. Macro-Etch

A cross-section was removed across the weld adjacent to the failure origin (see Fig. 24-25) and macro-etched, see Fig. 26.

The subsequent visual examination revealed an **adequate weld quality**, i.e. a proper weld fusion/penetration and throat profile were observed, see Fig. 27-29.

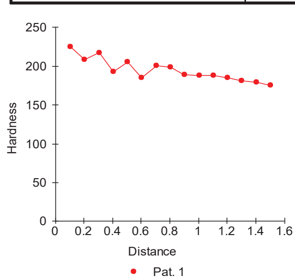
5. Metallurgical Examination

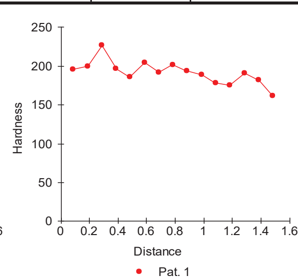
The macro-etched weld sections were metallographically prepared, see Fig. 39-42.

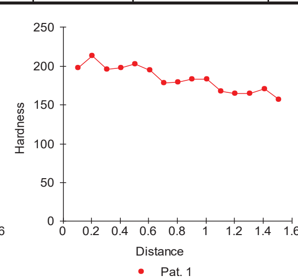
5.1 Microhardness Survey

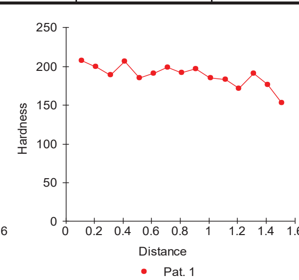
A microhardness survey across the HAZ of both legs revealed the following values:

Distance from Surface in mm	Hardness* at:							
	Location 1A		Location 1B		Location 2A		Location 2B	
	Vickers	HRC	Vickers	HRC	Vickers	HRC	Vickers	HRC
0.106	225	0	196	0	198	0	208	0
0.207	209	0	200	0	214	0	200	0
0.307	217	0	227	0	196	0	189	0
0.406	193	0	197	0	198	0	206	0
0.504	205	0	186	0	203	0	186	0
0.605	186	0	204	0	195	0	191	0
0.706	201	0	192	0	179	0	199	0
0.804	198	0	202	0	180	0	192	0
0.904	190	0	194	0	183	0	197	0
1.01	188	0	189	0	183	0	185	0
1.11	188	0	179	0	168	0	183	0
1.2	186	0	175	0	165	0	172	0
1.3	182	0	191	0	165	0	191	0
1.41	180	0	183	0	171	0	177	0
1.51	175	0	162	0	157	0	153	0









*obtained from Vickers/500 gr. load/400x magnification.
HRC = Rockwell C Hardness and converted per ISO 6336-5:1996.

5.2 Metallographic Examination

The microhardness tested sections were subsequently metallographically examined in the “as polished” and etched conditions.

The following observations were made:

- The padeye is made from a mild carbon steel, i.e. a ferritic/pearlitic microstructure was observed, see Fig. 47.
- The buoy shell is made from a low carbon steel, i.e. a primarily ferritic microstructure was observed, see Fig. 45.
- No undesirable phase transformation products were observed in any of the examined HAZ’s suggesting that a proper temperature control had been maintained at the time of welding, see Fig. 44, 46 and 50-53.
- **No weld defects were found to have encouraged the failure**.

6. At this junction the examination was terminated awaiting further instructions.

7. Conclusions

Based on the information obtained up to this point, the following preliminary conclusions are offered:

- The **buoy has functionally failed**, i.e. a **separating crack** had formed at the **fillet weld** of the **topside padeye** thus **allowing the separation (liberation) of the padeye from the buoy.**
- The **topside padeye** (buoy) **was structurally compromised at the time of the incident**, i.e. a small fatigue crack had been present thus providing a mechanical stress riser.
- **No metallurgical or welding related defects** related to the padeye failure were found to have caused or contributed to the failure.
- The topside padeye appears to be original to the buoy, i.e. no repair welds were observed.
- No analysis of the dynamics involved in the buoy failure will be offered at this point since it’s beyond the scope of this examination. However, to shed additional light onto the failure the following items should be explored/investigated.

1. Examine (visually and mag. particle or dye-penetrant) the bottom side padeye for evidence of cracking.

2. Conduct wall thickness measurements (UT) of the buoy shell (including top/bottom shell at the location of the pad eye).

3. Open buoy to determine if an internal stiffener (center rod) has been present.

4. Review the design of the buoy.

5. Review the operation history of the buoy to determine if the buoy has been subjected to undue loads in the past.

8. For further details, please see Fig. 1-57 and Attachments 1-3.

Sincerely,

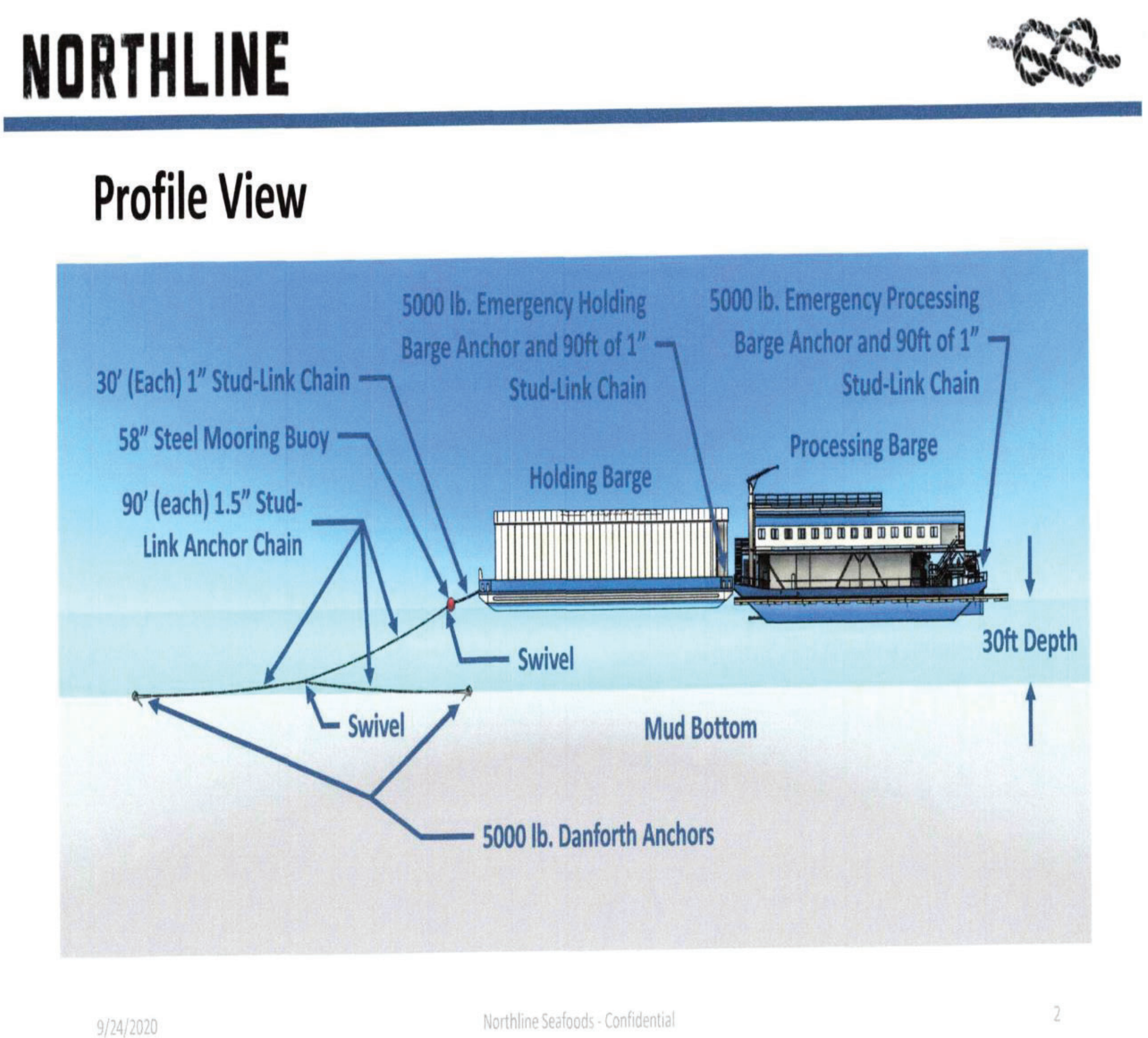
Simon Forensic, LLC.

[redacted]

Rainer Eckert
Sr. Material Scientist
E: [redacted]

Attachment 1

Layout of the mooring arrangements. Image courtesy of Mr. McFarland.



Attachment 2

View of the subject buoy (bottom side). Image courtesy of Mr. McFarland.

Attachment 3

View of the subject buoy (top side). Image courtesy of Mr. McFarland.

Fig. 1: Overall view of the submitted failed section that had reportedly been removed from the buoy (see Attachment 2-3) utilized in the moorage arrangement of barge SM3.

Fig. 2: Close up view of Fig. 1. Shell side of the failure.

Fig. 3: Same as Fig. 2, but the liberated padeye with shackles is shown.

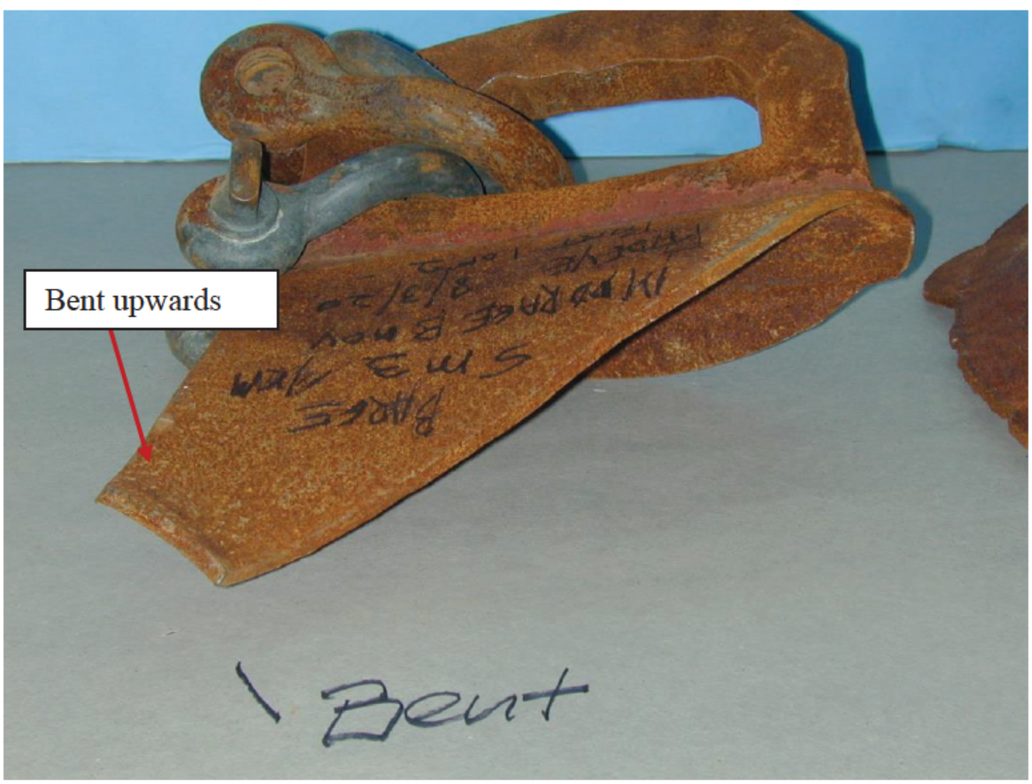


Fig. 4: Same as Fig. 3, but viewed from and different angle.

Fig. 5: Close up view of the 3x shackles.

