

Metallurgical Investigation Report

FA Log No. 18712

**METALLURGICAL EVALUATION OF
CFM56-7B STG. 1-2 HPC SPOOL AND
STG. 1 HPC VSV TRUNNION/LEVER
ARM HARDWARE FROM ESN 875-
318 OPERATED BY UNITED AIRLINES**

**P/N 1558M31G04
S/N FGB0864J**

Final Report Date: June 14, 2019

**W. Doug Pridemore
EMS - Metallurgical Investigations**

Export Control: 9E991-NLR



imagination at work



Background Information

Part Name:	Stg. 1-2 HPC Spool
Part Number:	1558M3G04
Part Serial Number:	FGB0864J
Part TSN/CSN:	5233 Hrs / 12,428 Cycles
Part Material:	Ti-17 (Beta Processed)
Part Material Specification:	C50TF20 CL-A or CL-B
Part Name:	Stg. 1 HPC Vane
Part Number:	P241P04
Part Material:	A286
Part Material Specification:	AMS 5737
Aircraft Model:	B737-924
Tail Number:	N30401
Engine Type:	CFM56-7B26
Engine Serial Number:	875-318
Operator:	United Airlines (UAL)
Occurrence Consequence:	IFSD
Occurrence Date:	February 21, 2019
Engine TSN/CSN:	59,395 Hrs / 21,364 Cycles
Engine TSLO/CSLO:	12,428 Hrs / 5233 Cycles
MAE:	J. Charles / P. Radowski
Design Engineer:	B. Hous
Date Assigned	March 4, 2019
FA Log No.:	FA18712
FA Report Author:	W. Doug Pridemore

Distribution

K. Wolski
R. Hous
J. Charles
P. Radowski
Author (1)

Summary Information

Initiation Site:	Stg. 2 Disk Post
Initiation Mode:	Fatigue
Propagation Mode:	Fatigue
Discrepancy:	AOC
Date Completed	June 14, 2019

Introduction:

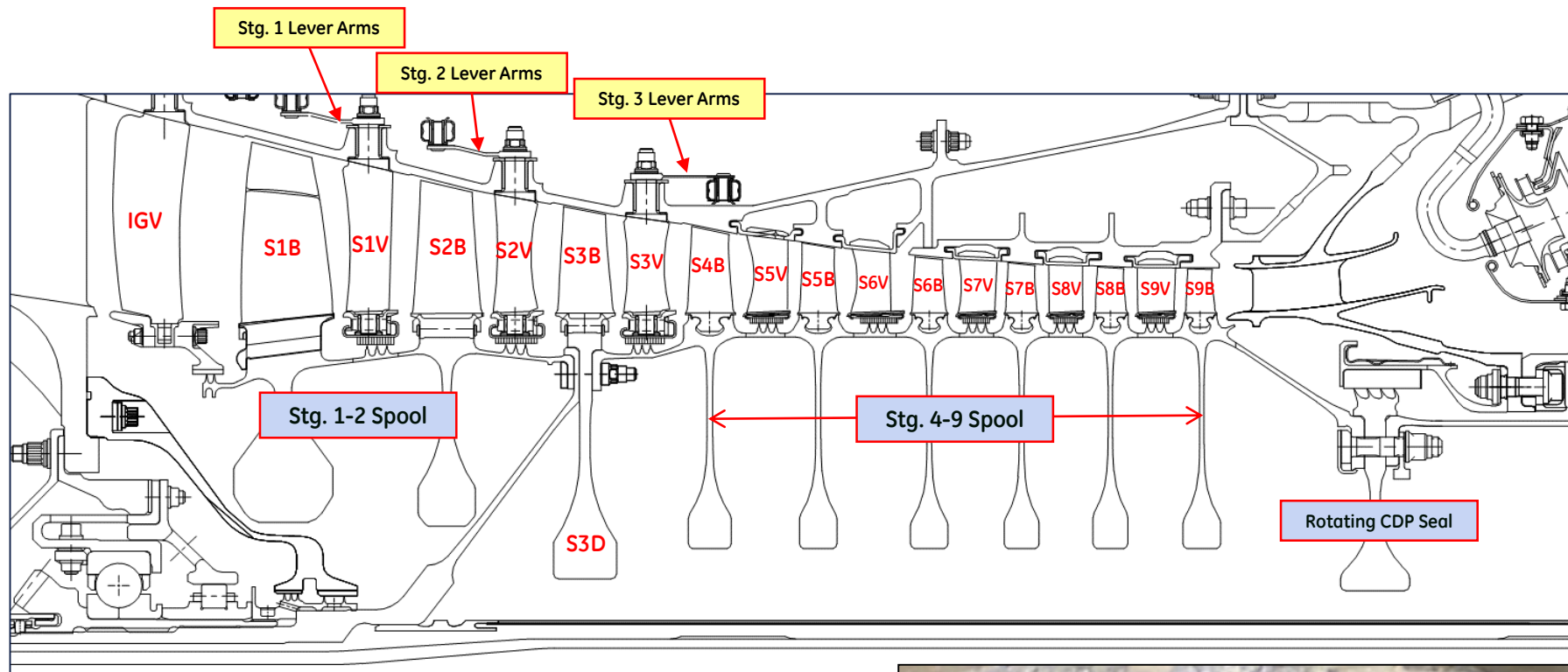
On February 21, 2019, a Boeing 737-924 aircraft operated by United Airlines (UAL) sustained a No. 2 engine event during climb from Orlando International Airport (MCO) at altitude of ~7000 feet. The flight crew reported a “shudder” followed by loss of power and uncommanded shutdown of CFM56-7B26 ESN 875-318. Aircraft completed an air turnback (ATB) making an overweight, uneventful single engine landing. Initial inspection by MCO ground maintenance personnel reported a visually evident high pressure compressor (HPC) case burn through with no noticeable damage to the engine cowling or aircraft structure. Stage 2 HPC Vanes were found outside of the case as well as lodged in the VBV (Variable Bleed Valve) system. It was later determined ~60% of the HPC forward case exhibited a burn through in the radial plane of Stg. 1 HPC Blades with intact case material located only at the thicker VSV (Variable Stator Vane) rub button pads.

The engine was disassembled at GE-Aviation, Evendale, OH from February 26-March 2 in the presence of associates from United Airlines, CFM International, Boeing, Federal Aviation Administration (FAA), GE-Aviation and National Transportation Safety Board (NTSB). Metallurgical work was conducted at GE-Evendale.

According to UAL records, ESN 875-381 had accumulated the following hours and cycles (see below), with the last shop visit for ESN 875-318 occurred in July 2014 at GE-Celma, Petropolis, Brazil. During the last shop visit 22 out of the 82 Stg. 1 HPC VSV's were replaced with the remainder being overhauled. Installation positions between the replaced and overhauled VSV's were not recorded.

Engine Position	Engine Serial Number	Time Since New (Hrs)	Cycles Since New	Time Since Last Overhaul (TSLO)	Cycles Since Last Overhaul (CSLO)
Right / No. 2	875-318	59,395	21,364	12,428	5233

CFM56-7B Compressor Cross-Section



Flowpath Thermal Distress

- Stator vane loss and molten metal adhering to interior surface of stator case.
- All remaining HPC blade airfoils showed evidence of thermal or mechanical distress.



Table I – Stg. 1 HPC Blades

Stg 1. Blade #	Weight (gms)	Cracked Dovetail	Part Number	Lot No.
1	69.22	No	P331P03	DCCP034
2	68.91	No	P331P03	DCCP069
3	69.7	No	P331P03	CGEN500
4	69.12	No	P331P03	CGEN500
5	69.5	No	P331P03	CGEN500
6	68.78	No	P331P03	CGEN500
7	69.12	No	P331P03	DCCP069
8	68.58	No	P331P03	CGEN511
9	68.45	No	P331P03	DCCP034
10	68.61	No	P331P03	CGEN511
11	68.26	No	P331P03	CGEN500
12	68.18	No	P331P03	DCCP069
13	68.62	No	P331P03	DCCP034
14	68.59	No	P331P03	CGEN511
15	69.3	No	P331P03	DCCP069
16	68.24	No	P331P03	DCCP034
17	67.94	No	P331P03	DCCP034
18	69.12	No	P331P03	CGEN511
19	68.13	No	P331P03	DCCP069
20	69.73	No	P331P03	DCCP069
21	69.34	No	P331P03	DCCP069
22	69.58	No	P331P03	DCCP069
23	70.13	No	P331P03	DCCP069
24	70.19	No	P331P03	DCCP069
25	70.11	No	P331P03	CGEN511
26	69.83	No	P331P03	CGEN500
27	70.65	No	P331P03	DCCP069
28	70.03	No	P331P03	CGEN500
29	69.56	No	P331P03	CGEN500
30	69.79	No	P331P03	DCCP069
31	69.2	No	P331P03	CGEN500
32	70.13	No	P331P03	DCCP069
33	70.41	No	P331P03	CGEM564
34	70.63	No	P331P03	DCCP034
35	70.88	No	P331P03	CGEN498
36	70.19	No	P331P03	DCCP034
37	70.19	No	P331P03	DCCP034
38	70.07	No	P331P03	DCCP069
Total wt.	2637.01			

CFM56-7B - Stg. 1 HPC Blades - ESN 875-318

- Weights and Part Markings Observed on Stg. 1 HPC Blade Remnants
- No Evidence of Dovetail Cracking Noted During Binocular Examination Following Toothbrush Scrubbing
- In General, More Severe Coating Distress Observed on CVX Airfoil Side Pressure Face Compared to CCV Side Pressure Face

Table II – Stg. 2 HPC Blades

Stg 2. Blade #	Weight (gms)	Cracked Dovetail	Part Number	Additional Markings	Coating Present (Both Sides)	Bottom Dovetail Shearing
1	0	Missing	Missing	Missing	Missing	Missing
2	25.09	No	P332P03	DCCF886	Damaged	Yes - Minimal
3	0	Missing	Missing	Missing	Missing	Missing
4	34.93	No	P332P03	DCCF886	Yes	No
5	0	Missing	Missing	Missing	Missing	Missing
6	0	Missing	Missing	Missing	Missing	Missing
7	0	Missing	Missing	Missing	Missing	Missing
8	26.84	No	P332P03	DCCF886	Yes	No
9	26.79	No	P332P04 P332P03	CGE1864 9664 G0	Yes	Yes
10	26.86	No	P332P04 P332P03	CGE1845 RP11 9665 G0	Yes	Yes
11	26.63	No	P332P03	DCCF883	Yes	Yes
12	26.67	No	P332P03	DCCF886	Yes	Yes
13	26.56	No	P332P04 P332P03	CGE1864 9966 G0	Yes	No
14	26.74	No	P332P03	DCCF883	Yes	No
15	26.51	No	P332P03	DCCF886	Yes	No
16	26.69	No	P332P03	DCCF883	Yes	No
17	26.72	No	P332P03	DCCF886	Yes	No
18	26.43	No	P332P03	DCCF883	Yes	No
19	27.07	No	P332P03	DCCF886	Yes	No
20	26.68	No	P332P03	DCCF886	Yes	Yes
21	26.14	No	P332P03	DCCF886	Yes	Yes
22	26.44	No	P332P03	DCCF886	Yes	No
23	26.38	No	P332P03	DCCF886	Yes	No
24	26.57	No	P332P03	DCCF886	Yes	No
25	27.08	No	P332P03	DCCF886	Yes	No
26	26.96	No	P332P03	DCCF883	Yes	No
27	27	No	P332P03	DCCF886	Yes	No
28	26.57	No	P332P03	DCCF779	Yes	No
29	26.97	No	P332P03	DCCF886	Yes	No
30	26.35	No	P332P04 P332P03	CGE1818 9664 G0	Yes	No
31	26.66	No	P332P03	DCCF886	Yes	No
32	26.22	No	P332P04 P332P03	CGE1818 RP11 9665 G0	Yes	No
33	26.34	No	P332P03	DCCF886	Yes	No
34	0	Missing	Missing	Missing	Missing	Missing
35	27.02	No	P332P03	DCCF886	Yes	No
36	26.9	No	P332P04 P332P03	CGE1864 9666 G0	Yes	Yes
37	26.78	No	P332P03	DCCF886	Yes	No
38	26.81	No	P332P03	DCCF883	Yes	Yes
39	26.25	No	P332P03	DCCF883	Yes	No
40	0	Missing	Missing	Missing	Missing	Missing
41	26.63	No	P332P03	DCCF886	Yes	Yes
42	26.94	No	P332P03	DCCF883	Yes	No
43	26.82	No	P332P03	DCCF886	Yes	Yes
44	27.27	No	P332P03	DCCF883	Yes	Yes
45	27.2	No	P332P03	CGEF534	Yes	Yes
46	26.9	No	P332P03	DCCF886	Yes	Yes
47	27.11	No	P332P03	DCCF886	Yes	Yes
48	26.68	No	P332P03	DCCF883	Yes	No
49	26.44	No	P332P03	DCCF886	Yes	Yes
50	26.4	No	P332P03	DCCF886	Yes	No
51	25.63	No	P332P03	DCCF886	Yes	No
52	25.63	No	P332P03	DCCF886	Yes	No
53	0	Missing	Missing	Missing	Missing	Missing
Total wt.	1206.3					

CFM56-7B - Stg. 2 HPC Blades - ESN 875-318

- Weights and Part Markings Observed on Stg. 1 HPC Blade Remnants
- No Evidence of Dovetail Cracking Noted on Remaining Blades During Binocular Examination Following Toothbrush Scrubbing

Table III – Stg. 2 Disk Posts

Stg. 2 Disk Post	Crack Location (Visual) Corner #	Comment
1	1	Missing Some Post Material
2	3	Missing Some Post Material
3	None Observed	
4	2,3	Missing Some Post Material
5	1,3,4	Missing Some Post Material
6	2,3,4	Missing Some Post Material
7	4	Missing Some Post Material
8	3	Crack Through Post Top
9	1	
10	1	
11	1,3	Crack Through Post Top
12	None Observed	
13	None Observed	
14	None Observed	
15	None Observed	
16	None Observed	
17	None Observed	
18	None Observed	
19	None Observed	
20	1	
21	1	Crack Through Post Top
22	None Observed	
23	None Observed	
24	None Observed	
25	None Observed	
26	None Observed	
27	None Observed	
28	None Observed	
29	3	Crack Through Post Top
30	1	
31	None Observed	
32	None Observed	
33	2,3	Missing Some Post Material
34	None Observed	
35	3	Crack Through Post Top
36	1	
37	3	Crack Through Post Top
38	None Observed	
39	2	Missing Some Post Material
40	1	Missing Some Post Material
41	1	
42	None Observed	
43	1	Crack Through Post Top
44	1,3	Crack Through Post Top
45	1	
46	1	
47	1	Crack Through Post Top
48	None Observed	
49	1	Crack Through Post Top
50	None Observed	
51	None Observed	
52	None Observed	
53	1,2	Missing Some Post Material

CFM56-7B - Stg. 2 HPC Disk Posts - ESN 875-318

- 1-2 HPC Spool Stg. 2 Disk Post Cracking (Visual Observations) – 28/53 Posts Exhibited Visually Evident Cracking in Pressure Face Region

Visual Observations:

Various views of the Compressor Inlet from CFM56-7B ESN 875-318 showing numerous missing IGV's along with molten metal splatter on the HPC Case ID are shown in Figures 1, 2 and 3. Remaining airfoil portions of the titanium based Stg. 1 HPC Blades exhibited a "tombstone" shape consistent with airfoil burning. Photographs documenting the condition of the HPC Case halves at the 12:00, 6:00, 9:00 and 3:00 positions prior to removal of actuation hardware are shown in Figures 4, 5, 6 and 7, respectively. HPC Case burn through occurred in the radial plane of the Stg.1 HPC Blades with additional melting of lever arms and actuation ring hardware. The HPC Case is manufactured from iron-based M152 material which possesses a melting point of ~2700°F. Continued examination revealed one (1) Stg. 1 VSV trunnion missing both the retaining nut and washer located at position #33. Closer views of Stg. 1 VSV trunnion location #33 and adjacent Stg. 1 IGV trunnion locations #32 and #34 are shown in Figures 8 and 9. The lever arm for trunnion #33 was found disengaged with the trunnion D-head feature. In its current state, the alignment mark on the top of trunnion #33 was ~31° different compared to adjacent trunnion #32. Molten splatter was only found on the forward side of trunnion #33 indicating retaining nut and washer was already missing at the time of the HPC Case burn through.

The condition of the internal surfaces of the HPC upper and lower cases are shown in Figures 10 and 11. Considerable amounts of molten material lined the ID surface of the HPC Case. Molten material was chipped away to reveal Stg. 1 VSV location #33 as shown in Figure 12. In their current state, a different vane angle difference of ~31° was observed between Stg. 1 VSV locations #33 (nut absent) and #32 (nut present). Panoramic views of the HPC Case halves following removal of Stg. 1 VSV hardware are shown in Figures 13 and 14. Approximately 60% circumferential burn through of the forward HPC Case was observed above the Stg. 1 HPC Blades. The only portions of the HPC Case not burned through were at the thicker rub button pad regions.

Various views of the Compressor Rotor from CFM56-7B ESN 875-318 are shown in Figures 15, 16 and 17. A total of eight (8) Stg. 2 HPC Blades were completely missing with missing material observed found on ten (10) Stg. 2 HPC disk posts, all associated with missing blade locations. A sketch illustrating Stg. 2 HPC disk post corner nomenclature is provided in Figure 18.

Visual Observations, cont'd:

Photographs documenting remaining Stg. 1 VSV hardware removed from locations #32, #33 and #34 are shown in Figure 19. All three (3) locations exhibited consumed portions of the titanium based lever arms and fragmented polymeric bushings (note absence of both the retaining nut and washer at location #33). Closer views of both the OD and ID sides of remaining lever arms in the slot regions in the uncleaned condition are shown in Figures 20 and 21. Lever arm OD surfaces at locations #32 and #34 exhibited a distinct, circular witness mark from contact with the washer supporting proper assembly. A faint, similarly shaped witness mark was observed on the lever arm OD surface at location #33 implying that a washer was likely present at one time. Lever arm ID surfaces at locations #32 and #34 revealed uniform contact patterns from contact with the Stg. 1 IGV trunnion surface, again supporting proper assembly. Although the lever arm ID surface a location #33 was more discolored and covered with debris a similarly shaped witness was present implying lever arm was properly in place at one time. Local deformation was also observed within the slot feature from abnormal contact/turning with the mating Stg. 1 IGV trunnion D-head feature as the lever arm started to disengaged from the trunnion D-head. Closer views of OD and ID sides of the remaining lever arm from position #33 are shown in Figure 22.

Side views within the remaining lever arm D-slot feature at IGV Stg. 1 locations #32, #33 and #34 are shown in Figure 24. Uniform, rectangularly shaped witness marks consistent with proper engagement between the trunnion D-head feature and the lever arm slot were observed at positions #32 and #34. The lever arm D-slot feature at location #33 was debris covered and did not exhibit a similar rectangular contact pattern indicating disengagement of the lever arm slot from the trunnion D-head feature at some point.

A direct comparison of Stg. 1 IGV trunnion D-head features from locations #32, #33 and #34 in the uncleaned condition is shown in Figure 24. Correct/fresh contact patterns with no evidence of corner deformation was observed on the outboard trunnion contact surface at locations #32 and #34 consistent with proper assembly and operation with the mating lever arm D-slot feature. Location #33 exhibited trunnion D-head deformation on all four (4) corners resulting from abnormal contact and seating with the mating lever arm D-slot feature.

Visual Observations, cont'd:

Following cleaning of trunnion #33 a similarly shaped witness mark, albeit slightly heat tinted, was observed at location #33 as shown in Figures 25 and 26. Evidence of similar light deformation was observed on the trunnion edge at both locations #32 and #33 supporting lever arm at location #33 was properly installed at some earlier time. Heat tinting of the witness mark occurred after the mating lever arm D-slot feature had lifted/disengaged from the trunnion head.

Photographs documenting Stg. 1 IGV trunnion threads from position #33 in the uncleaned condition are shown in Figures 27 and 28. Threads (aft side) exhibited uniform engine dirt accumulation along the entire length of the threads indicating retaining nut and washer had been completely missing for some period of time. The trunnion D-head surfaces also exhibited uniform engine dirt accumulation from the lever arm not being properly seated. Trunnion D-head corner and thread deformation was consistent with the lever arm D-slot turning/rotating around the corners and moving up the threads either in the complete absence of a retaining nut or as a loose nut moved outward. Various views of D-head corner damage from trunnion #33 are shown in Figure 29.

Comparative views of Stg. 1 IGV trunnion threads from locations #32, #33 and #34 in the uncleaned condition are shown in Figures 30 and 31. Once again, uniform engine dirt accumulation was observed along the entire length of the threads on trunnion #33 indicating retaining nut and washer had been completely missing for some period of time. General condition of trunnion D-head faces from locations #32, #33 and #34 in the uncleaned condition are shown in Figures 32, 33, 34 and 35. Trunnion #33 exhibited deformation at all four (4) corners from abnormal contact with the mating lever arm D-slot where as locations #32 and #34 exhibited rectangular contact marks from properly assembled lever arms. The general condition of washers removed from trunnion locations #32 and #34 are shown in Figures 36 and 37, respectively. Expected witness marks were observed on both the nut and trunnion sides of the washers.

Visual Observations, cont'd:

General comparison of loaded thread flank side at trunnion thread locations #32 and #33 in the uncleaned condition at both lower and upper thread regions are shown in Figures 38, 39 and 40. Circumferential contact lines attributed to contact with the retaining nut were observed at both the lower and upper threads on trunnion #32. Accumulation of engine dirt obscured the thread surfaces for trunnion #33. Photographs documenting the loaded thread flank side of both trunnions #32 and #33 in the cleaned condition (toothbrush and ultrasonic) are shown in Figures 41, 42 and 43. Visually evident circumferential contact marks could now be observed on loaded thread side of trunnion #33 at both lower and upper loaded side thread flanks implying a retaining nut had been run down the threads at some point in time. Observed contact marks appeared heavier on trunnion #32 (nut present) compared to trunnion #33 (nut missing).

Scanning Electron Microscope (SEM) Examination:

SEM examination was conducted on the loaded thread flanks of Stg. 1 HPC trunnion threads at locations #32 and #33 in the cleaned condition as shown in Figures 44-48 and Figures 49-54, respectively. Evidence of circumferential contact with occasional smeared material was observed on trunnion #32 on both the lower and upper loaded thread flanks considered consistent with application of a retaining nut. Energy dispersive spectroscopy (EDS) performed on the Stg. 1 IGV trunnion thread at location #32 was more consistent with the required A286 material. Evidence of similar circumferential contact was observed on both the lower and upper loaded thread flanks implying a retaining nut having been run down the threads for trunnion #33. Contact marks were only observed on thread flanks with no evidence of contact noted in the thread root region. Both lower and upper thread flank surfaces exhibited EDS spectrum consistent with A286 material.

Surface contact and local deformation at the edge of trunnion #33 in the cleaned condition was confirmed as shown in Figures 55, 56 and 57 indicating that the mating lever arm D-slot had been properly installed at some point in time. Closer examination of trunnion #33 D-head corners revealed smearing type damage consistent with rotation of the lever arm D-slot feature as it was lifting off the D-head feature as shown in Figures 58-65. Some Ti-6Al-4V lever arm material transfer within the smearing damage. On one (1) trunnion corner, evidence of tensile shear dimples and pushed out material was present due to the abnormal lever arm D-slot contact as the lever arm started to become disengaged.

Visual Observations - Stg. 1-2 HPC Spool:

Overall views of the Stg. 1-2 HPC Spool prior to removal of blade remnants are shown in Figures 66 and 67. Remaining airfoil portions of both Stg. 1 and Stg. 2 HPC Blades both exhibited “tombstone” shape consistent with titanium airfoil burning. Additional photographs documenting the general condition of the Stg. 1-2 HPC Spool are shown in Figures 68-75. All Stg. 1 HPC Blade dovetails were intact and accounted for. A total of eight (8) Stg. 2 HPC Blades were completely missing. Ten (10) Stg. 2 HPC Disk posts exhibited missing material, all associated with missing Stg. 2 HPC Blades.

Part markings present on the Stg. 1-2 HPC spool following removal of HPC Blades are shown in Figure 76. Total weight of removed Stg. 1 and Stg. 2 HPC Blades was 2647 gms (5.81 lbs) and 1206 gms (2.66 lbs), respectively. Photographs documenting Stg. 2 HPC disk posts with missing material and cracked posts following steam cleaning are shown in Figures 77-81. Evidence of fatigue was observed on exposed disk post fractures. A closer view of the disk post fracture at post #40 is shown in Figure 82. Fracture exhibited a gold heat tint with numerous “beachmark” features consistent with fatigue propagation. Primary origin region was located ~0.16 inch off the corner #1 position progressing axially along the pressure face ~0.70 inch and along the forward post face ~0.52 inch and an angle of ~28° prior to liberation.

Scanning Electron Microscope (SEM) Examination - Stg. 1-2 HPC Spool:

Overall SEM views of Stg. 2 HPC disk post fracture #40 are shown in Figure 83. Primary origin region sustained secondary shear damage as the mating blade exited the disk slot as shown in Figure 84. Initial examination of the fracture surface at area 1 revealed light surface oxidation along with finer striations features at higher magnification as shown in Figure 85. Continued examination at areas 2, 3, 4 and 5 exhibited morphology consistent with lower alternating stress, high cycle fatigue (HCF) and/or mixed-mode LCF/HCF crack propagation mechanisms as shown in Figures 86-89.

Scanning Electron Microscope (SEM) Examination - Stg. 1-2 HPC Spool, cont'd:

Optical views of cracked Stg. 2 disk post #44 are shown in Figures 90 and 91. Cracks were observed at both the corner #1 and corner #3 locations with the crack at corner #1 starting to yield open in an outward direction. Fracture surface following lab fracture of the corner #1 from post #44 crack is shown in Figures 92 and 93. Fracture was exhibited numerous “beachmark” features, very similar to that observed on previously documented post #40 fracture.

Overall SEM views of Stg. 2 HPC disk post fracture #44 (outboard half) are shown in Figure 94. Primary origin region was located ~0.080 inch off the corner #1 position as shown in Figure 95. Examination of the fracture surface at areas 1, 2 and 3 revealed morphology consistent with lower alternating stress, high cycle fatigue (HCF) and/or mixed-mode LCF/HCF crack propagation mechanisms as shown in Figures 96, 97 and 98. Evidence of coarser fatigue striations features were observed inside the “beachmark” features near the crack end region implying two different propagation stimuli were active at this location on the fracture as shown in Figure 99. EDS spectrum obtained from a region of fresh tensile overload from Stg. 2 disk post #44 was consistent with Ti-17 material as required by the engineering drawing as shown in Figure 100.

Examination of the pressure face in the corner #1 region of Stg. 2 disk post #44 revealed heavier local contact at the fatigue origin region as shown in Figure 101. Evidence of transferred copper (Cu) from the Al-bronze coated Stg. 2 HPC blade pressure face was noted in the origin region. Original Stg. 1 disk post pressure faces are coated with moly-disulfide (both cured and brushed). Original Stg. 2 HPC Blade pressure faces also possess a cured moly-disulfide applied to the top of the aluminum bronze coating.

Metallographic Examination:

A metallographic cross-section was prepared through the fatigue origin region at Stg. 2 disk post #44 as shown in Figure 102. Transferred copper (Cu) from the aluminum-bronze coating applied to the Stg. 2 HPC Blade pressure face was observed in the origin region at the inboard edge of contact region adjacent to the corner 1 location. Transfer was attributed to greater contact pressure applied to this region during engine operation. No evidence of any material anomalies was observed at the origin region.

General microstructure at the Stg. 2 disk post location was comprised of acicular alpha (α) in a matrix of transformed beta (β) consistent with beta (β) forged Ti-17 material as required by the engineering drawing as shown in Figure 103.

Aft Sump Debris:

During teardown debris was found in the vicinity of the 4R Bearing as shown in Figure 104. A sample of debris was removed with carbon tape for analysis. Debris particles and associated EDS spectra are shown in Figures 105-115. Debris consisted of RBD modified steel (4R Bearing inner race material), silver (bearing cage), unidentifiable material exhibiting elevated titanium (Ti), iron (Fe), chromium (Cr) and nickel (Ni) and aluminum (Al) with silicon (Si).

Forward Sump Debris:

Photographs documenting debris attached to the forward sump chip detector are shown in Figure 116. An SEM image documenting a representative sample of debris is shown in Figure 117. Debris particles consisted of primarily M50NiL, 17-4 and/or 15-5 PH and 4340/9310 low alloy steel. No evidence of RBD modified steel was detected.

Metallurgical Summary:

- Subject CFM56-7B ESN 875-318 sustained a burn through of the M152 steel forward HPC Case radially in line with the Stg. 1 HPC Blades consuming ~60% of the steel case with the only intact region being the thicker rub button pads. External lever arms and actuator hardware were also consumed/melted in line with the case burn through.
- One (1) Stg. 1 HPC VSV (#33) was missing both a nut and washer which ultimately resulted in disengagement of the lever arm from the trunnion D-head feature causing the vane to go off-schedule. In its current position, trunnion #33 was off-schedule ~31° compared to adjacent vane assemblies. It is known that VSV misalignment (off-schedule vane) can result in 1/rev excitation within the HP Compressor leading to both HPC Blade dovetail and HPC disk post pressure face cracking.
- Stg. 1 VSV #33 had been operating without a nut and washer for enough time to accumulate a uniform coverage of engine dirt along the entire length of the exposed trunnion threads as well as the trunnion flats that fit with the lever arm D-slot. Witness marks indicated that the lever arm worked up the trunnion D-head feature shearing the head corners before moving outboard and smearing the trunnion threads. It could not be determined how long the lever arm was functioning properly prior to becoming disengaged.
- Examination revealed witness marks on VSV #33 indicating that a retaining nut and washer was present at some time. Additional witness marks on trunnion #33 indicated that the lever arm was properly assembled at one time. During the last shop visit 22 out of the 82 Stg. 1 HPC VSV's were replaced with the remainder being overhauled. Installation position between the replaced and overhauled VSV's was not recorded.
- Fracture morphology of Stg. 2 disk posts was consistent with a lower alternating stress, high cycle fatigue (HCF) and/or mixed-mode LCF/HCF mechanisms. Primary initiation region occurred adjacent to the corner #1 location initiating along the inboard edge of contact region. Contact appeared heavier at the origin region with the Al-bronze coated Stg. 2 HPC Blade pressure face.

Metallurgical Summary, cont'd:

- Metallographic examination through an origin region of Stg. 2 disk post did not reveal any material anomalies. General microstructure of Stg. 1-2 HPC Spool was consistent with properly processed beta (β) forged Ti-17 material as required by the engineering drawing.
- Some damage was sustained by the 4R Bearing as evidenced by presence of RBD modified steel and silver (Ag) plating found in debris removed from the aft sump region. Particles of M50Nil were detected in debris removed from the forward sump chip detector.

CFM56-7B Compressor Inlet - ESN 875-318

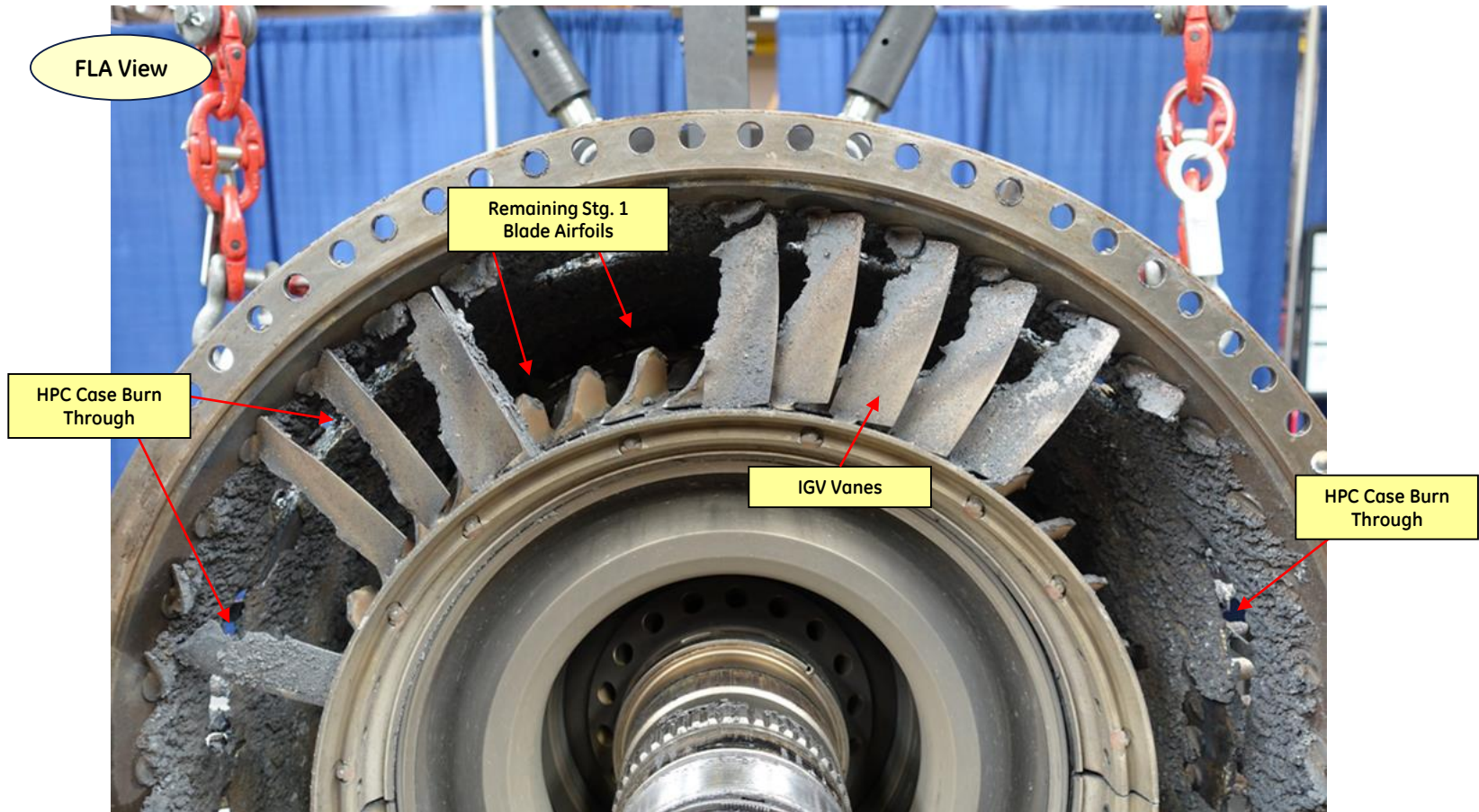
- Missing IGV Vanes and Significant Amounts Molten Material in Compressor Inlet



Figure 1. Photograph looking into compressor inlet (FLA). Numerous missing IGV's and abundant molten metal splatter observed on HPC Case ID surface.

CFM56-7B Compressor Inlet - ESN 875-318

- Missing IGV Vanes and Significant Amounts Molten Material in Compressor Inlet
- Numerous Regions of HPC Case Burn Through in Plane of Stage 1 HPC Blades
- Shape Remaining Stg. 1 HPC Blade Airfoils Consistent With Burning



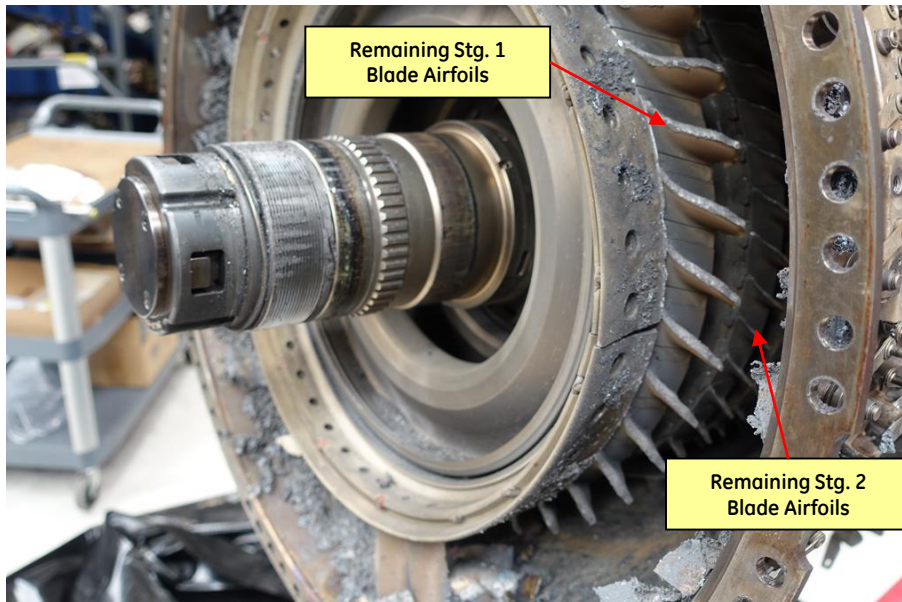
Compressor Inlet Condition

Figure 2. Photograph looking into compressor inlet (FLA). Numerous missing IGV's and abundant molten metal splatter observed on HPC Case ID surface.



CFM56-7B Compressor Inlet - ESN 875-318

- Missing IGV Vanes and Significant Amounts Molten Material in Compressor Inlet
- Shape Remaining Stg. 1 HPC Blade Airfoils Consistent With Burning



Compressor Inlet Condition

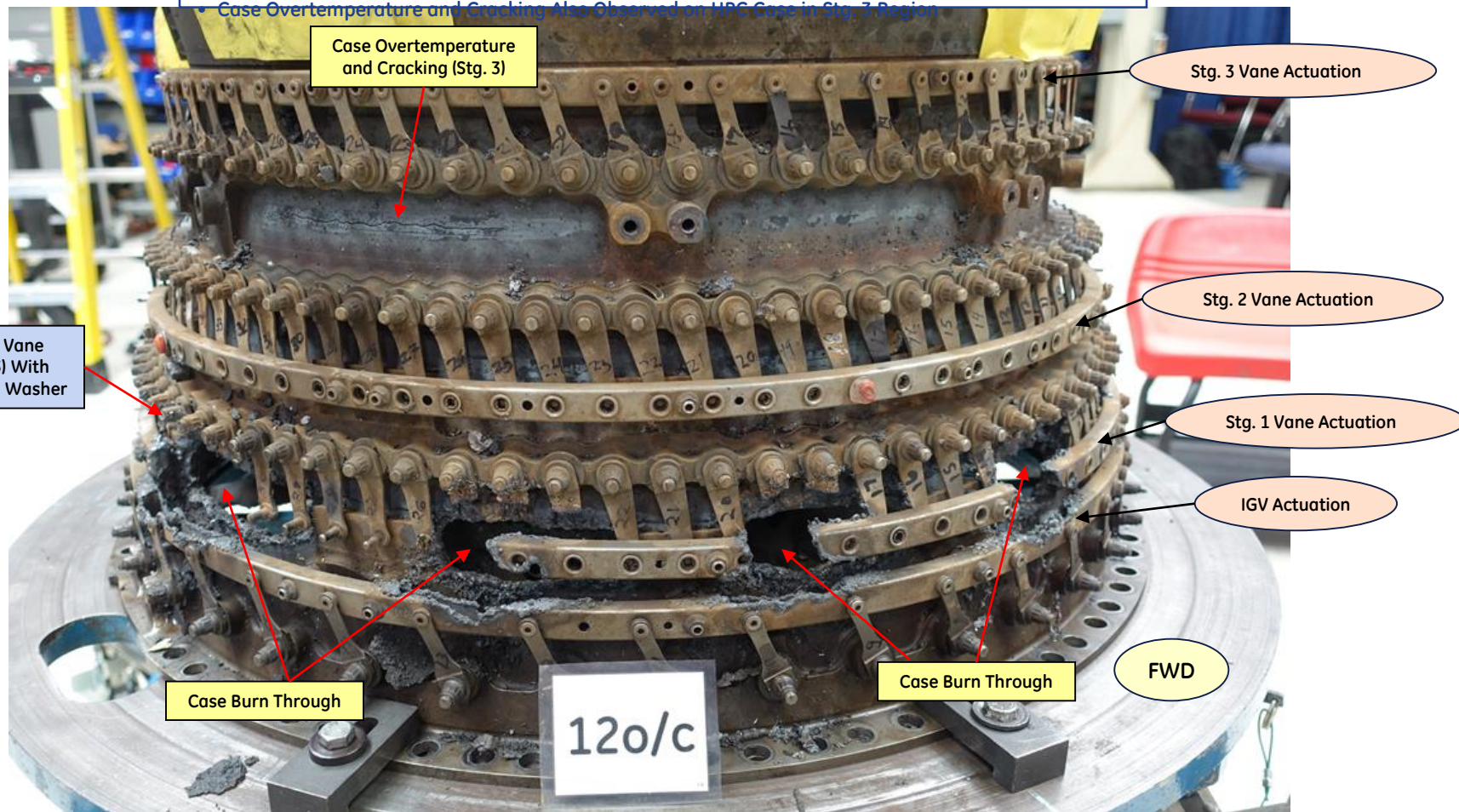


Compressor Inlet Condition

Figure 3. Photographs looking at angle into compressor inlet. Numerous missing IGV's and abundant molten metal splatter observed on HPC Case ID surface.

CFM56-7B HPC Case 12:00 Location - ESN 875-318

- Several Regions of Upper HPC Case Burn Through Plus Consumption of Lever Arms and Actuation Rings - Burn Throughs Located Between Thicker Rub Button Pad Regions in Plane With Stg. 1 HPC Rotor
- One (1) Stg. 1 Vane Trunnion With Missing Nut and Washer (Location #33)
- Case Overtemperature and Cracking Also Observed on HPC Case in Stg. 3 Region

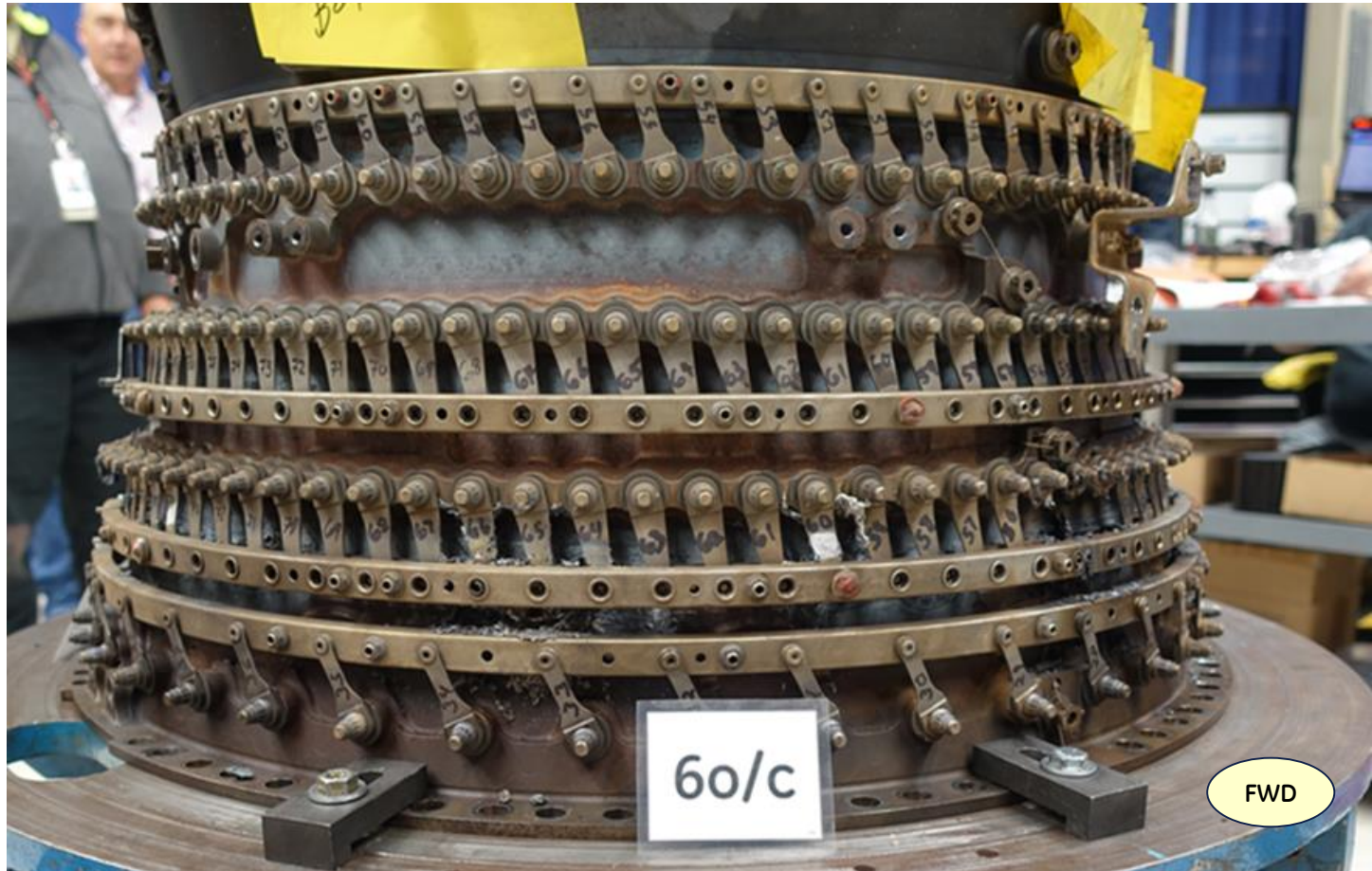


HPC Case - 12:00 Position

Figure 4. Photograph documenting condition HPC Case at 12 o'clock position denoting some of the locations of case burn through. Retaining nut and washer was missing at Stg. 1 HPC Vane Trunnion #33.

CFM56-7B HPC Case 6:00 Location - ESN 875-318

- Condition of Lower HPC Case - Several Regions of HPC Case Burn Through Plus Consumption of Lever Arms - Burn Throughs Located Between Thicker Rub Button Pad Regions in Plane With Stg. 1 HPC Rotor

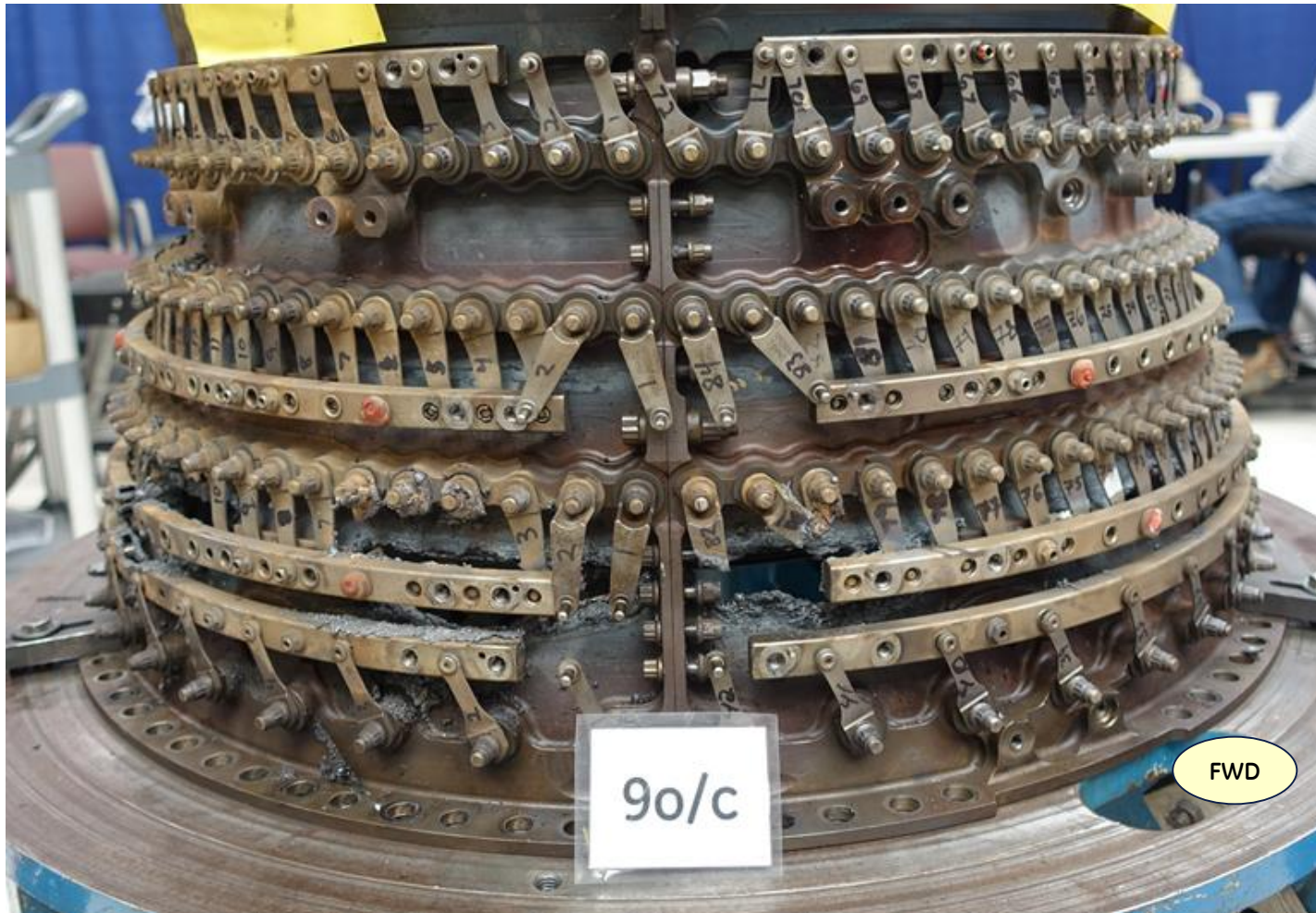


HPC Case – 6:00 Position

Figure 5. Photograph documenting condition HPC Case at 6 o'clock position.

CFM56-7B HPC Case 9:00 Location - ESN 875-318

- Condition of Lower HPC Case - Several Regions of HPC Case Burn Through Plus Consumption of Lever Arms - Burn Throughs Located Between Thicker Rub Button Pad Regions in Plane With Stg. 1 HPC Rotor

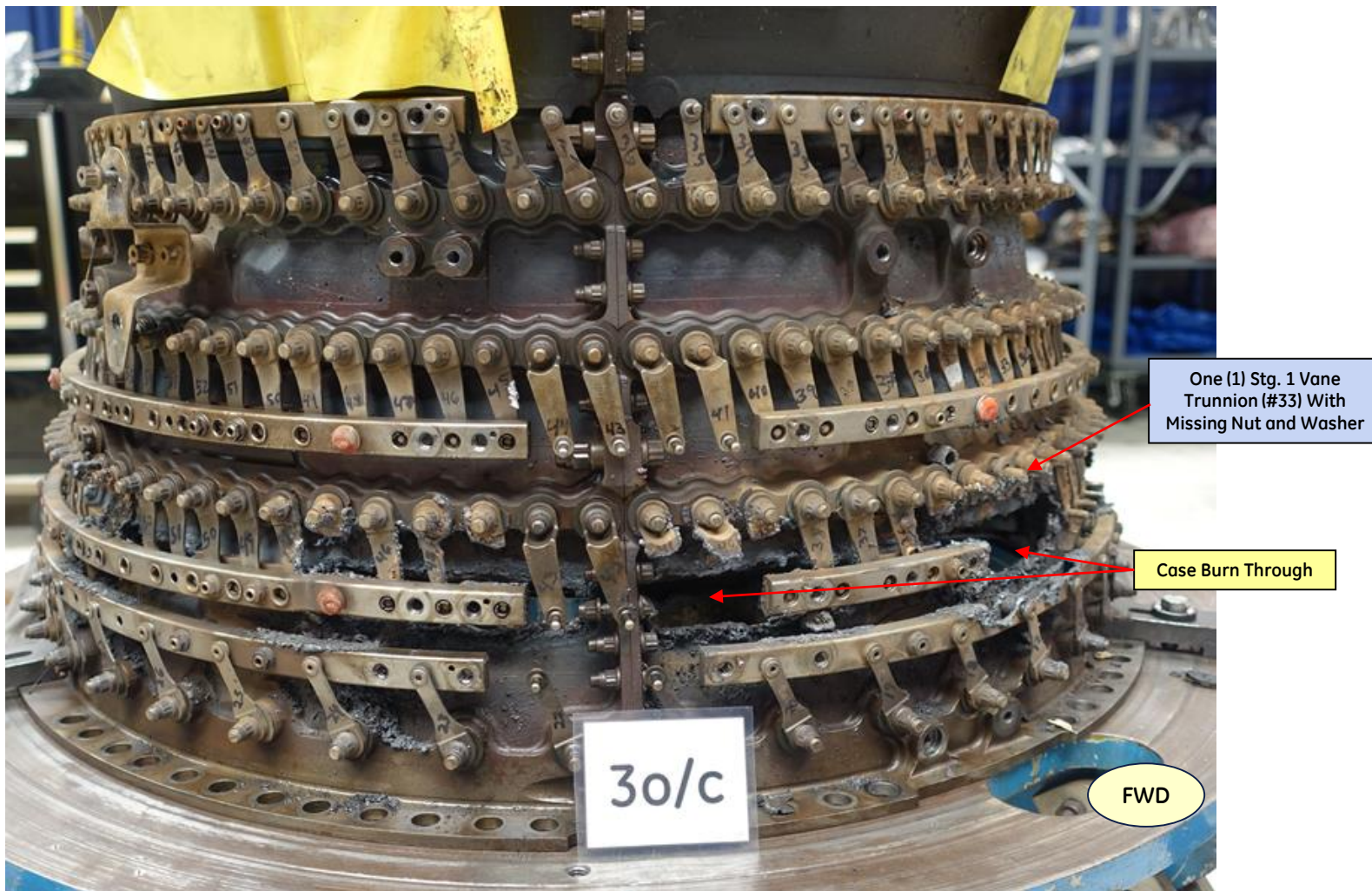


HPC Case - 9:00 Position

Figure 6. Photograph documenting condition HPC Case at 9 o'clock position.

CFM56-7B HPC Case 3:00 Location - ESN 875-318

- Condition of Lower HPC Case - Several Regions of HPC Case Burn Through Plus Consumption of Lever Arms - Burn Throughs Located Between Thicker Rub Button Pad Regions in Plane With Stg. 1 HPC Rotor



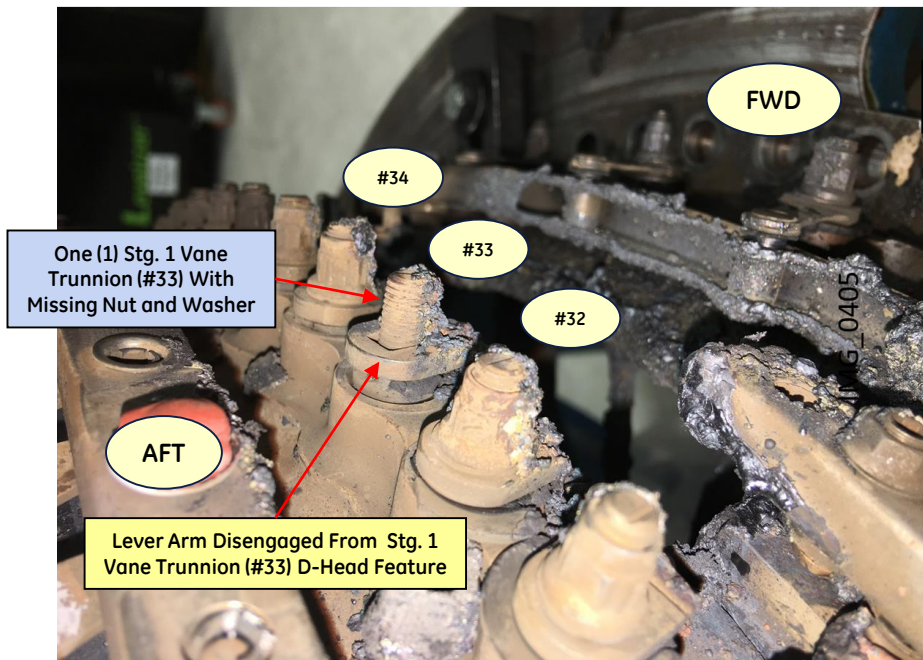
HPC Case - 3:00 Position

Figure 7. Photograph documenting condition HPC Case at 12 o'clock position denoting some of the locations of case burn through. Retaining nut and washer was missing at Stg. 1 HPC Vane Trunnion #33.

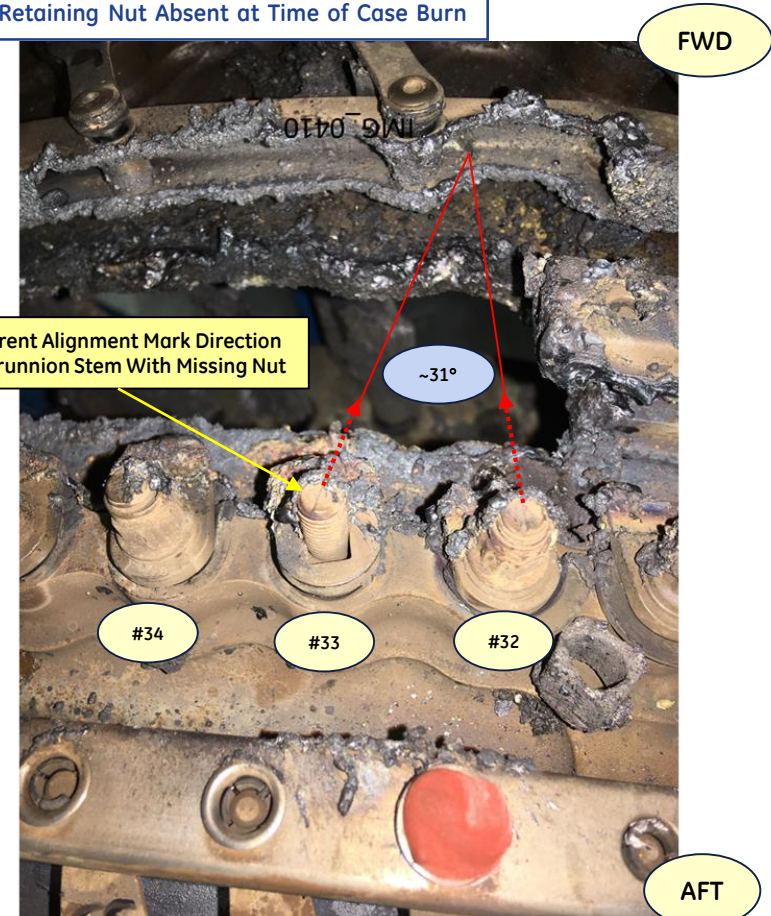


CFM56-7B Stg. 1 HPC Vane Trunnion #33 - ESN 875-318

- One (1) Stg. 1 Vane Trunnion With Missing Nut and Washer (Location #33) Located on Upper HPC Case
- Lever Arm Found Disengaged With Stg. 1 HPC Vane Trunnion D-Head
- Different Alignment Mark Angle on Top Trunnion Stem #33 Compared to Adjacent Trunnion #32 (Dashed Red Arrows) – Trunnion #33 Currently Off-Angle $\sim 31^\circ$
- Molten Splatter on Fwd Side Trunnion #33 Threads Indicating Retaining Nut Absent at Time of Case Burn Through



Stg. HPC Case – Stg. 1 Vane Positions #32, #33 and #34

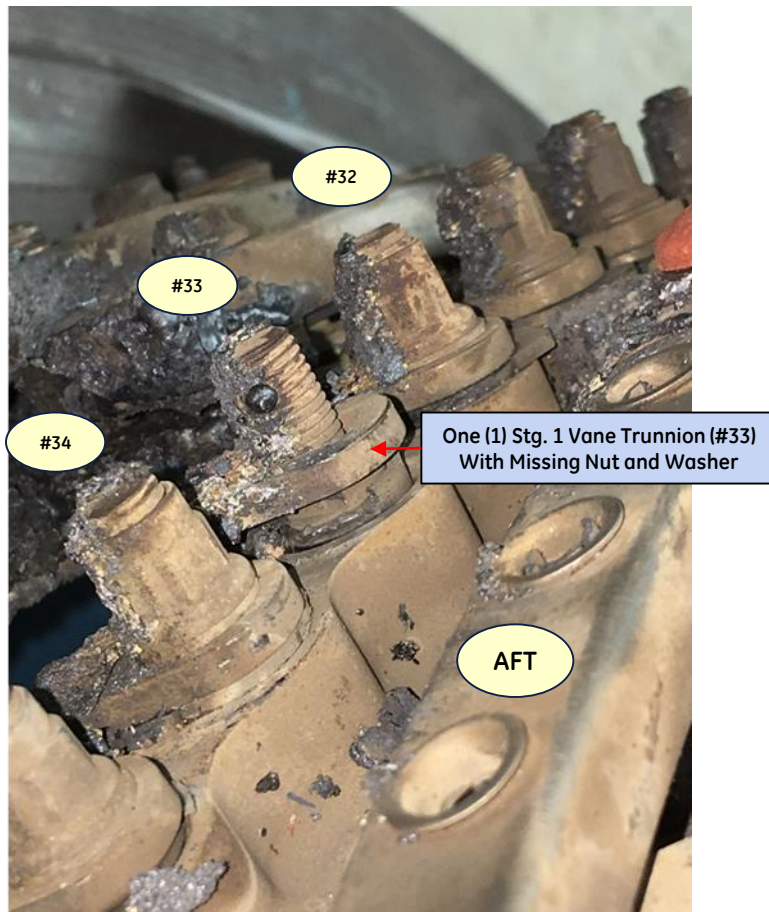


Stg. HPC Case – Stg. 1 Vane Positions #32, #33 and #34

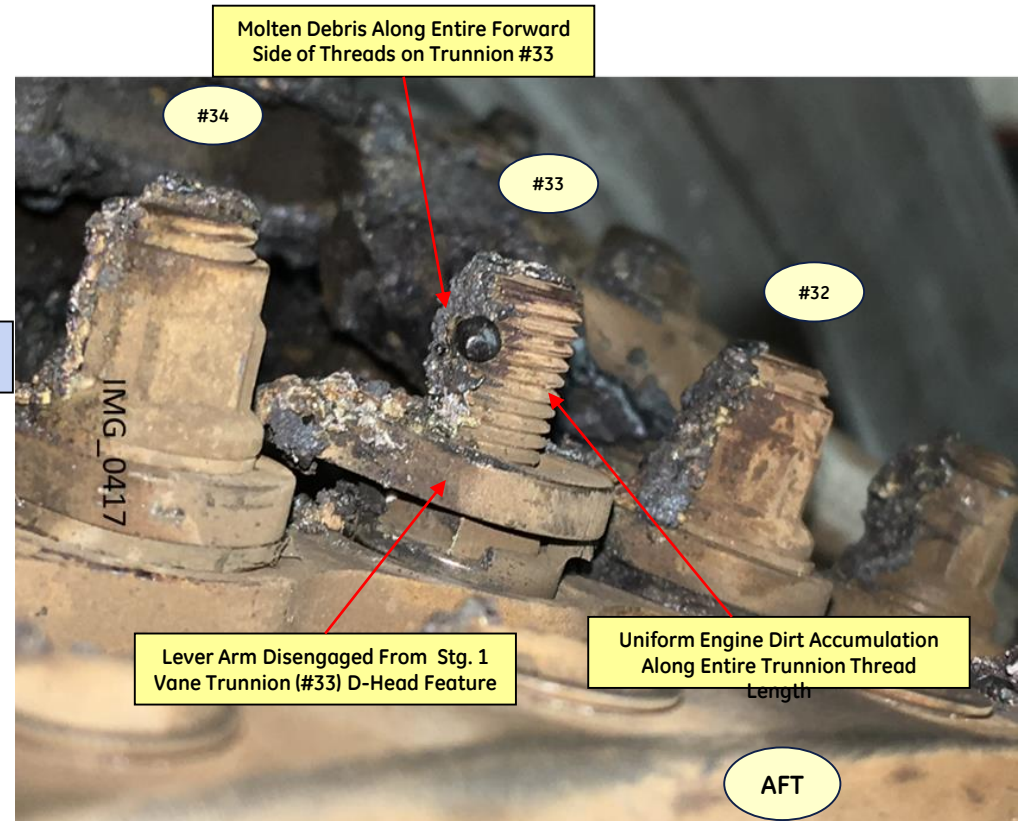
Figure 8. Photographs documenting missing nut and washer on Stg. 1 HPC Vane Trunnion #33 compared to adjacent Stg. 1 HPC Vane assemblies #32 and #34.

