

ENG23LA031

POWERPLANTS

Group Chair's Factual Report - Attachment # 2

Metallurgical Evaluation of LEAP-1B Fuel Nozzles, Fuel Manifold, and Fireproof Plate

January 7, 2025



Metallurgical Investigation Report DRB AvEng-548136

METALLURGICAL EVALUATION OF LEAP-1B FUEL NOZZLES

Part Number: 2085M31G03
Part Serial Number: Various

Date: 12/14/2023

Export Classification: **NLR**



Background

- An engine under-cowl fire occurred after a fuel leak. A leak test was performed, and a leak was noted in the secondary inlet of the #17 fuel nozzle. The b-nuts at the secondary inlet of fuel nozzles #17 and #18 were found with zero break-away torque. Comparisons were made to two other GE commercial engine model investigations (AvEng-536107A and AvEng-536108A). The fuel nozzles were previously replaced during a shop visit, but the fuel manifold was not.

Observations

- Four fuel nozzles were evaluated: the two suspected-loose nozzles (#17 and #18), one in the fire (#16), and one outside the fire (#4). No mechanical deformation was observed about any of the four nozzles' mating faces or threads. Unlike the other GE commercial engine investigation, no galling or thread damage was observed about any of the four manifold ferrules or b-nuts.
- Repo-rubber castings of the secondary manifold ferrules #4, #16, #17, and #18 were made. The sealing surfaces of each ferrule appeared slightly concave, consistent with plastic deformation from installation against the fuel nozzle bullnoses. These results are included in Appendix A.
- Coking was observed around the mating surface of the secondary inlet of fuel nozzles #17 and #18.
- FTIR was performed for the varnish on the 12 o'clock bifurcation heat shield. The varnish was a 40% match for coke but did not match well to other signatures in the GE library.
- A microprobe evaluation of the varnish did not show high fluorine levels as would be expected if Viton was in the residue.
- Distinct layers could not be seen optically, or in the SEM, in the varnish layer.

Summary

Castings of the fuel manifold (inside and outside of fire region) showed deformation of the ferrule sealing surface, consistent with deformation from sealing at original installation. Witness marks at the bullnoses of the fuel nozzles were parallel to the sealing interface, unlike the other GE commercial engine model investigations and consistent with proper alignment. No mechanical deformation or indication of cross-threading was observed on fuel nozzles #4, #16, #17, #18. Coking was observed on the secondary nozzle mating surface of nozzles #17 and #18, both of which had a zero break-away torque. However, there was insufficient evidence to determine how long in terms of cycles a fuel leak may have occurred.



Figure 1: Overall images of four fuel nozzles.

Nozzle 4
Not in Fire



Nozzle 16
In Fire



Nozzle 17
In Fire, Secondary B-nut
w/ Zero Breakaway Torque



Nozzle 18
In Fire, Secondary B-nut
w/ Zero Breakaway



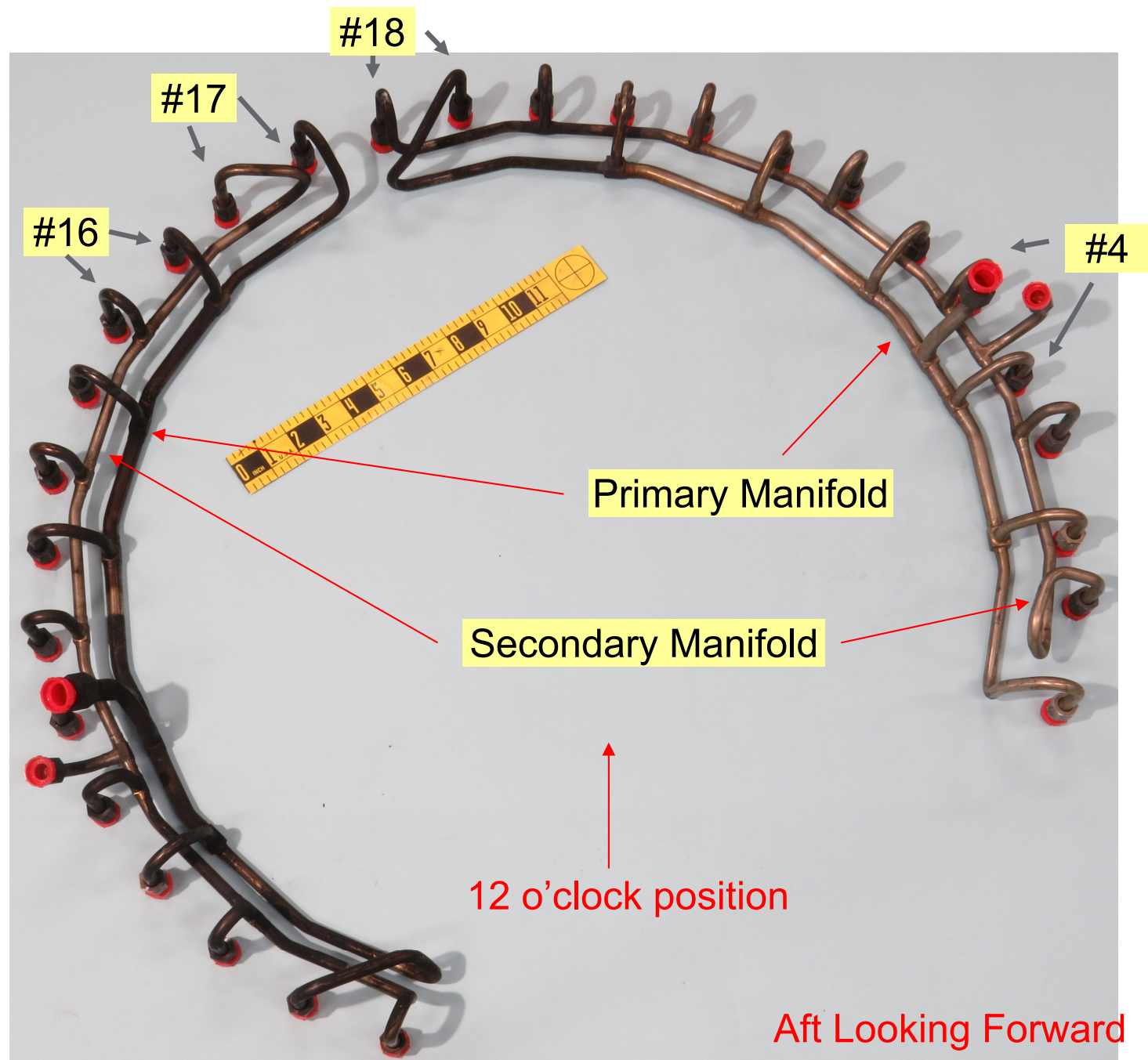


Figure 2: Overall images of fuel manifolds.



Fuel Nozzle Serial Numbers

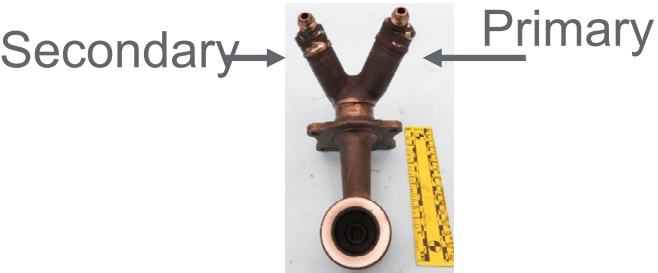
Fuel Nozzle Clocking	Part Number	Serial Number
4	M34P02 27515	237925
16	M34P02 27515	287779
17	M34P02 27515	250334
18	M34P02 27515	218173

Fuel Manifold Serial Numbers

Descriptor	Part Number	Serial Number
Primary, clocking 11-17	07482ASSY2585M71G01	6585709
Secondary, clocking 11-17	07482ASSY2572M40G01	6559053
Primary, clocking 1-6&18	07482ASSY2585M70G01	6560885
Secondary, clocking 1-6&18	07482ASSY2572M39G01	58450



Figure 3: Well-defined coking only present around nozzles in fire with zero break-away torque (secondary on nozzle 17 and 18, indicated by red arrows). All nozzles in fire show discoloration (yellowing) at threads and coking about nozzle.



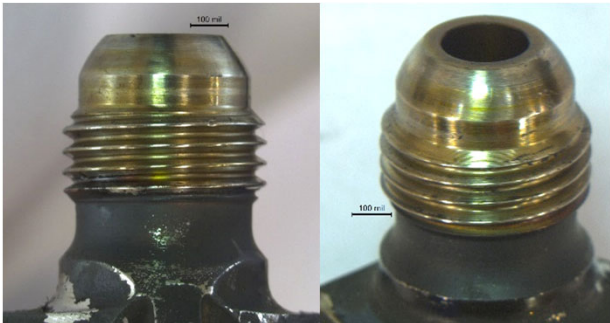
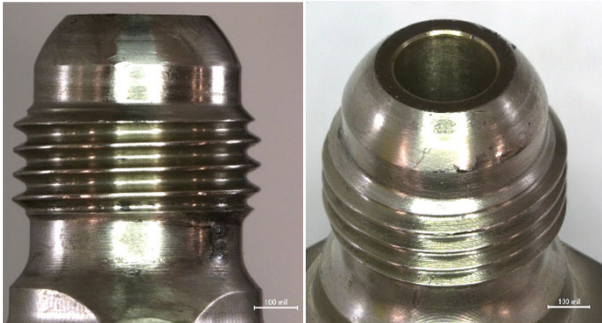
Nozzle 4
Not in Fire

Nozzle 16
In Fire

Nozzle 17
In Fire, Secondary B-nut
w/ Zero Breakaway Torque

Nozzle 18
In Fire, Secondary B-nut
w/ Zero Breakaway Torque

Primary Inlet



Secondary Inlet

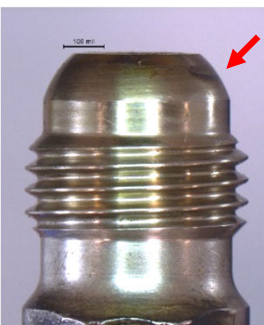
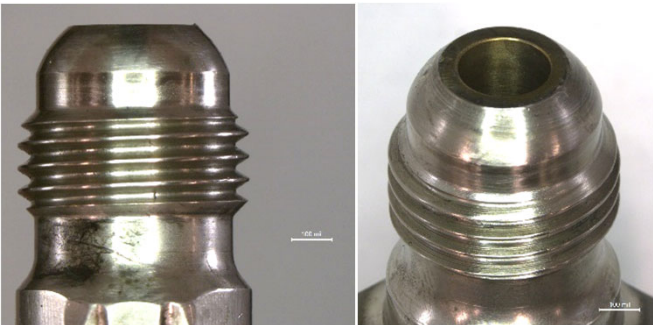
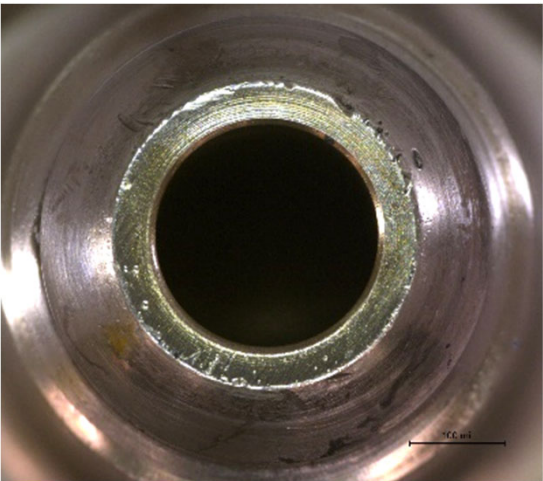


Figure 4: Images show top-down view of mating surfaces of the fuel nozzles, as well as coking present around the secondary mating surface of nozzles #17 and #18. No wear was noted about the mating surface of the fuel nozzles.