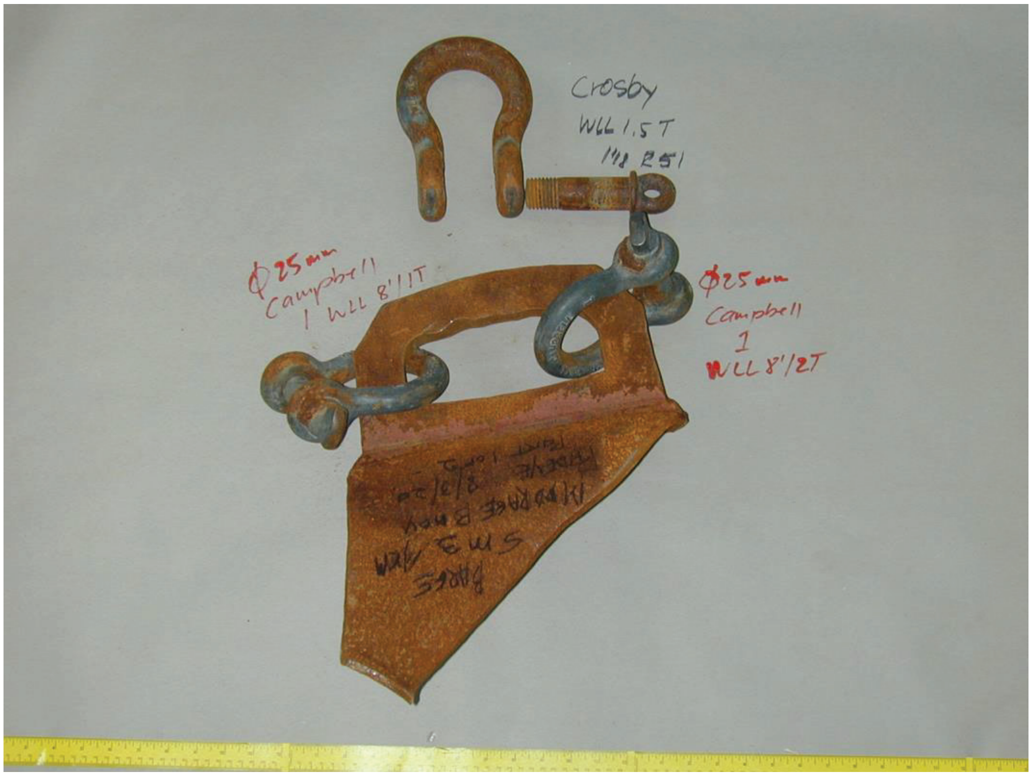


Fig. 6: Same as Fig. 5, but the Crosby shackle has been removed.

Fig. 7: Close up view of the **Crosby shackle**.

Fig. 8: Close up view of the **Campbell shackle** (#1).

Fig. 9: Same as Fig. 8, but the other **Campbell shackle** (#2) is shown.

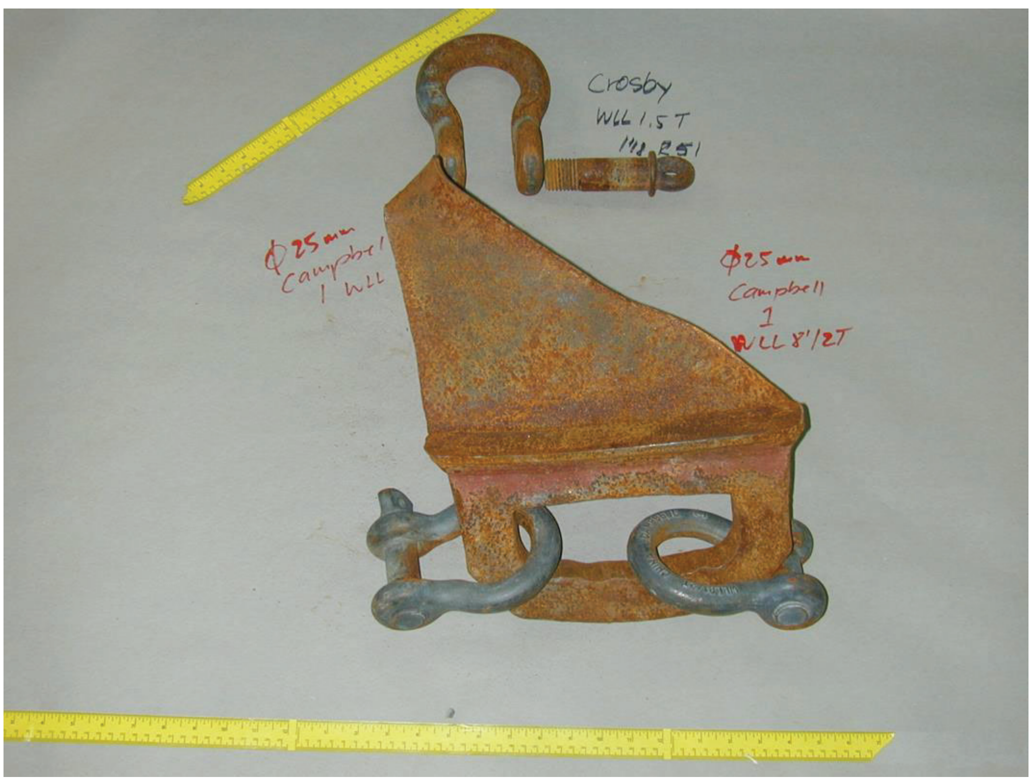


Fig. 10: Same as Fig. 6, but the padeye shown from a different angle.

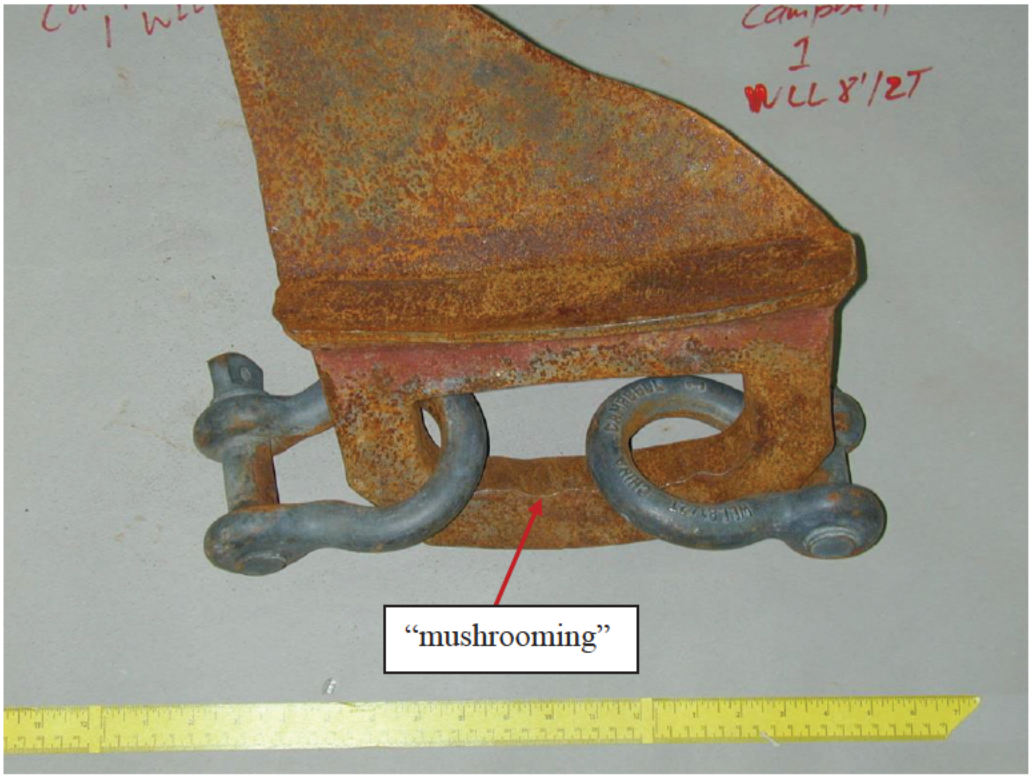


Fig. 11: Close up view of Fig. 5.

Fig. 12: Same as Fig. 2, but the shell is shown from a different angle.

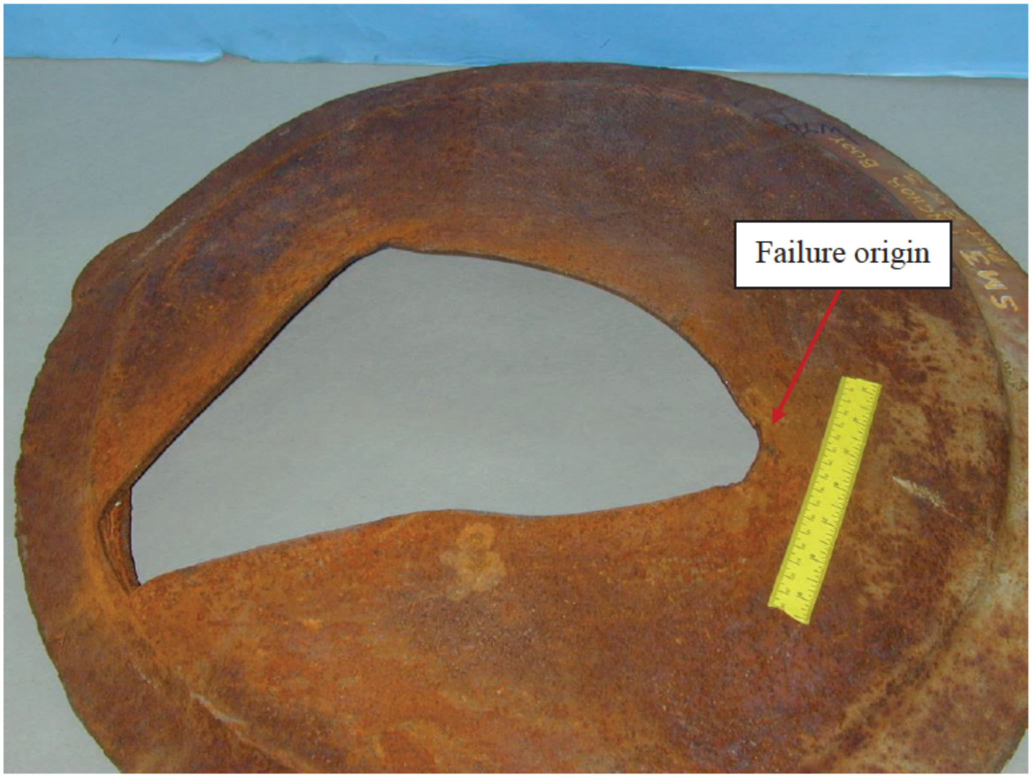


Fig. 13: Close up view of Fig. 12.

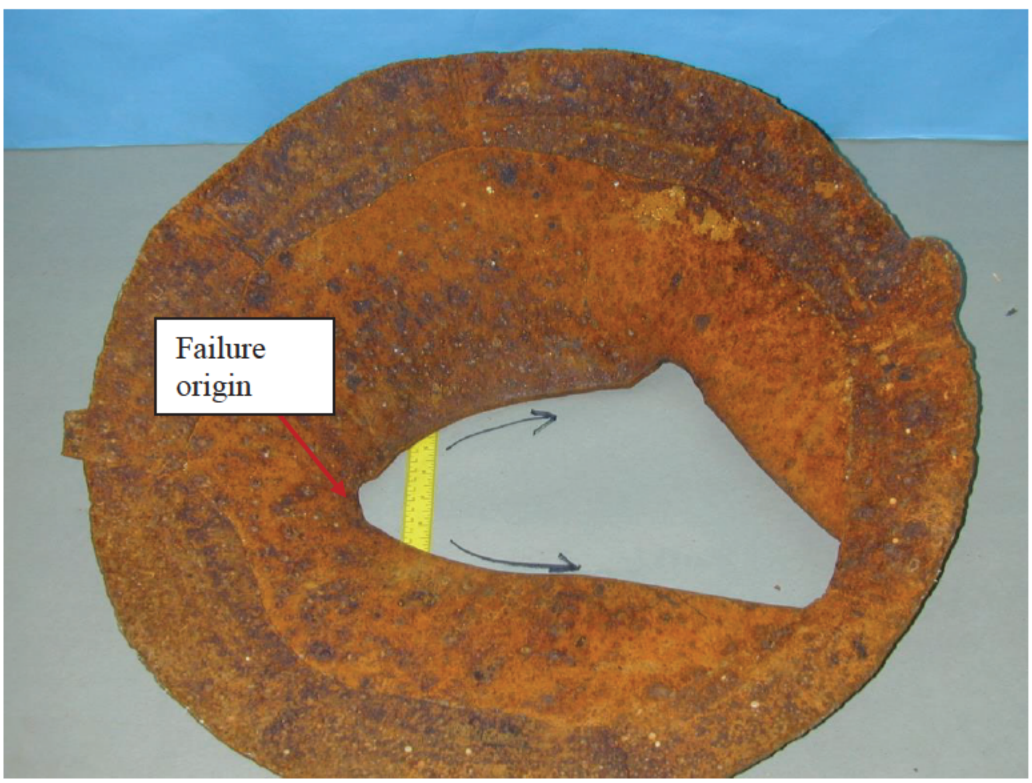


Fig. 14: Same as Fig. 13, but the inside surface is shown.