CFM56-7B Stg. 1 HPC Vane Trunnion #33 - ESN 875-318

- One (1) Stg. 1 Vane Trunnion With Missing Nut and Washer (Location #33) Located on Upper HPC Case
- Lever Arm Found Disengaged With Stg. 1 HPC Vane Trunnion D-Head
- Molten Splatter on Forward Side Trunnion #33 Threads Indicating Retaining Nut Absent at Time of Case Burn Through



Stg. HPC Case – Stg. 1 Vane Positions #32, #33 and #34



Stg. HPC Case – Stg. 1 Vane Positions #32, #33 and #34

Figure 9. Photographs documenting missing nut and washer on Stg. 1 HPC Vane Trunnion #33 compared to adjacent Stg. 1 HPC Vane assemblies #32 and #34.

CFM56-7B Upper HPC Case Location - ESN 875-318

- Considerable Amounts of Molten Material on Inside Surface of Upper HPC Case - Burn Throughs Occurred Between Thicker Button Rub Button Pad Regions in Plane With Stg. 1 HPC Rotor

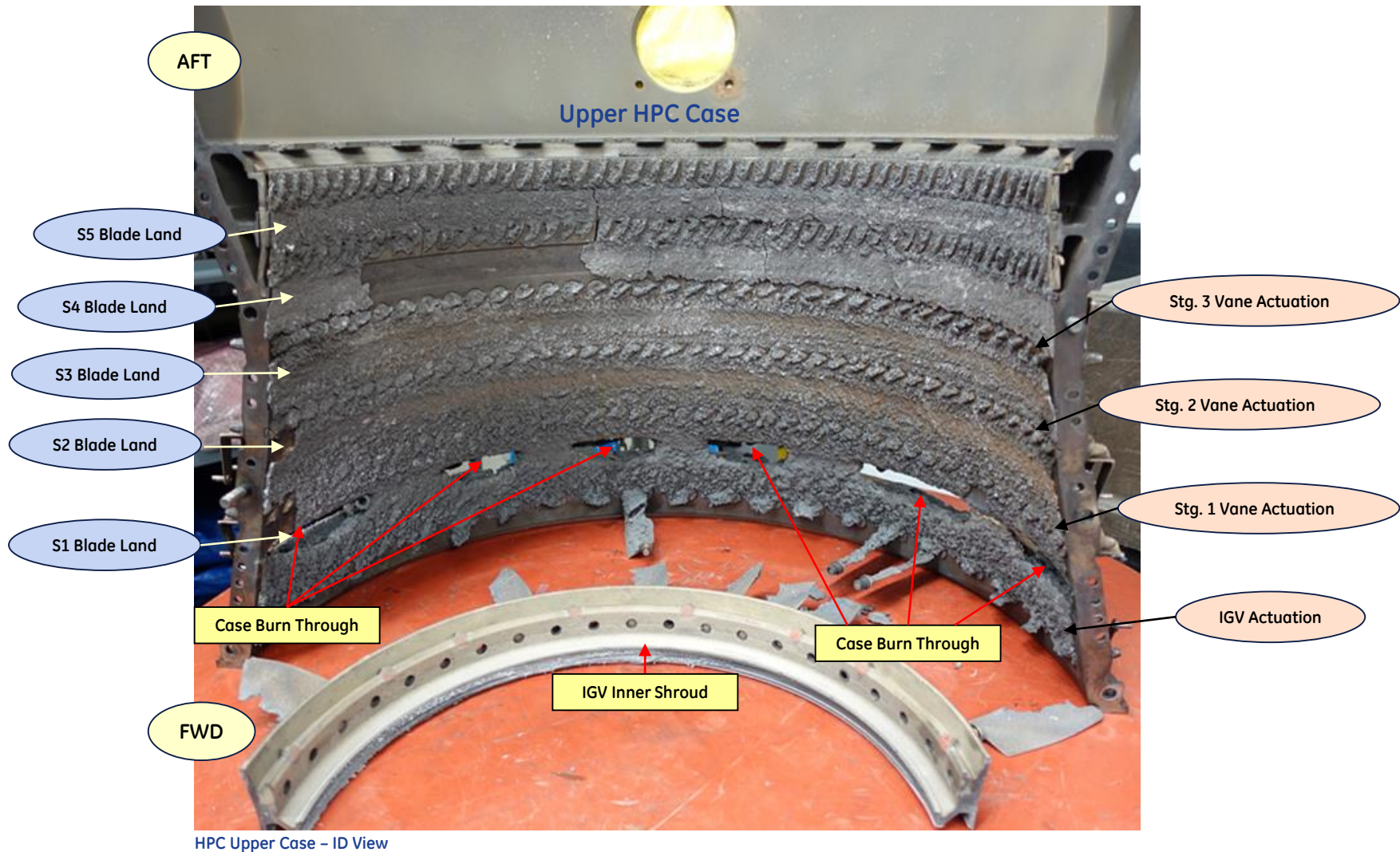


Figure 10. Photograph documenting inside surface condition of upper HPC Case. With exception of a few IGV Vanes all HPC Vanes airfoils were missing.

CFM56-7B Lower HPC Case Location - ESN 875-318

- Considerable Amounts of Molten Material on Inside Surface of Lower HPC Case - Burn Throughs Occurred Between Thicker Button Rub Button Pad Regions in Plane With Stg. 1 HPC Rotor

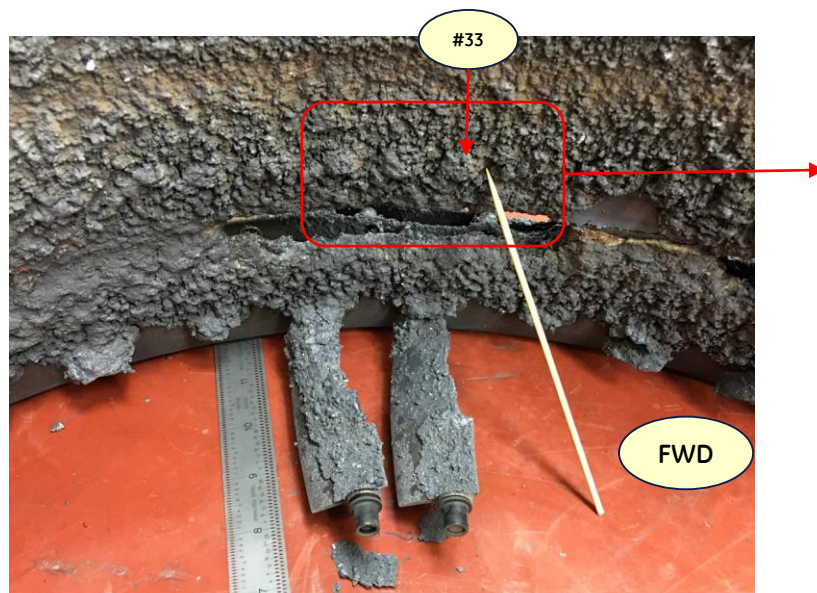


HPC Lower Case – ID View

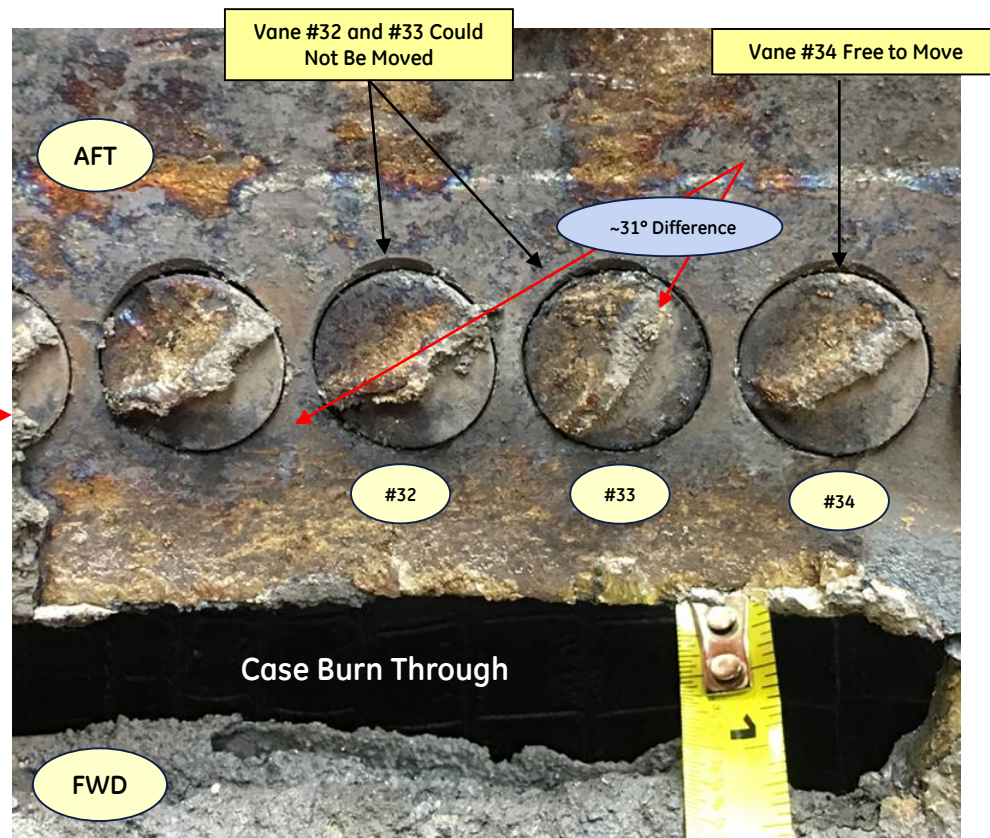
Figure 11. Photograph documenting inside surface condition of lower HPC Case. With exception of a few IGV Vanes all HPC Vanes airfoils were missing.

CFM56-7B Upper HPC Case Location - ESN 875-318

- Chipping Away Molten Material Revealed Stg. 1 Vane #33 With Different Vane Angle (Currently ~31°) Compared to Adjacent Vane #32



HPC Upper Case – IGV #33 Location



HPC Upper Case – IGV #33 Location – Molten Debris Chipped Away

Figure 12. Photographs documenting location of Stg. 1 HPC Vane #33 on upper HPC Case following removal of molten splatter. Note difference in the vane angle compared to adjacent vane #32.

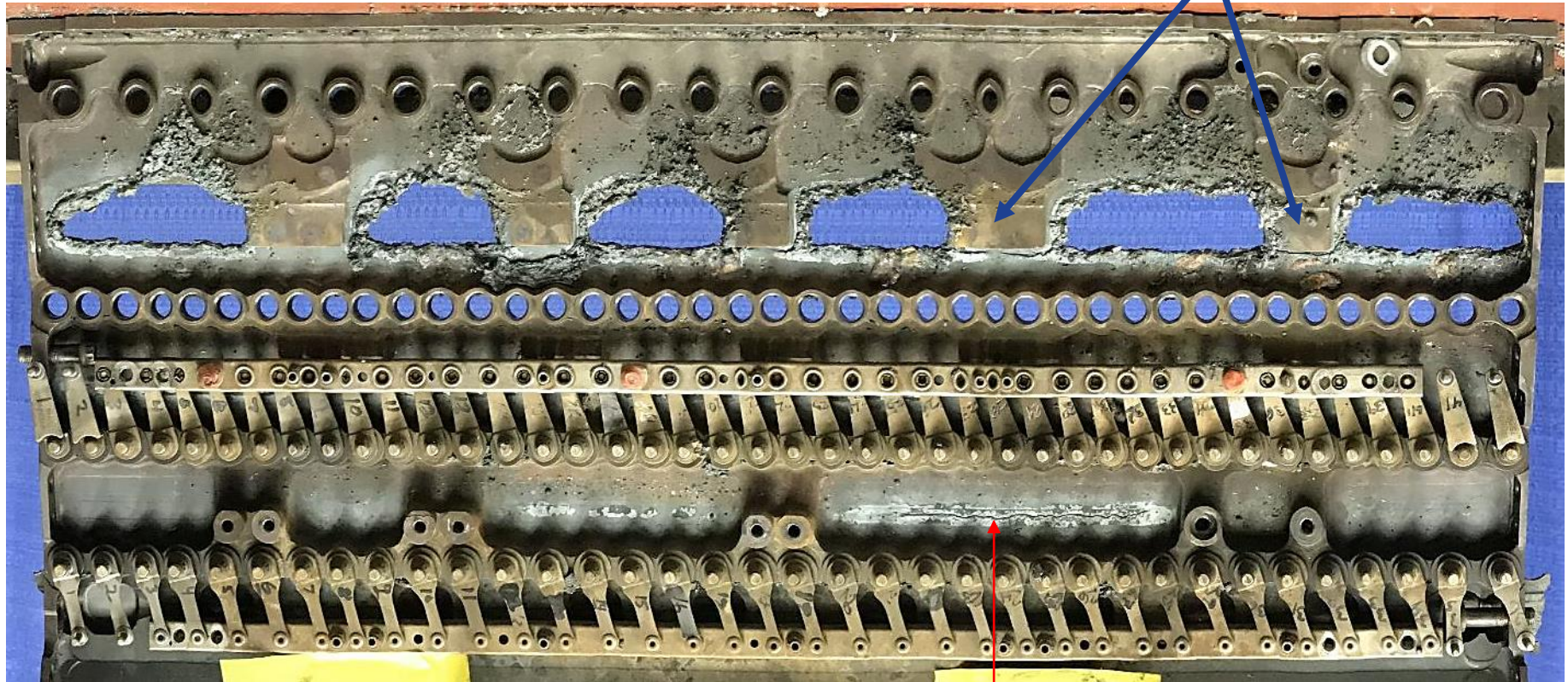
CFM56-7B Upper HPC Case Location - ESN 875-318

- Panoramic View of Top HPC Case Following Removal of Stg. 1 HPC Actuators Showing Burn Through Location in Line With Stg. 1 HPC Blades

FWD (IGV)

Upper HPC Case Half

Rub button pads



Aft (Stage 3)

Case Cracking

Figure 13. Photograph documenting locations of upper HPC Case burn through in line with Stg. 1 HPC Blades. Flanges and rub button pads were only locations which did not get consumed during the event.

CFM56-7B Lower HPC Case Location - ESN 875-318

- Panoramic View of Lower HPC Case Following Removal of Stg. 1 HPC Actuators Showing Burn Through Location in Line With Stg. 1 HPC Blades

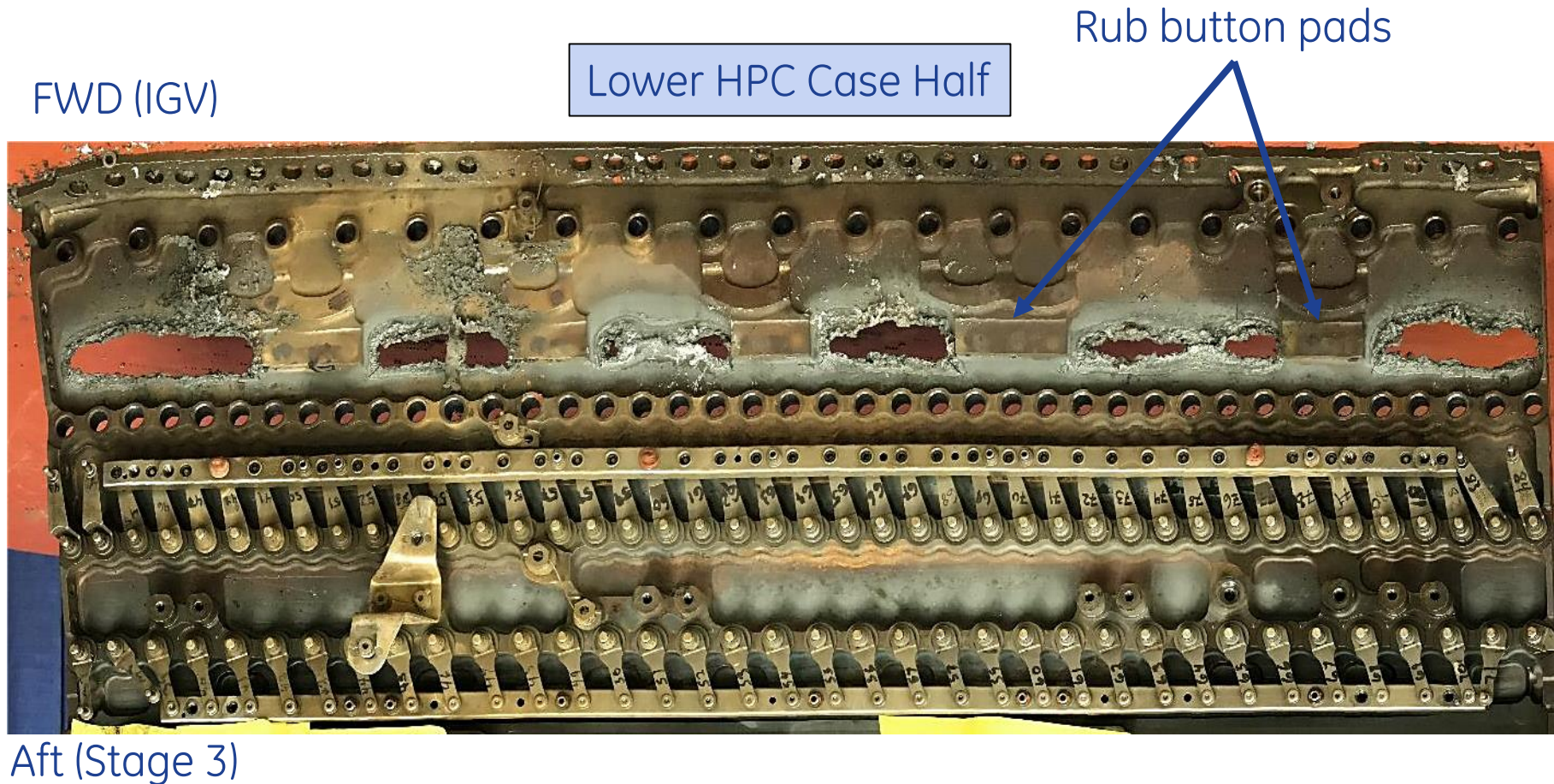


Figure 14. Photograph documenting locations of lower HPC Case burn through in line with Stg. 1 HPC Blades. Flanges and rub button pads were only locations which did not get consumed during the event.

CFM56-7B HPC Rotor - ESN 875-318

- HPC Rotor Condition – Eight (8) Stg. 2 HPC Blades Observed (Locations #1, #3, #5, #6, #7, #34, #40 and #53)
- Missing Material Observed on Ten (10) Stg. 2 Disk Posts (#1, #2, #4, #5, #6, #7, #33, #39, #40 and #53) All Associated With Missing Stg. 2 HPC Blades

HPC Blade Numbering Performed ALF- CW
Direction Starting at 1-2 Spool Drain Hole



HPC Rotor Condition

Figure 15. Photographs documenting condition of HPC Rotor assembly during disassembly. Arrows denote locations of entirely missing Stg. 2 HPC Blades.

CFM56-7B HPC Rotor - ESN 875-318

- HPC Rotor Condition – Eight (8) Stg. 2 HPC Blades Observed (Locations #1, #3, #5, #6, #7, #34, #40 and #53)
- Missing Material Observed on Ten (10) Stg. 2 Disk Posts (#1, #2, #4, #5, #6, #7, #33, #39, #40 and #53) All Associated With Missing Stg. 2 HPC Blades

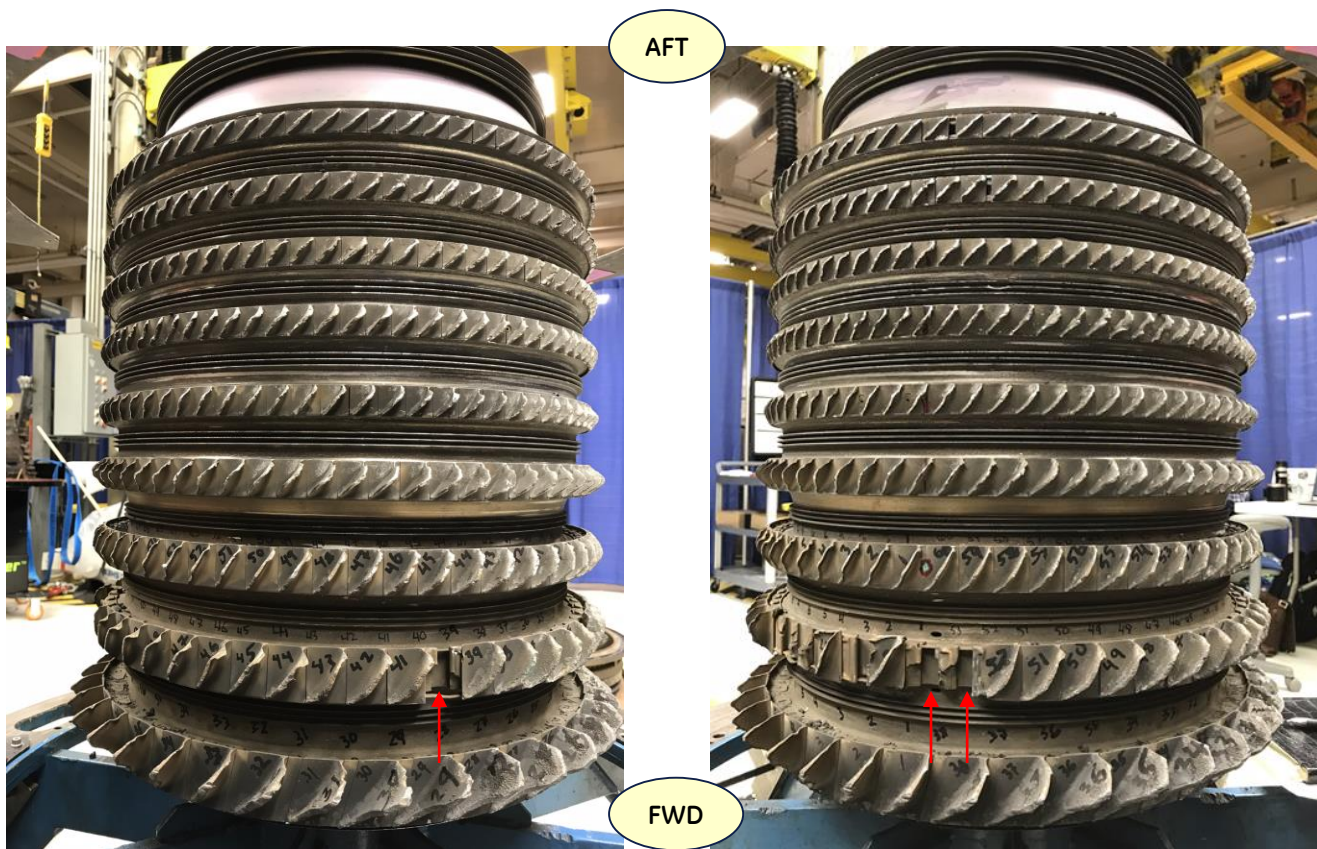


HPC Rotor Condition

Figure 16. Photographs documenting condition of HPC Rotor assembly during disassembly. Arrows denote locations of entirely missing Stg. 2 HPC Blades.

CFM56-7B HPC Rotor - ESN 875-318

- HPC Rotor Condition – Eight (8) Stg. 2 HPC Blades Observed (Locations #1, #3, #5, #6, #7, #34, #40 and #53)
- Missing Material Observed on Ten (10) Stg. 2 Disk Posts (#1, #2, #4, #5, #6, #7, #33, #39, #40 and #53) All Associated With Missing Stg. 2 HPC Blades



HPC Rotor Condition

Figure 17. Photographs documenting condition of HPC Rotor assembly during disassembly. Arrows denote locations of entirely missing Stg. 2 HPC Blades.

Stg. 2 Blade Slot (Missing Blade)	Retaining Ring Condition
1	Aft present, Fwd missing
3	Aft missing, Fwd present
5	Aft missing, Fwd present
6	Aft missing, Fwd present (bent fwd)
7	Aft missing, Fwd present (bent fwd)
34	Aft missing, Fwd present (bent fwd)
40	Aft missing, Fwd present (bent fwd)
53	Aft present, Fwd missing

Stg. 2 HPC Post #	Missing Post Material (Corner #)
1	1
2	3
4	2,3
5	1,3,4
6	2,3,4,
7	4
33	2,3
39	2
40	1
53	1,2

CFM56-7B HPC Rotor - ESN 875-318

- HPC Rotor Condition – Eight (8) Stg. 2 HPC Blades Observed (Locations #1, #3, #5, #6, #7, #34, #40 and #53)
- Missing Material Observed on Ten (10) Stg. 2 Disk Posts (#1, #2, #4, #5, #6, #7, #33, #39, #40 and #53)
All Associated With Missing Stg. 2 HPC Blades

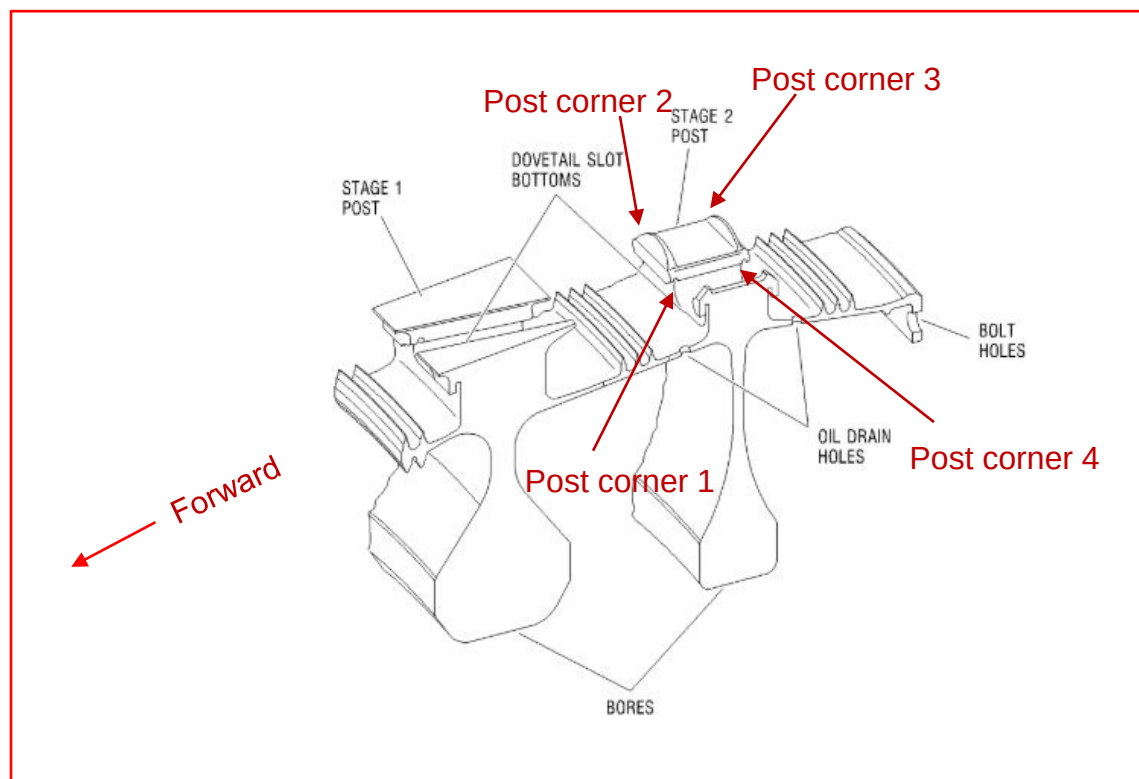
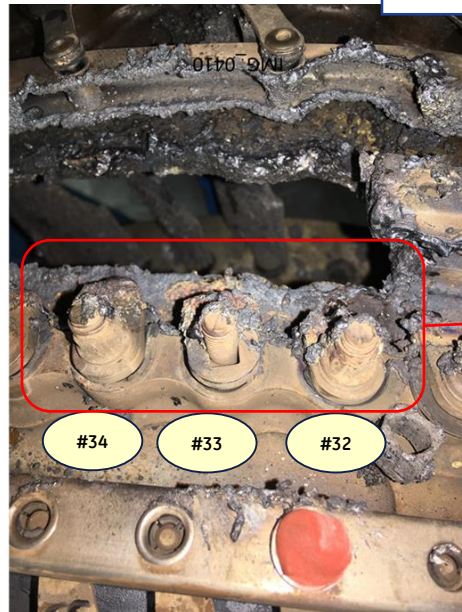


Figure 18. Sketch showing Stg. 2 HPC disk post corner nomenclature. Eight (8) Stg. 2 HPC Blades were liberated with ten (10) Stg. 2 disk posts exhibited missing material.

CFM56-7B HPC Stg. 1 Vane and Lever Arms - ESN 875-318

- Remaining VSV Hardware Removed From Stg. 1 Vane Positions #32, #33 and #34 – Exposed Portion of Lever Arm Consumed/Melted During Event



Examined Stg. 1 Vane VSV Hardware



Stg. 1 VSV Hardware Positions #32, #33 and #34

Figure 19. Photographs documenting condition of Stg. 1 HPC VSV Hardware from locations #32, #33 and #34 following removal from HPC Case.



CFM56-7B Lever Arm Locations #32, #33 and #34 - ESN 875-318

- Circular Washer Witness Marks Present on Lever Arm OD Side at Locations #32 and #34 Indicative of Proper Assembly
- Faint Witness Mark With Similar Curvature Present on Lever Arm OD Side at Location #33 Implying Washer Was Present at One Time

OD Side Remaining Lever Arm Slots – Uncleaned Condition

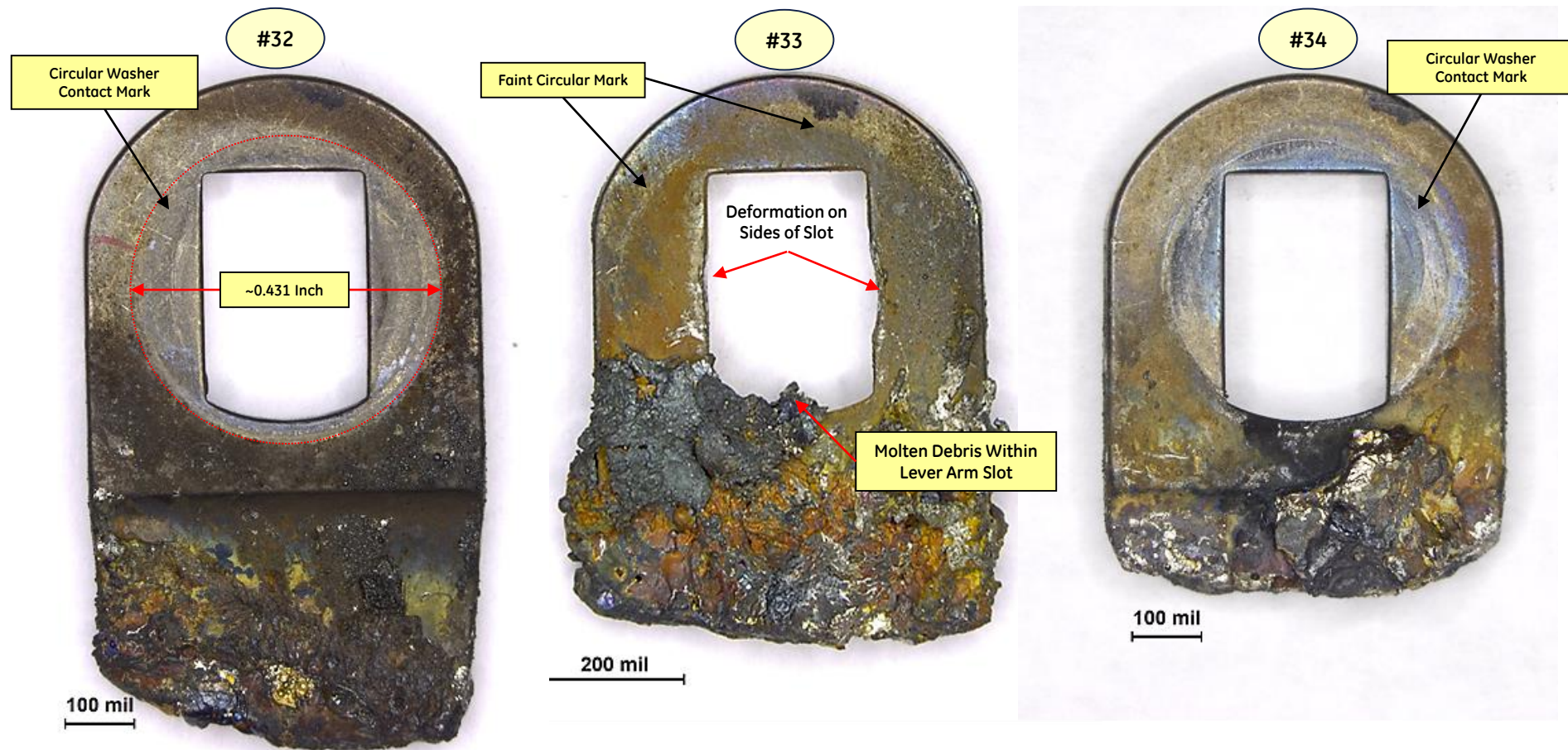


Figure 20. Photographs documenting OD side condition of remaining Stg. 1 HPC lever arms from locations from locations #32, #33 and #34 in the uncleaned condition. Distinct difference in OD surface condition present between location #33 (nut and washer absent) and location #32 and #34 (nut and washer present).

CFM56-7B Lever Arm Locations #32, #33 and #34 - ESN 875-318

- Uniform Contact With Trunnion Seat on ID Side Remaining Lever Arms at Locations #32 and #34
- Unique, Deformation Pattern in Lever Arm Slot Location #33 Consistent With Lever Arm Turning on Outboard Surface of Mating Trunnion D-Head Feature – Uniform Discoloration (Debris Accumulation) Supports Lever Arm Exposed to Environment For Some Unknown Period to Time
- Faint Trunnion Contact Pattern on Lever Arm Slot #33 Implying Proper Assembly at One Time

ID Side Remaining Lever Arm Slots – Uncleaned Condition

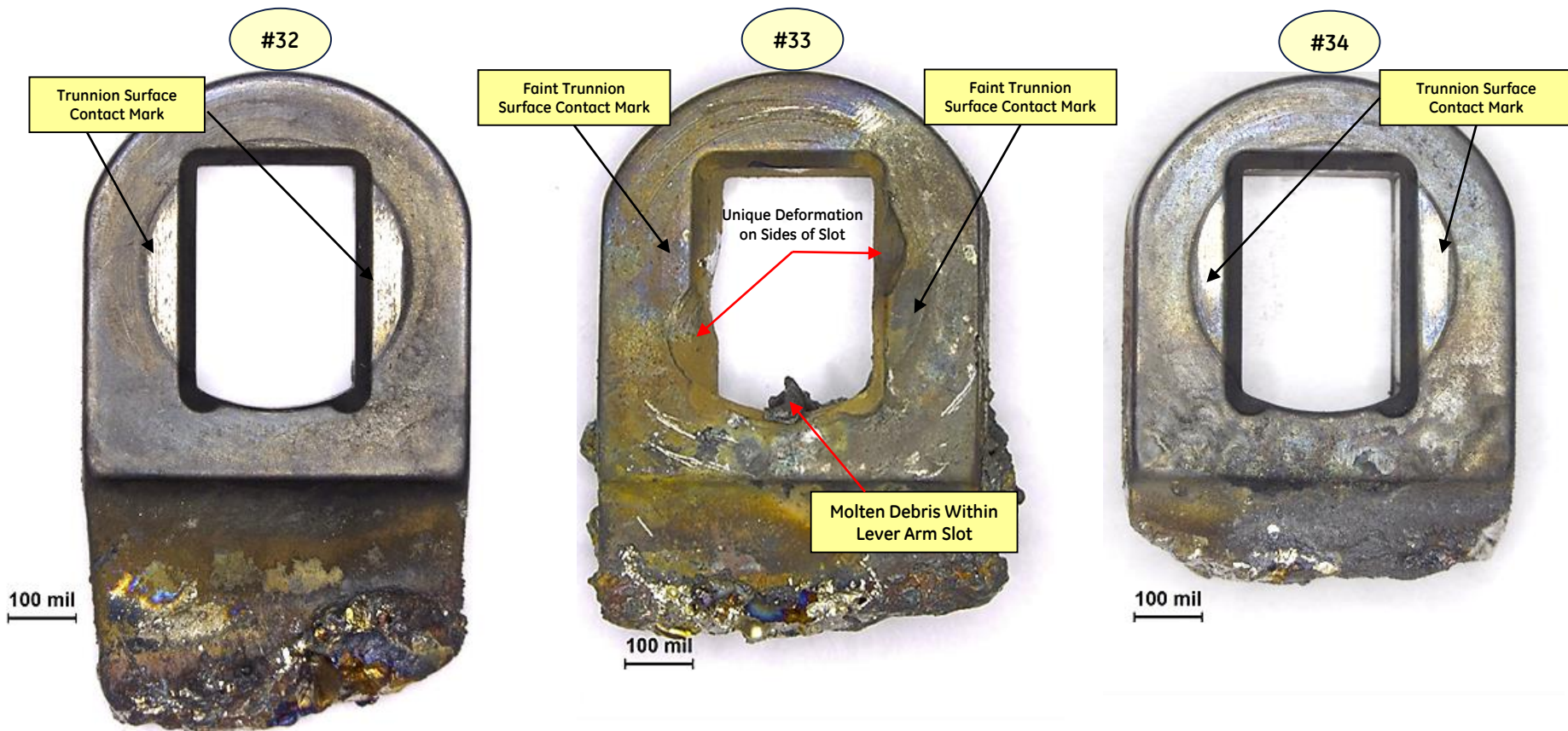


Figure 21. Photographs documenting ID side condition of remaining Stg. 1 HPC lever arms from locations from locations #32, #33 and #34 in the uncleaned condition. Note unique deformation pattern within slot of lever arm #33 attributed to abnormal contact with trunnion D-head outboard surface.

CFM56-7B Lever Arm Location #33 - ESN 875-318

- Unique, Deformation Pattern in Lever Arm Slot Location #33 Consistent With Lever Arm Turning on Outboard Surface of Mating Trunnion D-Head Feature – Uniform Discoloration (Debris Accumulation) Supports Lever Arm Exposed to Environment For Some Unknown Period to Time Following Disengagement
- Faint Trunnion Contact Pattern on Lever Arm Slot #33 Implying Proper Assembly at One Time

OD and ID Sides Remaining Lever Arm Slot #33 – Uncleaned Condition

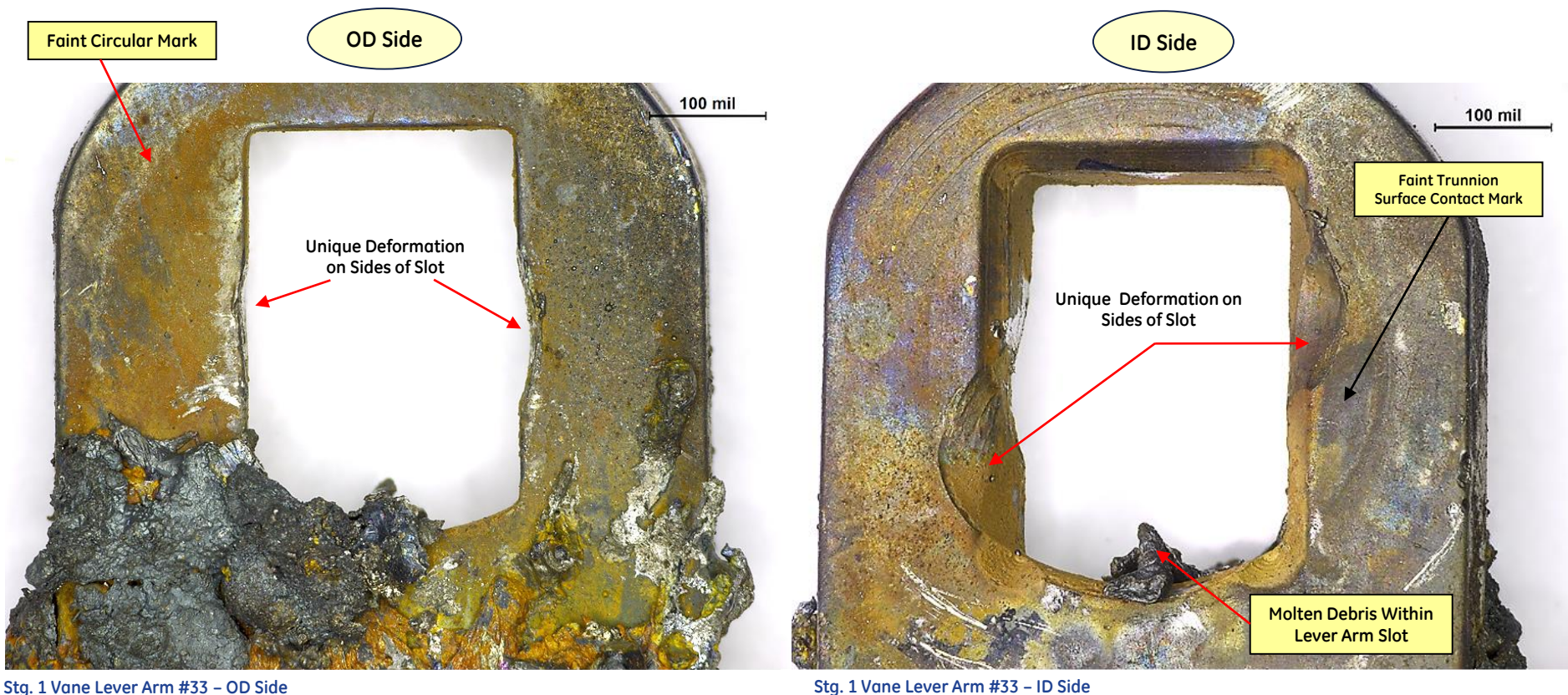


Figure 22. Photographs documenting ID side condition of remaining Stg. 1 HPC lever arms from locations from locations #32, #33 and #34 in the uncleaned condition. Note unique deformation pattern within slot of lever arm #33 attributed to abnormal contact with trunnion D-head outboard surface .

CFM56-7B Lever Arm Locations #32, #33 and #34 - ESN 875-318

Side View From
OD Side
(Uncleaned)

- Rectangular Witness Mark Proper Contact With Stg. 1 Vane Trunnion D-Head Feature Within Lever Arm Slots #32 and 34
- Absence of Similar Rectangular Contact Pattern on Both Sides of Lever Arm Slot #33 - Accumulation of Engine Dirt Following Disengagement From Trunnion D-Head Feature

Rectangular Contact Pattern
With Vane Trunnion

#32

100 mil

Absence Rectangular Contact
Pattern With Vane Trunnion

#33

100 mil

Rectangular Contact Pattern
With Vane Trunnion

#34

100 mil

Stg. 1 Vane Lever Arm #32 – Slot Contact Pattern

Stg. 1 Vane Lever Arm #33 – Slot Contact Pattern

Stg. 1 Vane Lever Arm #34 – Slot Contact Pattern

Rectangular Contact Pattern
With Vane Trunnion

#32

100 mil

Absence Rectangular Contact
Pattern With Vane Trunnion

#33

100 mil

Rectangular Contact Pattern
With Vane Trunnion

#34

100 mil

Stg. 1 Vane Lever Arm #32 – Slot Contact Pattern

Stg. 1 Vane Lever Arm #33 – Slot Contact Pattern

Stg. 1 Vane Lever Arm #34 – Slot Contact Pattern

Figure 23. Photographs documenting inside lever arm slot contact patterns for Stg. 1 HPC locations #32, #33 and #34 in the uncleaned condition. Absence of rectangular contact marks observed at location #33.

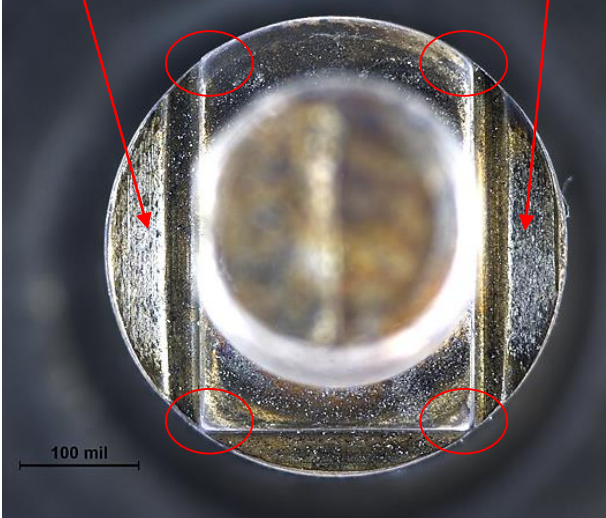
CFM56-7B Stg. 1 Vane Trunnion Locations #32, #33 and #34 - ESN 875-318

- Correct Contact Pattern With Mating Lever Arm Slots on Stg. 1 Vane Trunnion Surface for Locations #32 and #34 Observed in Uncleaned Condition – No Evidence of Deformation/Smearing Noted on Trunnion D-Head Corners Indicating Proper Assembly
- Similar Contact Pattern Difficult to Distinguish Due to Surfaces Covered With Engine Dirt at Location #33 Indicating Lever Arm Not Properly Seated For Some Period of Time During Engine Operation – Also Note Deformation/Smearing Damage Noted on Trunnion D-Head Corners Consistent With Abnormal Contact With Lever Arm

#32

Correct Contact on Stg. 1 Vane Trunnion Surface

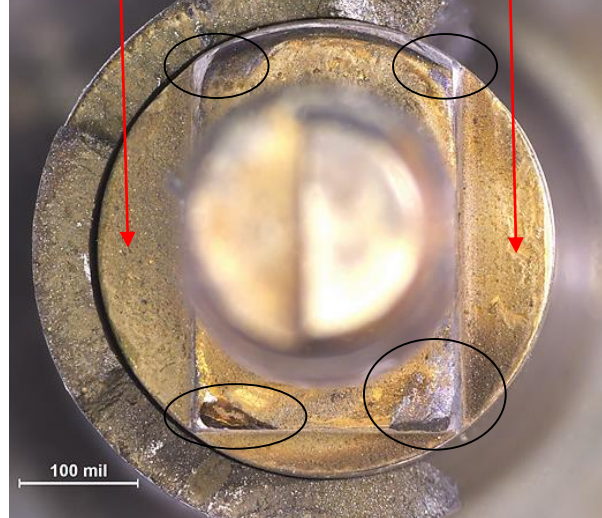
Correct Contact on Stg. 1 Vane Trunnion Surface



#33

Surface Covered Engine Dirt

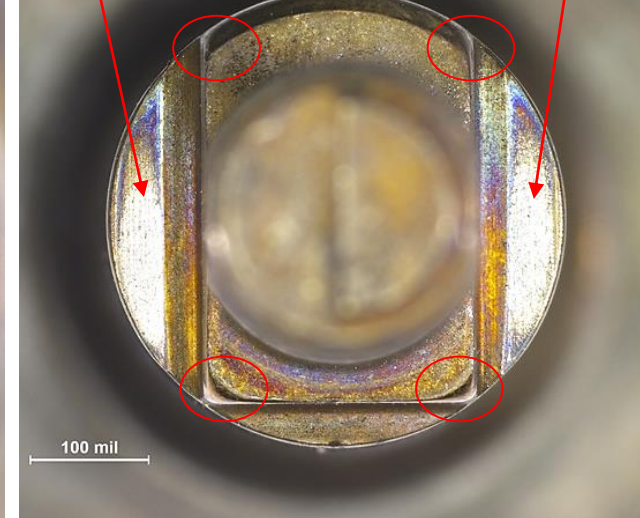
Surface Covered Engine Dirt



#34

Correct Contact on Stg. 1 Vane Trunnion Surface

Correct Contact on Stg. 1 Vane Trunnion Surface



Stg. 1 Vane Trunnion #32

Stg. 1 Vane Trunnion #33

Stg. 1 Vane Trunnion #34



No Deformation Noted At D-Head Corners



Deformation Noted At D-Head Corners

Uncleaned Condition

Figure 24. Photographs documenting Stg. 1 HPC trunnion contact patterns for locations #32, #33 and #34 in the uncleaned condition. Note absence of contact pattern at location #33.

CFM56-7B Stg. 1 Vane Trunnion Locations #32 and #33 - ESN 875-318

- Shiny Contact on Face Stg. 1 Vanes Trunnion #32 Attributed to Proper Contact With Mating Lever Arm Following Cleaning
- Faint, Heat Tinted, Similarly Shaped Contact on Trunnion Face Observed on Stg. 1 Vane Trunnion #33 Implying Lever Arm Properly Installed at Some Point Following Cleaning

Cleaned Condition

#32

Lever Arm Contact

Lever Arm Contact

100 mil

Stg. 1 Vane Trunnion #32

#33

Similarly Shaped
Discolored Witness Mark

Similarly Shaped
Discolored Witness Mark

100 mil

Stg. 1 Vane Trunnion #33

Figure 25. Photographs documenting Stg. 1 HPC trunnion contact patterns for locations #32 and #33 in the cleaned condition. Faint, similarly shaped contact pattern now observed at location #33 indicating properly installed lever arm at some point.

CFM56-7B Stg. 1 Vane Trunnion Locations #32 and #33 - ESN 875-318

- Similar Light Deformation Observed at Edge of Trunnion Face For Both Stg. 1 Vane Trunnion #32 and #33 Implying Lever Arm #33 Properly Installed at Some Point

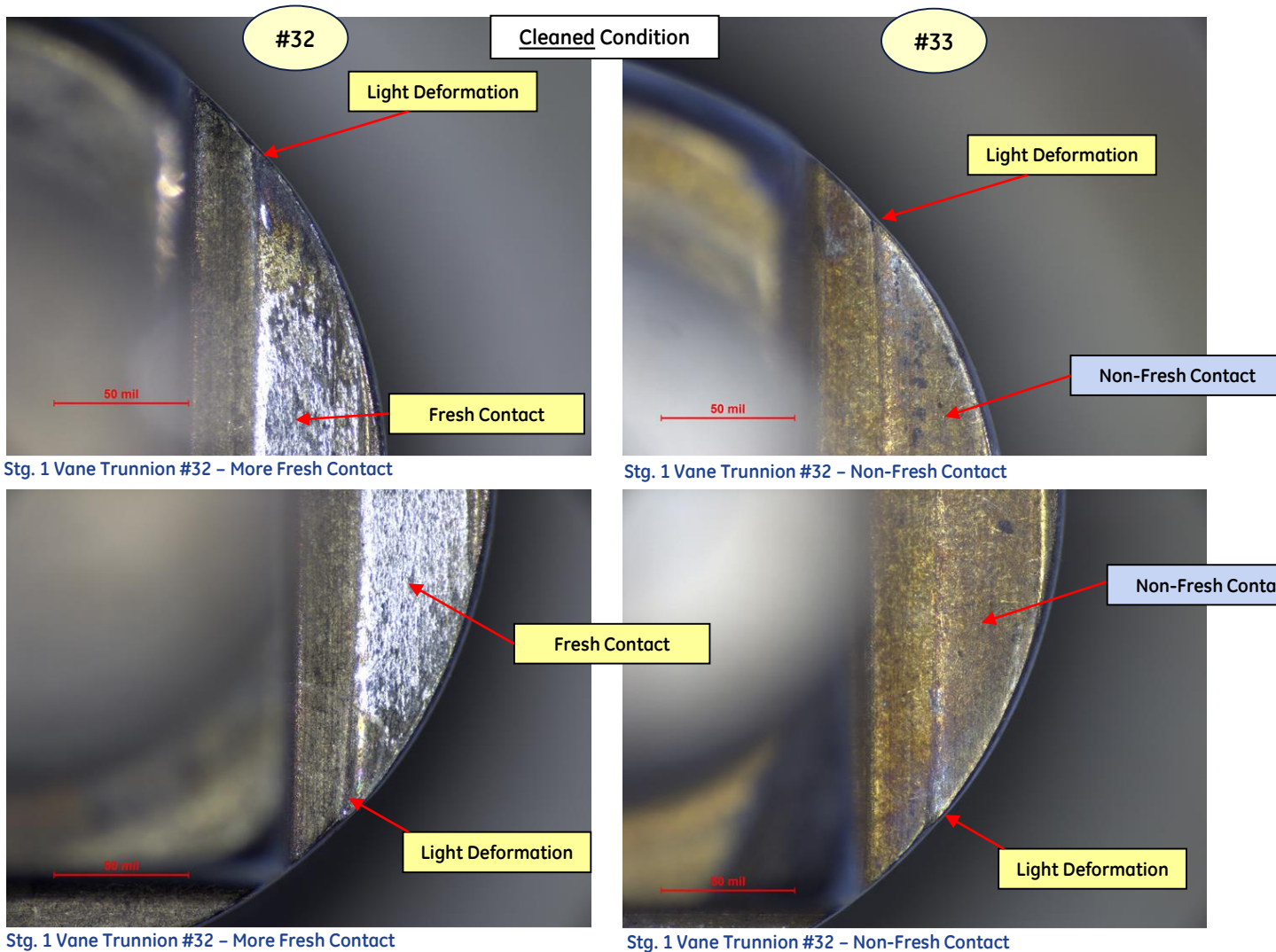


Figure 26. Photographs showing closer views comparing Stg. 1 HPC trunnion contact patterns at locations #32 and #33 in the cleaned condition. Faint, similarly shaped contact pattern now observed at location #33 indicating properly installed lever arm at some point.

CFM56-7B Stg. 1 Vane Trunnion Location #33 - ESN 875-318

- Uniform Engine Dirt Accumulation Present on Stg. 1 Vane Trunnion Threads at Location #33 Indicating Nut Missing During Engine Operation
- Uniform Engine Dirt Accumulation on Trunnion D-Head Surfaces at Location #33 Indicating Mating Lever Arm Slot Not Properly Seated During Engine Operation
- Deformed/Smeared Trunnion Corner and Lower Threads Attributed to Disengagement of Mating Lever Arm

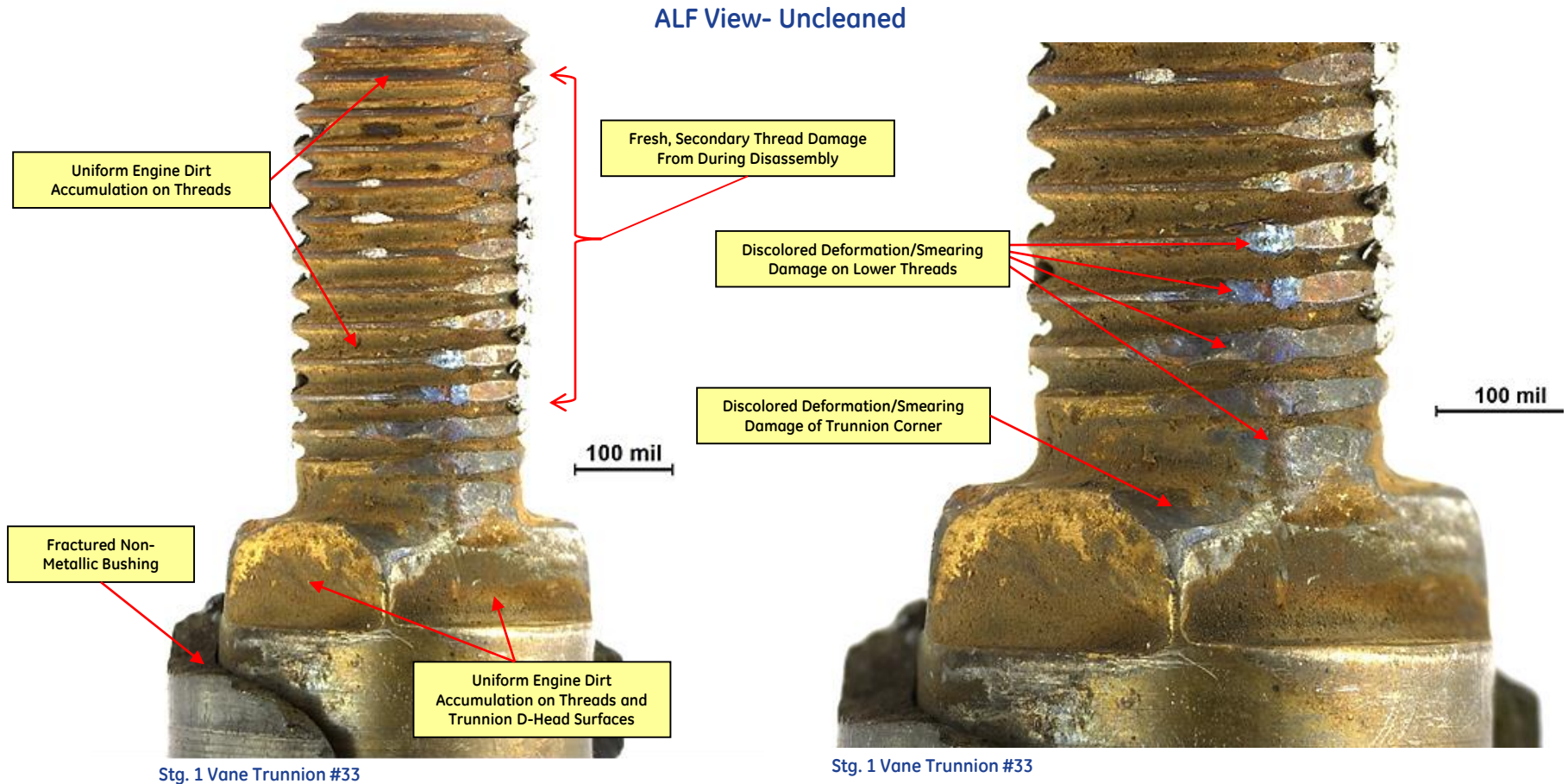


Figure 27. Photographs documenting thread condition of Stg. 1 HPC Trunnion #33 in the uncleaned condition.

