August 23, 2021

Mr. [redacted]
Special Agent/ CFI
ATF - National Response Team
Fire Investigation and Arson Enforcement

RE: NRT 21-11 Los Angeles, CA - TCV Failure Analysis
File C21062

Dear Mr. [redacted]:

At your request I made an investigation to determine if the flanged collars on the threaded rods of the subject total containment vessel (TCV) failed suddenly as a onetime overload event or if they failed slowly over time and repeated use.

You shipped the two threaded rod and four flanged collars to me, and I examined them at Micron Inc. in Wilmington, De and had chemical analysis of the rod metal and flanged collar metal performed at Laboratory Testing Inc. in Hatfield, PA.

During my investigation you informed me that damage to the threads on the rods of a second TCV in service with the Los Angeles Police Department (LAPD) had been observed. I travelled to Los Angeles to inspect this damage to determine the nature of the damage and if it provided any insight into the cause of the subject failure. During this visit I was also able to examine the remains of the incident unit.

The components as received are shown in Figure 1.

The upper threaded rod is shown in Figure 2. Figure 3 shows that the bronze threads of the left (driver's) side flanged collar have been shear off and remain in the threads of the steel rod. Figure 4 shows that the right (passenger's) side flanged collar has broken. The flange is broken away from the rest of the collar. The threads that had been inboard of the flange have been sheared off and remain in the mating threads of the steel rod. The threads of the remainder of the collar are still intact and that portion of the collar turns freely on the steel threaded rod. The flanged collar that had been attached to the top of left side yoke (based on site photographs) is shown in Figures 5 and 6. All the threads have been sheared from this collar, the collar has a crack on a radial-axial plane through one of the bolt holes, and a piece of the collar is broken away.

The lower threaded rod is shown in Figure 7. Figure 8 shows that the bronze threads of the left-side flanged collar have been sheared off and remain in the threads of the steel rod. Figure 9 shows that the right-side flanged collar has broken. The flange is broken away from the rest of the collar. The threads that had been inboard of the flange have been shear off and remain in the mating threads of the steel rod. The threads of the remainder of the collar are still intact and that portion of the collar turns freely on the steel threaded rod. The flanged collar that had been attached to the bottom of left side yoke (based on site photographs) is shown in Figures 10 and 11. All the threads have been sheared from this collar and the collar has a crack on a radial-axial plane through one of the bolt holes.

A scene photograph reproduced as Figure 12 shows that the threaded rods remained with the right-side yoke. The scene photographs reproduced as Figures 13 and 14 show that the left-side yoke has separated from the threaded rod and struck an automobile.

As shown in the image of the harden steel insert in the yoke of Figure 15, the clamping surface between the vessel and door flanges and the yoke surface is sloped at approximately 20 degrees from the plane of the door. This results in part of the outward explosion force on the door being directed radially outward against the yokes and part of that load is carried by the flanged collars on the threaded rods.

The threads were sheared from the left side flanged collar by a force pushing the flanged collars on the yoke to the left. This is consistent with an outward force on the yoke from the explosion having caused the failure at this location. However, the failure of the flanged collars on the right-side were caused by outward force (to the right) attempting to pull the collars from the yoke.

Examination of evidence at the ATF Los Angeles facility showed that the vertical columns of the vessel support structure had been bent severely outward by impact from the yokes as they travelled laterally away from the door. This is indicated by the red arrows on Figure 16. The corresponding impact witness marks on the yokes are shown in Figures 17 and 18.

When the flanged collars on the left side yoke failed, the left-side yoke began traveling to the left off the threaded rods and the right-side yoke began traveling to the right with the threaded rods attached. When the right-side yoke struck the support structure column on the right, the yoke was slowed down while the momentum of the threaded rod acted to keep the rods moving to the right. This created the load on the flanged collars that broke collars away from the flanges and sheared the threads under the flanges.

The point of this is that the fracture and failure of the right-side flanged collars was secondary and a consequence of the primary failure of the left-side flanged collars. The failure of the flanged collars on the left-side was what allowed the door to separate from the vessel.

For this reason, the microscopic laboratory exam was focused of the left side failures. Since the failures of the top and bottom left-side flanged collars were virtually identical (the threads were entirely sheared off and the collars fractured longitudinally through a bolt hole) only one flanged collar was subjected to destructive examination.

The top left-side flanged collar is shown in Figure 19. It was sectioned to facilitate direct examination of the longitudinal fracture and to obtain a section through the sheared threads for metallographic examination as shown in Figure 20.

The fracture surfaces indicated by the yellow arrows on Figure 20 are shown in the stereo microscope images of Figure 21. The fracture appears to be a onetime overload fracture starting at the bolt hole in the flange. The black arrows show the fracture propagation direction.

The fracture was examined with the scanning electron microscope (SEM). SEM images obtained at Location 2, 5, and 4 (on Figure 21) are shown in Figures 22 through 33. These images show a mostly brittle, onetime overload fracture morphology. This confirms that the fracture occurred as a onetime, rapid event and that there was no prior slow crack growth.

It was noted that the collars of the broken flanged collars on the right-side still rotated smoothly on the threaded rods. To remove one of these collars and to facilitate cleaning of the threaded rod, a section was cut from the bottom threaded rod as shown in Figure 34.

The removed section of the bottom threaded rod after degreasing is shown in Figure 35. The sheared off collar threads are visible. The distance between where the threads were sheared off is consistent with the yokes having been in the fully closed position when this occurred. The threads which sheared off the left-side flanged collar are shown in Figures 36 and 37. The threads which had sheared off from the flange on the right-side are shown in Figures 38 and 39. This type of shear failure of entire threads does not occur slowly over time; it occurs as a rapid onetime event. The longitudinal break in the threads visible in Figure 37 shows that the longitudinal cracking of the collar occurred slightly before the threads were completely sheared off.

The threads of the collars were highly loaded at the time of this incident. The first threads to fail were on the left-side. As the threads of the collar began to shear over the stronger rod threads a hoop stress was created in the collar which fractured the collar longitudinally starting at a bolt hole.

The portion of the right-side collar that had remained intact is shown in Figures 40 and 41after removal from the threaded rod. The threads are in good condition and undamaged. This shows that the threads of the bronze collars had not worn down in service prior to the subject incident.

A section on a radial-axial plane was cut at the location indicated by the dashed red line on Figure 40 for metallographic examination. This section after mounting, polishing, and etching is shown in Figure 42. The thread profile shows no indication of significant wear. Higher magnification images in Figures 43 and 44 show typical microstructure for C954 cast aluminum bronze.

A section on the radial-axial plane indicated by the red X on Figure 20 was cut for metallographic examination of the sheared threads. This section after mounting, polishing, and etching is shown in Figure 45. Higher magnification images in Figures 46 and 47 show the tearing and shearing of the threads. The general microstructure of this collar is shown in Figures 48 and 49 and is also typical microstructure for C954 cast aluminum bronze.

A radial-axial section through the steel threaded rod after mounting, polishing, and etching is shown in Figure 50. The higher magnification images in Figures 51 and 52 show typical microstructure for quenched and tempered alloy steel.

Samples of a collar and a threaded rod were submitted for chemical analysis. The certified laboratory test report with the results is included as Appendix I. The analysis shows that the collar is type C954 aluminum bronze and that the rod is 4140 alloy steel.

Microhardness testing showed the collars to be an average of Knoop 187 and the steel rod to be an average of Knoop 336. The steel strength is approximately 160 ksi which is about double the strength of the bronze.

These chemistries and strengths are typical of bronze and steel used for this type of threaded drive in which sliding friction is a major concern.

As mentioned above, I traveled to Los Angeles to examine damage to the threaded rods on another LAPD TCV. Photographs of this vessel by others are reproduced as Figures 53 and 54 with the door closed and opened, respectively. The yokes and rods had been removed as shown in Figure 55. After significant effort, a rod was removed as shown in Figure 56 to allow examination of the internal threads of a collar to determine the amount of wear.

The damage to the threads of the steel rod is shown in Figures 57 and 58 (red arrows). This is galling type of damage caused by lubrication failure. It occurs when surfaces of metals that have a high coefficient of friction slide across each other under high load.

When the collar (see Figure 59) was removed it was determined that the collar was steel, not bronze as was the incident collar. Steel on steel is not a good combination for a rod and collar of a threaded drive. The coefficient of friction if lubrication breaks down is very high and galling can occur.

The exemplar vessel was older than the incident vessel. It appears that the manufacturer changed to bronze collars to address this problem.

CONCLUSION

The failure of the flanged collars on the threaded rod which held the yokes in place on the door of the subject TCV was a onetime overload event. The flange collars showed no evidence of prior cracking or any significant wear.

The location of the sheared flanged collar threads on the threaded rods was consistent with the yokes having been fully closed at the time of the incident failure.

This unit had reportedly been used successfully on numerous prior occasions with no damage to the components suggesting that the loading on the flanged collar threads was significantly higher at the time of this incident.

Sincerely,

[redacted]