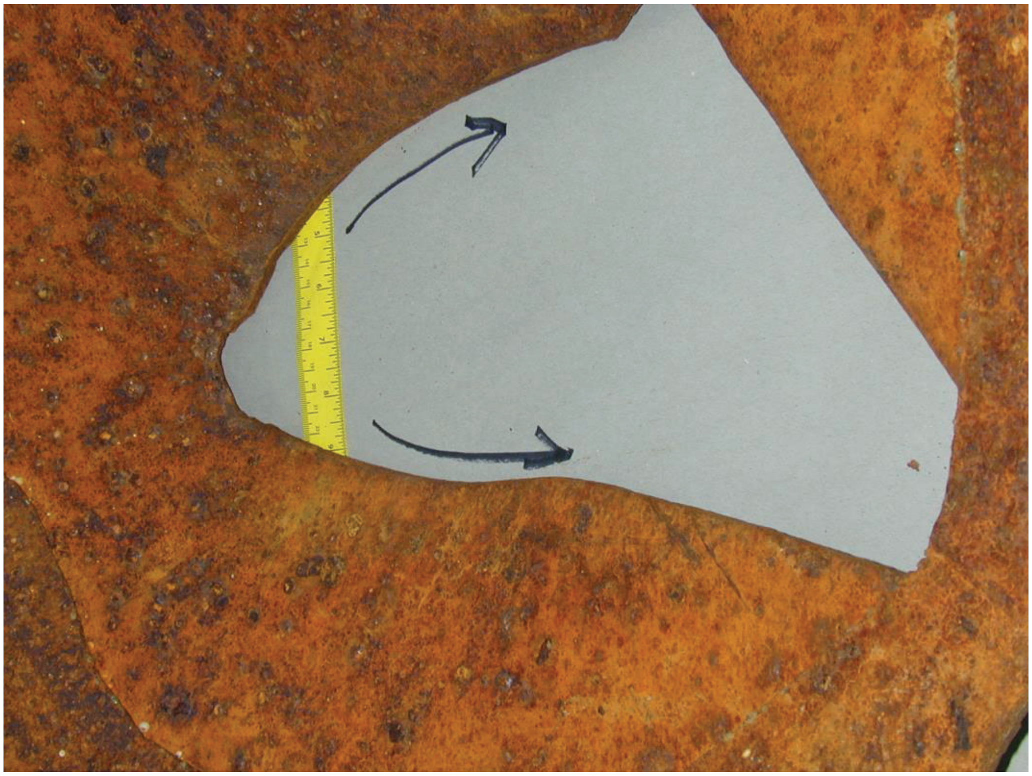


Fig. 15: Close up view of Fig. 14. Black arrows indicate the direction of crack advancement.

Fig. 16: Close up view of Fig. 15.

Fig. 17: Same as Fig. 13, but the liberated section has been superimposed for demonstrational purposes.

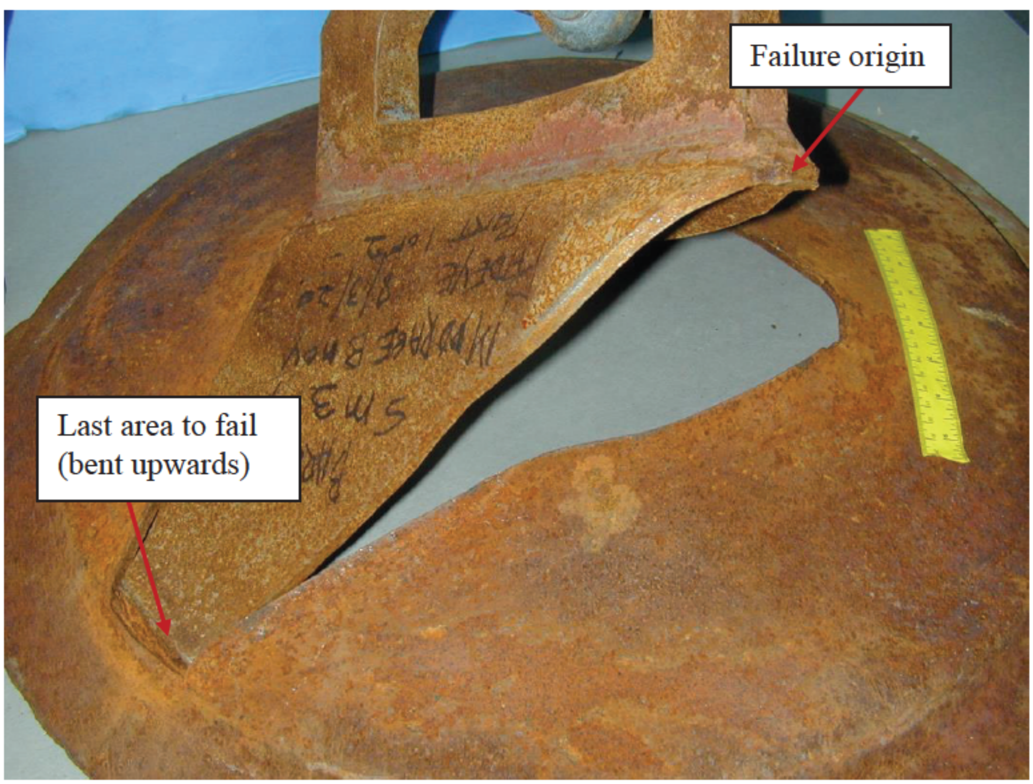


Fig. 18: Same as Fig. 17, but the direction of failure is been simulated.

Fig. 19: Overall view of the liberated failure origin.

Fig. 20: Same as Fig. 19, but viewed from a different angle.

Fig. 21: Close up view of Fig. 20.

Fig. 22: Same as Fig. 21, but viewed from a different angle.

Fig. 23: Same as Fig. 22, but viewed from the opposite side.

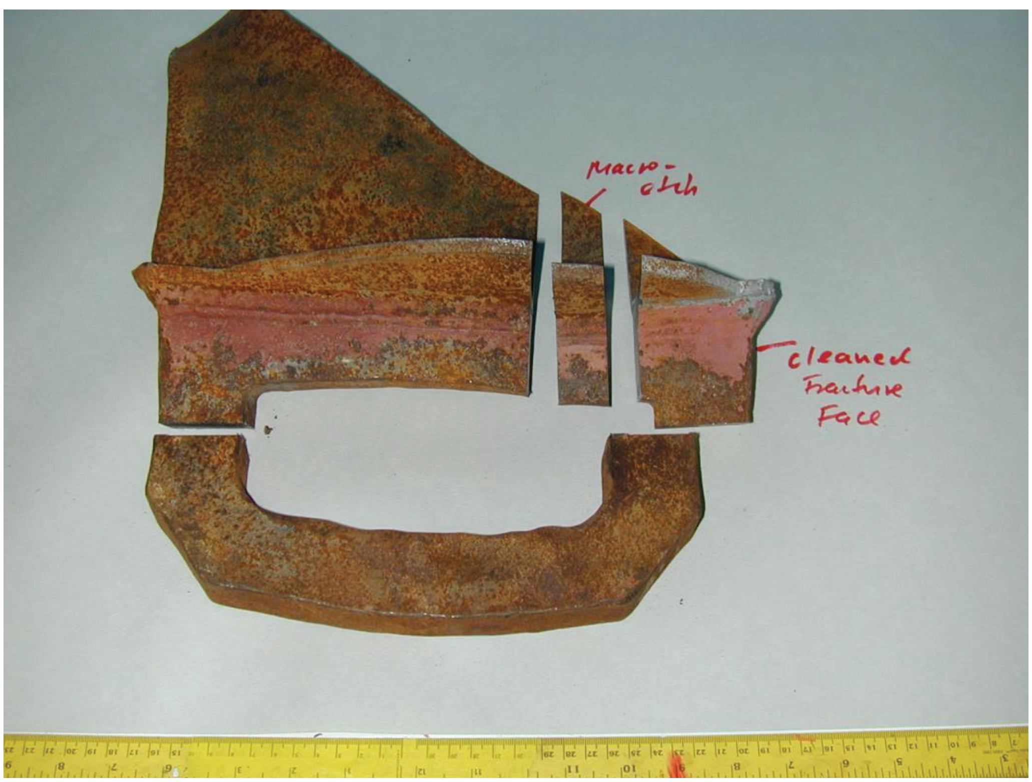


Fig. 24: Same as Fig. 11, but he padeye has been removed and an x-section removed from the weld and macro-etched.

Fig. 25: Same as Fig. 24, but viewed from a different angle.

Fig. 26: Close up view of the macro-etched weld x-section and ultrasonically cleaned failure origin.

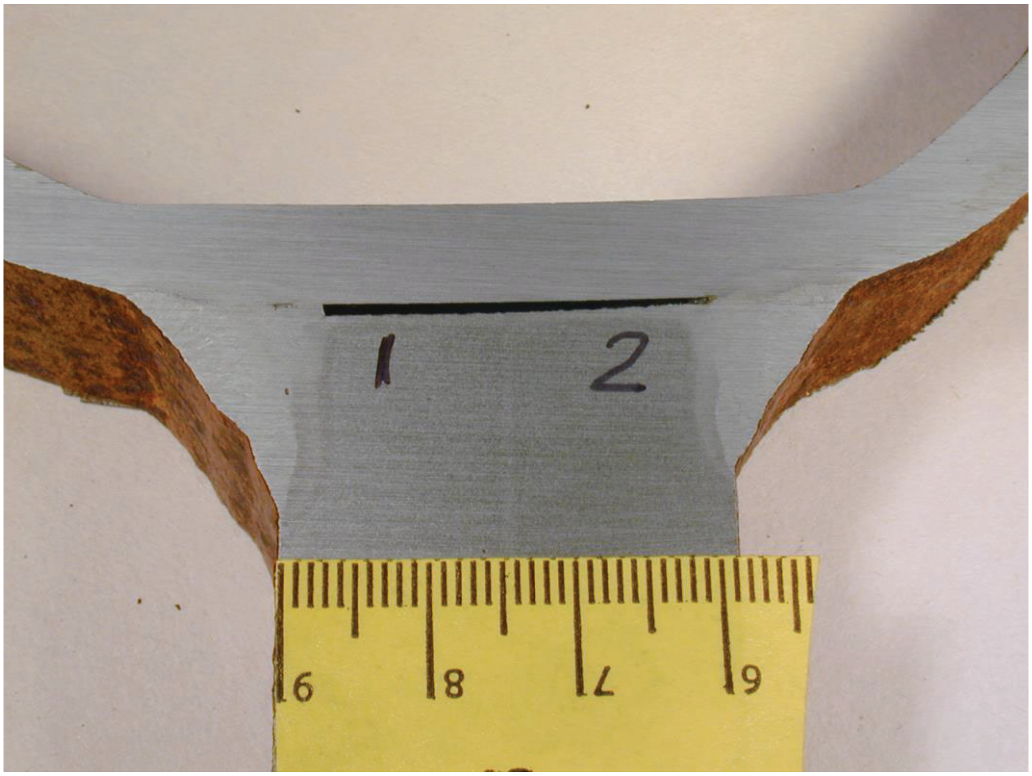


Fig. 27: Close up view of the etched weld x-section. Note, **no defects were observed**.

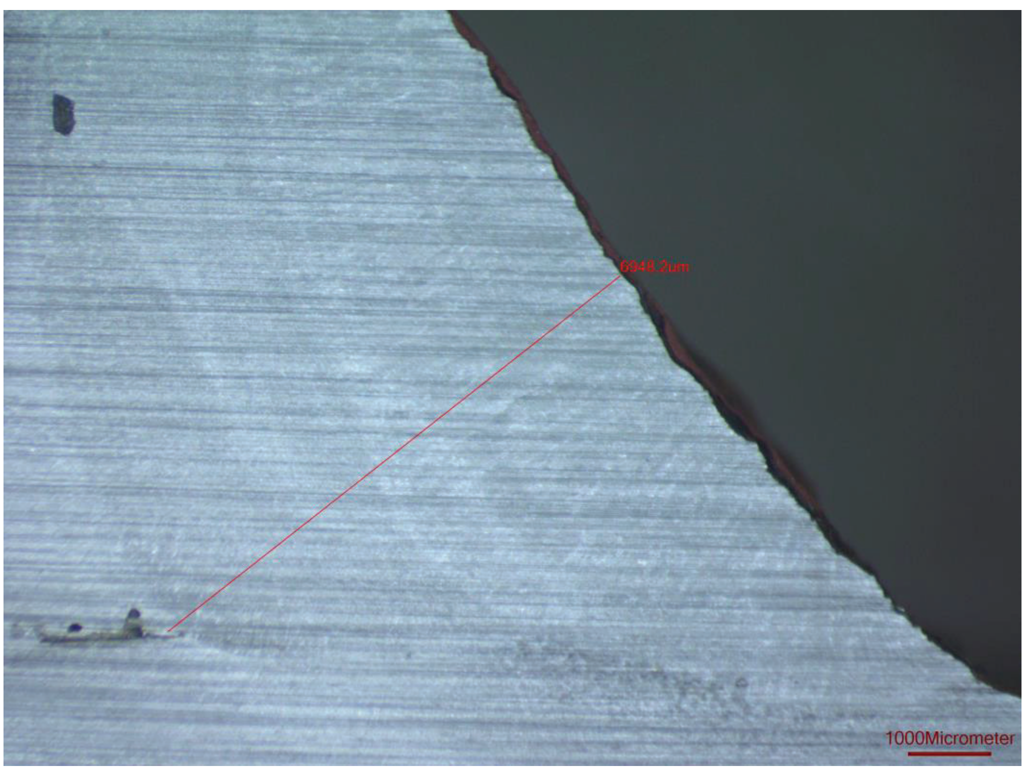


Fig. 28: Close up view of Fig. 27 (weld #1) at 10x.