CFM56-7B Stg. 1 Vane Trunnion Location #33 - ESN 875-318

- Opposite Side of Stg. 1 Vane Trunnion Surface for Locations #33 - Trunnion D-Head Corner Smearing

FLA View - Uncleaned

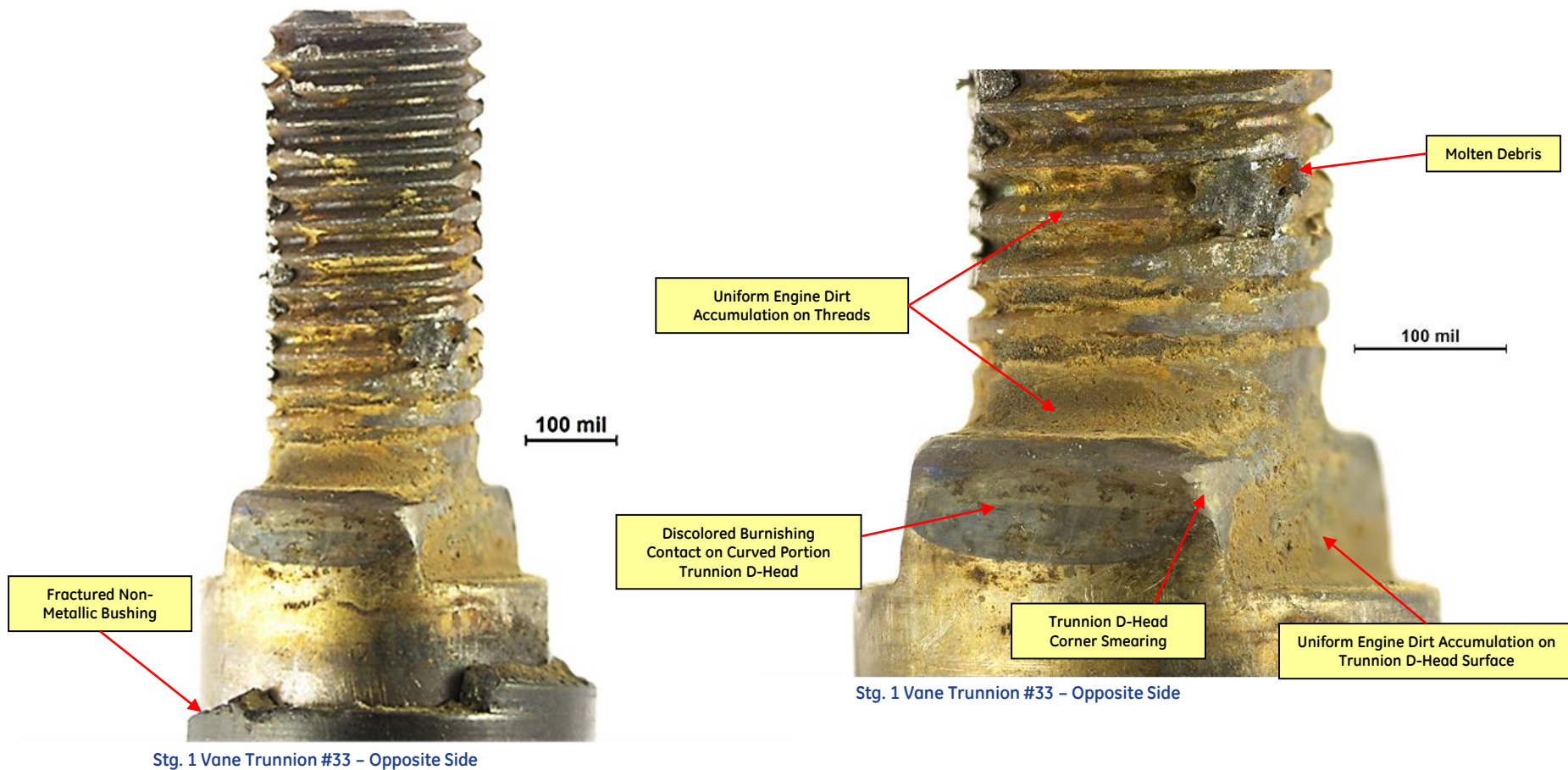


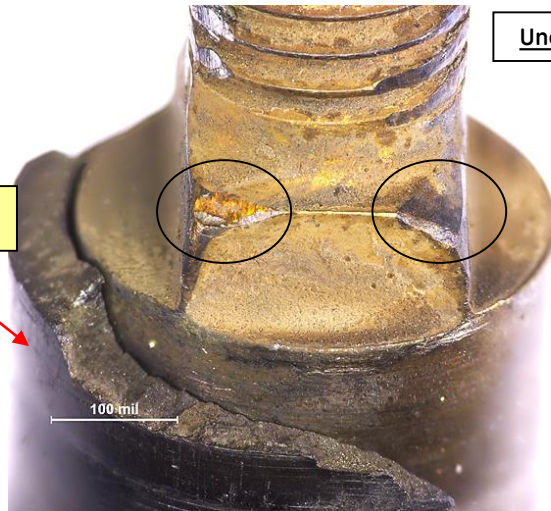
Figure 28. Photographs documenting thread condition of Stg. 1 HPC Trunnion #33 in the uncleaned condition (opposite side).

CFM56-7B Stg. 1 Vane Trunnion Location #33 - ESN 875-318

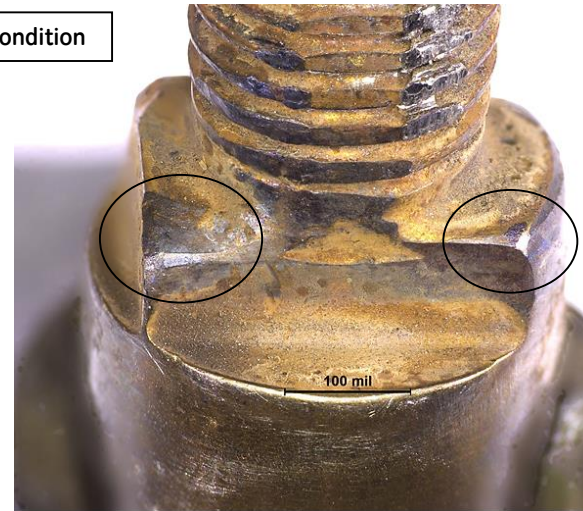
- Stg. 1 Vane Trunnion Location #33 D-Head Corner Deformation/Smearing Damage From Abnormal Contact With Mating Lever Arm

Uncleaned Condition

Fractured Non-Metallic Bushing



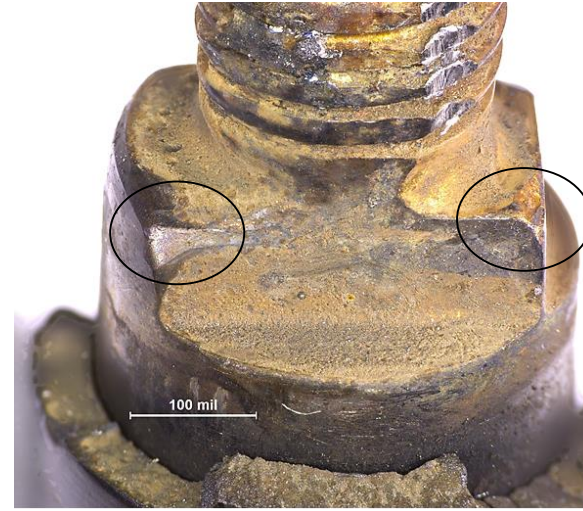
Stg. 1 Vane Trunnion #33 – Corner Damage



Stg. 1 Vane Trunnion #33 – Corner Damage



Stg. 1 Vane Trunnion #33 – Corner Damage



Stg. 1 Vane Trunnion #33 – Corner Damage

Figure 29. Photographs documenting Stg. 1 HPC Trunnion #33 corner damage in the uncleaned condition

CFM56-7B Stg. 1 Vane Trunnion Locations #32, #33 and #34 - ESN 875-318

- General Condition of Stg. 1 Vane Trunnion Threads

Uncleaned Condition

#32



Stg. 1 Vane Trunnion #32

#33



Stg. 1 Vane Trunnion #33

#34



Stg. 1 Vane Trunnion #34

Figure 30. Photographs comparing general condition of Stg. 1 HPC Trunnions #32, #33 and #34 in the uncleaned condition.

CFM56-7B Stg. 1 Vane Trunnion Locations #32, #33 and #34 - ESN 875-318

- General Condition of Stg. 1 Vane Trunnion Threads

Uncleaned Condition

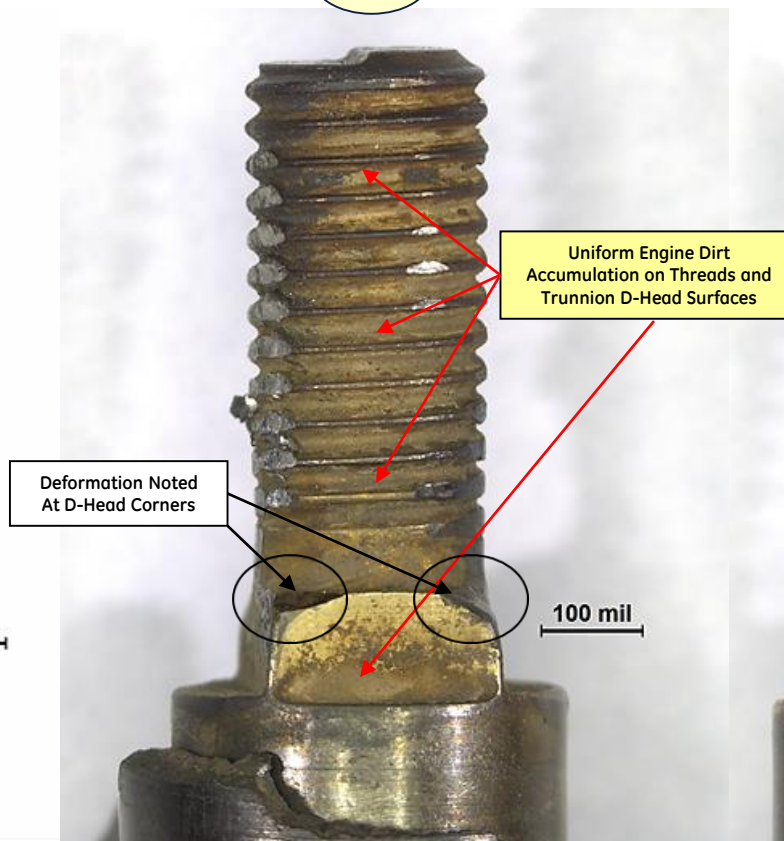
#32

#33

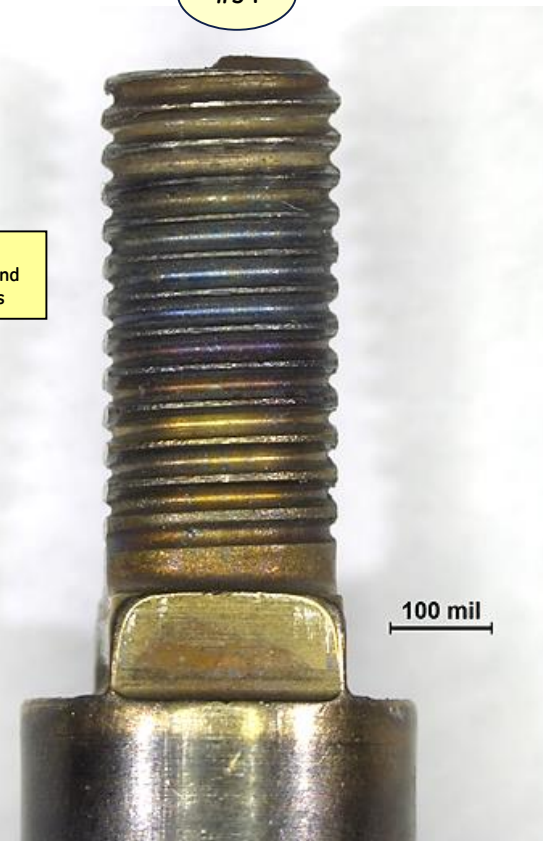
#34



Stg. 1 Vane Trunnion #32 – Opposite Side



Stg. 1 Vane Trunnion #33 – Opposite Side



Stg. 1 Vane Trunnion #34 – Opposite Side

Figure 31. Photographs comparing general condition of Stg. 1 HPC Trunnions #32, #33 and #34 in the uncleaned condition (opposite side).



imagination at work

FA Log No. 18712 – Final Report
Export Control: 9E991-NLR

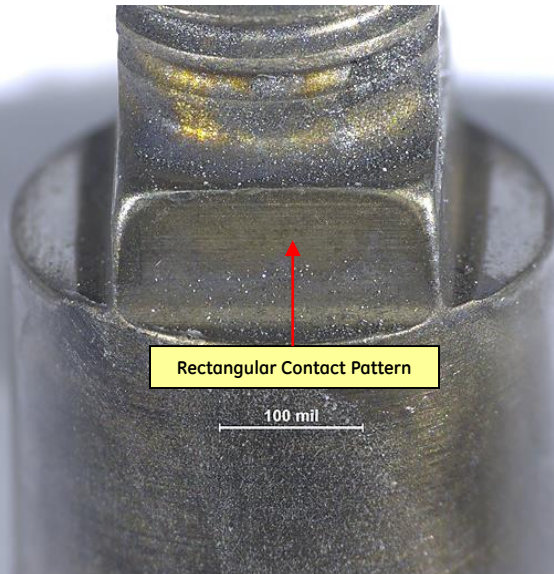
48 of 136
GE Aviation

CFM56-7B Stg. 1 Vane Trunnion Locations #32, #33 and #34 - ESN 875-318

- General Condition of Stg. 1 Vane Trunnion D-Head - Corner Deformation/Smearing Noted on Trunnion #33 Attributed to Abnormal Contact With Mating Lever Arm Contact During Engine Operation

Uncleaned Condition

#32

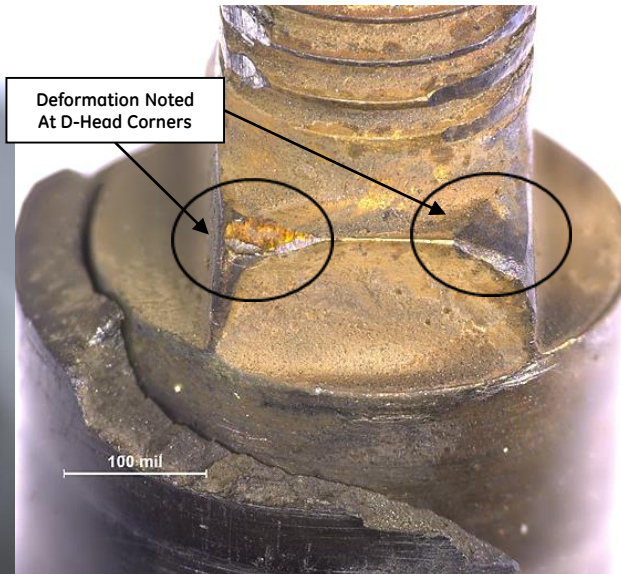


Rectangular Contact Pattern

100 mil

Stg. 1 Vane Trunnion #32

#33

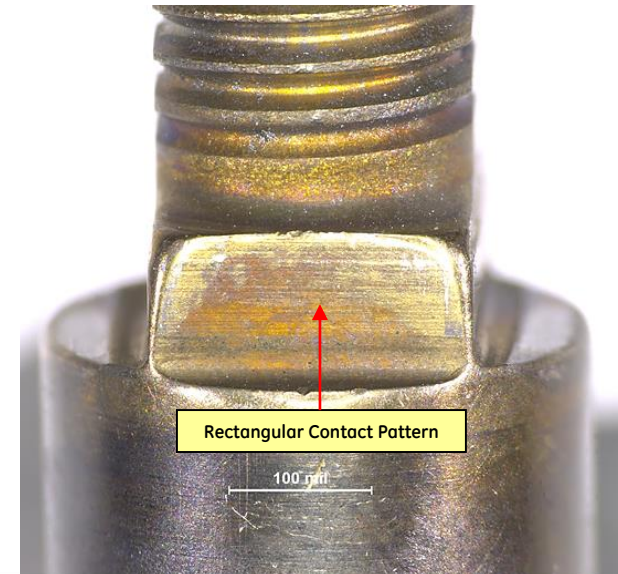


Deformation Noted
At D-Head Corners

100 mil

Stg. 1 Vane Trunnion #33

#34



Rectangular Contact Pattern

100 mil

Stg. 1 Vane Trunnion #34

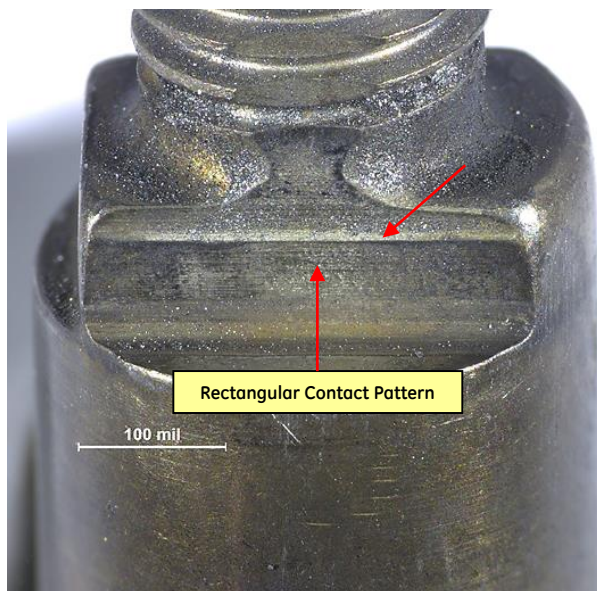
Figure 32. Photographs comparing Stg. 1 HPC Trunnions #32, #33 and #34 D-head corners and contact faces in the uncleaned condition.

CFM56-7B Stg. 1 Vane Trunnion Locations #32, #33 and #34 - ESN 875-318

- General Condition of Stg. 1 Vane Trunnion D-Head - Corner Deformation/Smearing Noted on Trunnion #33 Attributed to Abnormal Contact With Mating Lever Arm During Engine Operation

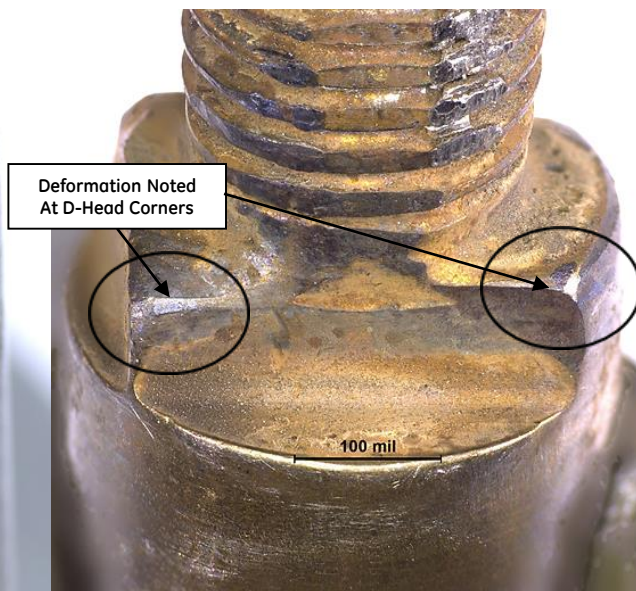
Uncleaned Condition

#32



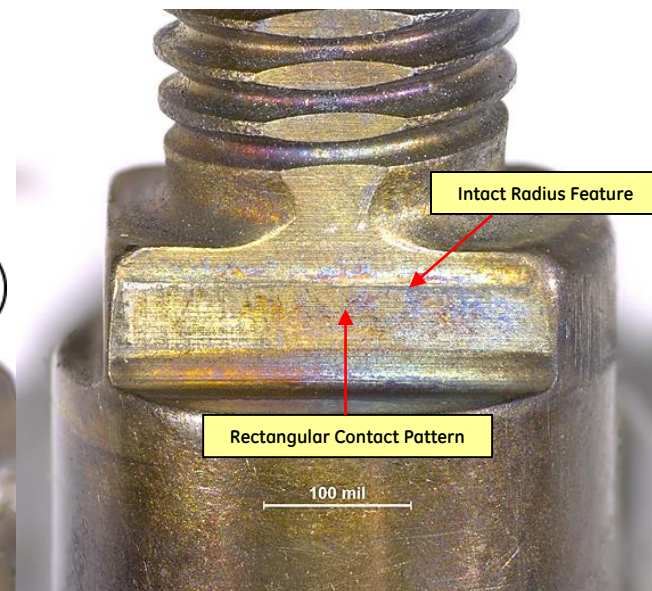
Stg. 1 Vane Trunnion #32

#33



Stg. 1 Vane Trunnion #33

#34



Stg. 1 Vane Trunnion #34

Figure 33. Photographs documenting comparing general condition of Stg. 1 HPC Trunnions #32, #33 and #34 in the uncleaned condition (opposite side).

CFM56-7B Stg. 1 Vane Trunnion Locations #32, #33 and #34 - ESN 875-318

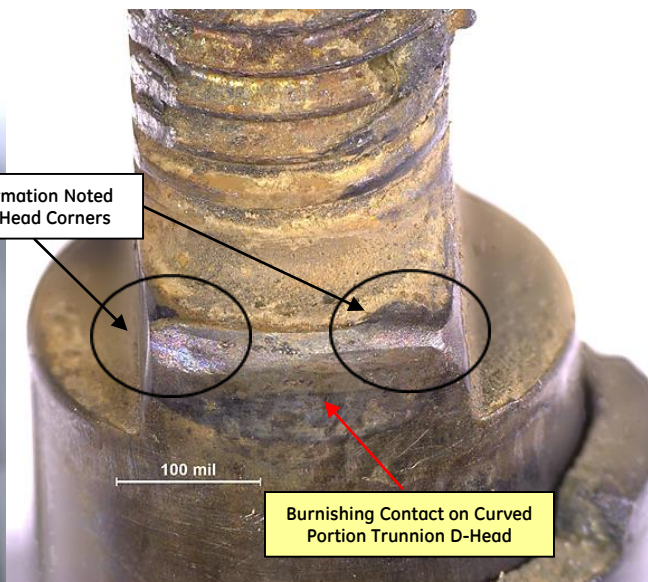
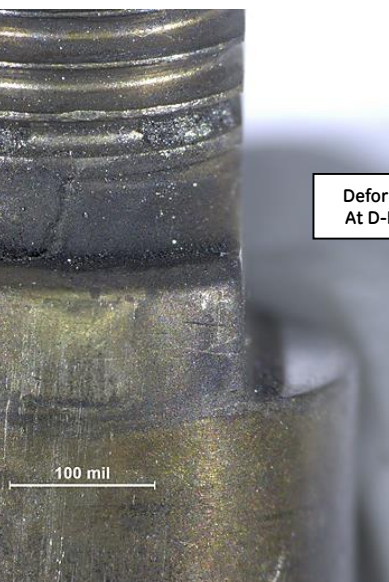
- General Condition of Stg. 1 Vane Trunnion D-Head - Corner Deformation/Smearing Noted on Trunnion #33 Attributed to Abnormal Contact With Mating Lever Arm During Engine Operation

Uncleaned Condition

#32

#33

#34



Stg. 1 Vane Trunnion #32

Stg. 1 Vane Trunnion #33

Stg. 1 Vane Trunnion #34

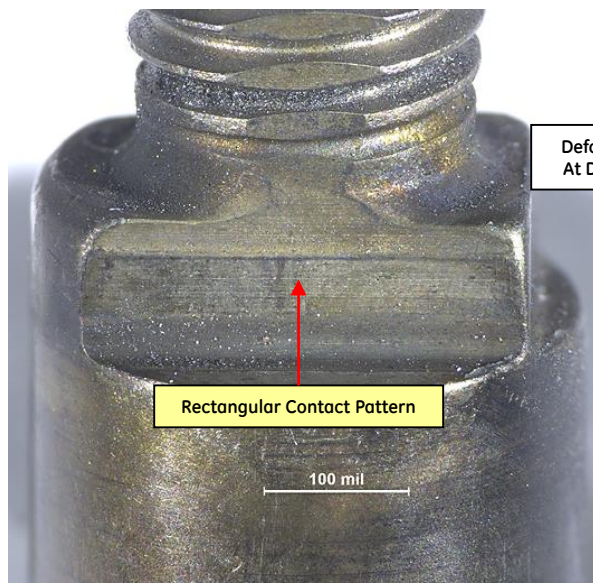
Figure 34. Photographs documenting comparing general condition of Stg. 1 HPC Trunnions #32, #33 and #34 in the uncleaned condition (opposite side).

CFM56-7B Stg. 1 Vane Trunnion Locations #32, #33 and #34 - ESN 875-318

- General Condition of Stg. 1 Vane Trunnion D-Head - Corner Deformation/Smearing Noted on Trunnion #33 Attributed to Abnormal Contact With Mating Lever Arm During Engine Operation

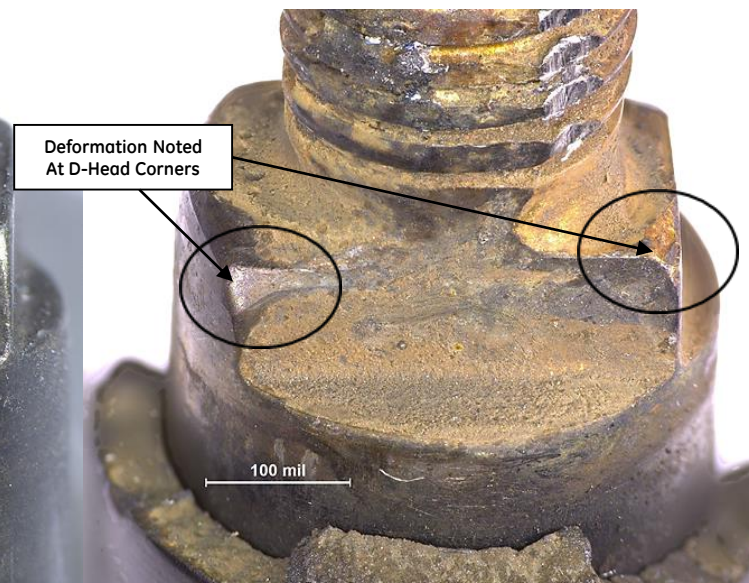
Uncleaned Condition

#32



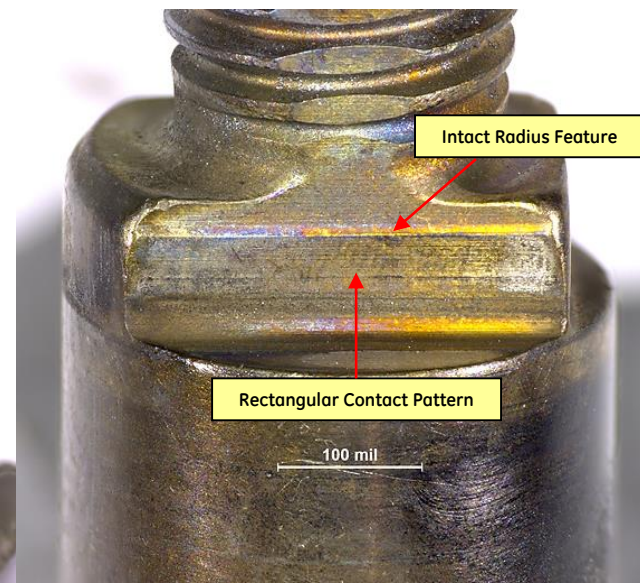
Stg. 1 Vane Trunnion #32

#33



Stg. 1 Vane Trunnion #33

#34



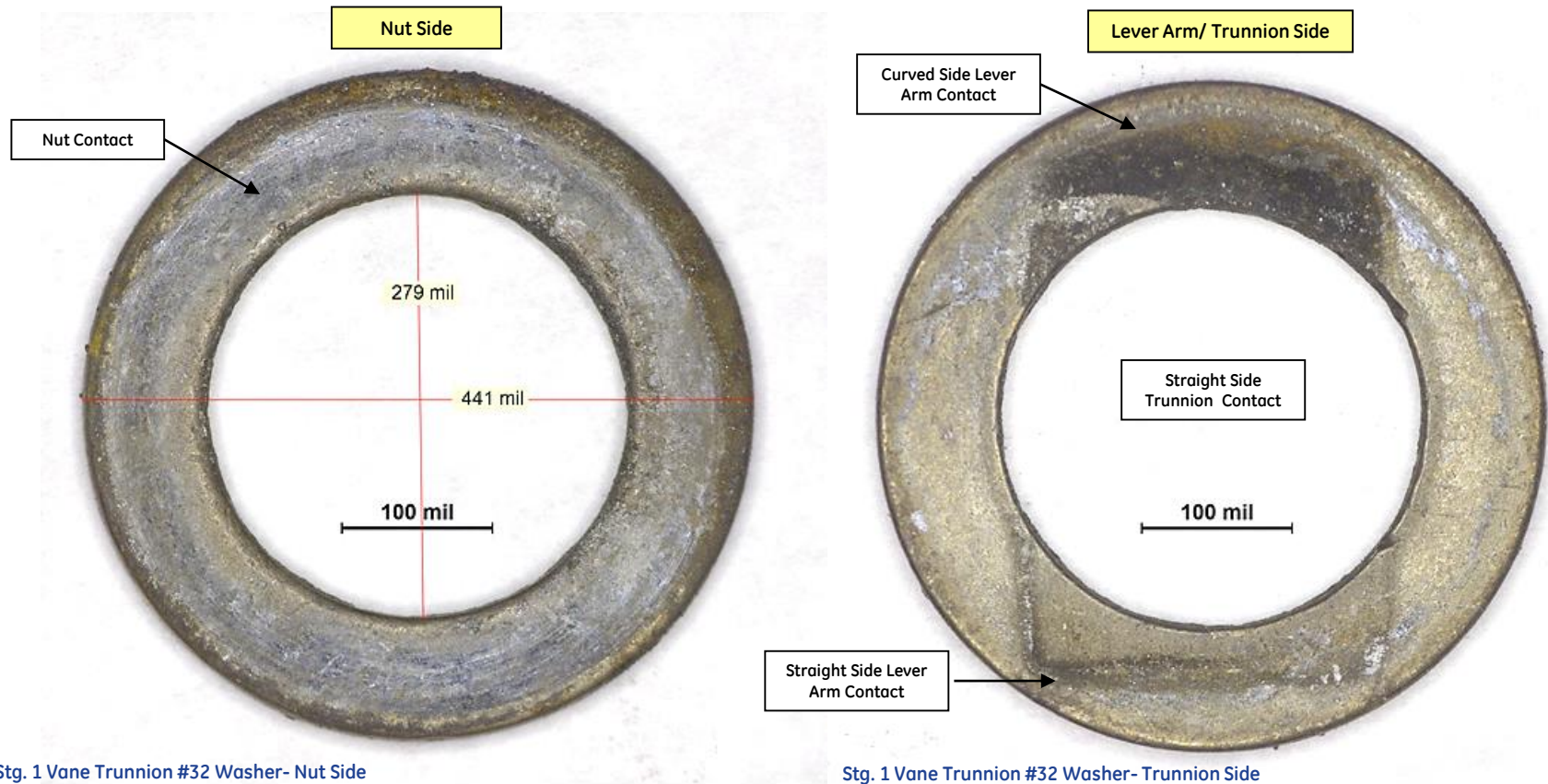
Stg. 1 Vane Trunnion #34

Figure 35. Photographs documenting comparing general condition of Stg. 1 HPC Trunnions #32, #33 and #34 in the uncleaned condition (opposite side).

CFM56-7B Stg. 1 Vane Trunnion Washer Location #32 - ESN 875-318

- General Condition of Stg. 1 Vane Trunnion #32 Washer – Trunnion Witness Marks From Contact With Retaining Nut and Lever Arm Face

Uncleaned Condition



Stg. 1 Vane Trunnion #32 Washer- Nut Side

Stg. 1 Vane Trunnion #32 Washer- Trunnion Side

Figure 36. Photographs documenting contact patterns present on both sides of washer from Stg. 1 HPC Trunnions #32 in the uncleaned condition.

CFM56-7B Stg. 1 Vane Trunnion Washer Location #34 - ESN 875-318

- General Condition of Stg. 1 Vane Trunnion #34 Washer – Trunnion Witness Marks From Contact With Retaining Nut and Lever Arm Face



Figure 37. Photographs documenting contact patterns present on both sides of washer from Stg. 1 HPC Trunnions #34 in the uncleaned condition.

CFM56-7B Stg. 1 Vane Trunnion Locations #32 and #33 - ESN 875-318

- Thread Comparison Between Stg. 1 Vane Trunnion #32 With Nut and Stg. 1 Vane Trunnion #33 Without Nut (No Cleaning)
- Circumferential Contact Marks Observed on Loaded Side Thread Flanks on Trunnion #32 Consistent With Nut Contact
- Debris Obscured Any Evidence of Loaded Side Thread Flank Contact on Trunnion #33

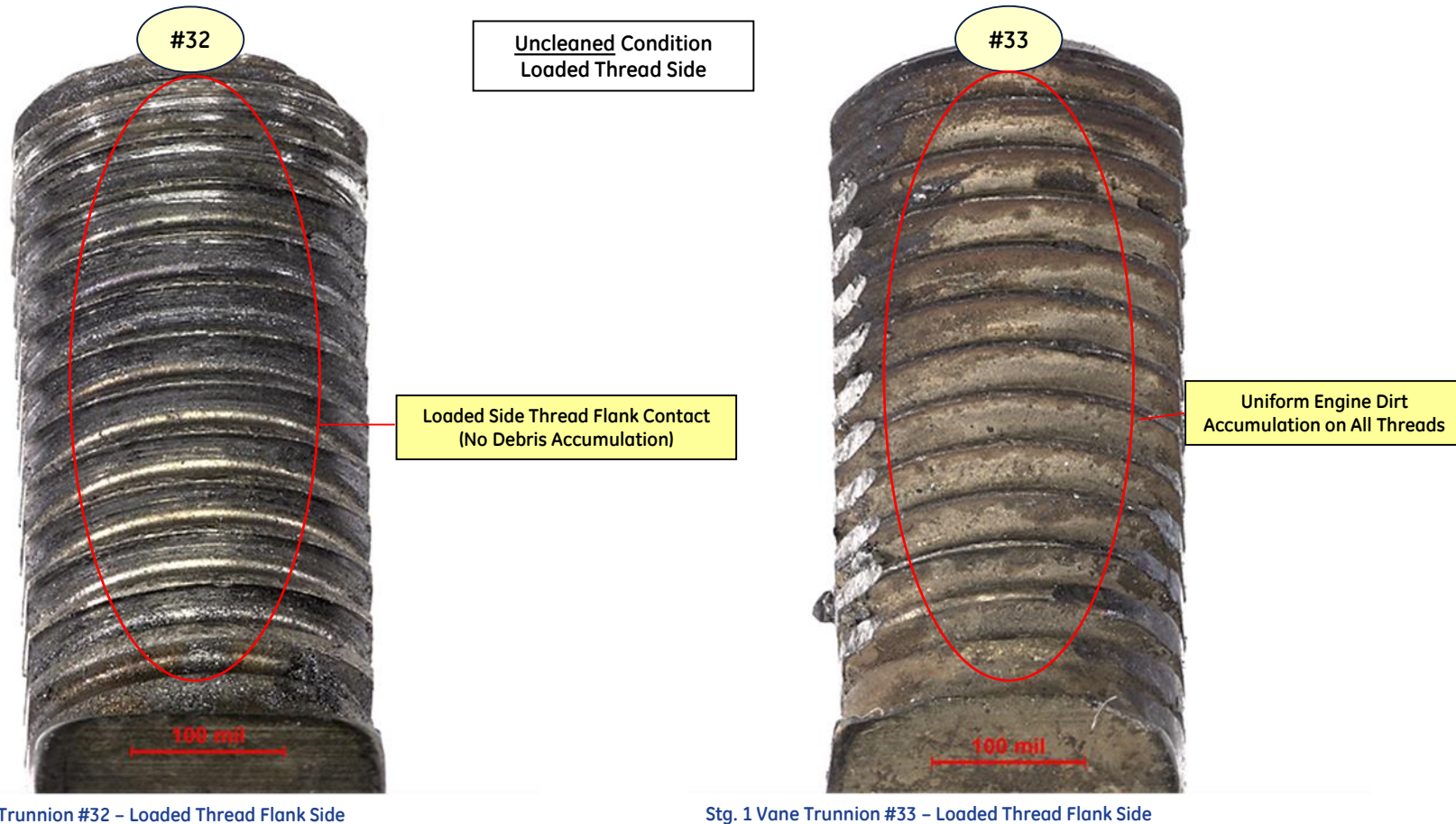


Figure 38. Photographs comparing loaded thread side of Stg. 1 HPC Trunnions #32 and #33 in the uncleaned condition.

CFM56-7B Stg. 1 Vane Trunnion Locations #32 and #33 - ESN 875-318

- Thread Comparison Between Stg. 1 Vane Trunnion #32 With Nut and Stg. 1 Vane Trunnion #33 Without Nut
- Circumferential Contact Marks Observed on Lower Loaded Side Thread Flanks on Trunnion #32 Consistent With Nut Contact
- Debris Obscured Any Evidence of Lower Loaded Side Thread Flank Contact on Trunnion #33

#32

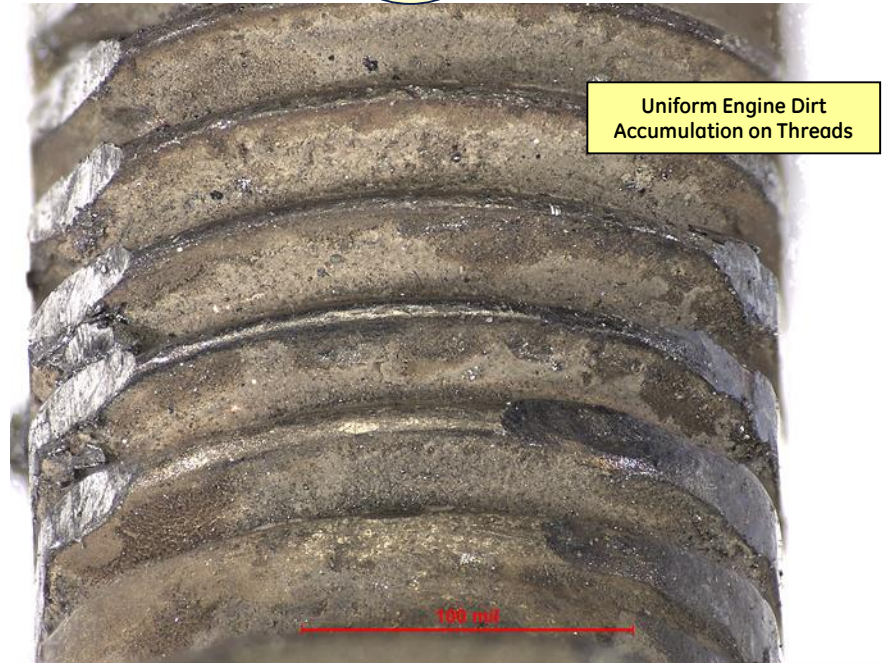
Uncleaned Condition
Loaded Thread Side
Lower Threads



Stg. 1 Vane Trunnion #32 - Loaded Thread Flank Side - Lower Threads

#33

Uniform Engine Dirt
Accumulation on Threads



Stg. 1 Vane Trunnion #33 - Loaded Thread Flank Side - Lower Threads

Figure 39. Photographs showing closer views comparing loaded thread side of Stg. 1 HPC Trunnions #32 and #33 in the uncleaned condition (lower threads).

CFM56-7B Stg. 1 Vane Trunnion Locations #32 and #33 - ESN 875-318

- Thread Comparison Between Stg. 1 Vane Trunnion #32 With Nut and Stg. 1 Vane Trunnion #33 Without Nut
- Circumferential Contact Marks Observed on Upper Loaded Side Thread Flanks on Trunnion #32 Consistent With Nut Contact
- Debris Obscured Any Evidence of Upper Loaded Side Thread Flank Contact on Trunnion #33

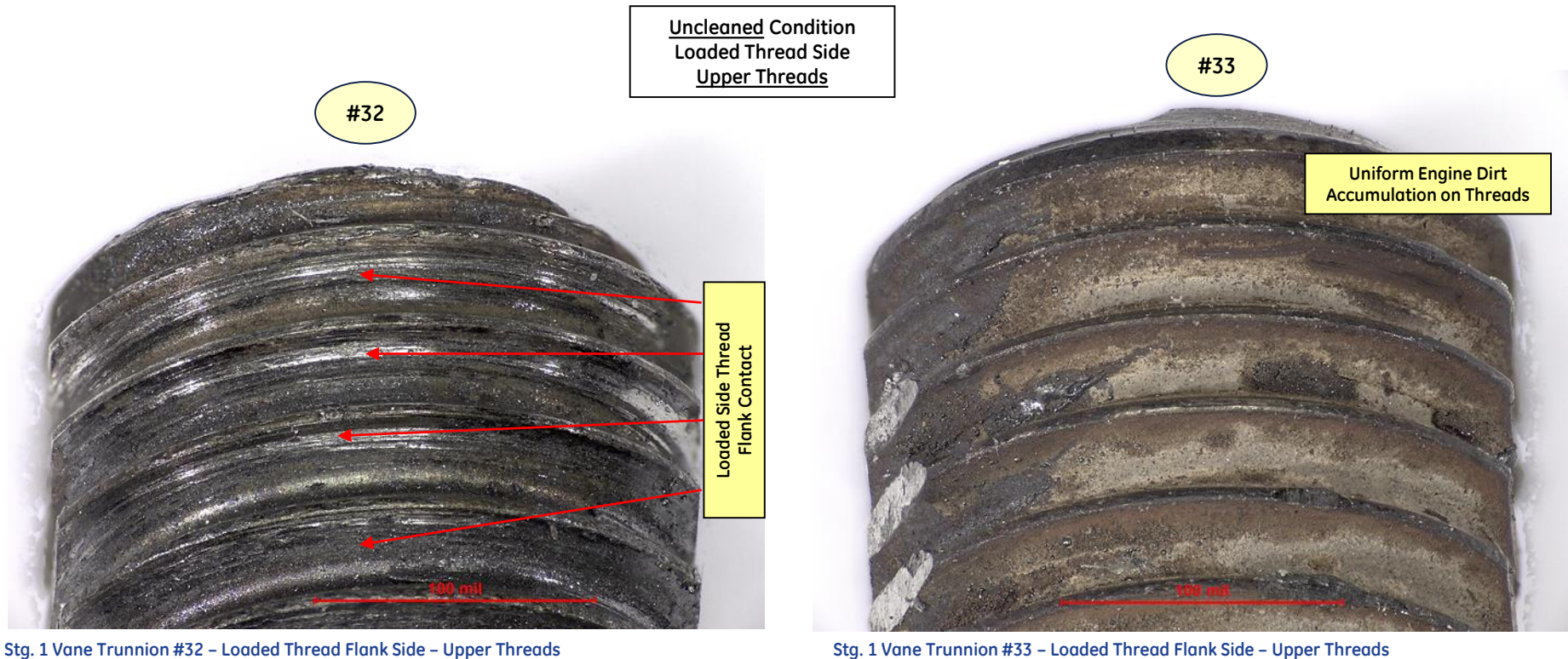


Figure 40. Photographs showing closer views comparing loaded thread side of Stg. 1 HPC Trunnions #32 and #33 in the uncleaned condition (upper threads).

CFM56-7B Stg. 1 Vane Trunnion Locations #32 and #33 - ESN 875-318

- Thread Comparison Between Stg. 1 Vane Trunnion #32 With Nut and Stg. 1 Vane Trunnion #33 Without Nut (Cleaned)
- Circumferential Contact Marks Observed on Loaded Side Thread Flanks on Trunnion #32 Consistent With Nut Contact
- Removal of Debris Revealed Visual Evidence of Circumferential Contact Marks on Loaded Thread Flanks on Trunnion #33 Implying Retaining Nut Had Been Run Down Threads at Some Point

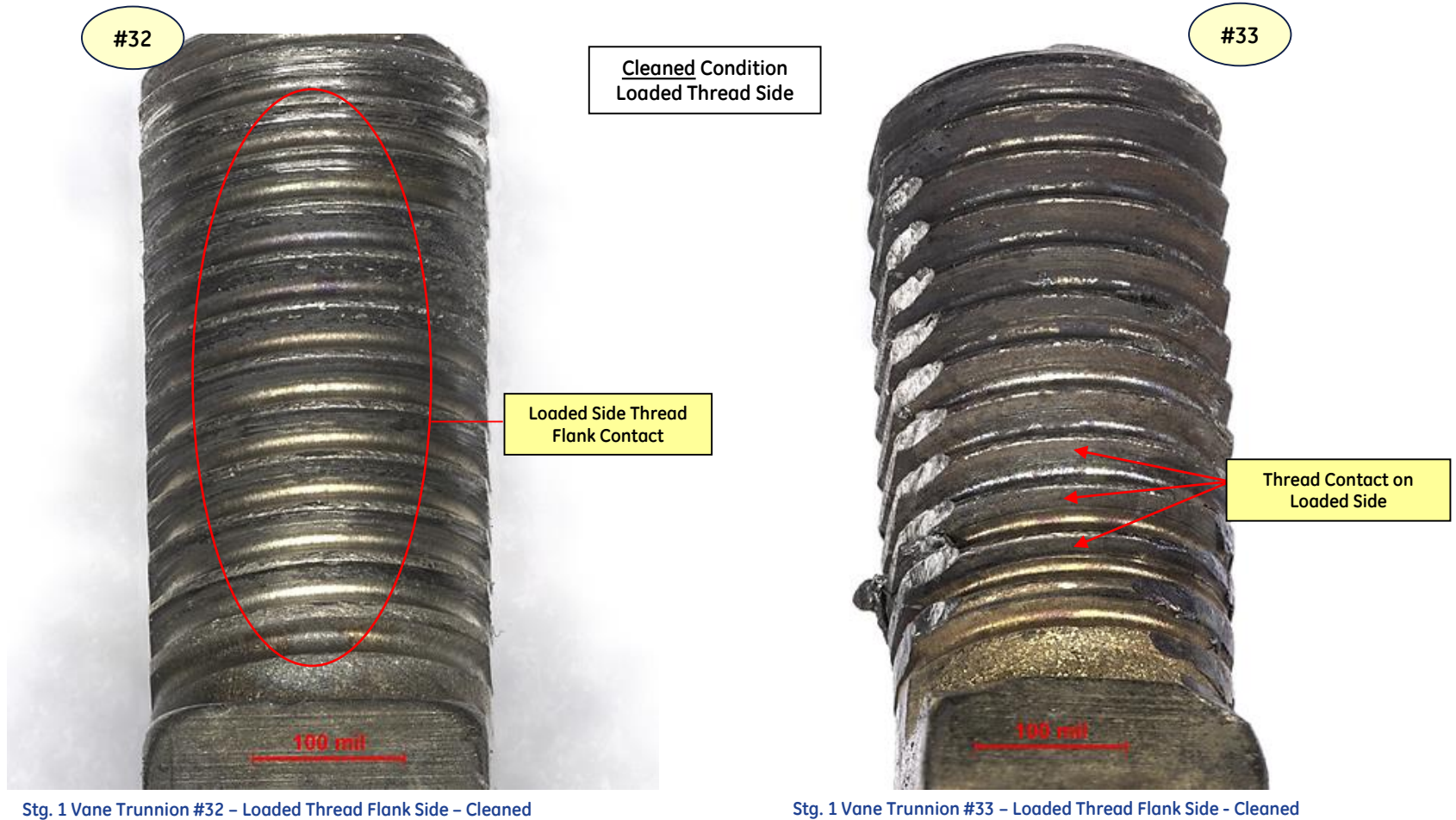


Figure 41. Photographs comparing loaded thread side of Stg. 1 HPC Trunnions #32 and #33 in the cleaned condition.

CFM56-7B Stg. 1 Vane Trunnion Locations #32 and #33 - ESN 875-318

- Thread Comparison Between Stg. 1 Vane Trunnion #32 With Nut and Stg. 1 Vane Trunnion #33 Without Nut (Cleaned)
- Circumferential Contact Marks Observed on Loaded Side Thread Flanks on Trunnion #32 Consistent With Nut Contact
- Removal of Debris Revealed Visual Evidence of Circumferential Contact Marks on Loaded Thread Flanks on Trunnion #33 Implying Retaining Nut Had Been Run Down Threads at Some Point

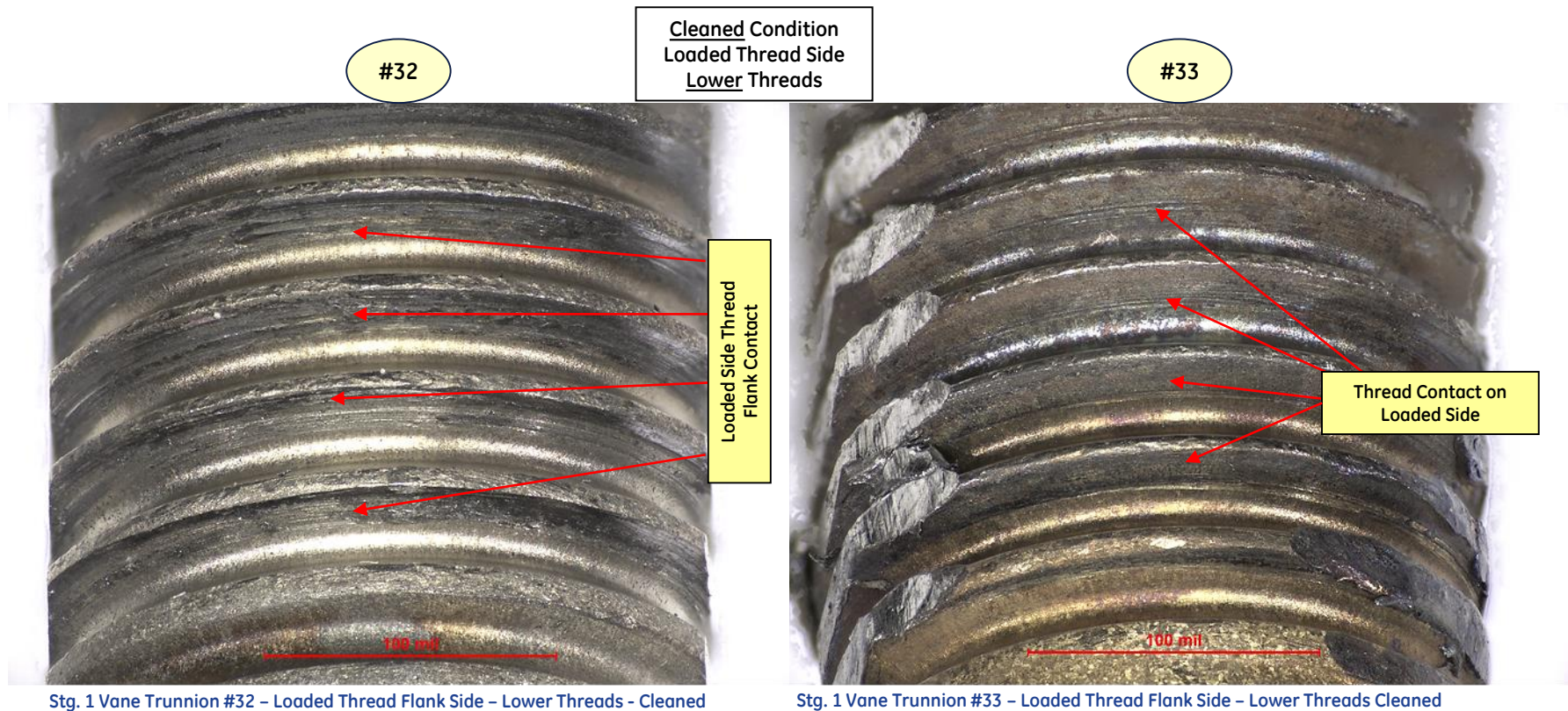


Figure 42. Photographs showing closer views comparing loaded thread side of Stg. 1 HPC Trunnions #32 and #33 in the cleaned condition (lower threads).

CFM56-7B Stg. 1 Vane Trunnion Locations #32 and #33 - ESN 875-318

- Thread Comparison Between Stg. 1 Vane Trunnion #32 With Nut and Stg. 1 Vane Trunnion #33 Without Nut (Cleaned)
- Circumferential Contact Marks Observed on Loaded Side Thread Flanks on Trunnion #32 Consistent With Nut Contact
- Removal of Debris Revealed Visual Evidence of Circumferential Contact Marks on Loaded Thread Flanks on Trunnion #33 Implying Retaining Nut Had Been Run Down Threads at Some Point

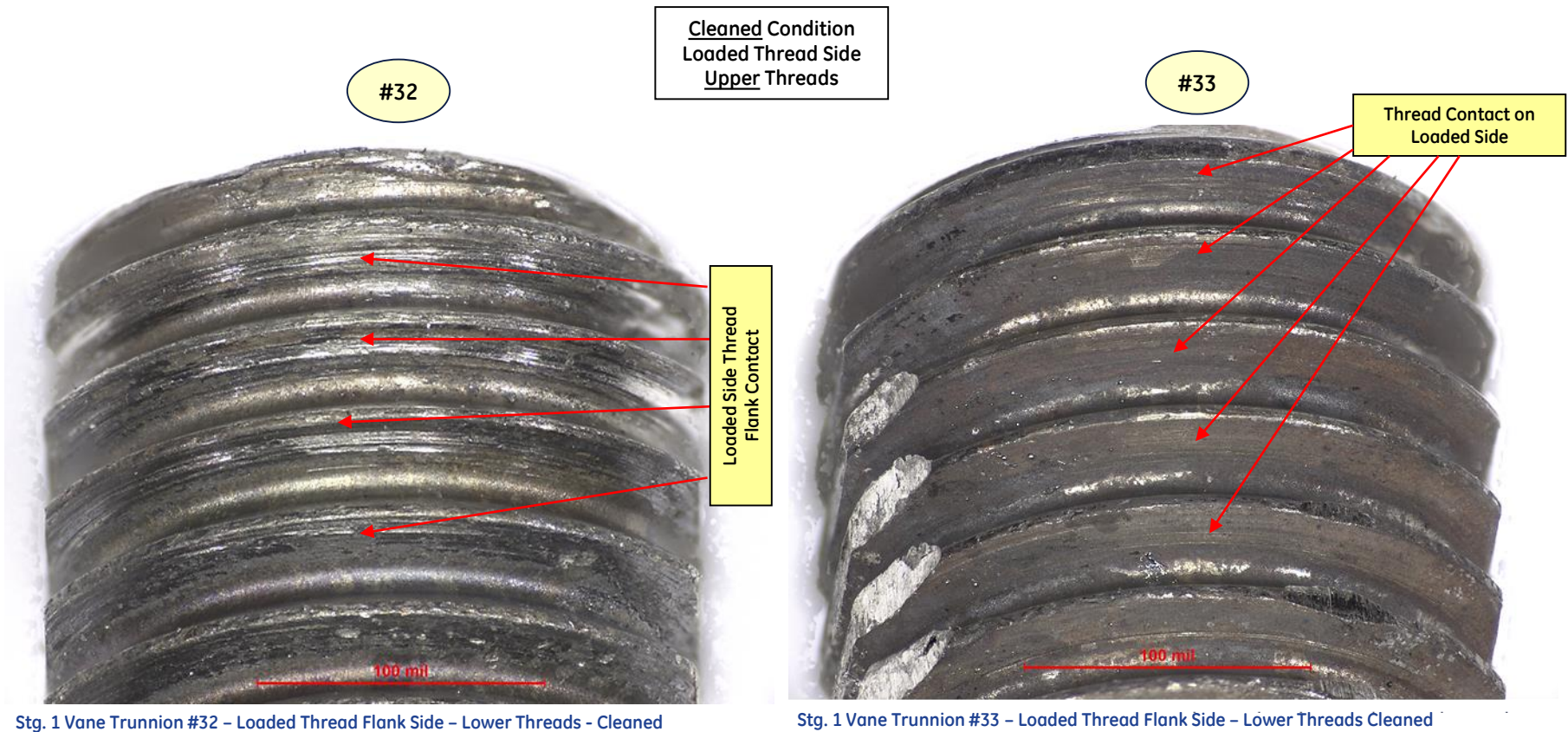


Figure 43. Photographs showing closer views comparing loaded thread side of Stg. 1 HPC Trunnions #32 and #33 in the cleaned condition (upper threads).

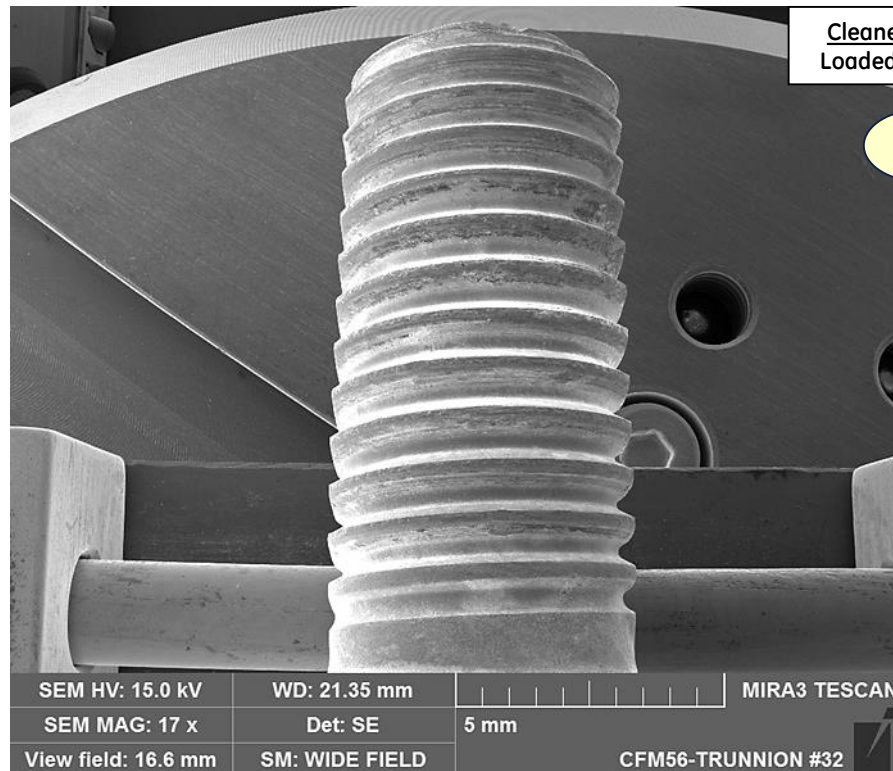
CFM56-7B Stg. 1 Vane Trunnion Location #32 - ESN 875-318

- Loaded Side Thread Flank Contact With Nut Observed on Stg. 1 Vane Trunnion #32

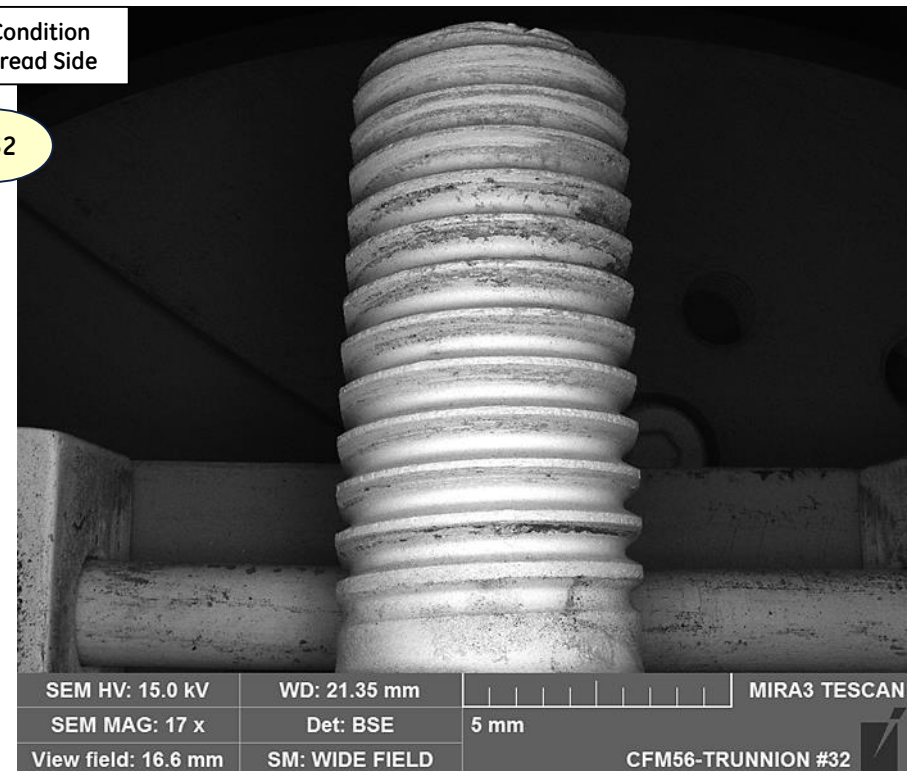
Stg. 1 Vane (P/N P241P01):
Nut (P/N J626P04)

C50TF20 CL-A, CL-B
AMS 5737

A286
A286 (Dry Film Lubricated Self-Locking Nut)



Stg. 1 Vane Trunnion #32 – Threads – SEI



Stg. 1 Vane Trunnion #32 – Threads – BEI

Figure 44. SEM secondary (SEI) and backscatter (BEI) images documenting Stg. 1 HPC Trunnion #32 threads in the cleaned condition.

CFM56-7B Stg. 1 Vane Trunnion Location #32 - ESN 875-318

- Circumferential Loaded Side Thread Flank Contact Observed on Lower Threads of Stg. 1 Vane Trunnion #32 Considered Consistent With Nut Contact

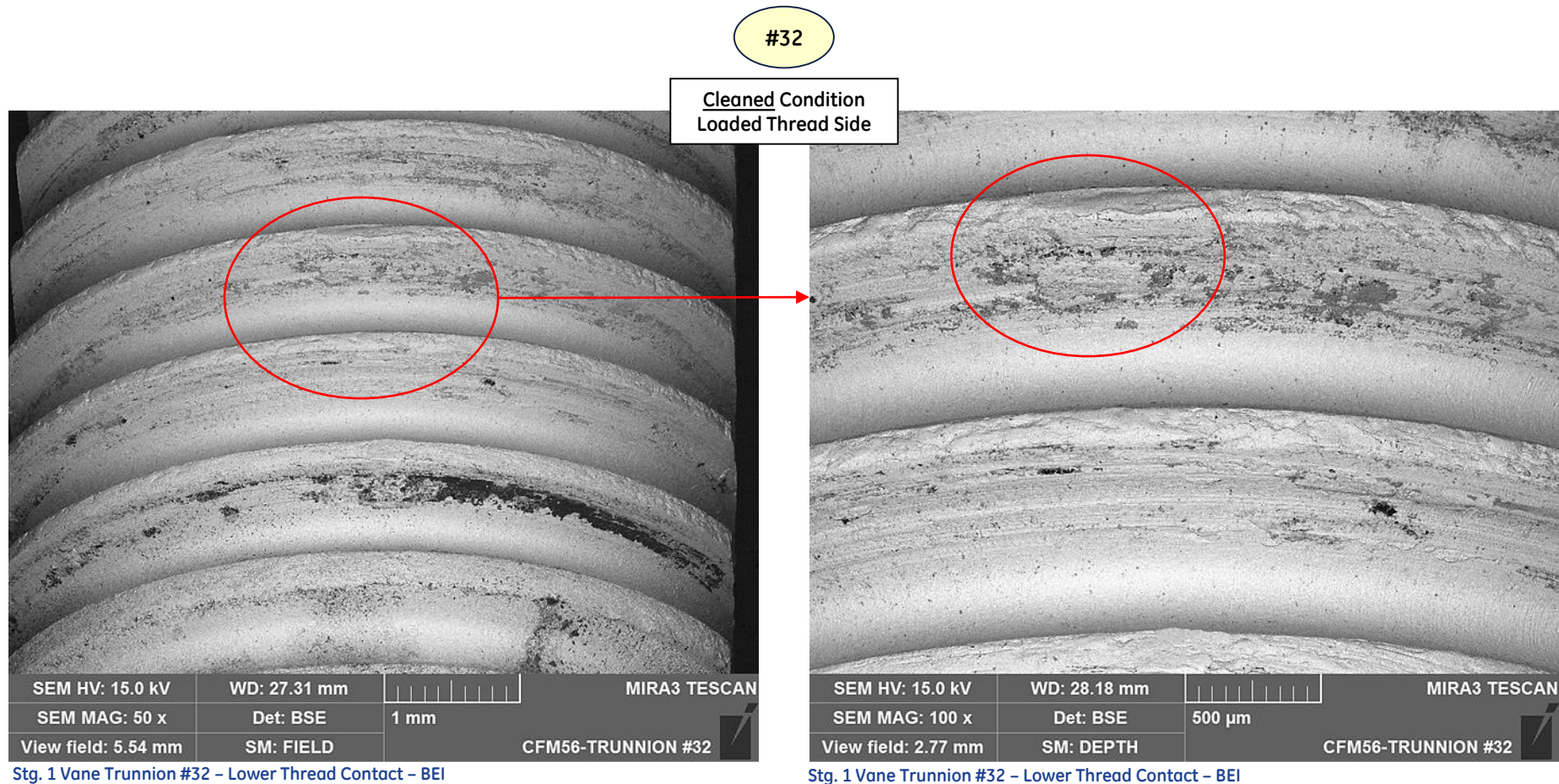


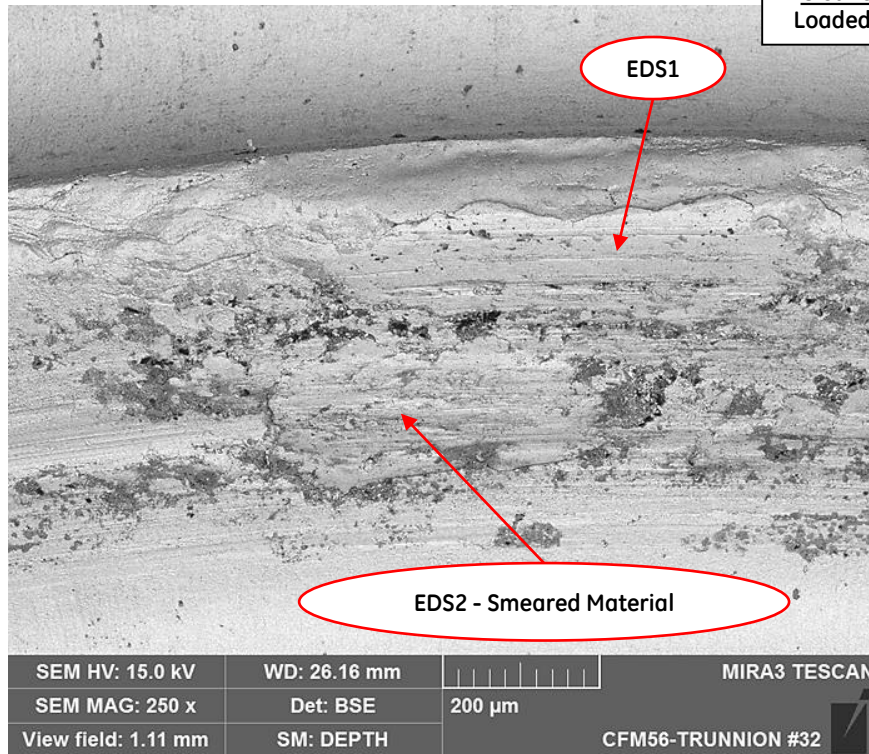
Figure 45. SEM backscatter (BEI) images documenting Stg. 1 HPC Trunnion #32 threads in the cleaned condition (lower threads).