[redacted], P.E., FASM

FIGURE 1

FIGURE 2

FIGURE 3

FIGURE 4

FIGURE 5

FIGURE 6

FIGURE 7

FIGURE 8

FIGURE 9

FIGURE 10

FIGURE 11

FIGURE 12

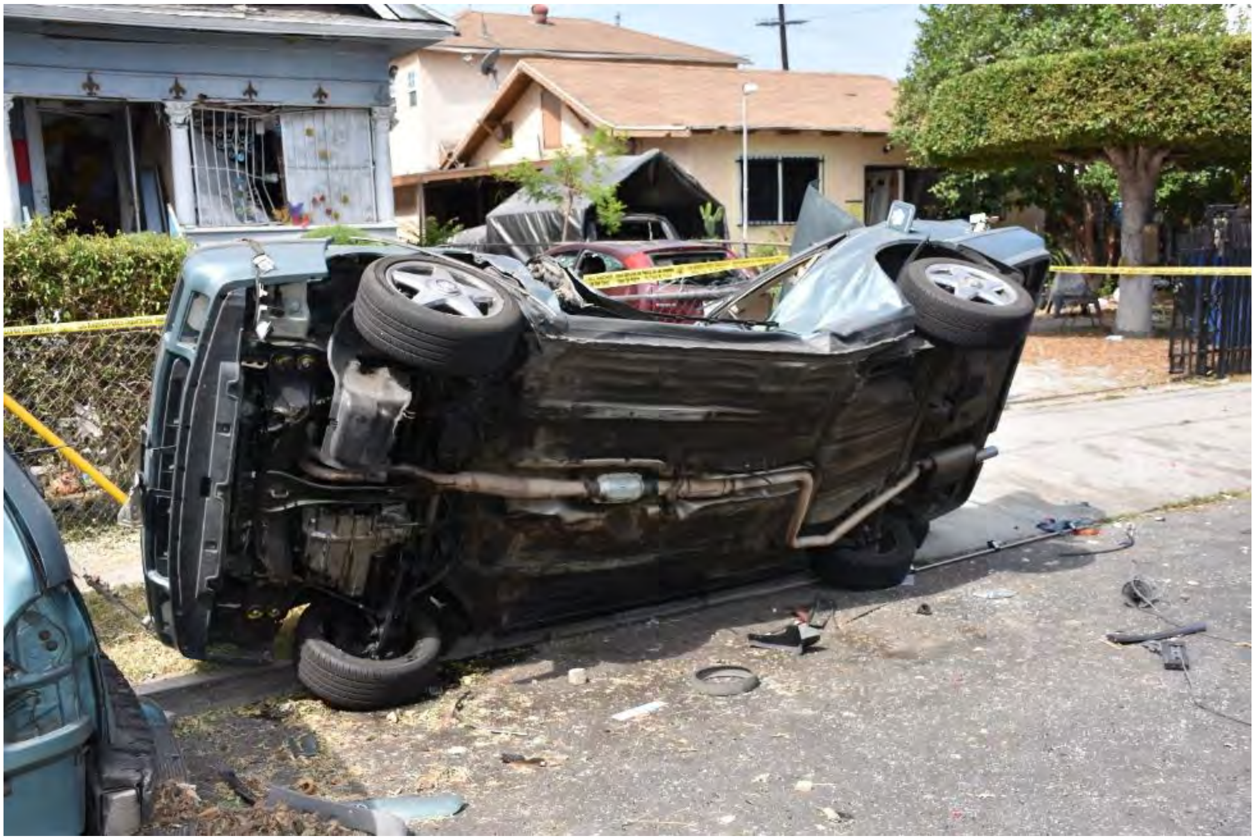


FIGURE 13

FIGURE 14

FIGURE 15

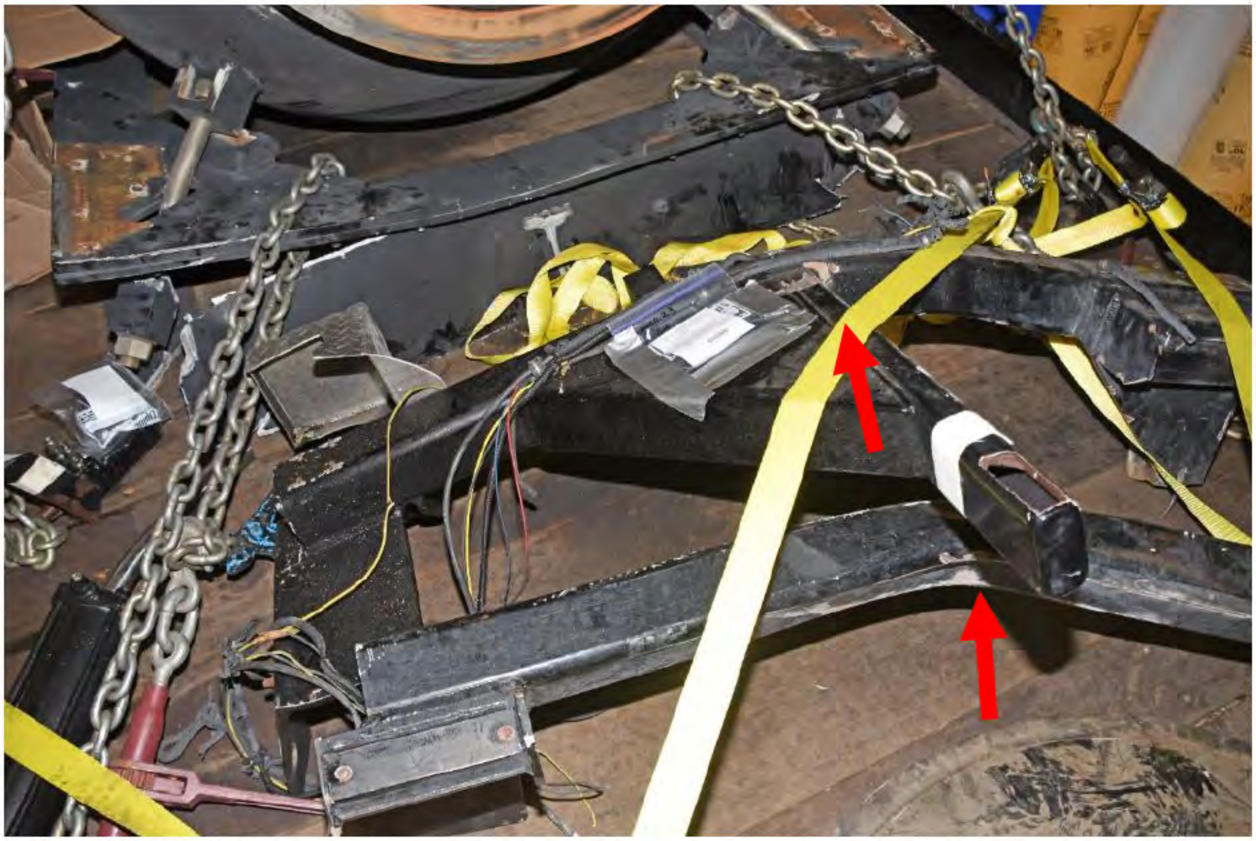


FIGURE 16

FIGURE 17

FIGURE 18

FIGURE 19

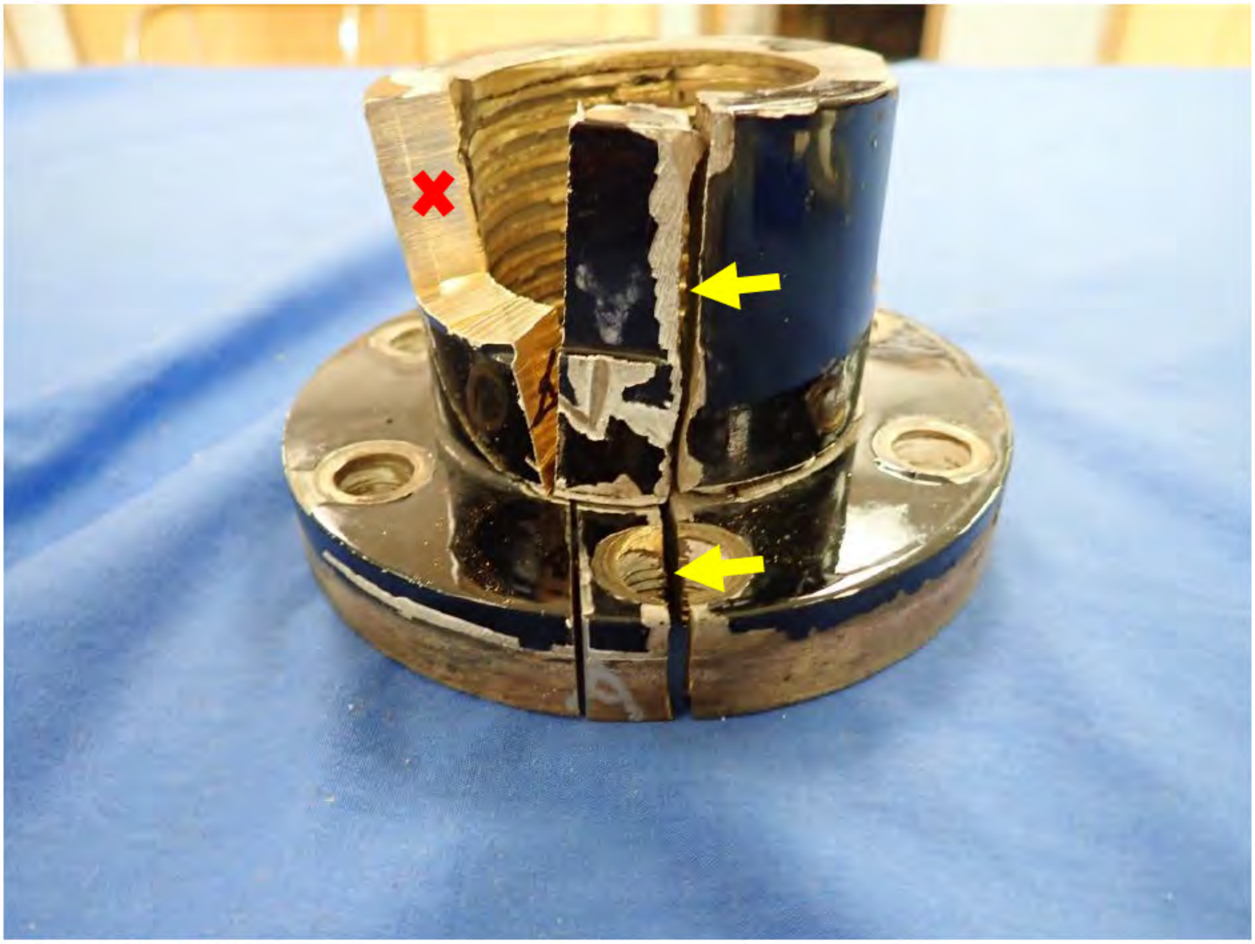


FIGURE 20

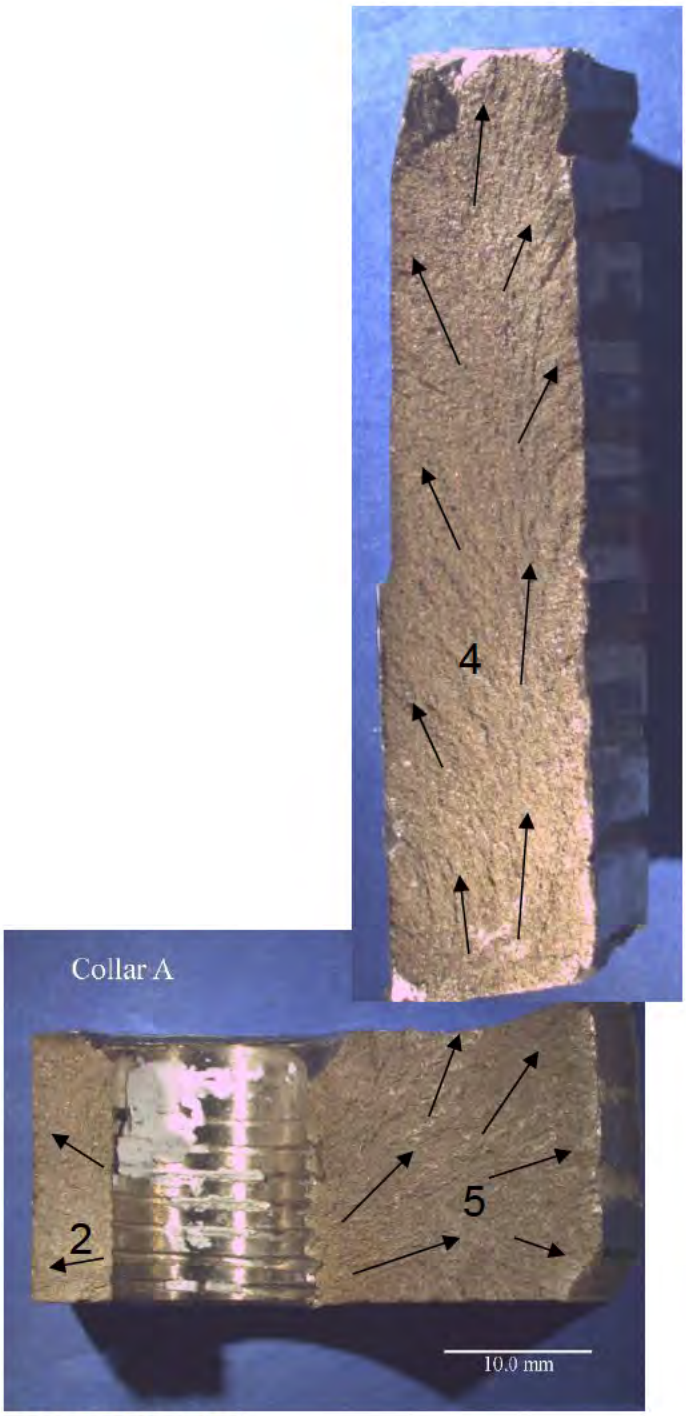


FIGURE 21

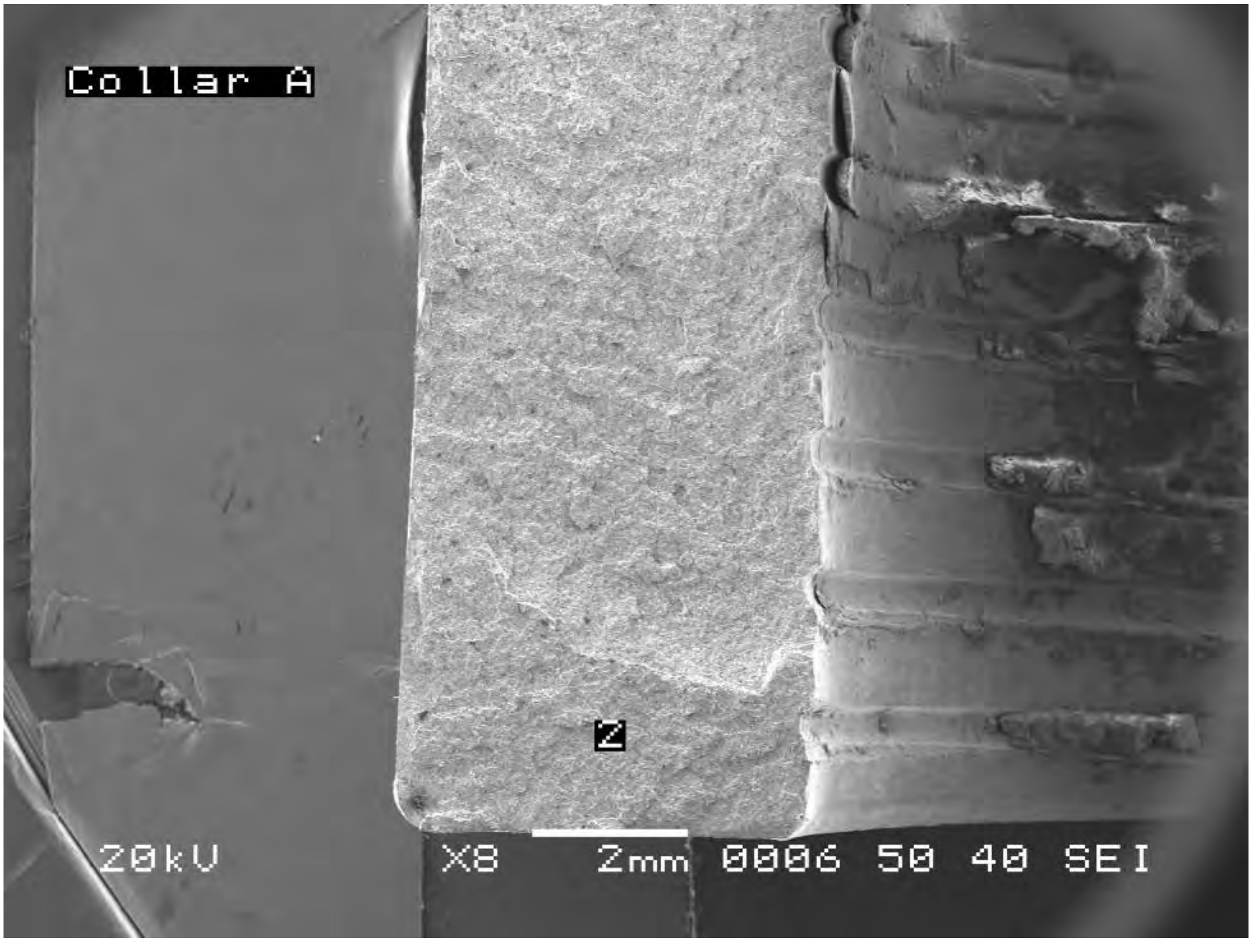
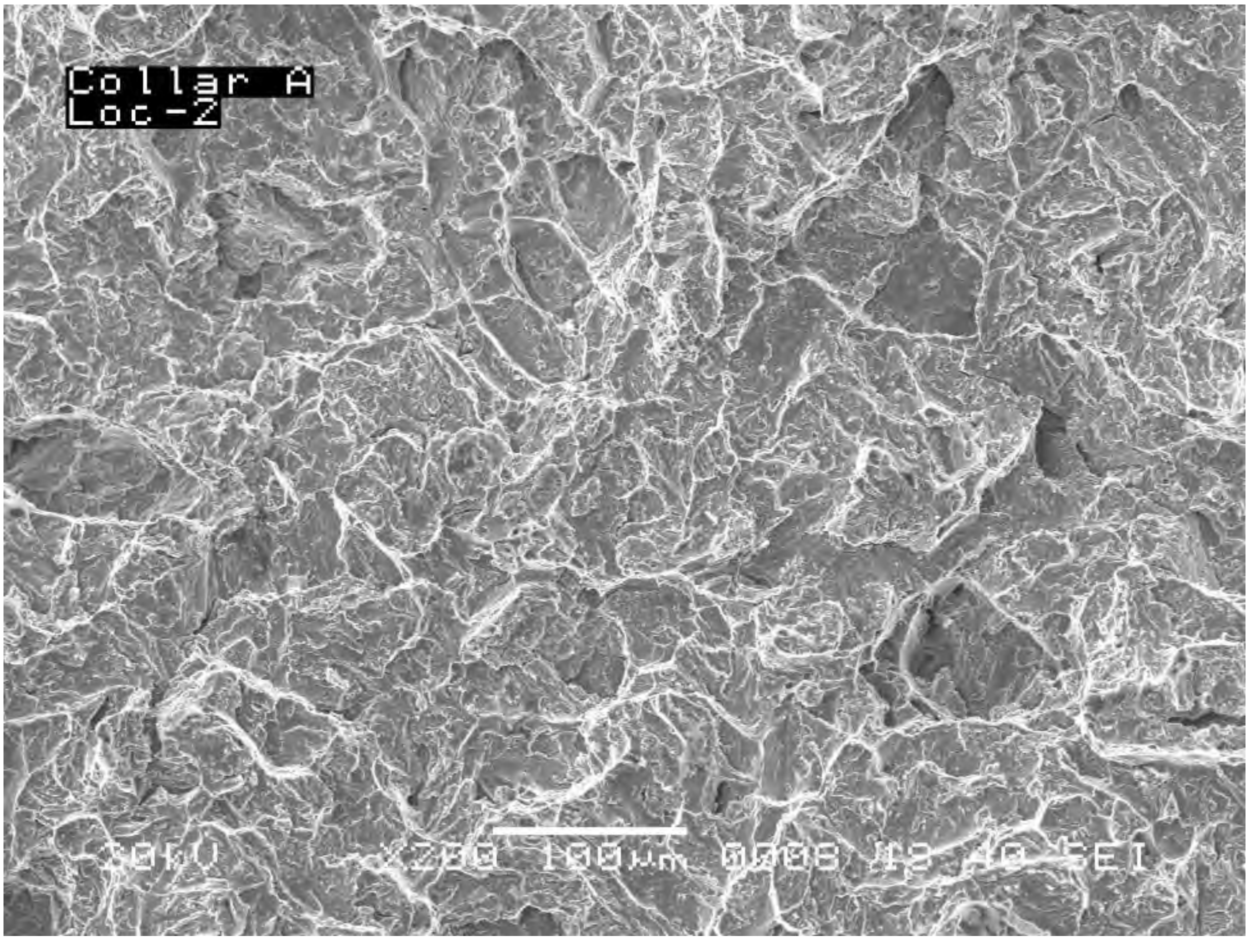


FIGURE 22



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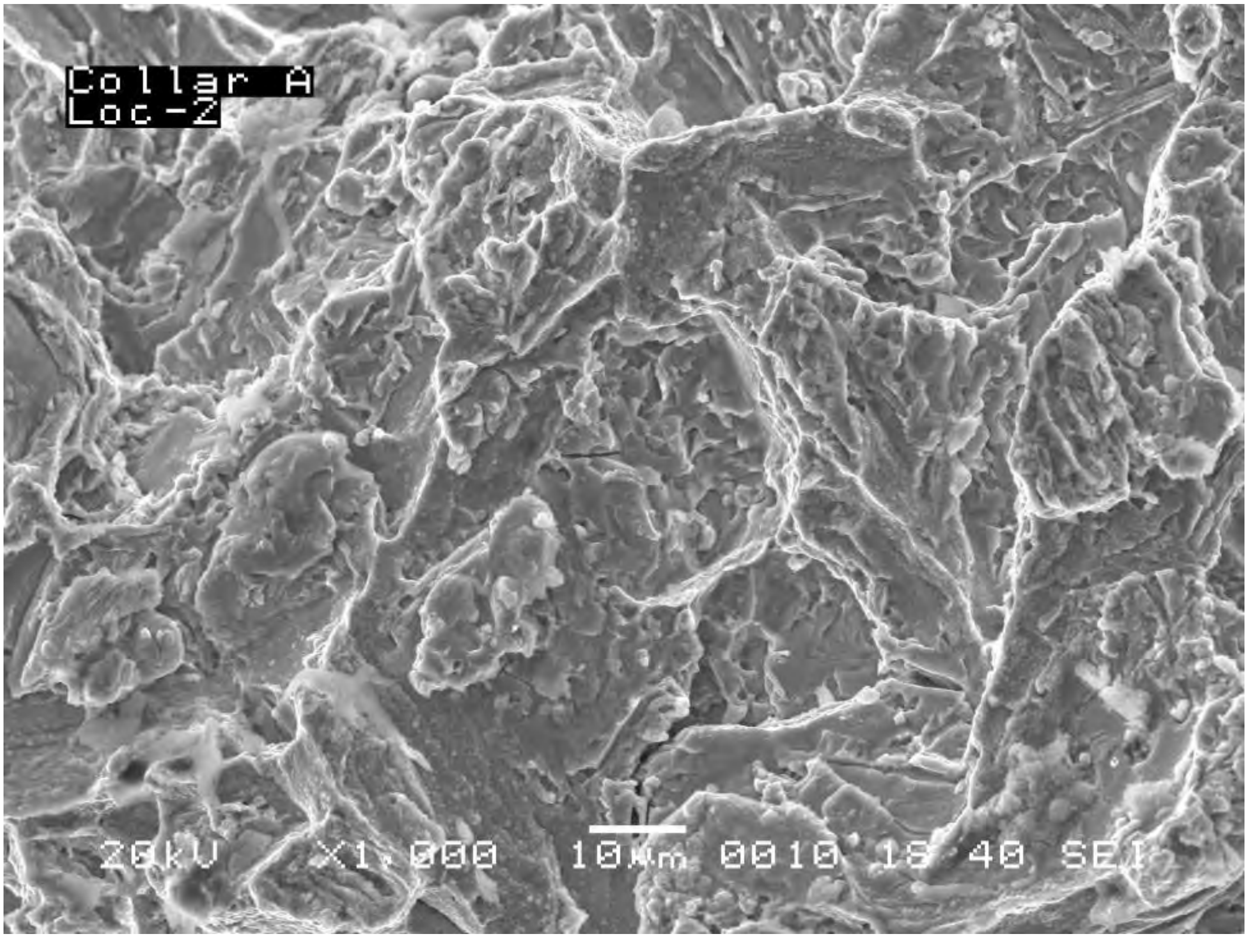

