EAGLE Alloy, Inc.
Steel Castings
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To: Whom it may concern

From: Bruce Gilbert
Quality Control Manager

Subject: Weld Sample Analysis – High Alloy

Customers often express concern over cosmetic welding of castings. We define cosmetic welding as less than 20% of the part wall thickness. Most surface defects in a sand casting end up in this realm.

We have put together this small report showing that welding can become near transparent with the base material if done properly.

PROCESS:
The defects must first be excavated, usually using an air-arc process.
Then the defect is welded using rod of similar chemistry as the base material.
The weld is then ground flush to the casting surface.

At this point, there are a couple of options, depending on the material.

1) In low alloy materials, a temper is usually sufficient if the defect is in a non-machined area.
2) In higher alloy materials, a complete re-heat treat is recommended because there is a more distinct heat affected zone and the base material is usually martensitic.

TESTING:
For this test, we used a casting with a diameter of 3-1/4". The base material was ASTM A487 Gr 4 alloyed steel quenched and tempered to a 241 BHN (100 R_b) hardness.

We arced out a section ~1/2" deep and welded it back up using the TIG method and CM-86-10 weld rod. The chemistries for the base material and weld rod were taken and reported in the report.

After welding, we re-heat treated the casting to the original heat treat cycle:
Normalized @ 1750^{o}F for 3 hours, air cooled.
Austenitized @ 1750^{o}F for 3 hours, oil quenched.
Tempered @ 1150^{o}F for 3 hours to hardness.

The attached report describes the hardness and metallographic results of this test across the base metal, heat affected zone, and into the weld material. As you will see, the transition is virtually transparent.

This report shows there should be no concern for welding defects in castings if done properly.

Thank you!