CFM56-7B Stg. 1 Vane Trunnion Locations #32 - ESN 875-318

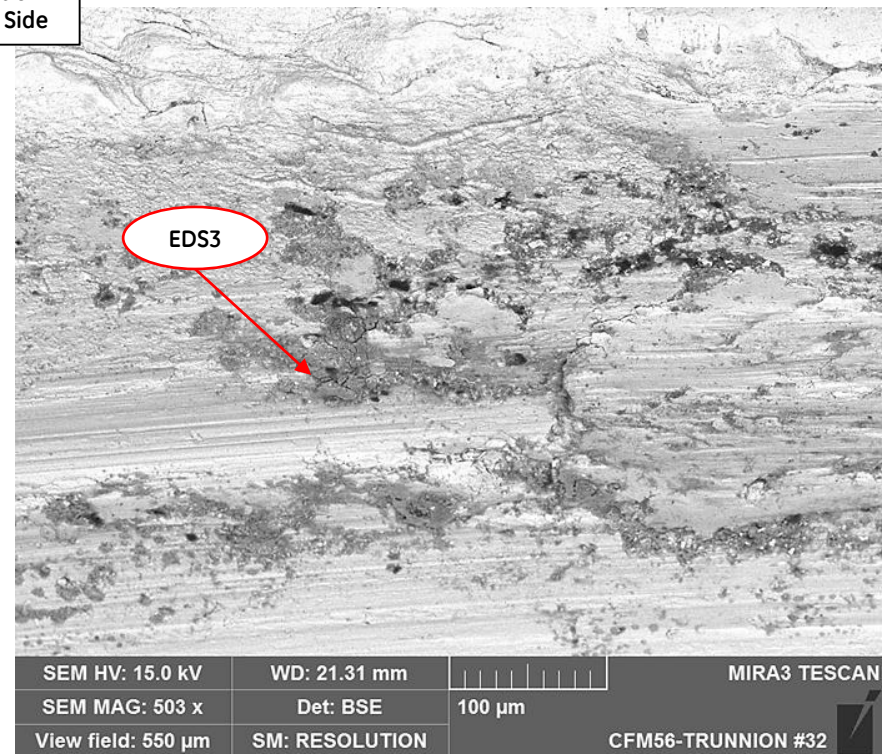
- Circumferential Loaded Side Thread Flank Contact Plus Smeared/Transferred Material Present on Lower Threads of Stg. 1 Vane Trunnion #32 Considered Consistent With Nut Contact

#32

Cleaned Condition
Loaded Thread Side



Stg. 1 Vane Trunnion #32 - Lower Thread Contact - BEI



Stg. 1 Vane Trunnion #32 - Lower Thread Contact - BEI

Figure 46. SEM backscatter (BEI) images showing closer views of Stg. 1 HPC Trunnion #32 threads in the cleaned condition (lower threads). EDS spectrum obtained at locations EDS1, EDS2 and EDS3.

CFM56-7B Stg. 1 Vane Trunnion Location #32 ESN 875-318

- EDS1: IGV Trunnion Thread Surface - Spectrum Consistent With A286 With Elevated Molybdenum (Mo) and Silicon (Si)
- EDS2: IGV Trunnion Thread Material Transfer/Smear - Spectrum Consistent With A286 With Elevated Molybdenum (Mo) and Silicon (Si)
- EDS3: IGV Trunnion Thread Debris - Spectrum Consistent With A286 With Elevated Molybdenum (Mo), Chlorine (Cl), Sodium (Na) and Potassium (K)

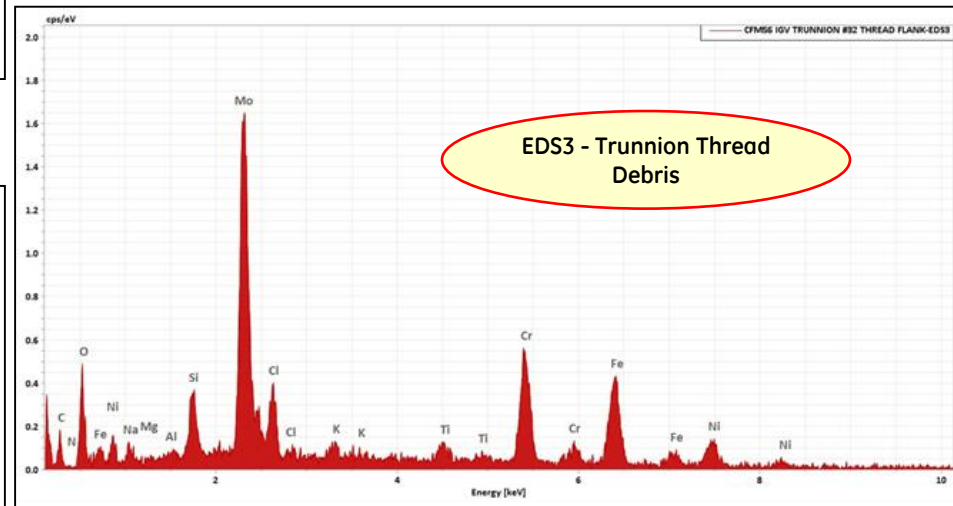
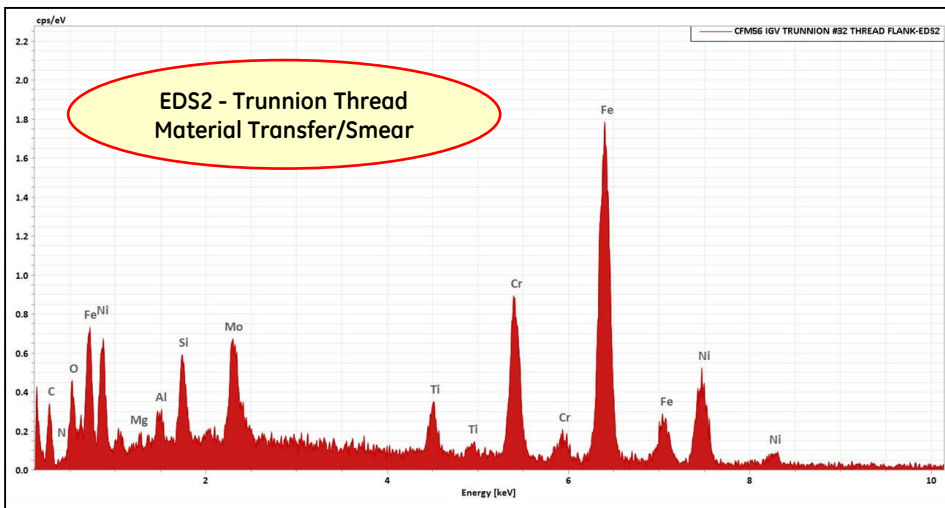
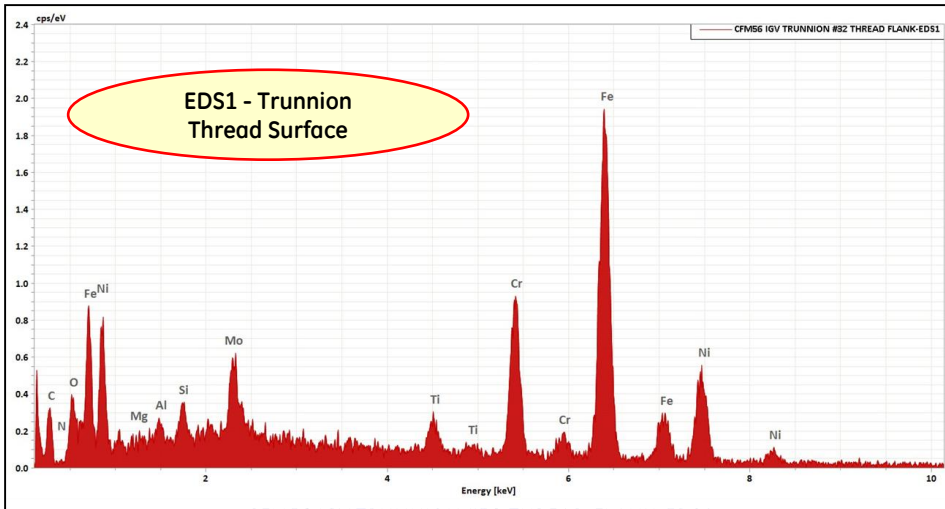


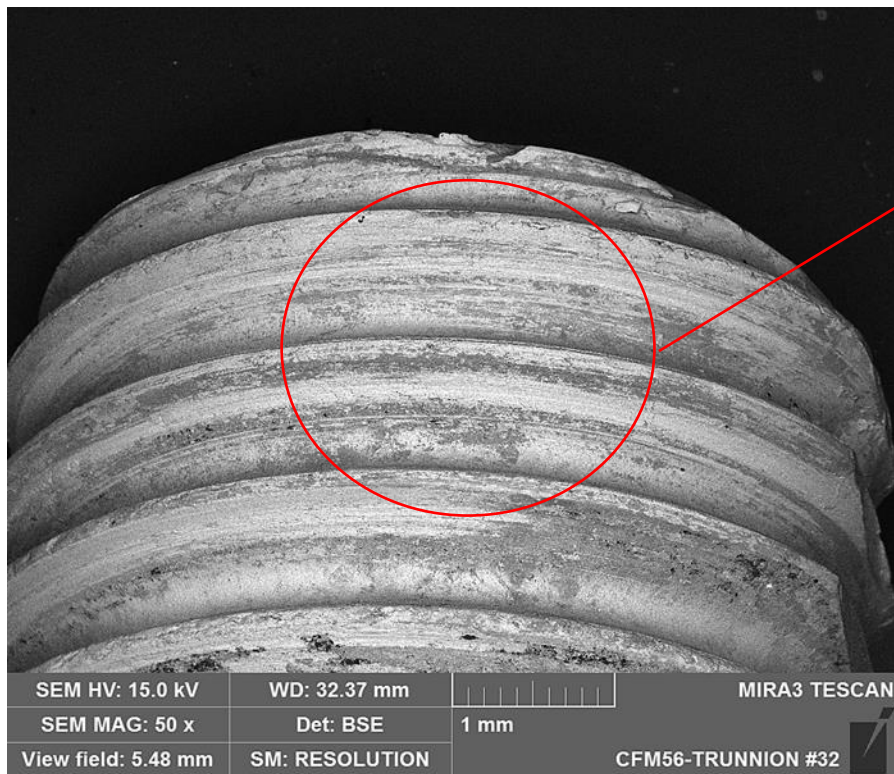
Figure 47. EDS spectrum obtained from the lower threads of Stg. 1 HPC Trunnion #32 at locations EDS1, EDS2 and EDS3.

CFM56-7B Stg. 1 Vane Trunnion Location #32 - ESN 875-318

- Circumferential Loaded Side Thread Flank Contact Observed on Upper Threads of Stg. 1 Vane Trunnion #32 Consistent With Nut Contact

#32

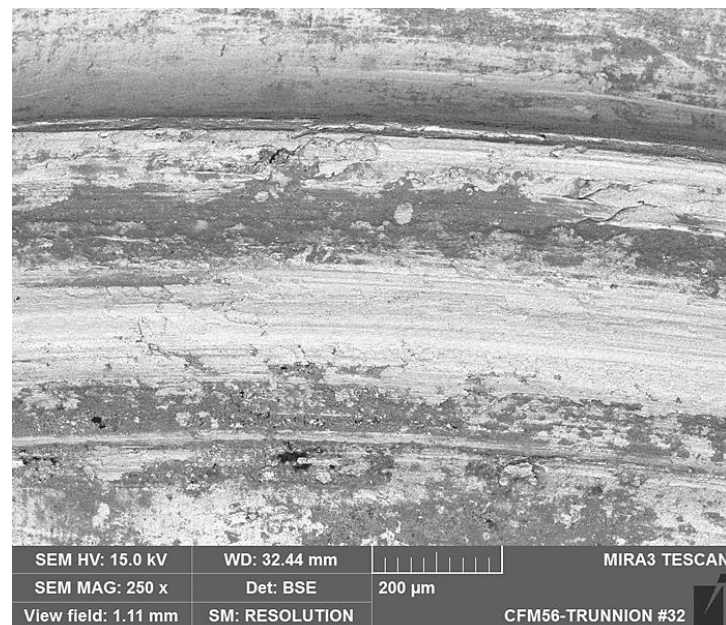
Cleaned Condition
Loaded Thread Side



Stg. 1 Vane Trunnion #32 – Upper Thread Contact – BEI



Stg. 1 Vane Trunnion #32 – Upper Thread Contact – BEI



Stg. 1 Vane Trunnion #32 – Upper Thread Contact – BEI

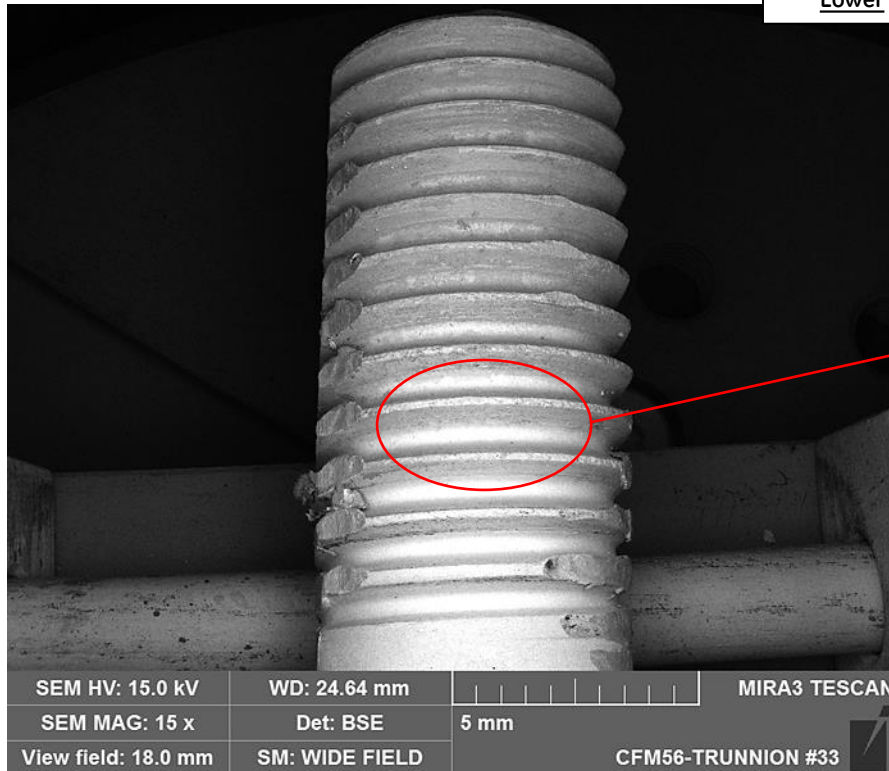
Figure 48. SEM backscatter (BEI) images documenting Stg. 1 HPC Trunnion #32 threads in the cleaned condition (upper threads).

CFM56-7B Stg. 1 Vane Trunnion Location #33 - ESN 875-318

- Loaded Side Thread Flank Contact Observed on Lower Threads of Stg. 1 Vane Trunnion #33 Consistent With Nut Contact at Some Point
- Note Circumferential Grooves Present on Thread Flank But Not in Root Region

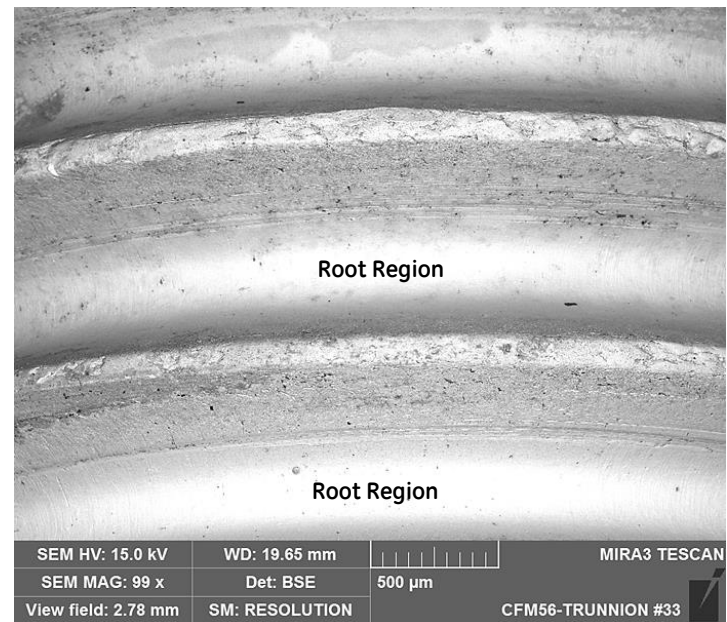
#33

Cleaned Condition
Loaded Thread Side
Lower Threads



Stg. 1 Vane Trunnion #33 - Lower Thread Contact - BEI

Figure 49. SEM backscatter (BEI) and secondary (SEI) images documenting Stg. 1 HPC Trunnion #33 threads in the cleaned condition (lower threads).



Stg. 1 Vane Trunnion #33 - Lower Thread Contact - BEI



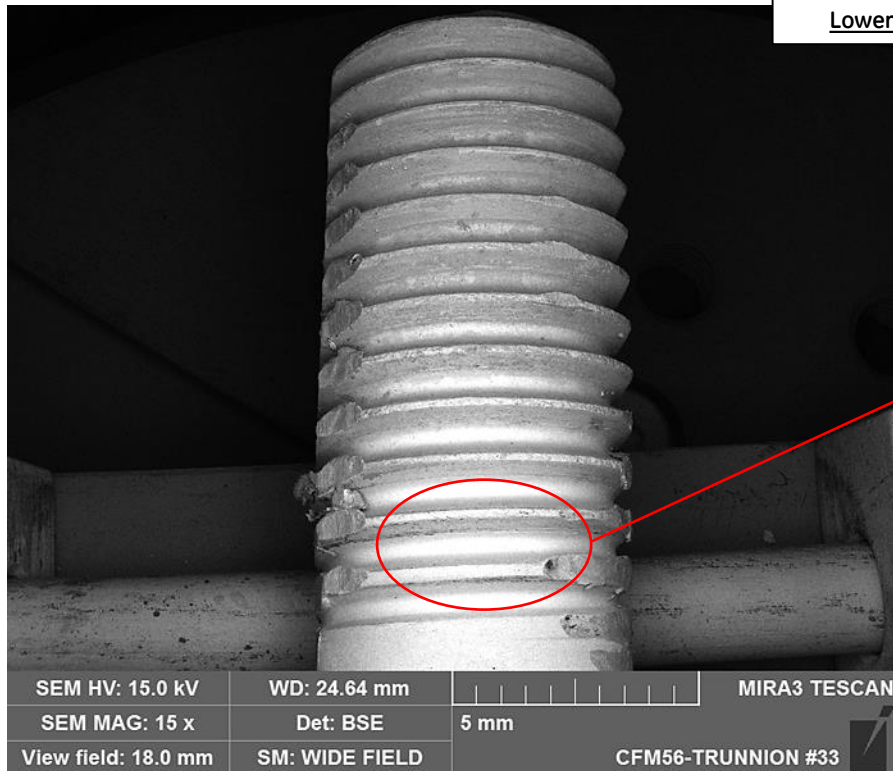
Stg. 1 Vane Trunnion #33 - Lower Thread Contact - SEI

CFM56-7B Stg. 1 Vane Trunnion Location #33 - ESN 875-318

- Loaded Side Thread Flank Contact Observed on Lower Threads of Stg. 1 Vane Trunnion #33 Consistent With Nut Contact at Some Point
- Note Circumferential Grooves Present on Thread Flank But Not in Root Region

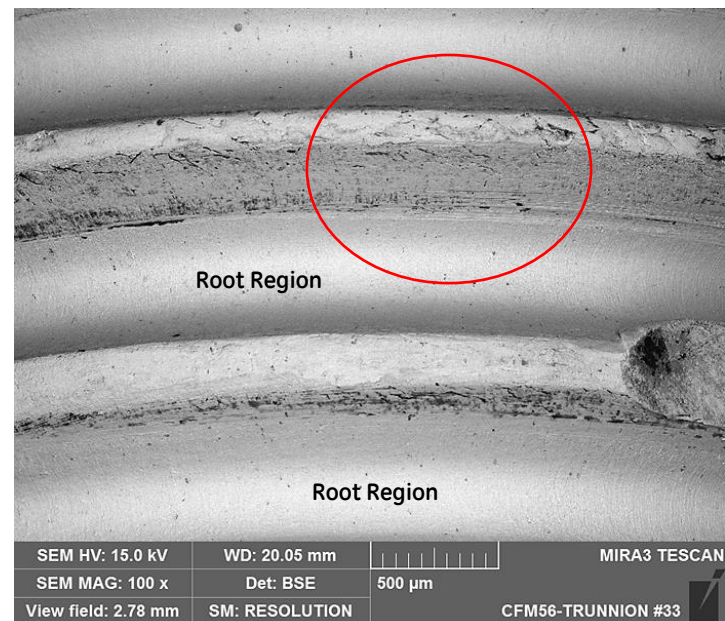
#33

Cleaned Condition
Loaded Thread Side
Lower Threads

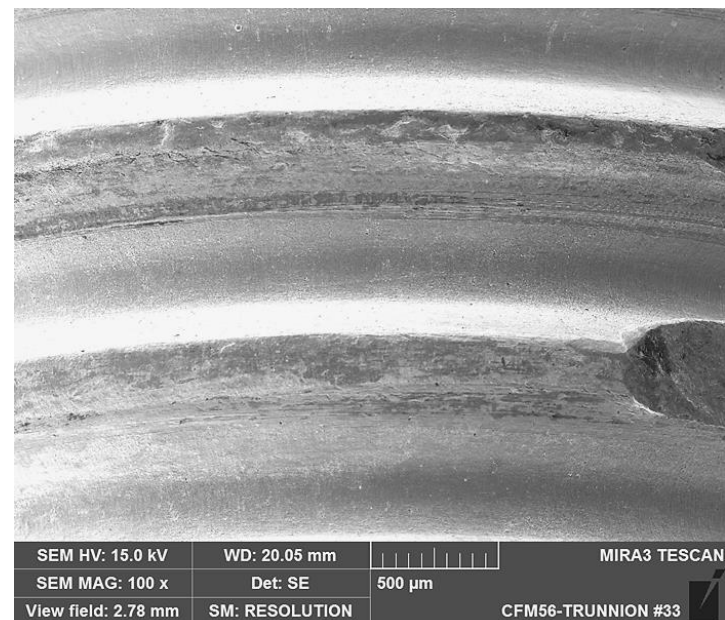


Stg. 1 Vane Trunnion #33 – Lower Thread Contact – BEI

Figure 50. SEM backscatter (SEI) images documenting Stg. 1 HPC Trunnion #33 threads in the cleaned condition (lower threads).



Stg. 1 Vane Trunnion #33 – Lower Thread Contact – BEI



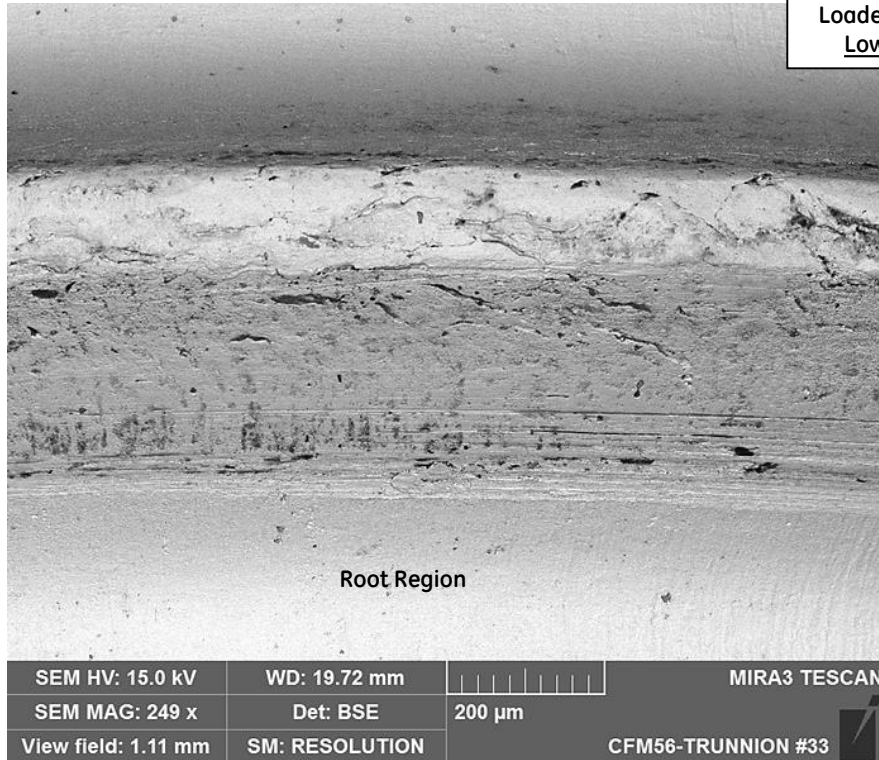
Stg. 1 Vane Trunnion #33 – Lower Thread Contact – SEI

CFM56-7B Stg. 1 Vane Trunnion Location #33 - ESN 875-318

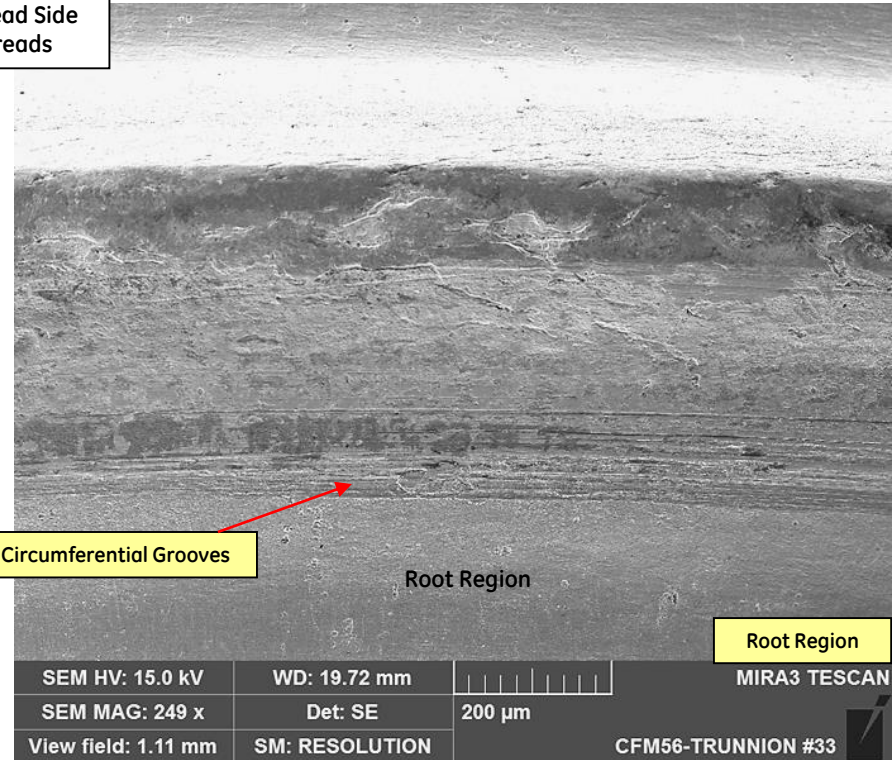
- Loaded Side Thread Flank Contact Observed on Lower Threads of Stg. 1 Vane Trunnion #33 Indicating Contact With a Nut Occurred at Some Point
- Note Circumferential Grooves Present on Thread Flank But Not in Root Region

#33

Cleaned Condition
Loaded Thread Side
Lower Threads



Stg. 1 Vane Trunnion #33 – Lower Thread Contact – BEI

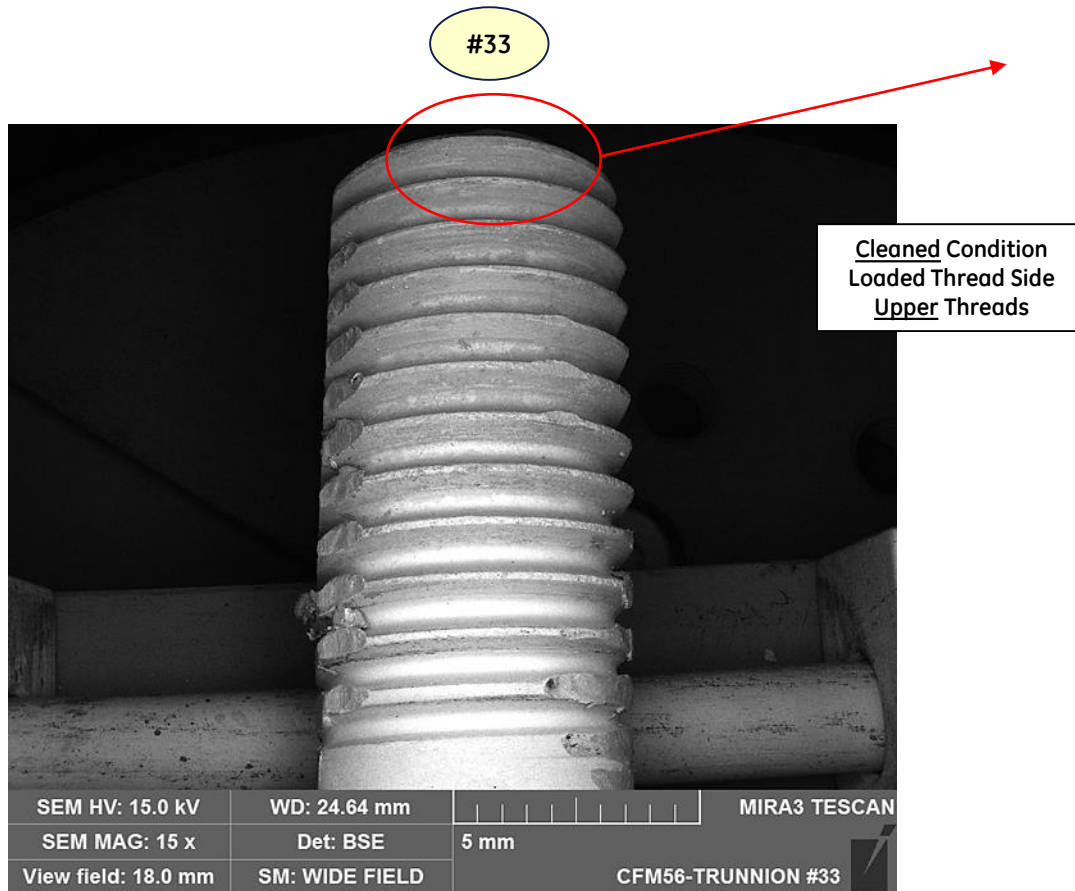


Stg. 1 Vane Trunnion #33 – Lower Thread Contact – SEI

Figure 51. Closer SEM backscatter (BEI) and secondary (SEI) images showing closer views of Stg. 1 HPC Trunnion #33 thread contact after cleaning (lower threads).

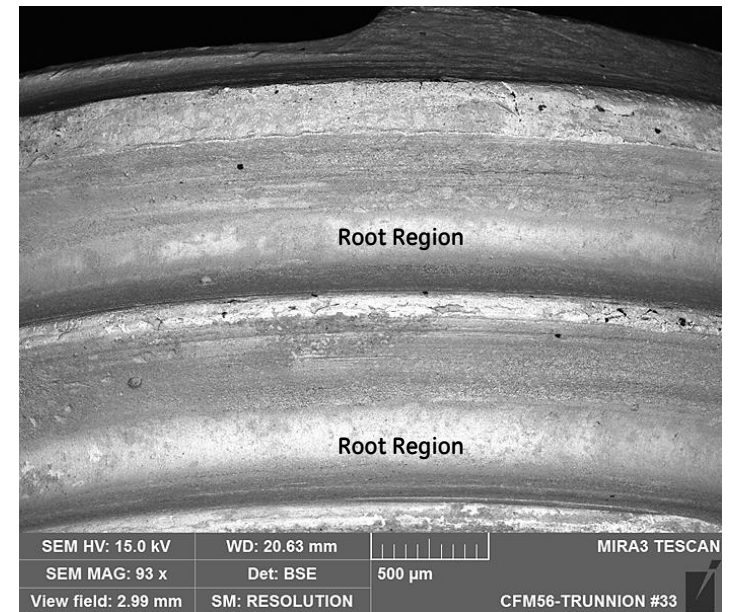
CFM56-7B Stg. 1 Vane Trunnion Location #33 - ESN 875-318

- Loaded Side Thread Flank Contact Observed on Upper Threads of Stg. 1 Vane Trunnion #33 Compared to Trunnion #34
- Note Circumferential Grooves Present on Thread Flank But Not in Root Region



Stg. 1 Vane Trunnion #33 – Upper Thread Contact – BEI

Figure 52. SEM backscatter (SEI) images documenting Stg. 1 HPC Trunnion #33 threads in the cleaned condition (upper threads).



Stg. 1 Vane Trunnion #33 – Upper Thread Contact – BEI



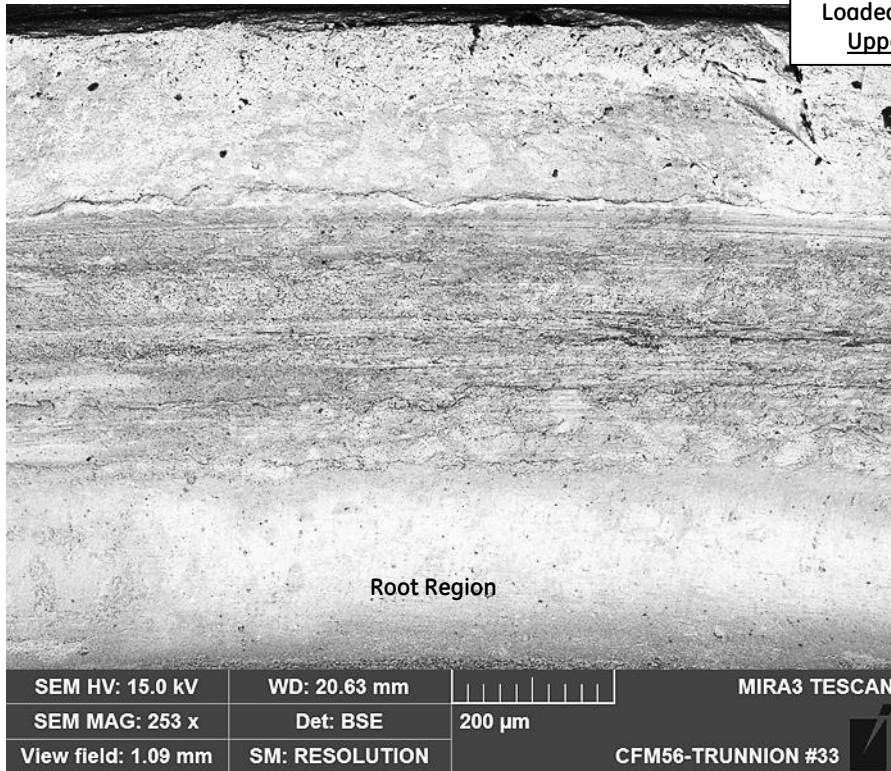
Stg. 1 Vane Trunnion #33 – Upper Thread Contact – SEI

CFM56-7B Stg. 1 Vane Trunnion Location #33 - ESN 875-318

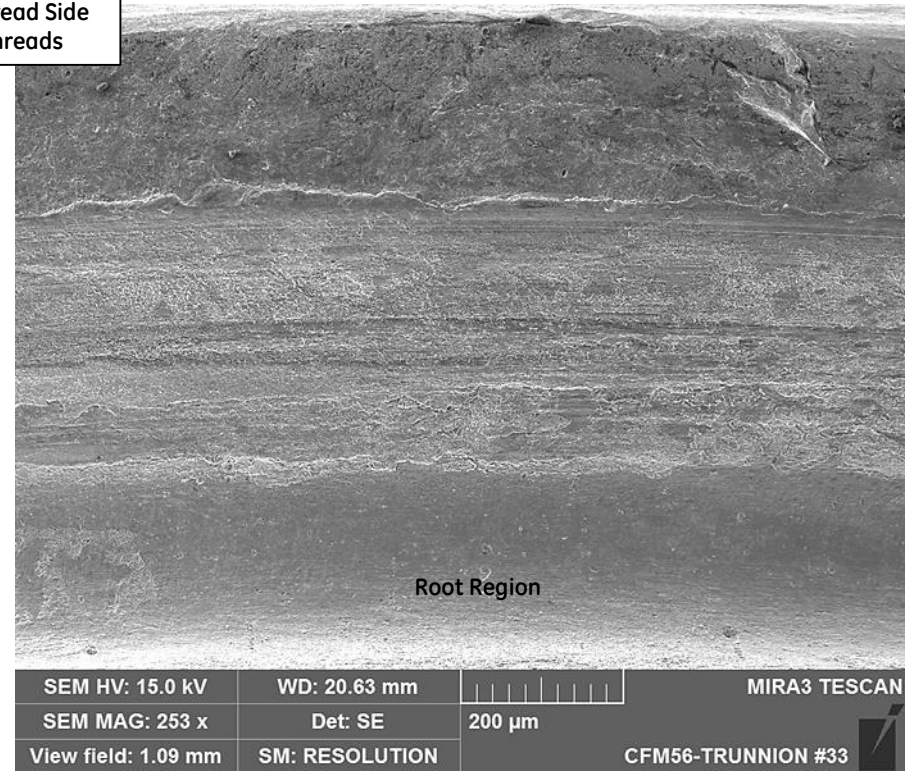
- Loaded Side Thread Flank Contact Observed on Lower Threads of Stg. 1 Vane Trunnion #33 Compared to Trunnion #34
- Note Circumferential Grooves Present on Thread Flank But Not in Root Region

#33

Cleaned Condition
Loaded Thread Side
Upper Threads



Stg. 1 Vane Trunnion #33 – Upper Thread Contact – BEI



Stg. 1 Vane Trunnion #33 – Upper Thread Contact – SEI

Figure 53. Closer SEM backscatter (BEI) and secondary (SEI) images showing closer views of Stg. 1 HPC Trunnion #33 thread contact after cleaning (upper threads).

CFM56-7B Stg. 1 Vane Trunnion Location #33 - ESN 875-318

- EDS1: Upper Thread Flank Surface - Spectrum Consistent With A286 With Elevated Molybdenum (Mo) and/or Sulfur (S) With Silicon (Si)
- EDS2: Lower Thread Flank Surface - Spectrum Consistent With A286

Cleaned Condition
Loaded Thread Side

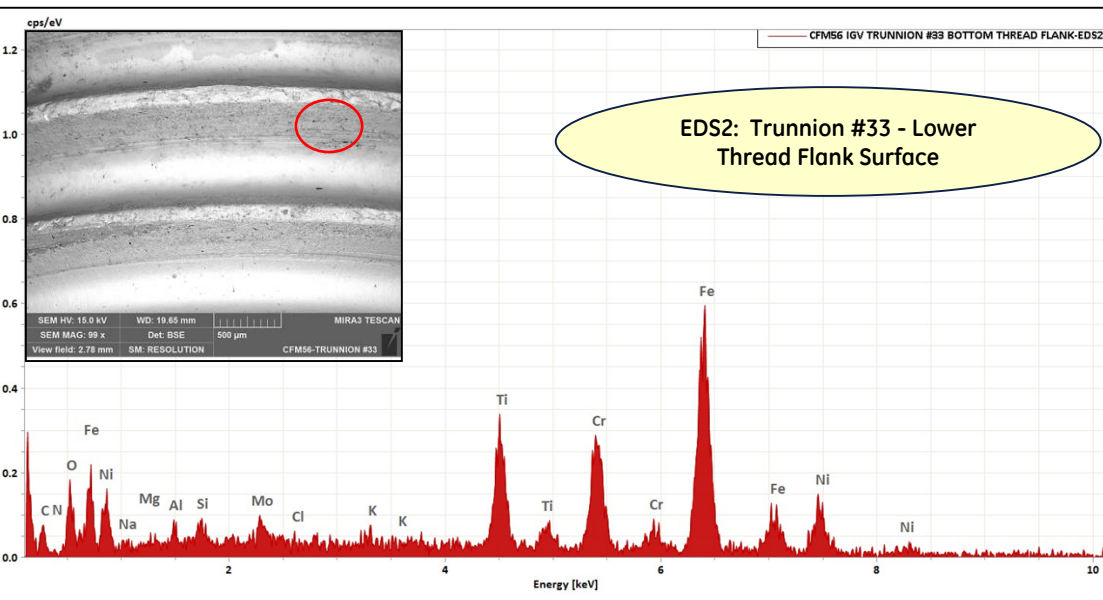
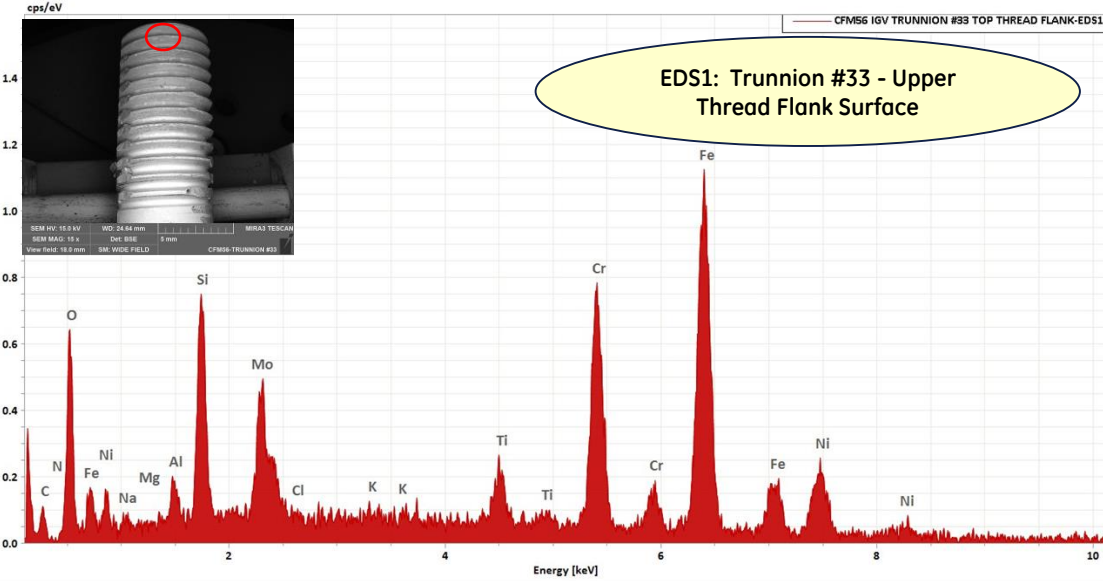
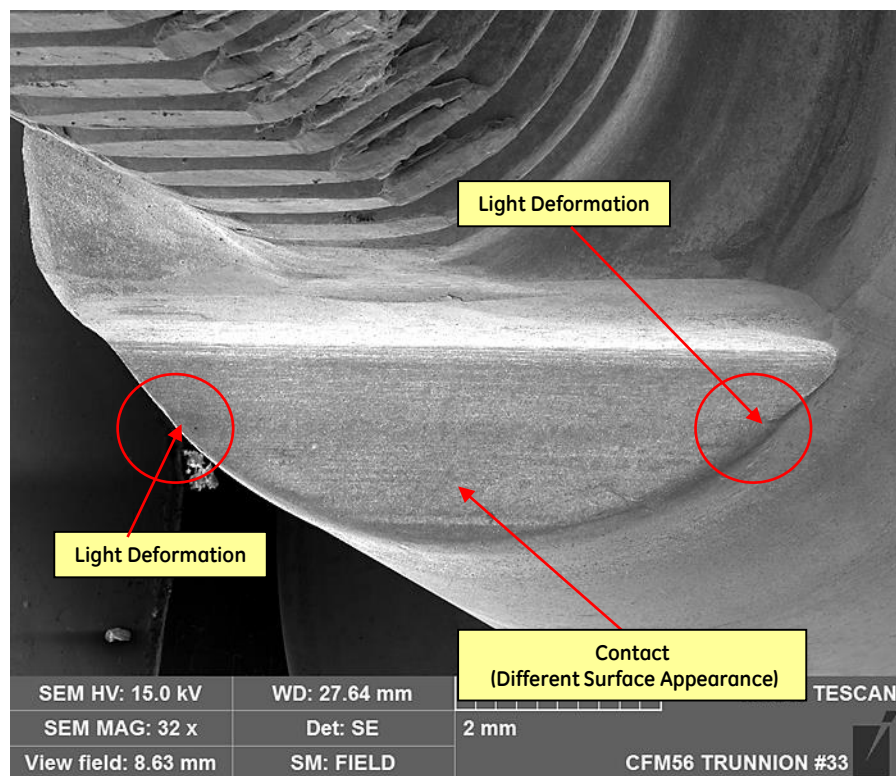


Figure 54. EDS spectra obtained from both the upper and lower thread flank surfaces of Stg. 1 HPC Trunnion #33 threads after cleaning. Trunnion most consistent with A286 type material as required.

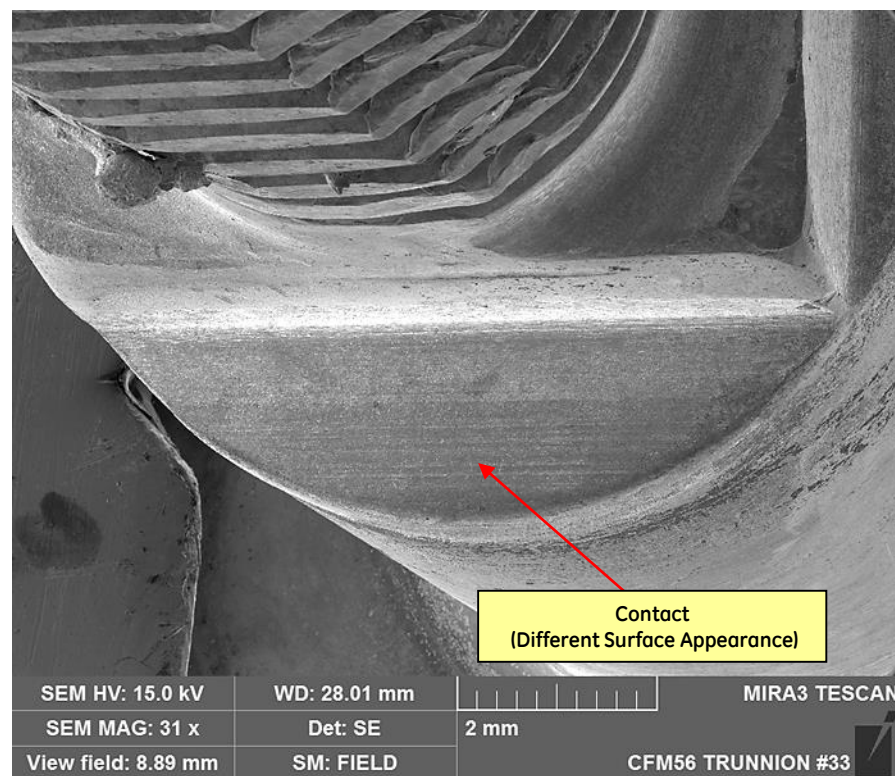
CFM56-7B Stg. 1 Vane Trunnion Location #33 - ESN 875-318

- Witness Marks With Lever Arm Along With Light Edge Deformation Observed on Stg. 1 Vane Trunnion #33

Cleaned Condition



Stg. 1 Vane Trunnion #33 - Lever Arm Seat - SEI

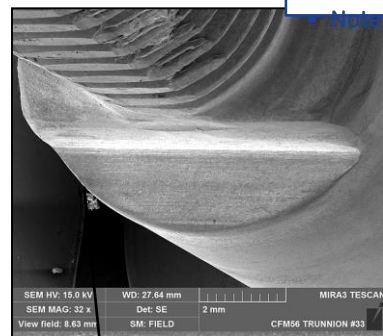


Stg. 1 Vane Trunnion #33 - Lever Arm Seat - Opposite Side - SEI

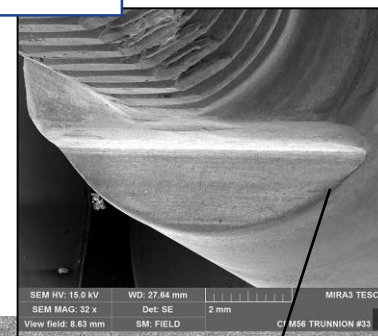
Figure 55. SEM backscatter secondary (SEI) images documenting presence of witness mark and light deformation attributed to contact with a properly installed lever arm at some point on Stg. 1 Vane Trunnion #33.

CFM56-7B Stg. 1 Vane Trunnion Location #33 - ESN 875-318

- Light Deformation Observed on Trunnion Edge From Lever Arm Contact For Properly Installed Trunnion #33
- Note Difference in Surface Appearance Between Contacted and Non-Contacted Surfaces



Cleaned Condition

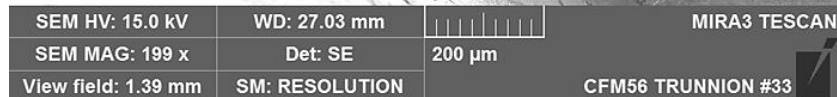


Non-Contacted

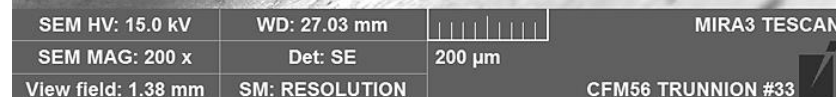
Light Deformation

Contacted

Light Deformation



Stg. 1 Vane Trunnion #33 – Lever Arm Seat - SEI



Stg. 1 Vane Trunnion #33 – Lever Arm Seat - SEI

Figure 56. Closer SEM backscatter secondary (SEI) images documenting presence of witness mark and light deformation attributed to contact with a properly installed lever arm at some point on Stg. 1 Vane Trunnion #33.

CFM56-7B Stg. 1 Vane Trunnion Location #33 - ESN 875-318

- Light Deformation Observed on Trunnion Edge From Lever Arm Contact For Trunnion #33 (Nut Washer Missing) - Implies Lever Arm Properly in Place at One Time
- Note Difference in Surface Appearance Between Contacted and Non-Contacted Surfaces

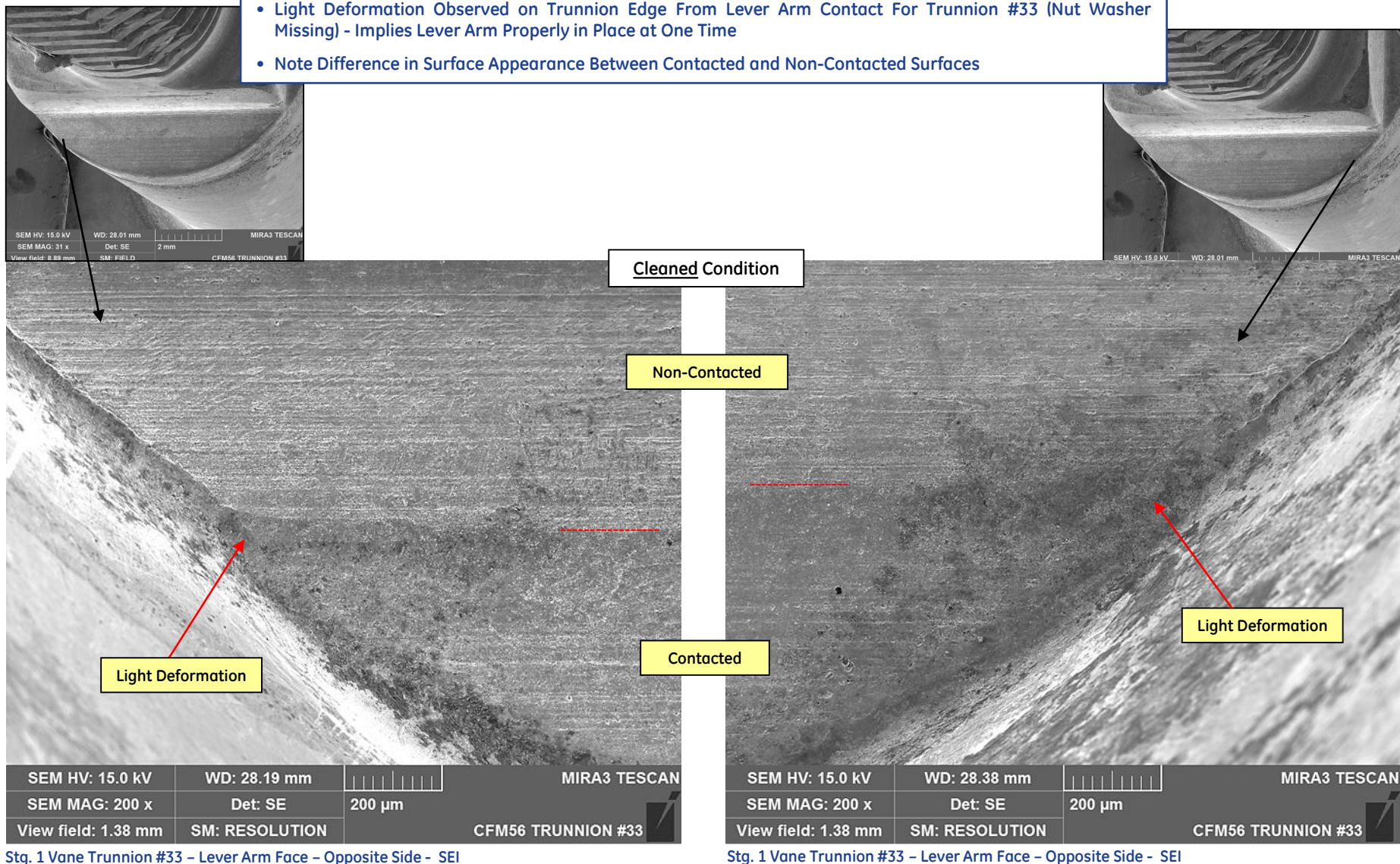
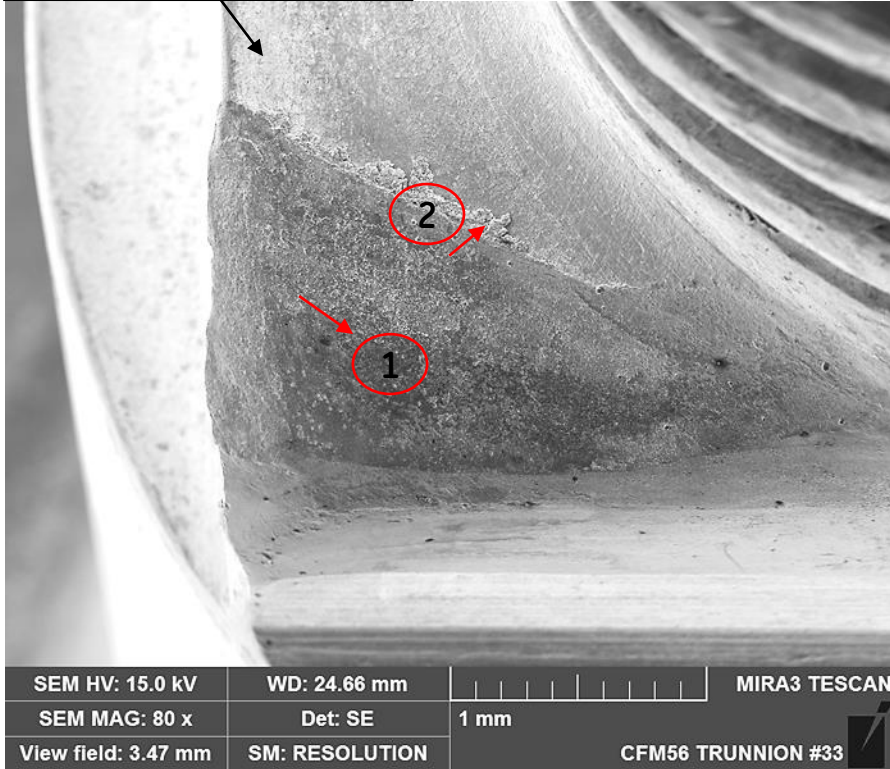
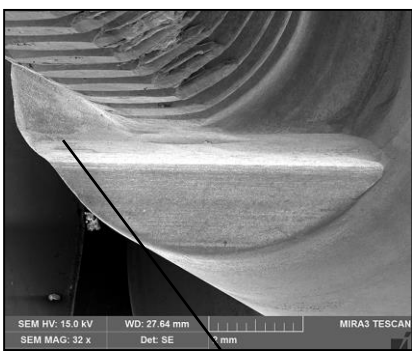


Figure 57. Closer SEM backscatter secondary (SEI) images documenting presence of witness mark and light deformation (opposite side) attributed to contact with a properly installed lever arm at some point on Stg. 1 Vane Trunnion #33.