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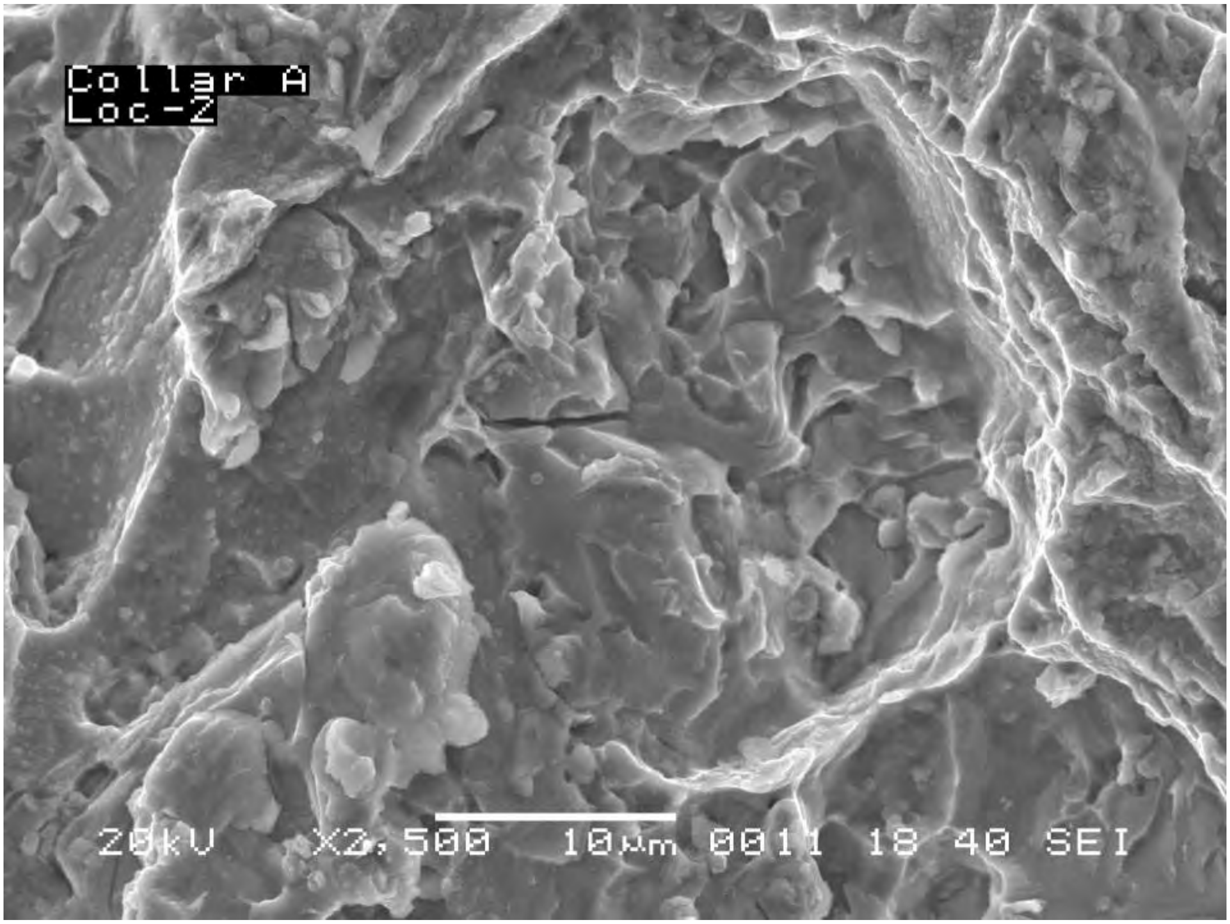
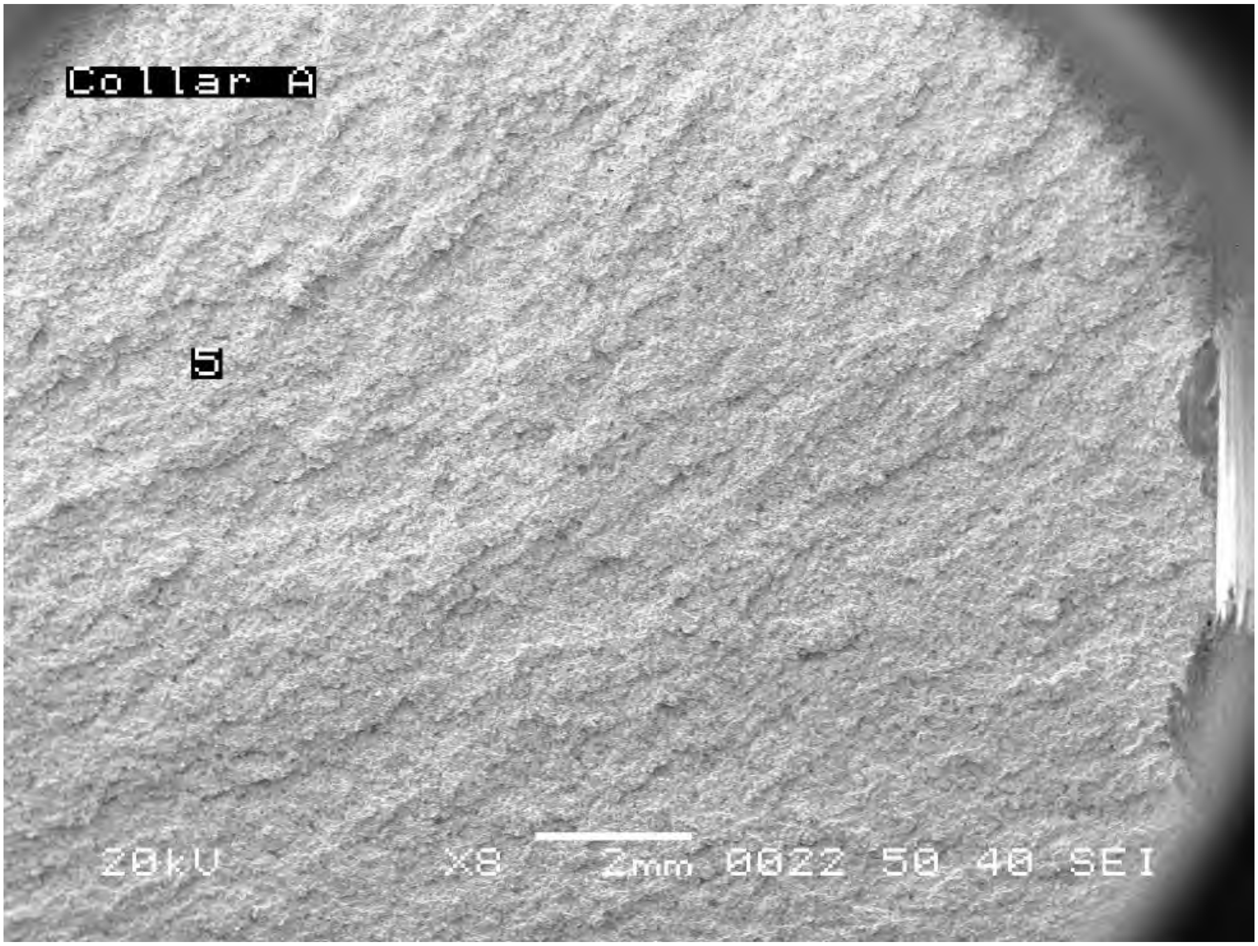


FIGURE 25



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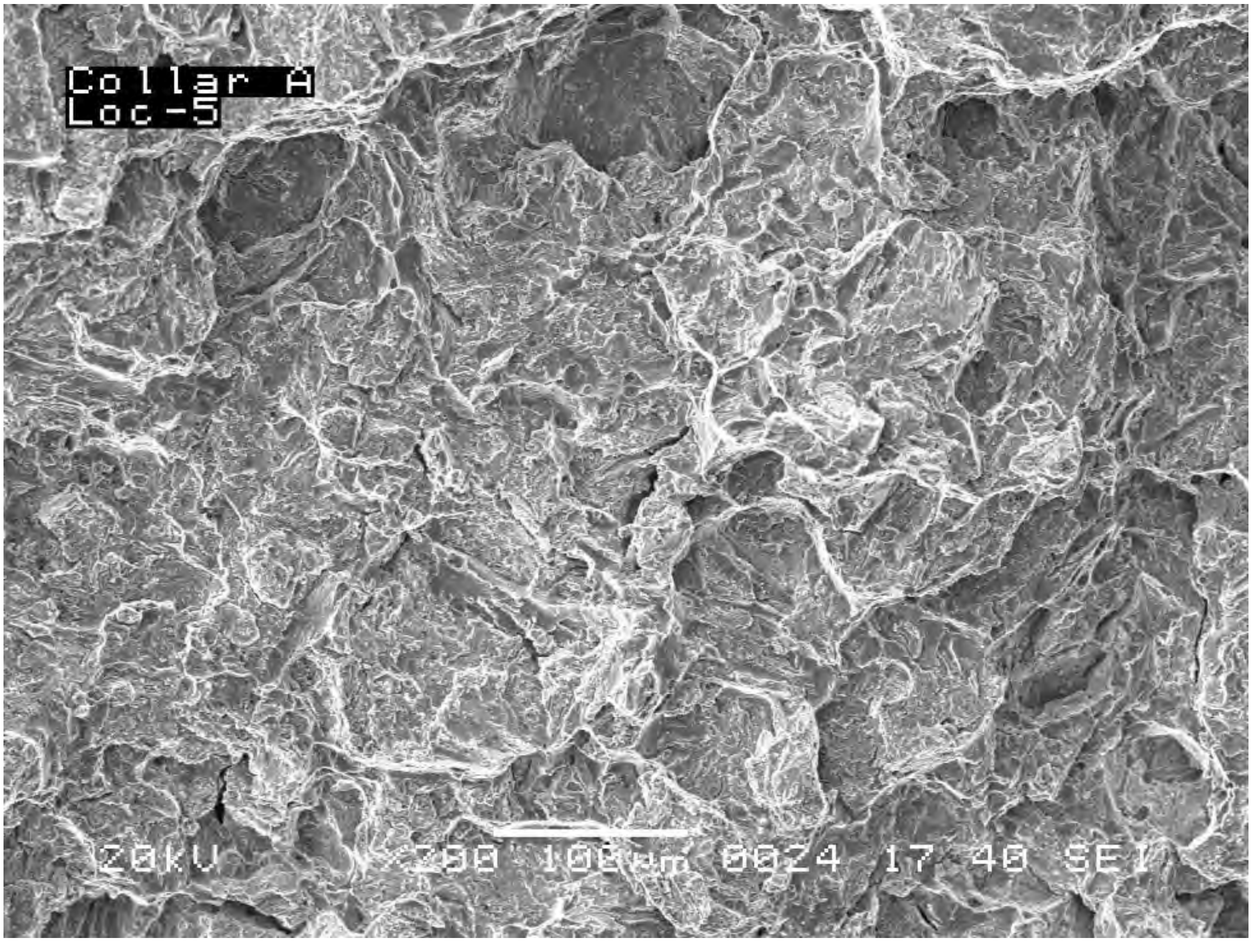

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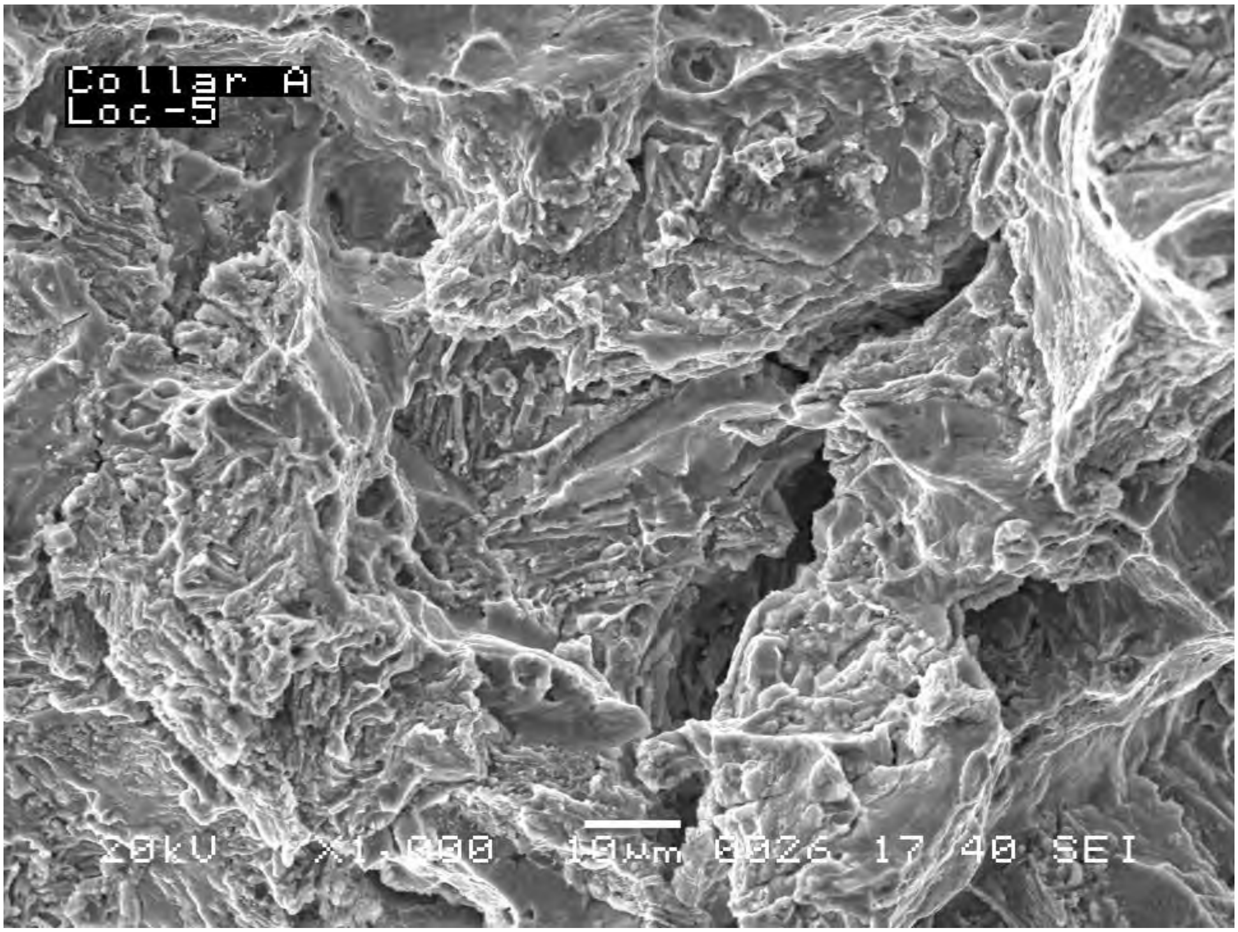