Bag

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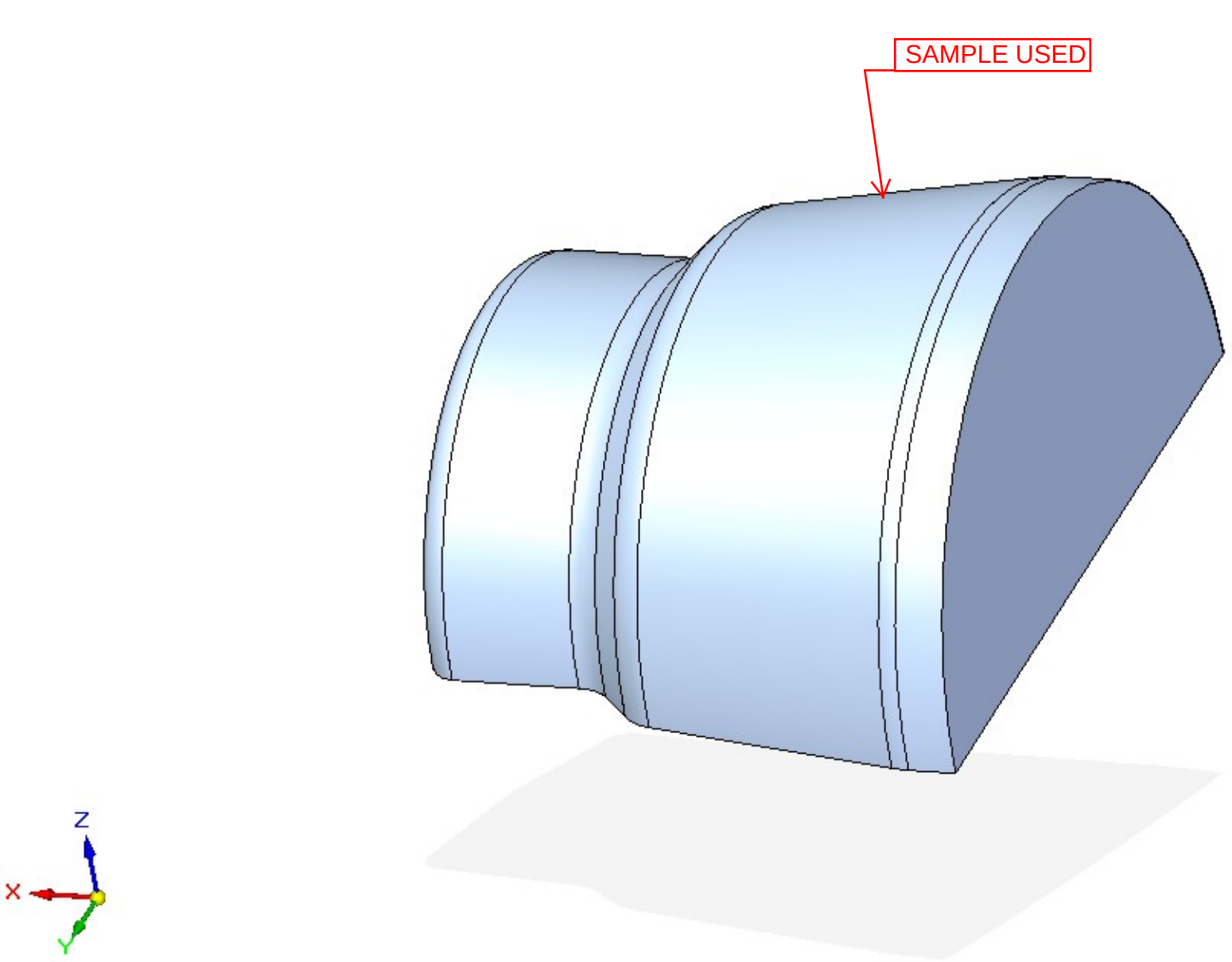