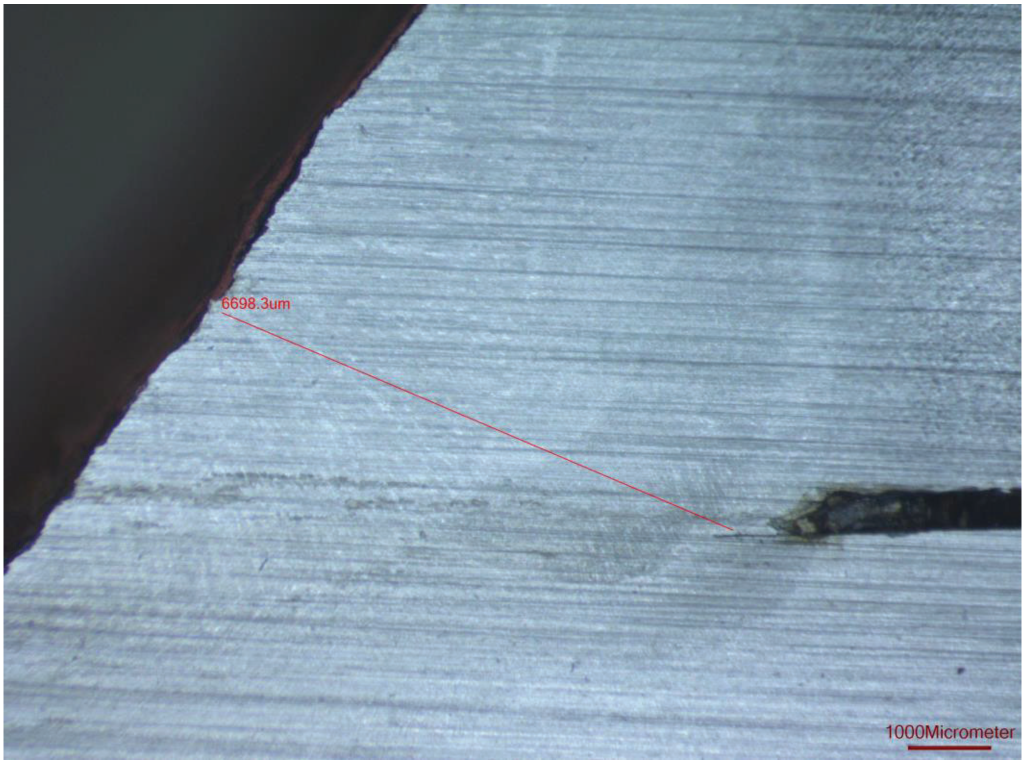


Fig. 29: Same as Fig. 28, but the other weld (#2) is shown.

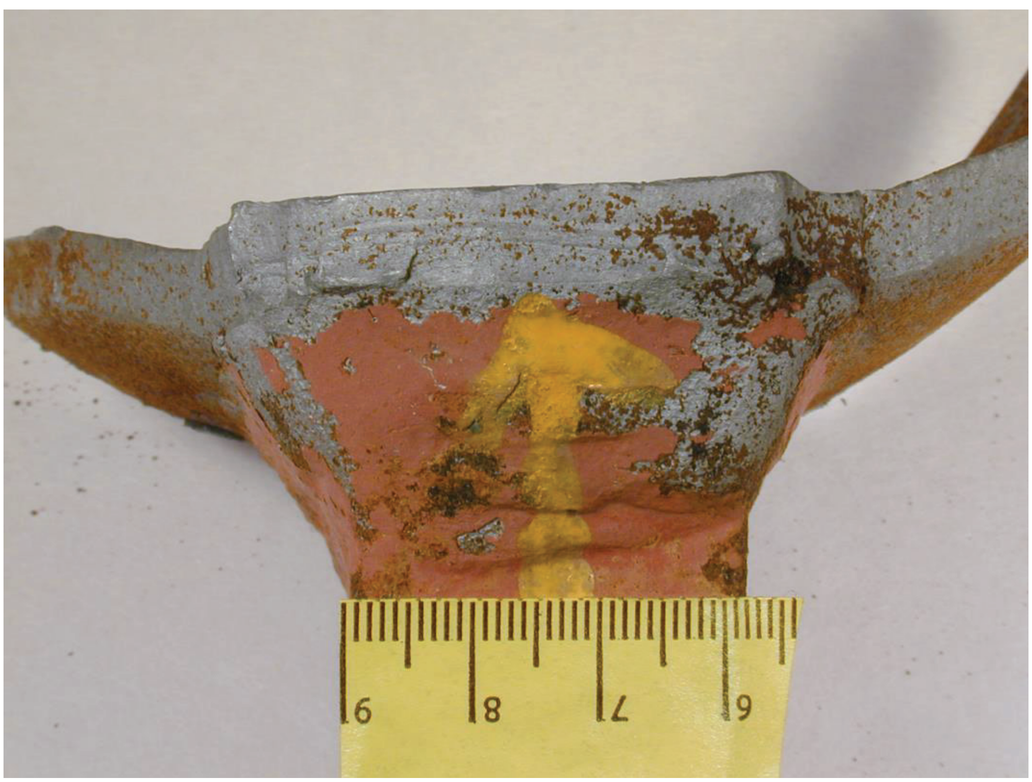


Fig. 30: Close up view of the cleaned failed origin.

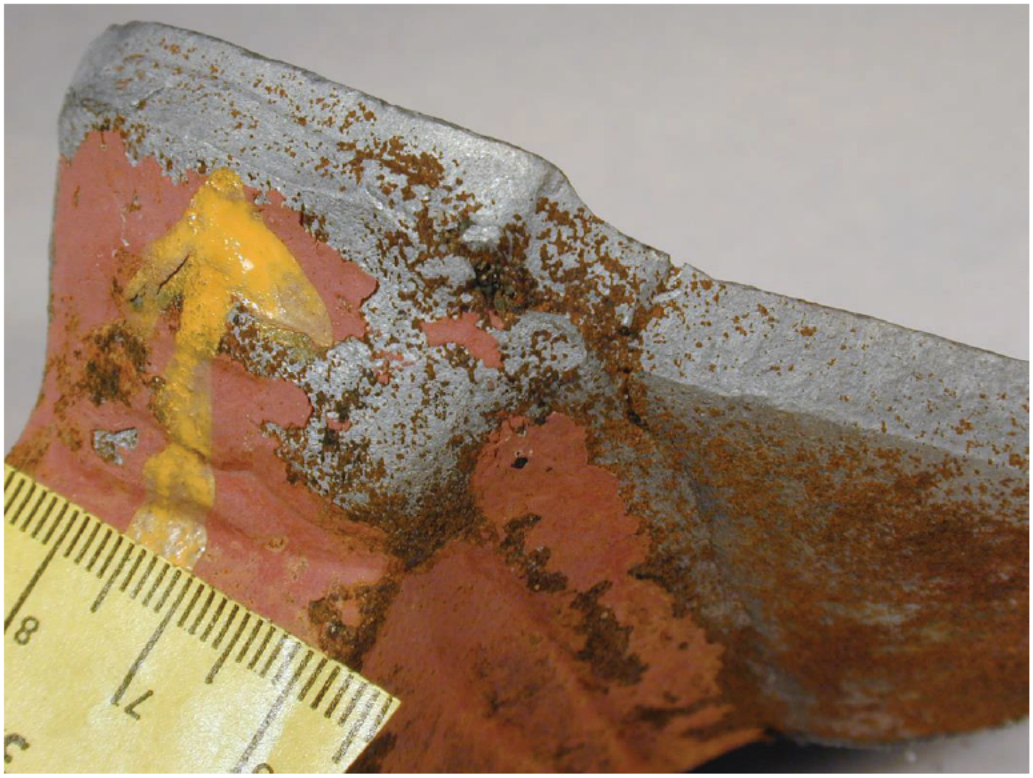


Fig. 31: Same as Fig. 30, but viewed from a different angle.

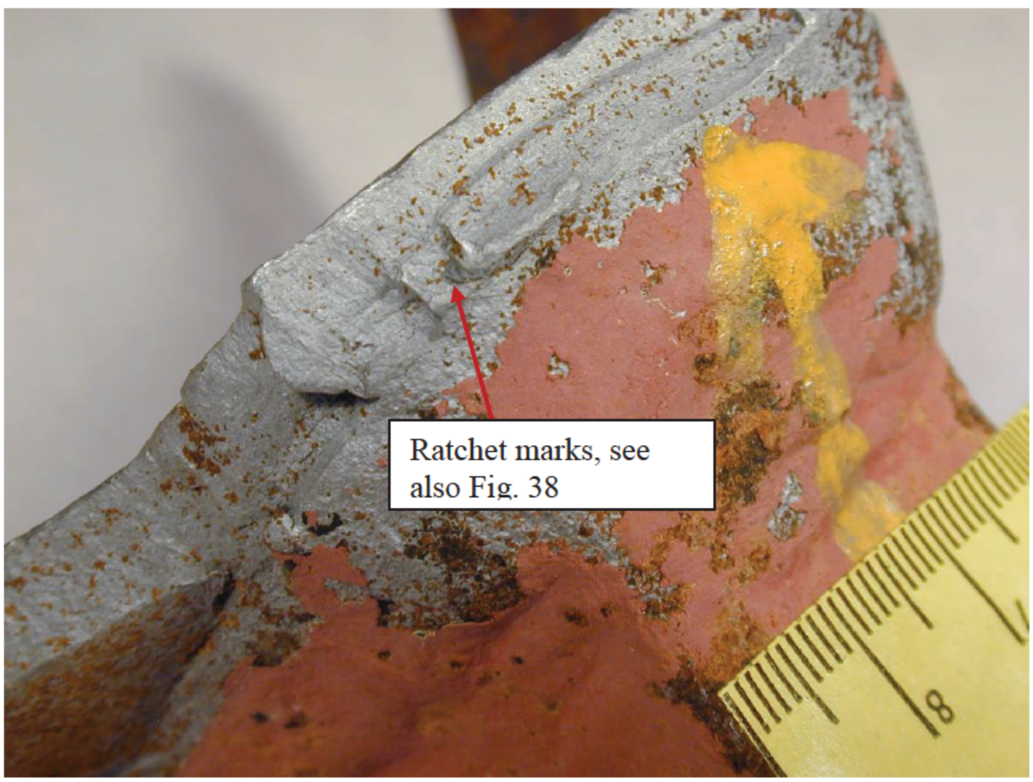


Fig. 32: Same as Fig. 31, but viewed from the opposite side.

Fig. 33: Close up view of Fig. 30.

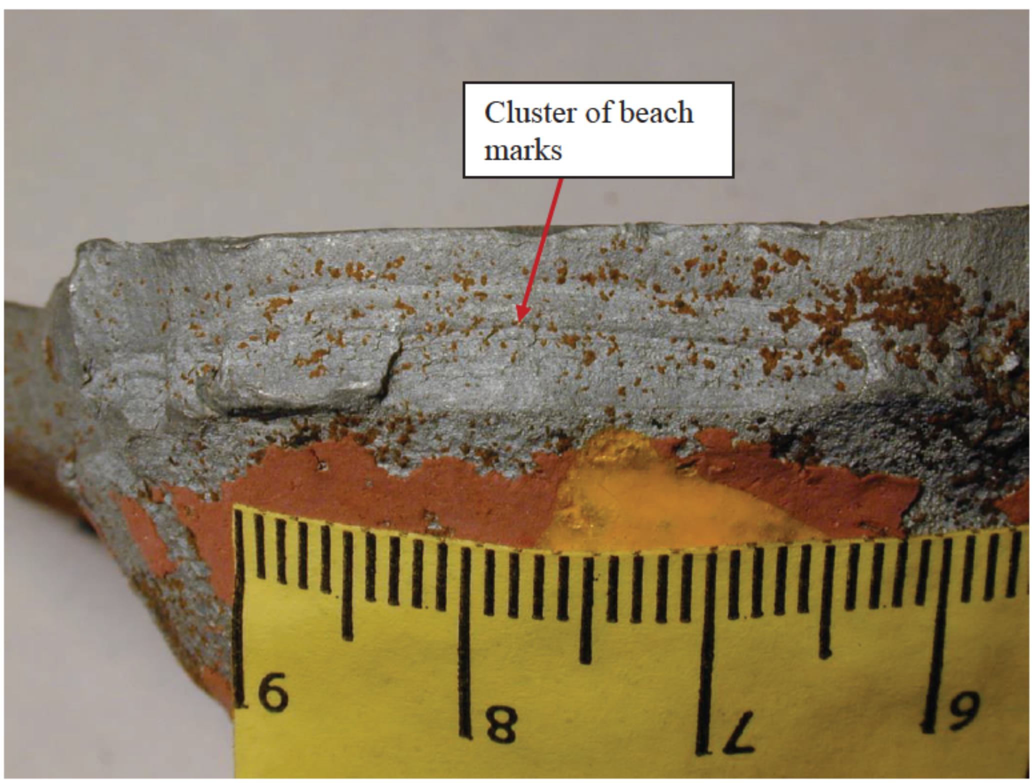


Fig. 34: Close up view of Fig. 33.