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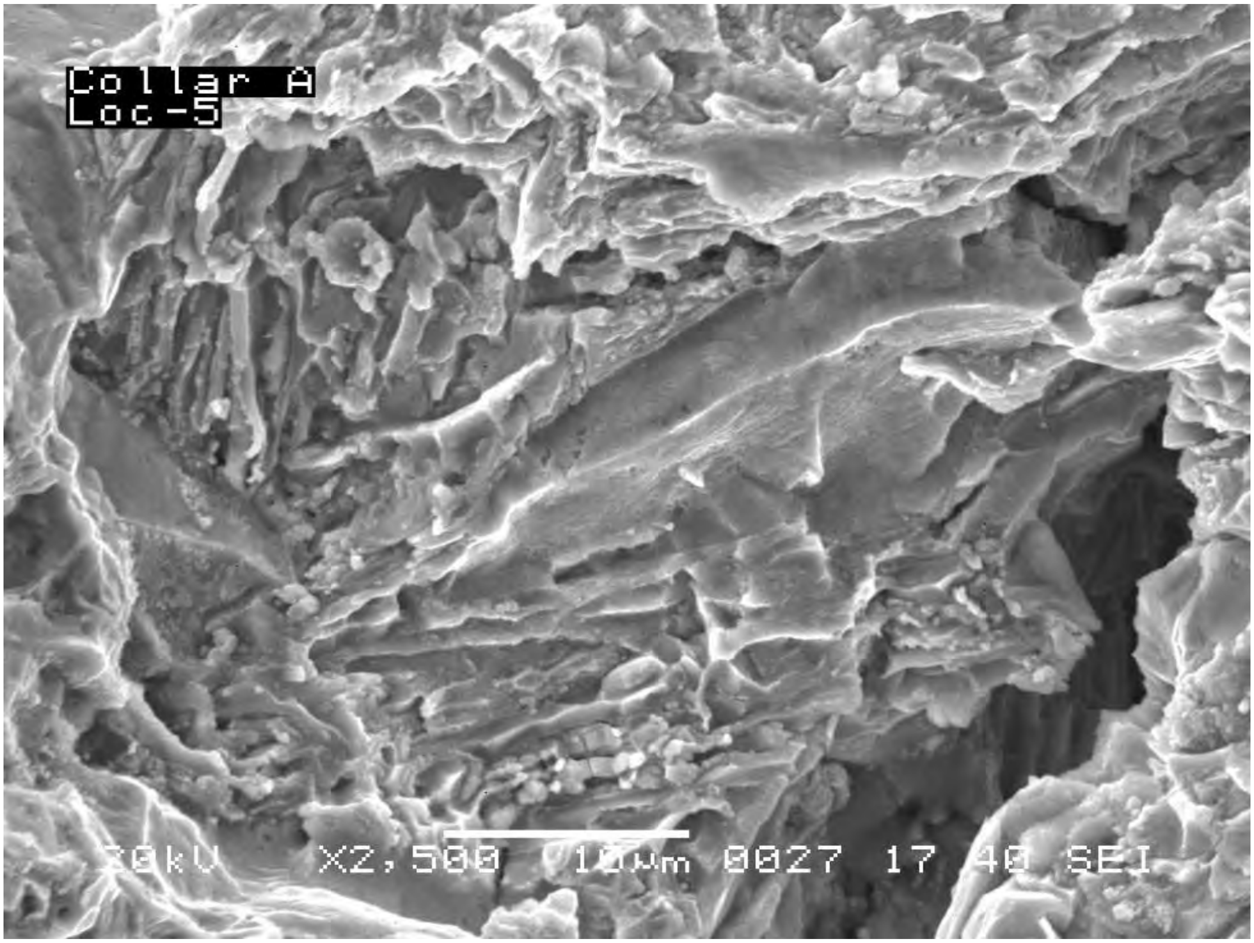

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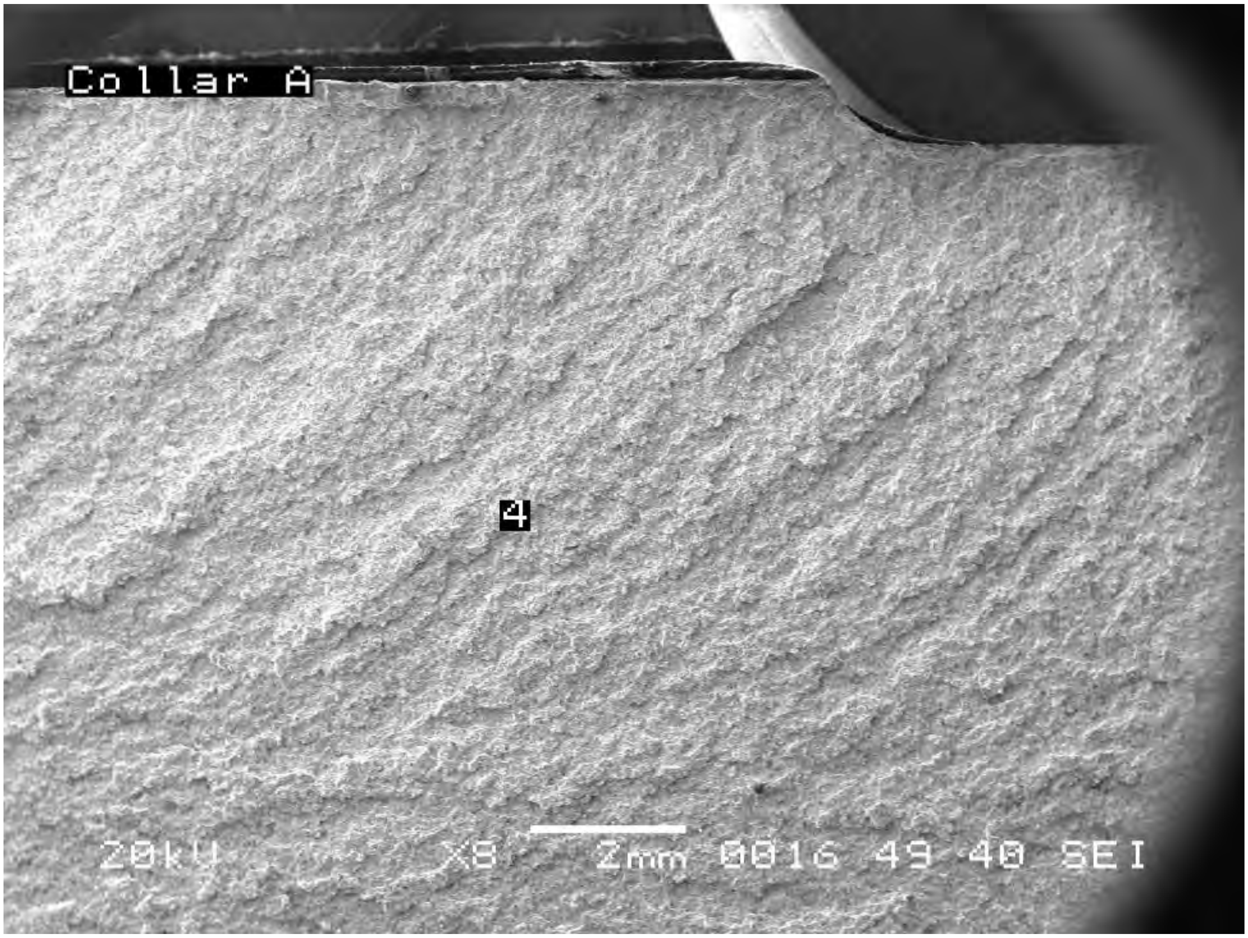

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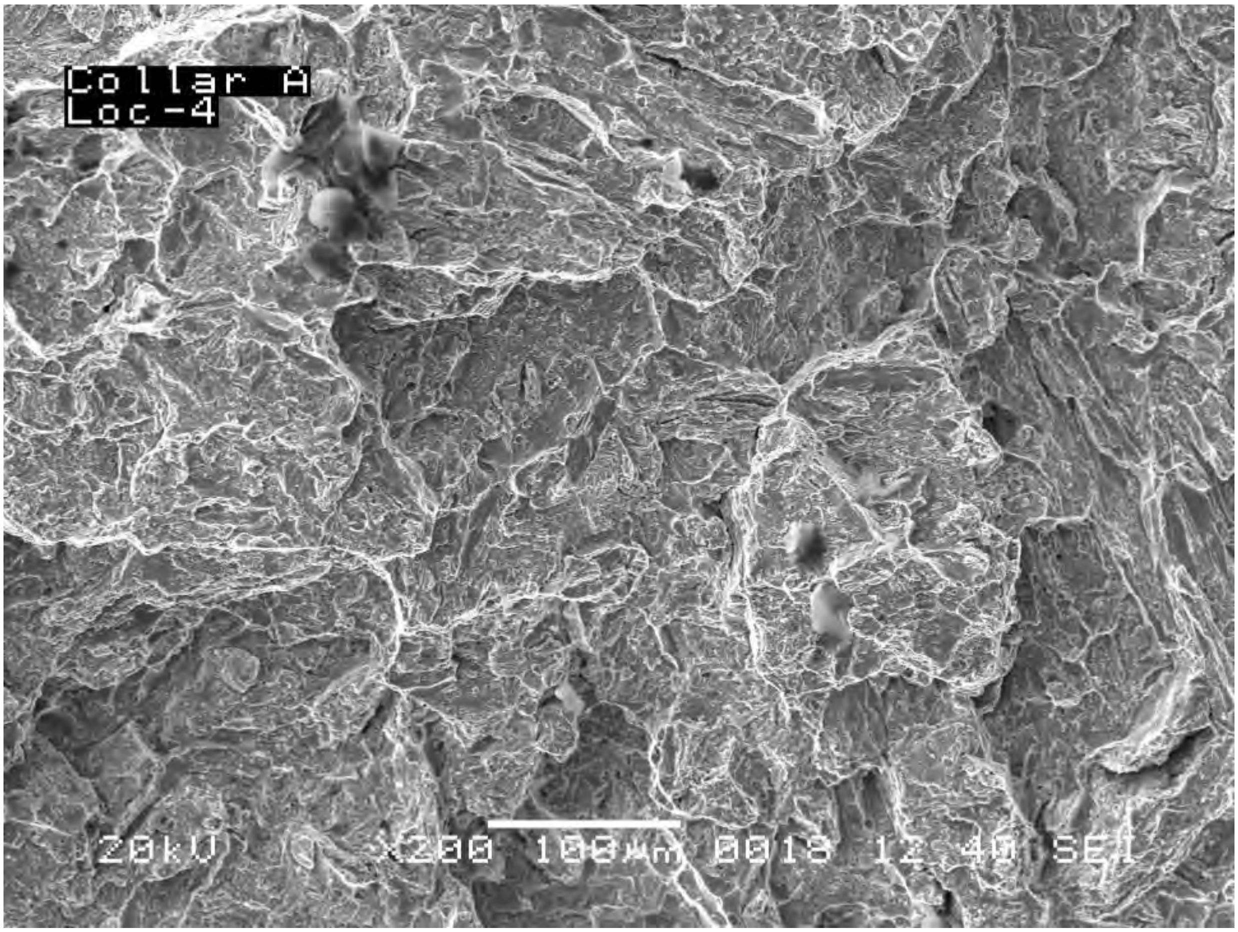

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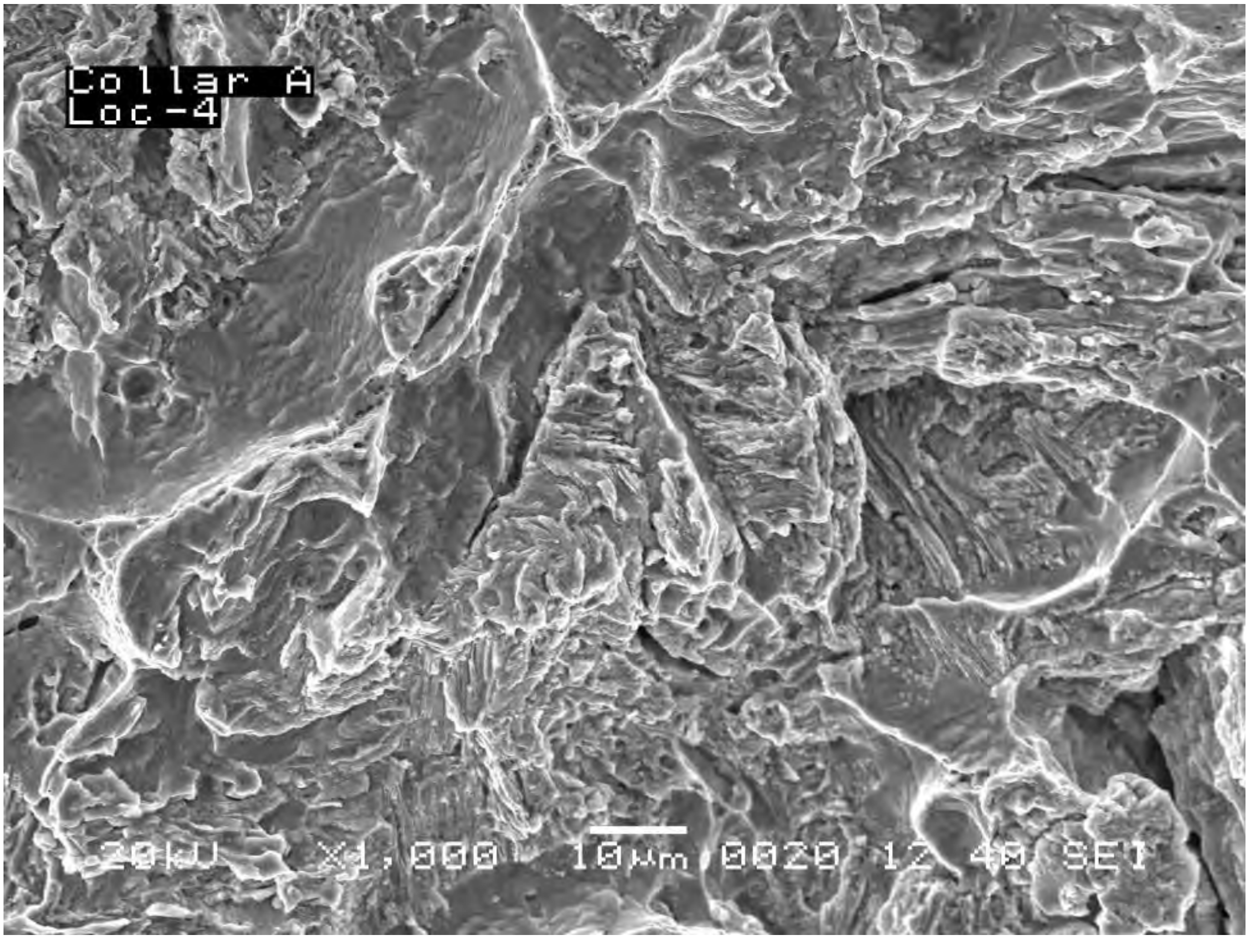

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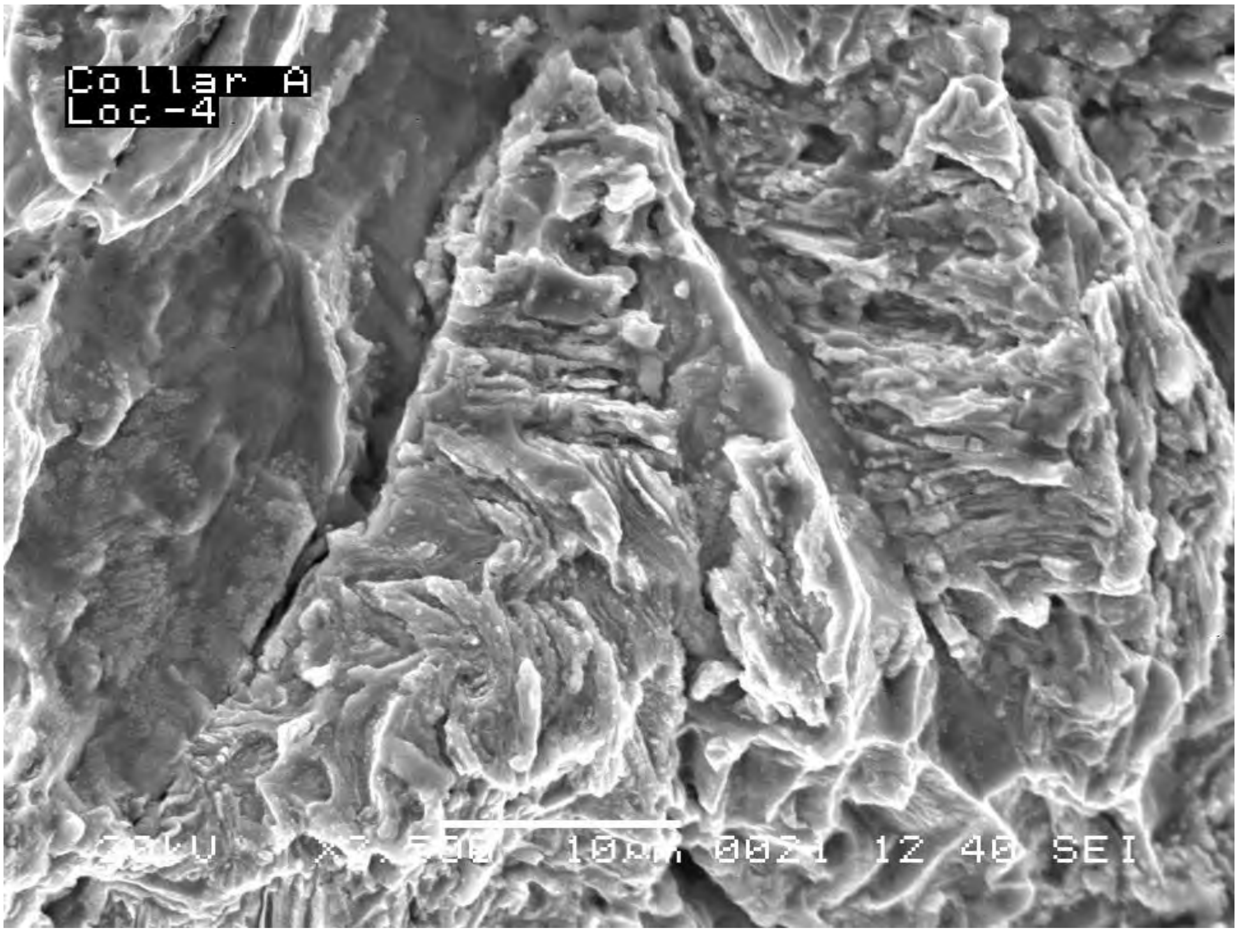