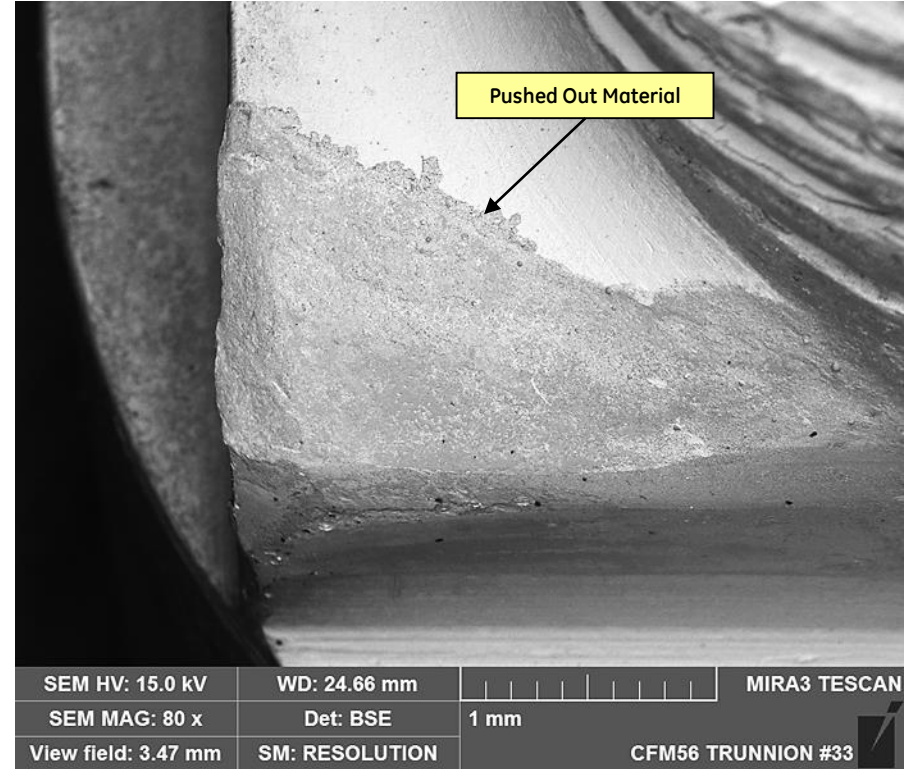
CFM56-7B Stg. 1 Vane Trunnion Location #33 - ESN 875-318

- Rotational Smearing Type Damage Observed on Stg. 1 Vane Trunnion #33 Corner Region

Cleaned Condition



Stg. 1 Vane Trunnion #33 - Damaged Corner - SEI

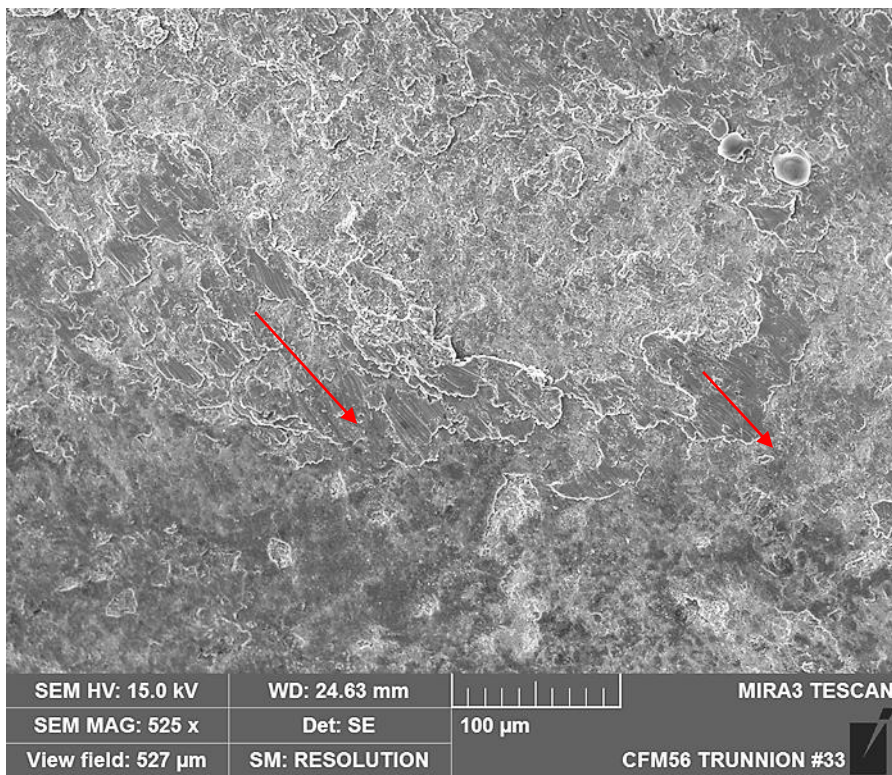


Stg. 1 Vane Trunnion #33 - Damaged Corner - BEI

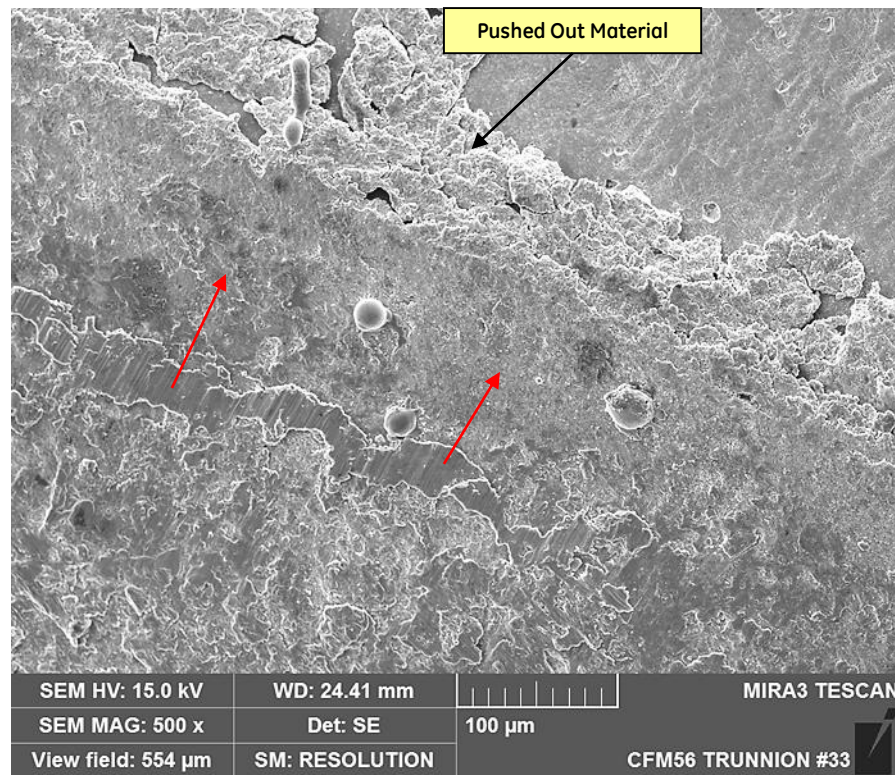
Figure 58. SEM backscatter secondary (SEI) and backscatter (BEI) images documenting Stg. 1 Vane Trunnion #33 corner damage attributed to contact with the mating lever arm slot. Areas 1 and 2 were examined in greater detail. Red arrows denote smearing direction.

CFM56-7B Stg. 1 Vane Trunnion Location #33 - ESN 875-318

- Rotational and Outboard Smearing Type Damage Observed on Stg. 1 Vane Trunnion #33 Corner Region



Stg. 1 Vane Trunnion #33 – Damaged Corner - Area 1 - SEI

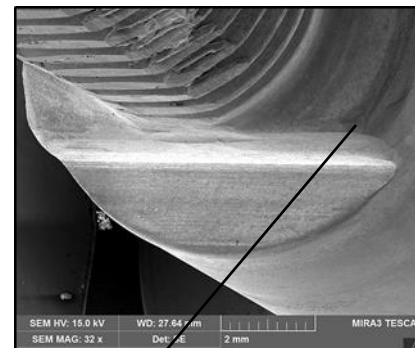


Stg. 1 Vane Trunnion #33 – Damaged Corner - Area 2 - SEI

Figure 59. SEM backscatter secondary (SEI) images documenting Stg. 1 Vane Trunnion #33 trunnion smearing damage at areas 1 and 2 as shown in Figure 58. Red arrows denote smearing direction.

CFM56-7B Stg. 1 Vane Trunnion Location #33 - ESN 875-318

- Rotational Smearing Type Damage Observed on Stg. 1 Vane Trunnion #33 Corner Region



SEM HV: 15.0 kV	WD: 24.47 mm	200 μm	MIRA3 TESCAN
SEM MAG: 201 x	Det: SE		
View field: 1.38 mm	SM: RESOLUTION		CFM56 TRUNNION #33

Stg. 1 Vane Trunnion #33 - Damaged Corner - SEI



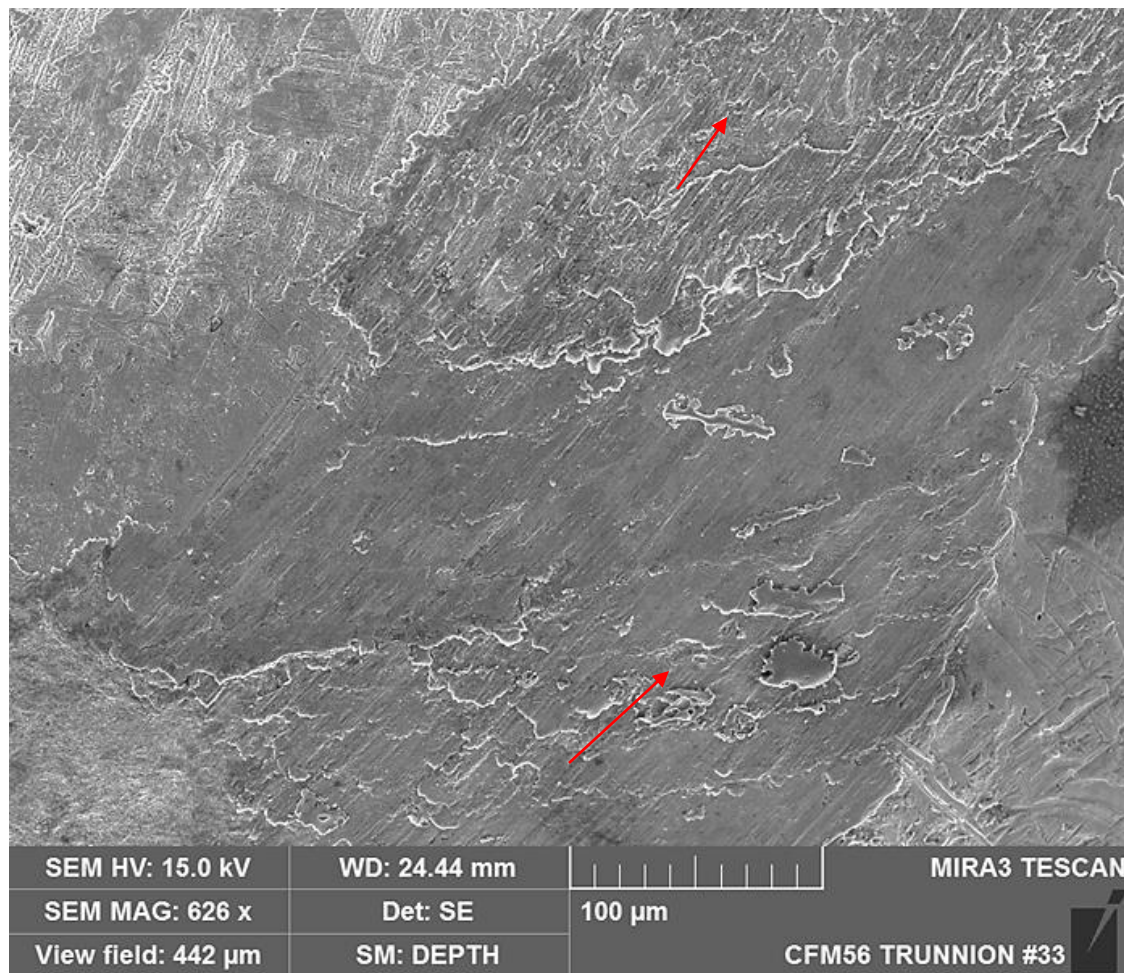
SEM HV: 15.0 kV	WD: 24.47 mm	200 μm	MIRA3 TESCAN
SEM MAG: 201 x	Det: BSE		
View field: 1.38 mm	SM: RESOLUTION		CFM56 TRUNNION #33

Stg. 1 Vane Trunnion #33 - Damaged Corner - BEI

Figure 60. SEM backscatter secondary (SEI) and backscatter (BEI) images documenting Stg. 1 Vane Trunnion #33 corner damage attributed to contact with the mating lever arm slot. Area 3 was examined in greater detail. Red arrow denote smearing direction.

CFM56-7B Stg. 1 Vane Trunnion Location #33 - ESN 875-318

- Rotational Smearing Type Damage Observed on Stg. 1 Vane Trunnion #33 Corner Region

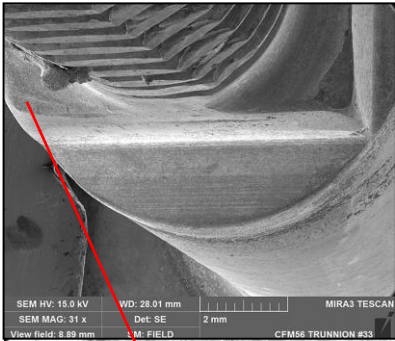


Stg. 1 Vane Trunnion #33 - Damaged Corner - Area 3 - SEI

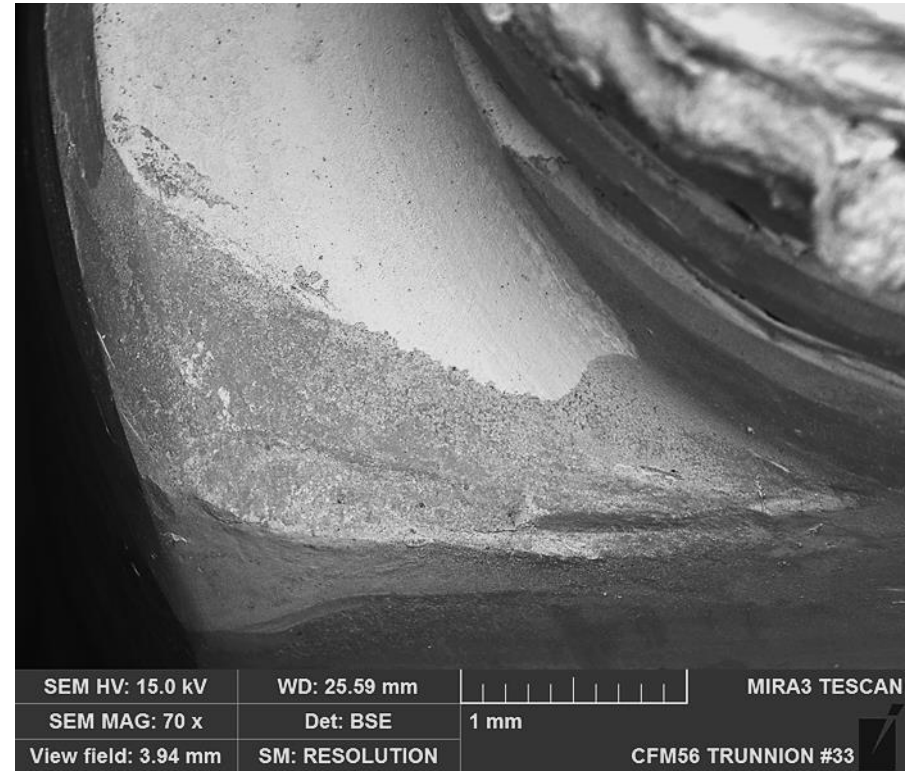
Figure 61. SEM backscatter secondary (SEI) images documenting Stg. 1 Vane Trunnion #33 trunnion smearing damage at area 3 as shown in Figure 60. Red arrow denotes smearing direction.

CFM56-7B Stg. 1 Vane Trunnion Location #33 - ESN 875-318

- Rotational and Outboard Smearing Type Damage Observed on Stg. 1 Vane Trunnion #33 Corner Region



Stg. 1 Vane Trunnion #33 – Damaged Corner - SEI

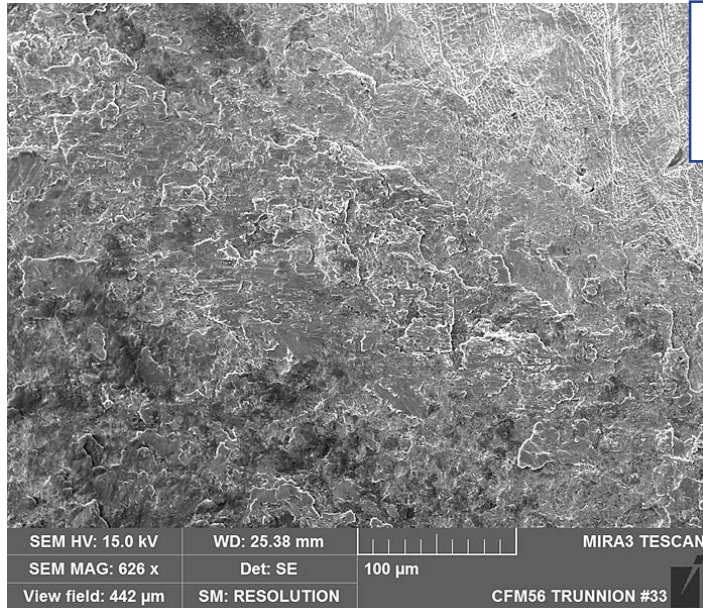


Stg. 1 Vane Trunnion #33 – Damaged Corner - BEI

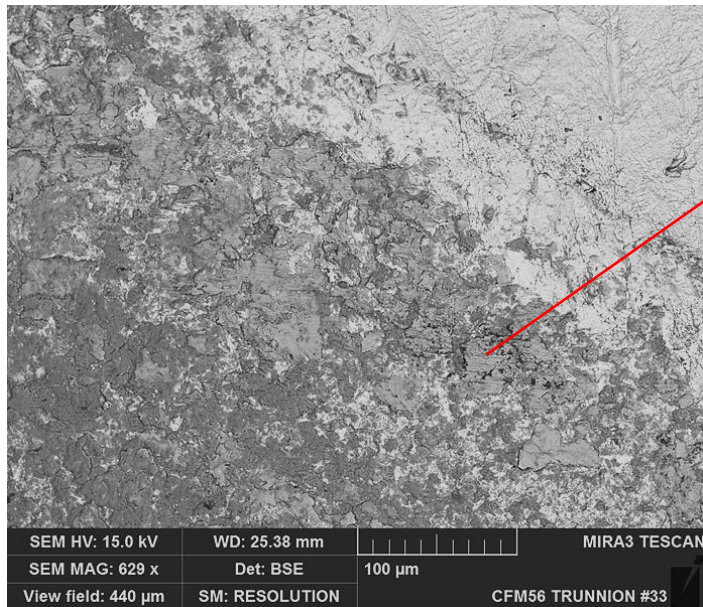
Figure 62. SEM backscatter secondary (SEI) and backscatter (BEI) images documenting Stg. 1 Vane Trunnion #33 corner damage attributed to contact with the mating lever arm slot. Area 4 was examined in greater detail.

CFM56-7B Stg. 1 Vane Trunnion Location #33 - ESN 875-318

- Rotational and Outboard Smearing Type Damage Observed on Stg. 1 Vane Trunnion #33 Corner Region
- Evidence of Ti-6Al-4V Metal Transfer on Smeared Trunnion Corner From Lever Arm



Stg. 1 Vane Trunnion #33 - Damaged Corner - Area 4 - SEI



Stg. 1 Vane Trunnion #33 - Damaged Corner - Area 4 - BEI

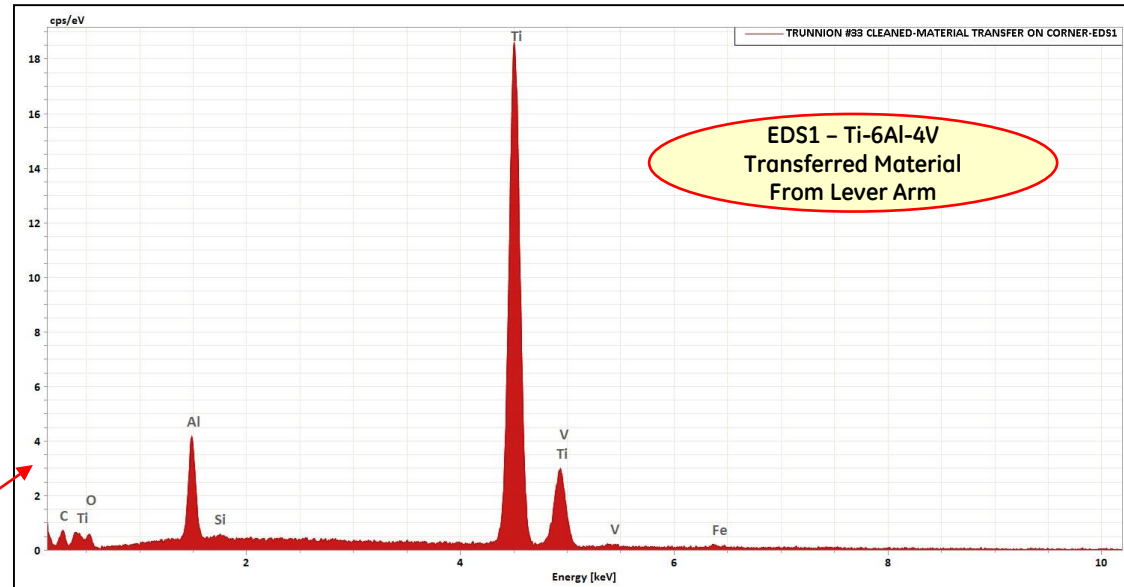
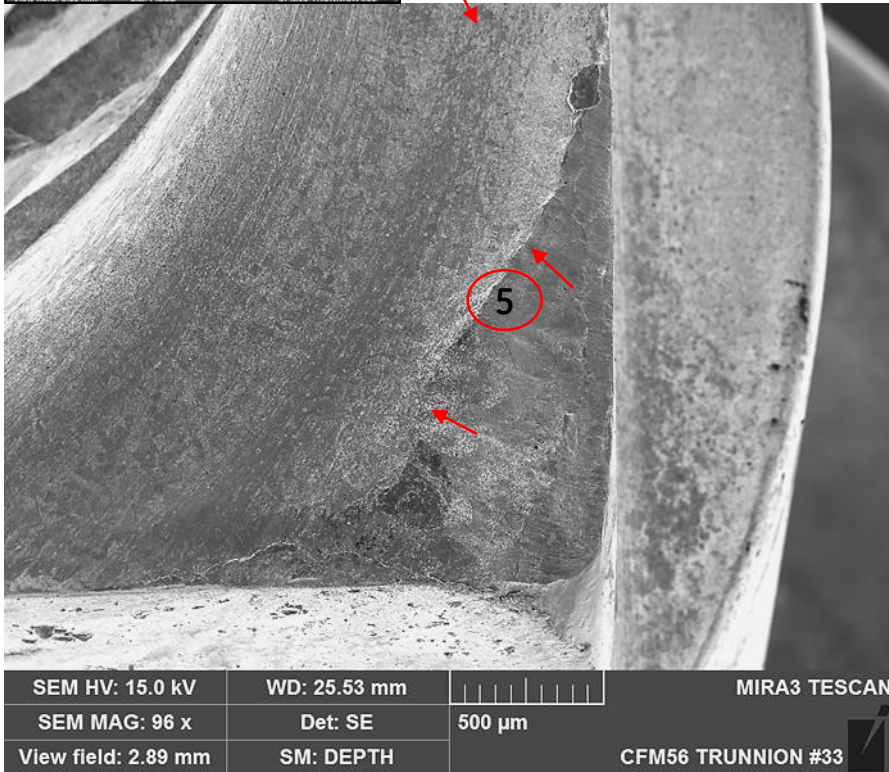
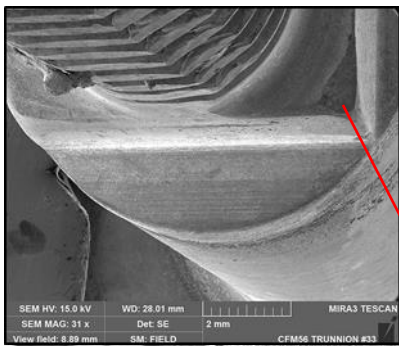


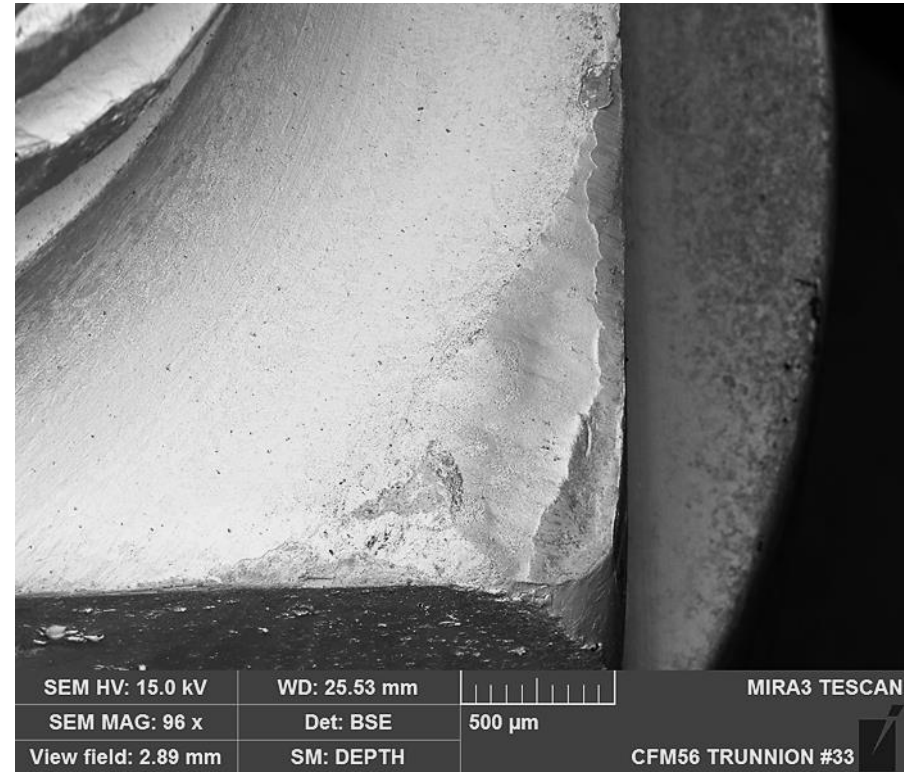
Figure 63. SEM backscatter secondary (SEI) images and accompanying EDS spectrum documenting Stg. 1 Vane Trunnion #33 trunnion smearing damage at area 4 as shown in Figure 62.

CFM56-7B Stg. 1 Vane Trunnion Location #33 - ESN 875-318

- Primarily Outward Smearing Damage Observed on Stg. 1 Vane Trunnion #33 Corner Region



Stg. 1 Vane Trunnion #33 – Damaged Corner – SEI

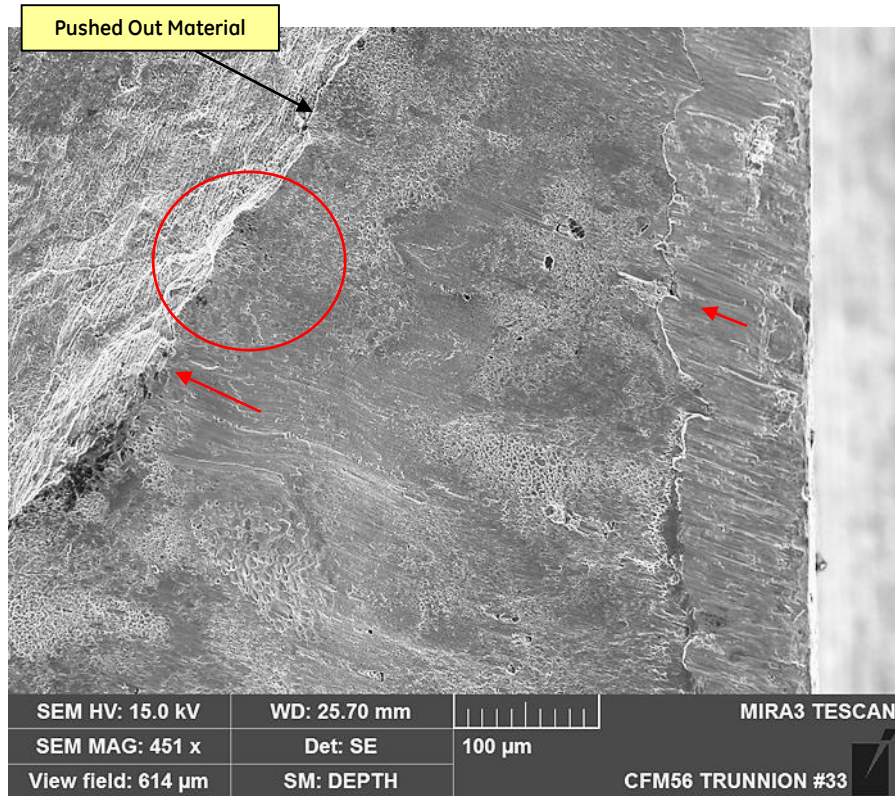


Stg. 1 Vane Trunnion #33 – Damaged Corner – SEI

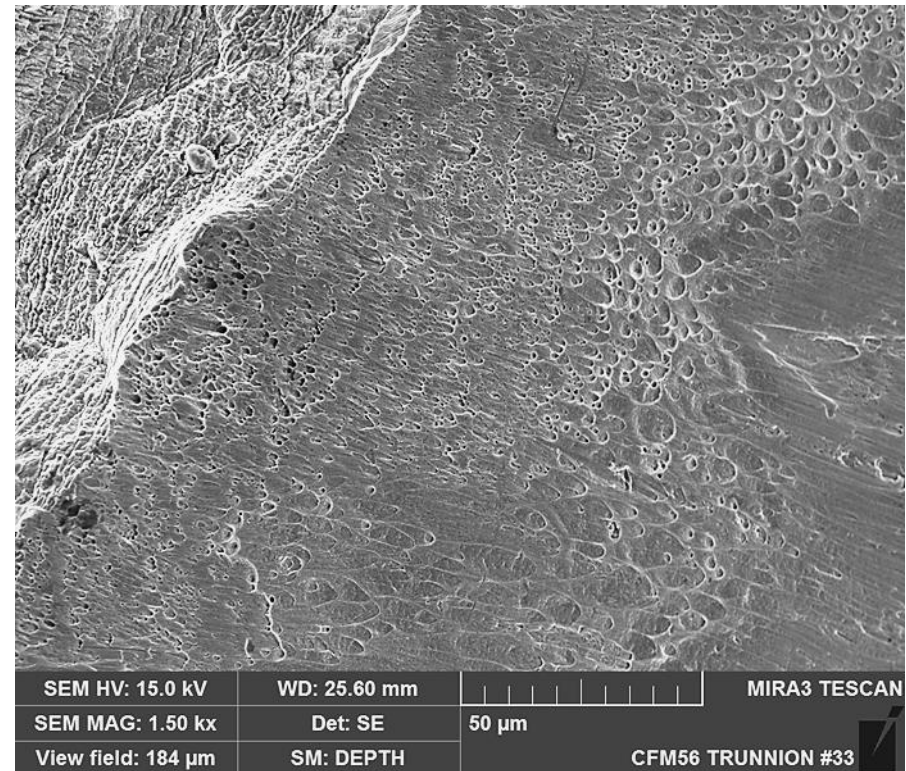
Figure 64. SEM backscatter secondary (SEI) and backscatter (BEI) images documenting Stg. 1 Vane Trunnion #33 corner damage attributed to contact with the mating lever arm slot. Area 5 examined in greater detail. Arrows denote an outward smearing direction.

CFM56-7B Stg. 1 Vane Trunnion Location #33 - ESN 875-318

- Primarily Outboard Smearing Type Damage Observed on Stg. 1 Vane Trunnion #33 Corner Region – Tensile Shear Dimples Present on Smeared Corner Surface



Stg. 1 Vane Trunnion #33 – Damaged Corner – SEI



Stg. 1 Vane Trunnion #33 – Damaged Corner – SEI
Tensile Shear Dimples

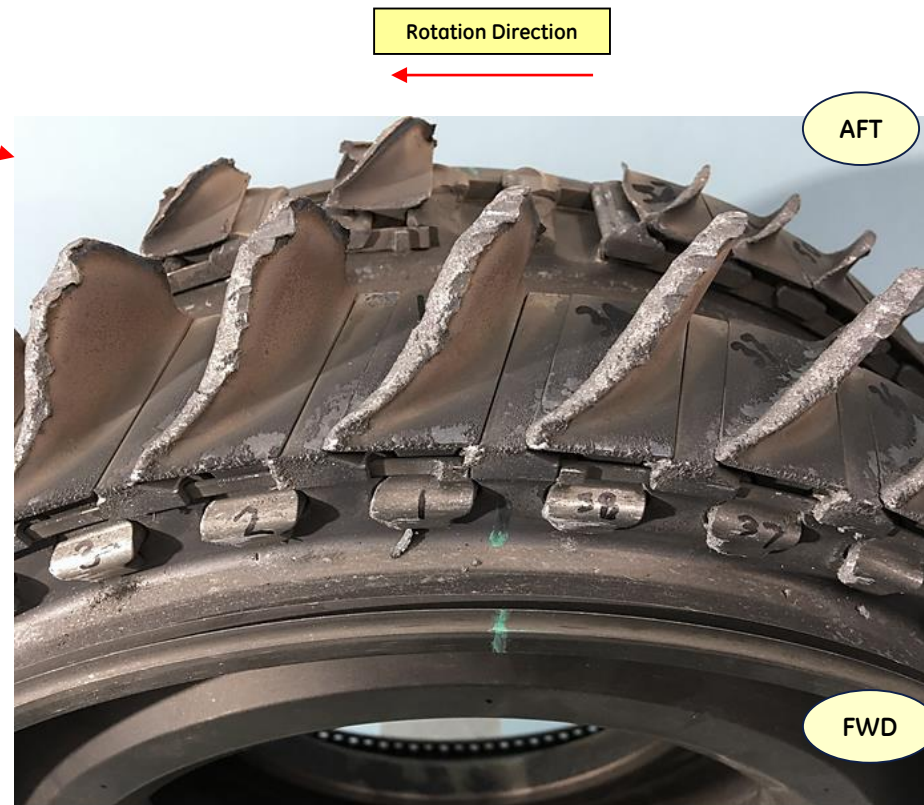
Figure 65. SEM backscatter secondary (SEI) images documenting Stg. 1 Vane Trunnion #33 trunnion smearing damage at area 5 as shown in Figure 64. Red arrow denotes smearing direction. Tensile shear dimples observed on surface.

CFM56-7B Stg. 1-2 HPC Spool - ESN 875-318

- All Stg. 1 HPC Blade Dovetails Were Present – Eight (8) Stg. 2 HPC Blades Completely Missing With Missing Material Observed on Ten (10) Disk Posts
- Both Remaining Stg. 1 and Stg. 2 Airfoils Exhibited Shape/Appearance Consistent With Burning



Stg. 1-2 HPC Spool – Fwd View



Stg. 1-2 HPC Spool – Fwd View

Figure 66. Photographs documenting Stg. 1-2 HPC Spool prior to removing remnant HPC Blades.

CFM56-7B Stg. 1-2 HPC Spool - ESN 875-318

- All Stg. 1 HPC Blade Dovetails Were Present – Eight (8) Stg. 2 HPC Blades Completely Missing With Missing Material Observed on Ten (10) Disk Posts
- Both Remaining Stg. 1 and Stg. 2 Airfoils Exhibited Shape/Appearance Consistent With Burning

Uncleaned Condition

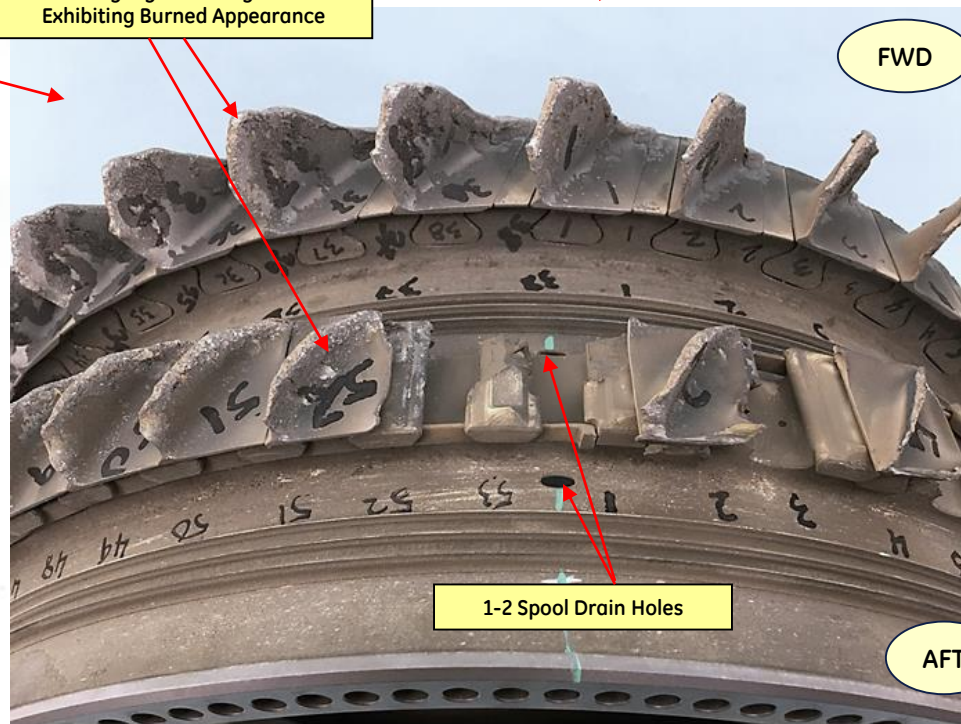
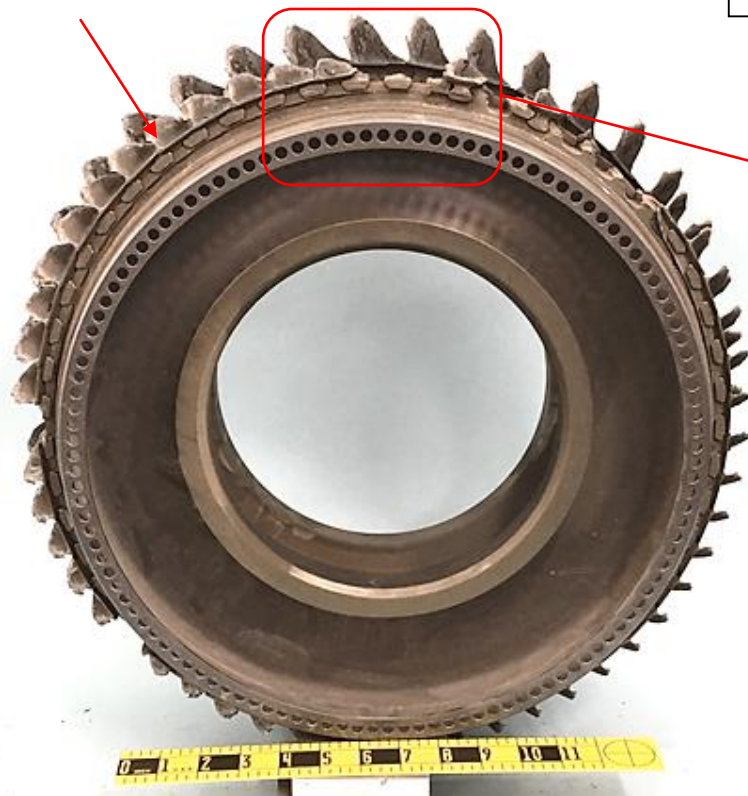
Rotation Direction

Remaining Stg. 1 and Stg. 2 Airfoils
Exhibiting Burned Appearance

FWD

1-2 Spool Drain Holes

AFT



Stg. 1-2 HPC Spool – Aft View

Stg. 1-2 HPC Spool – Aft View

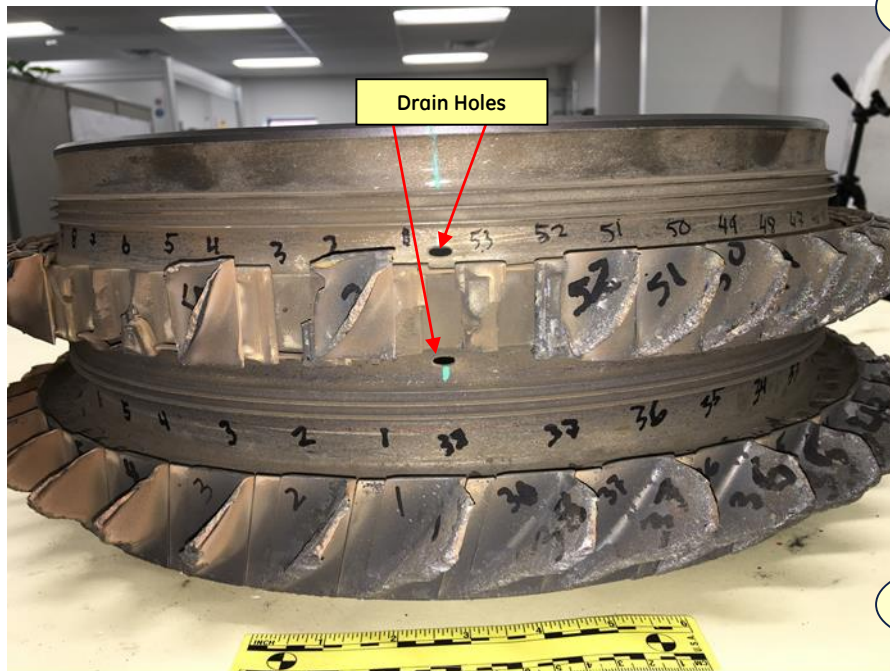
Figure 67. Photographs documenting Stg. 1-2 HPC Spool prior to removing remnant HPC Blades.

CFM56-7B Stg. 1-2 HPC Spool - ESN 875-318

- General Condition of Stg. 1-2 HPC Spool

Uncleaned Condition

HPC Blade Numbering Performed ALF- CW
Direction Starting at 1-2 Spool Drain Holes



Stg. 1-2 HPC Spool – Radial View

AFT



Stg. 1-2 HPC Spool – Radial View

FWD

Figure 68. Photographs documenting Stg. 1-2 HPC Spool prior to removing remnant HPC Blades.

CFM56-7B Stg. 1-2 HPC Spool - ESN 875-318

- General Condition of Stg. 1-2 HPC Spool

Uncleaned Condition

AFT



Stg. 1-2 HPC Spool – Radial View

FWD



Stg. 1-2 HPC Spool – Radial View

Figure 69. Photographs documenting Stg. 1-2 HPC Spool prior to removing remnant HPC Blades.

CFM56-7B Stg. 1-2 HPC Spool - ESN 875-318

- General Condition of Stg. 1-2 HPC Spool

Uncleaned Condition



Stg. 1-2 HPC Spool – Radial View

AFT



Stg. 1-2 HPC Spool – Radial View

FWD

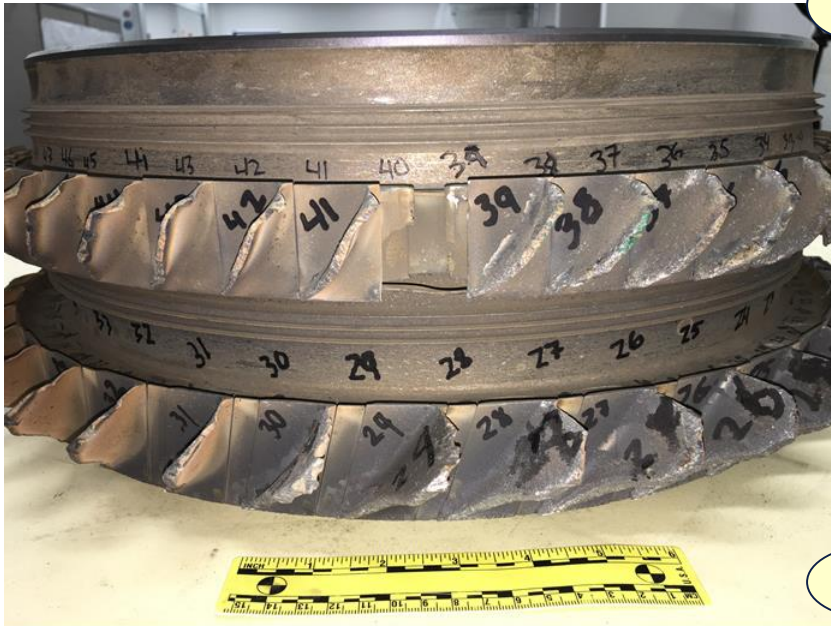
Figure 70. Photographs documenting Stg. 1-2 HPC Spool prior to removing remnant HPC Blades.

CFM56-7B Stg. 1-2 HPC Spool - ESN 875-318

- General Condition of Stg. 1-2 HPC Spool

Uncleaned Condition

AFT



FWD



Stg. 1-2 HPC Spool – Radial View

Stg. 1-2 HPC Spool – Radial View

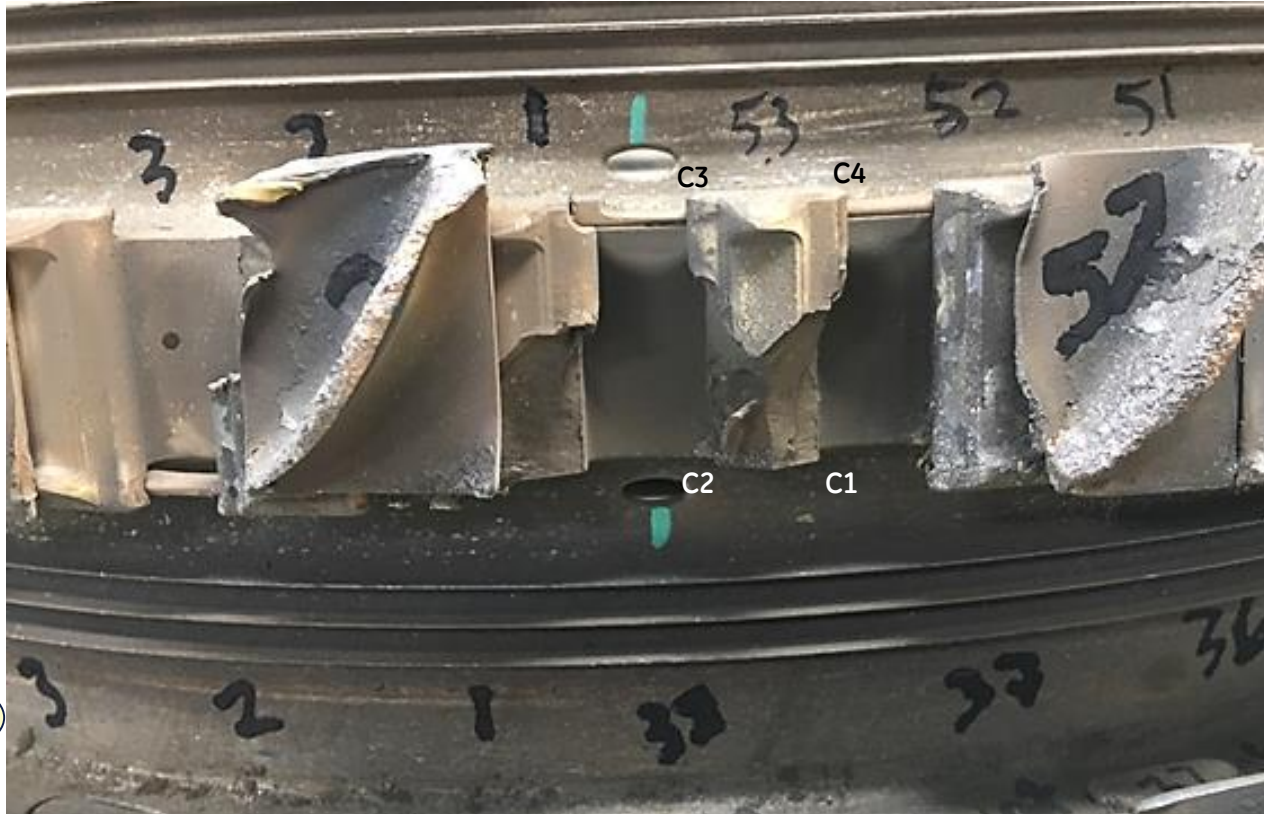
Figure 71. Photographs documenting Stg. 1-2 HPC Spool prior to removing remnant HPC Blades.

CFM56-7B Stg. 1-2 HPC Spool - ESN 875-318

- Missing Stg. 2 HPC Blades #1, #3 and #53 – Missing Stg. 2 Disk Post Material at Posts #1, #2 and #53

Uncleaned Condition

AFT



C1 Corner #1

C2 Corner #2

C3 Corner #3

C4 Corner #4

FWD

Stg. 1-2 HPC Spool – Missing Stg. 2 Blades and Disk Post Material

Figure 72. Photograph showing closer view of missing Stg. 2 HPC Blades and missing Stg. 2 disk post material.

CFM56-7B Stg. 1-2 HPC Spool - ESN 875-318

- Missing Stg. 2 HPC Blades #5, #6 and #7 – Missing Stg. 2 Disk Post Material at Posts #4, #5, #6 and #7
- “Beachmark” Features Consistent With Fatigue Observed on Post #7-Corner #4

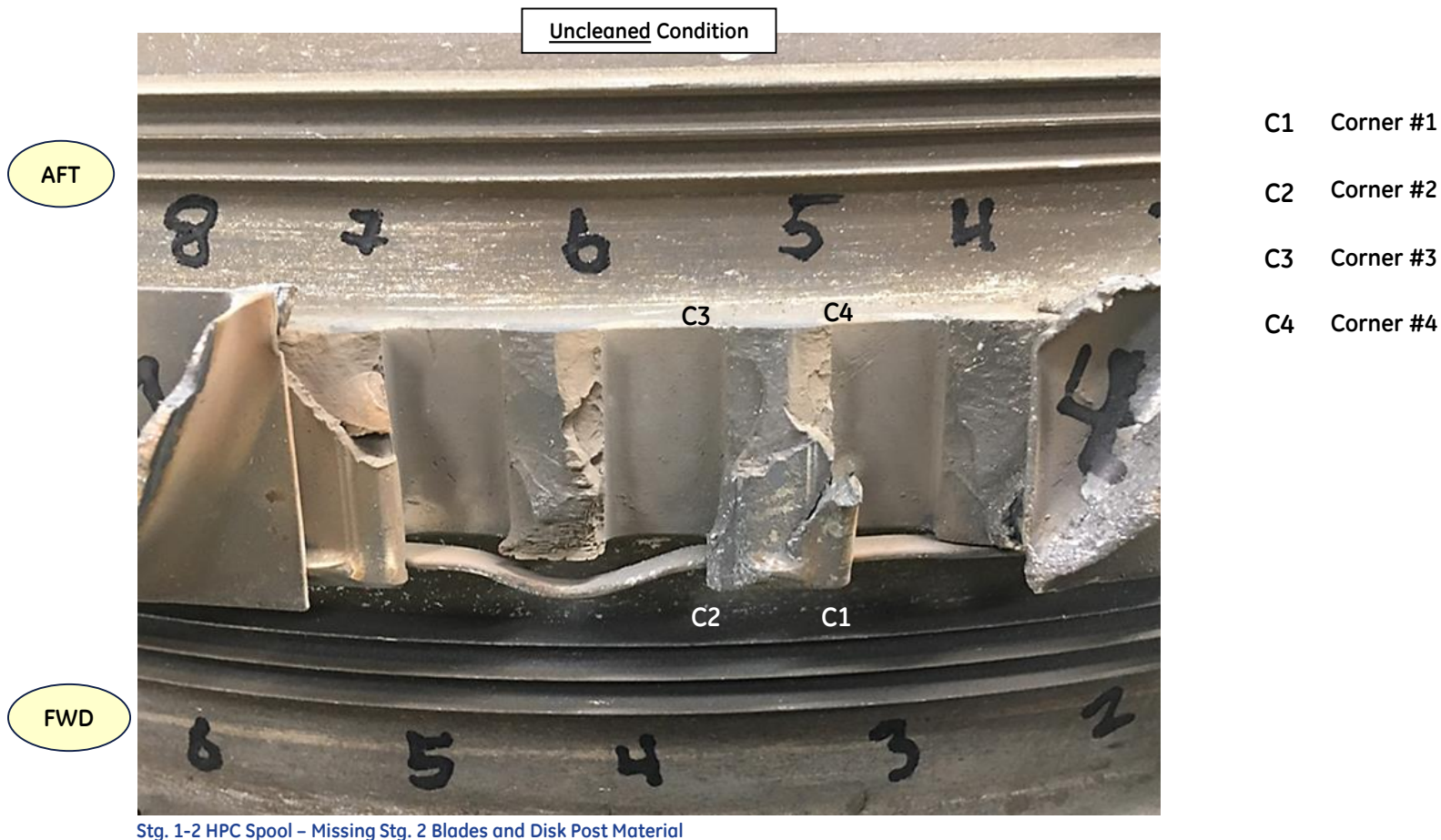


Figure 73. Photograph showing closer view of missing Stg. 2 HPC Blades and Stg. 2 disk post material.

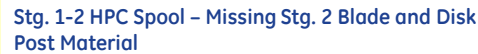
CFM56-7B Stg. 1-2 HPC Spool - ESN 875-318

- Missing Stg. 2 HPC Blades #34 – Missing Stg. 2 Disk Post Material at Posts #33



Figure 74. Photograph showing closer view of missing Stg. 2 HPC Blade and missing Stg. 2 disk post material.

- Missing Stg. 2 HPC Blades #40 – Missing Stg. 2 Disk Post Material at Posts #39 and #40
- Visual Evidence of “Beachmark” Feature Consistent With Fatigue at Post #39-Corner #2 and Post #40-Corner #1



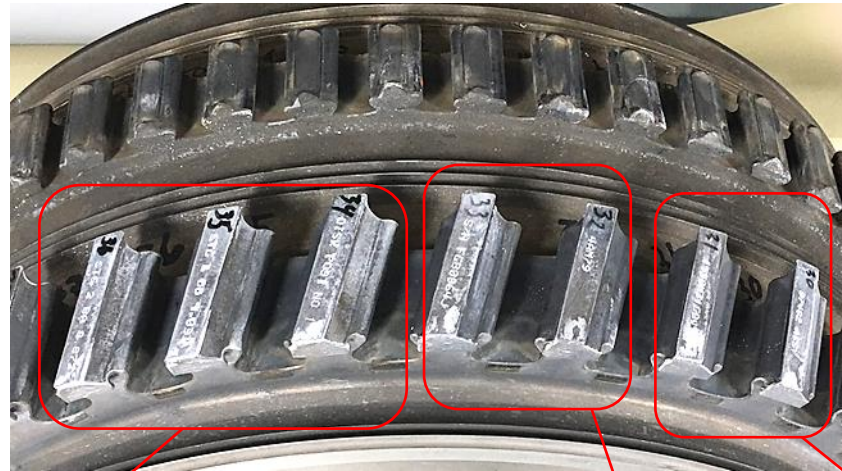
imagination at work

CFM56-7B Stg. 1-2 HPC Spool - ESN 875-318

- Part Numbers on Stg. 1 Disk Posts Following Removal of Compressor Blades in Stg. 1-2 HPC Spool (P/N 1558M31G04, S/N FGB0864J)

Total Remaining Stg. 2 Blade Weight
1206 Grams (2.66 Lbs)

Total Remaining Stg. 1 Blade Weight
2637 Grams (5.81 Lbs)



Uncleaned Condition

Stg. 1-2 HPC Spool – Blades Removed



STG 2 BA 8.72

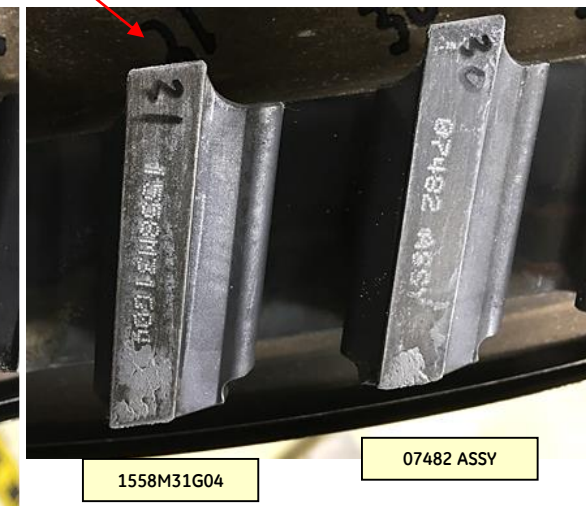
STG 1 BB 9.031

DISK POST NO. 1



S/N FGB0864J

4AM79



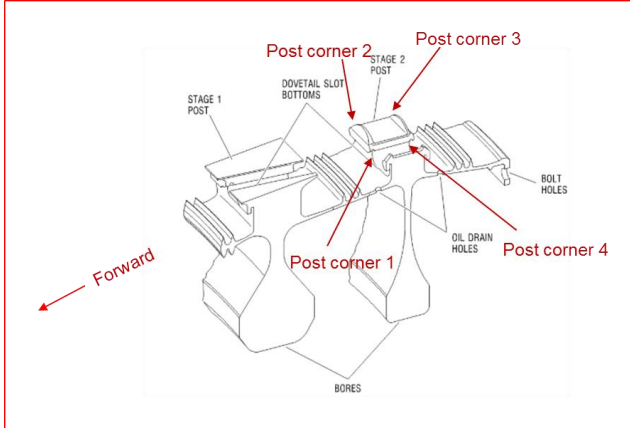
1558M31G04

07482 ASSY

Figure 76. Photographs showing part numbers present on Stg. 1-2 HPC Spool on top surface of Stg. 1 disk posts.

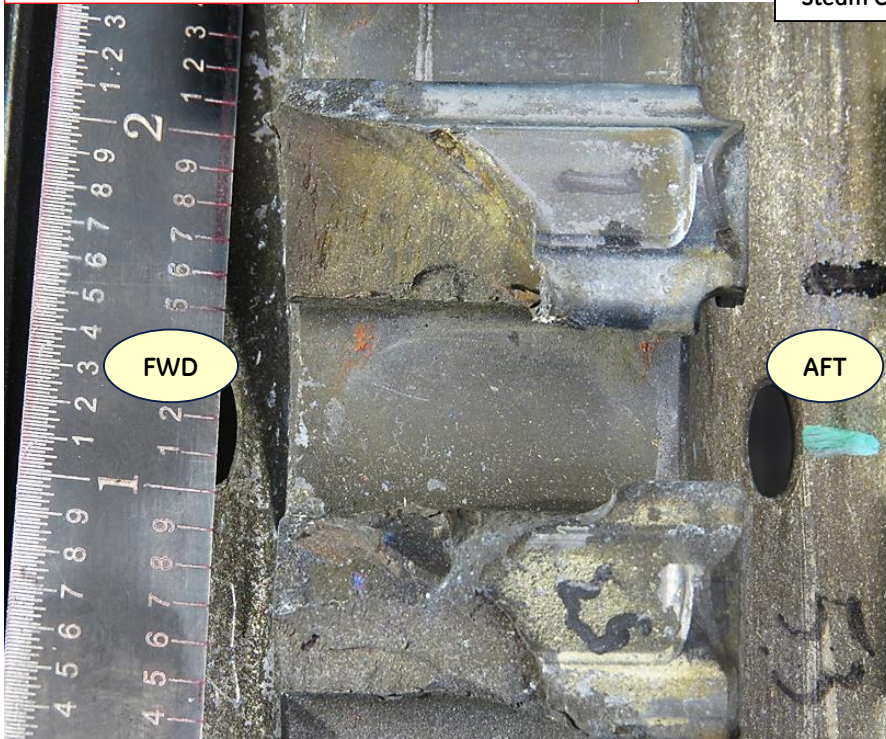
CFM56-7B Stg. 1-2 HPC Spool - ESN 875-318

- Stg. 2 Disk Post Cracking Leading to Liberated Post Material (#1, #2 and #53) - Fractures Consistent With Fatigue

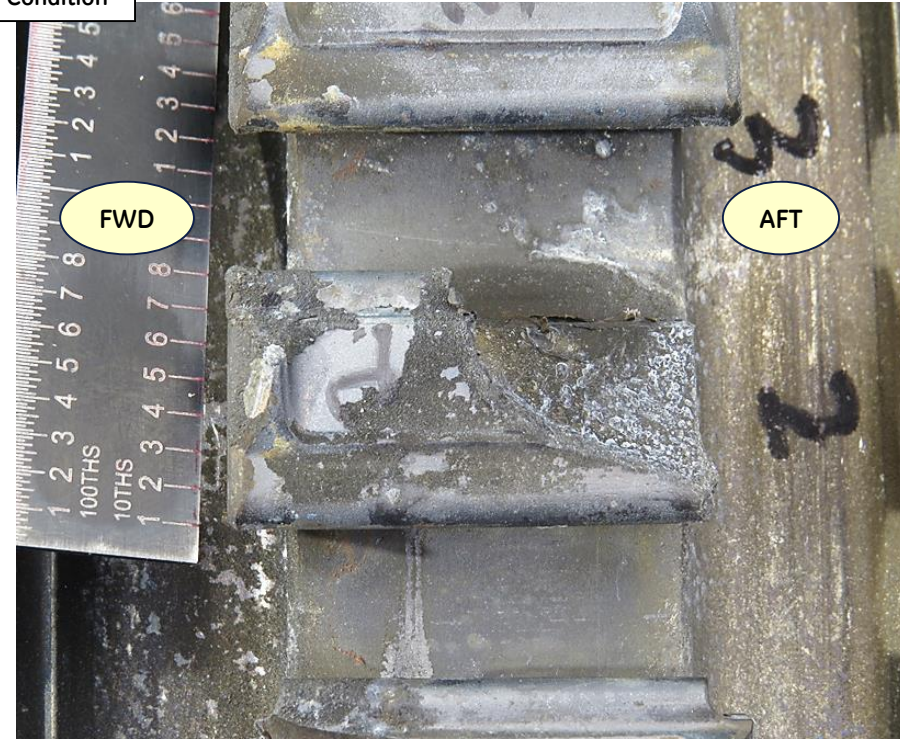


Rotor Rotation

Steam Cleaned Condition



Stg. 2 HPC Disk Posts #1 and #53



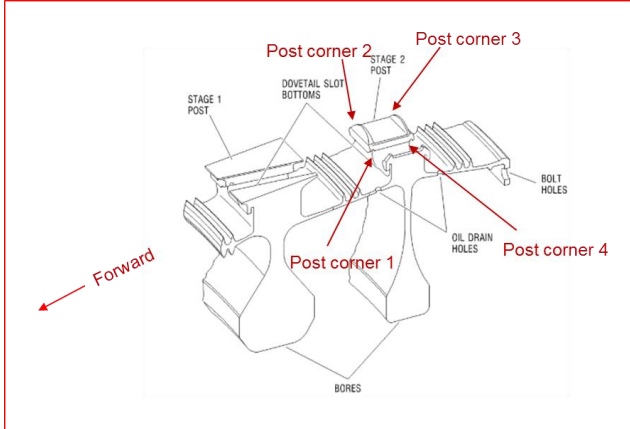
Stg. 2 HPC Disk Post #2

Figure 77. Photographs documenting missing Stg. 2 disk post material following removal of Stg. 2 HPC Blades and steam cleaning.