Nozzle 4
Not in Fire



Nozzle 16
In Fire



Nozzle 17
In Fire, Secondary B-nut
w/ Zero Breakaway



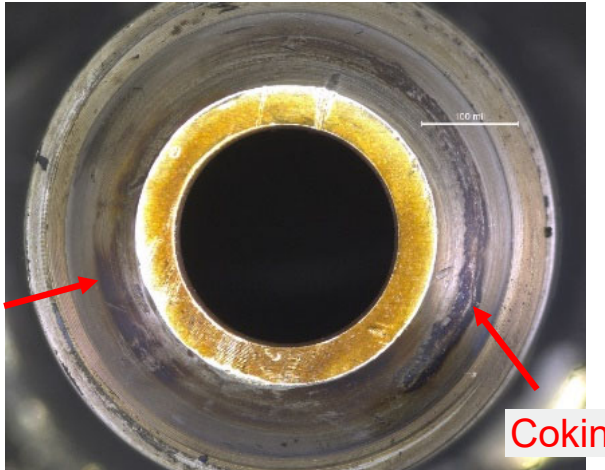
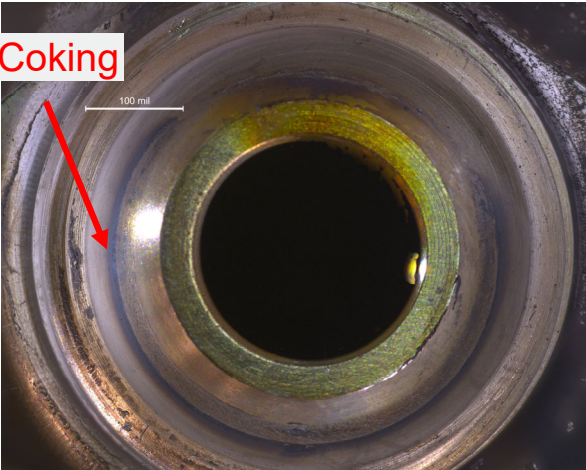
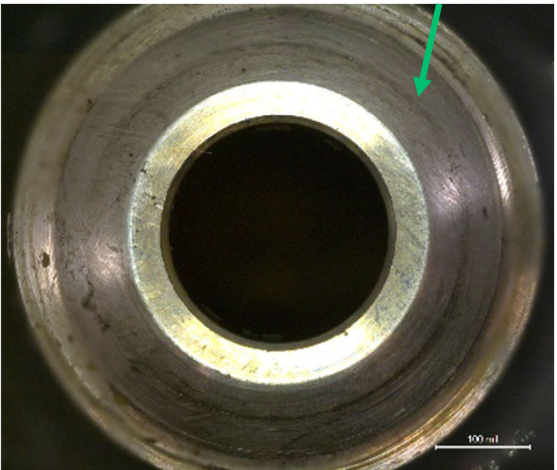
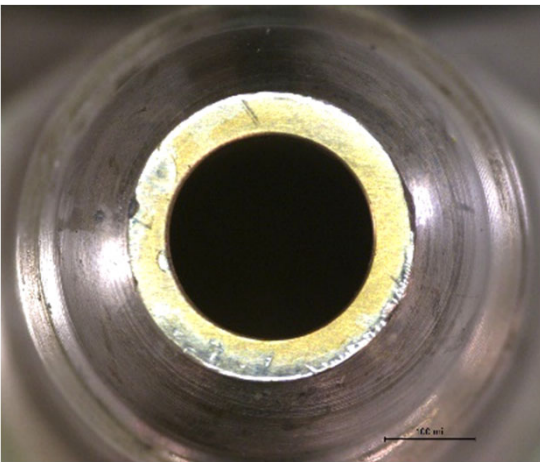
Nozzle 18
In Fire, Secondary B-nut
w/ Zero Breakaway Torque



Primary
Inlet

Discoloration

Secondary
Inlet



Coking



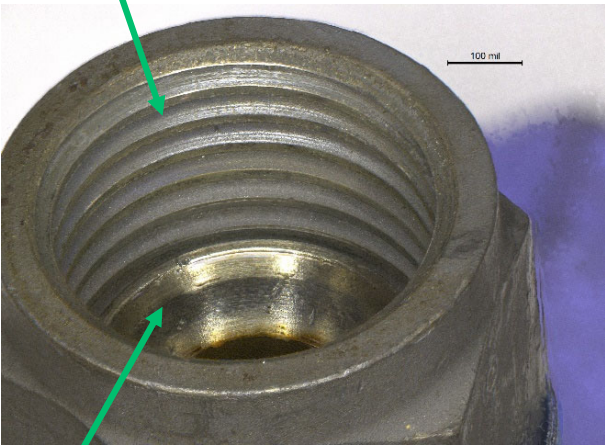
AvEng-548136.A

Figure 5: The fuel manifold b-nuts were inspected for damage that would result in a lack of sealing. Macrographs show no indication of cross-threading. No evidence of wear (scratching, bench marks) was noted about the mating surface of the fuel manifold ferrules.

Minor wear, no damage to threads

Nozzle 4
Not in Fire

Primary Inlet



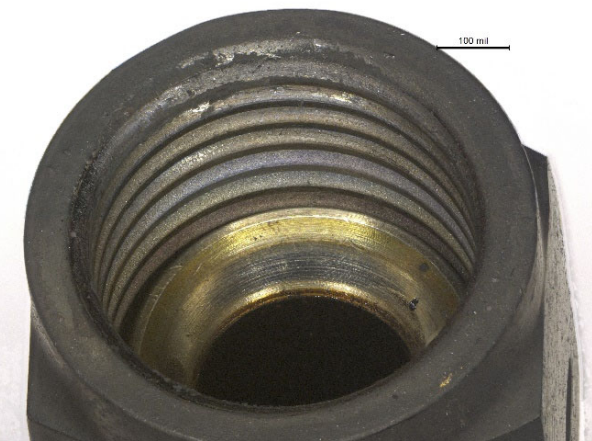
Nozzle 16
In Fire



Nozzle 17
In Fire, Secondary B-nut
w/ Zero Breakaway Torque



Nozzle 18
In Fire, Secondary B-nut
w/ Zero Breakaway Torque



No wear observed on ferrule mating surface

Secondary Inlet

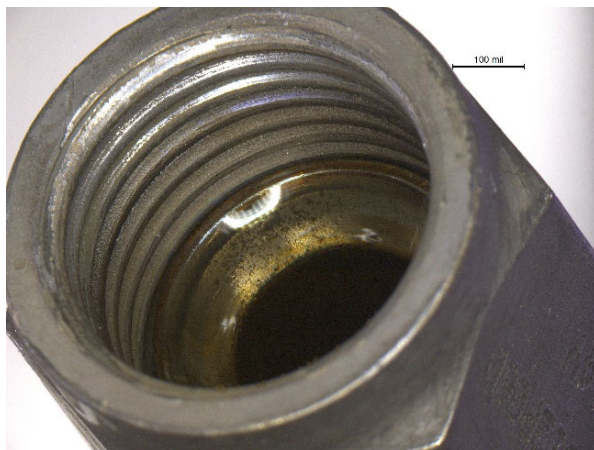


Figure 6: The fuel manifold ferrules were inspected for damage that would result in a lack of sealing. Macrographs show no indication of galling, cracking, or mechanical deformation present at fuel manifold ferrules.



Figure 7: The fuel manifold b-nuts were inspected for damage that would result in a lack of sealing. Macrographs show no indication of mechanical deformation present on the fuel manifold b-nut surfaces.

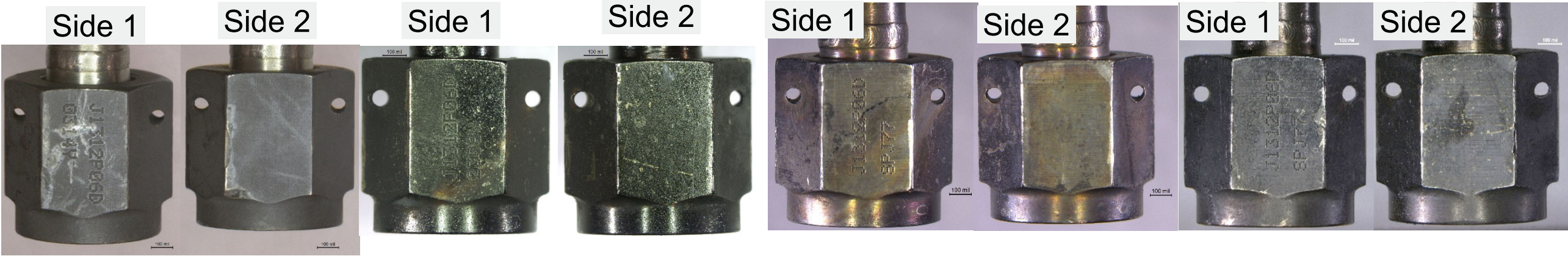
Nozzle 4
Not in Fire

Nozzle 16
In Fire

Nozzle 17
In Fire, Secondary B-nut
w/ Zero Breakaway Torque

Nozzle 18
In Fire, Secondary B-nut
w/ Zero Breakaway Torque

Primary Inlet



Secondary Inlet

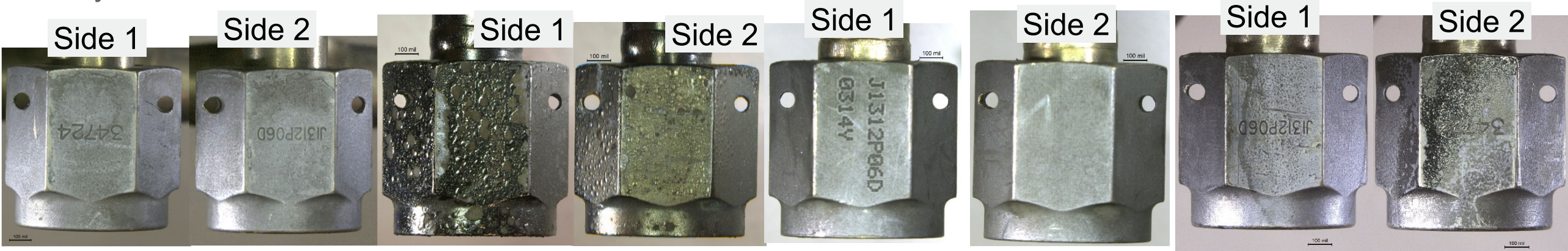


Figure 8: Overall image of 12 o'clock position bifurcation heat shield, and a close-up image of varnishing on the surface.

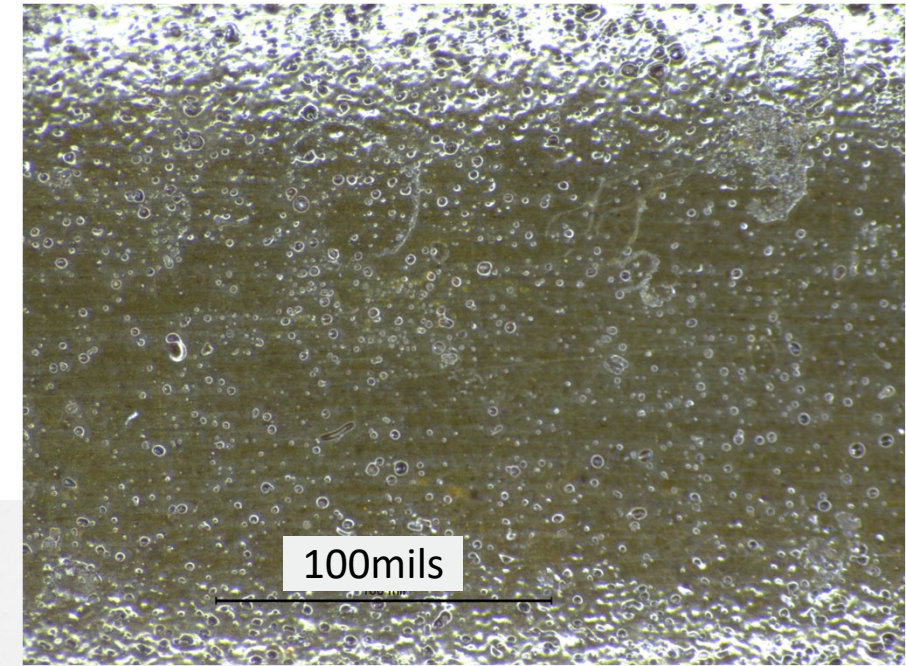
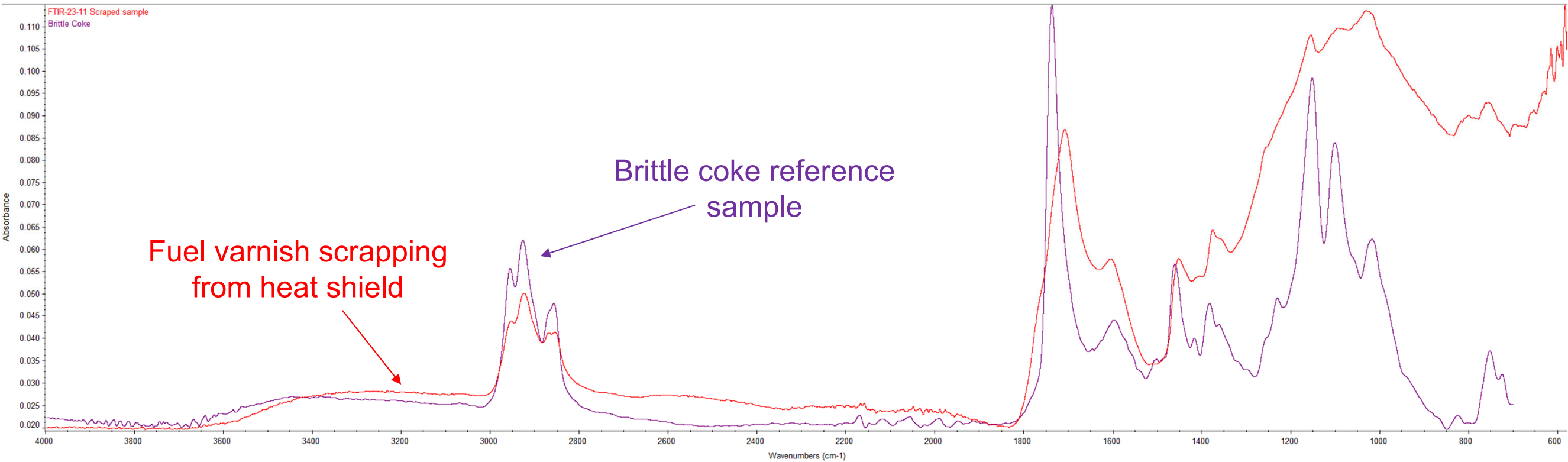


Figure 9: The FTIR spectrum (absorbance v. wavelength) indicates coke is present on heat shield. No additional matches could be made to materials in the GE FTIR library.

Comparison of Scraping from Fuel Varnish to IR Spectral Database



The scraping showed a 40.40% match to a brittle coke sample.