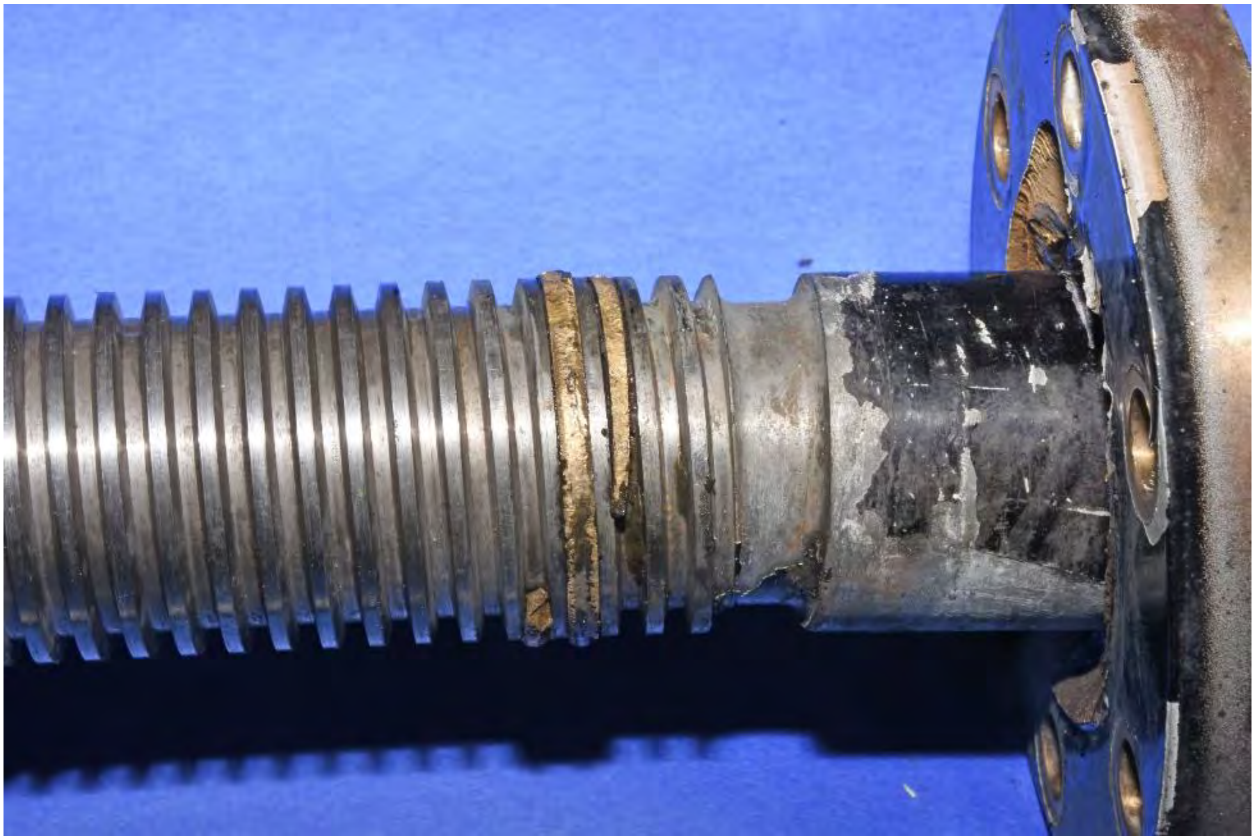
FIGURE 33

FIGURE 34

FIGURE 35

FIGURE 36

FIGURE 37



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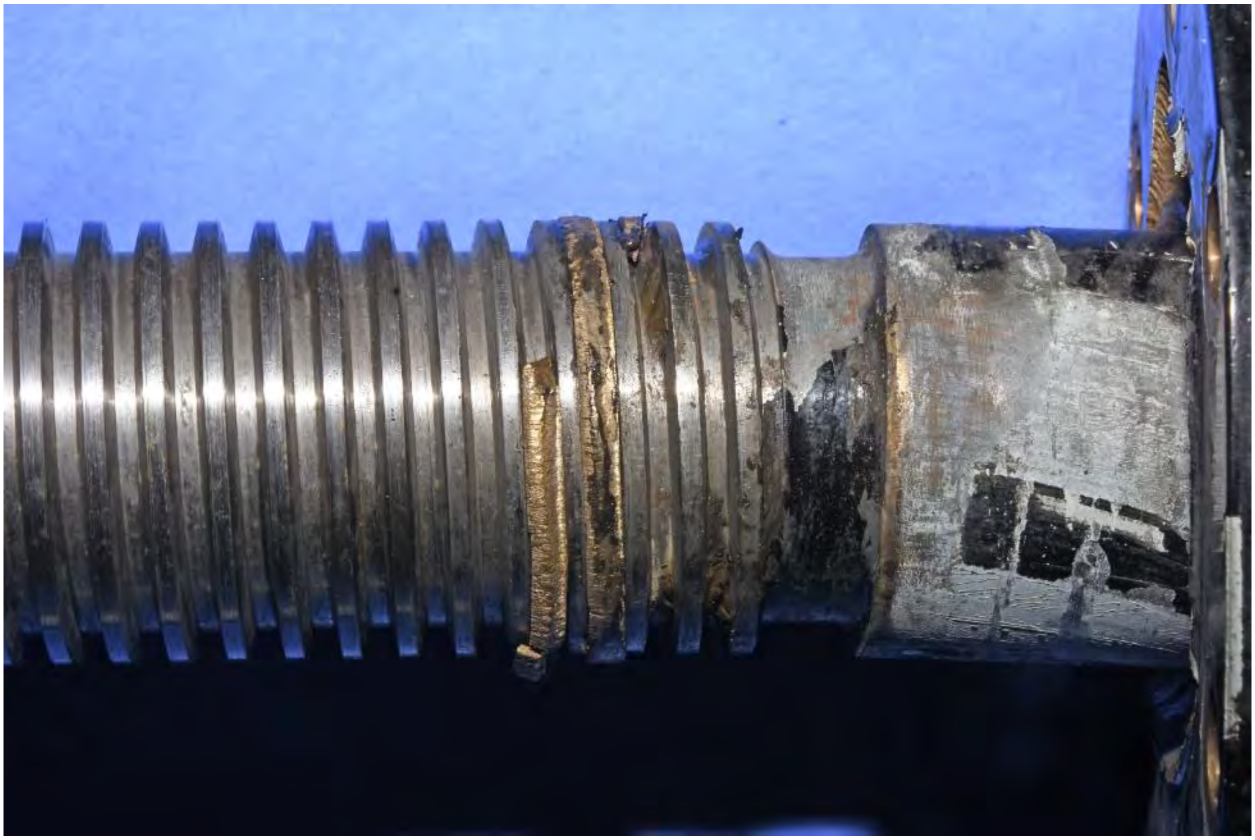

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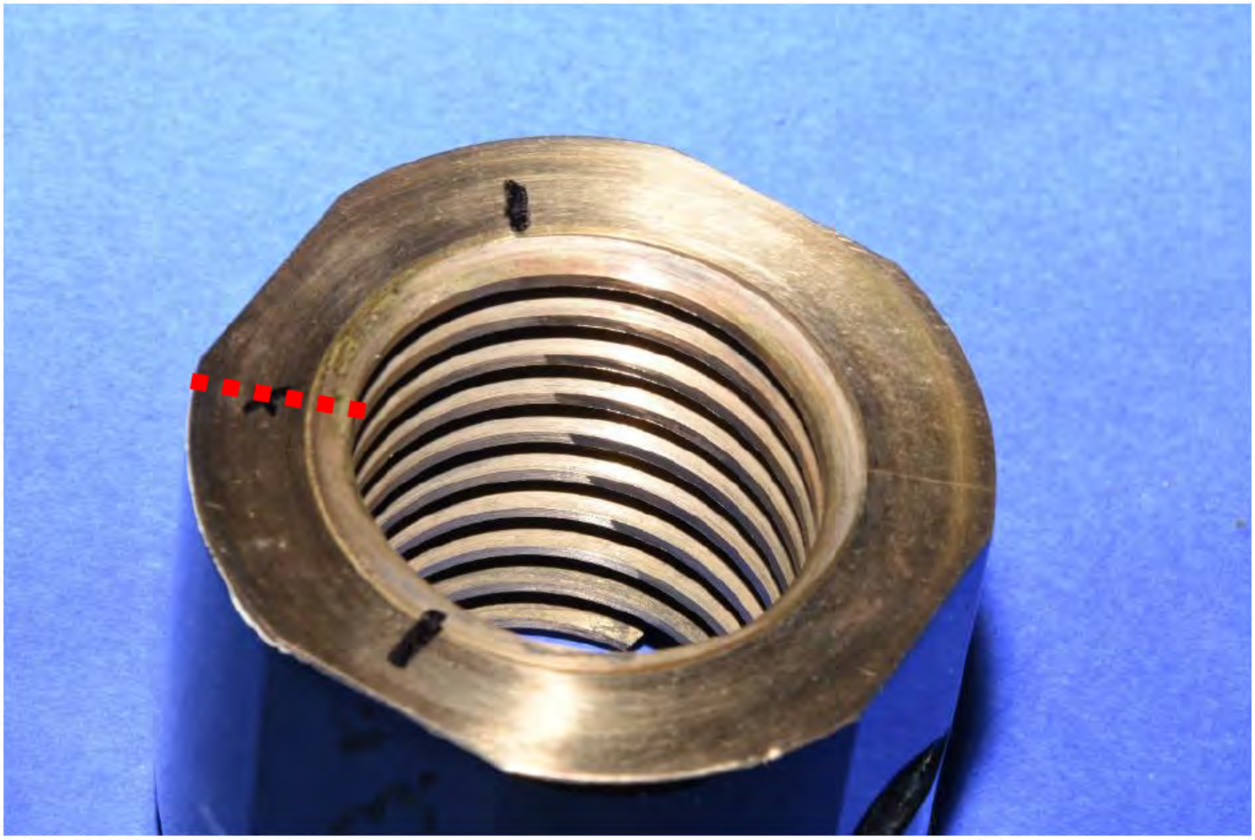


FIGURE 40

FIGURE 41

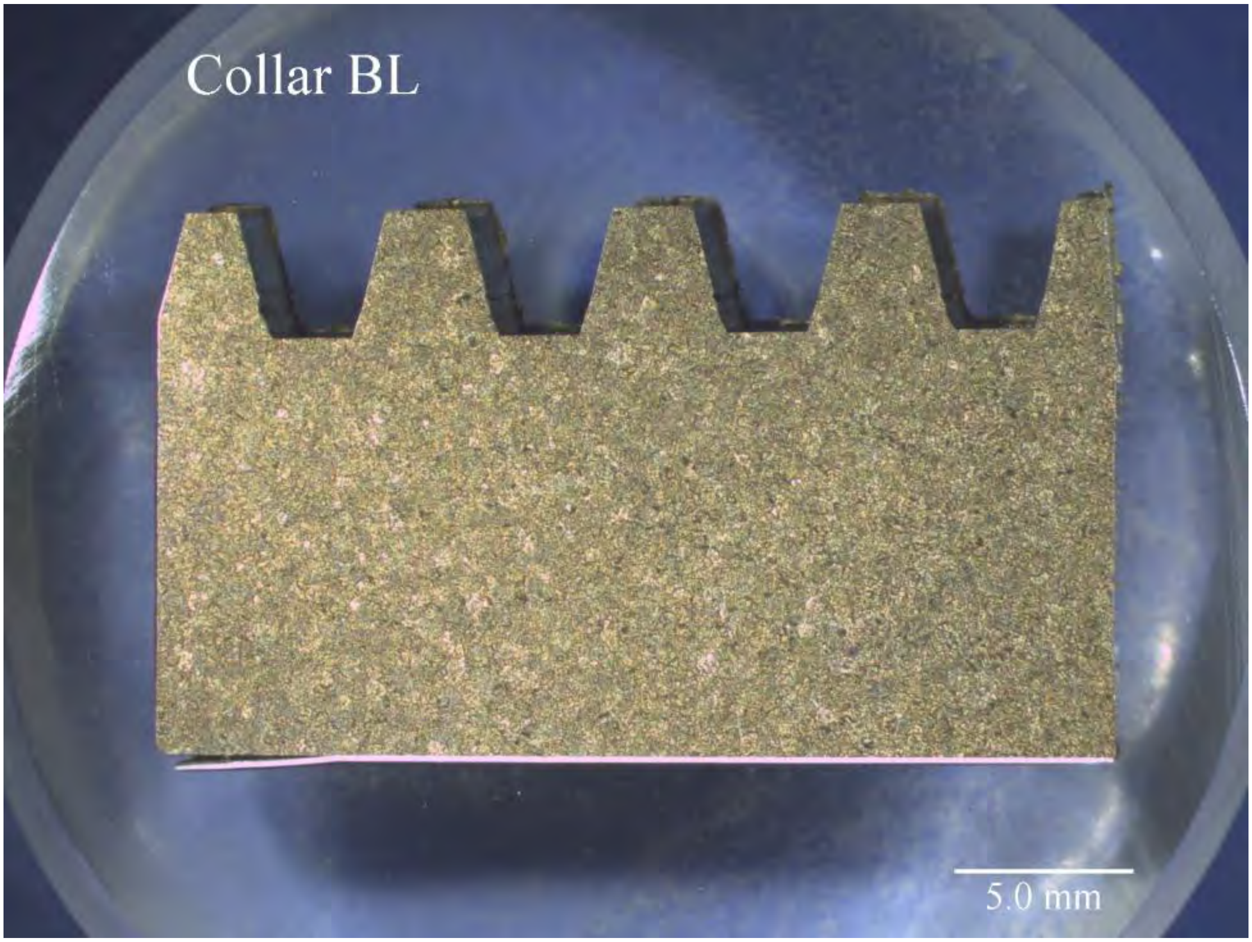
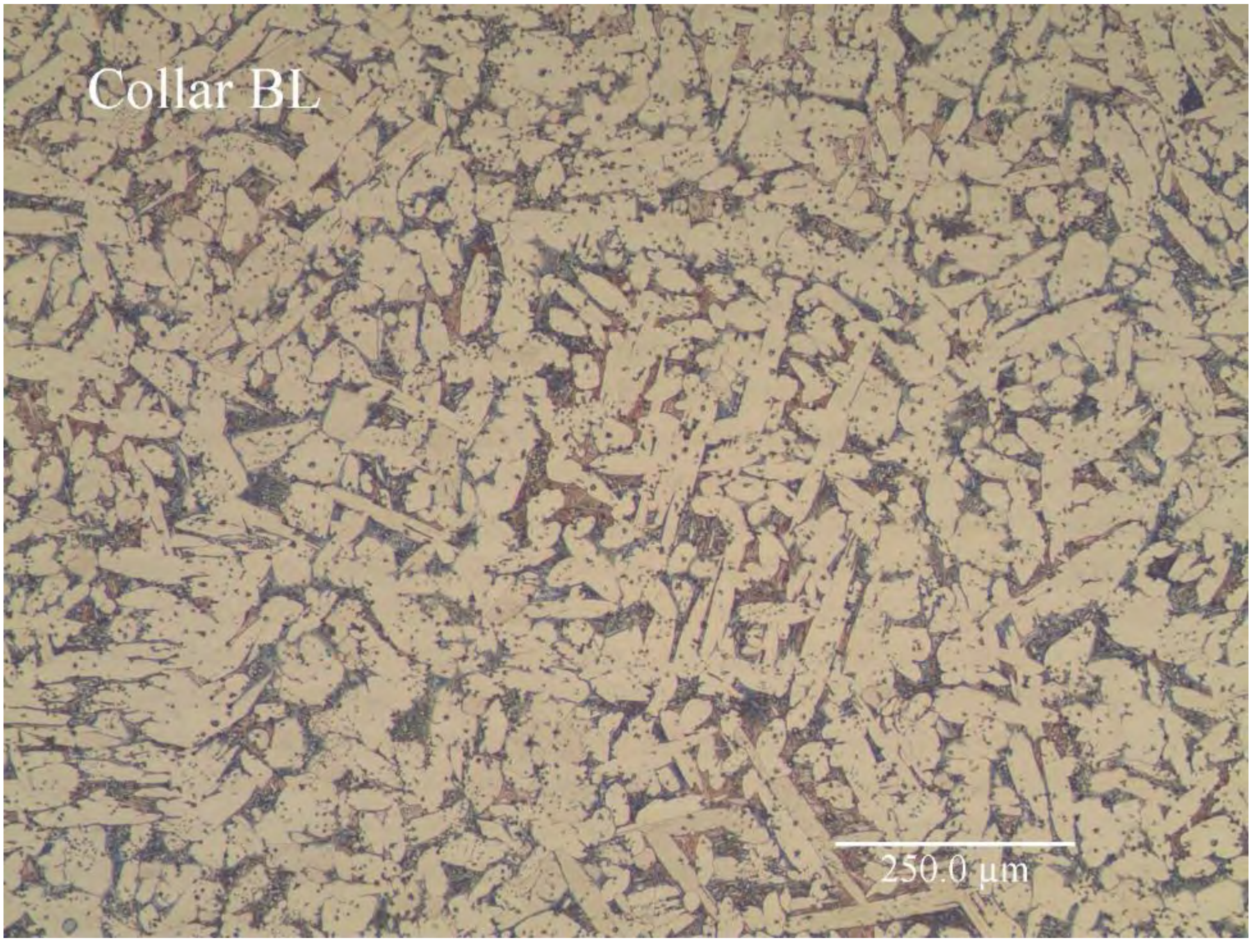