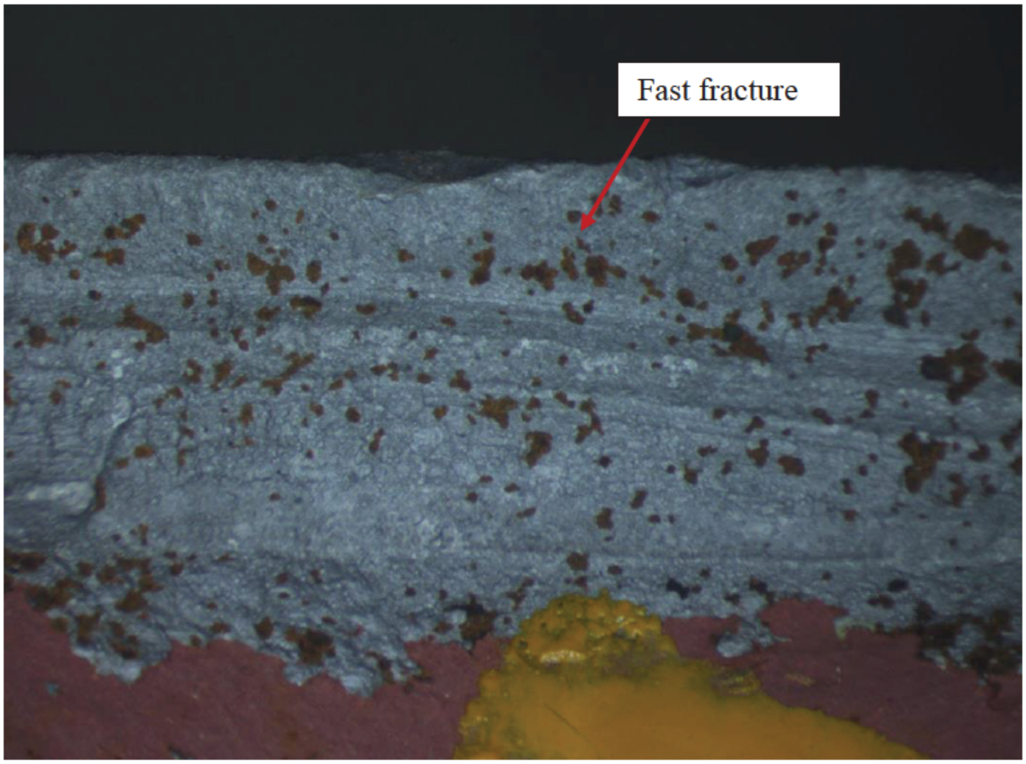


Fig. 35: Close up view of Fig. 34 at 10x.

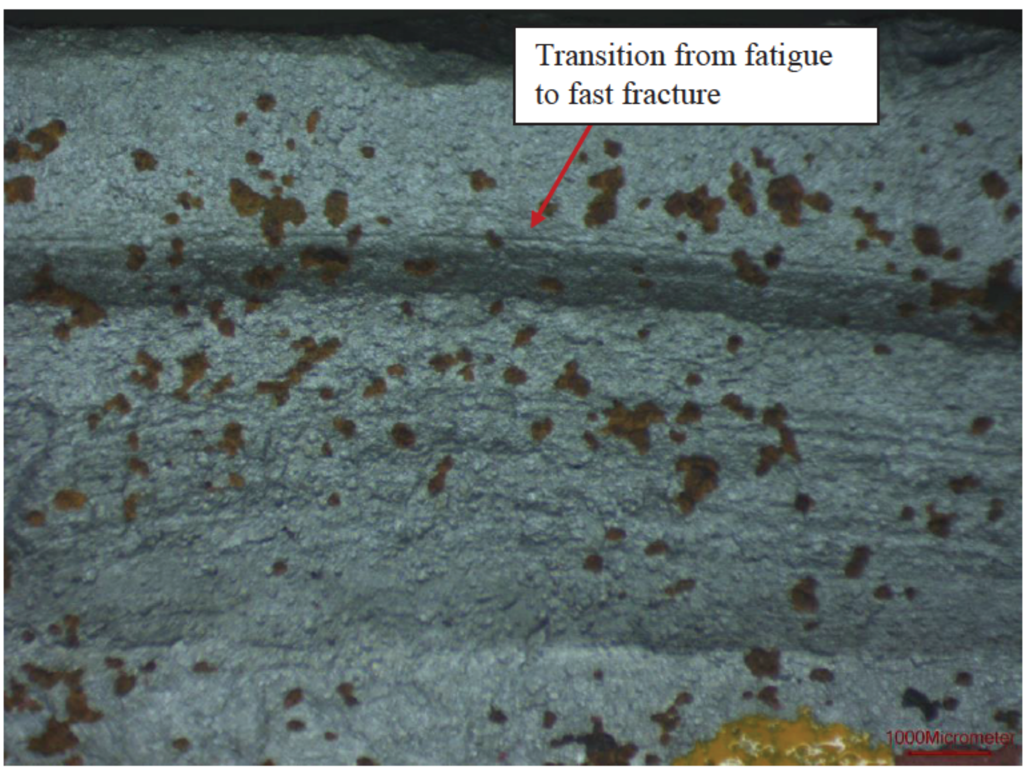


Fig. 36: Same as Fig. 35, but differently illuminated.

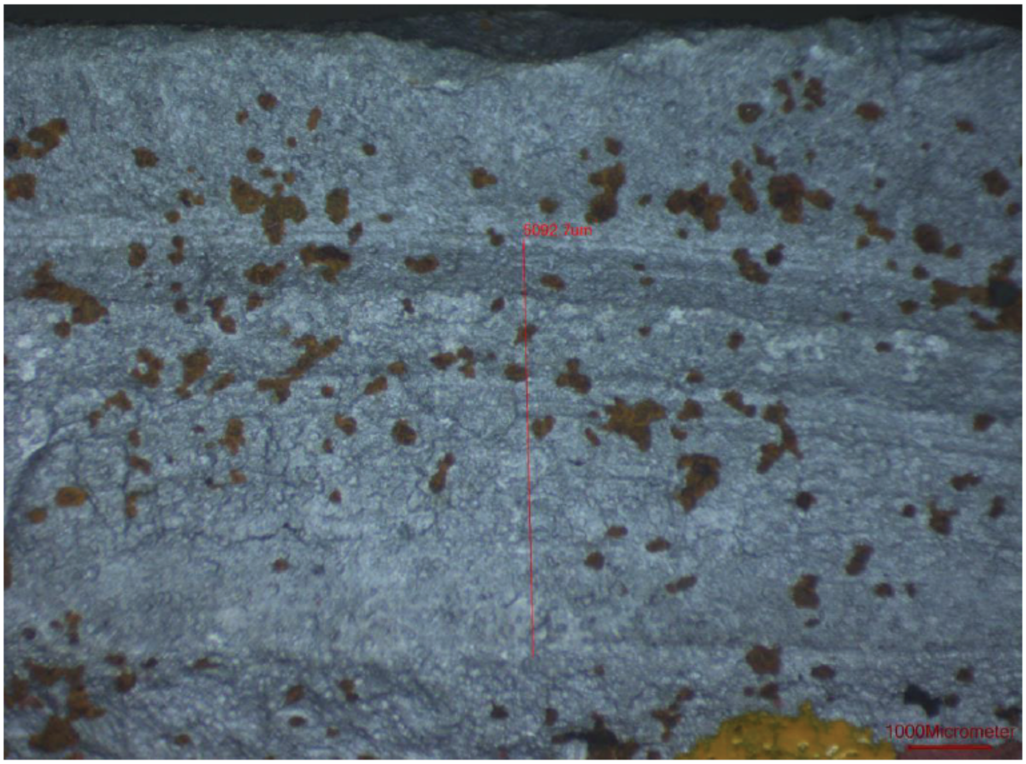


Fig. 37: Same as Fig. 36, but the depth of the fatigue zone has been measured, see annotations,

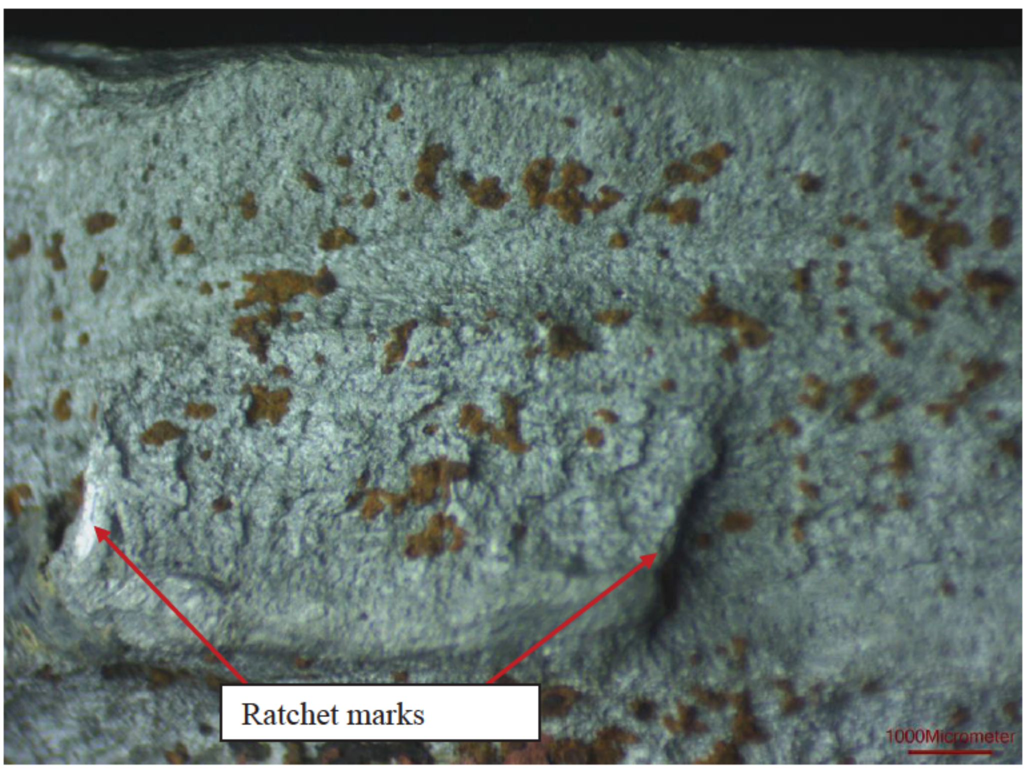


Fig. 38: Same as Fig. 37, but the area to the left is shown.

Fig. 39: Overall view of the metallographically prepared sections.

Fig. 40: Same as Fig. 39, but the cleaned failure origin is shown from the end.