CFM56-7B Stg. 1-2 HPC Spool - ESN 875-318

- Stg. 2 Disk Post Cracking Leading to Liberated Post Material (#4, #5, #6 and #7) - Exposed Fractures Consistent With Fatigue

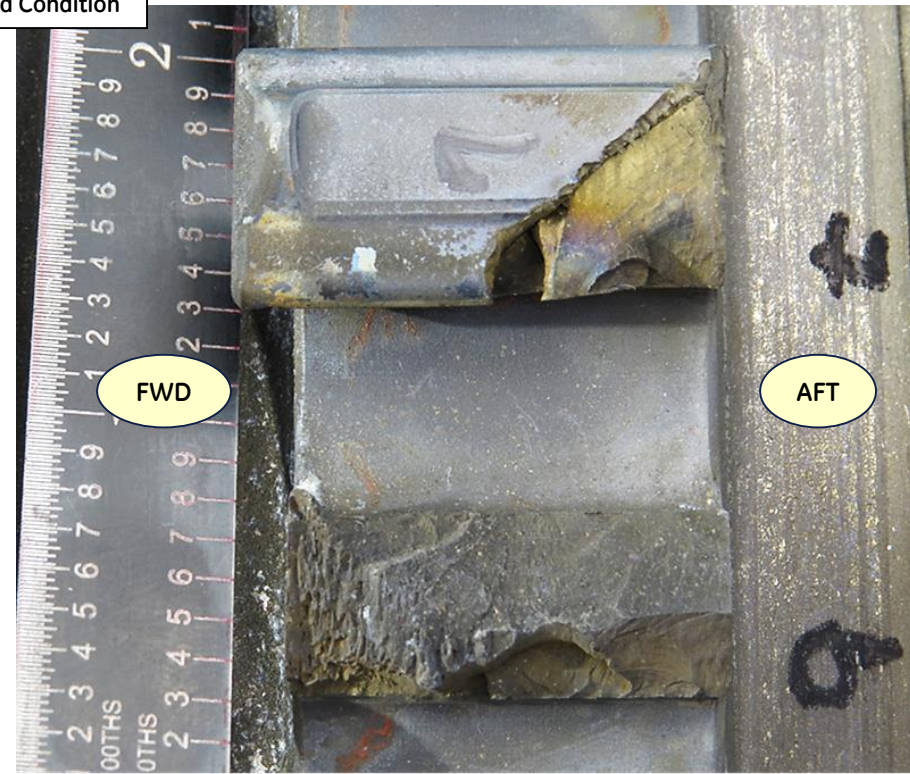
Rotor Rotation



Steam Cleaned Condition



Stg. 2 HPC Disk Posts #4 and #5

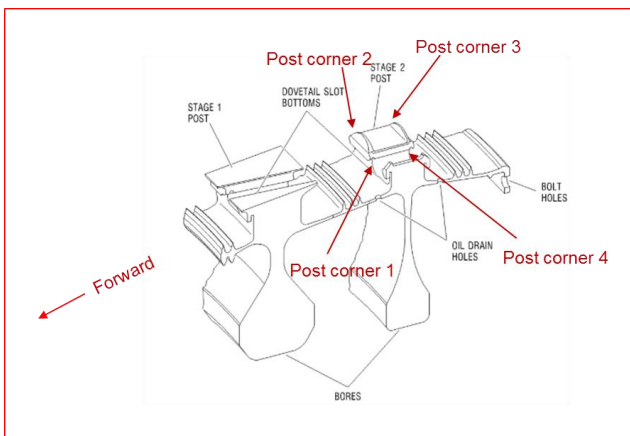


Stg. 2 HPC Disk Posts #6 and #7

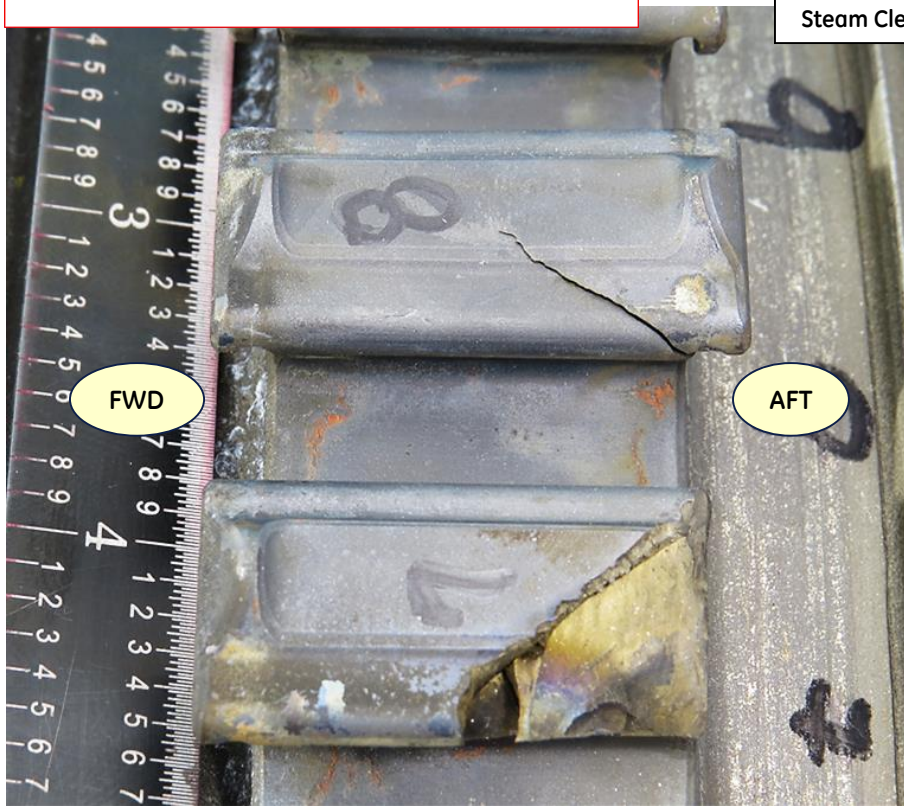
Figure 78. Photographs documenting missing Stg. 2 disk post material following removal of Stg. 2 HPC Blades and steam cleaning.

CFM56-7B Stg. 1-2 HPC Spool - ESN 875-318

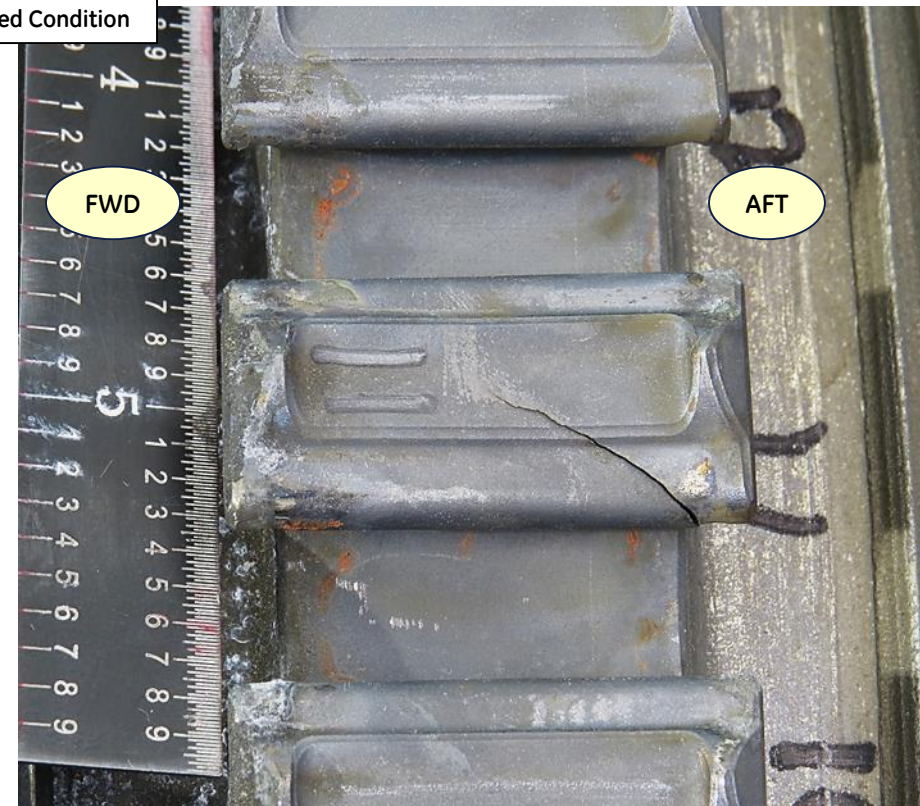
- Stg. 2 Disk Post Cracking Leading to Liberated Post Material (#7) and Cracking Extending Into Top of Disk Post (#8 and #11) - Exposed Fractures Consistent With Fatigue



Rotor Rotation



Stg. 2 HPC Disk Posts #7 and #8

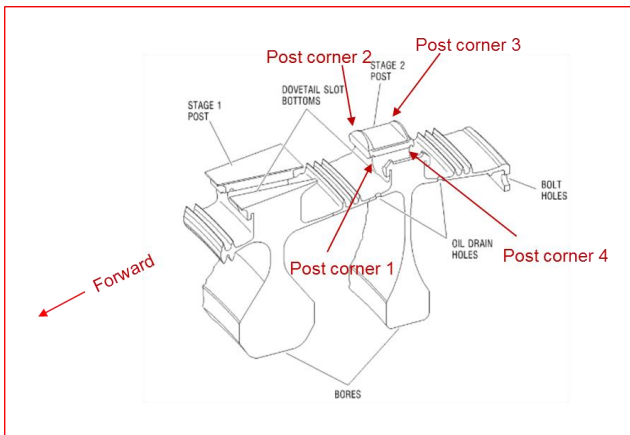


Stg. 2 HPC Disk Post #11

Figure 79. Photographs documenting cracked and missing Stg. 2 disk post material following removal of Stg. 2 HPC Blades and steam cleaning.

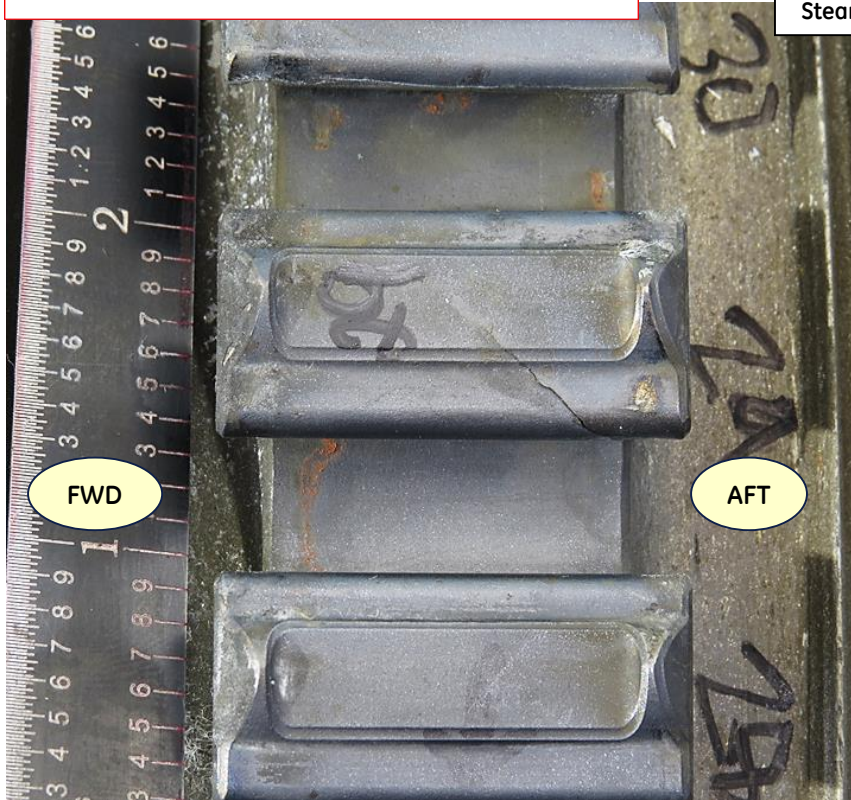
CFM56-7B Stg. 1-2 HPC Spool - ESN 875-318

- Stg. 2 Disk Post Cracking Extending Into Top of Disk Post (#29) Plus Liberated Material (#33) – Exposed Fractures Consistent With Fatigue

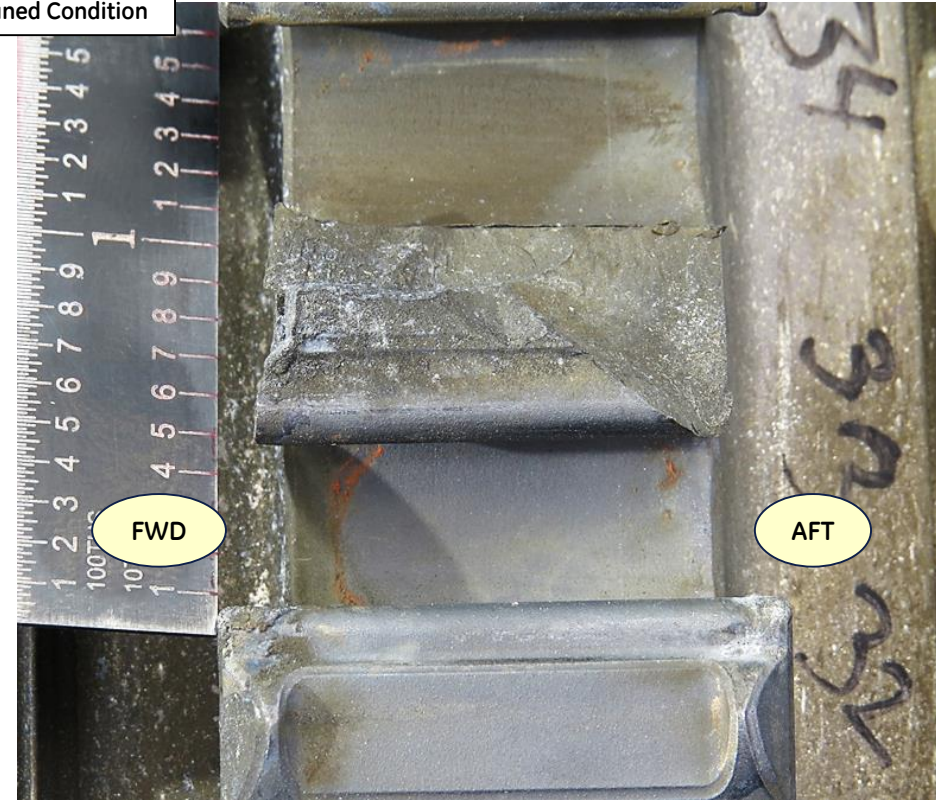


Rotor Rotation

Steam Cleaned Condition



Stg. 2 HPC Disk Post #29



Stg. 2 HPC Disk Post #33

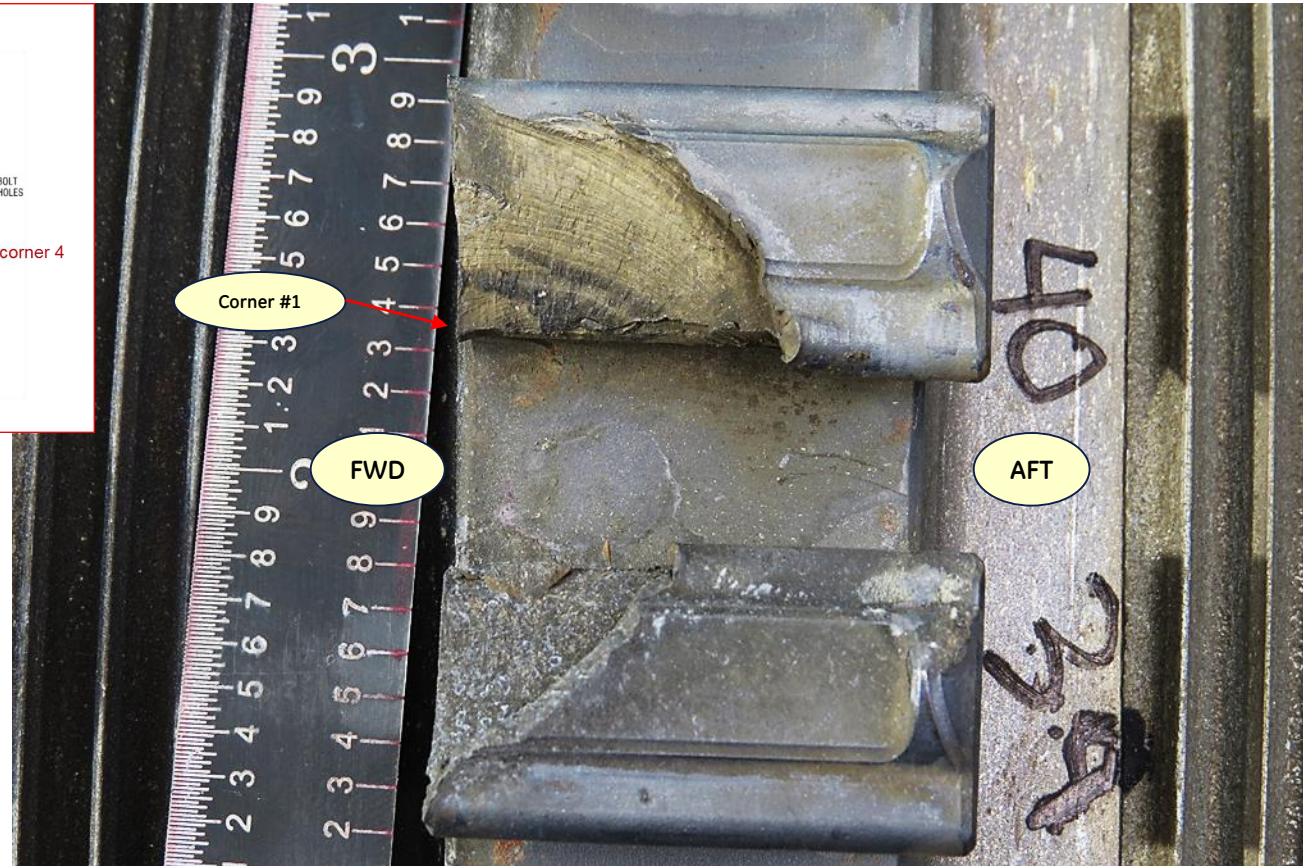
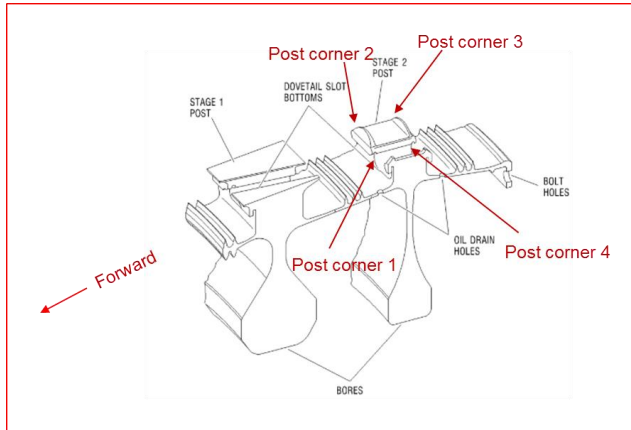
Figure 80. Photographs documenting cracked and missing Stg. 2 disk post material following removal of Stg. 2 HPC Blades and steam cleaning.

CFM56-7B Stg. 1-2 HPC Spool - ESN 875-318

- Stg. 2 Disk Post Cracking Leading to Liberated Post Material (#39 and #40) – Exposed Fractures Consistent With Fatigue

Steam Cleaned Condition

Rotor Rotation



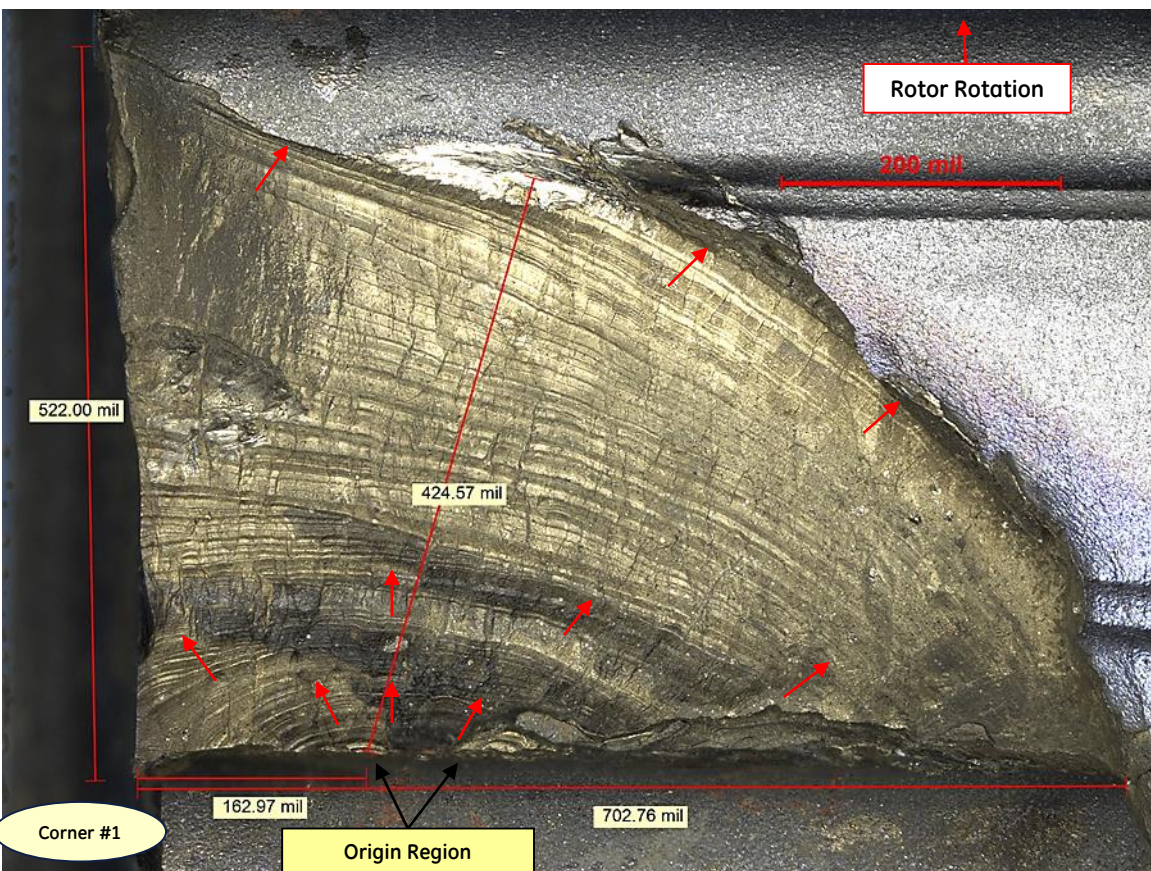
Stg. 1-2 HPC Spool Stg. 2 Disk Posts #39 and #40

Figure 81. Photographs documenting cracked and missing Stg. 2 disk post material following removal of Stg. 2 HPC Blades and steam cleaning.

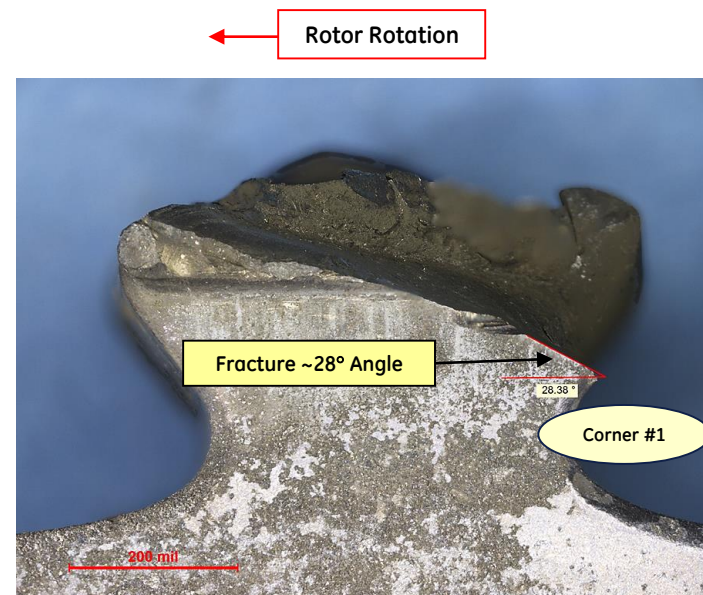
CFM56-7B Stg. 1-2 HPC Spool - ESN 875-318

- Gold Heat Tinted Stg. 2 Disk Post #40 Fracture Surface Exhibiting Fatigue Morphology With Numerous “Beachmark” Features
- Crack Measured ~0.70 Inch Along the Pressure Face and ~0.52 Inch Along the Forward Post Face Prior to Liberation of Disk Post Top Fragment
- Origin Region Located ~0.16 Inch From Corner #1 (Fwd Face)

FWD



Stg. 1-2 HPC Spool Stg. 2 Disk Post #40 Fracture Surface



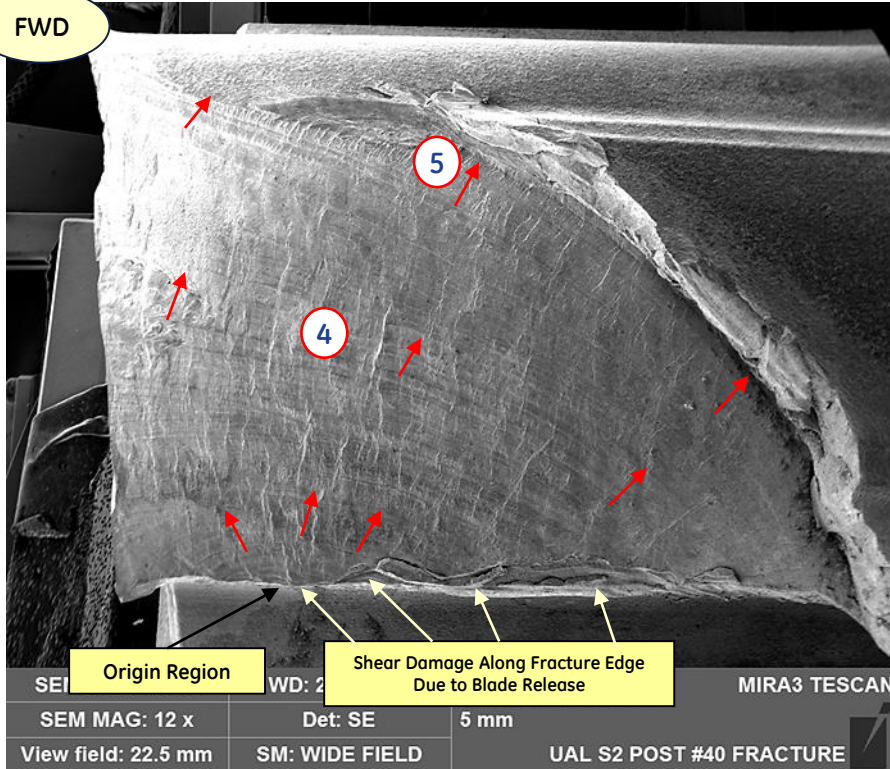
Stg. 1-2 HPC Spool Stg. 2 Disk Post #40 Fwd Face

Figure 82. Photographs documenting Stg. 2 disk post #40 fracture surface and forward face. Origin region located ~0.16 inch off corner #1. Red arrows denote crack propagation direction.

CFM56-7B Stg. 1-2 HPC Spool - ESN 875-318

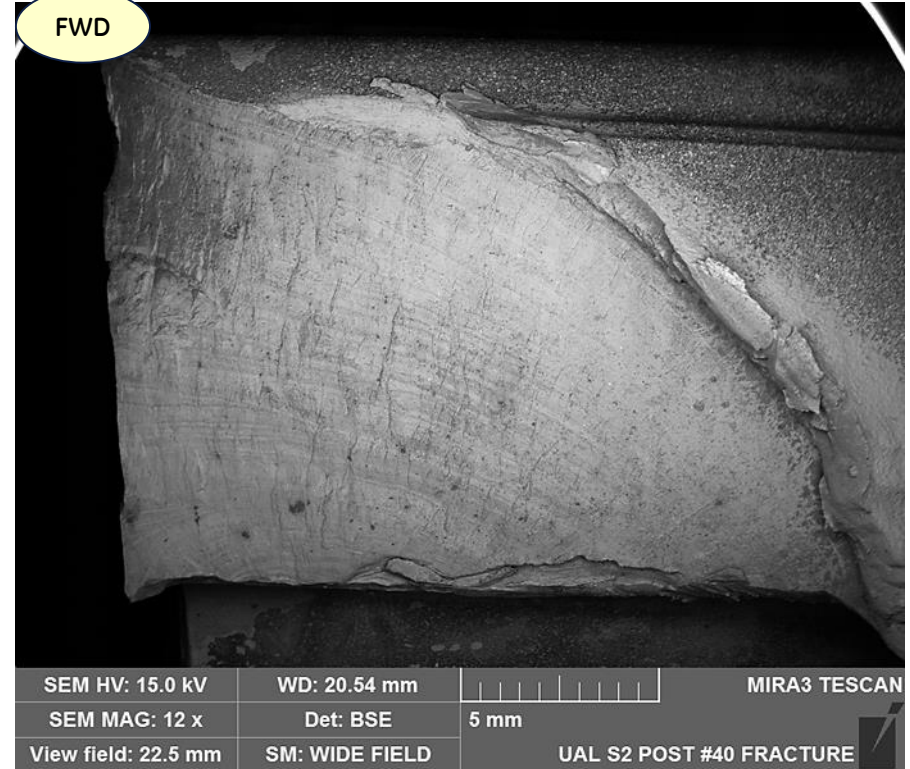
- Stg. 2 Disk Post #40 Fatigue Initiation ~0.16 Inch From Corner #1 Location - Fracture Surface Exhibited Numerous "Beachmark" Features

FWD



Stg. 1-2 HPC Spool Stg. 2 Disk Post #40 Fracture Surface - SEI

FWD

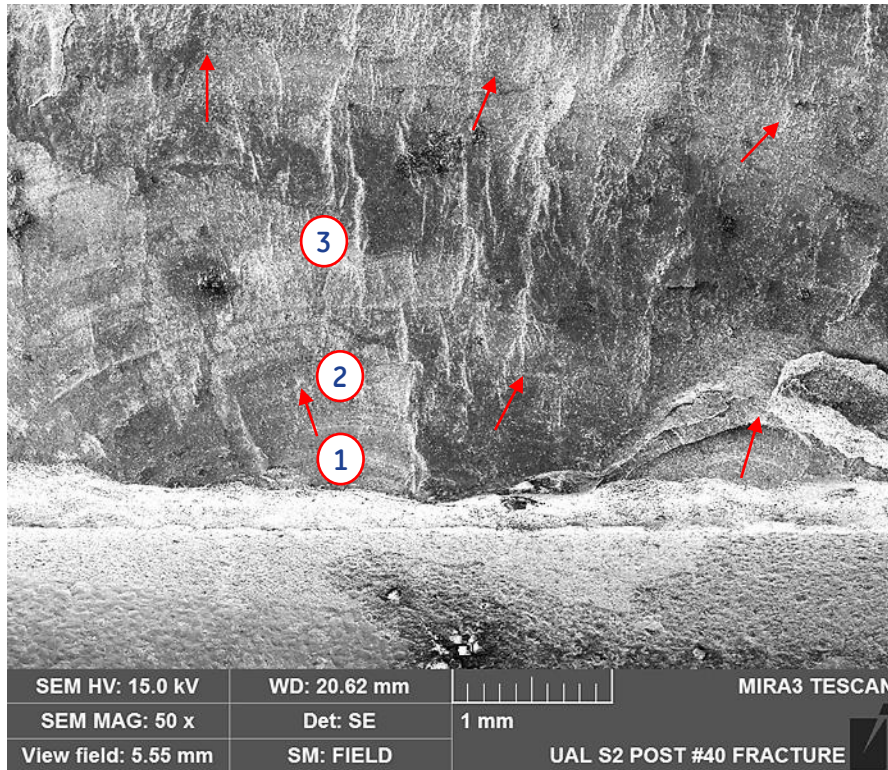


Stg. 1-2 HPC Spool Stg. 2 Disk Post #40 Fracture Surface - BEI

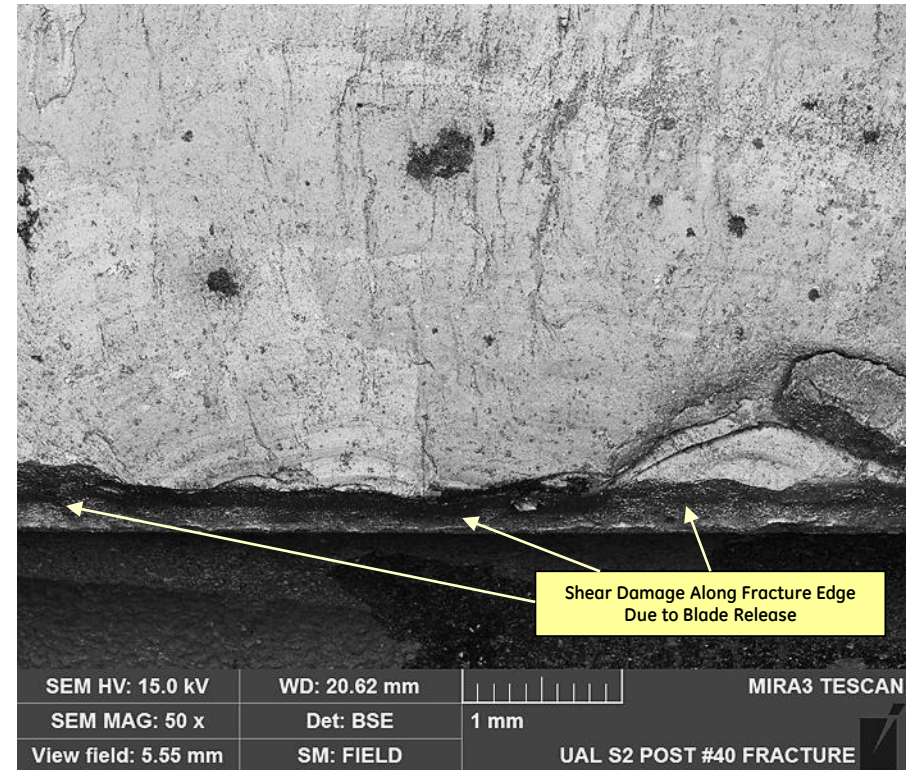
Figure 83. SEM secondary (SEI) and backscatter (BEI) images documenting Stg. 2 disk post #40 fracture surface. Arrows denote crack propagation direction. Areas 4 and 5 were examined in greater detail.

CFM56-7B Stg. 1-2 HPC Spool - ESN 875-318

- Stg. 2 Disk Post #40 Fatigue Crack Origin Region - Secondary Shear Damage Observed Along Fracture Edge Attributed to Stg. 2 HPC Blade Release



Stg. 1-2 HPC Spool Stg. 2 Disk Post #40 Fracture Surface – Origin Region - SEI

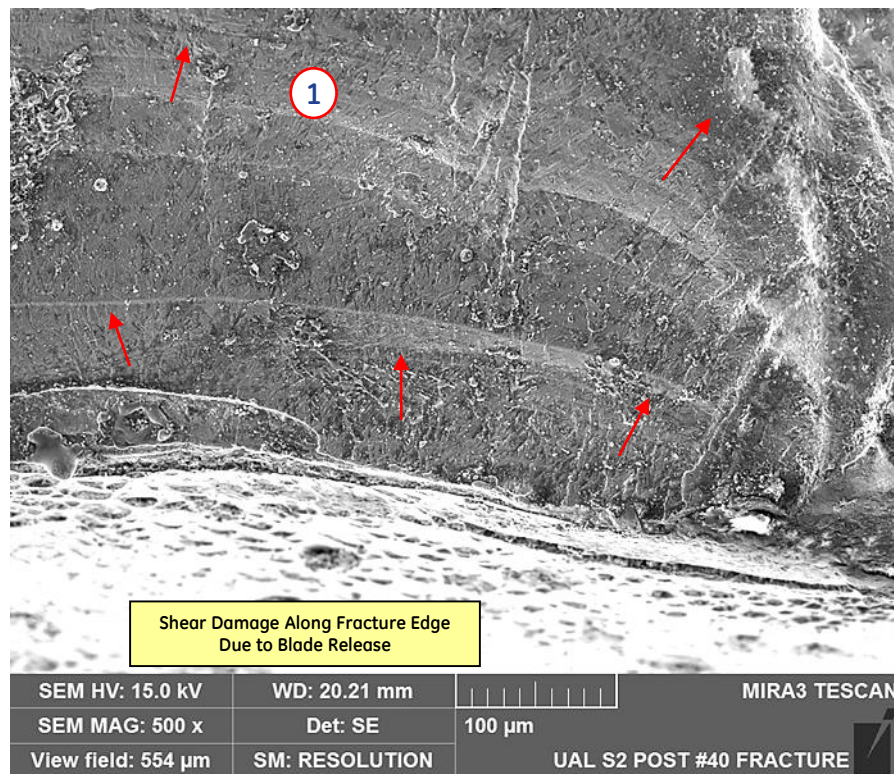


Stg. 1-2 HPC Spool Stg. 2 Disk Post #40 Fracture Surface – Origin Region - BEI

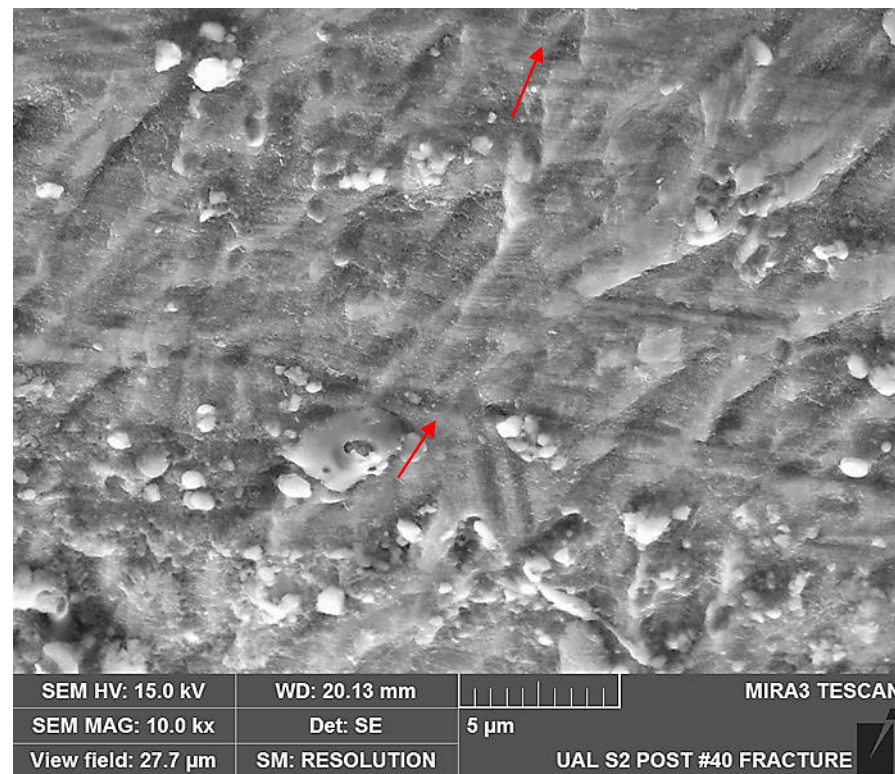
Figure 84. SEM secondary (SEI) and backscatter (BEI) images documenting origin region of Stg. 2 disk post #40 fracture surface. Arrows denote crack propagation direction. Areas 1, 2 and 3 were examined in greater detail.

CFM56-7B Stg. 1-2 HPC Spool - ESN 875-318

- Stg. 2 Disk Post #40 Fatigue Crack Origin Region Damaged By Secondary Shear Along Fracture Edge Due to Blade Release - Finer Striation Appearing Features Observed at Area 1
- Entire Fracture Surface Exhibited Light Surface Oxidation Along With Regions of Molten Debris Splatter



Stg. 1-2 HPC Spool Stg. 2 Disk Post #40 Fracture Surface – Origin Region - SEI

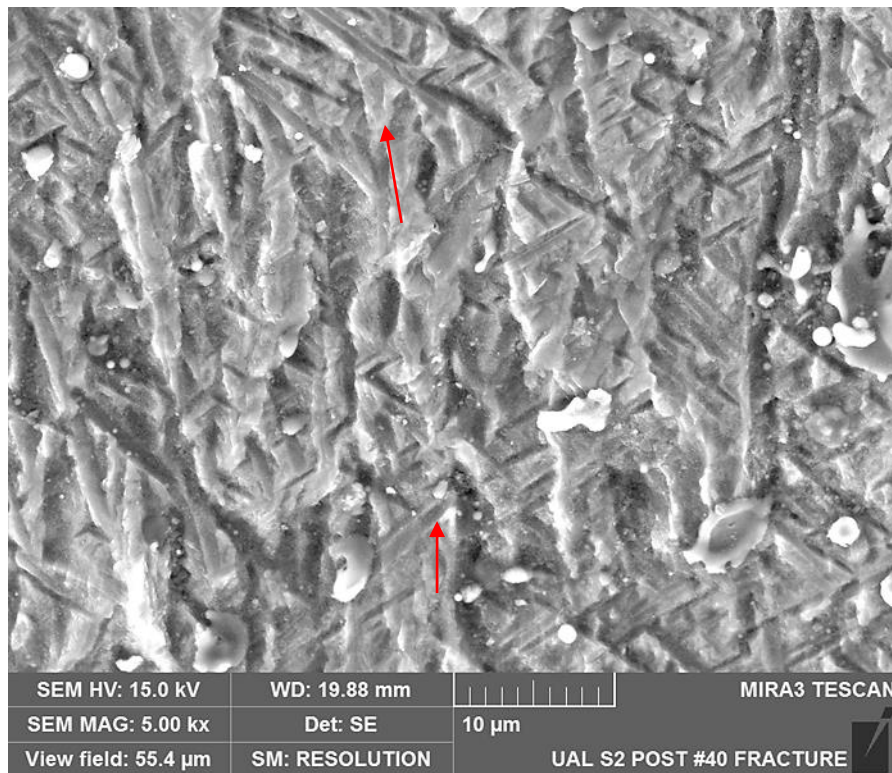


Stg. 2 Disk Post Fracture #40 - Area 1 - SEI

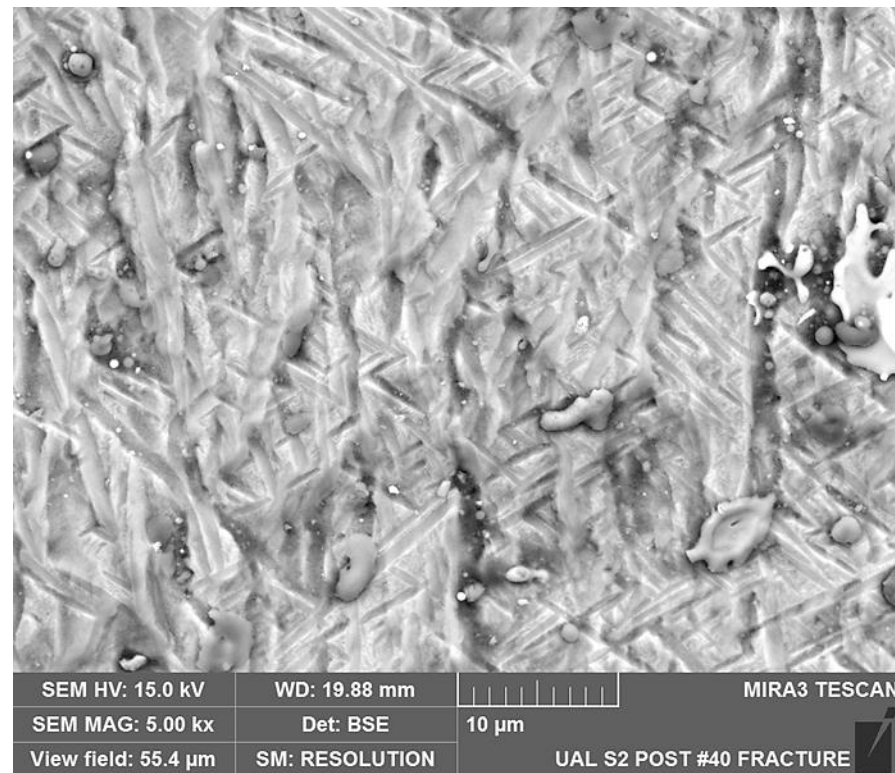
Figure 85. SEM secondary (SEI) images documenting fracture morphology at area 1 in the origin region on Stg. 2 disk post #40 fracture surface. Arrows denote crack propagation direction.

CFM56-7B Stg. 1-2 HPC Spool - ESN 875-318

- Fracture Morphology Consistent With Lower Alternating Stress, High Cycle Fatigue (HCF) or Mixed-Mode LCF/HCF Crack Propagation Mechanisms – No Evidence of Coarser Fatigue Striations Observed
- Acicular Microstructure Resulting From Beta (β) Processing Showing Through on Fracture



Stg. 2 Disk Post Fracture #40 - Area 2 - SEI

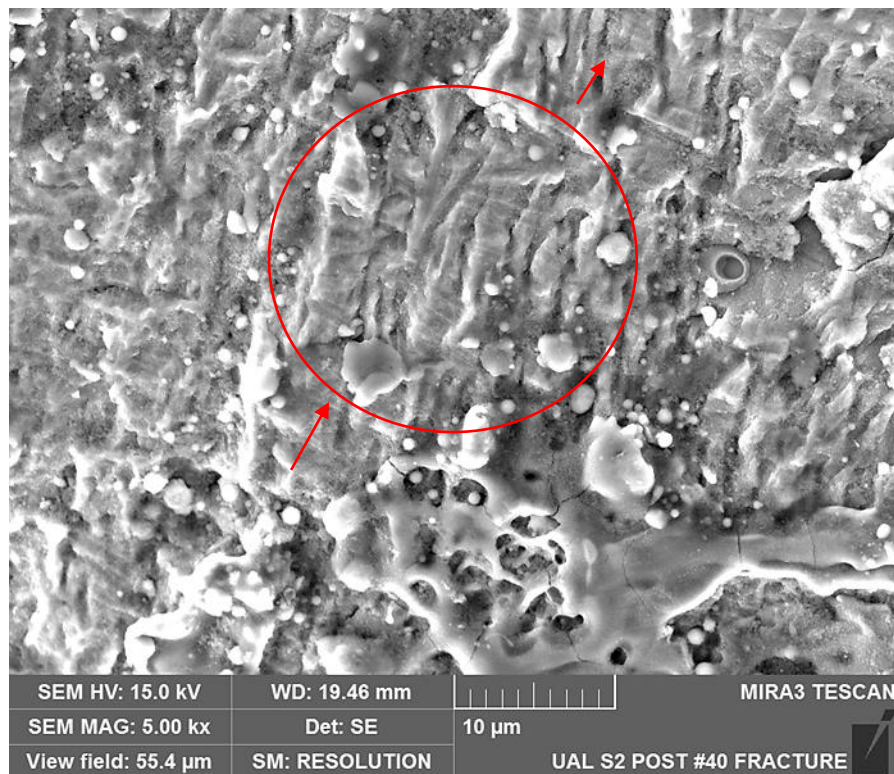


Stg. 2 Disk Post Fracture #40 - Area 2 - BEI

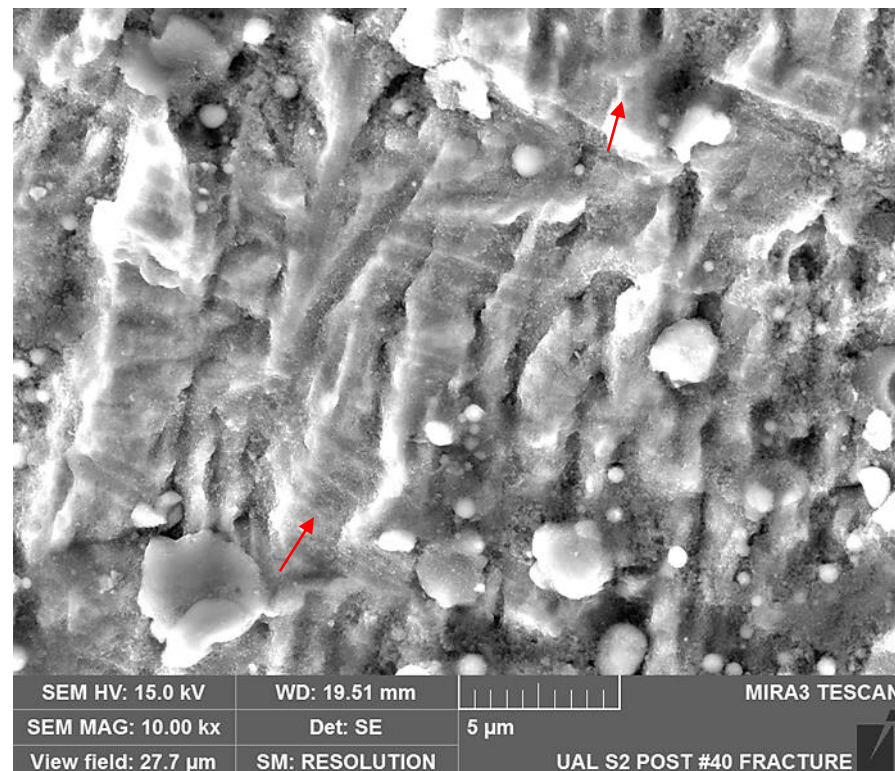
Figure 86. SEM secondary (SEI) images documenting fracture morphology at area 2 on Stg. 2 disk post #40 fracture surface. Arrows denote crack propagation direction.

CFM56-7B Stg. 1-2 HPC Spool - ESN 875-318

- Fracture Morphology Consistent With Lower Alternating Stress, High Cycle Fatigue (HCF) or Mixed-Mode LCF/HCF Crack Propagation Mechanisms – No Evidence of Coarser Fatigue Striations Observed
- Entire Fracture Surface Exhibited Light Surface Oxidation Along With Regions of Molten Debris Splatter



Stg. 2 Disk Post Fracture #40 - Area 3 - SEI

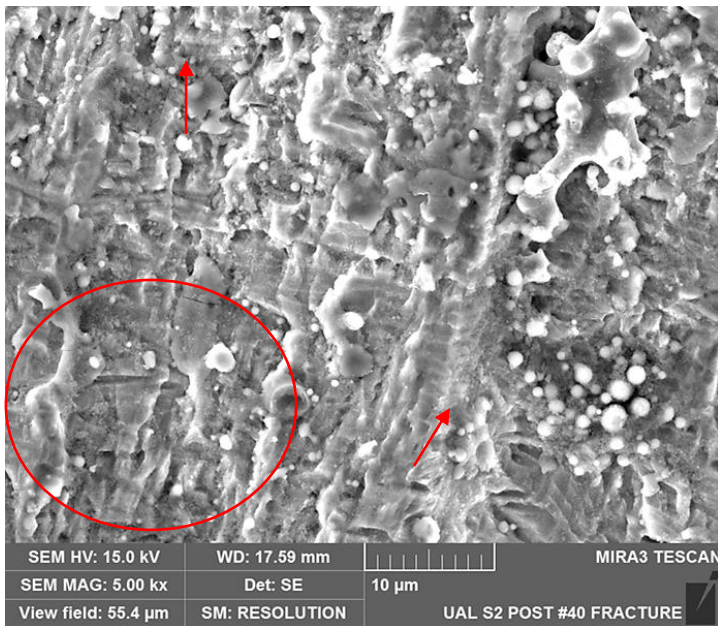


Circled Region - SEI

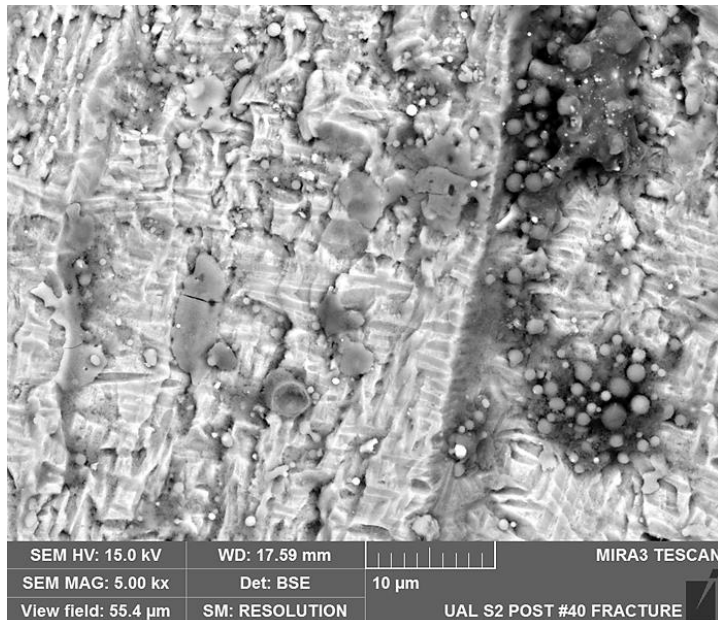
Figure 87. SEM secondary (SEI) images documenting fracture morphology at area 3 on Stg. 2 disk post #40 fracture surface. Arrows denote crack propagation direction.

CFM56-7B Stg. 1-2 HPC Spool - ESN 875-318

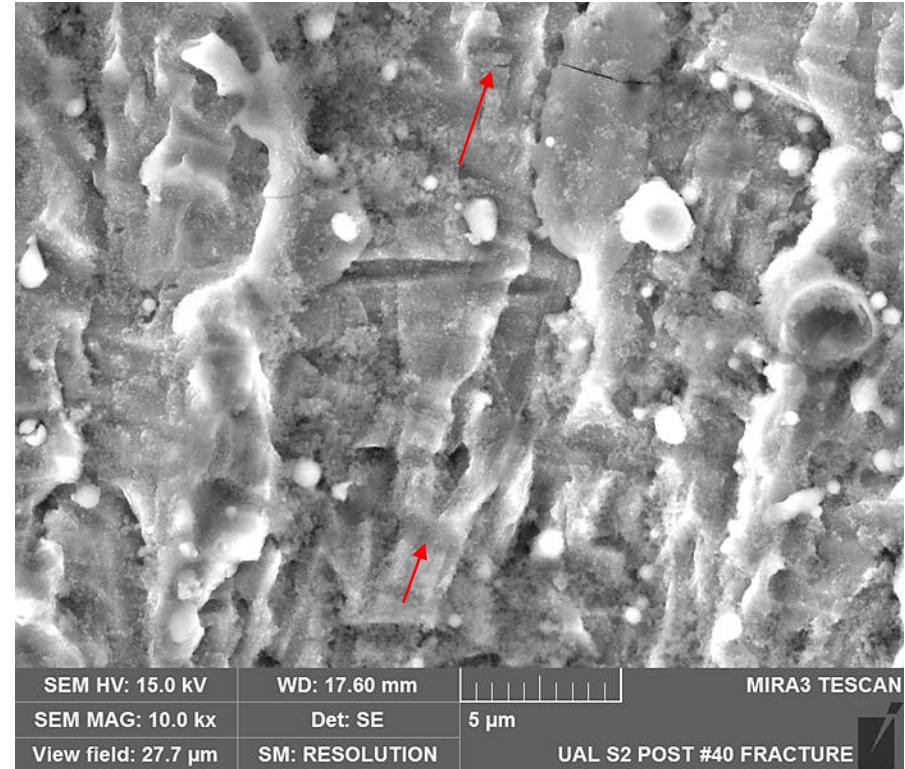
- Fracture Morphology Consistent With Lower Alternating Stress, High Cycle Fatigue (HCF) or Mixed-Mode LCF/HCF Crack Propagation Mechanisms – No Evidence of Coarser Fatigue Striations Observed
- Entire Fracture Surface Exhibited Light Surface Oxidation Along With Regions of Molten Debris Splatter



Stg. 2 Disk Post Fracture #40 – Area 4 – SEI



Stg. 2 Disk Post Fracture #40 – Area 4 – BEI

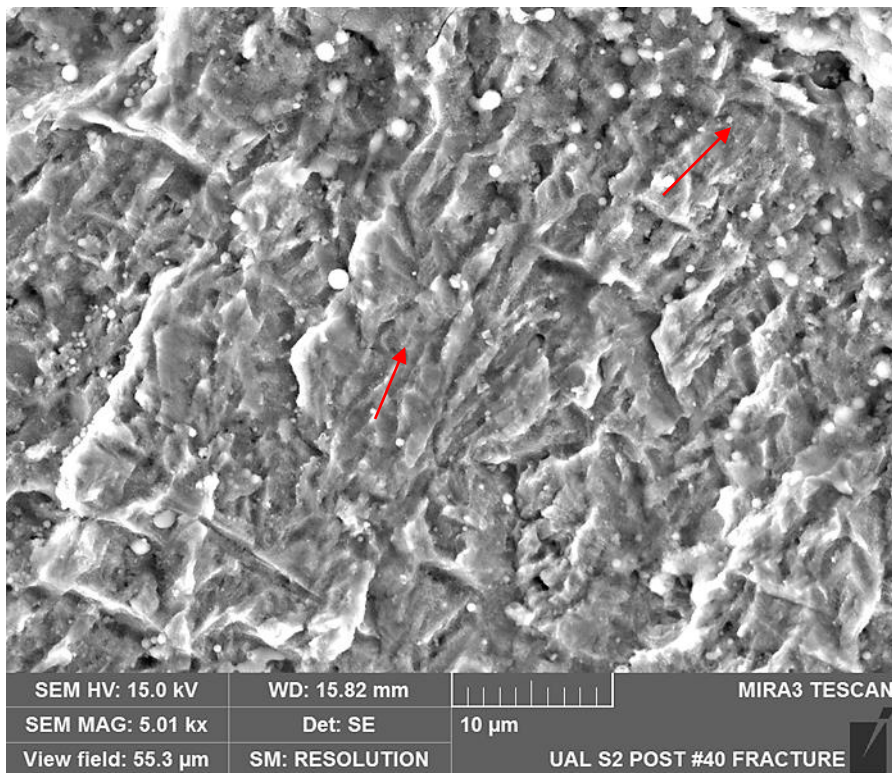


Circled Region – SEI

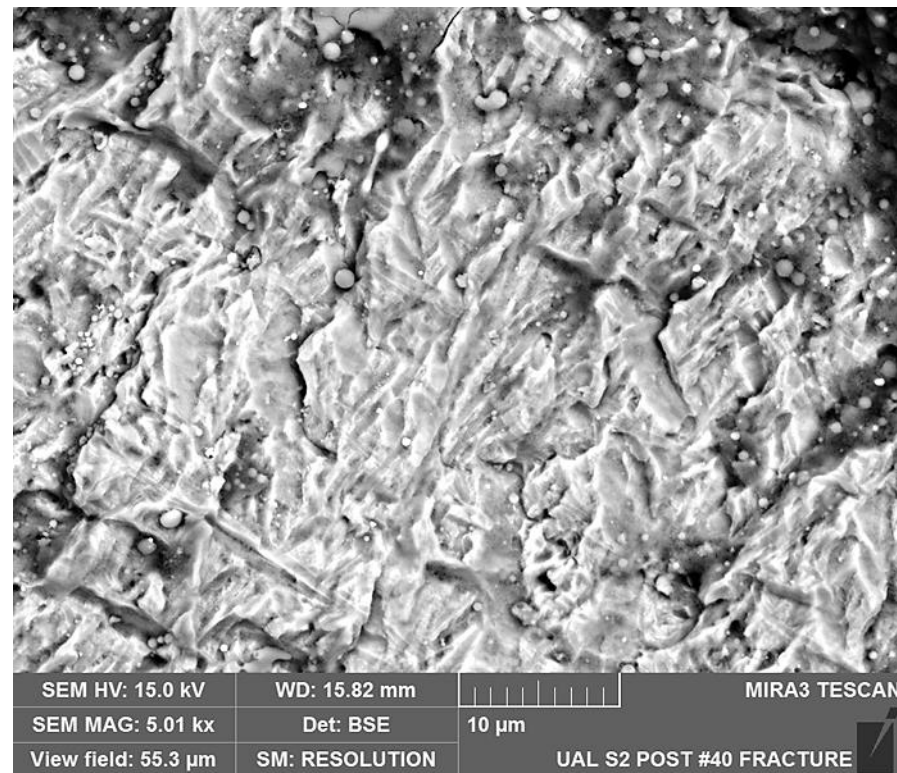
Figure 88. SEM secondary (SEI) images documenting fracture morphology at area 4 on Stg. 2 disk post #40 fracture surface. Arrows denote crack propagation direction.

CFM56-7B Stg. 1-2 HPC Spool - ESN 875-318

- Fracture Morphology Consistent With Lower Alternating Stress, High Cycle Fatigue (HCF) or Mixed-Mode LCF/HCF Crack Propagation Mechanisms – No Evidence of Coarser Fatigue Striations Observed
- Entire Fracture Surface Exhibited Light Surface Oxidation Along With Regions of Molten Debris Splatter



Stg. 2 Disk Post Fracture #40 – Area 5 – Crack End Region - SEI

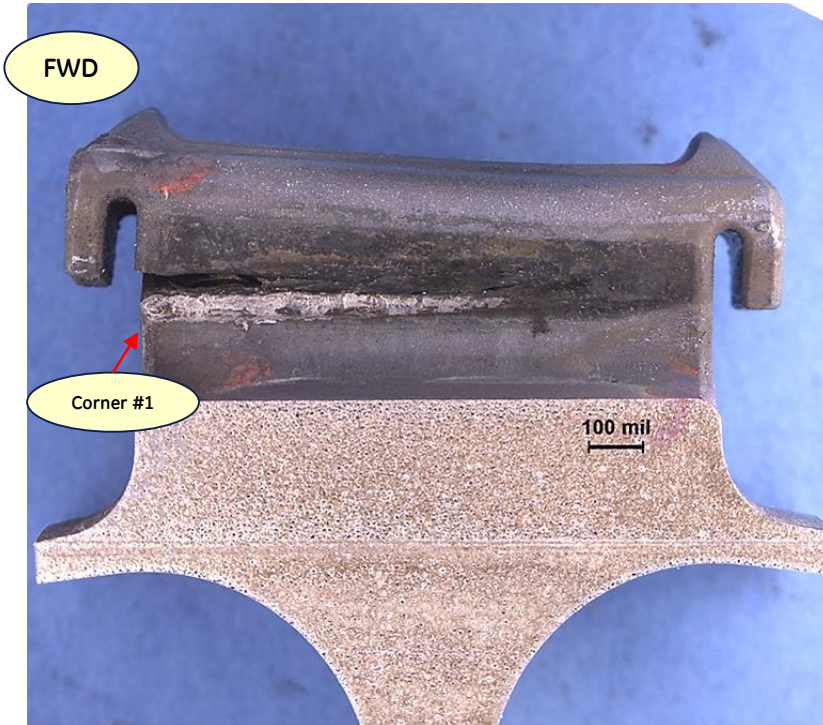


Stg. 2 Disk Post Fracture #40 – Area 5 – Crack End Region - BEI

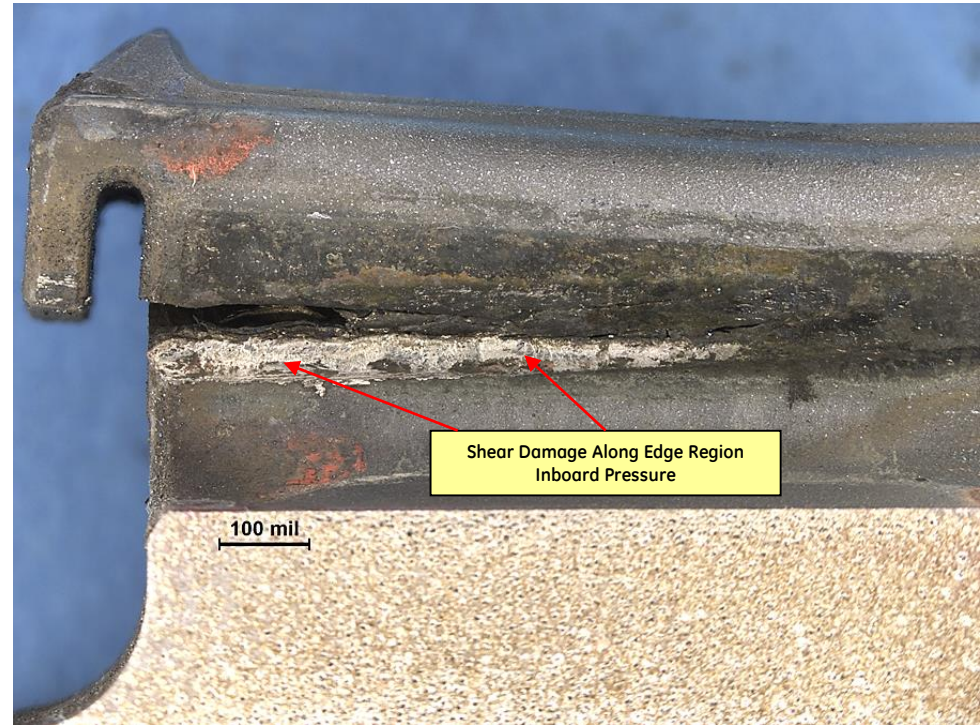
Figure 89. SEM secondary (SEI) images documenting fracture morphology at area 5 on Stg. 2 disk post #40 fracture surface. Arrows denote crack propagation direction.