FIGURE 42



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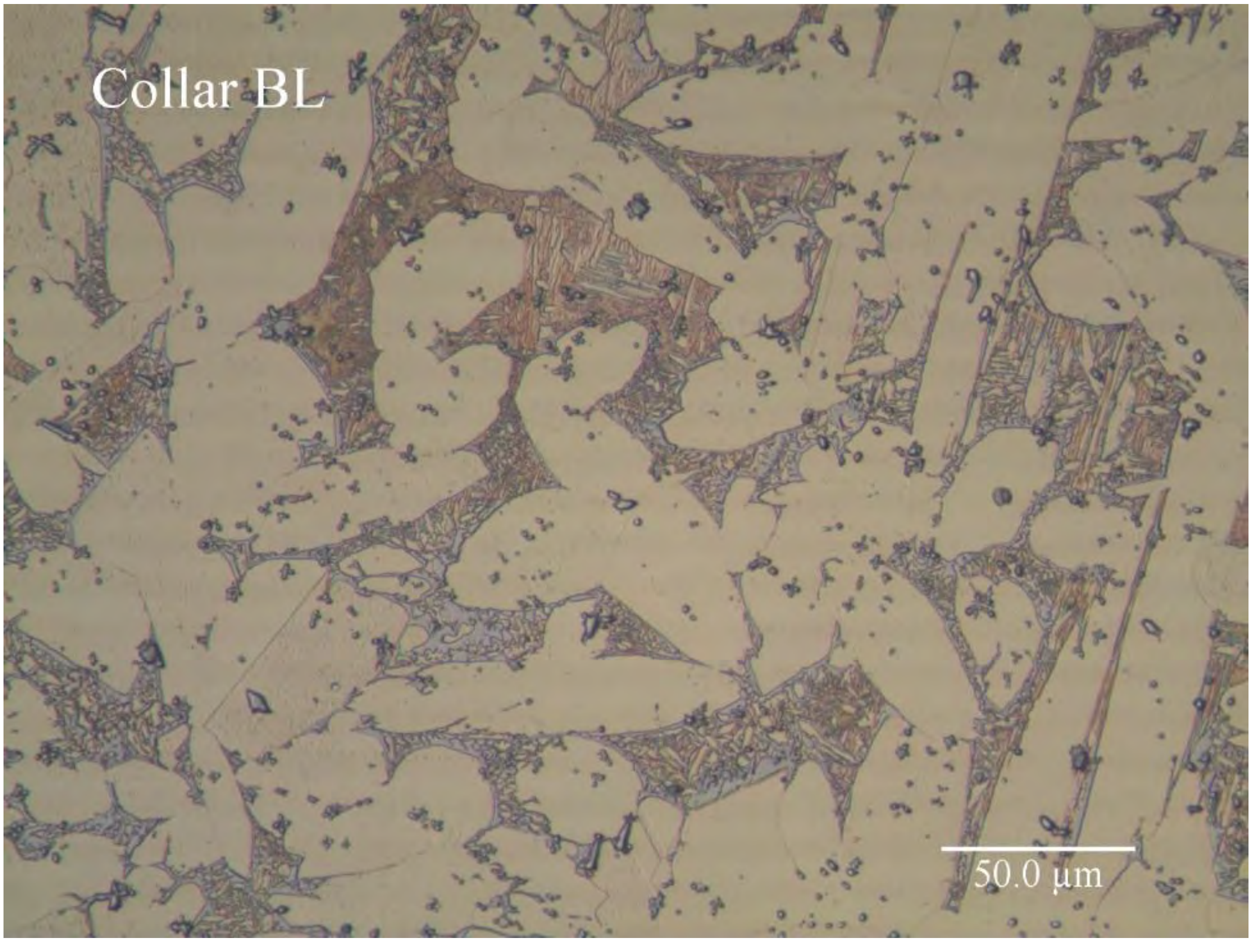


FIGURE 44

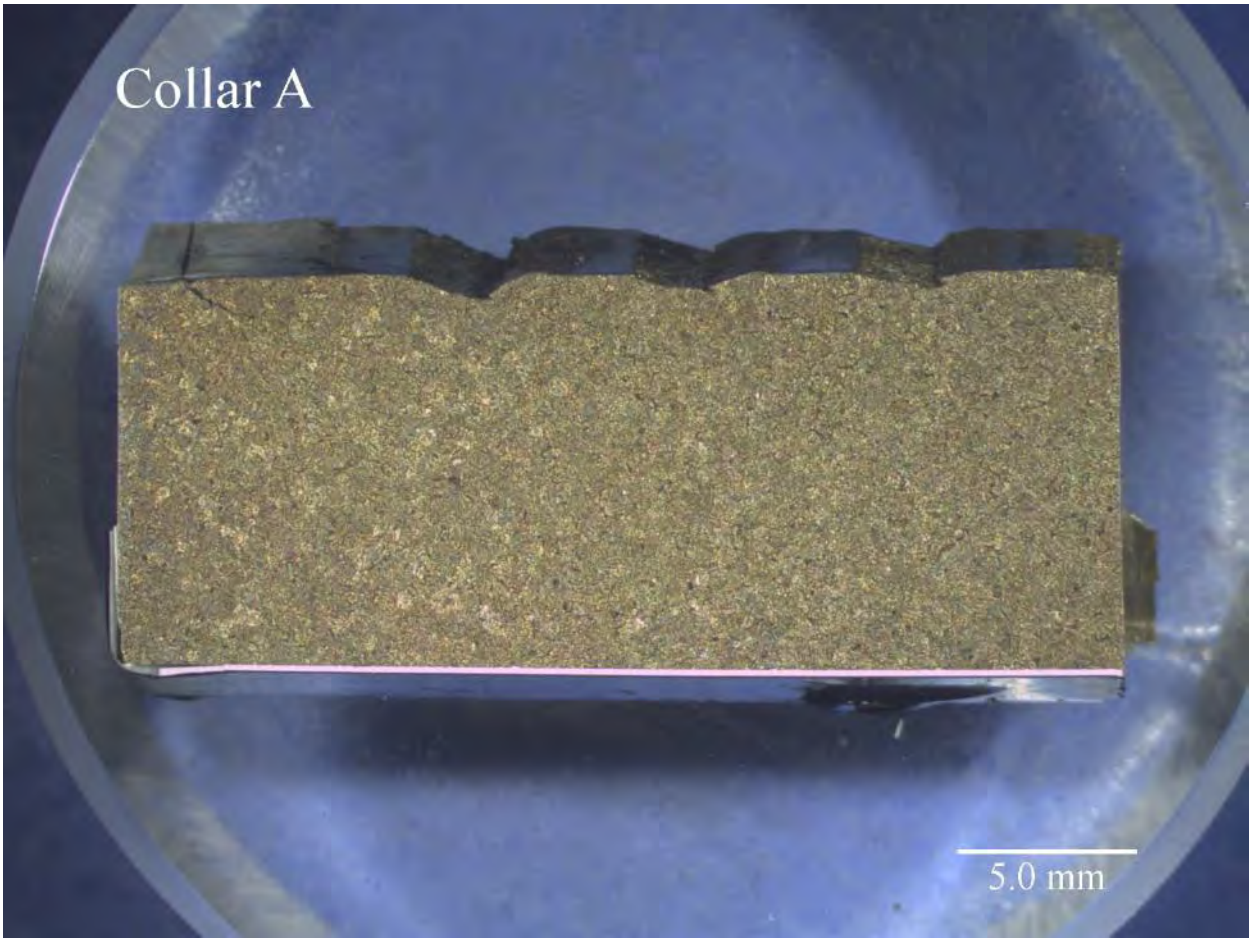


FIGURE 45

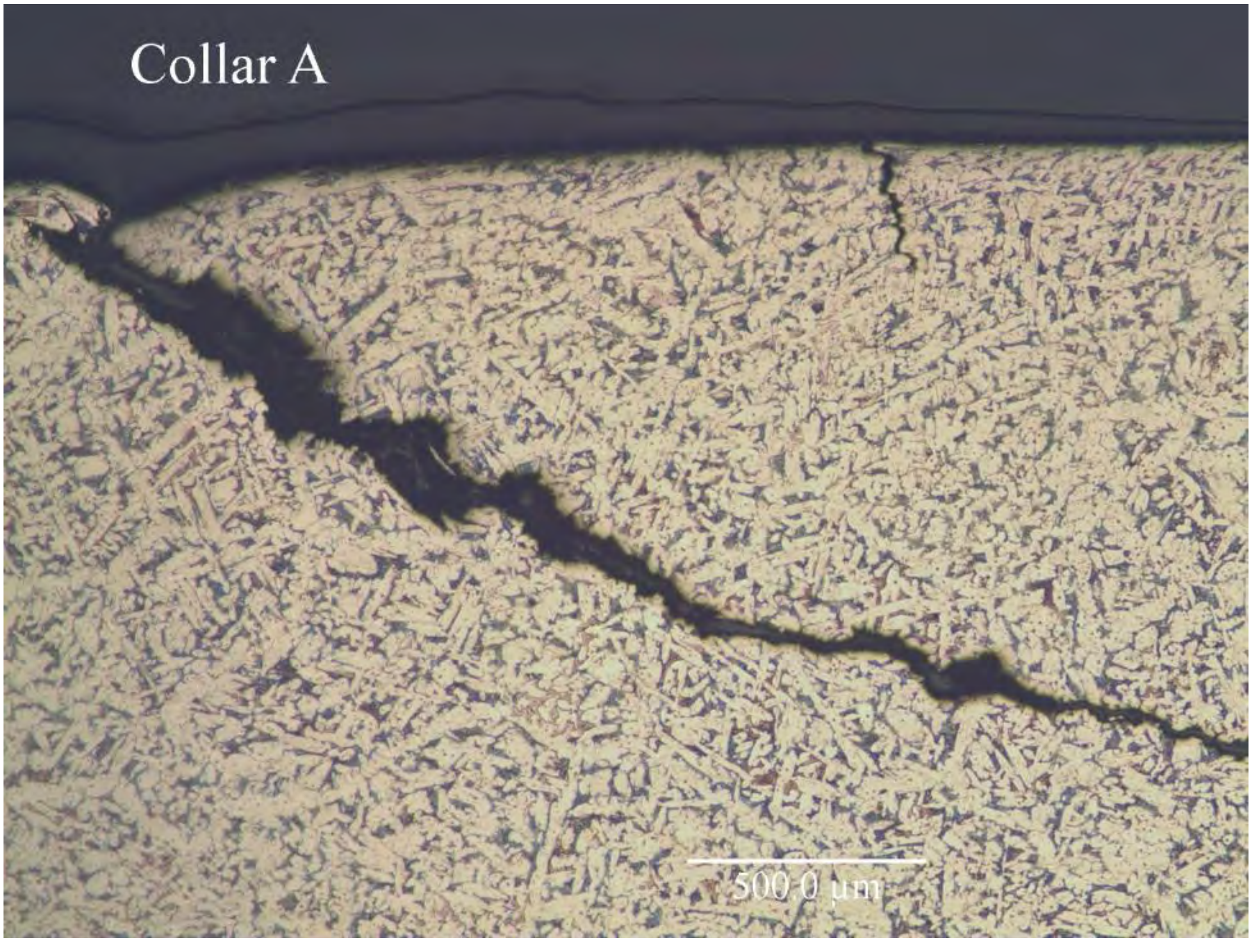
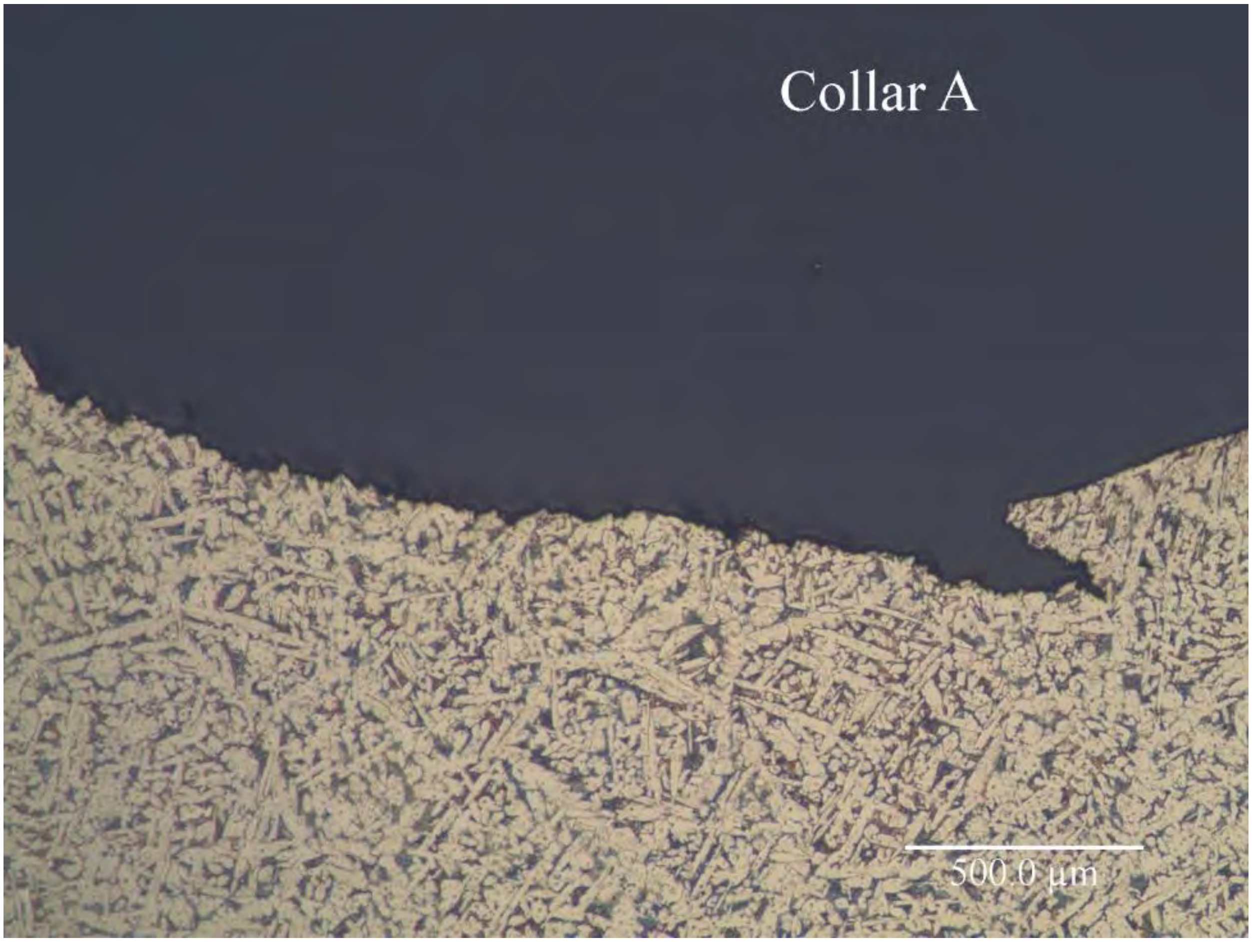