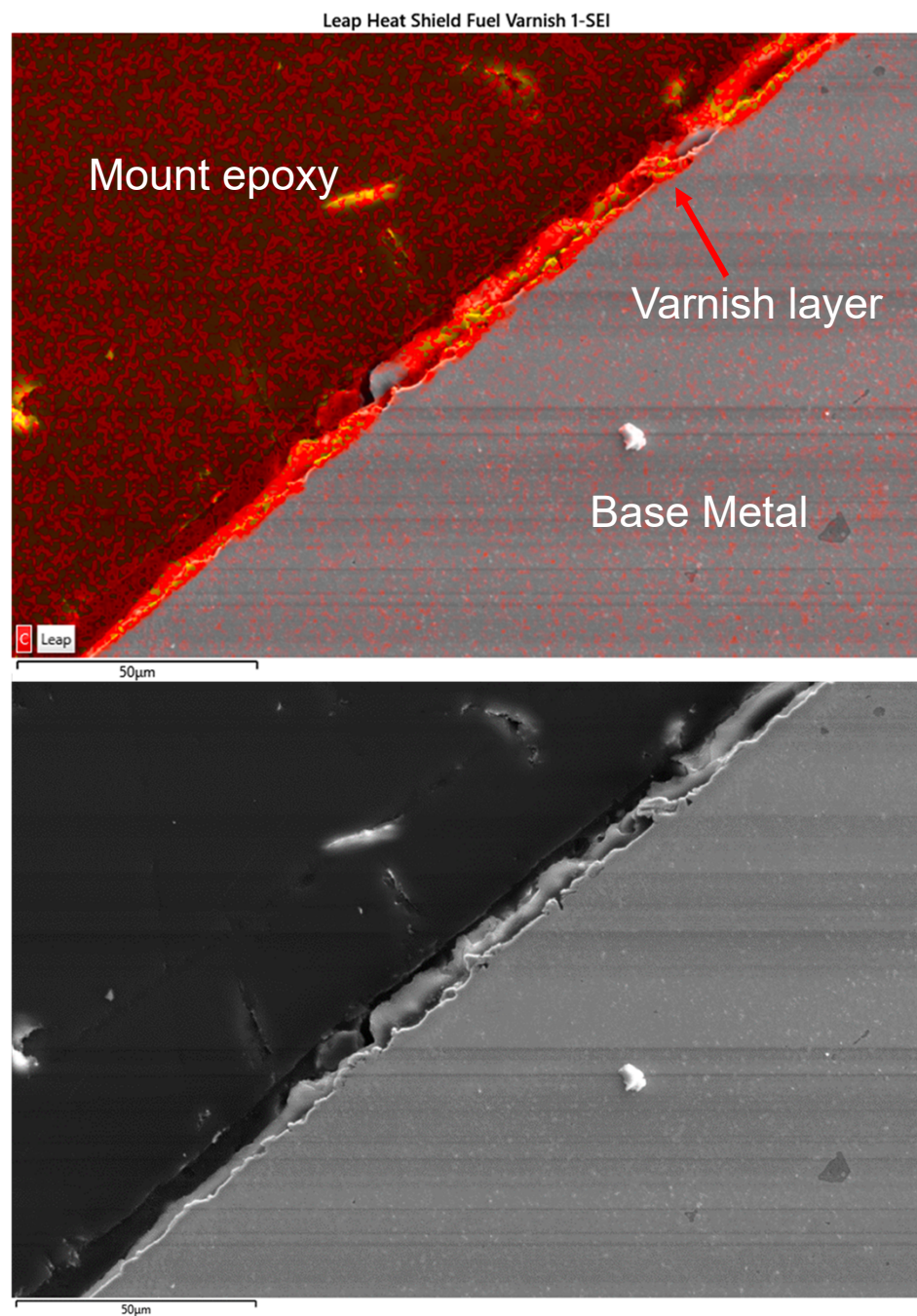
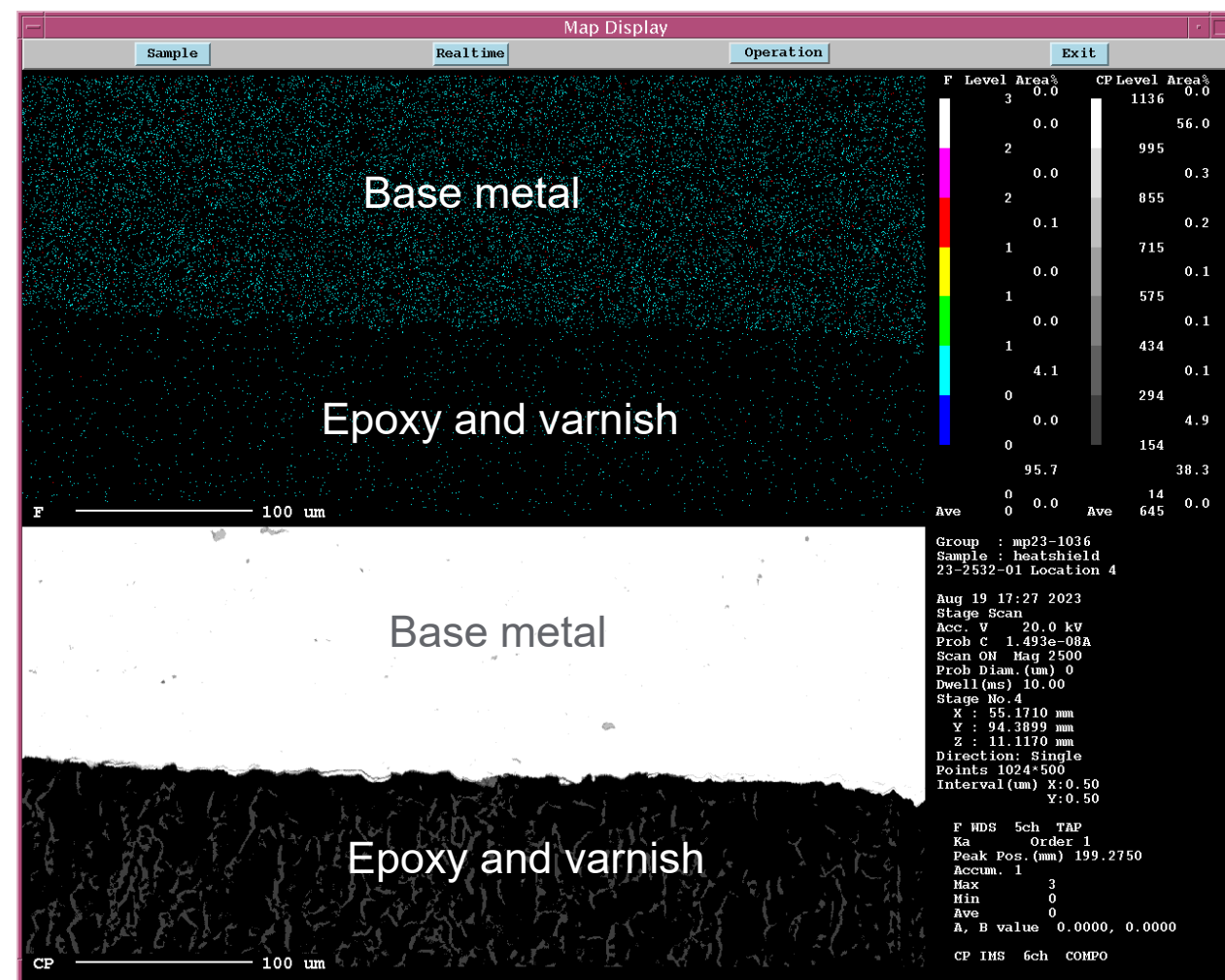


Figure 10: SEM and EDS images (shown left) of the cross-section of the heat shield show a carbon-rich region where varnish is present. Layers cannot be distinctly seen. Microprobe evaluation (shown below) of the cross-section did not show high levels of fluorine, a component in Viton, in the varnish.



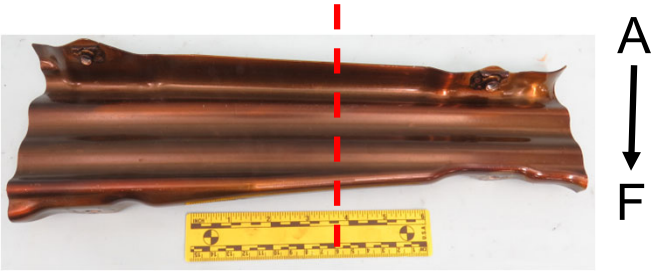
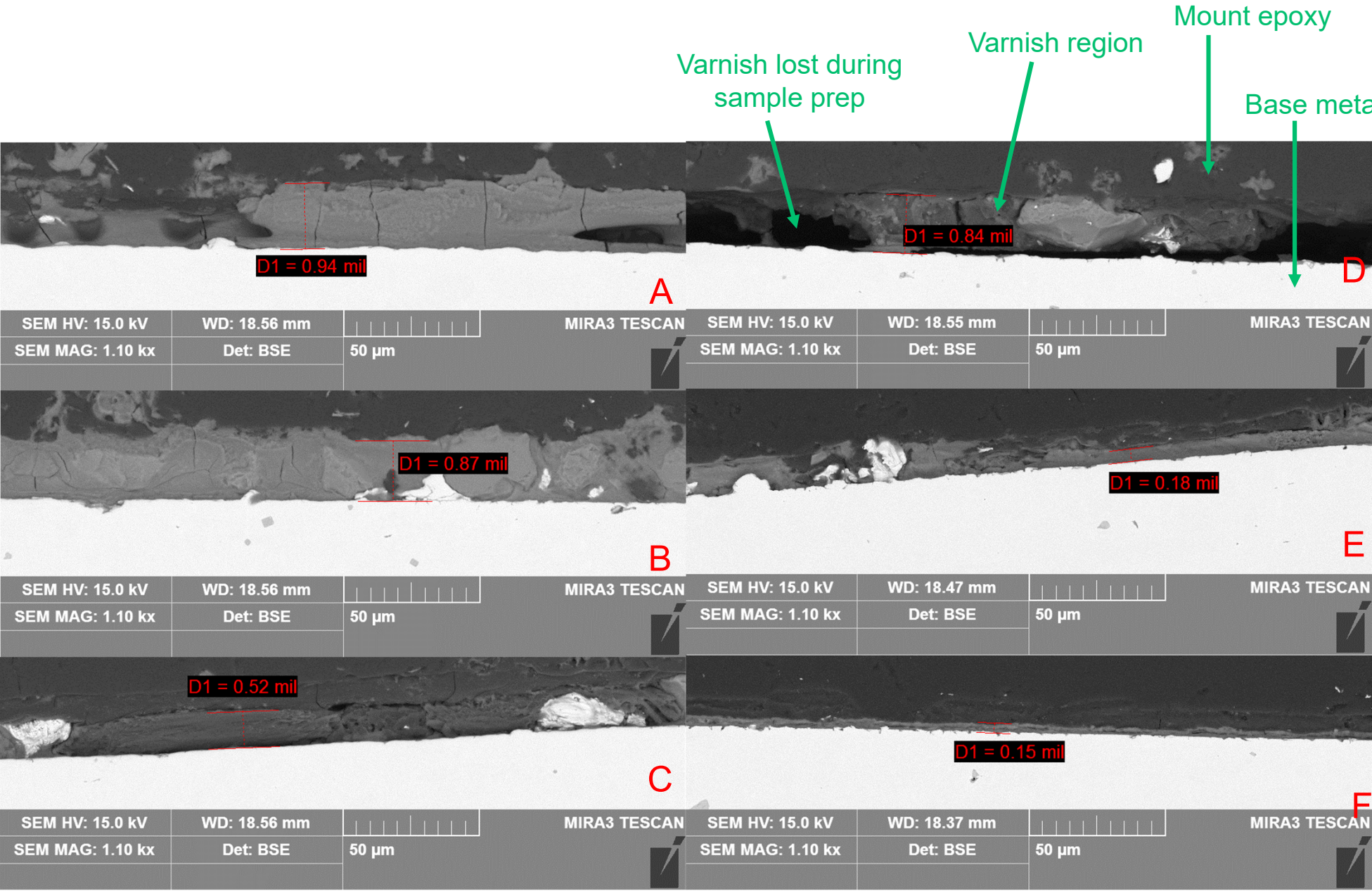


Figure 11: SEM images indicate varnish thickness variation, as expected based on variation in varnish color on hardware. The varnish thickness was <1mil in all areas observed.

Location	Varnish Thickness (mils)
A	0.94
B	0.87
C	0.52
D	0.84
E	0.18
F	0.15

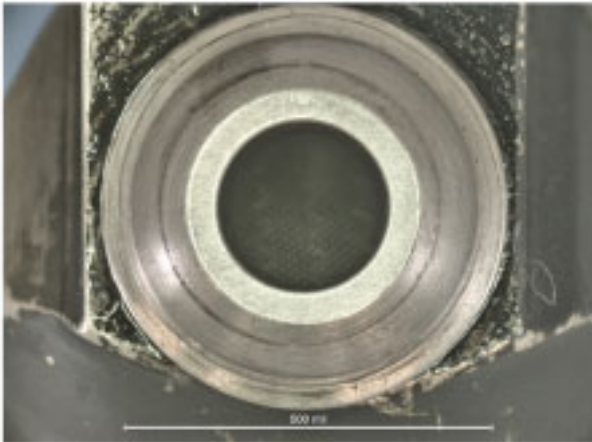


Appendix A: Comparison to other GE Commercial Engine Fuel Leak Investigations

*items referring to different DRB number than on the cover page are for comparison uses only