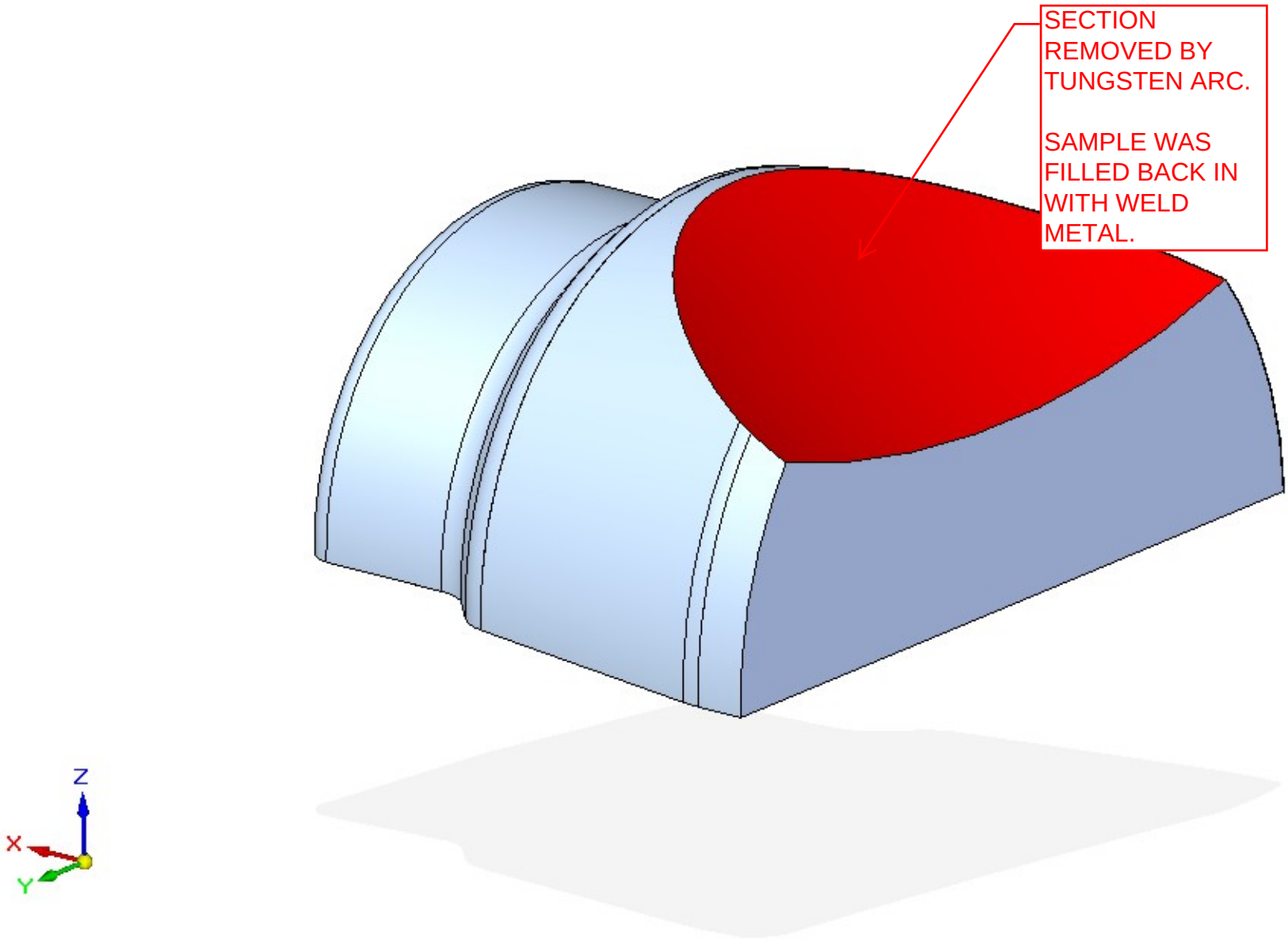
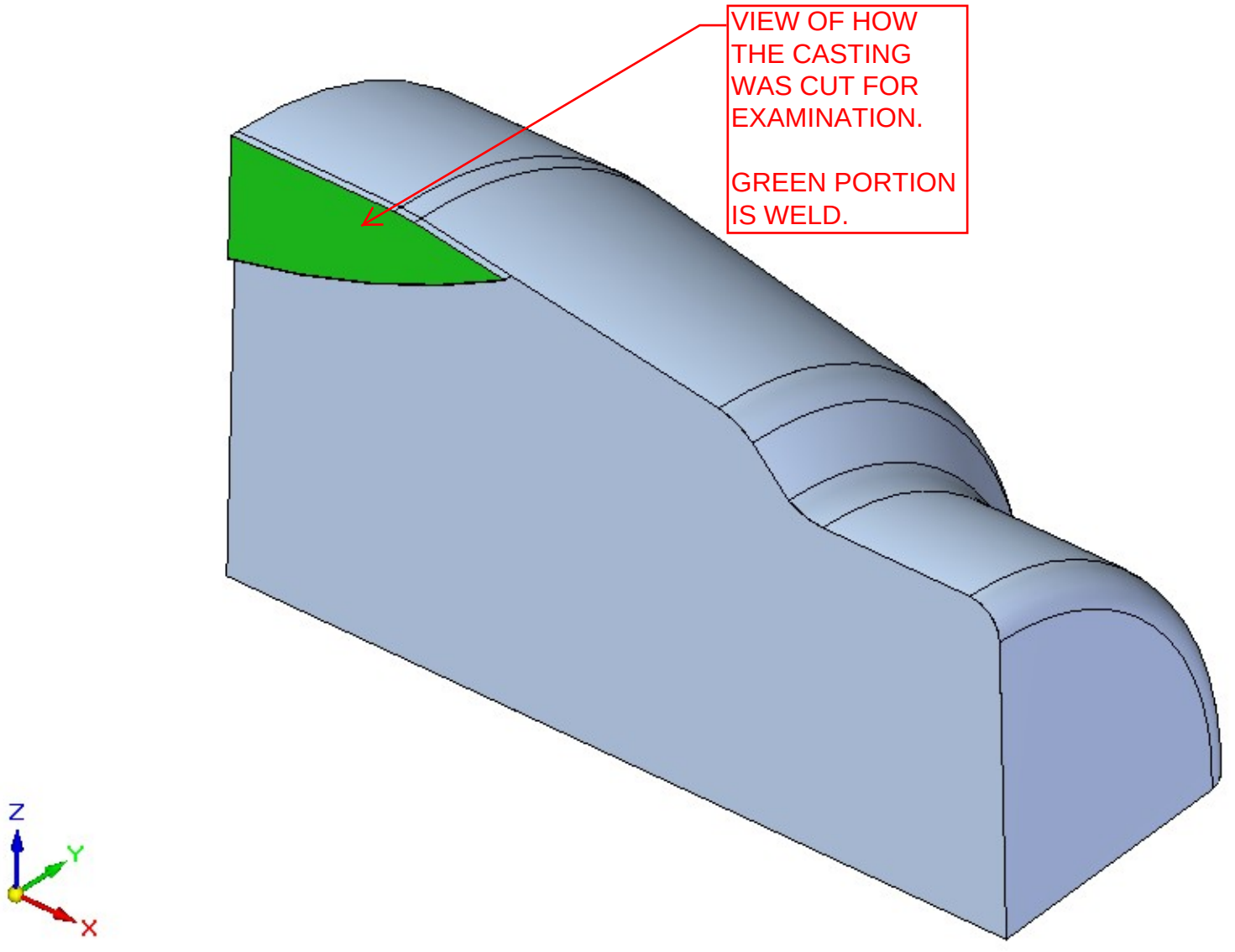