FIGURE 46



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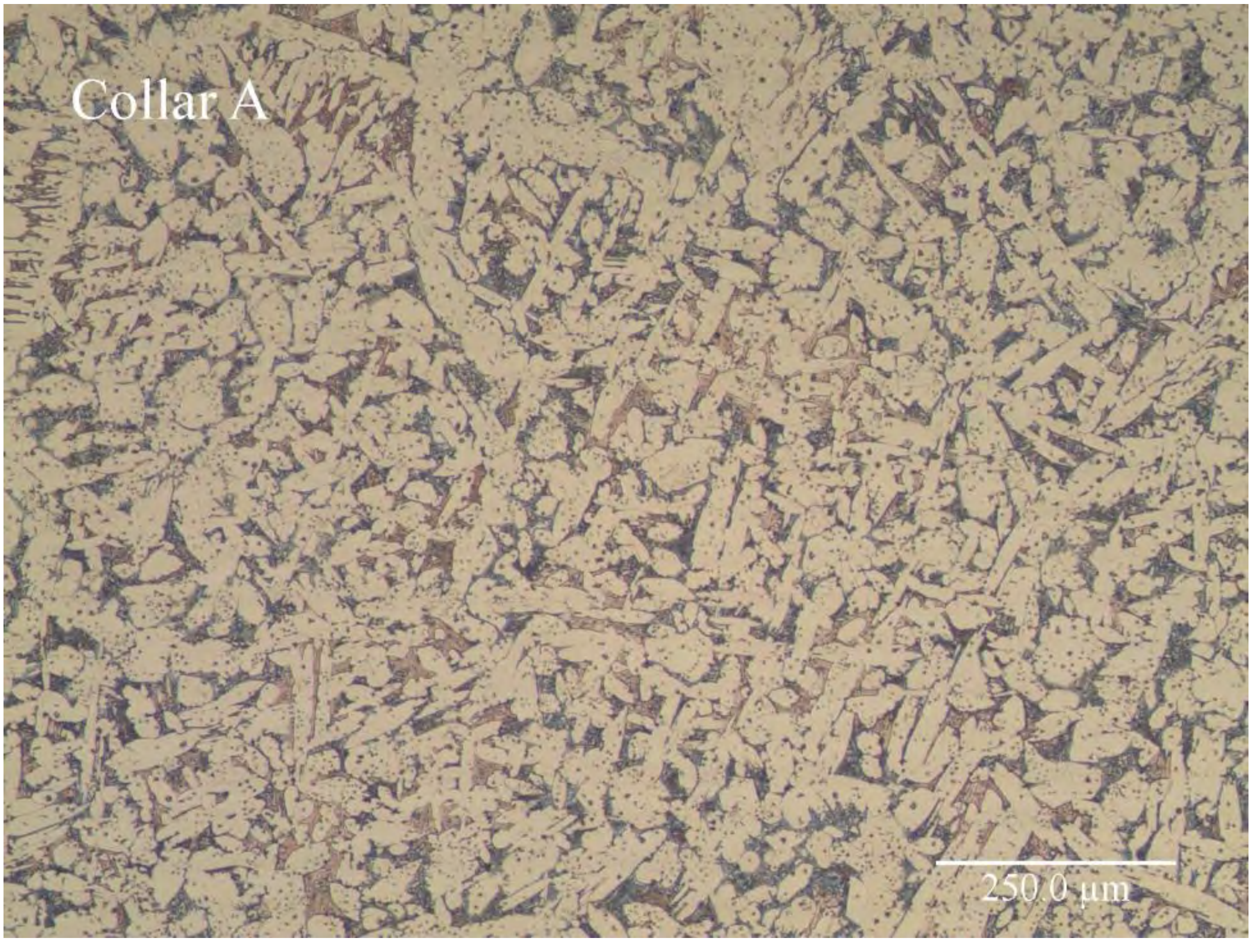
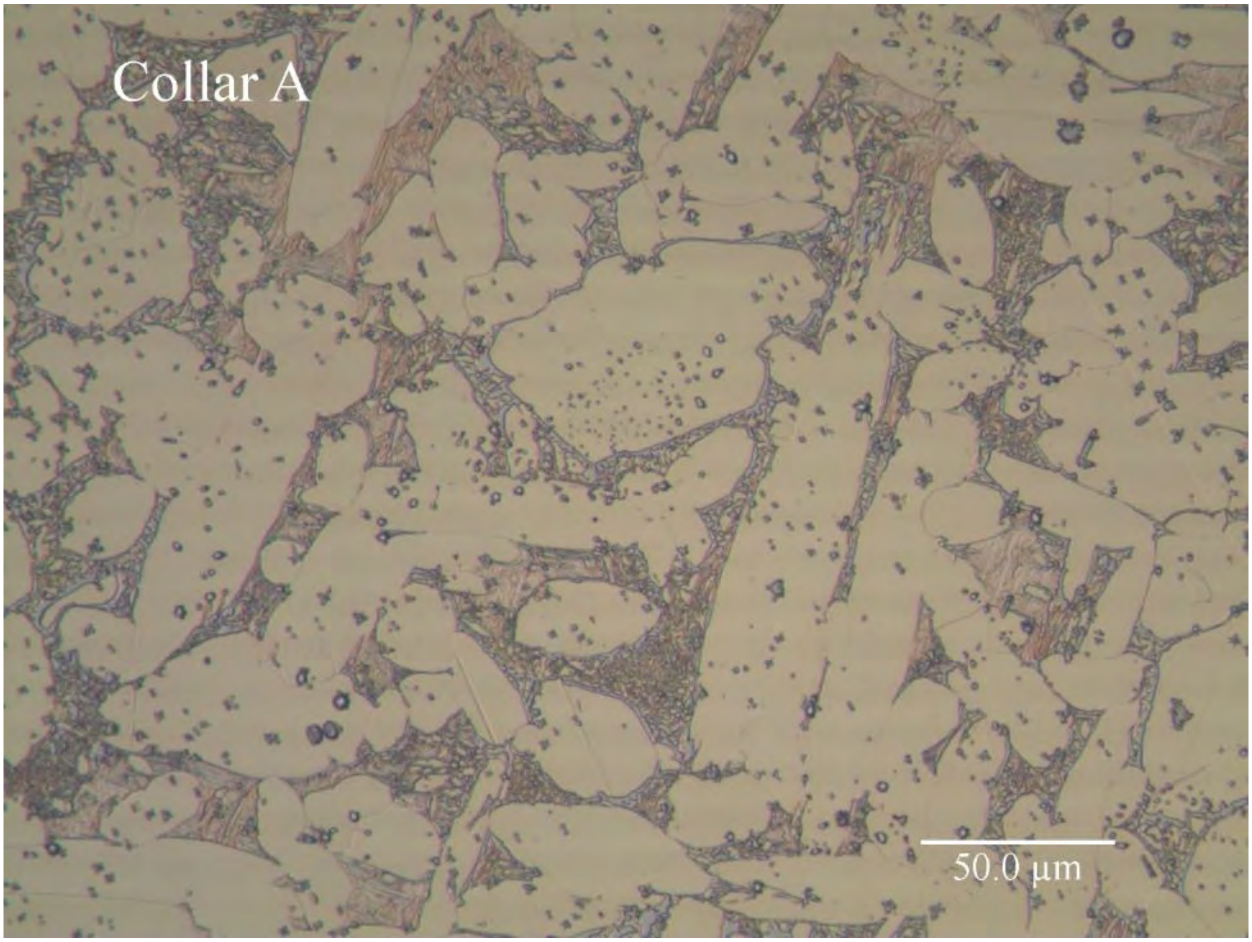


FIGURE 48



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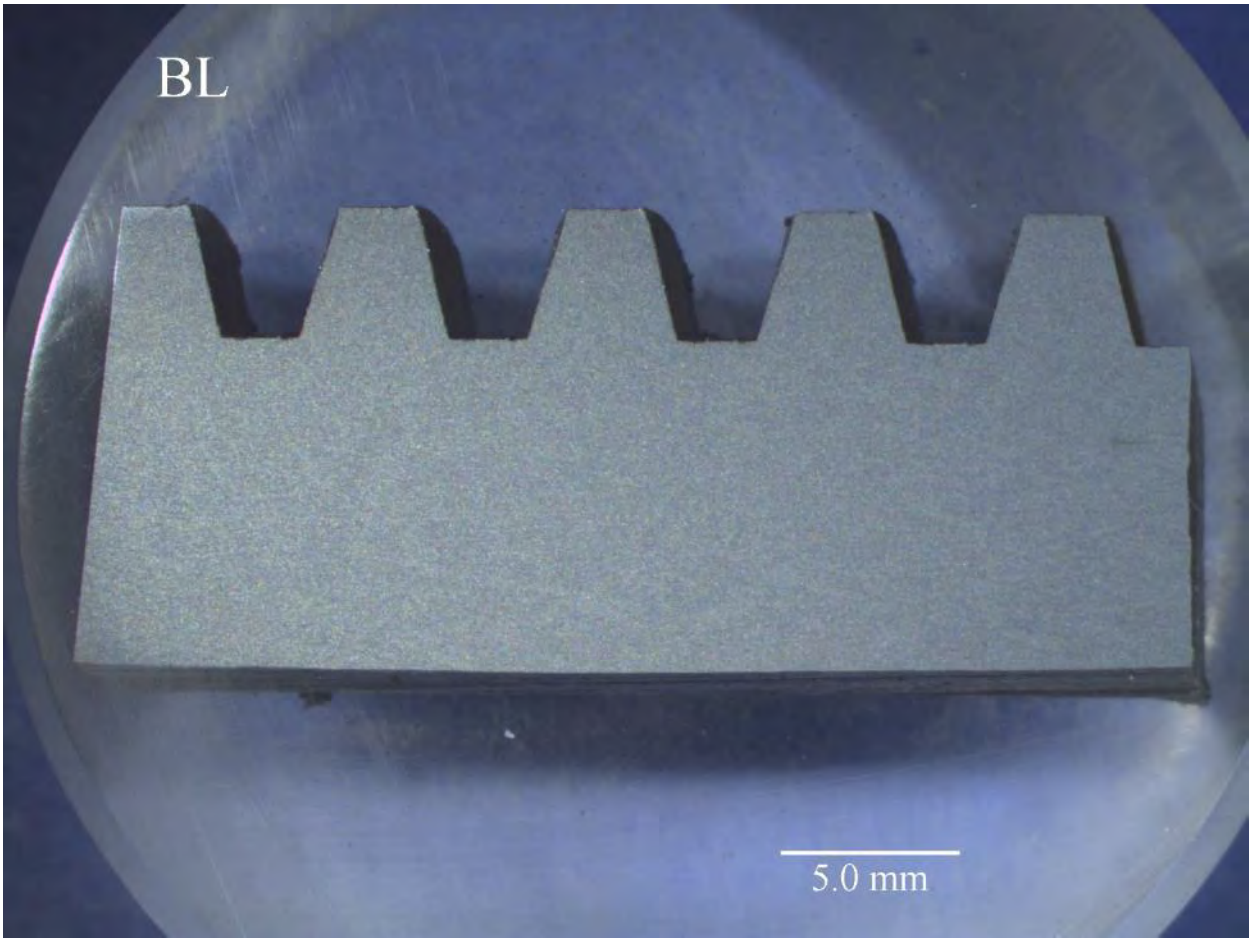

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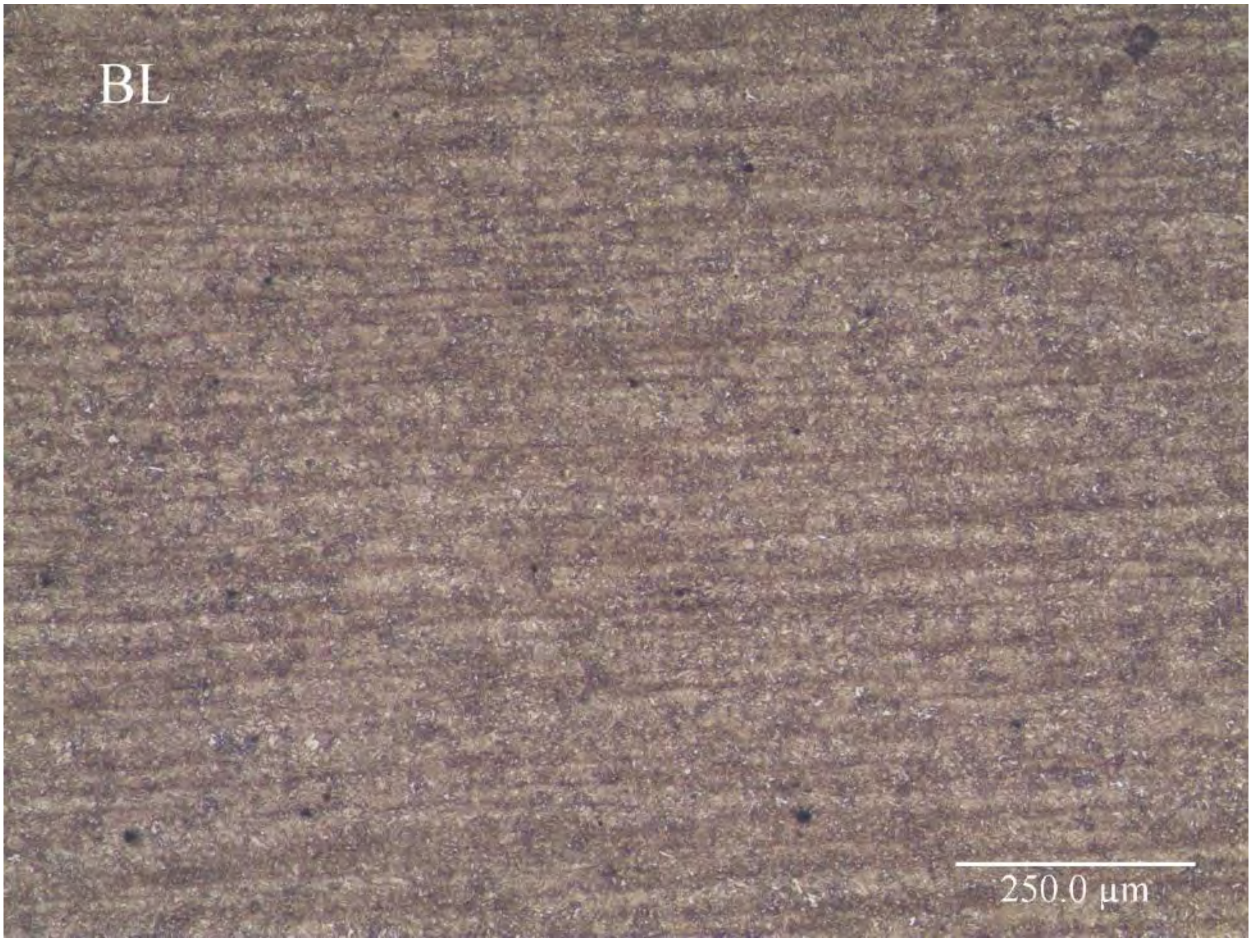