Excerpts from AvEng-536107



Nozzle #16

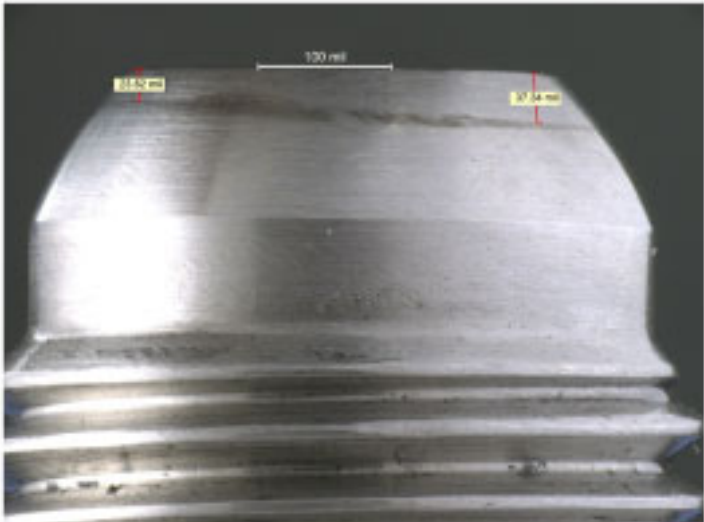
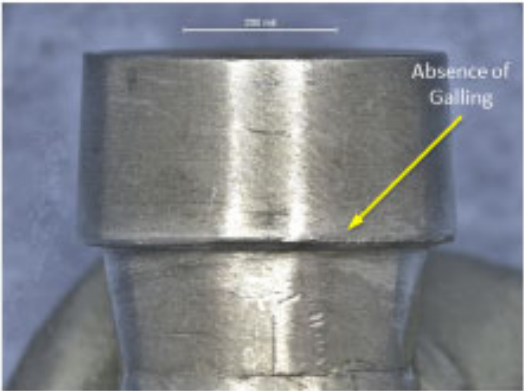
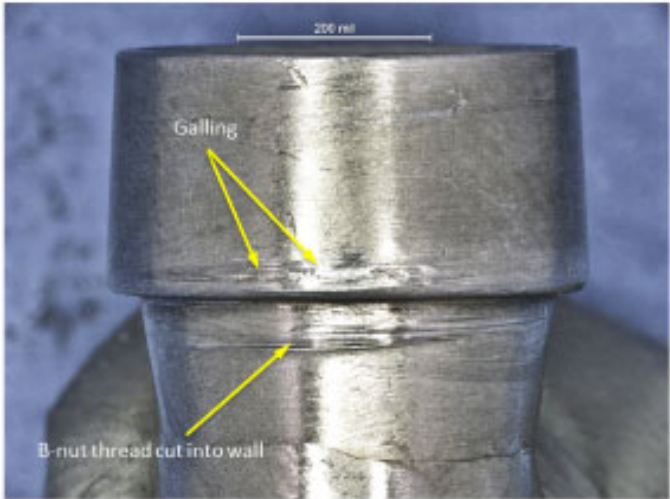


Figure 7: The bullnose from fuel nozzle #16 is shown. A witness mark from contact between the bullnose and the ferrule on the pigtail is clearly visible. From the end, the mark is slightly off center from the centerline of the hole. Viewed from the side, the witness mark is clearly at an angle. These observations are consistent with a slight misalignment of the centerlines of the nozzle and the pigtail – they are not parallel.



6 o'clock

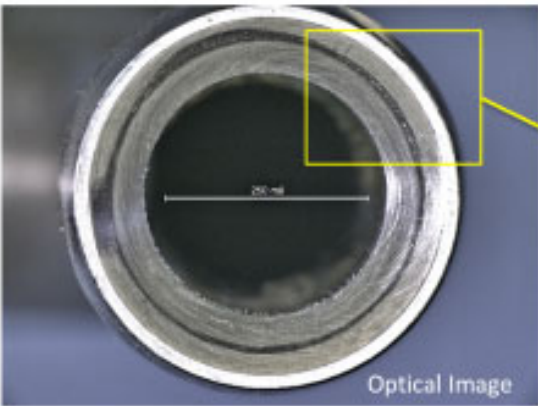


12 o'clock

Pigtail #16

Figure 22: The OD surface of the ferrule from pigtail #16 is shown at the 6 o'clock (inboard) and 12 o'clock (outboard) locations. At the 12 o'clock position, galling from contact with the threads (on the inside) of the B-nut was noted. This is consistent with a rotational misalignment of the bullnose to the pigtail ferrule. A radial or circumferential misalignment could also cause the B-nut threads to contact the ferrule. (The centerlines of the parts are not concentric and parallel.)

Excerpts from AvEng-536107 and AvEng-536108



Pigtail #16

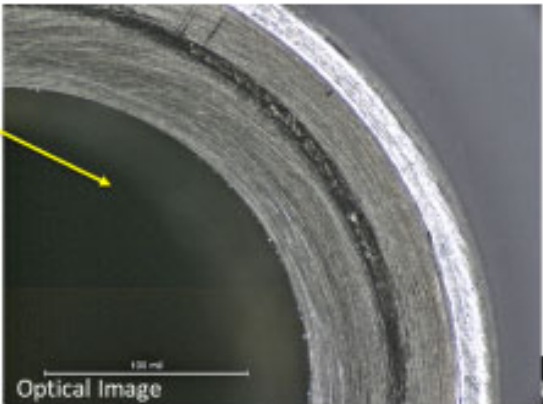
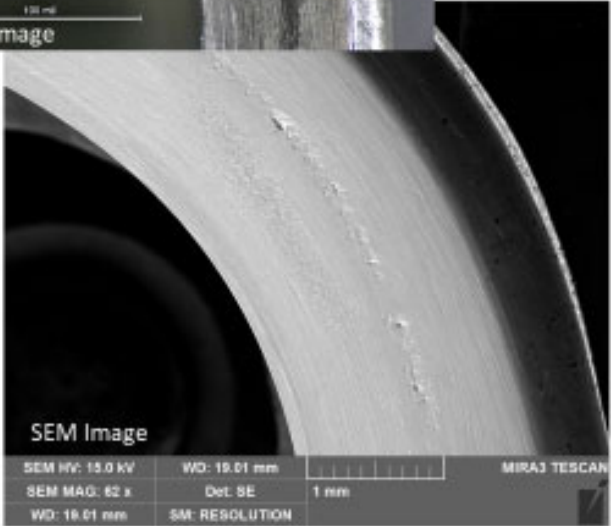


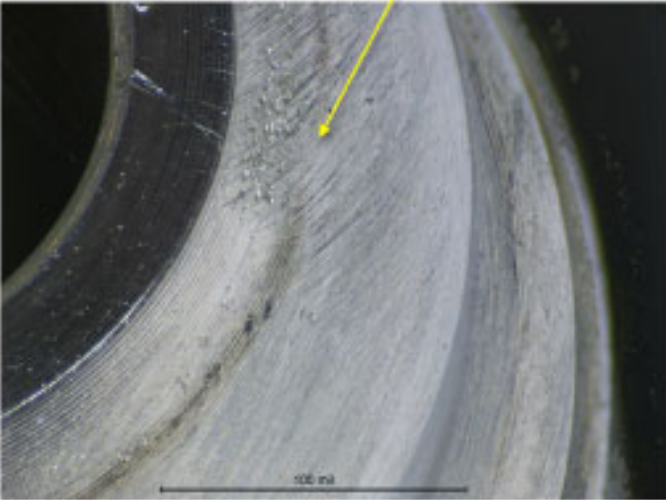
Figure 15: On the ferrule sealing surface of pigtail #16, some surface distress was noted. This is shown here and in the following figures. The location was within the witness mark on the ferrule surface and appeared to be galling with metal loss.



Nozzle #18

Figure 11: At the location where the witness mark (from sealing against the ferrule), scratches were noted that are consistent with benching. This is shown at higher magnification in the following figure.

- Faint/missing witness mark.
- Benching marks (scratches) visible



Nozzle 4, Primary Fuel Nozzle

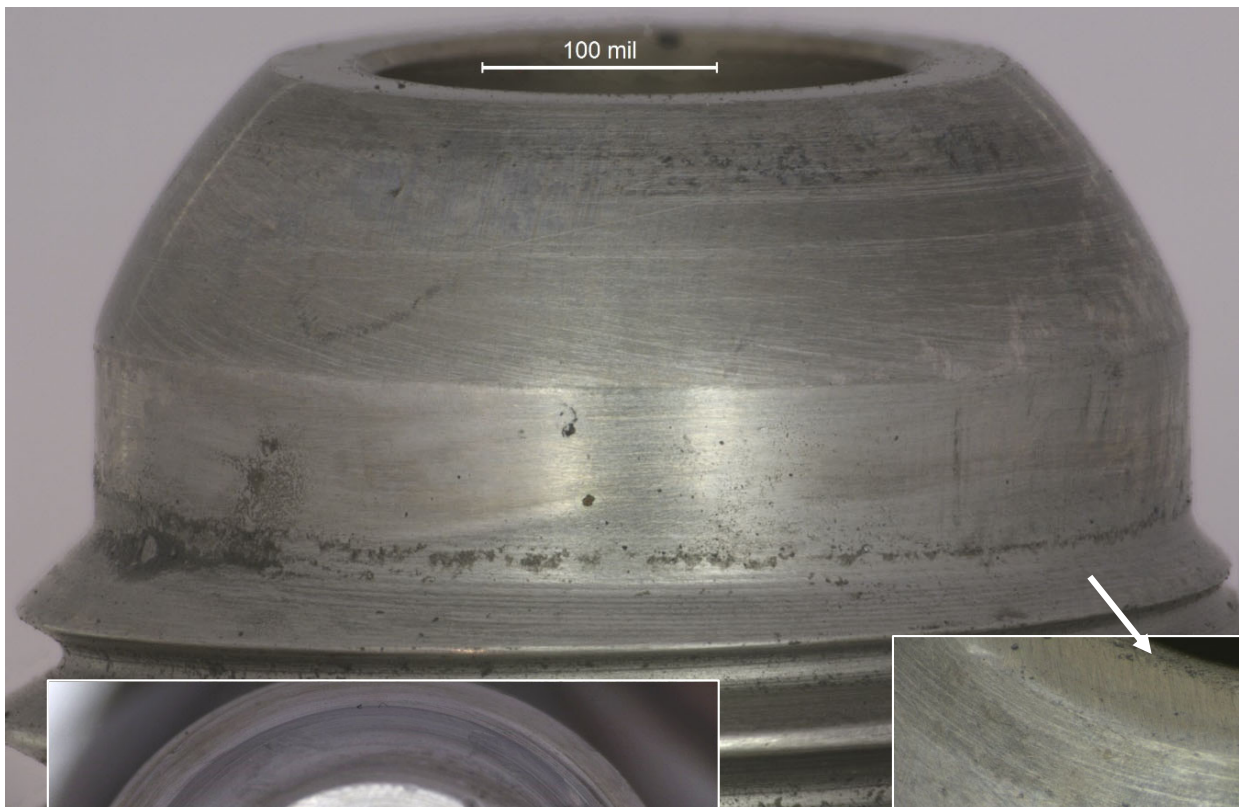
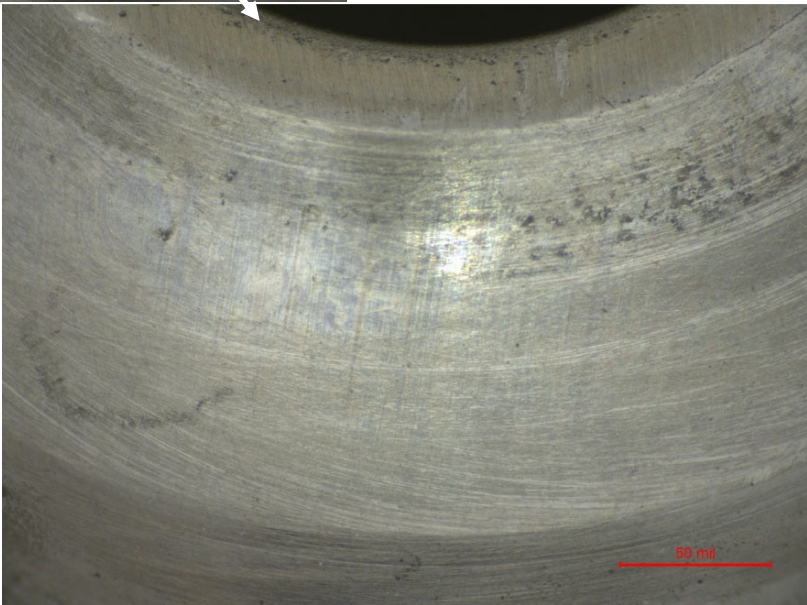
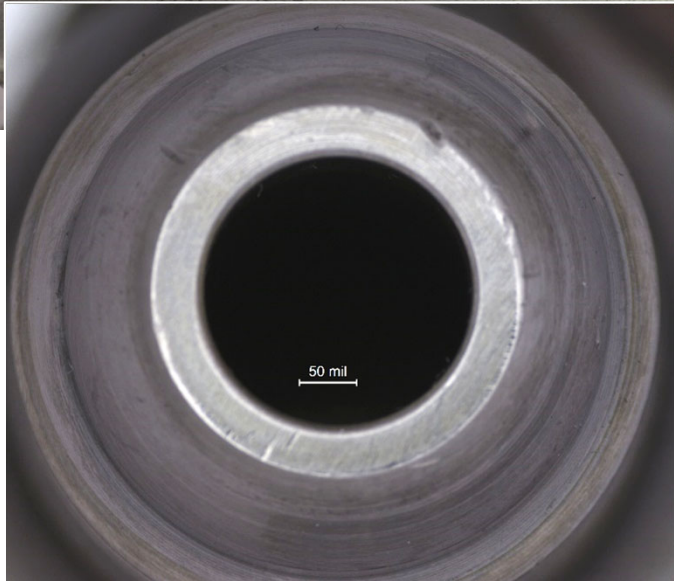
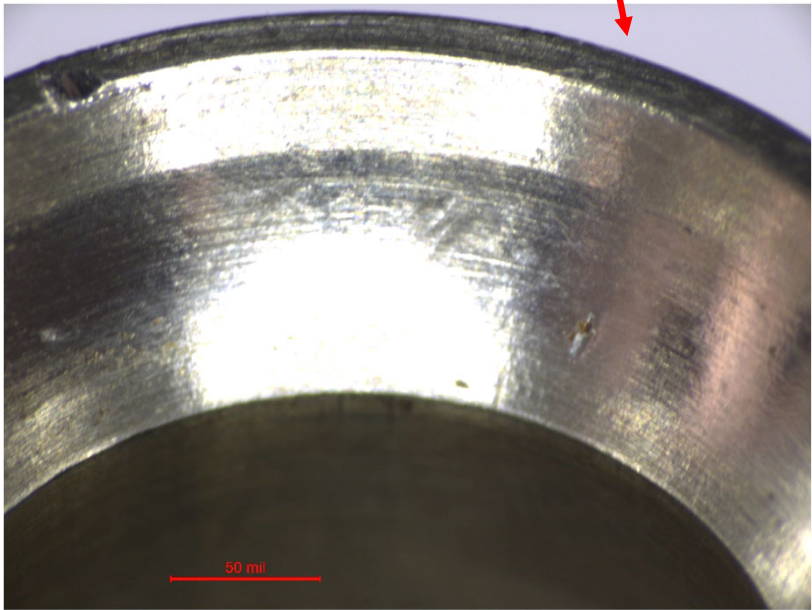
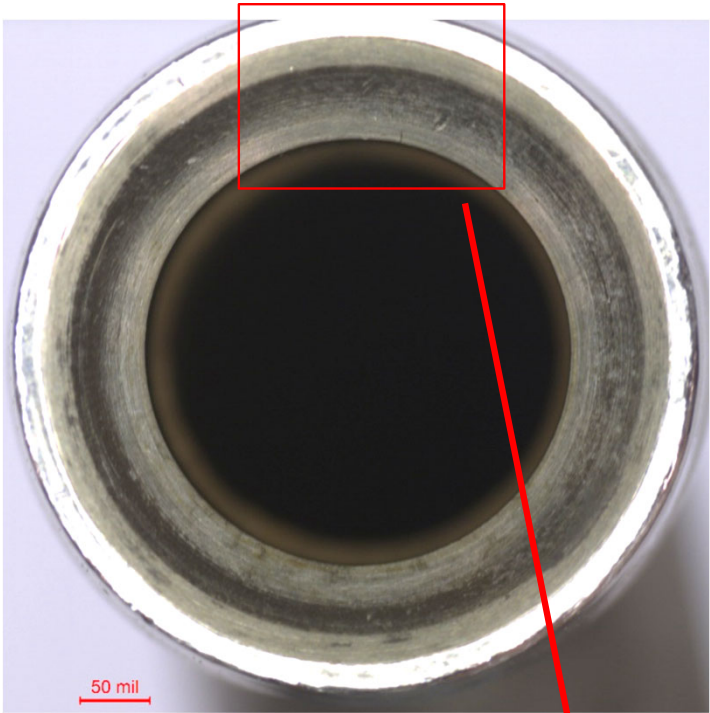