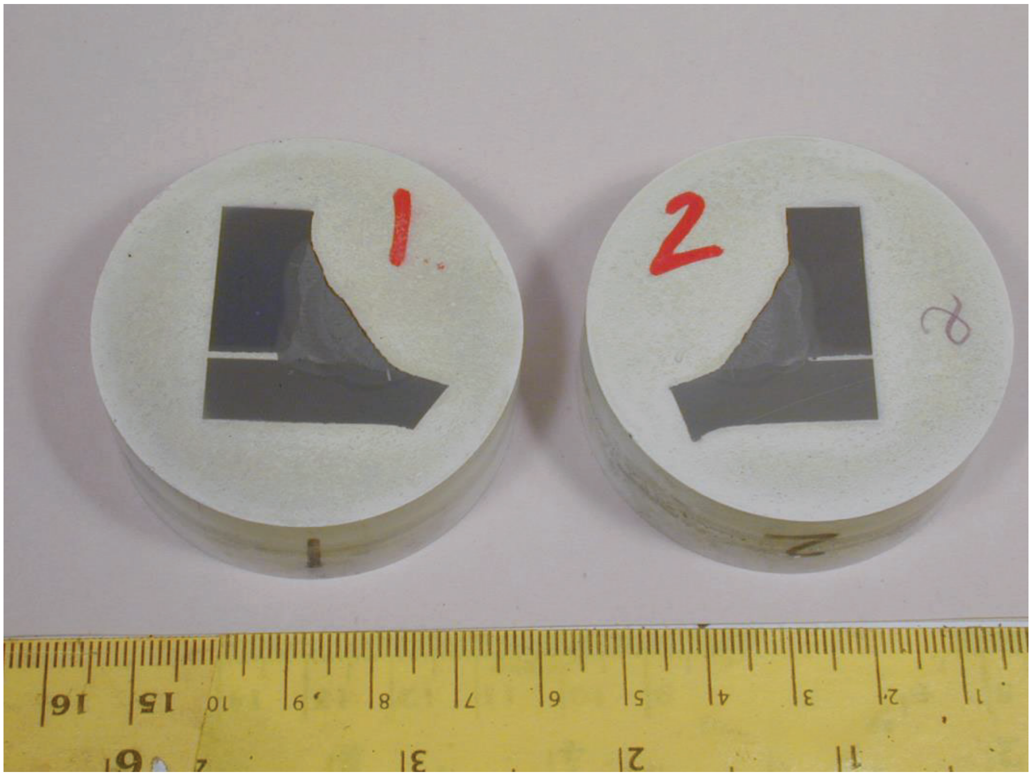


Fig. 41: Close up view of Fig. 40.

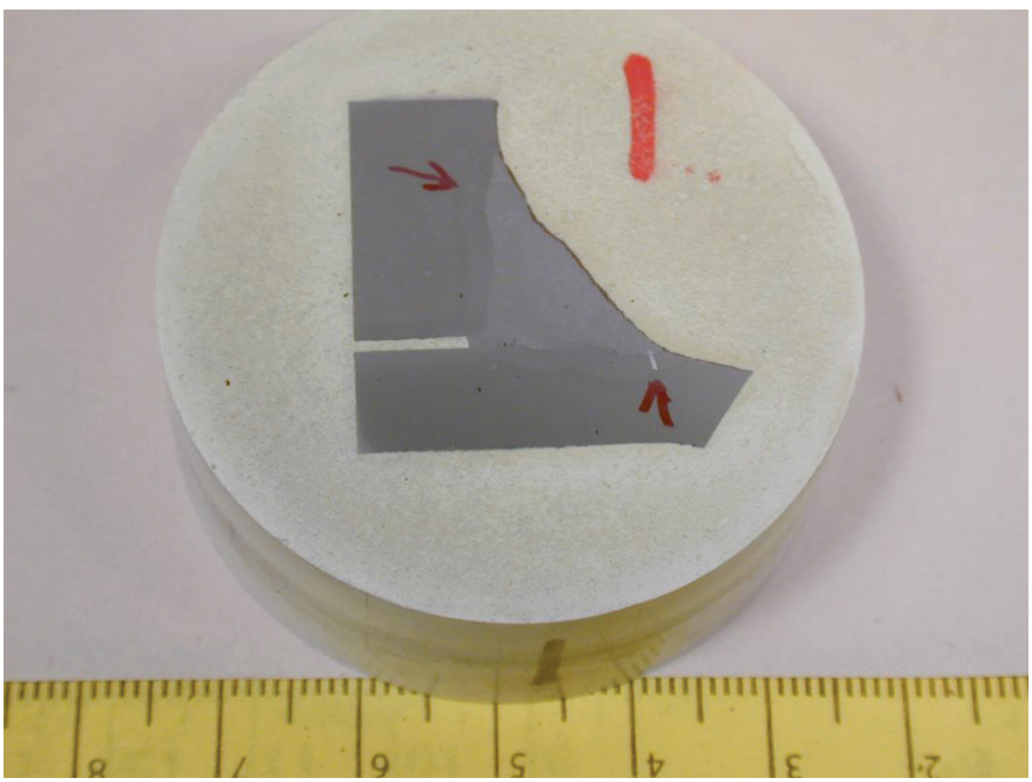


Fig. 42: Close up view of Fig. 41 (weld #1). Red arrows indicate the locations of microhardness survey.

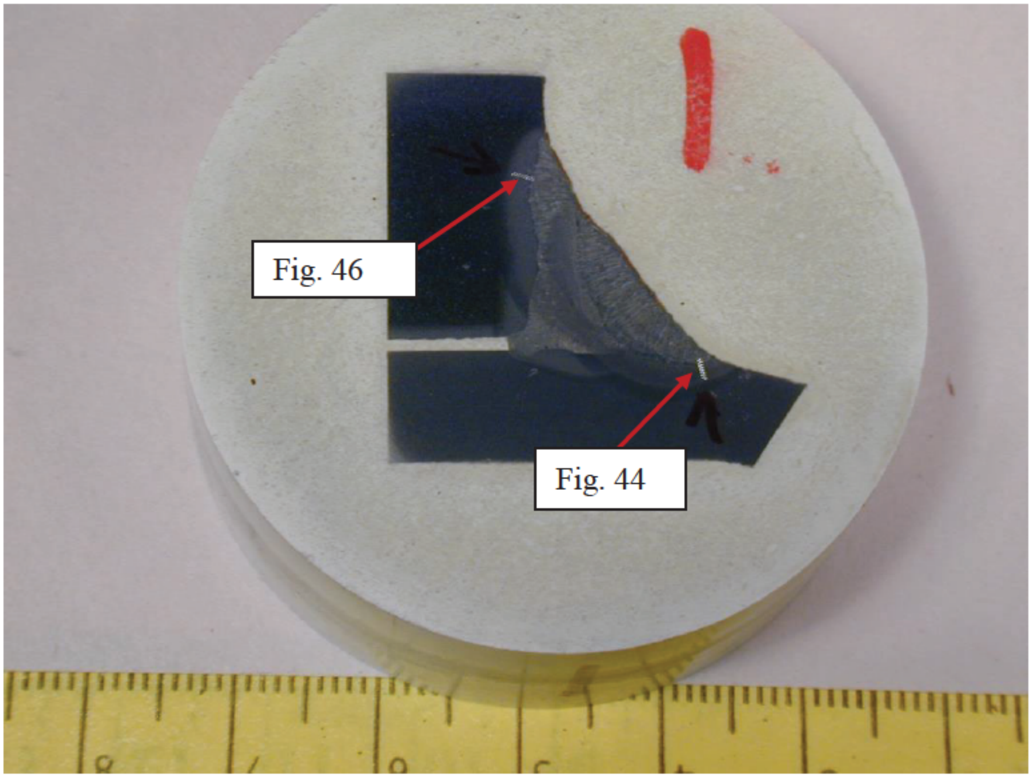


Fig. 43: Same as Fig. 42, but differently illuminated.

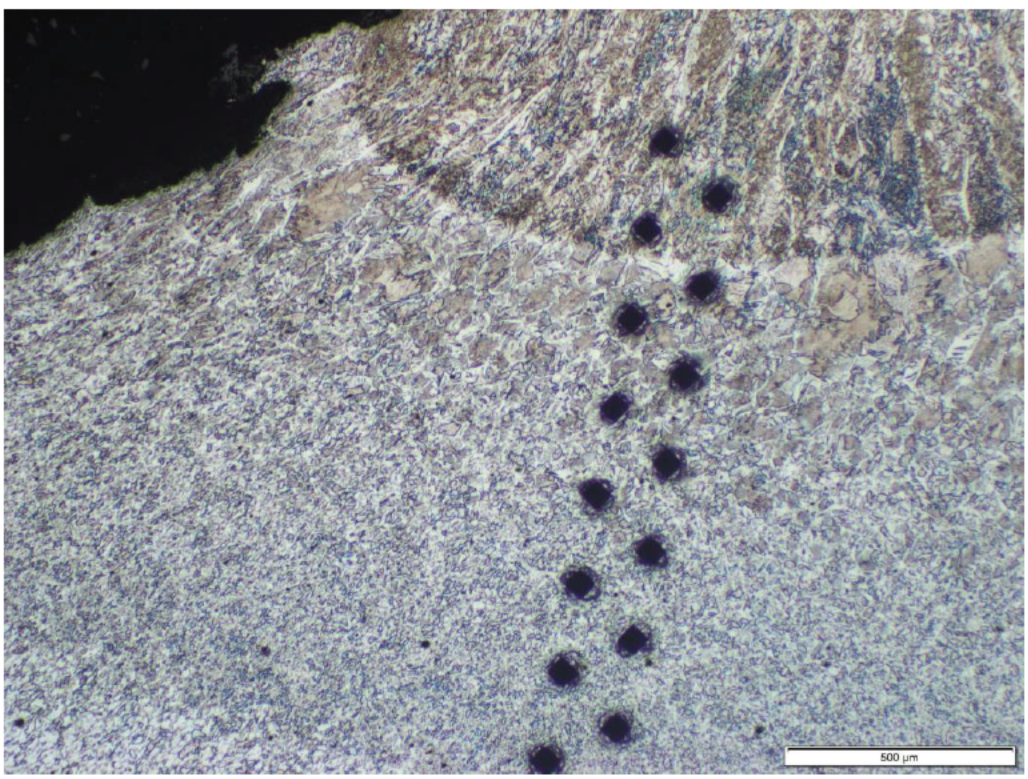


Fig. 44: Close up view of Fig. 43 at 50x. Note, no undesirable phase transformation products were observed.

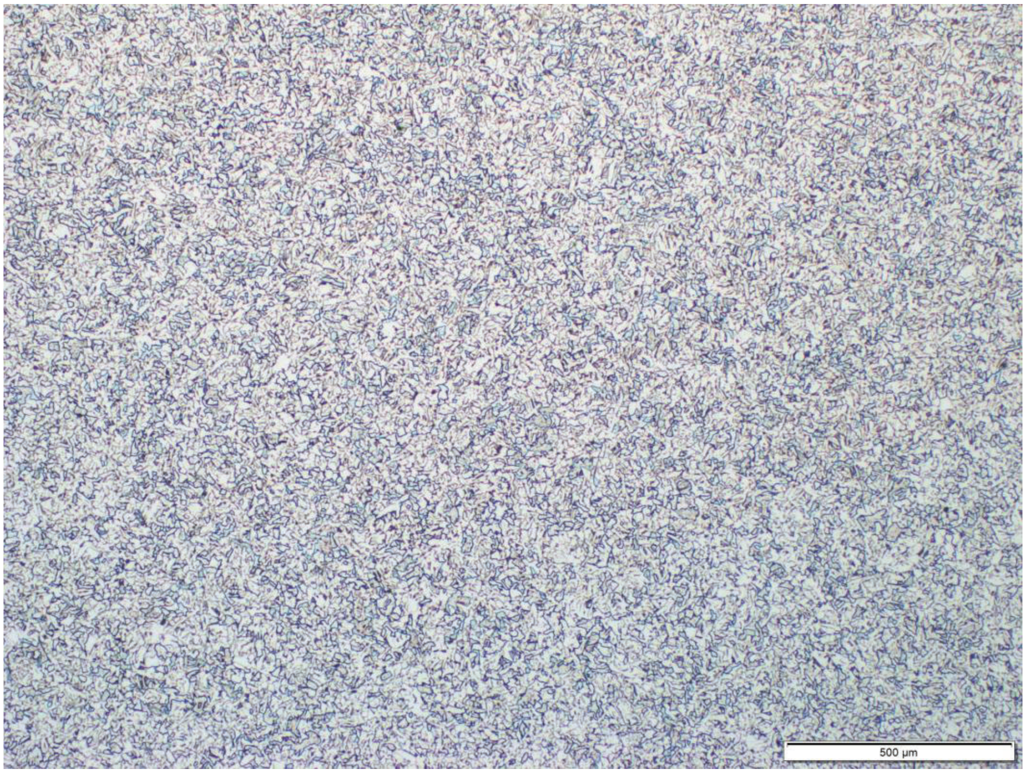


Fig. 45: Same as Fig. 44, but the base metal (buoy shell) is shown.