CFM56-7B Stg. 1-2 HPC Spool - ESN 875-318

- Stg. 2 Disk Post #44 Exhibiting Corner #1 Crack Along Inboard Pressure Face Edge



Stg. 1-2 HPC Spool Stg. 2 Disk Post #44 – Corner #1 Crack



Stg. 1-2 HPC Spool Stg. 2 Disk Post #44 – Corner #1 Crack

Figure 90. Photographs documenting cracked Stg. 2 disk post #44 at the corner #1 location.

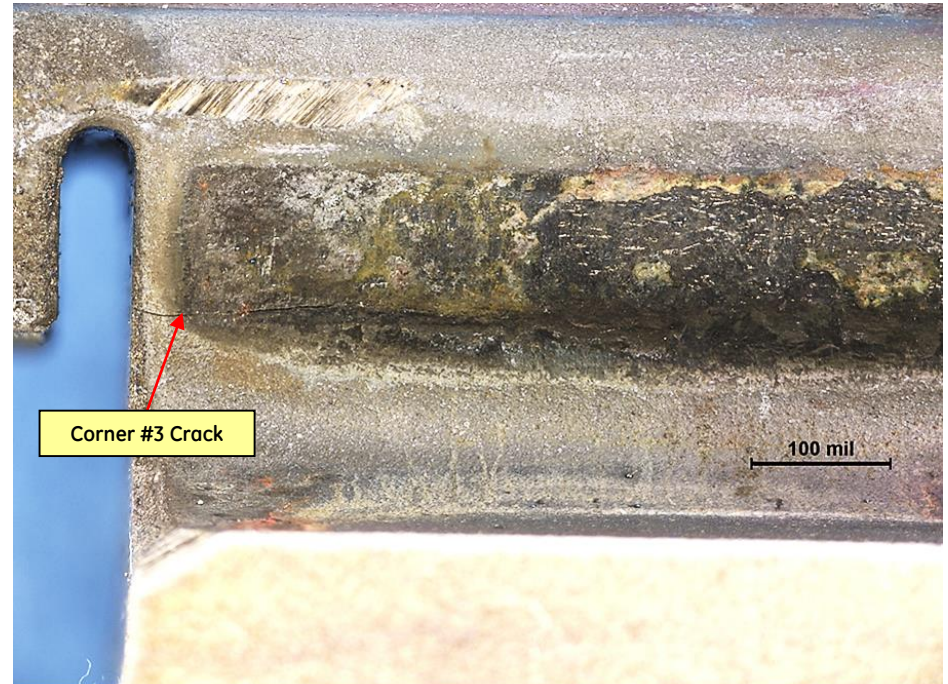
CFM56-7B Stg. 1-2 HPC Spool - ESN 875-318

- Stg. 2 Disk Post #44 Exhibiting Corner #3 Crack Along Inboard Pressure Face Edge

AFT



Stg. 1-2 HPC Spool Stg. 2 Disk Post #44 – Corner #3 Crack

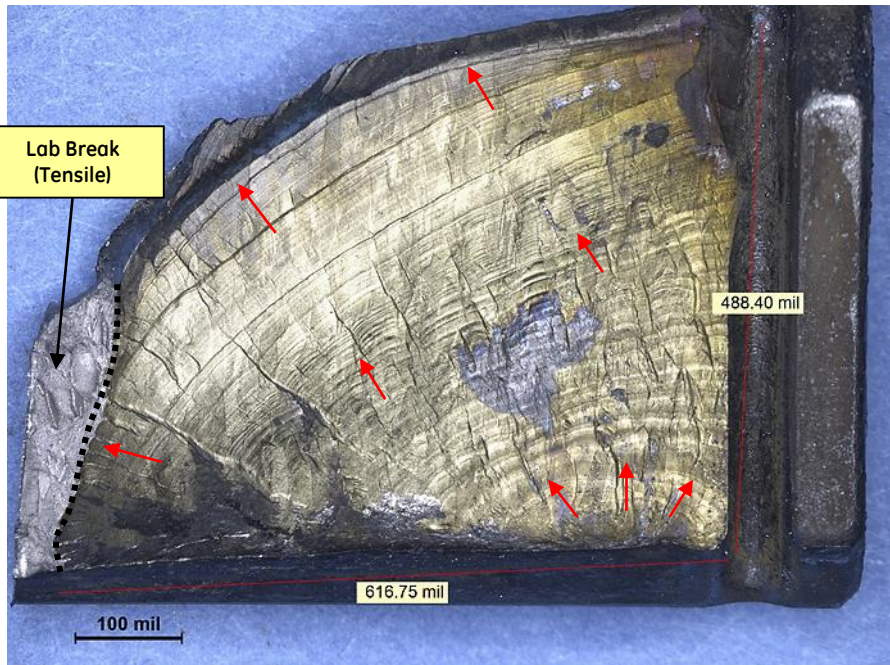


Stg. 1-2 HPC Spool Stg. 2 Disk Post #44 – Corner #3 Crack

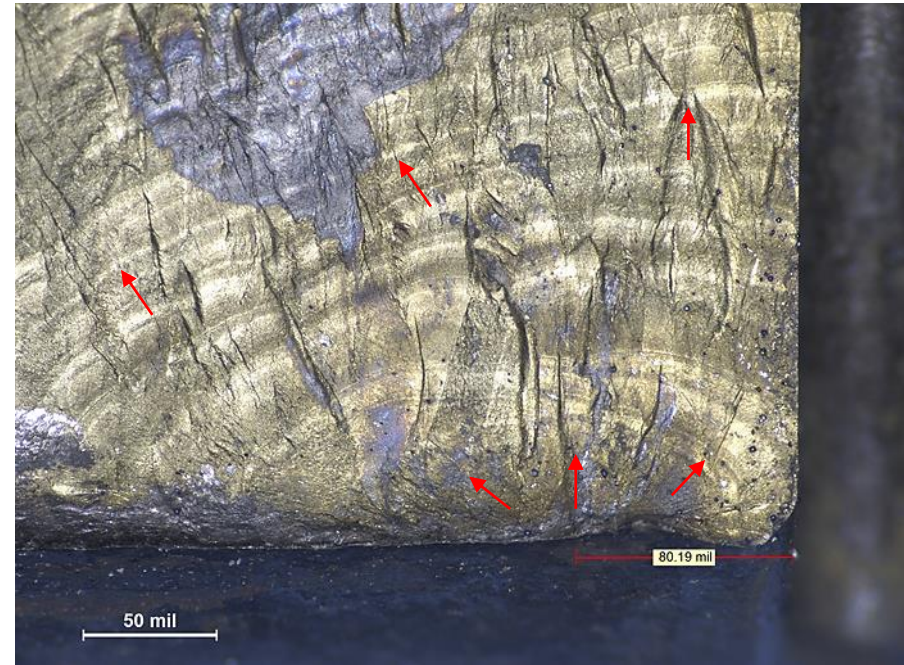
Figure 91. Photographs documenting cracked Stg. 2 disk post #44 at the corner #3 location.

CFM56-7B Stg. 1-2 HPC Spool - ESN 875-318

- Lab Fractured Stg. 2 Disk Post #44 Corner #1 Fracture Surface (Outboard Half) Exhibiting Fatigue Morphology With Numerous "Beachmark" Features
- Crack Measured ~0.62 Inch Along the Pressure Face and ~0.49 Inch Along the Forward Post Face
- Origin Region Located ~0.080 Inch From Corner #1 (Fwd Face)



Stg. 1-2 HPC Spool Stg. 2 Disk Post #44 – Outboard Fracture Half - Corner #1 Crack

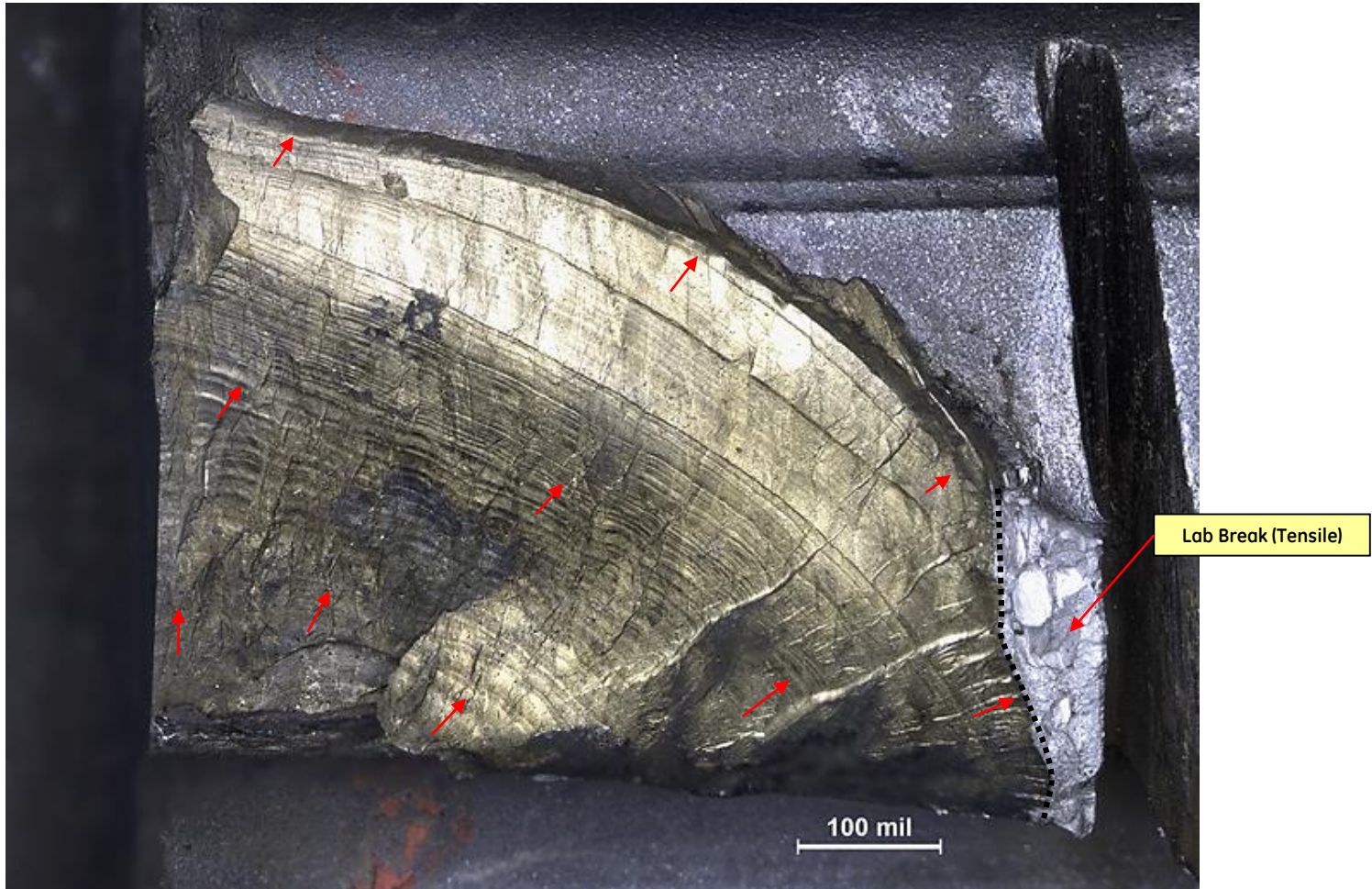


Stg. 1-2 HPC Spool Stg. 2 Disk Post #44 – Outboard Fracture Half - Corner #1 Crack

Figure 92. Photographs documenting Stg. 2 disk post #44 fracture surface at the corner #1 location (outboard half) following lab fracture. Origin region located ~0.080 inch off corner #1. Arrows denote crack propagation direction.

CFM56-7B Stg. 1-2 HPC Spool - ESN 875-318

- Stg. 2 Disk Post #44 Corner #1 Fracture Surface Exhibiting Fatigue Morphology With Numerous "Beachmark" Features

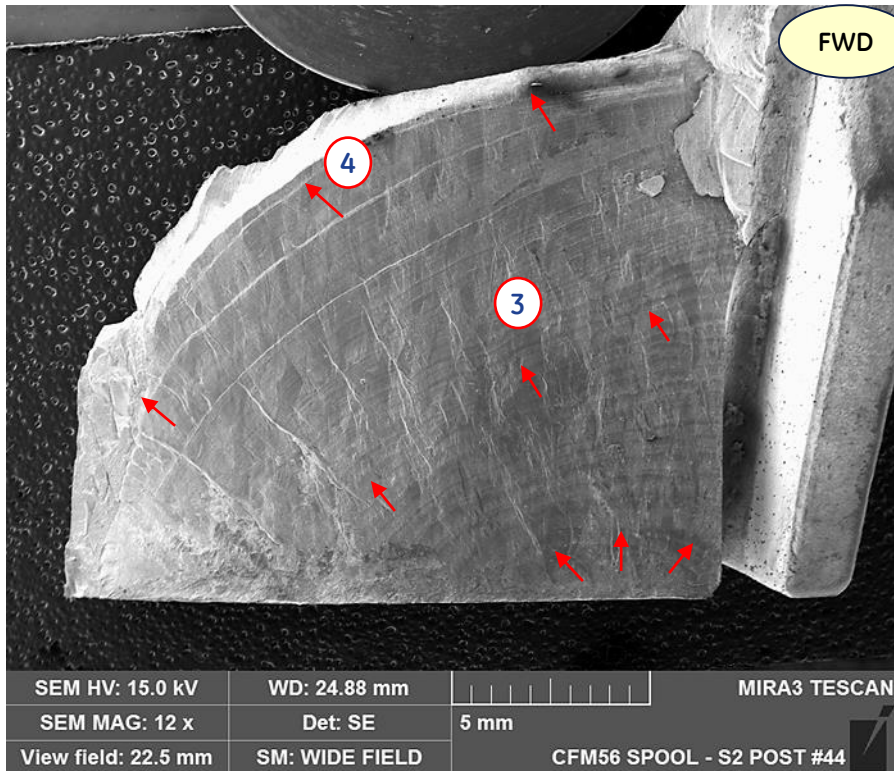


Stg. 1-2 HPC Spool Stg. 2 Disk Post #44 - Inboard Fracture Half - Corner #1 Crack

Figure 93. Photographs documenting Stg. 2 disk post #44 fracture surface at the corner #1 location (inboard half) following lab fracture. Arrows denote crack propagation direction.

CFM56-7B Stg. 1-2 HPC Spool - ESN 875-318

- Stg. 2 Disk Post #40 Fatigue Fracture Emanating From Corner #1 Region - Fracture Surface Exhibited Numerous "Beachmark" Features



Stg. 1-2 HPC Spool Stg. 2 Disk Post #44 – Outboard Fracture Half - SEI

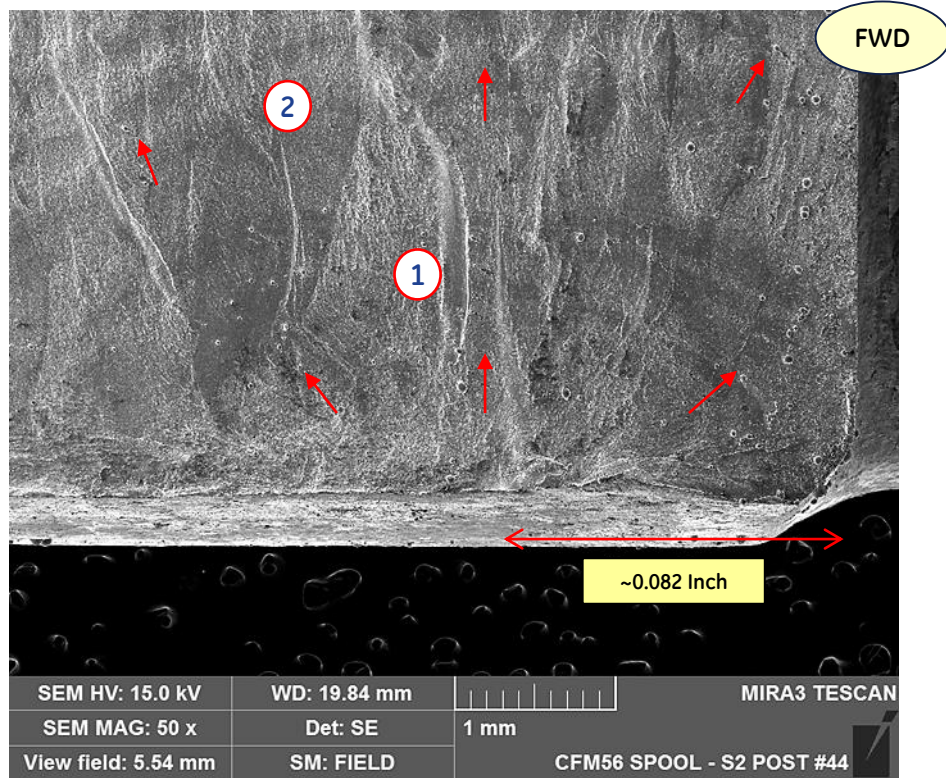


Stg. 1-2 HPC Spool Stg. 2 Disk Post #44 – Outboard Fracture Half - BEI

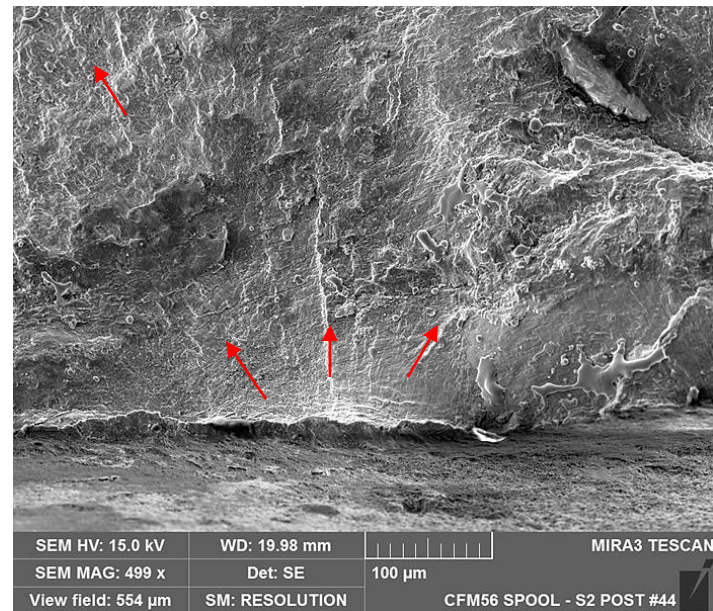
Figure 94. SEM secondary (SEI) and backscatter (BEI) images documenting Stg. 2 disk post #44 fracture surface (outboard half). Arrows denote crack propagation direction. Areas 3 and 4 were examined in greater detail.

CFM56-7B Stg. 1-2 HPC Spool - ESN 875-318

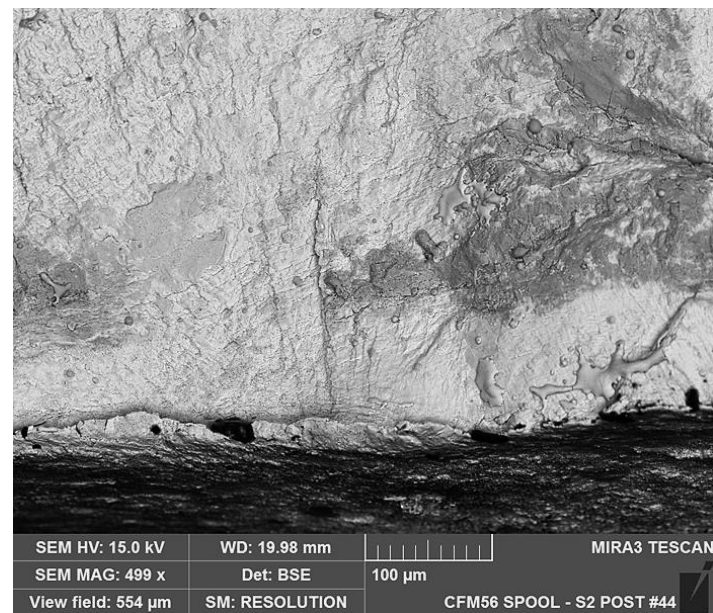
- Stg. 2 Disk Post #44 Fatigue Initiation ~0.082 Inch From Corner #1 Location - Fracture Surface Exhibited Numerous "Beachmark" Features
- No Evidence of Any Material Anomalies Located at Fatigue Origin Region



Stg. 1-2 HPC Spool Stg. 2 Disk Post #44 - Outboard Fracture Half - SEI



Stg. 1-2 HPC Spool Stg. 2 Disk Post #44 - Origin Region - SEI

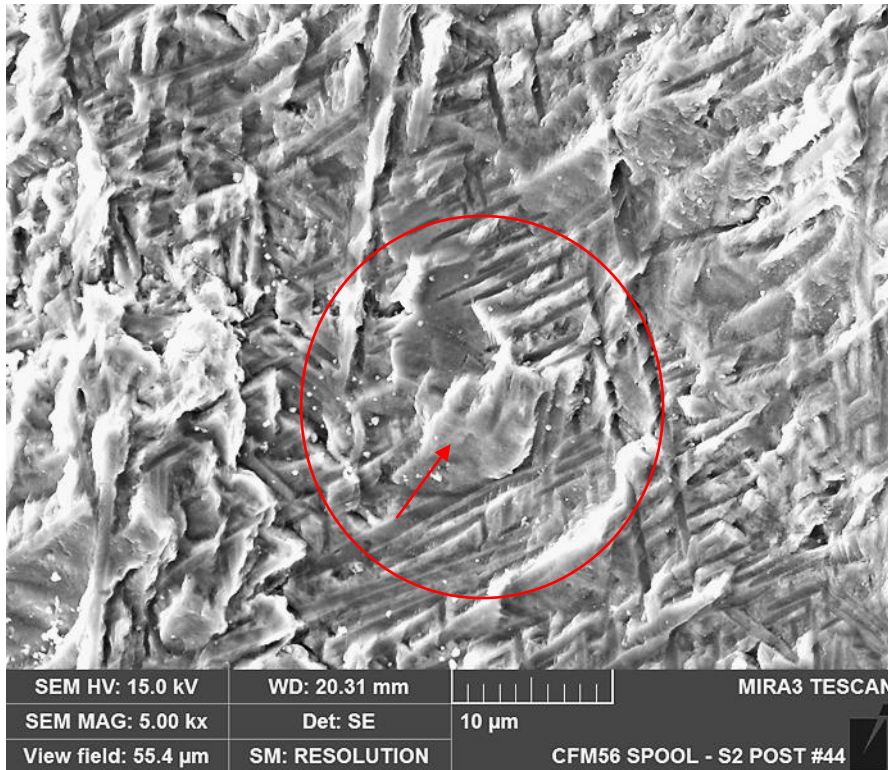


Stg. 1-2 HPC Spool Stg. 2 Disk Post #44 - Origin Region - BEI

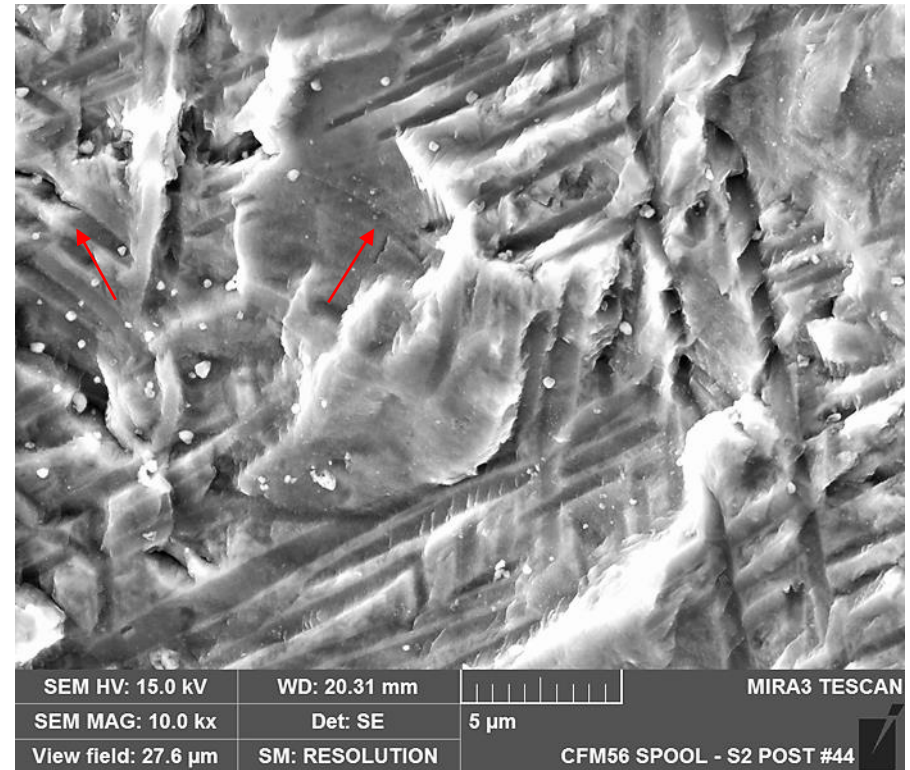
Figure 95. SEM secondary (SEI) and backscatter (BEI) images documenting origin region of Stg. 2 disk post #44 fracture surface. Arrows denote crack propagation direction. Areas 1 and 2 were examined in greater detail.

CFM56-7B Stg. 1-2 HPC Spool - ESN 875-318

- Fracture Morphology Consistent With Lower Alternating Stress, High Cycle Fatigue (HCF) or Mixed-Mode LCF/HCF Crack Propagation Mechanisms – No Evidence of Coarser Fatigue Striations Observed
- Acicular Microstructure Resulting From Beta (β) Processing Showing Through on Fracture



Stg. 2 Disk Post Fracture #44 - Area 1 - SEI

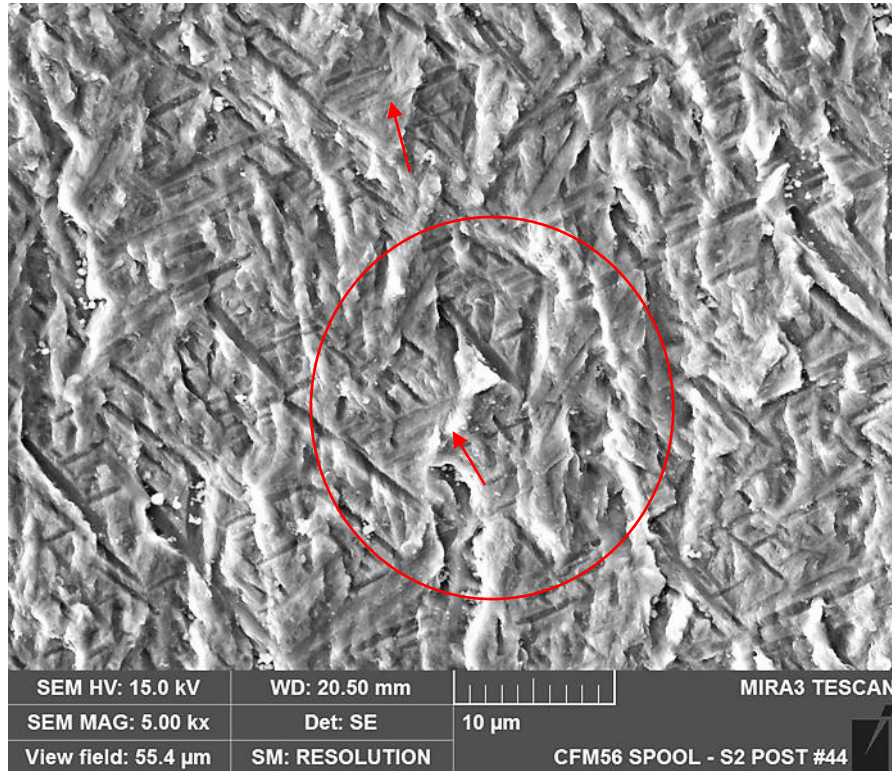


Circled Region - SEI

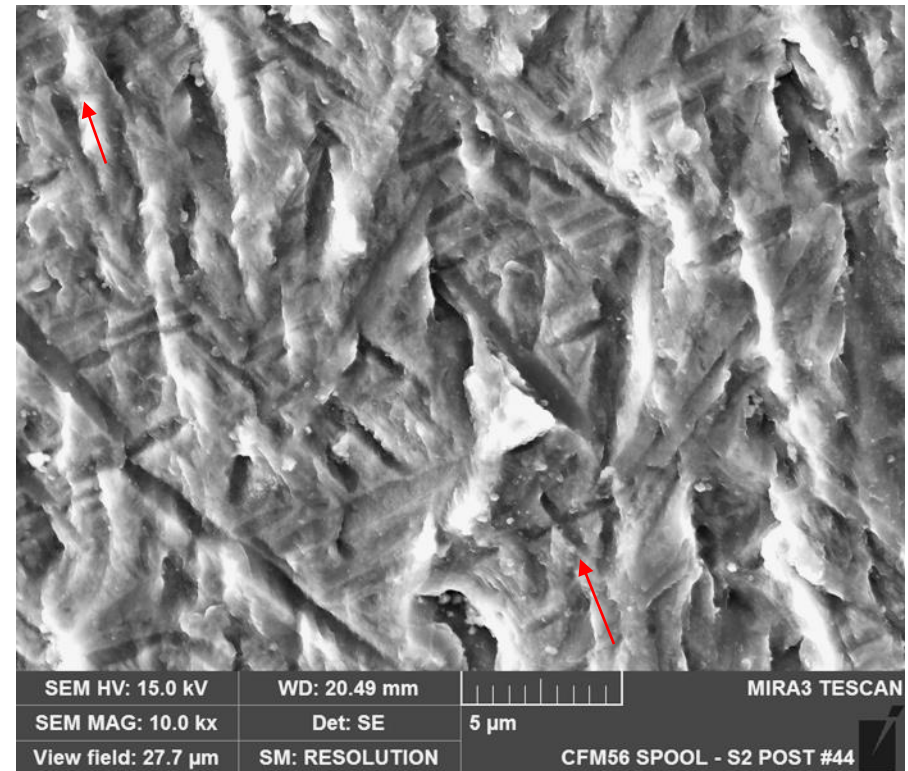
Figure 96. SEM secondary (SEI) images documenting fracture morphology at area 1 on Stg. 2 disk post #44 fracture surface. Arrows denote crack propagation direction.

CFM56-7B Stg. 1-2 HPC Spool - ESN 875-318

- Fracture Morphology Consistent With Lower Alternating Stress, High Cycle Fatigue (HCF) or Mixed-Mode LCF/HCF Crack Propagation Mechanisms – No Evidence of Coarser Fatigue Striations Observed
- Acicular Microstructure Resulting From Beta (β) Processing Showing Through on Fracture



Stg. 2 Disk Post Fracture #44 - Area 2 - SEI

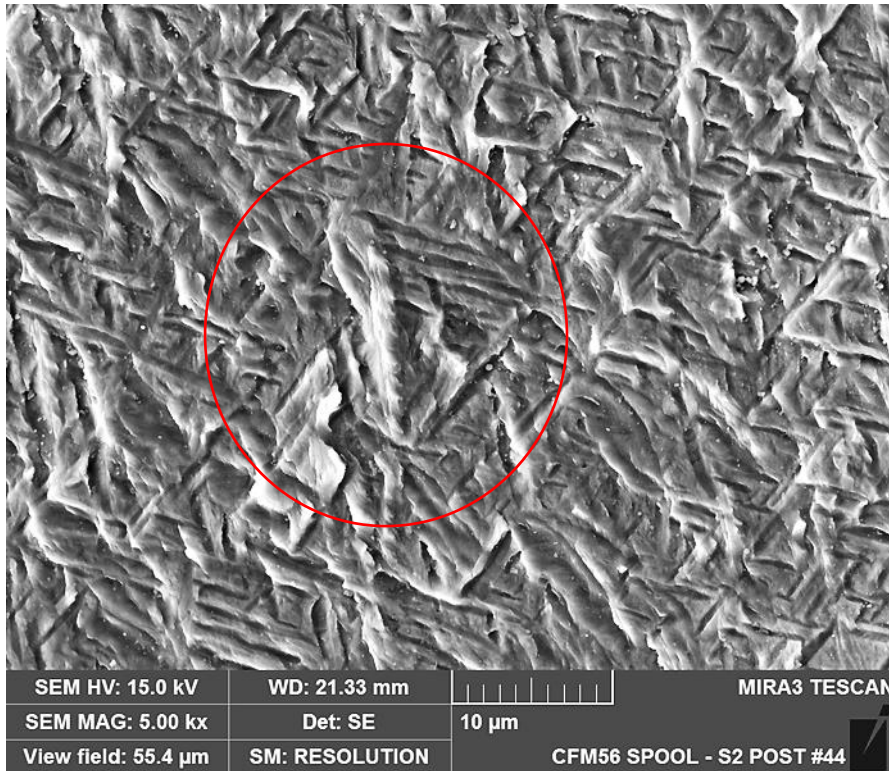


Circled Region - SEI

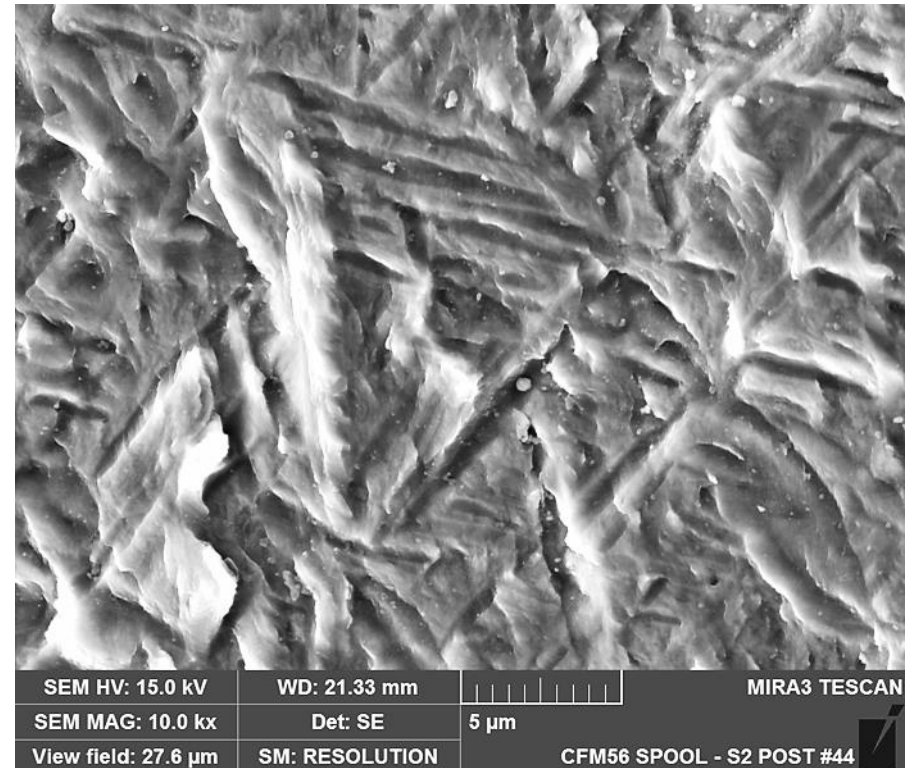
Figure 97. SEM secondary (SEI) images documenting fracture morphology at area 2 on Stg. 2 disk post #44 fracture surface. Arrows denote crack propagation direction.

CFM56-7B Stg. 1-2 HPC Spool - ESN 875-318

- Fracture Morphology Consistent With Lower Alternating Stress, High Cycle Fatigue (HCF) or Mixed-Mode LCF/HCF Crack Propagation Mechanisms – No Evidence of Coarser Fatigue Striations Observed
- Acicular Microstructure Resulting From Beta (β) Processing Showing Through on Fracture

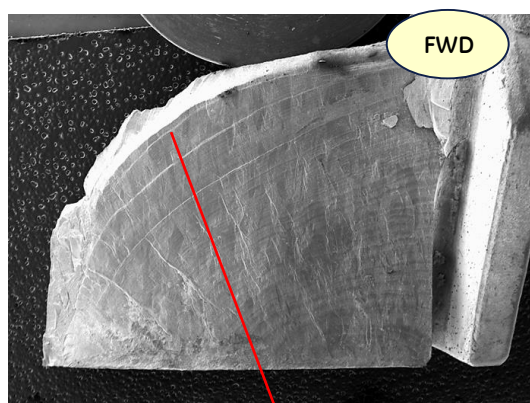


Stg. 2 Disk Post Fracture #44 - Area 3 - SEI



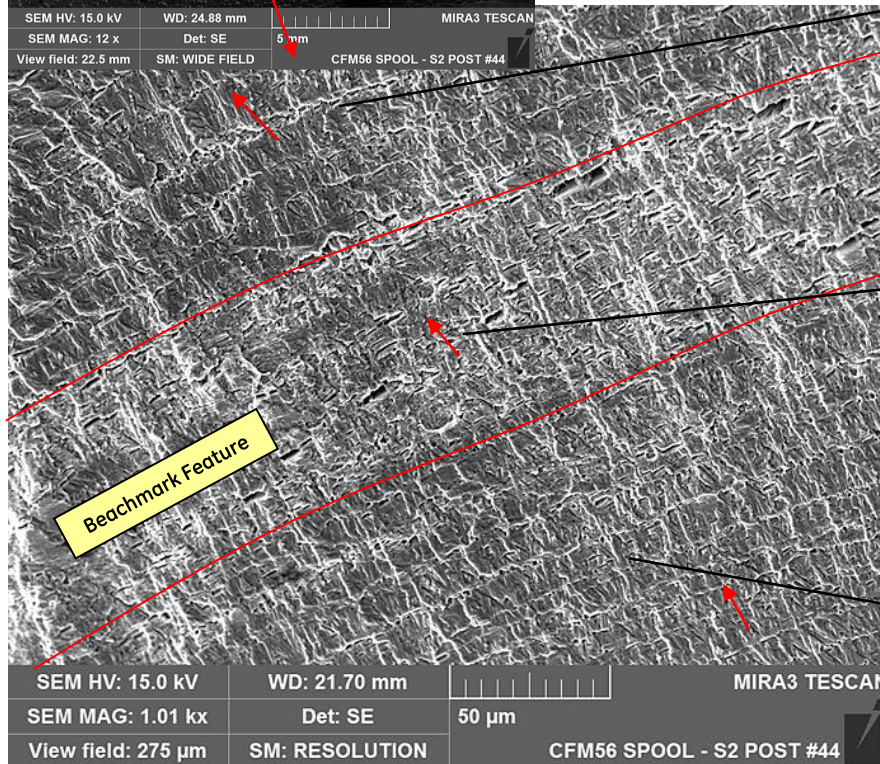
Circled Region - SEI

Figure 98. SEM secondary (SEI) images documenting fracture morphology at area 3 on Stg. 2 disk post #44 fracture surface. Arrows denote crack propagation direction.

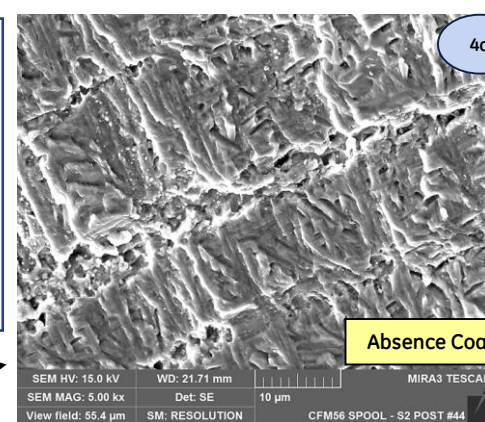


CFM56-7B Stg. 1-2 HPC Spool ESN 875-318

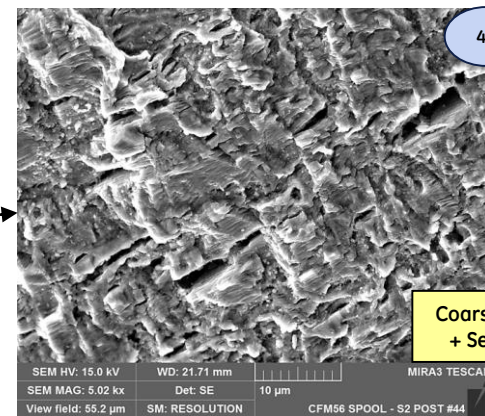
- Areas 4A and 4C Fracture Morphology Consistent With Lower Alternating Stress, High Cycle Fatigue (HCF) or Mixed-Mode LCF/HCF Crack Propagation Mechanisms
- Fracture 4B Within "Beachmark" Feature Exhibited Coarser Fatigue Striations Plus Secondary Cracking Consistent With Brief Increase in Alternating Stress



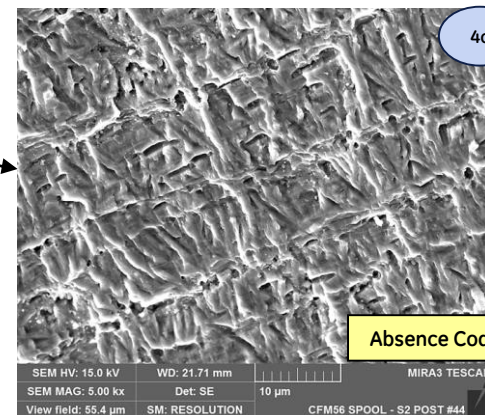
Stg. 2 Disk Post Fracture #44 - Area 4 - SEI



Stg. 2 Disk Post Fracture #44 - Area 4b - SEI



Stg. 2 Disk Post Fracture #44 - Area 4b - SEI



Stg. 2 Disk Post Fracture #44 - Area 4c - SEI

Figure 99. SEM secondary (SEI) images documenting fracture morphology at area 4 near the crack end region on Stg. 2 disk post #44 fracture surface. Arrows denote crack propagation direction. Higher alternating stress fatigue morphology observed within "beachmark" feature.

CFM56-7B Stg. 1-2 HPC Spool - ESN 875-318

- EDS Spectra Obtained From Lab Fracture Region (Fresh Tensile Overload) From Stg. 2 Disk Post #44 – Spectrum Consistent With Required Ti-17 Material

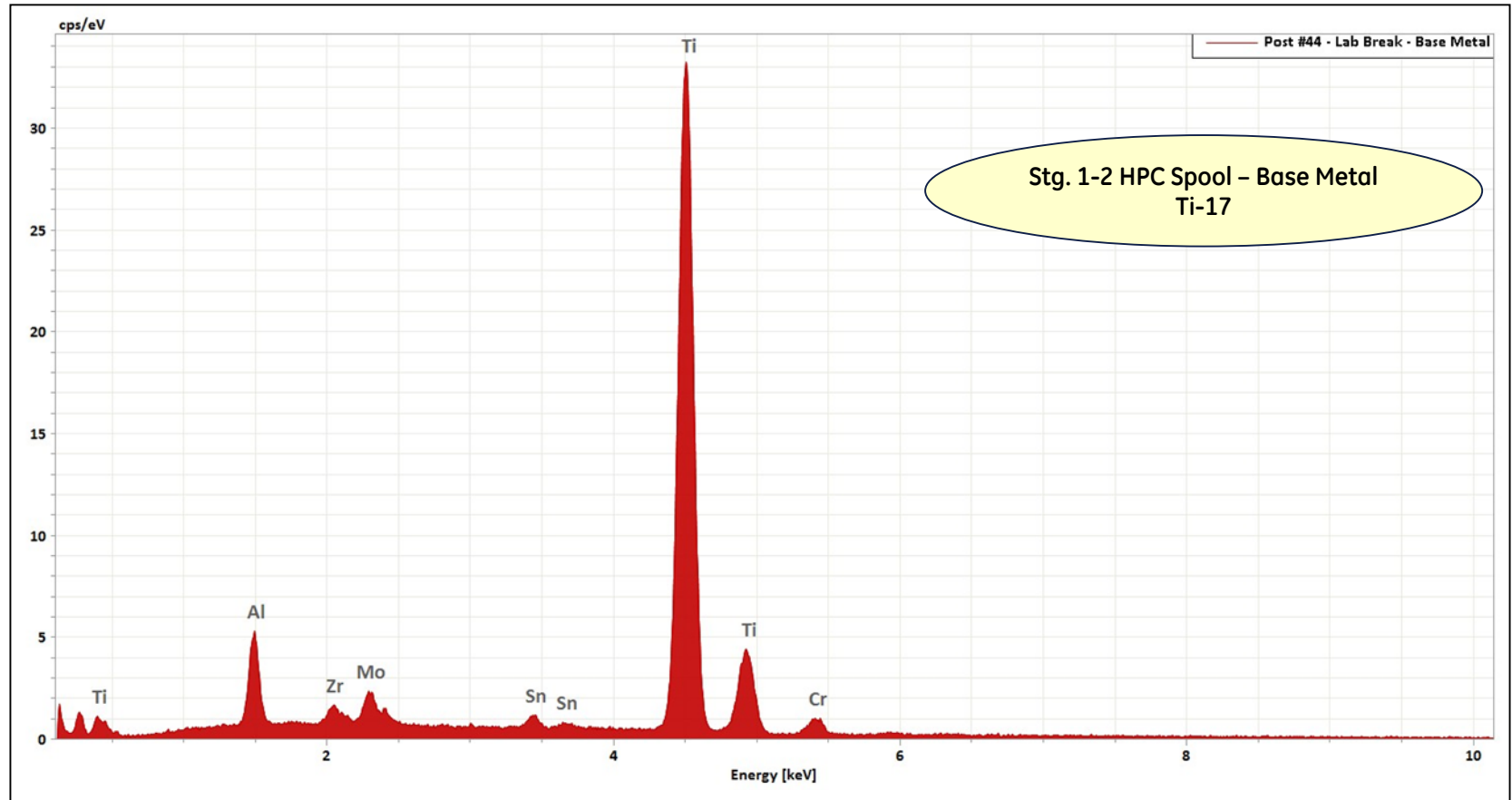
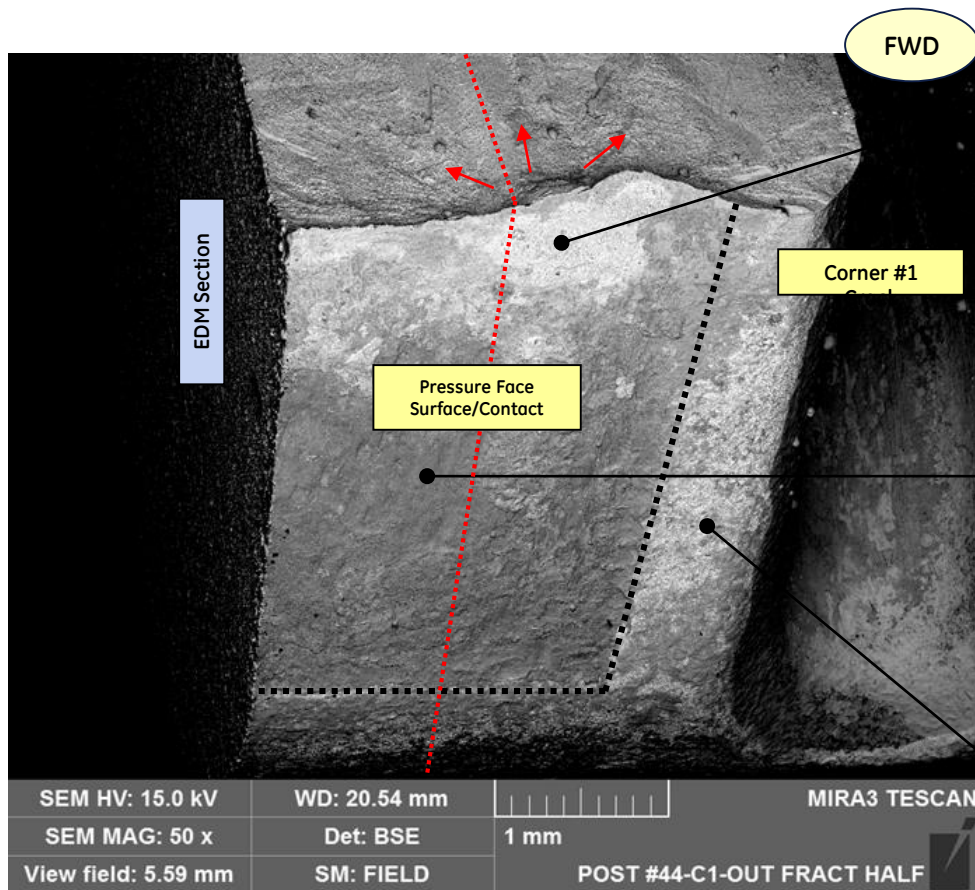


Figure 100. EDS spectra obtained from fresh tensile lab fracture from Stg. 2 disk post #44 fracture surface consistent with required Ti-17 material.

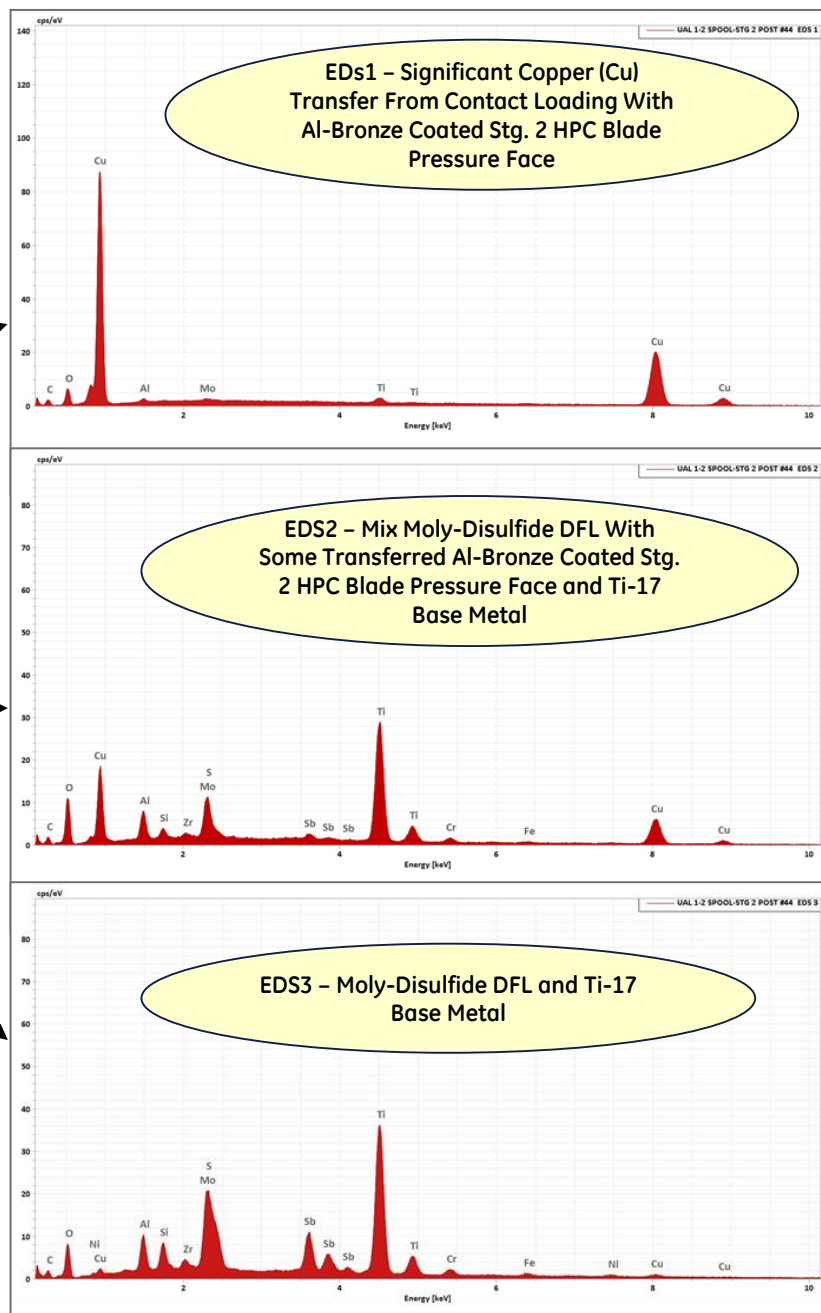
CFM56-7B Stg. 1-2 HPC Spool - ESN 875-318

- Locally Heavier Pressure Face Contact With Edge of Stg. 2 HPC Blade at Corner #1 Position of Stg. 2 Disk Post #44 as Evidenced by Elevated Copper (Cu) Transfer (EDS1) From Stg. 2 HPC Blade Al-Bronze Pressure Face Coating



Stg. 2 Disk Post #44 – FWD Pressure Face (Corner #1) – BEI

Figure 101. SEM backscatter (BEI) image and accompanying EDS spectra obtained from pressure face of Stg. 2 HPC Disk post #44 after lab fracture. Locally heavier contact with copper (Cu) material transfer was observed in the origin region. Red arrows denote crack propagation direction. Location of metallographic cross-section prepared through the pressure face indicated by dashed red lines.