Figure 12: Markings on bullnose of fuel nozzle are centered about the nozzle, inconsistent with the other GE commercial engine investigation (AvEng-536107 and AvEng-536108).



Fuel Manifold Ferrule



Nozzle 4, Secondary Nozzle

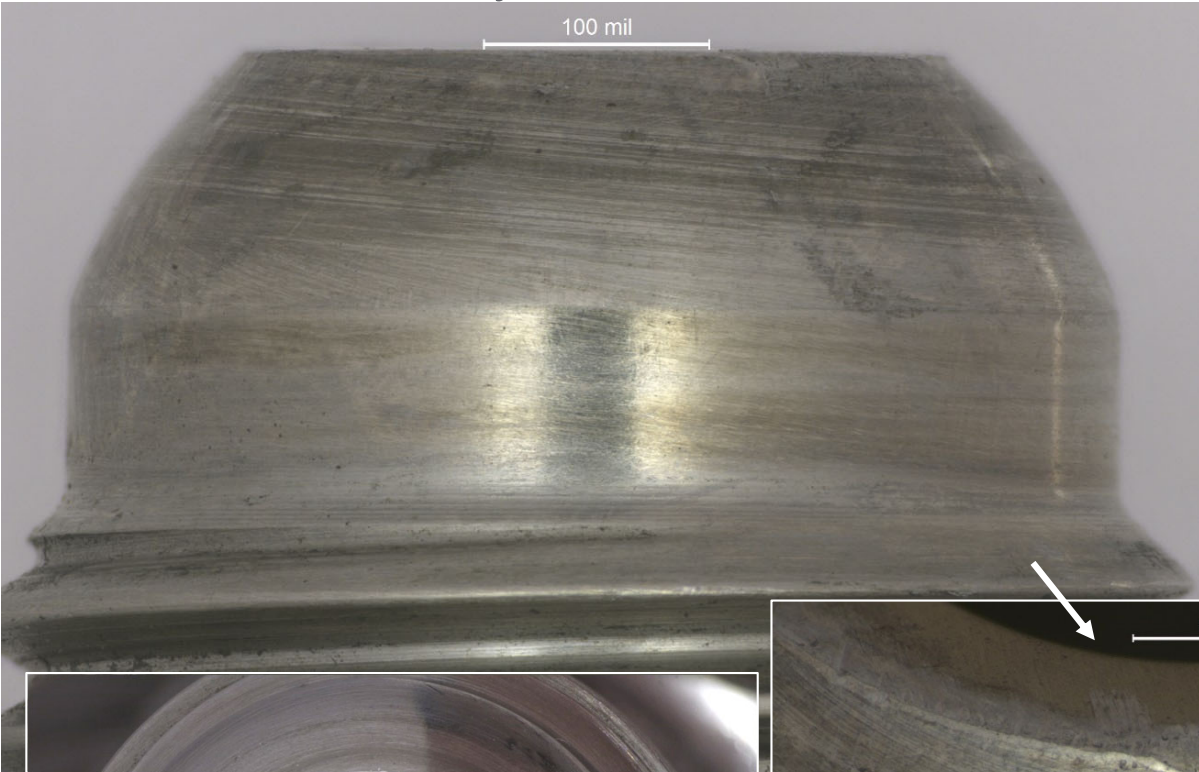
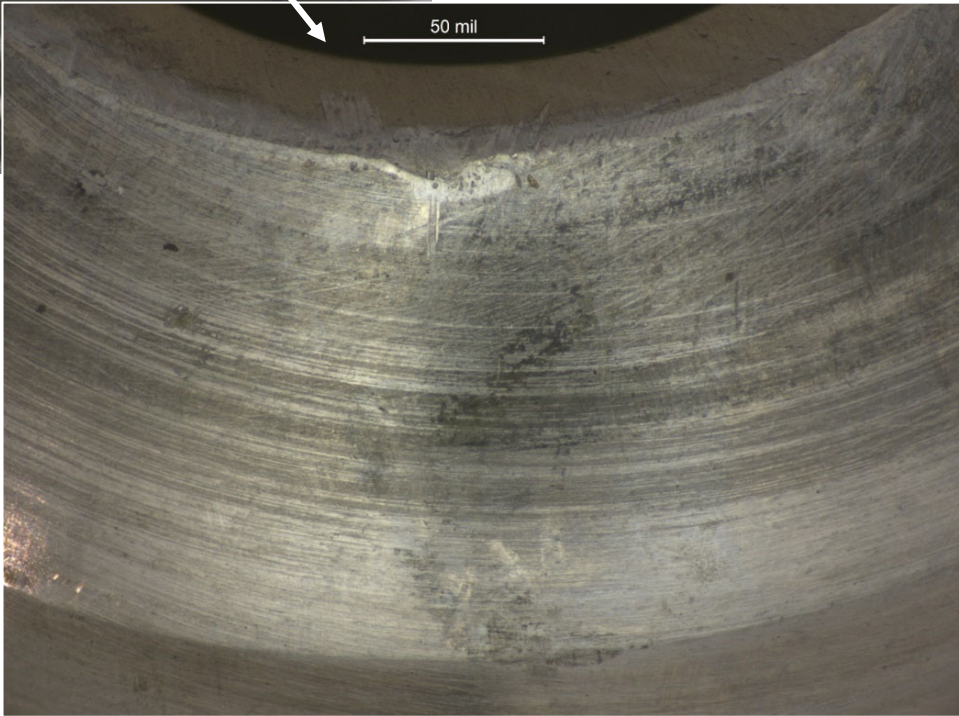
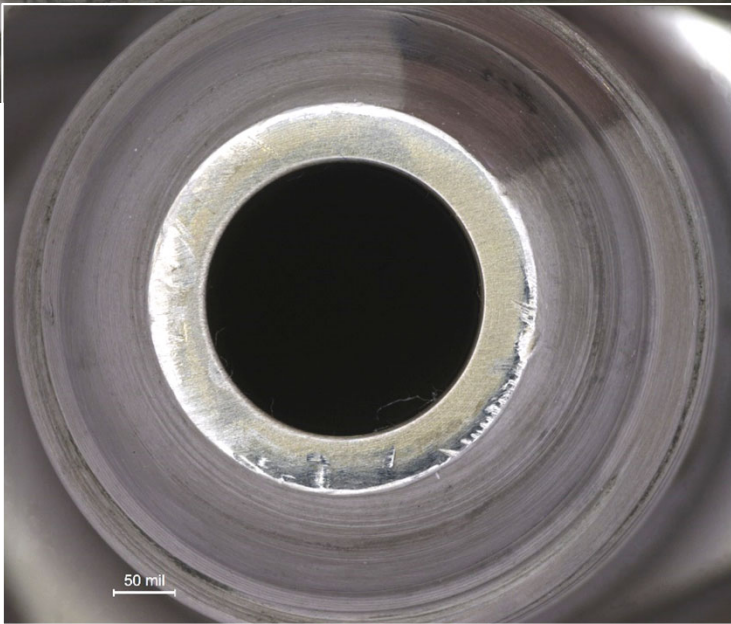
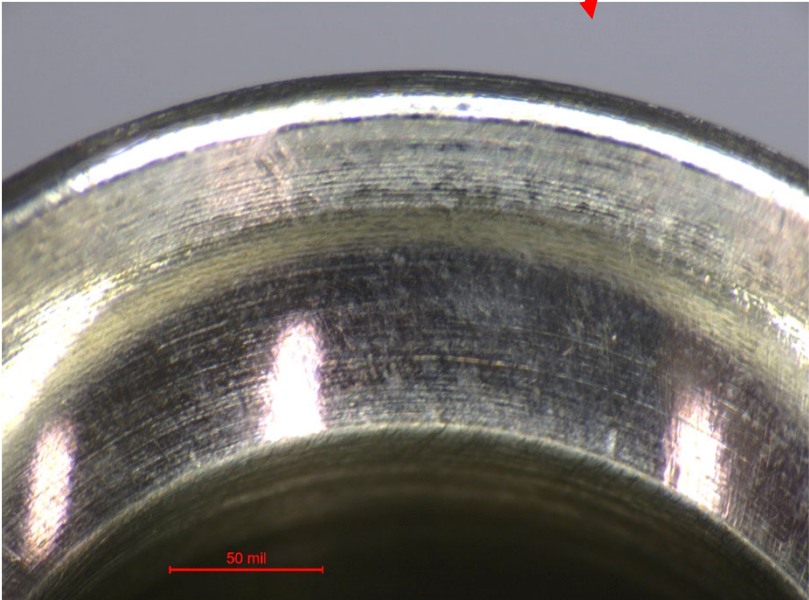
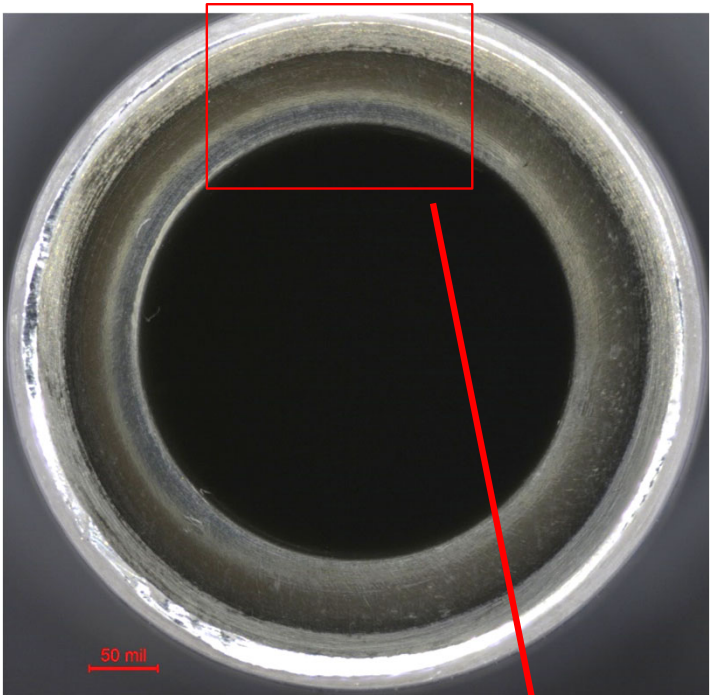


Figure 13: Witness marks are less distinct than in the other GE commercial engine investigation (AvEng-536107 and AvEng-536108), but benching marks were not observed.