SAMPLE USED
Z
X
Y


SECTION REMOVED BY TUNGSTEN ARC.
SAMPLE WAS FILLED BACK IN WITH WELD METAL.
Z
X
Y


VIEW OF HOW
THE CASTING
WAS CUT FOR
EXAMINATION.
GREEN PORTION
IS WELD.
Z
Y
X

ANDERSON LABORATORIES, INC.
Specialists in Materials Evaluation

Mr. Brian Hampton
Eagle Alloy, Inc. E141
5142 Evanston Avenue
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August 12, 2009

Sample Identification - **Welded Educational Sample**

Purchase Order Number: QC0728BH1 Project Number: P09-1407

Objective – We were requested to (1) provide microstructural photographs of the base metal, the heat-affected zone, and the weld filler metal of the sample, (2) perform hardness profiles across the weldment, and (3) perform chemical analysis of the base metal and the weld filler metal.

Data and Procedures

Chemical Analysis

Chemical analysis was performed on the weld filler and base materials. Results of the testing are as follows.

	Weld Filler	**Base Metal**
Lab File No.	*H9-35418*	*H9-35419*
Silicon	0.14	0.49
Sulfur	0.010	0.009
Phosphorous	0.009	0.13
Manganese	0.54	0.84
Carbon	0.22	0.24
Chromium	0.44	0.50
Nickel	0.51	0.75
Molybdenum	0.18	0.27
Copper	0.18	0.06
Aluminum	0.01	0.04
Titanium	<0.005	0.035
Iron	Base	Base

Metallography

A section across the weldment and into the base material was metallographically-prepared for microstructural examination. The typical structures of the weld filler, heat-affected zone in the base metal and base material away from the weldment are illustrated in Images #1 through #3.

Hardness Testing

Microhardness profiles were performed on the metallographically-prepared sample. The profiles were initiated at the weld-base interface. Microhardness testing was performed using a Knoop diamond indenter and a 500 gram-force load. Indentations were measured at a magnification of 400 diameters or greater. Test results, along with the approximate conversions to the Rockwell scale, are as follows:

Distance from Interface (in.)	Weld Filler		Base Metal	
	HK500	Approx. HRB	HK500	Approx. HRB
0.005	226	95	256	100
0.010	241	98	249	99
0.015	236	97	244	98
0.020	234	97	250	99
0.025	227	95	253	100
0.035	231	96	247	99
0.050	225	95	239	98
0.075	223	95	235	97
0.100	225	95	239	98
0.150	223	95	235	97
0.200	219	94	230	96
0.250	213	93	232	96

ANDERSON LABORATORIES, INC.