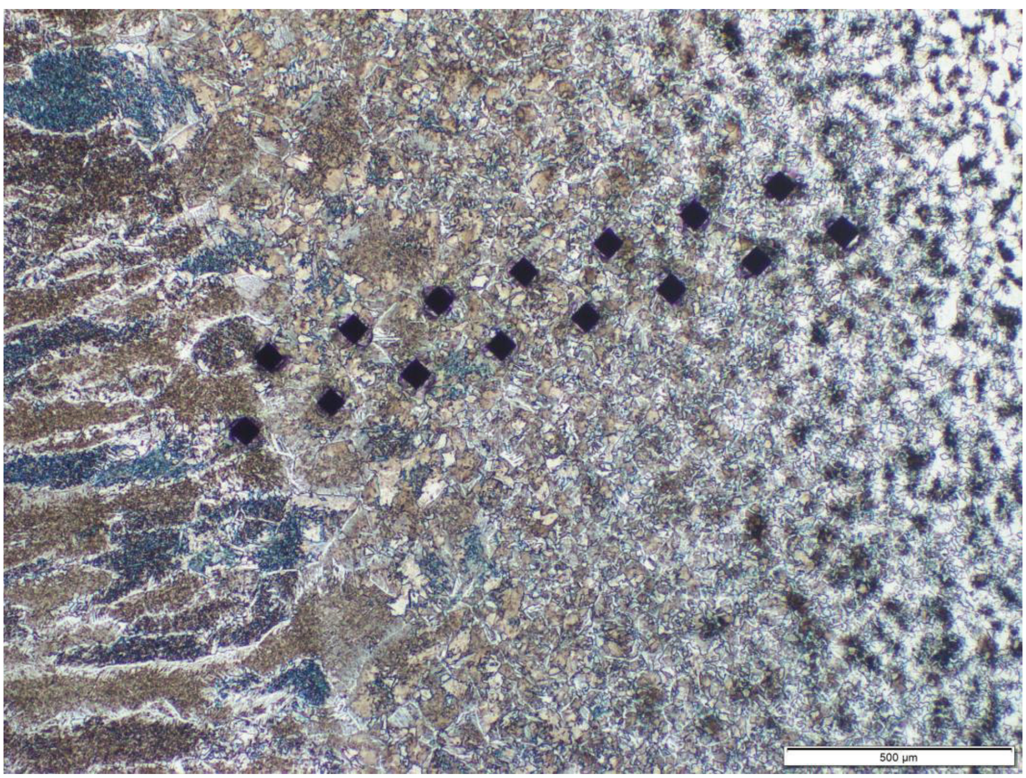


Fig. 46: Same as Fig. 44, but the other weld (see Fig. 43) is shown. Note, no undesirable phase transformation products were observed.

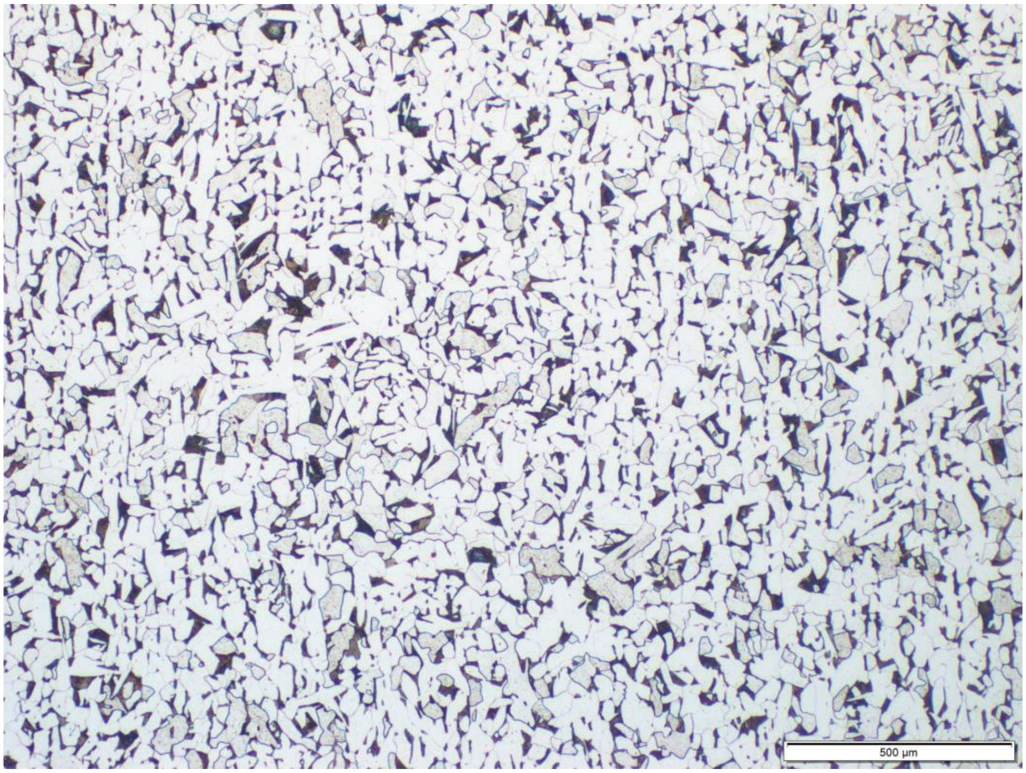


Fig. 47: Same as Fig. 46, but the base metal (padeye) is shown.

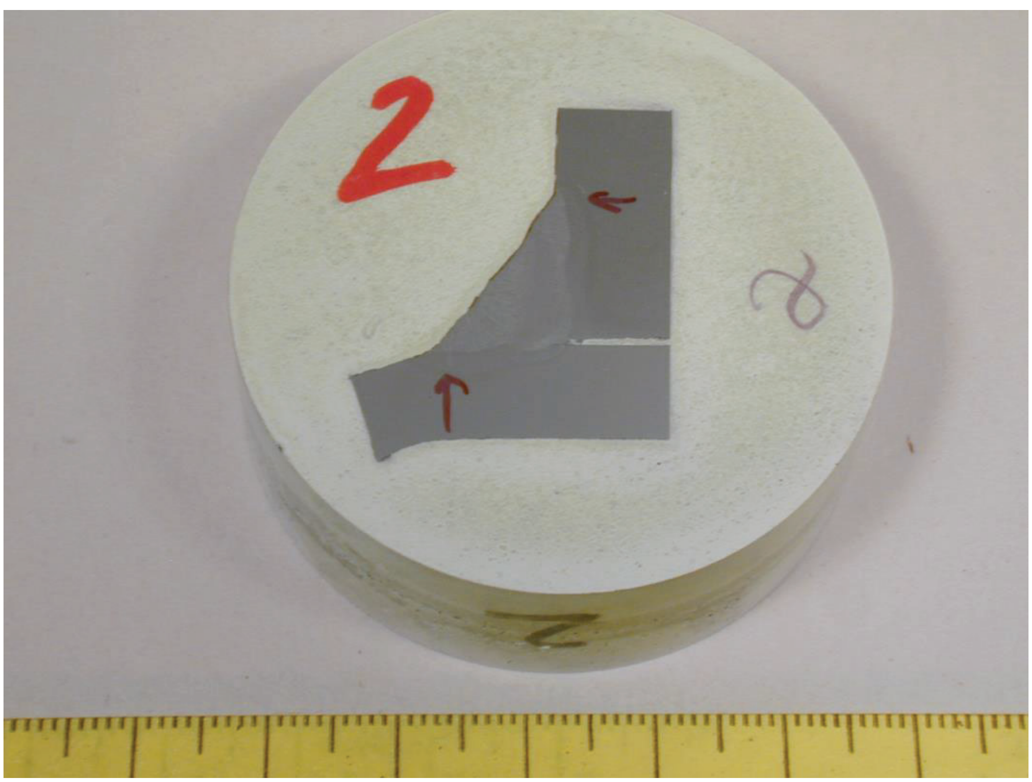


Fig. 48: View of weld section #2.

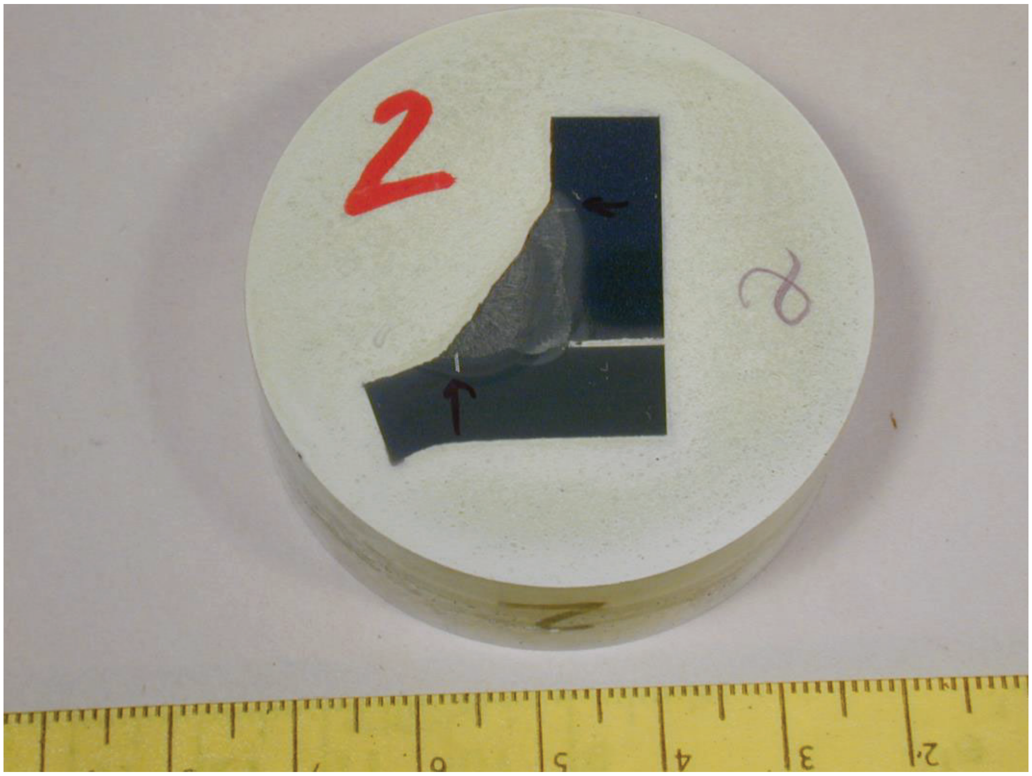


Fig. 49: Same as Fig. 48, but differently illuminated.

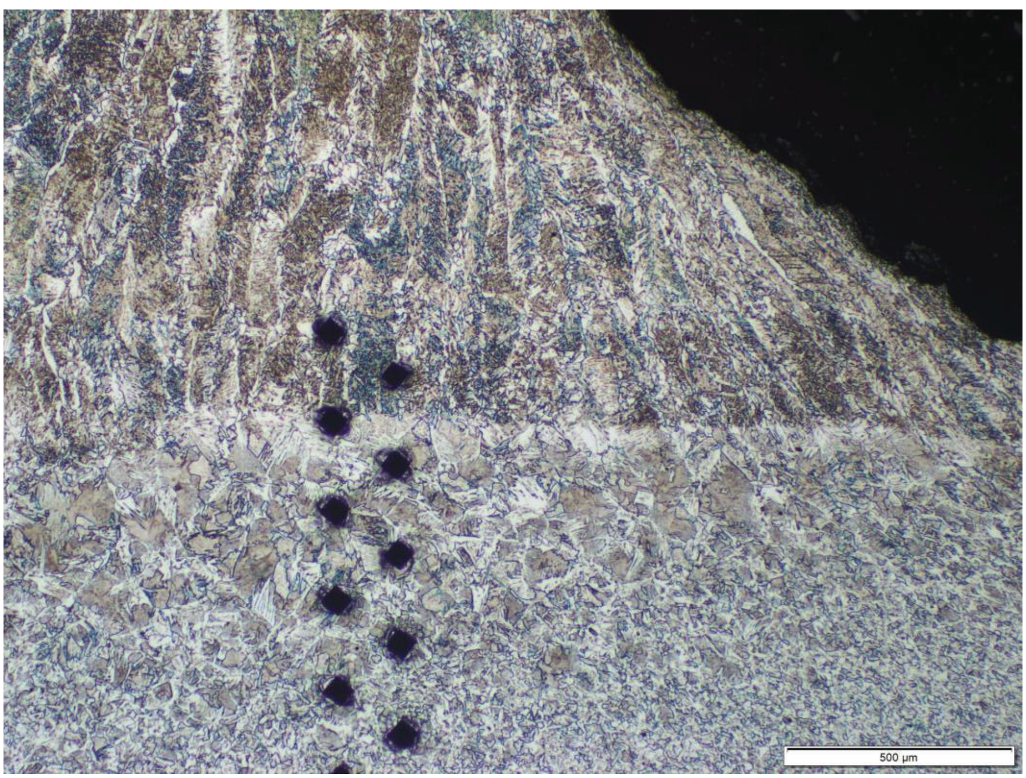


Fig. 50: Close up view of Fig. 51 at 50x. Note, no undesirable phase transformation products were observed.