FIGURE 51

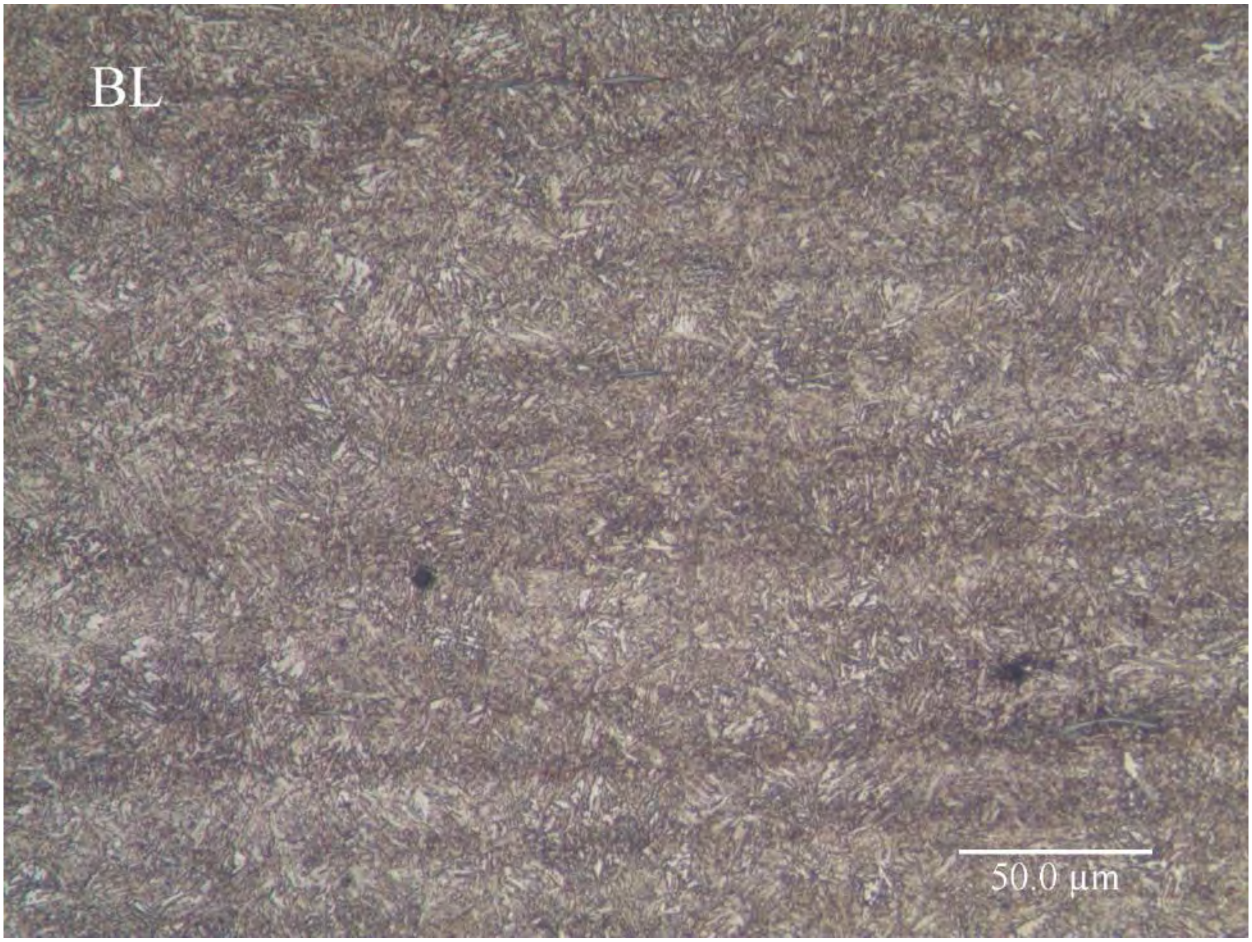

FIGURE 52

FIGURE 53

FIGURE 54

FIGURE 55

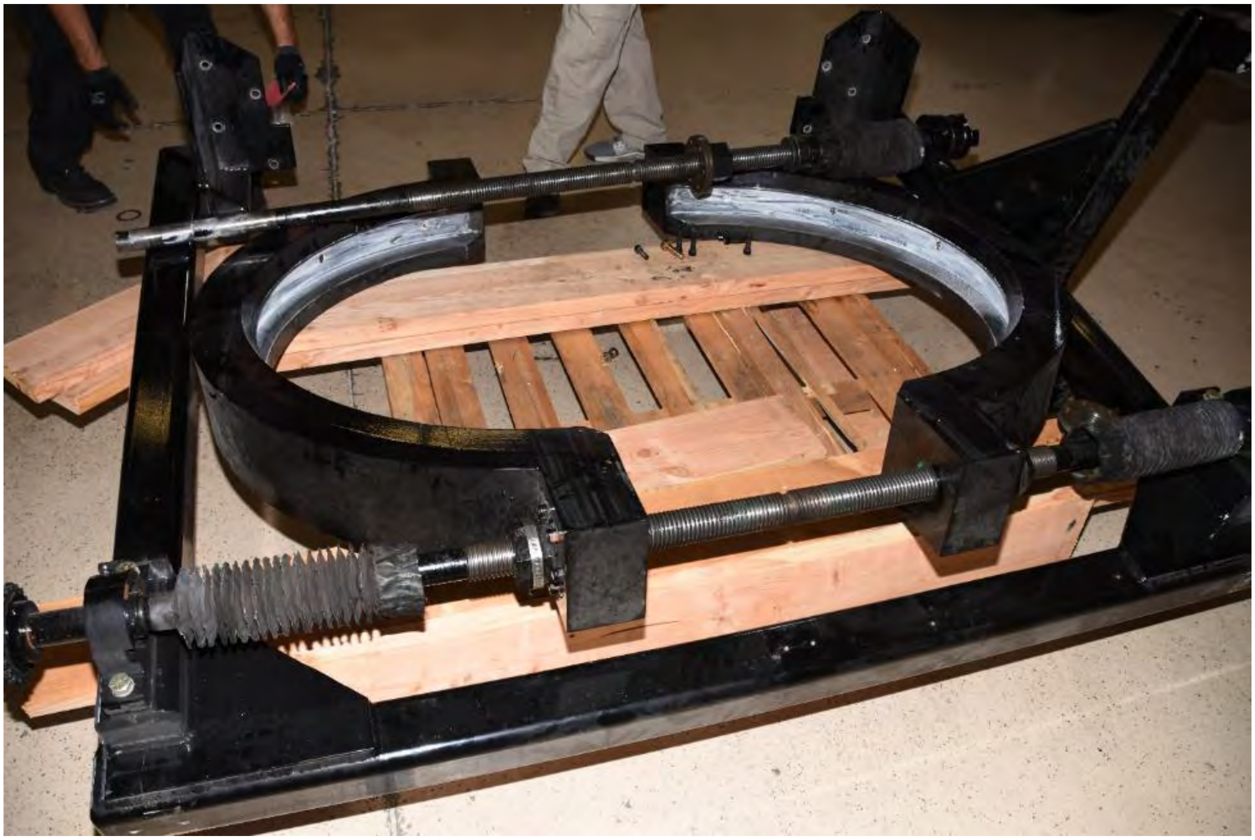

FIGURE 56

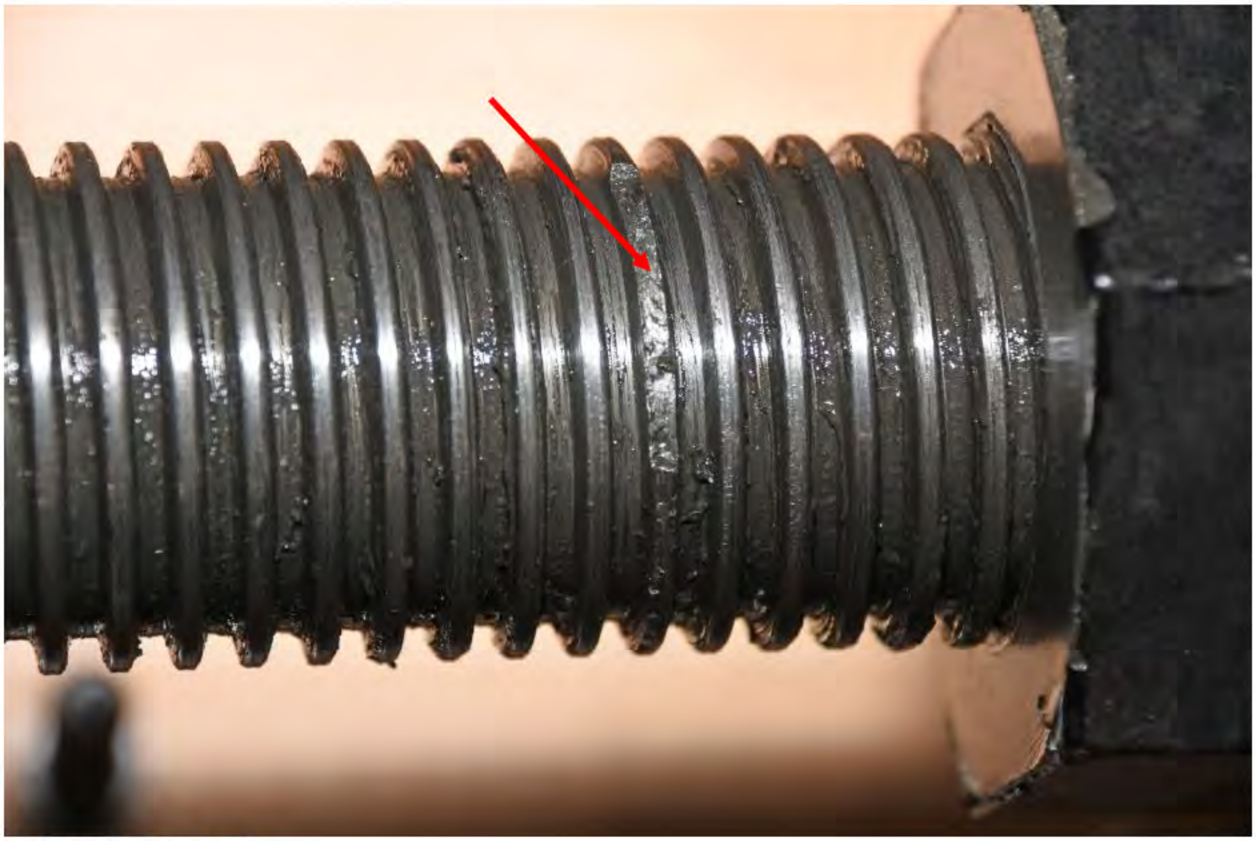

FIGURE 57

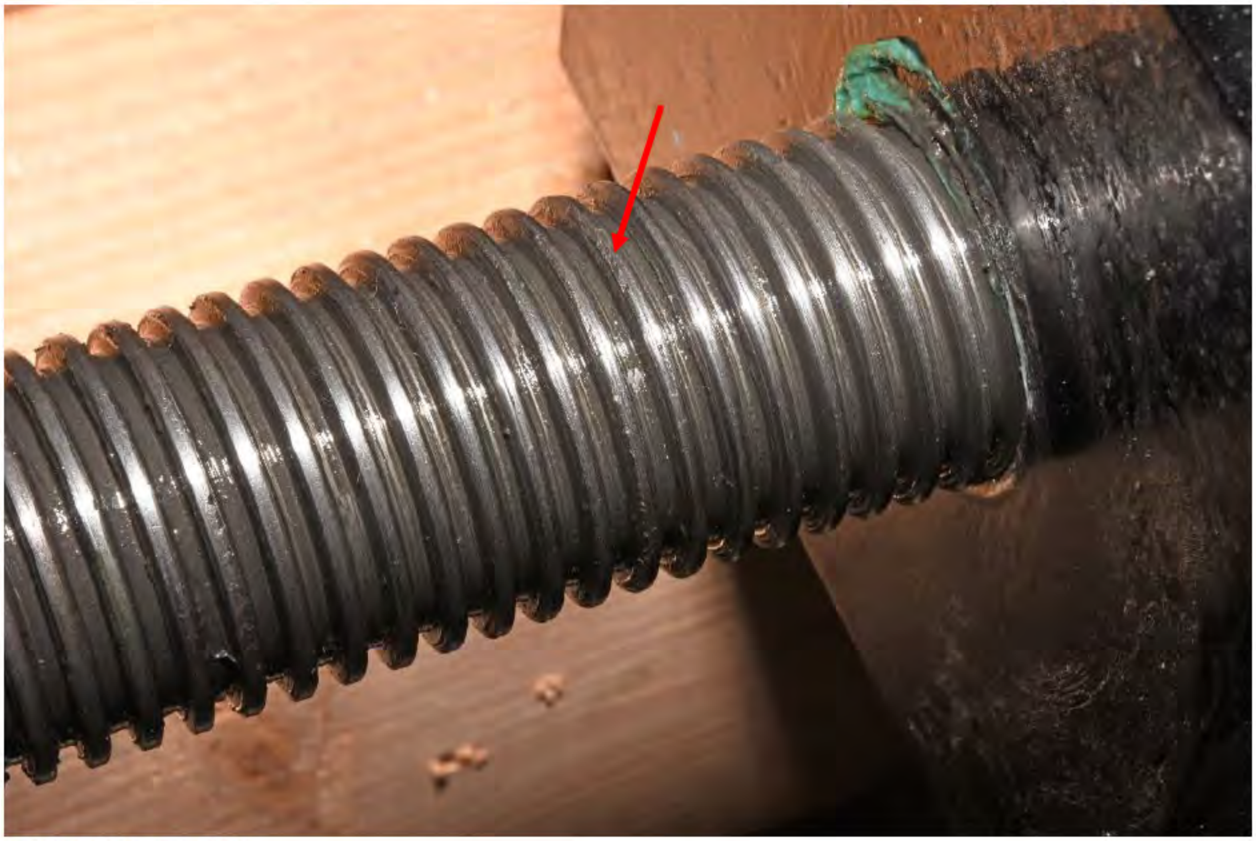

FIGURE 58

FIGURE 59

APPENDIX I

LABORATORY TESTING INC.

Certified Test Report
CCE001-21-08-24566-1

Nadcap Administered by PRI ACCREDITED
Materials Testing Laboratories
NonDestructive Testing

2331 Topaz Drive, Hatfield, PA 19440
TEL: 800-219-9095 • FAX: 800-219-9096

SOLD TO
Craig Clauser Eng. Consulting
1610 Hunter Circle
West Chester, PA 19380

SHIP TO
Craig Clauser Eng. Consulting
1610 Hunter Circle
West Chester, PA 19380
ATTN: [redacted]

CUSTOMER P.O.	CERTIFICATION DATE	SHIP VIA
C21062	8/19/2021	EMAIL

DESCRIPTION

Quantity:	1	**Quantity:**	1
Material:	Bronze	**Material:**	Steel
Identified as:	A	**Identified as:**	BL
Job No.:	C21062	**Job No.:**	C21062

***REVISED CERTIFICATION**

***CHEMICAL ANALYSIS:**
APPLICABLE SPECIFICATIONS: Customer's Information
KEY: C - Conforms NC - Non-Conformance R-Report for Information

ELEMENT	A
Al	10.20%
C	0.006%
Co	0.006%
Cr	0.003%
Fe	3.63%
Mn	0.013%
Ni	0.36%
P	0.008%
Pb	0.013%
S	0.001%
Sb	0.001%
Si	0.038%
Sn	0.010%
Zn	0.079%
KEY (C/NC/R):	R

---CHEMICAL ANALYSIS RESULTS CONTINUED ON NEXT PAGE---

LABORATORY TESTING INC.

Certified Test Report
CCE001-21-08-24566-1

Nadcap ACCREDITED
Materials Testing Laboratories
NonDestructive Testing

2331 Topaz Drive, Hatfield, PA 19440
TEL: 800-219-9095 • FAX: 800-219-9096

*REVISED CERTIFICATION

***CHEMICAL ANALYSIS (Continued...)**
APPLICABLE SPECIFICATIONS: Customer's Information
KEY: C - Conforms NC - Non-Conformance R-Report for Information

ELEMENT	BL
Al	0.026%
B	0.0002%
C	0.39%
Co	0.009%
Cr	0.95%
Cu	0.29%
Mn	0.82%
Mo	0.17%
Nb	<0.001%
Ni	0.096%
P	0.011%
S	0.016%
Si	0.24%
Ti	0.001%
V	0.003%
W	0.004%
KEY (C/NC/R):	R

Date Completed: 8/19/2021 (C and S) / 8/20/2021 (Balance of elelments)*
Procedures/Methods: MAS-CS, Rev. 7, Carbon and Sulfur Analysis; 86-SCA-0, Rev. 22, Direct Reading Atomic Emissions Spectroscopy*

CERTIFICATION REVISION HISTORY:

*REVISION DATE:	SUMMARY OF CHANGE:
8/20/2021	Amended with additional elements

The services performed above were done in accordance with LTI's Quality System Program Manual Revision 21 dated 5/1/2019 and ISO/IEC 17025:2017. These results relate only to the items tested and this report shall not be reproduced, except in full, without the written approval of Laboratory Testing, Inc. The services provided on this certificate have been performed in conformance with the customer's purchase order requirements. L.T.I. is accredited by Nadcap for NDT and Materials Testing for the test methods and specific services as listed in the Scopes of Accreditation available at www.labtesting.com and www.eAuditNet.com. The results reported on this test report represent the actual attributes of the material tested and indicate full compliance with all applicable specification and contract requirements. This is a shared risk decision rule which the customer also has responsibility for determining acceptance of the results.

MERCURY CONTAMINATION: During the testing and inspection, the product did not come in direct contact with mercury or any of its compounds nor with any mercury containing devices employing a single boundary of containment.

NOTE: The recording of false, fictitious or fraudulent statements or entries on this document may be punishable as a felony under Federal Statutes.

[redacted]
QA Specialist

[redacted]
Authorized Signature