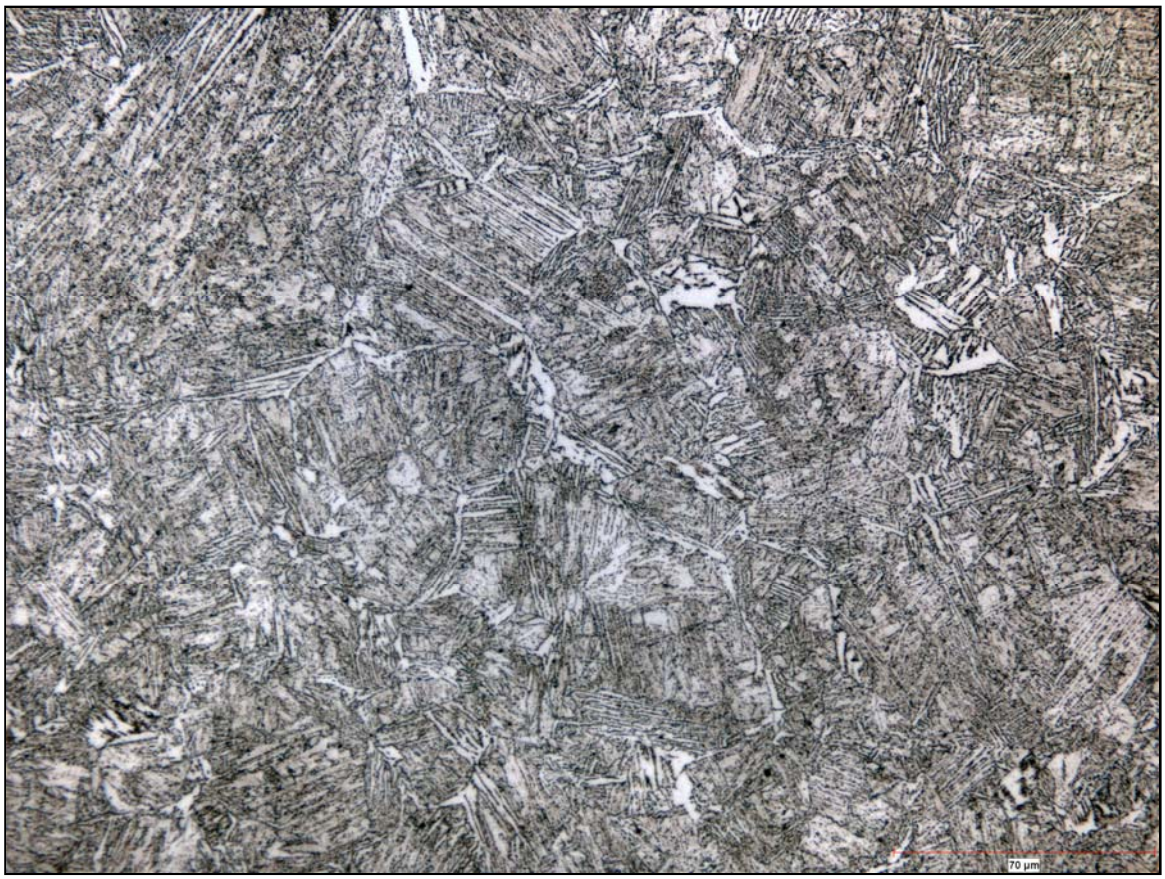
Michael Porfilio
Director of Operations / CI
NDE Level III / Certified Lead Auditor

Lori M. Felber
Quality Assurance Manager
Certified Lead Auditor

DAM

The above tests were performed using one or more of the following specifications: ASTM A48, A247, A262, A370, B117, B328, B368, B748, E2 (SM 11-22), E3, E8, E9, E10, E18, E21, E23, E34, E45, E92, E112, E212, E290, E340, E350, E352, E353, E381, E384, E404, E407, E415, E562, E663, E766, E883, E986, E1019, E1024, E1077, E1086, E1251, E1508, G053, G154, ASME IX, AWS D1.1, MIL-S-867A, NAVSEA S9074-AQ-GIB-010/248, SAE J81, EN 10002 Part 1, EN 10045 Parts 1 & 2, EN 10204 Section 3.1.C and Anderson Laboratories Quality Manual Revision J dated 5/14/08.