Fuel Manifold Ferrule



AvEng-548136.A

Nozzle 16, Primary Nozzle

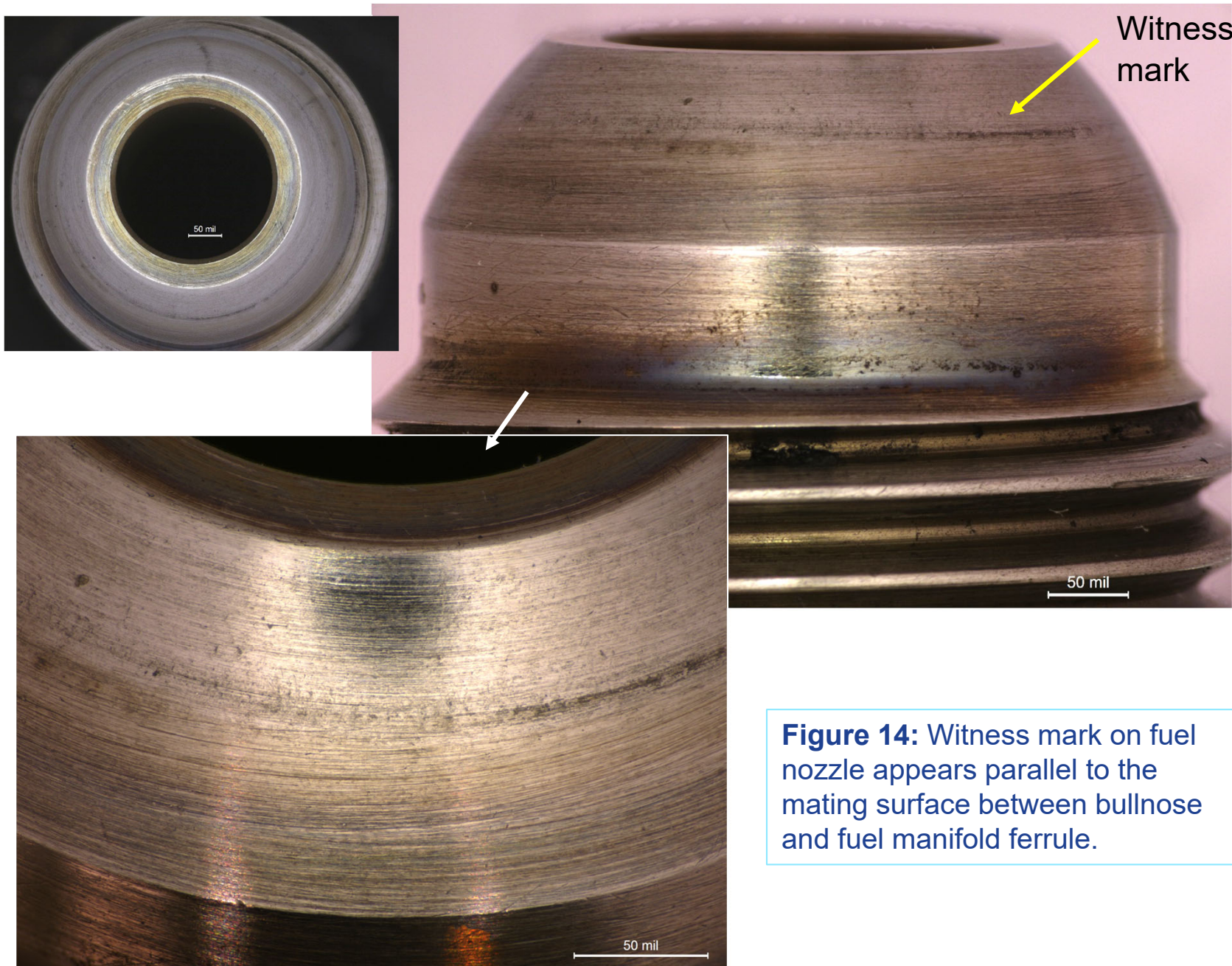
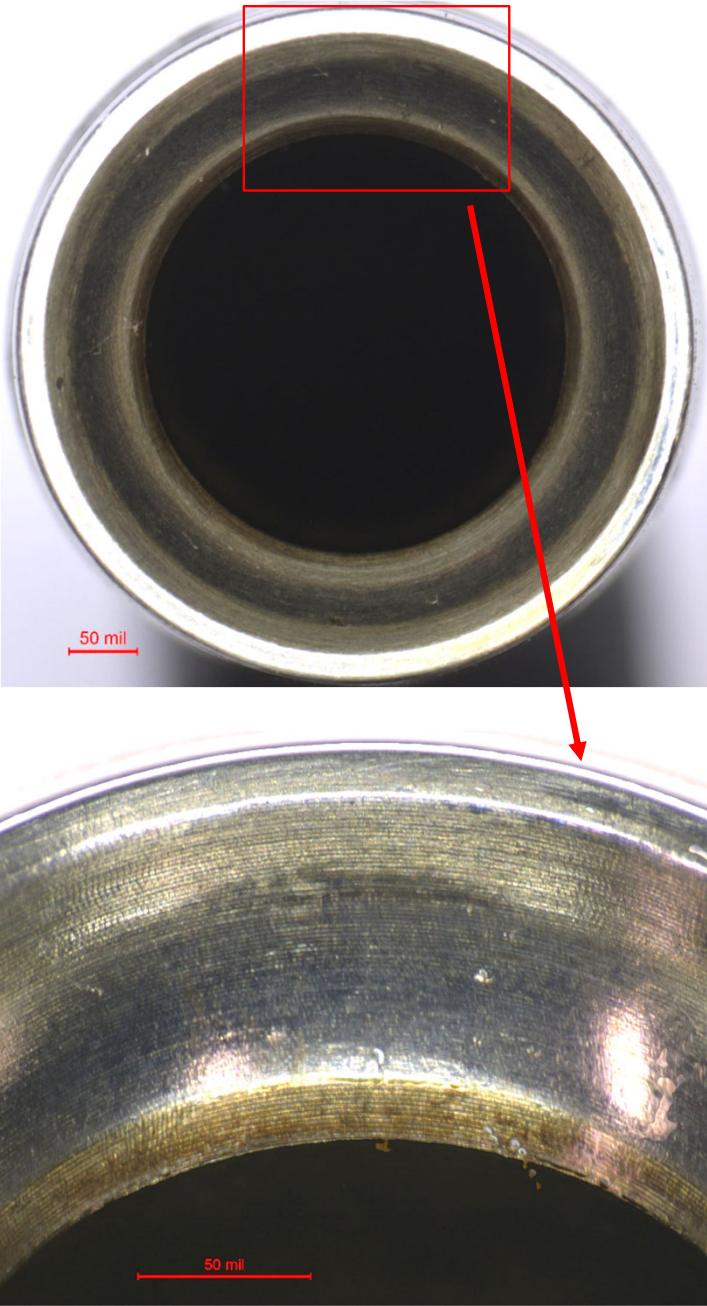


Figure 14: Witness mark on fuel nozzle appears parallel to the mating surface between bullnose and fuel manifold ferrule.

Fuel Manifold Ferrule



Nozzle 16, Secondary Nozzle

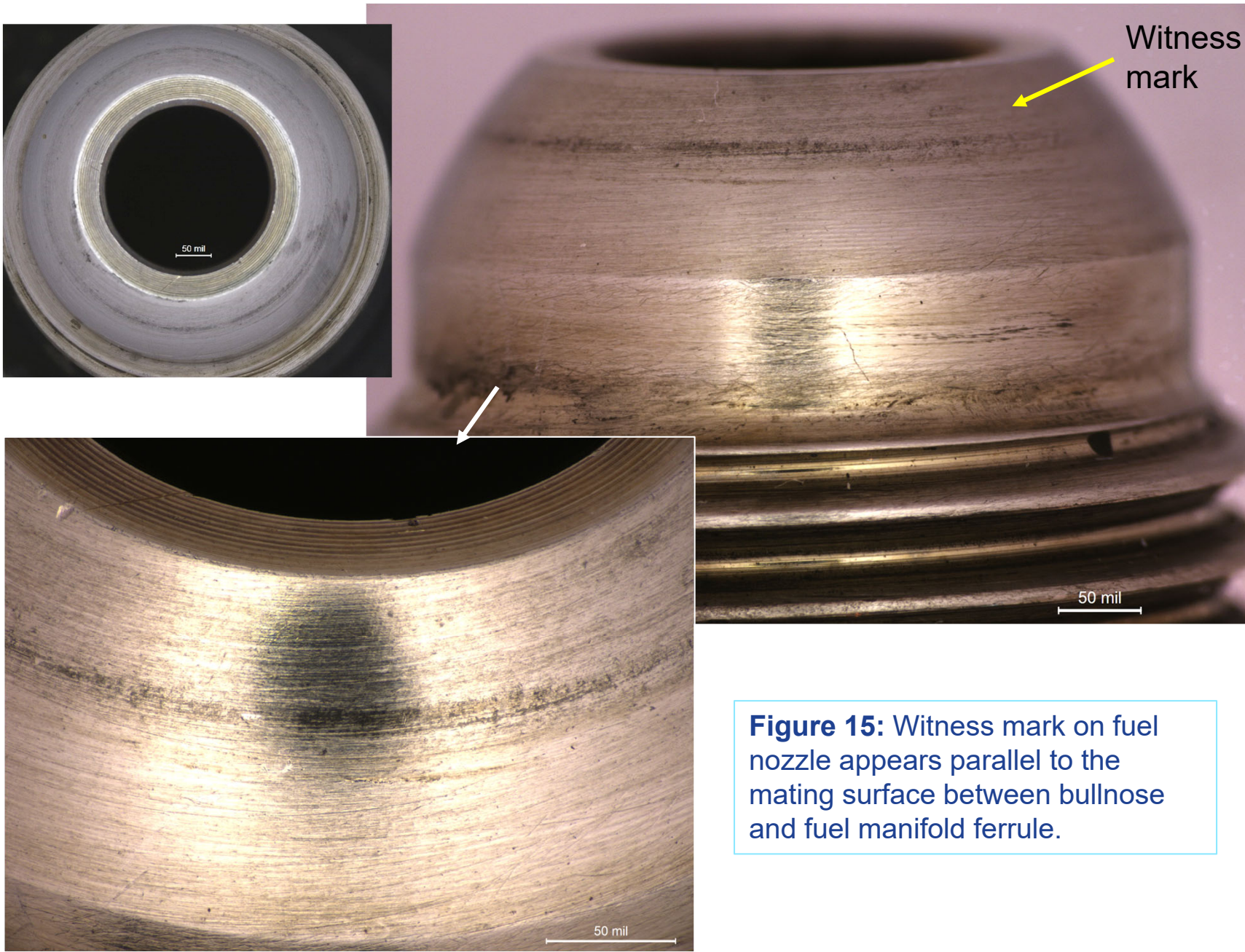
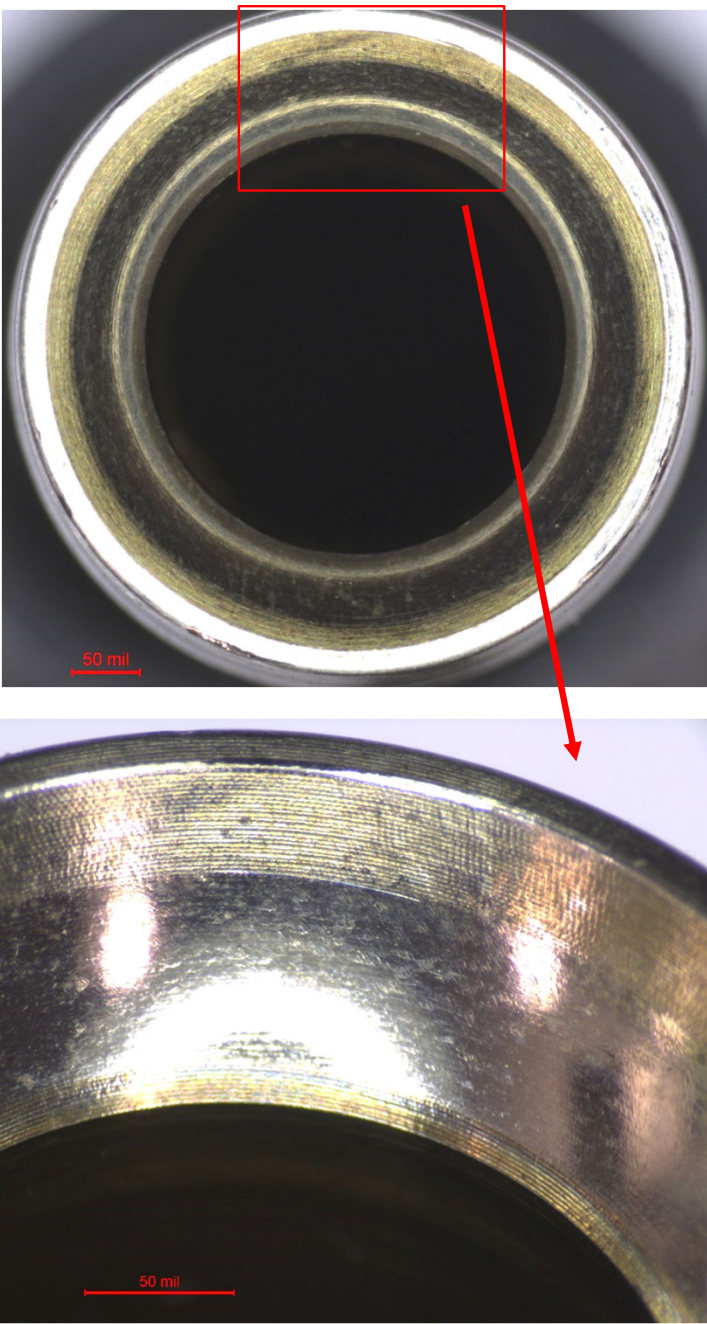


Figure 15: Witness mark on fuel nozzle appears parallel to the mating surface between bullnose and fuel manifold ferrule.