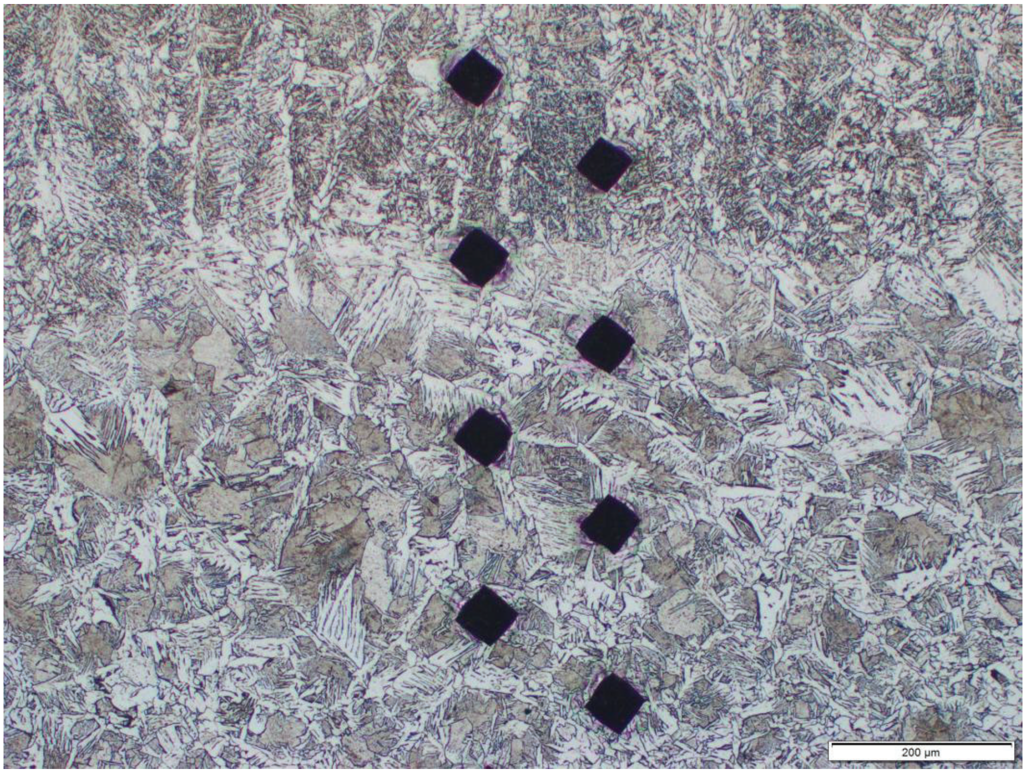


Fig. 51: Close up view of Fig. 50 at 100x.

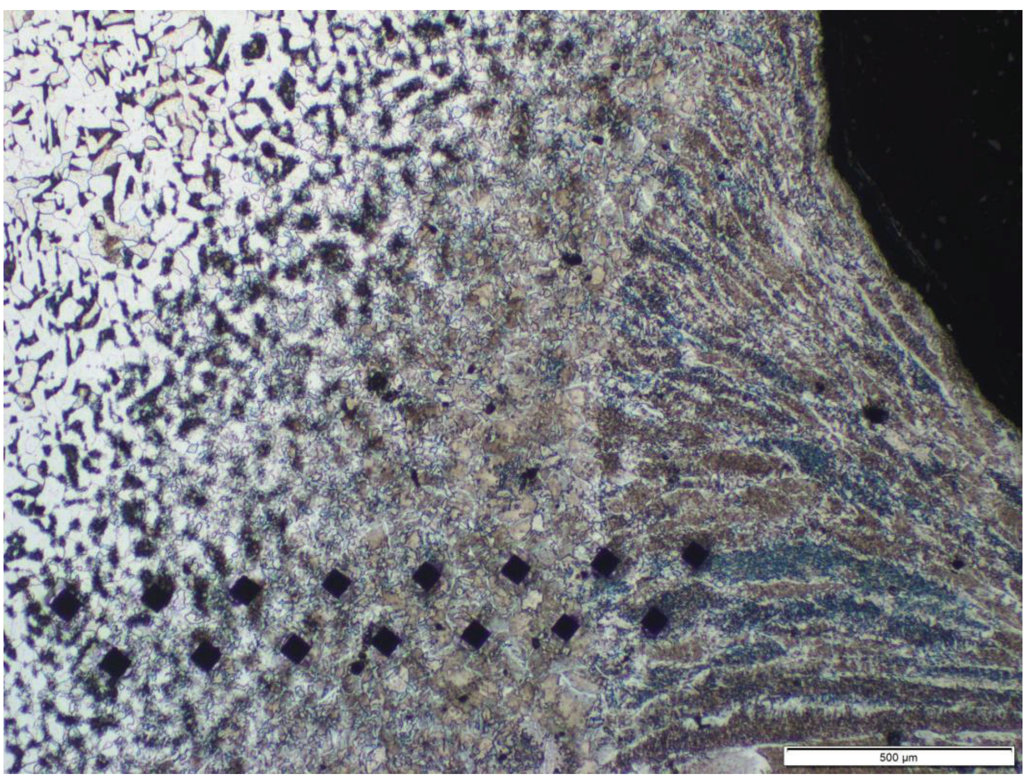


Fig. 52: Same as Fig. 50, but the other weld is shown. Note, no undesirable phase transformation products were observed.

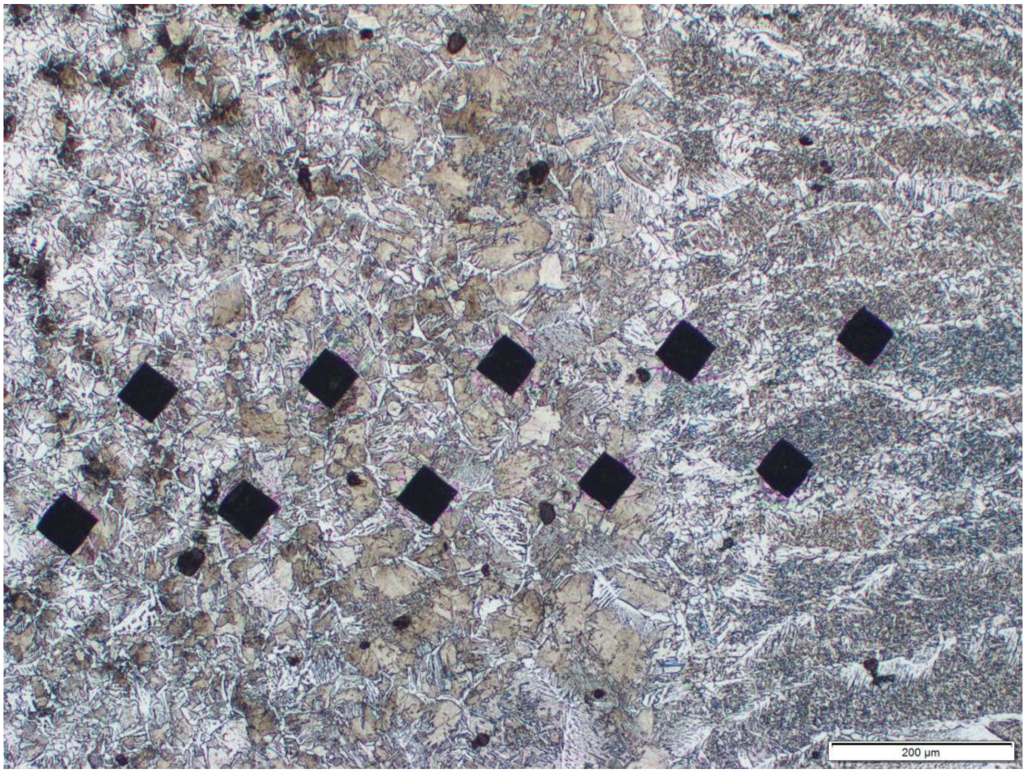


Fig. 53: Close up view of Fig. 52 at 100x.

Fig. 54: Same as Fig. 20, but the other end of the padeye is shown.

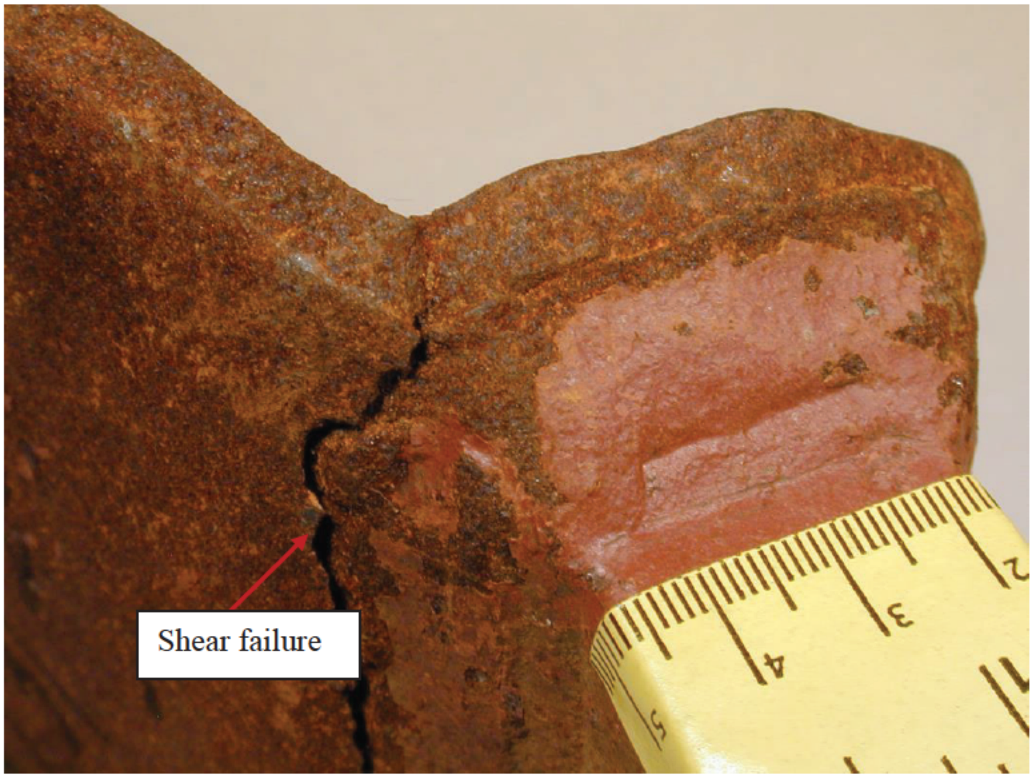


Fig. 55: Close up view of Fig. 54.

Fig. 56: Same as Fig. 55, but the other side of the padeye end is shown.

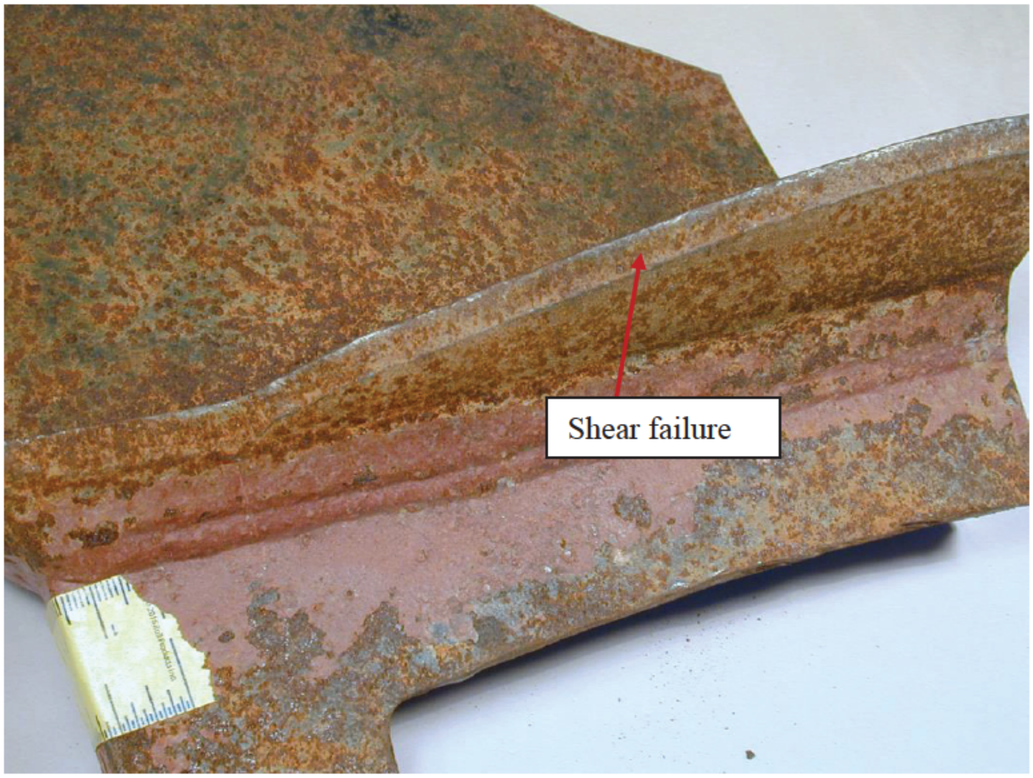


Fig. 57: View of the buoy shell failure.