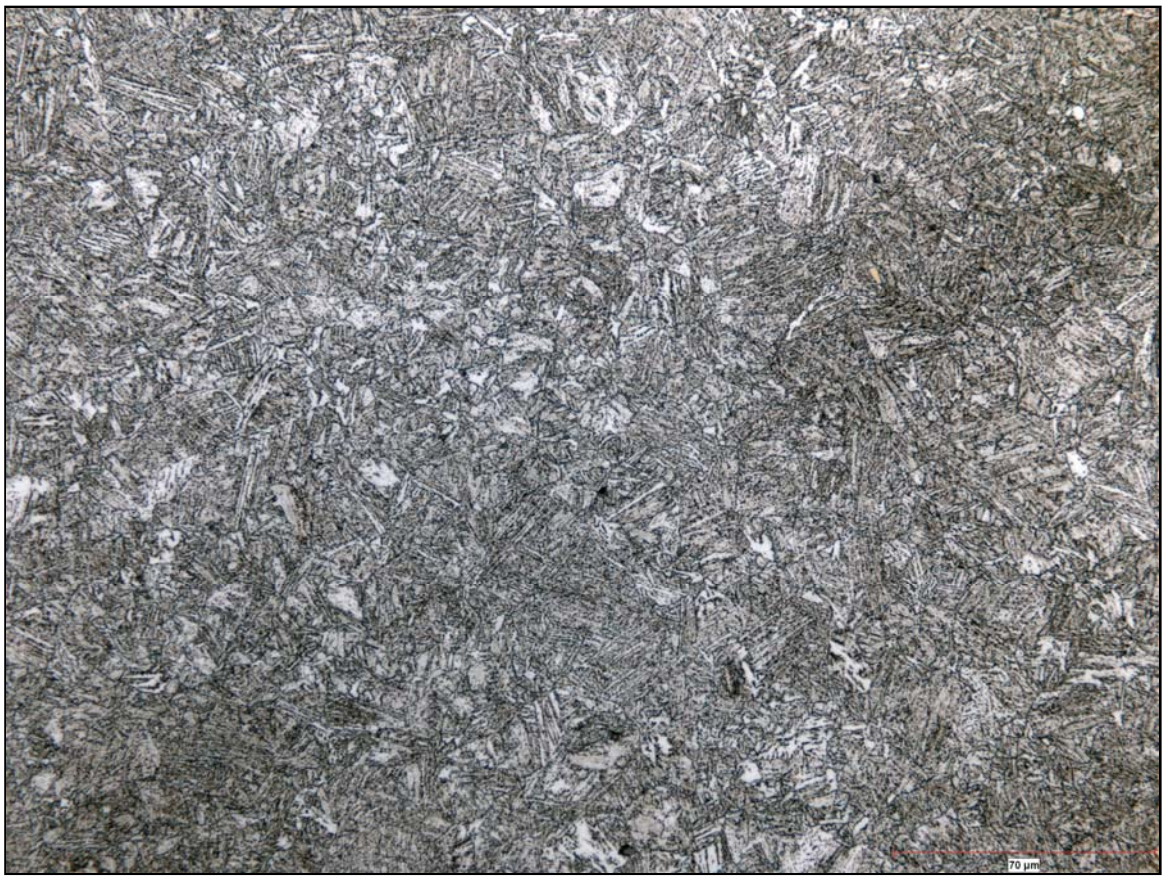
Eagle Alloy, Inc. E141
Welded Educational Sample – Weld Filler Metal
Image #1



Magnification: 500X Etchant: Nital

The typical microstructure of the weld filler metal is shown.