Fuel Manifold Ferrule



Nozzle 17, Primary Nozzle

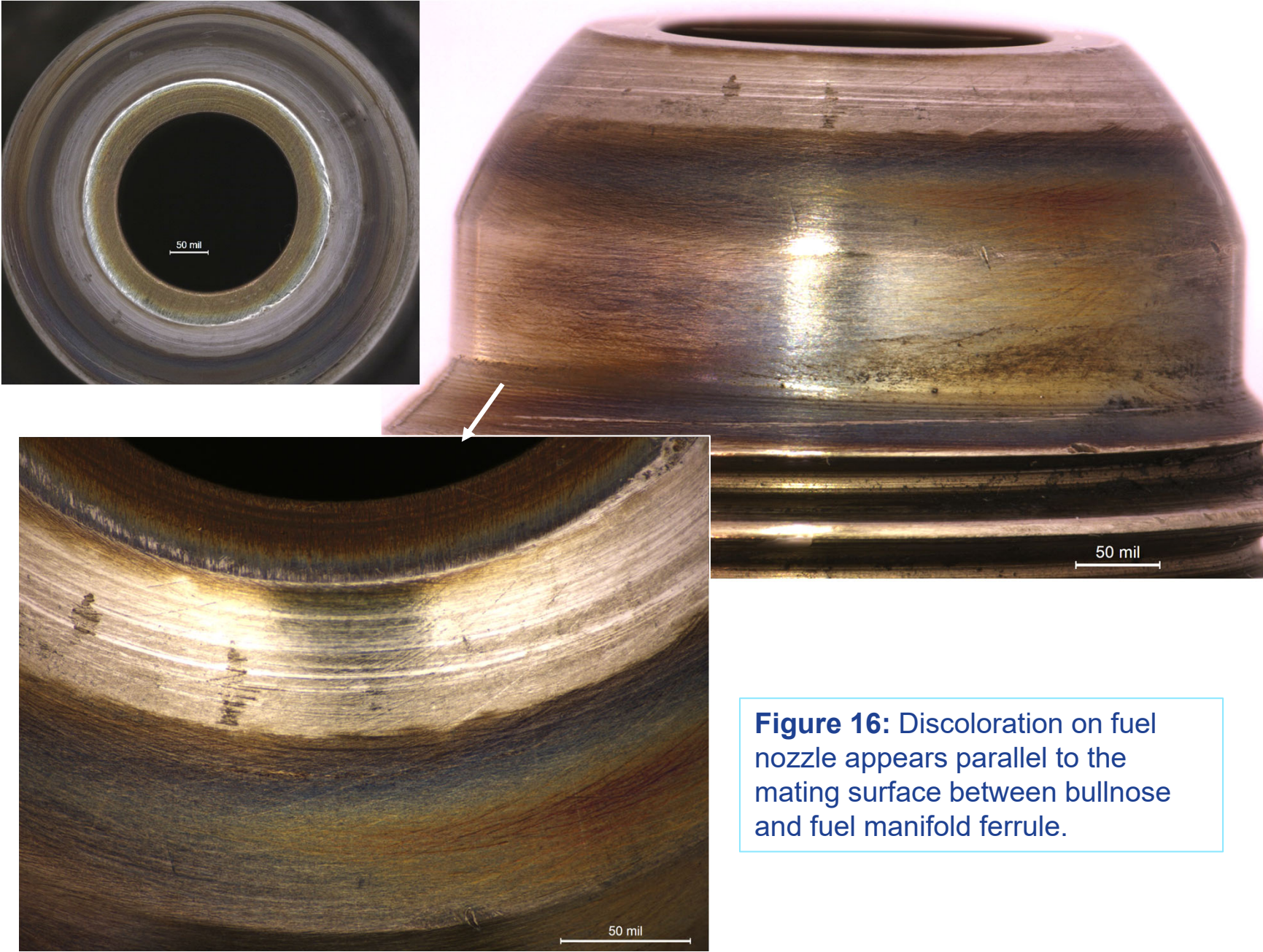
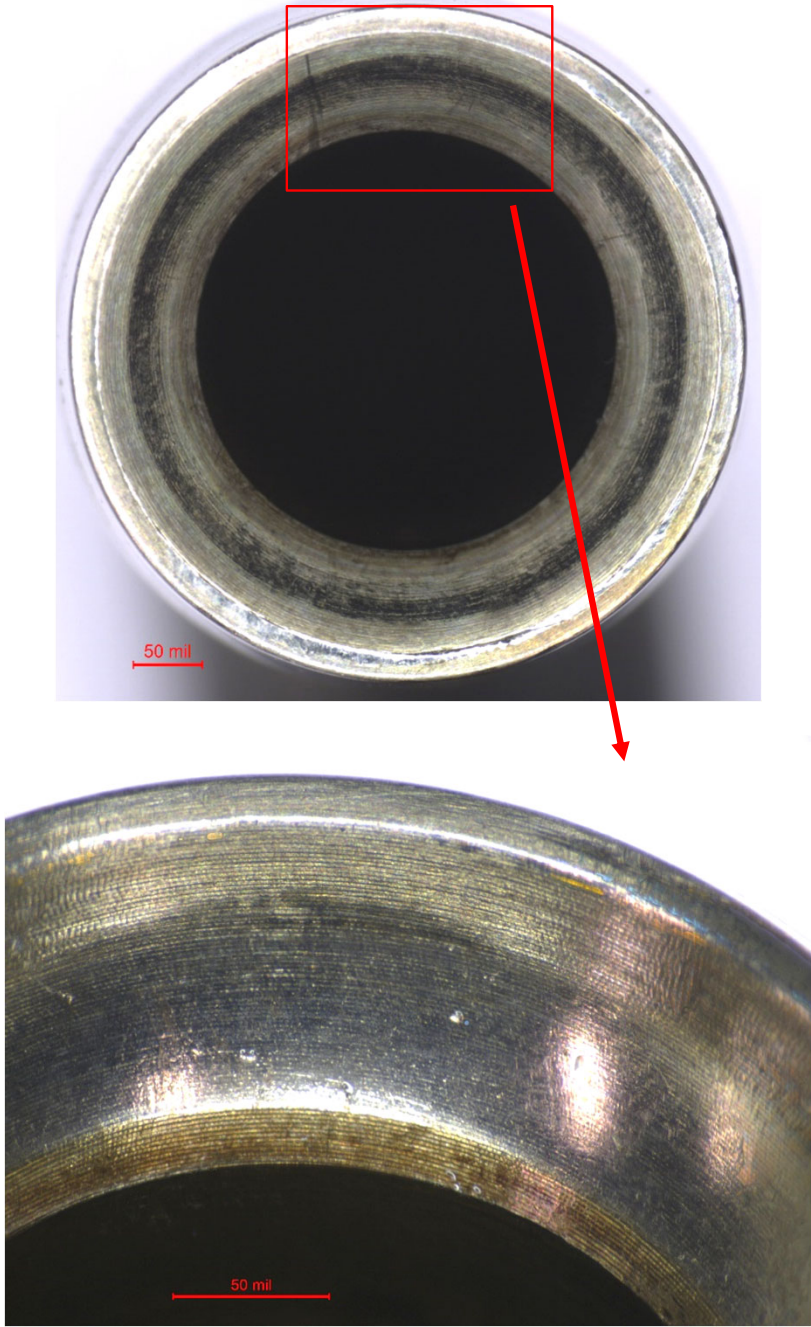


Figure 16: Discoloration on fuel nozzle appears parallel to the mating surface between bullnose and fuel manifold ferrule.

Fuel Manifold Ferrule

Appendix A



Nozzle 17, Secondary Nozzle

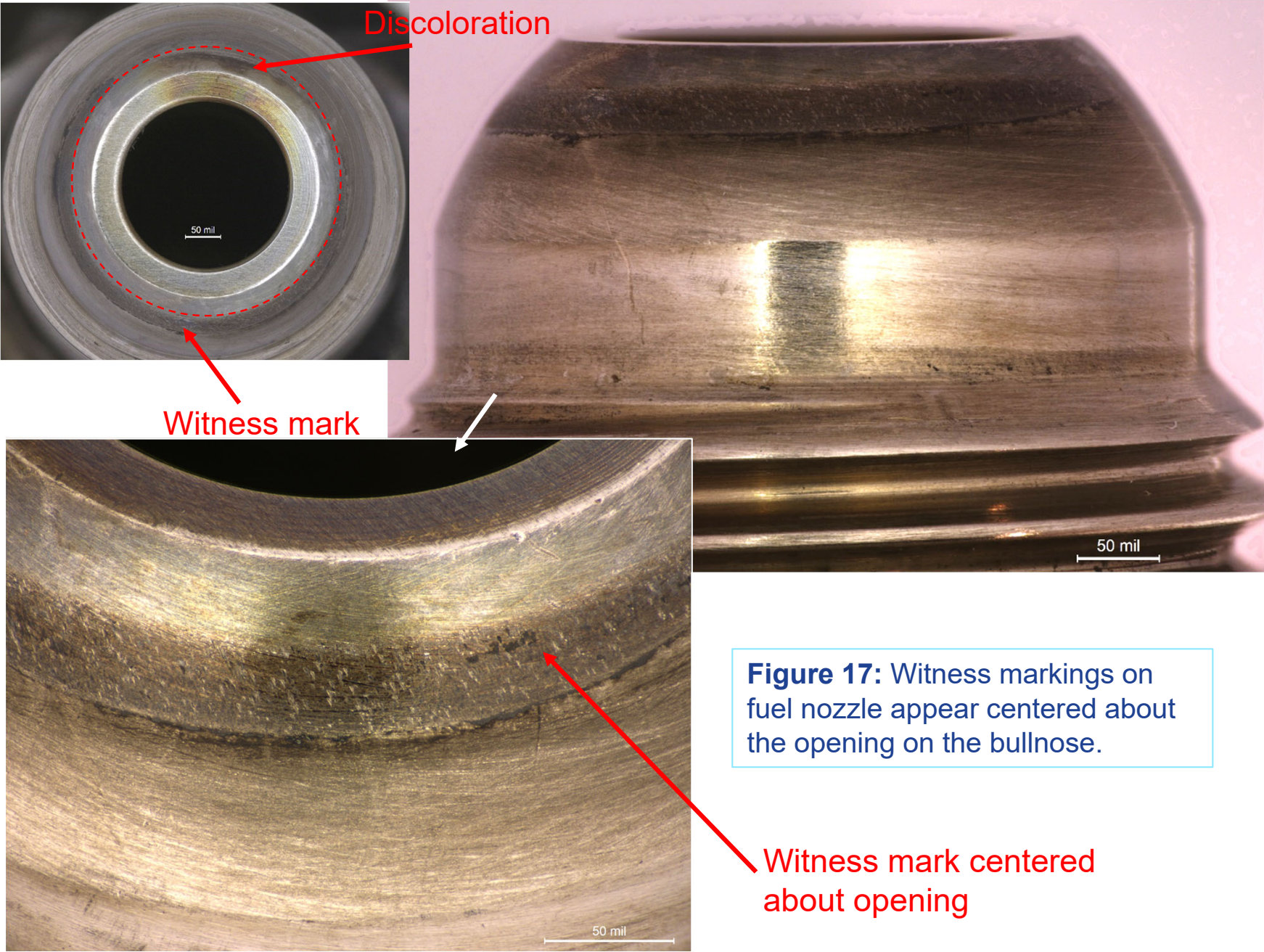


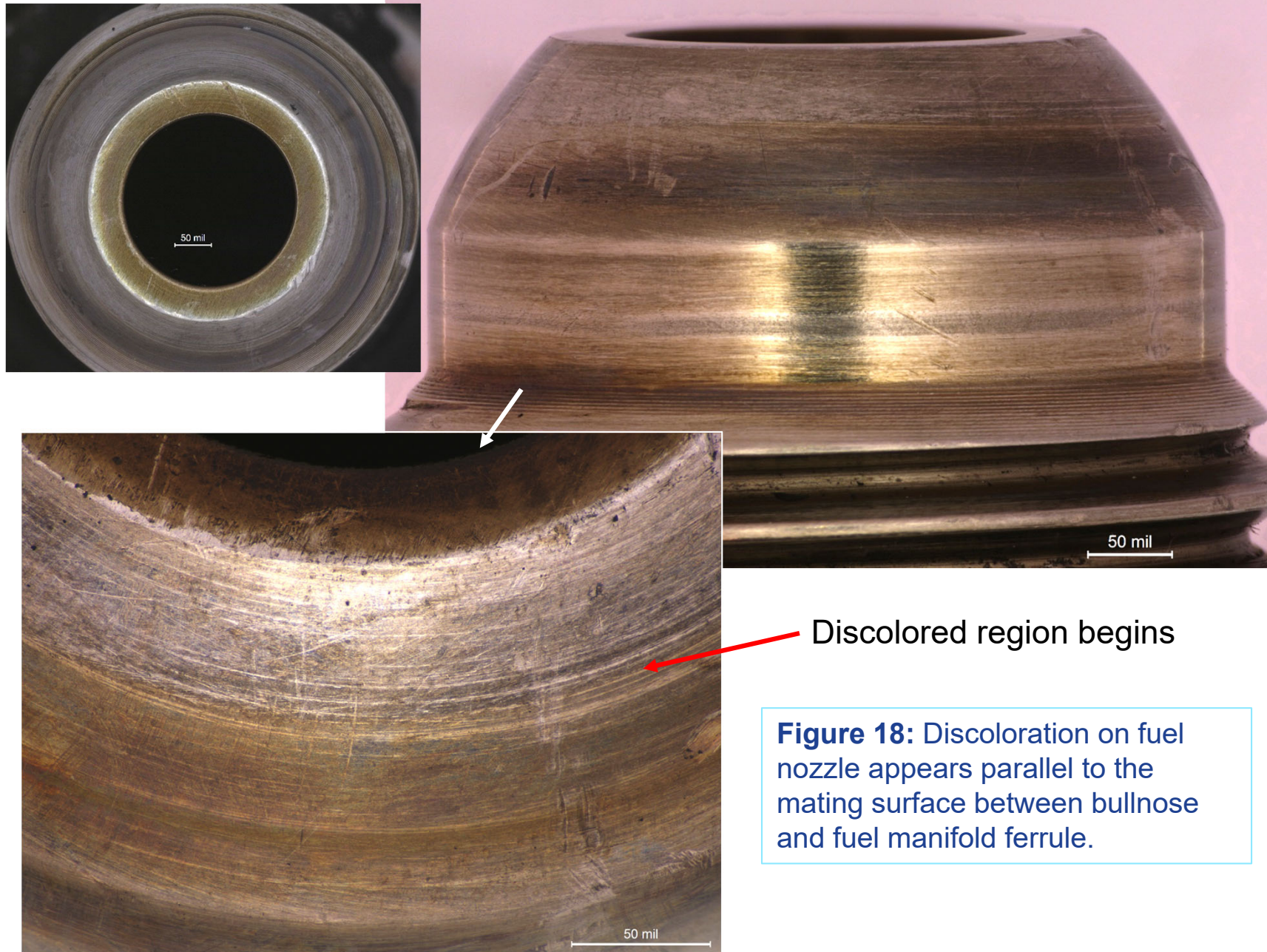
Figure 17: Witness markings on fuel nozzle appear centered about the opening on the bullnose.