CFM56-7B Stg. 1-2 HPC Spool - ESN 875-318

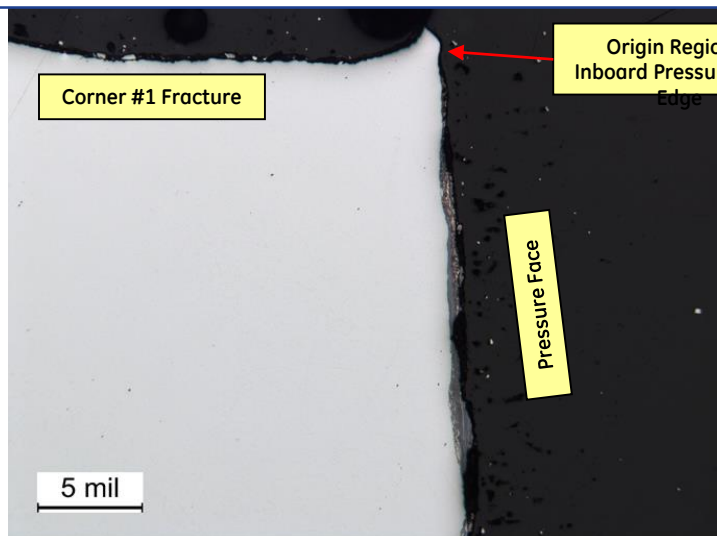
- Metallographic Polish Into Origin Region Located on Inboard Pressure Face Edge in Corner #1 Region - Transferred Copper (Cu) Detected in Deposit at Origin Region

EMP19-1257-01

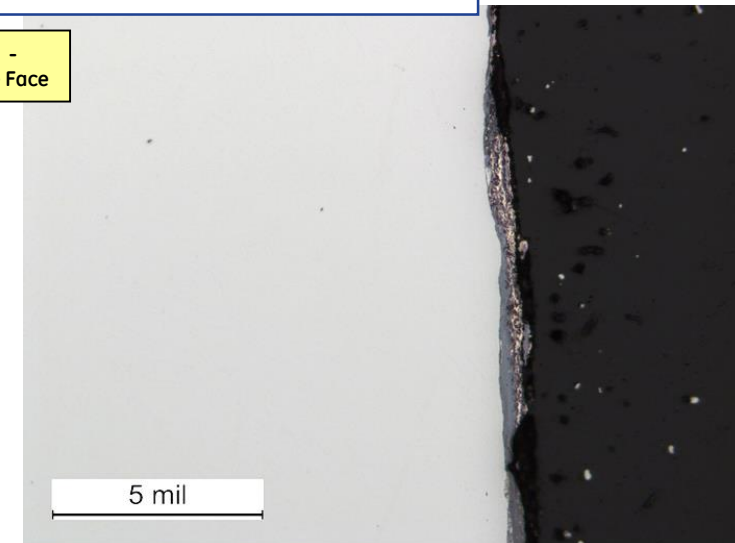
Outboard

Pressure Face

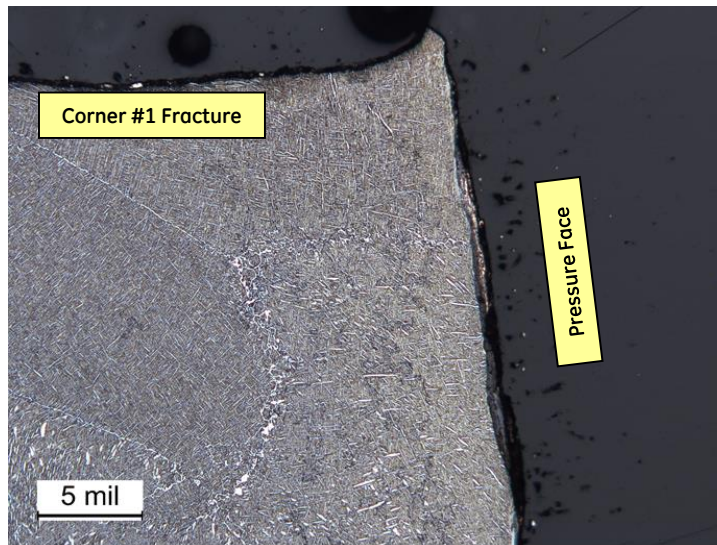
Corner #1 Fracture



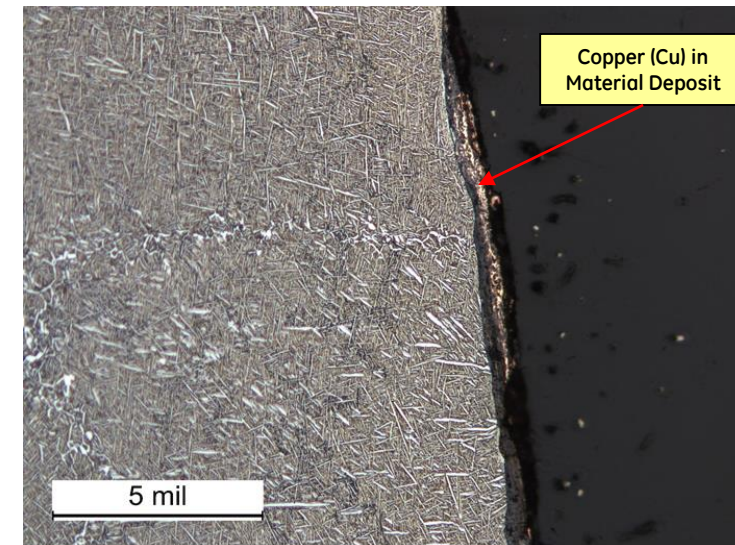
Stg. 2 Disk Post #44 - Origin Region (Corner #1) - Unetched



Stg. 2 Disk Post #44 - Origin Region (Corner #1) - Unetched



Stg. 2 Disk Post #44 - Origin Region (Corner #1) - Etched

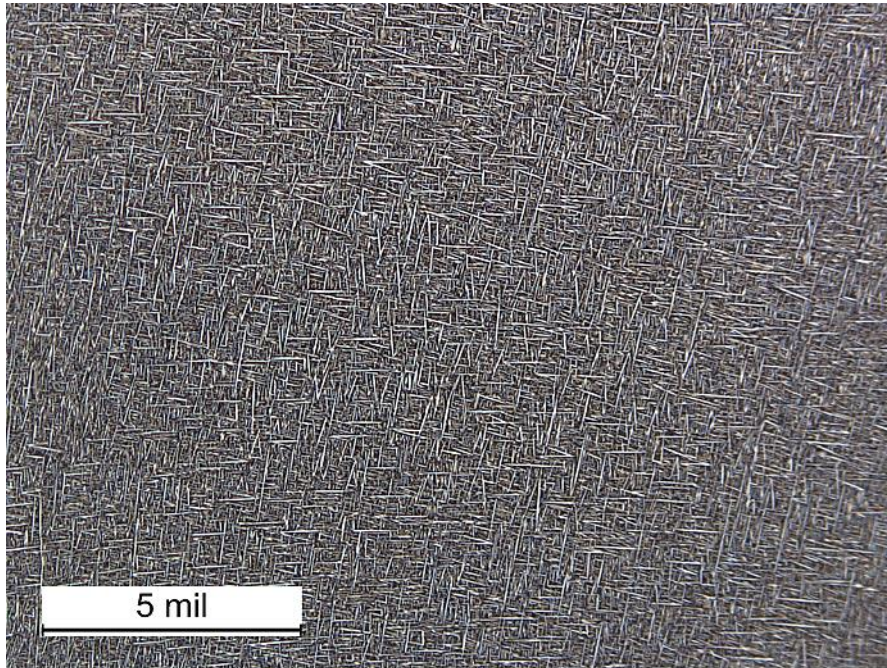


Stg. 2 Disk Post #44 - Origin Region (Corner #1) - Etched

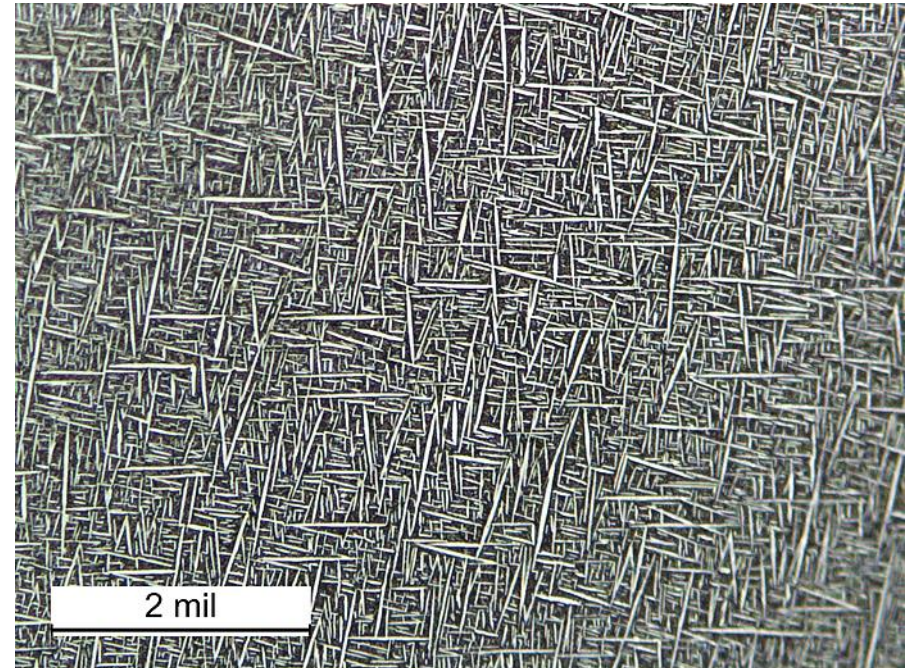
Figure 102. Photomicrographs documenting metallographic cross-section prepared into pressure face of Stg. 2 disk post #44 at fatigue origin region. Etchant: Kroll's

CFM56-7B Stg. 1-2 HPC Spool - ESN 875-318

- General Microstructure of Stg. 1-2 HPC Spool Consisted of Acicular Alpha (α) and Transformed Beta (β) Consistent With Properly Processed Ti-17 Material



Stg. 2 Disk Post #44 – General Microstructure - Etched



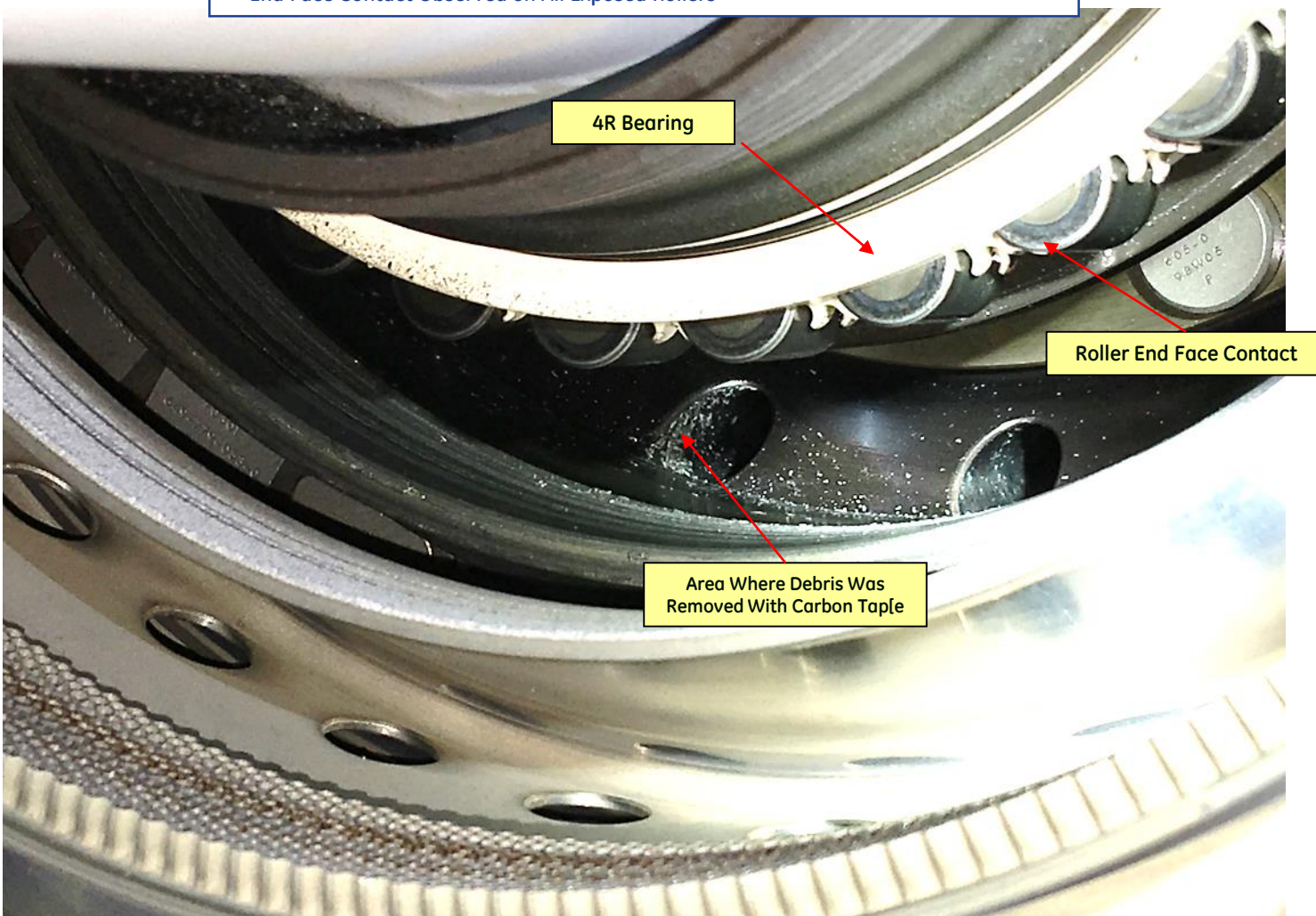
Stg. 2 Disk Post #44 – General Microstructure - Etched

Figure 103. Photomicrographs documenting general microstructure obtained from Stg. 2 HPT disk post #44. Structure consisted of acicular alpha (α) and transformed beta (β) consistent with properly processed Ti-17 material. Etchant: Kroll's

Aft Sump Debris - ESN 875-318

CFM56-7B - Aft Sump Debris - ESN 875-318

- Debris Removed With Carbon Tape in Aft Sump Adjacent to 4R Bearing
- End Face Contact Observed on All Exposed Rollers

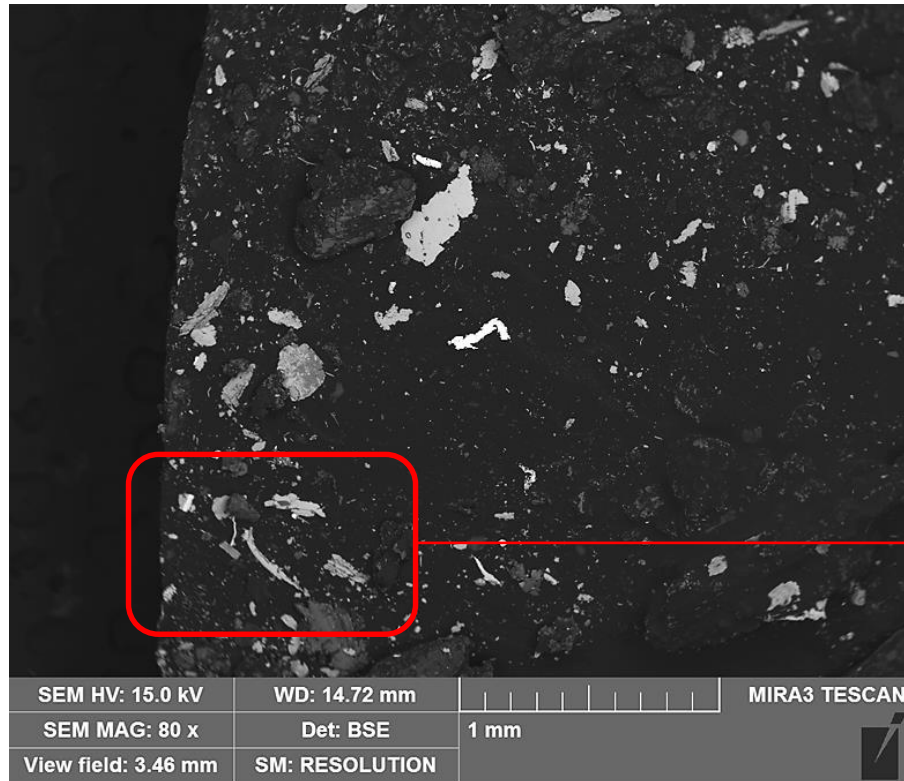


Aft Sump Region - 4R Bearing

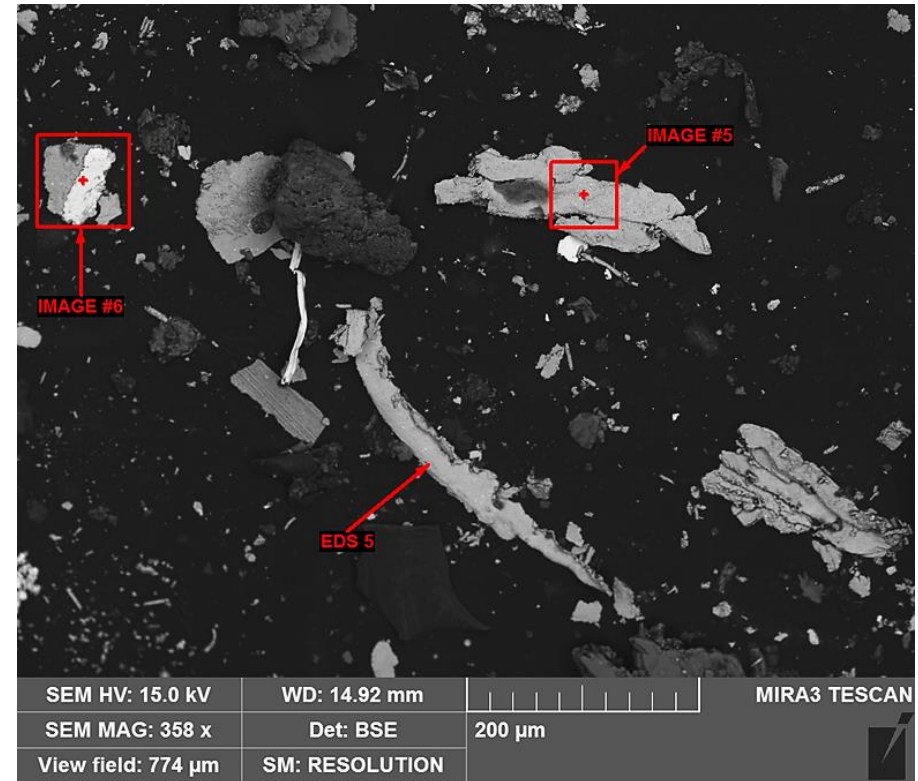
Figure 104. Photograph documenting loose debris in the aft sump region adjacent to 4R Bearing found during engine disassembly.

CFM56-7B - Aft Sump Debris - ESN 875-318

- Debris Removed With Carbon Tape in Aft Sump Adjacent to 4R Bearing
- Random Energy Dispersive Spectroscopy (EDS) Performed on Several Debris Particles



Aft Sump Debris - BEI

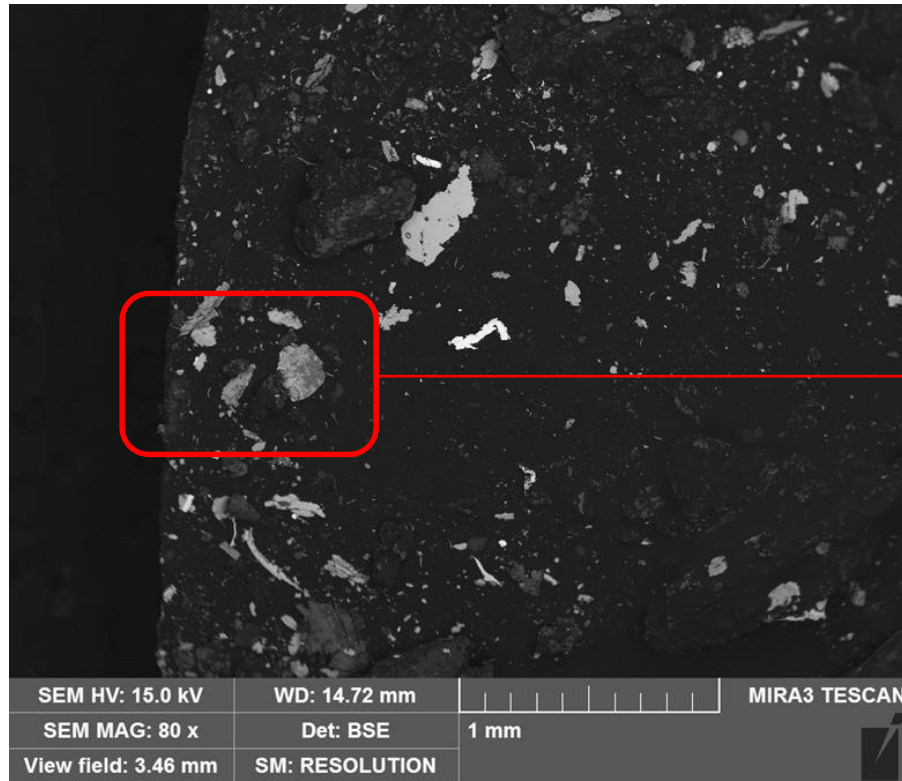


Aft Sump Debris - BEI

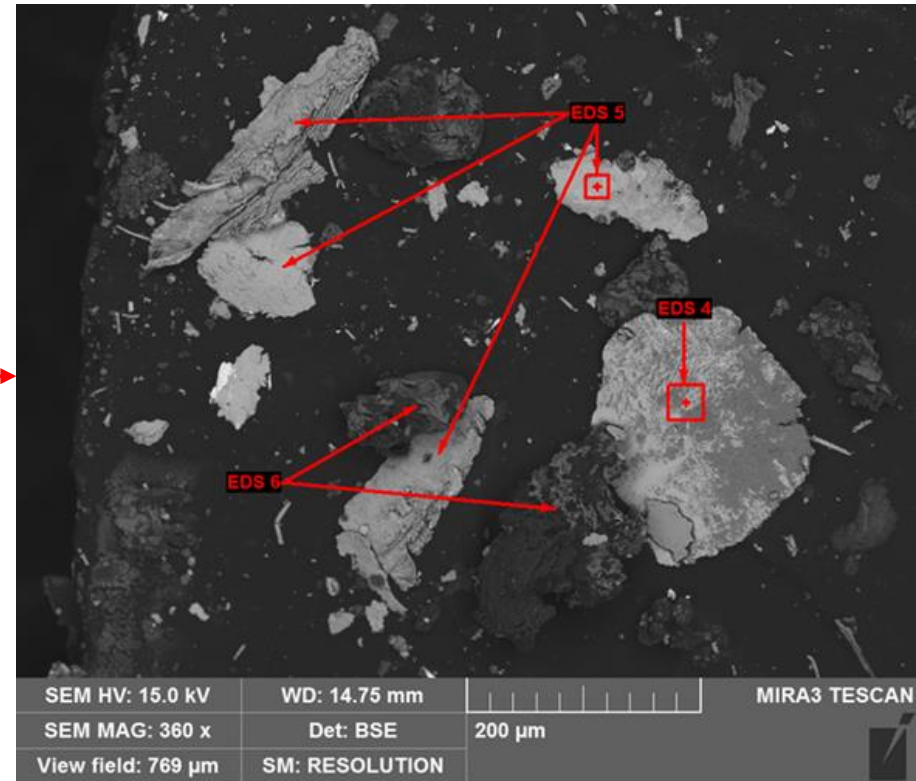
Figure 105. SEM backscatter (BEI) photograph documenting sample of loose debris in the aft sump region adjacent to 4R Bearing found during engine disassembly. EDS analysis performed on debris.

CFM56-7B - Aft Sump Debris - ESN 875-318

- Debris Removed With Carbon Tape in Aft Sump Adjacent to 4R Bearing
- Random Energy Dispersive Spectroscopy (EDS) Performed on Several Debris Particles



Aft Sump Debris - BEI

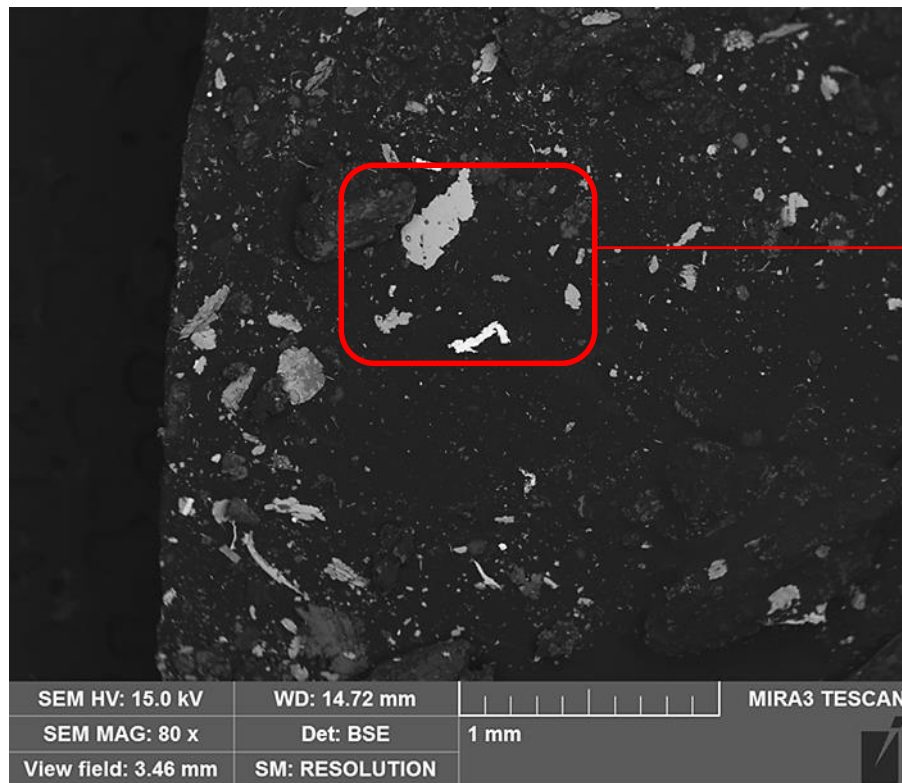


Aft Sump Debris - BEI

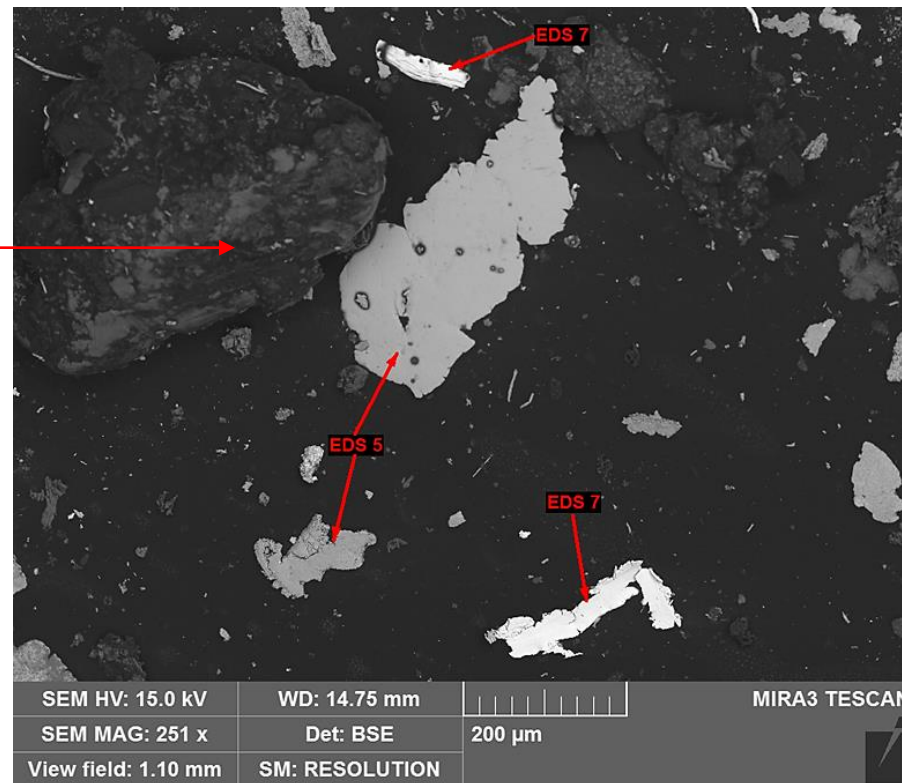
Figure 106. SEM backscatter (BEI) photograph documenting sample of loose debris in the aft sump region adjacent to 4R Bearing found during engine disassembly. EDS analysis performed on debris.

CFM56-7B - Aft Sump Debris - ESN 875-318

- Debris Removed With Carbon Tape in Aft Sump Adjacent to 4R Bearing
- Random Energy Dispersive Spectroscopy (EDS) Performed on Several Debris Particles



Aft Sump Debris - BEI



Aft Sump Debris - BEI

Figure 107. SEM backscatter (BEI) photograph documenting sample of loose debris in the aft sump region adjacent to 4R Bearing found during engine disassembly. EDS analysis performed on debris.

Iron-Based Materials

MATERIAL COMMERCIAL DESIGNATION	Fe	Cu	Zn	Cr	Ni	Ti	Al	C	Si	Mn	V	Mg	Mo	Nr	Co	B	W	Other
30CD12 (GK3)	96				3			0,30					0,40					
AISI 4340 (E-40NCD7)	96			0,80	1,7			0,40	0,27	0,75			0,25					
VASCOJET90 15CDV6	96			1,25				0,12		0,8	0,2		0,8					
AISI 9315 16NCD13	95			1	3			0,15	0,30	0,40			0,2					
30NCD16	94			1,3	3,8			0,30					0,45					
32CDV13 *	94			3,2	0,15			0,32	0,25	0,55	0,5		1					0,03
40CDV12 (GH4)	94			3,25				0,40	0,20	0,55	0,20		0,95					
35NCD16	93			1,8	4			0,35					0,4					
M50 (E-80DCV40)	90			4				0,80	0,17	0,25	1		4,2					
AISI 410 Z12C13	86			13				0,12										
EZ20WC10 RBD MODIFIED	85			3	0,7			0,2		0,3	0,4						10	
M50NIL (E-13DCNV40)	84	0,1		4,2	3,4			0,8	0,19	0,25	1,2		4,3		0,2			
Z180CDW13	84			13				1,7					0,5				0,5	
Z15CN17	83			15	2			0,12										
JETHETE M152 Z12CNDV12	82			12	2,5			0,12		0,7	0,30		1,7	0,03				
17-4 PH ZCNU17	75	3		16	4			0,05	0,7	0,5			0,5					0,45

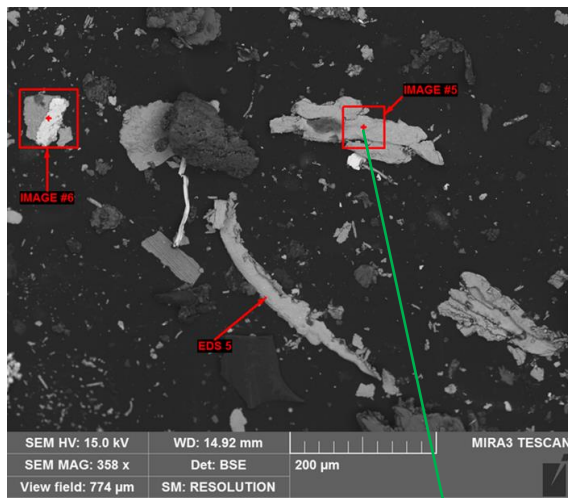
No.4 BEARING AREA (AFT SUMP)

No	DESIGNATION	MATERIAL
91	No.4 ROLLER BEARING ROLLERS	M50 (E-80DCV40)
92	No.4 ROLLER BEARING OUTER FACE	M50 (E-80DCV40) or 32CDV13
93	No.4 ROLLER BEARING INNER FACE	RBD MODIFIED (EZ20WC10)
94	No.4 ROLLER BEARING CAGE	AISI 4340 (E-40NCD7) SILVER COATED
95	No.4 ROLLER BEARING RETAINER	17-4PH (Z5CNU17)
96	LPT SHAFT	MARAGING 300 (Z2NKDT 18-9-5) MARAGING 250 (Z2NKDT 18-8-5)
97	HPT ROTOR SHAFT (REAR)	INCO 718 (NC19FeNb)
98	ROTATING OIL SEAL (FORWARD)	JETHETE M152 (Z12CNDV12)
99	ROTATING OIL SEAL (REAR)	17-4PH (Z5CNU17)

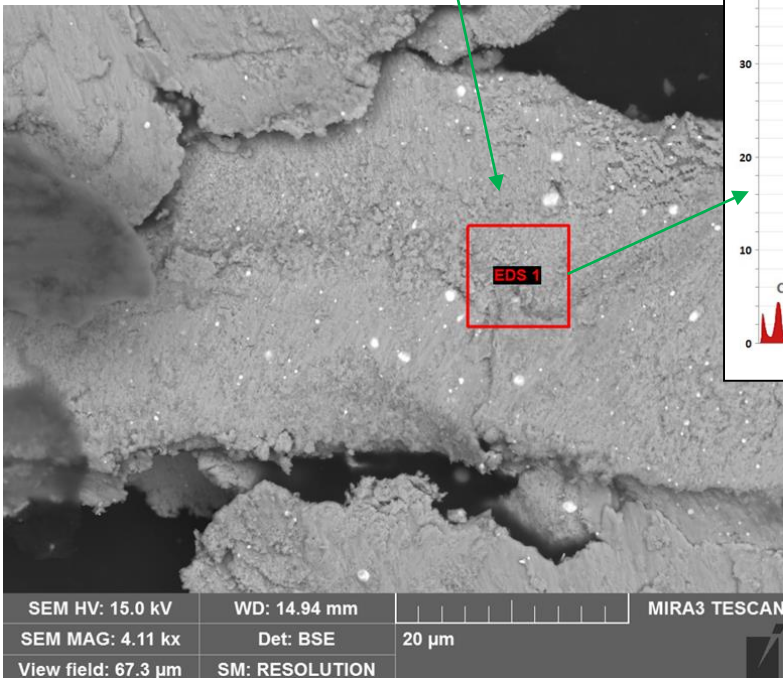
Figure 108. Image showing list of iron-based materials in the aft sump region of CFM56-7 engine.

CFM56-7B - Aft Sump Debris - ESN 875-318

- Debris Removed With Carbon Tape in Aft Sump Adjacent to 4R Bearing
- EDS1: Primarily RBD Modified Steel (4R Bearing Inner Race Material) as Evidenced by Presence Tungsten (W)



Aft Sump Debris - BEI



Aft Sump Debris - BEI

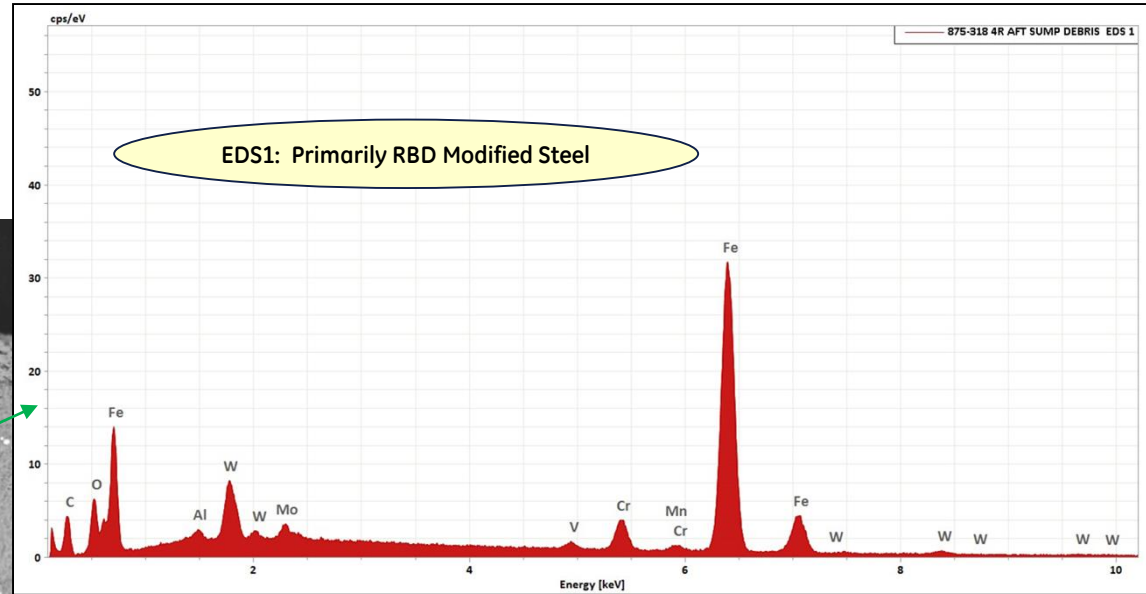
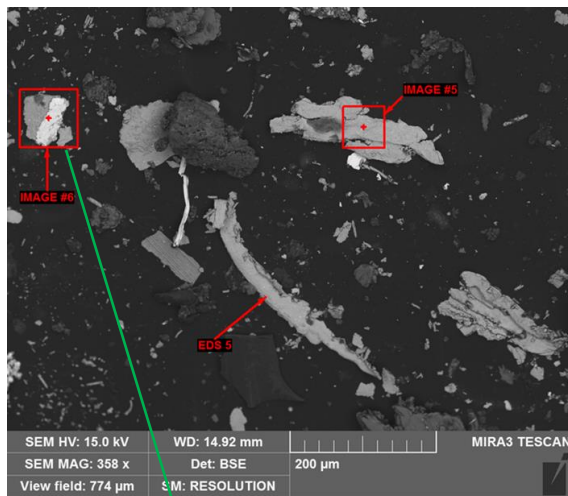


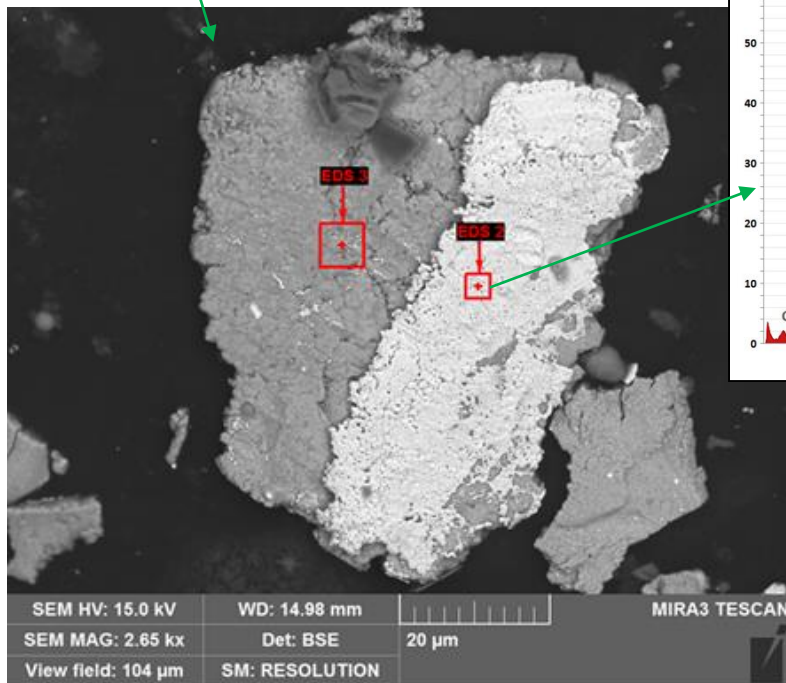
Figure 109. SEM backscatter (BEI) photographs and accompanying EDS spectrum (EDS1) documenting debris from aft sump region adjacent to 4R Bearing found during engine disassembly.

CFM56-7B - Aft Sump Debris - ESN 875-318

- Debris Removed With Carbon Tape in Aft Sump Adjacent to 4R Bearing
- EDS2: Silver (Ag) Likely From Bearing Cage Plating



Aft Sump Debris - BEI



Aft Sump Debris - BEI

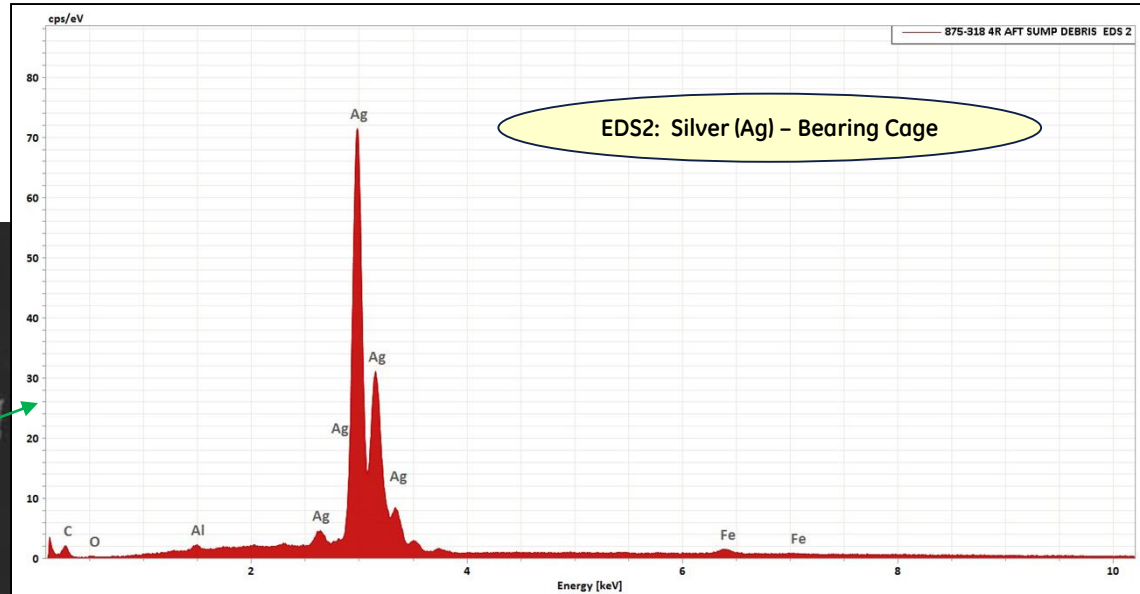
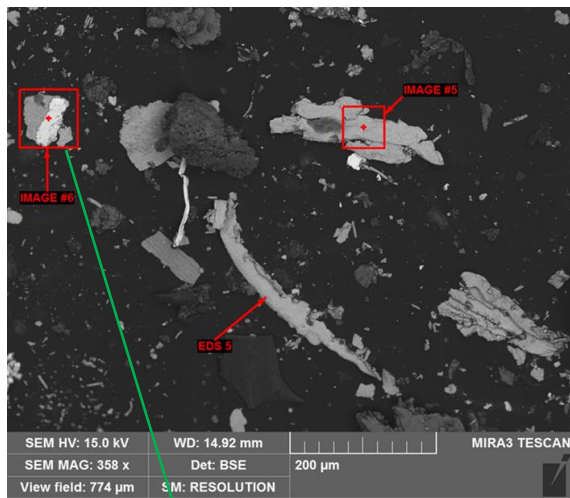


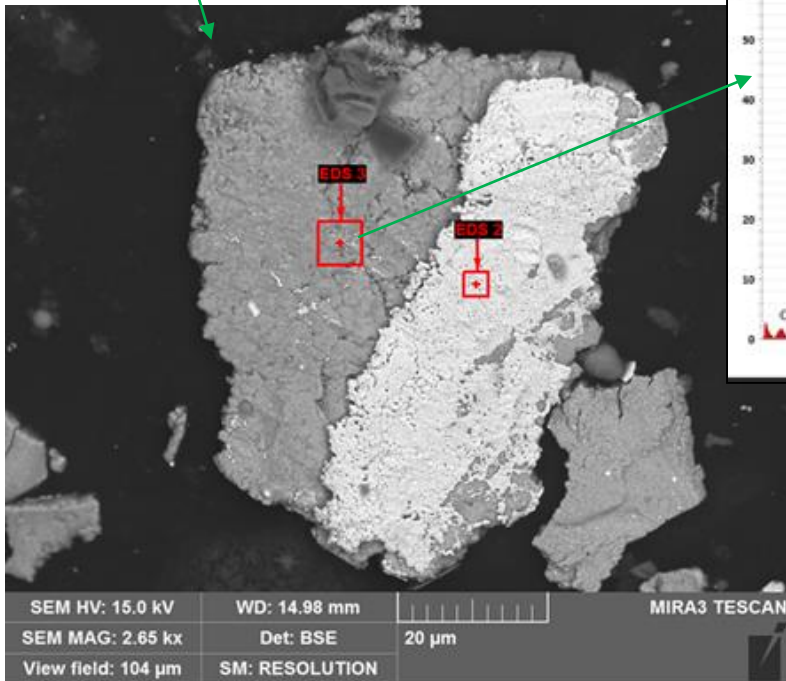
Figure 110. SEM backscatter (BEI) photographs and accompanying EDS spectrum (EDS2) documenting debris from aft sump region adjacent to 4R Bearing found during engine disassembly.

CFM56-7B - Aft Sump Debris - ESN 875-318

- Debris Removed With Carbon Tape in Aft Sump Adjacent to 4R Bearing
- EDS3: Primarily RBD Modified Steel (4R Bearing Inner Race Material) as Evidenced by Presence Tungsten (W)



Aft Sump Debris - BEI



Aft Sump Debris - BEI

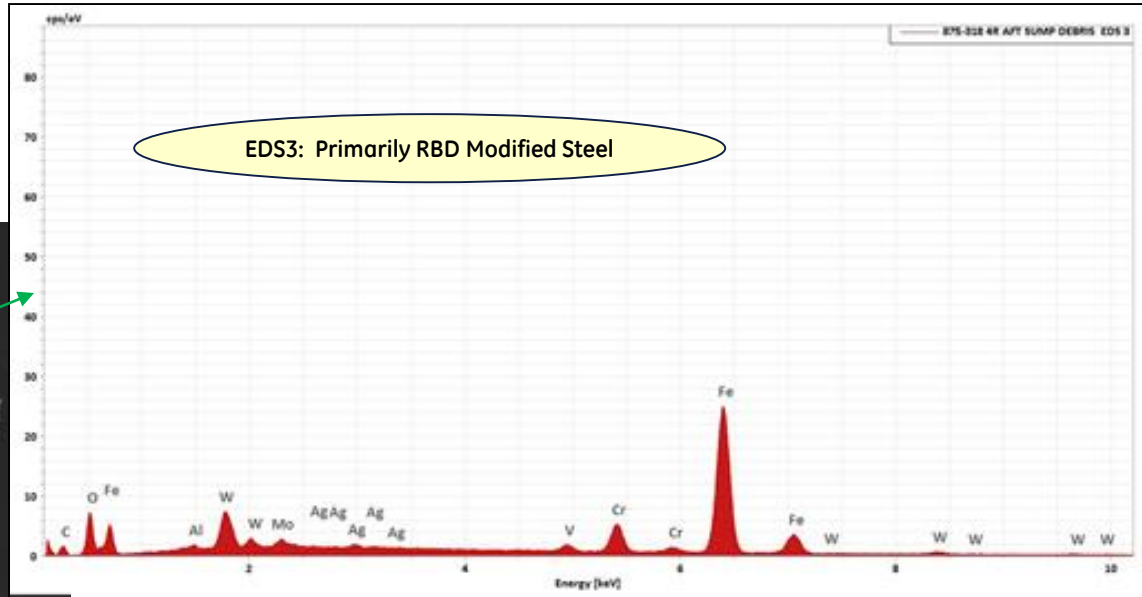
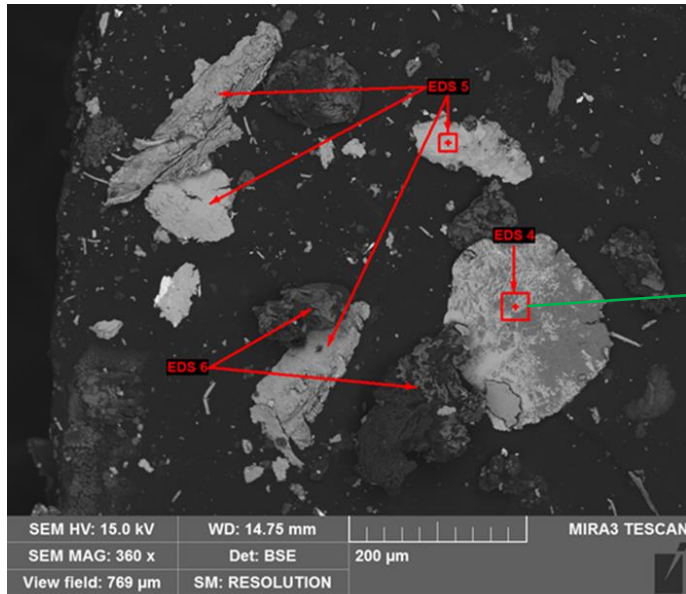


Figure 111. SEM backscatter (BEI) photographs and accompanying EDS spectrum (EDS3) documenting debris from aft sump region adjacent to 4R Bearing found during engine disassembly.

CFM56-7B - Aft Sump Debris - ESN 875-318

- Debris Removed With Carbon Tape in Aft Sump Adjacent to 4R Bearing
- EDS4: Titanium (Ti), Nickel (Ni), Chromium (Cr) and Iron (Fe) Detected



Aft Sump Debris - BEI

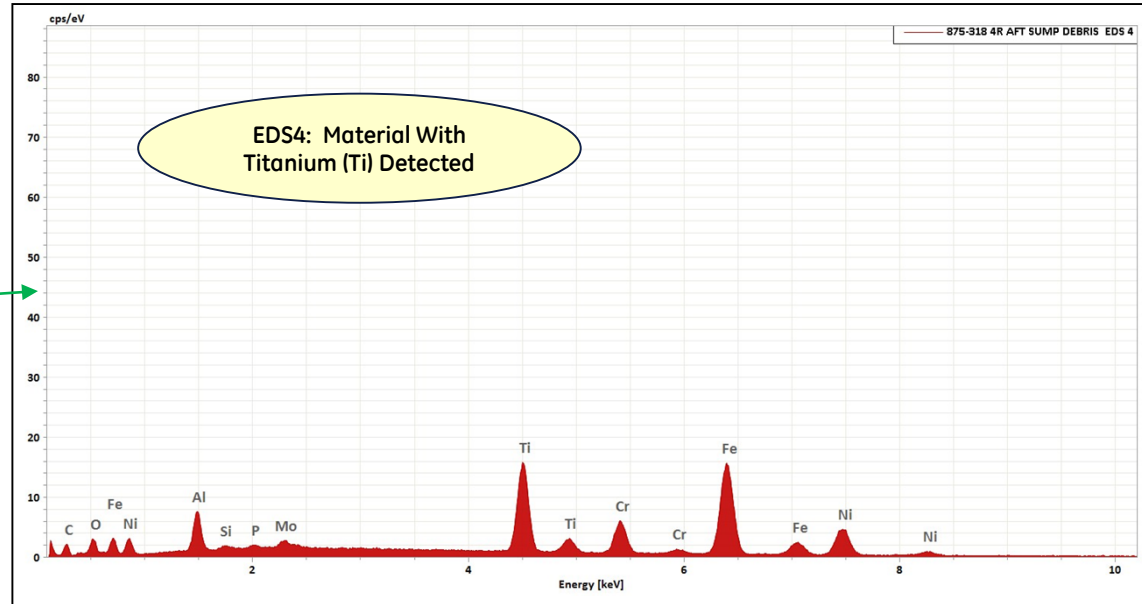


Figure 112. SEM backscatter (BEI) photographs and accompanying EDS spectrum (EDS4) documenting debris from aft sump region adjacent to 4R Bearing found during engine disassembly.

CFM56-7B - Aft Sump Debris - ESN 875-318

- Debris Removed With Carbon Tape in Aft Sump Adjacent to 4R Bearing
- EDS5: Primarily RBD Modified Steel (4R Bearing Inner Race Material) as Evidenced by Presence Tungsten (W)

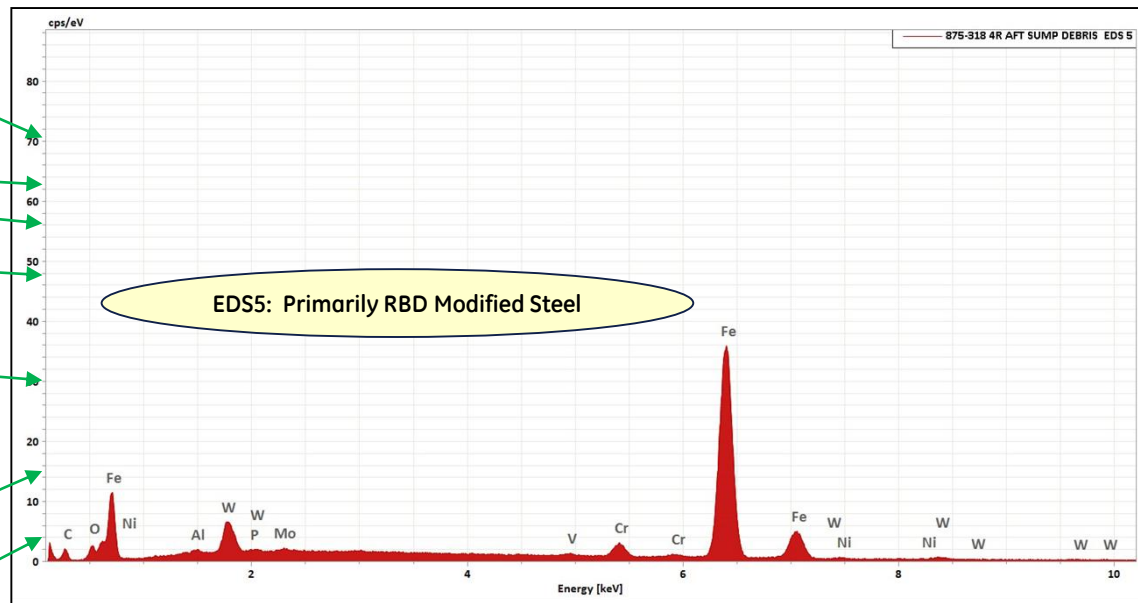
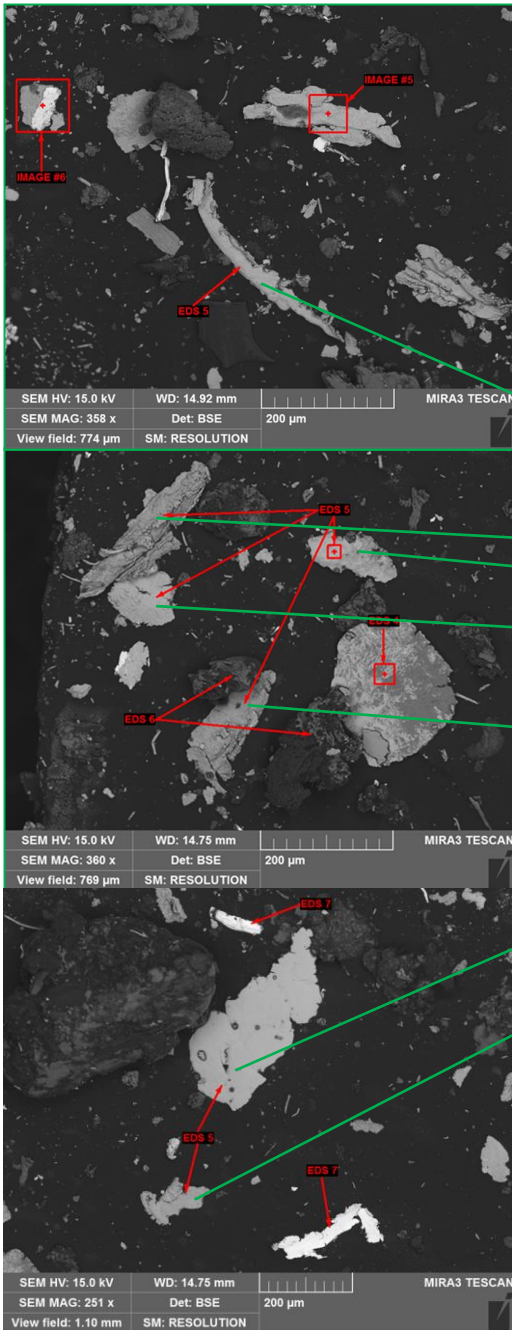
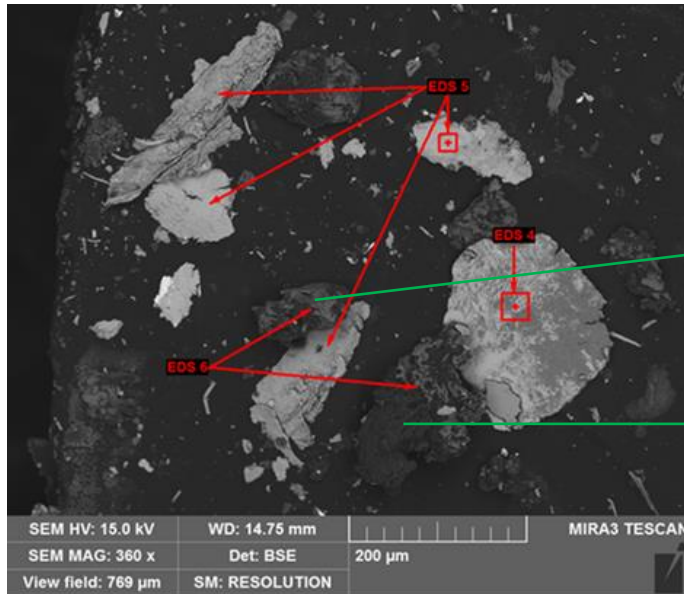


Figure 113. SEM backscatter (BEI) photographs and accompanying EDS spectrum (EDS5) documenting debris from aft sump region adjacent to 4R Bearing found during engine disassembly.

CFM56-7B - Aft Sump Debris - ESN 875-318

- Debris Removed With Carbon Tape in Aft Sump Adjacent to 4R Bearing
- EDS6: Elevated Aluminum (Al) with Silicon (Si) Detected in Darker Debris



Aft Sump Debris - BEI

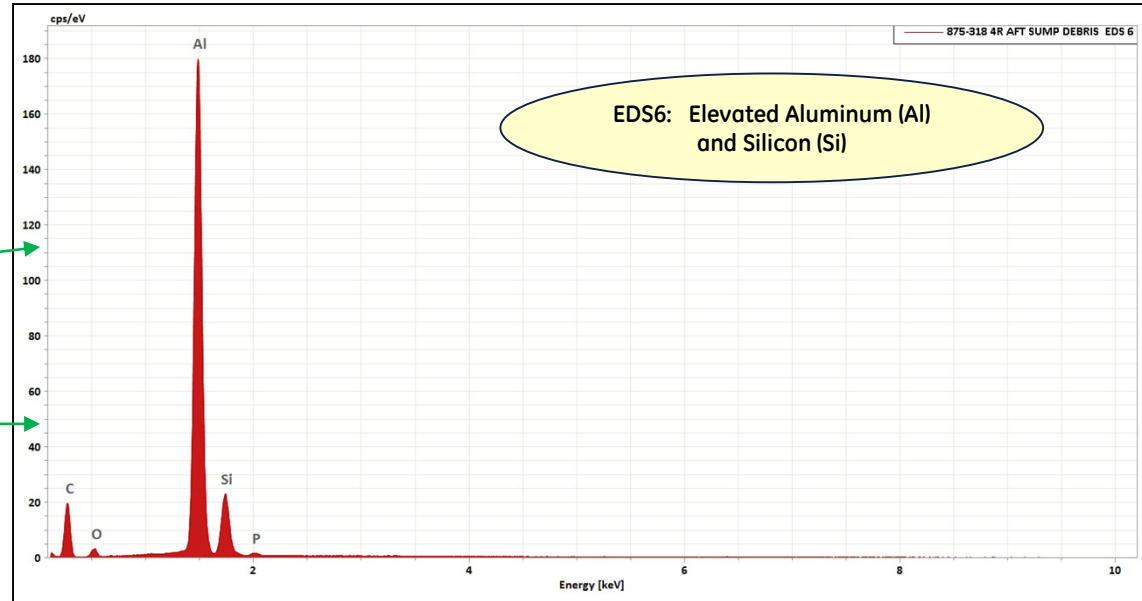
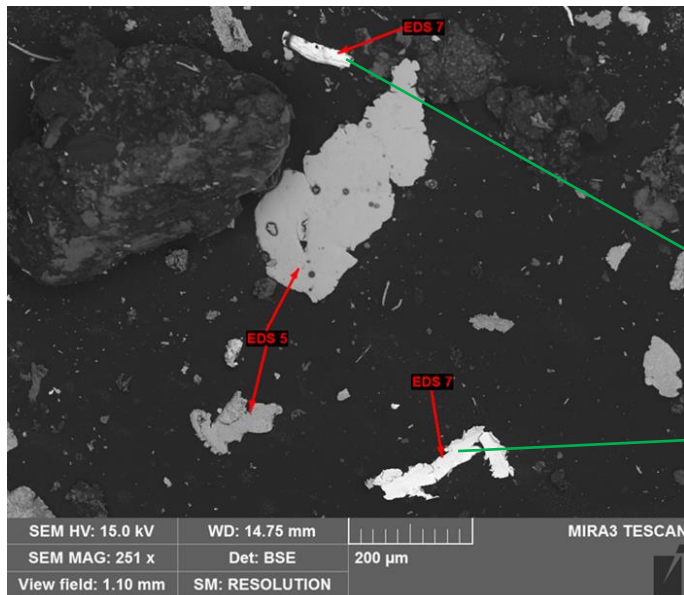


Figure 114. SEM backscatter (BEI) photographs and accompanying EDS spectrum (EDS6) documenting debris from aft sump region adjacent to 4R Bearing found during engine disassembly.

CFM56-7B - Aft Sump Debris - ESN 875-318

- Debris Removed With Carbon Tape in Aft Sump Adjacent to 4R Bearing
- EDS7: Silver (Ag) Likely From Bearing Cage Plating



Aft Sump Debris - BEI

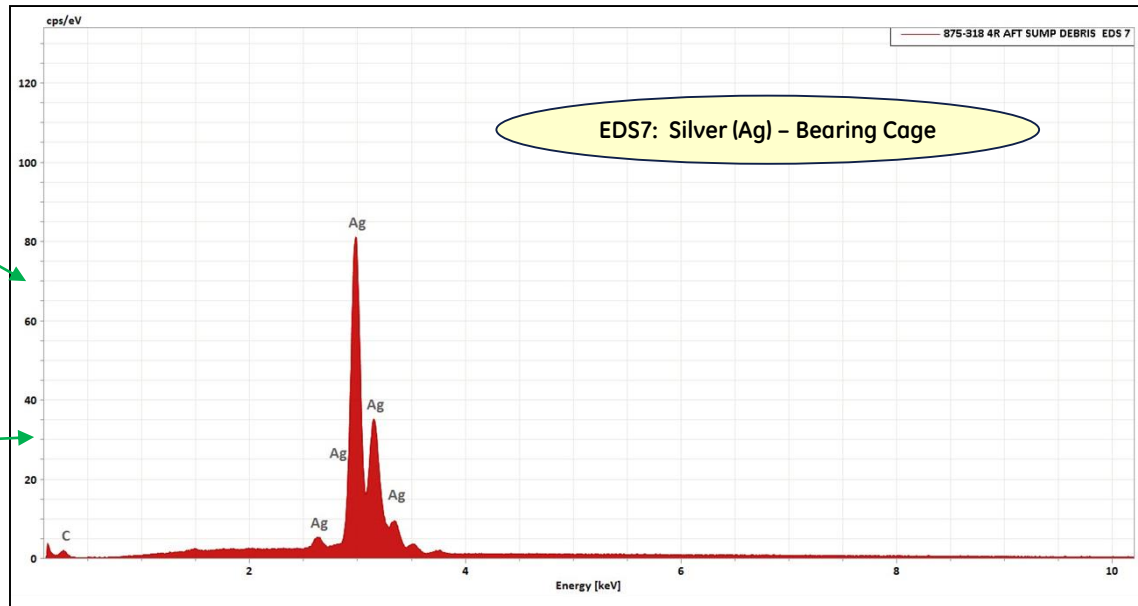


Figure 115. SEM backscatter (BEI) photographs and accompanying EDS spectrum (EDS7) documenting debris from aft sump region adjacent to 4R Bearing found during engine disassembly.

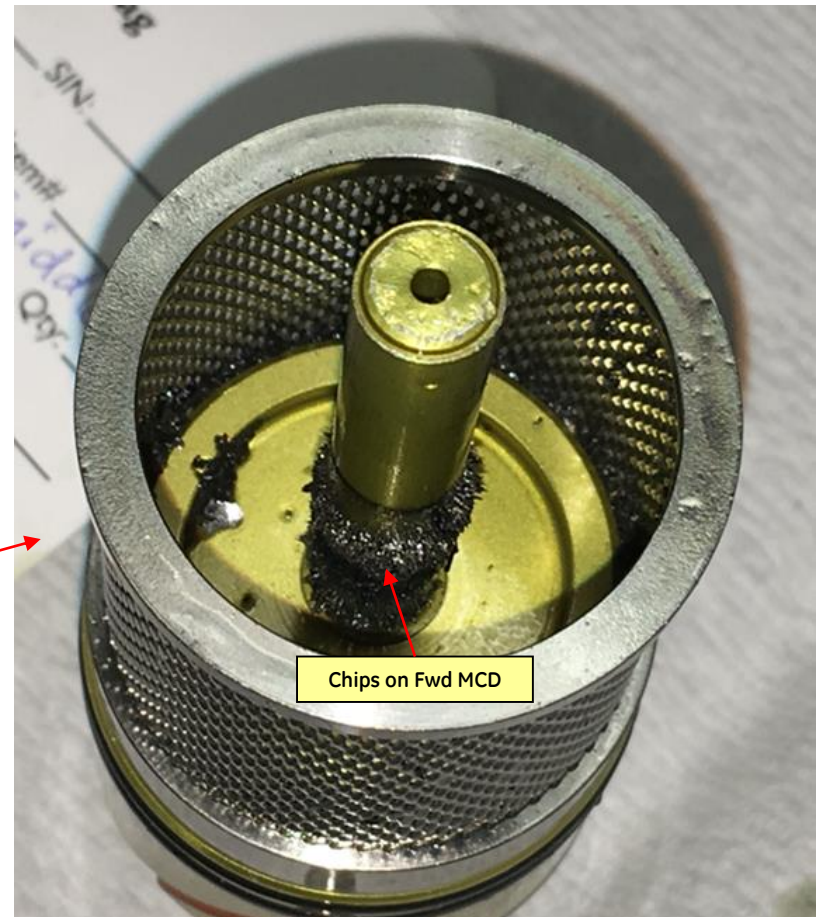
Fwd Sump Debris - ESN 875-318

CFM56-7B - Fwd Sump Debris - ESN 875-318

- Debris Attached to Forward Sump Magnetic Chip Detector (MCD)



Fwd Sump MCD and Attached Debris

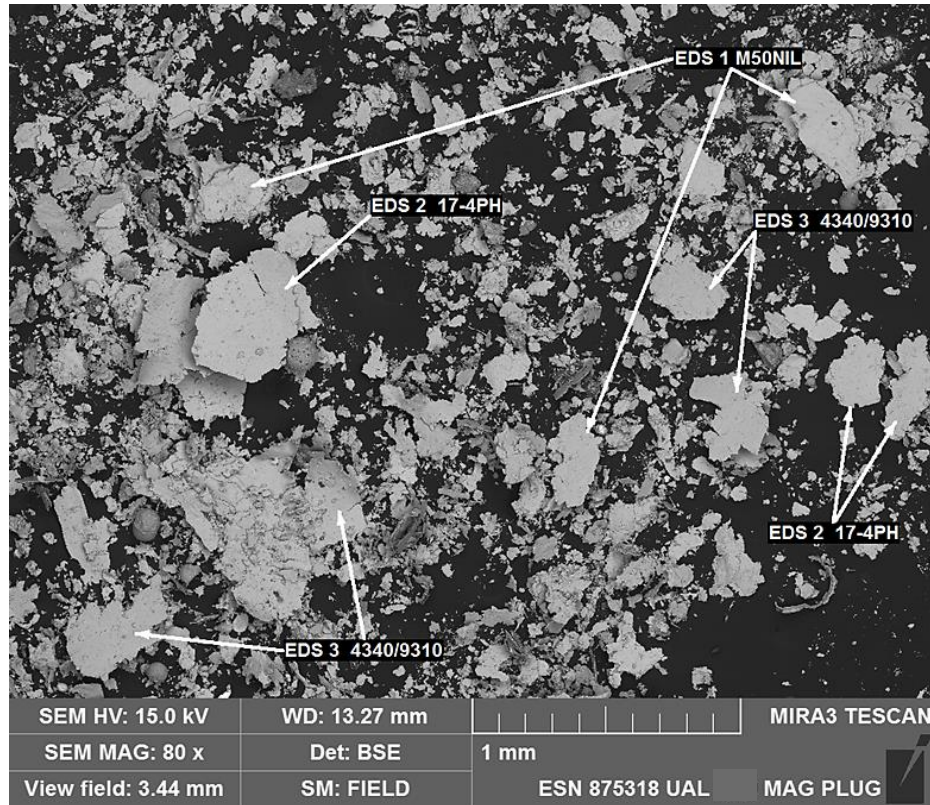


Fwd Sump MCD and Attached Debris

Figure 116. Photographs documenting debris on the forward MCD found during engine disassembly.

CFM56-7B - Fwd Sump Debris - ESN 875-318

- EDS1: M50NiL Detected in Debris
- EDS2: 17-4 PH Steel in Debris
- EDS3: 4340/9310 Low Alloy Steel in Debris
- No RBD Modified Steel Detected



Fwd Sump MCD Debris

Figure 117. SEM backscatter (BEI) photographs and accompanying EDS spectrum (EDS1, EDS2 and EDS3) documenting debris from forward sump MCD.