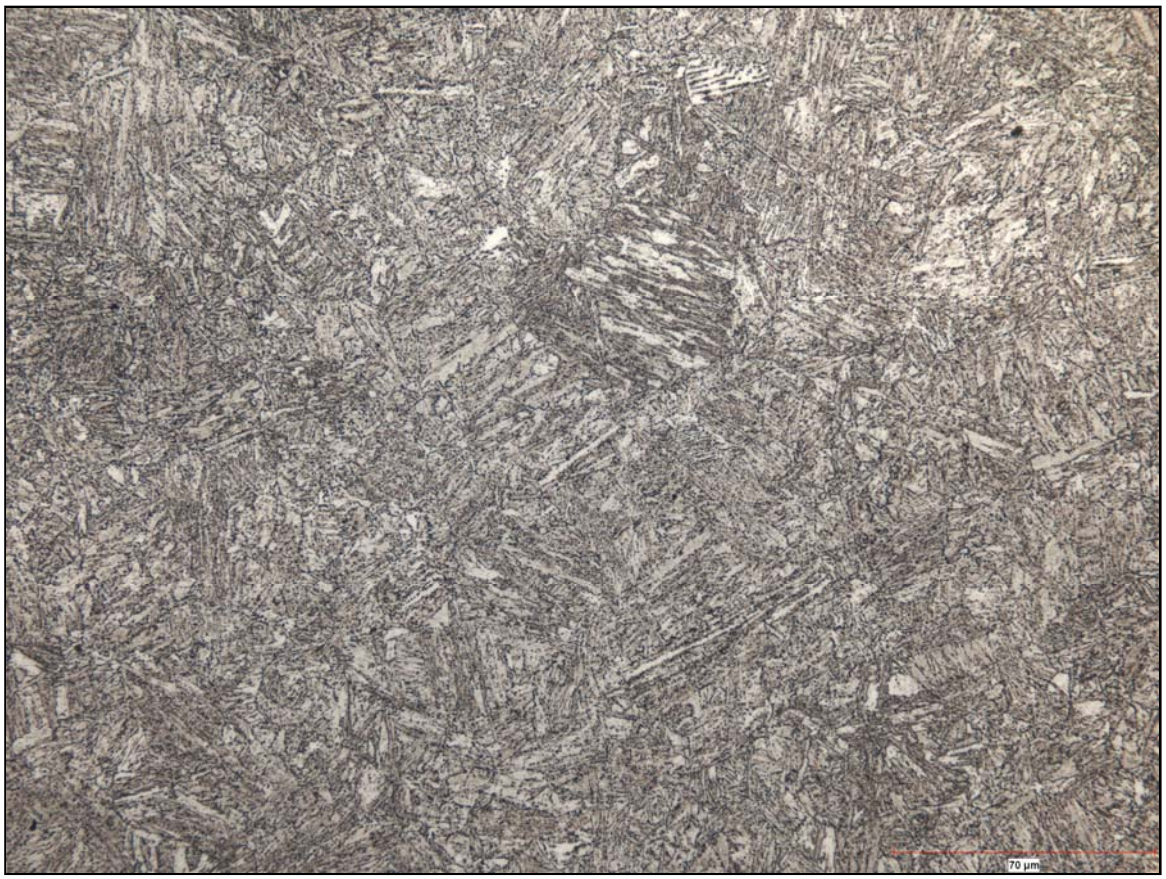
Eagle Alloy, Inc. E141
Welded Educational Sample – Heat-Affected Zone
Image #2



Magnification: 500X Etchant: Nital

The typical microstructure of the heat-affected zone is shown.

Eagle Alloy, Inc. E141
Welded Educational Sample – Base Metal
Image #3



Magnification: 500X Etchant: Nital

The typical microstructure of the base metal away from the weldment is shown.