Witness mark centered about opening

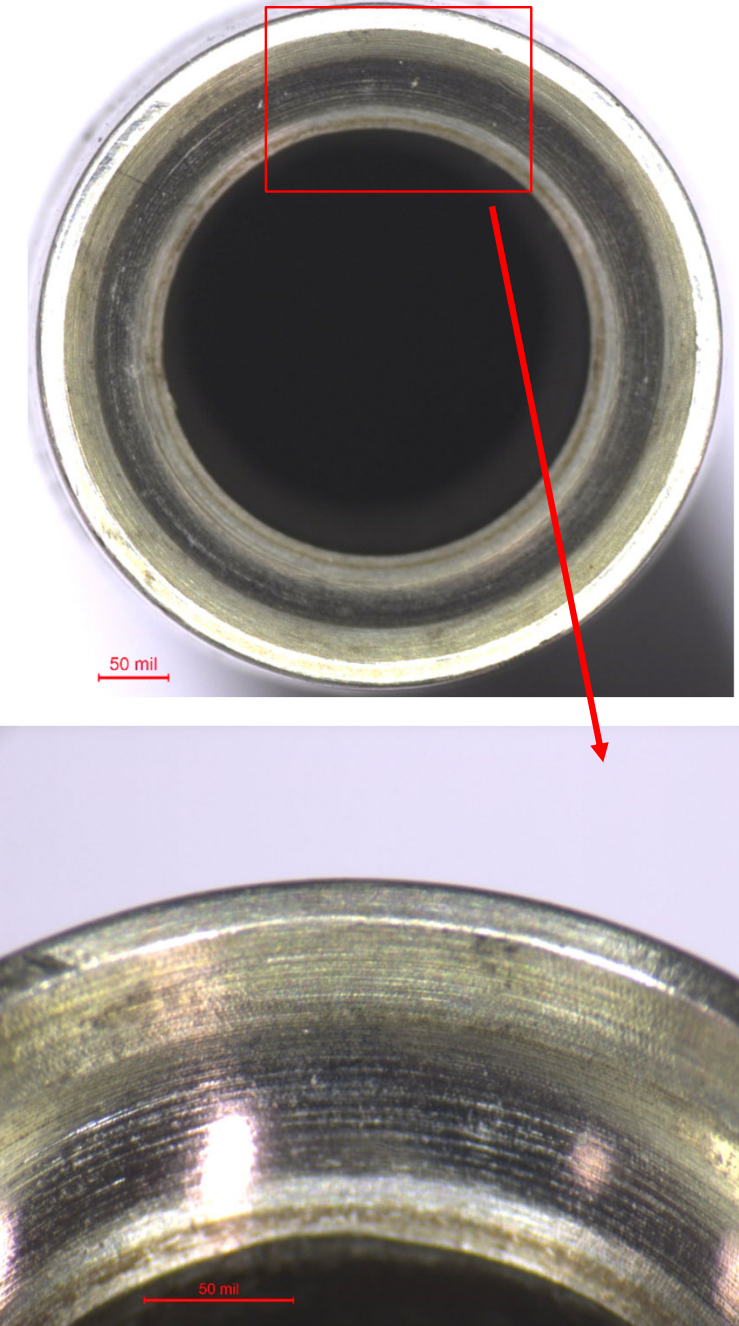
Fuel Manifold Ferrule



Nozzle 18, Primary Nozzle

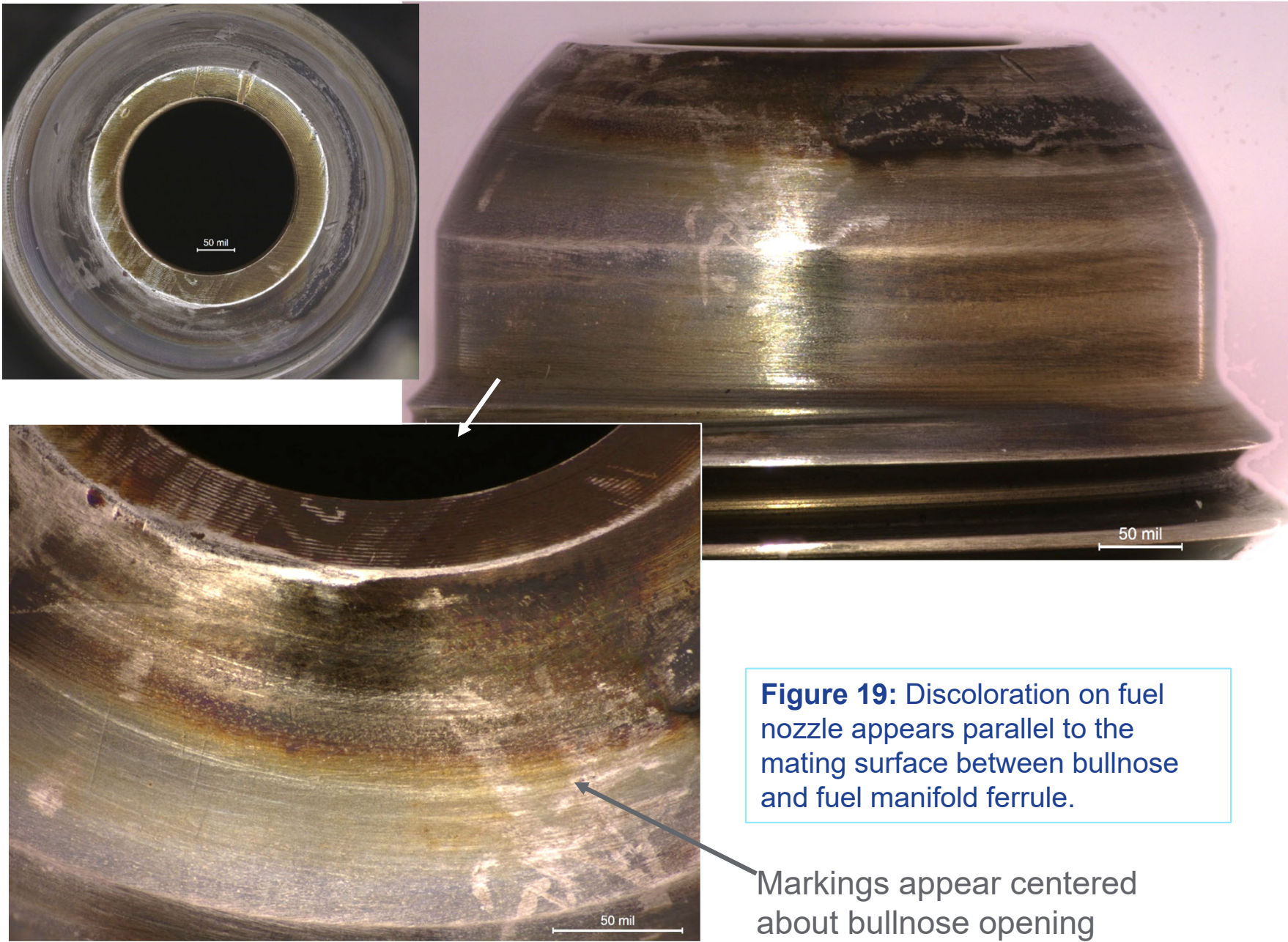


Fuel Manifold Ferrule



AvEng-548136.A

Nozzle 18, Secondary Nozzle

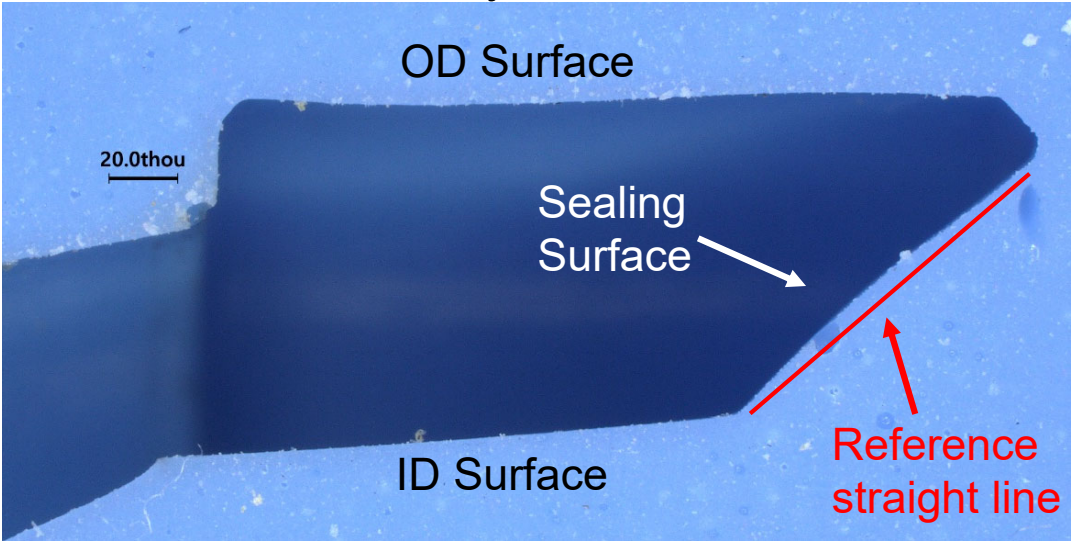


Fuel Manifold Ferrule

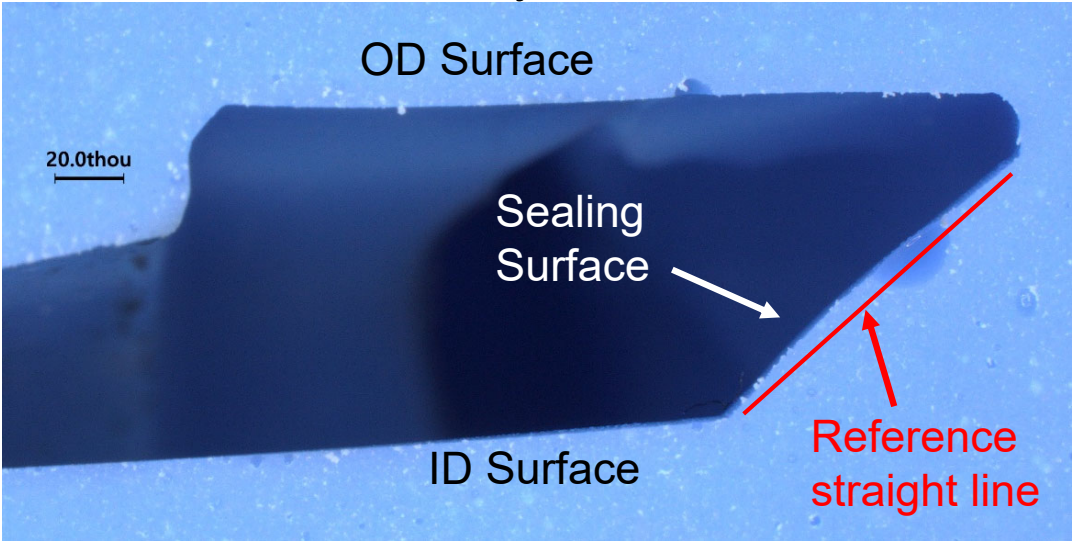


Figure 20: Repo-rubber castings were made of the secondary fuel manifold #4, #16, #17, and #18 ferrules. The sealing surfaces are no longer straight, consistent with plastic deformation from contact with the bullnose of the fuel nozzle during installation. The degree of deformation is greater for ferrules 4, 16, and 18 than 17.

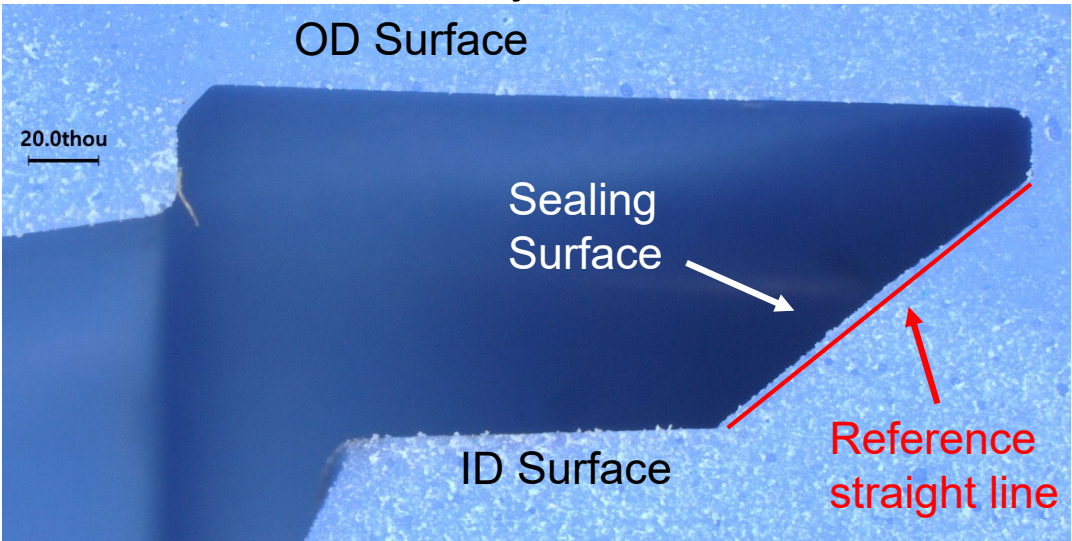
Secondary Ferrule #4



Secondary Ferrule #16



Secondary Ferrule #17



Secondary Ferrule #18

