

NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594

September 22, 2021

**Attachment 7 –Honeywell No. 2 Engine (P36235C) Materials Laboratory
Analysis Report**

POWERPLANTS

CEN20LA215

BACKGROUND

Two (2) TPE331 engines were torn down at Product Integrity (PI) in support of a NTSB accident investigation. The engines had been removed from the left and right sides of the same aircraft. The left engine was identified as ESN P36058C. The right engine was identified as ESN P36235C. Note that only the hardware from the right engine was submitted for evaluation. Analysis of the hardware from the left engine was reported in ERS-ASYS-PENG-MA-0000800.

PROBLEM STATEMENT

Perform non-destructive evaluations of the separated coupling shaft and starter shaft to determine the modes of separation. Document the condition of the compressor bearing. Filter the submitted magnetic plug and analyze the collected debris.

SUMMARY/CONCLUSIONS

- The separation of the coupling shaft was the result of torsional overload. Overload dimples were observed to be elongated in the counterclockwise direction (forward looking aft (FLA)) which indicated that the aft section separated as a result of torsional loading in the clockwise direction, relative to the forward section.
- The separation of the starter shaft could not be determined due to secondary smearing and damage of the fracture features.
- Wear and damage were observed on the components of the compressor bearing in multiple locations.
- Debris collected from the magnetic plug was suggestive of steel similar to 9310 or 4340, steel similar M50, and debris suggestive of an aluminum alloy.
- Debris collected near the compressor bearing was suggestive of a steel similar to M50, debris suggestive of an aluminum alloy, and debris rich in carbon.
- See Findings.

PART NAME:	Coupling Shaft
PART NUMBER:	894119-1
PART L/N:	1050
MODEL/PROGRAM:	TPE331
MODEL/PROGRAM S/N:	P36235C (Right Engine)
OPERATING TIME:	Not Reported
OPERATING CYCLES:	Not Reported
MATERIAL:	H11
MATERIAL SPEC:	AMS6487
SUPPLIER:	Not Reported
SUPPLIER P/N:	Not Reported

Findings

After takeoff, the right wing of the airplane dipped until the airplane nosed down to the ground. The coupling shaft (P/N 894119-1), a separated piece of the starter shaft (P/N not provided), compressor bearing (P/N 3101405-1), and debris collected from the right engine S/N P36235C were submitted for analysis. Investigation of the left engine S/N P36058C from the same aircraft is shown in ERS-ASYS-PENG-MA-0000800.

Coupling Shaft Separation

The coupling shaft (Lot Number 1050) from the left engine S/N P36235C had separated approximately 0.632" from the aft end (Figure 1). The fracture surface of the separation was oriented normal to the shaft axis and was flat in appearance. Wear was observed on and adjacent to the shoulder of the shaft (Figure 2). Contact/wear patterns were observed on the loaded side of the gear teeth from the aft end of the coupling shaft (Figure 3).

The fracture surface of the coupling shaft was examined in the scanning electron microscope (SEM) and is shown in Figure 4. Examination revealed that most of the fracture features were obscured by smearing and secondary damage. In some areas, overload dimples elongated in the counterclockwise direction (forward looking aft (FLA)) were observed, which indicated that the aft section of the coupling shaft had separated as a result of torsional loading in the clockwise direction relative to the forward section (aft looking forward (ALF)). The specified direction of rotation of the shaft was counterclockwise FLA.

Energy dispersive X-ray (EDX) analysis of the coupling shaft produced a spectrum indicative of the specified H11 tool steel material (Figure 5).

No additional work was performed on the coupling shaft from the right engine S/N P36235C per customer request.

Starter Shaft Separation

The starter shaft has separated approximately 0.690" from the forward end (Figure 6). Wear was observed on both sides of the gear teeth.

The fracture surface of the starter shaft was examined in the SEM and is shown in Figure 7. Fracture features indicative of overload were observed in some locations; however, most of the finer fracture features could not be determined due to smearing and secondary damage of the fracture surface. The specified direction of rotation of the shaft was clockwise ALF.

EDX analysis of the starter shaft produced a spectrum suggestive of a steel similar to 4340 (Figure 8). Note that the specified base material of the starter shaft was not reported.

No additional work was performed on the starter shaft from the right engine S/N P36235C per customer request.

Compressor Bearing

The as-received condition of the compressor bearing is shown in Figure 9. The bearing was disassembled for evaluation purposes and is shown in Figure 10. Damage and non-uniform wear were observed on the outer ring raceway (Figure 11). Deformed material

from the outer ring raceway onto the aft shoulder was observed in some locations.

Roller material was observed on the OD shoulder of the forward side of the split inner ring (Figure 12). Damage was observed on both split inner ring raceways. The aft side of the bearing cage was discolored compared to the forward side (Figure 13). Wear was observed on both end rails of the cage and in the cage pockets. Damage and discoloration were observed on all the rolling elements (Figure 14).

Debris Analysis

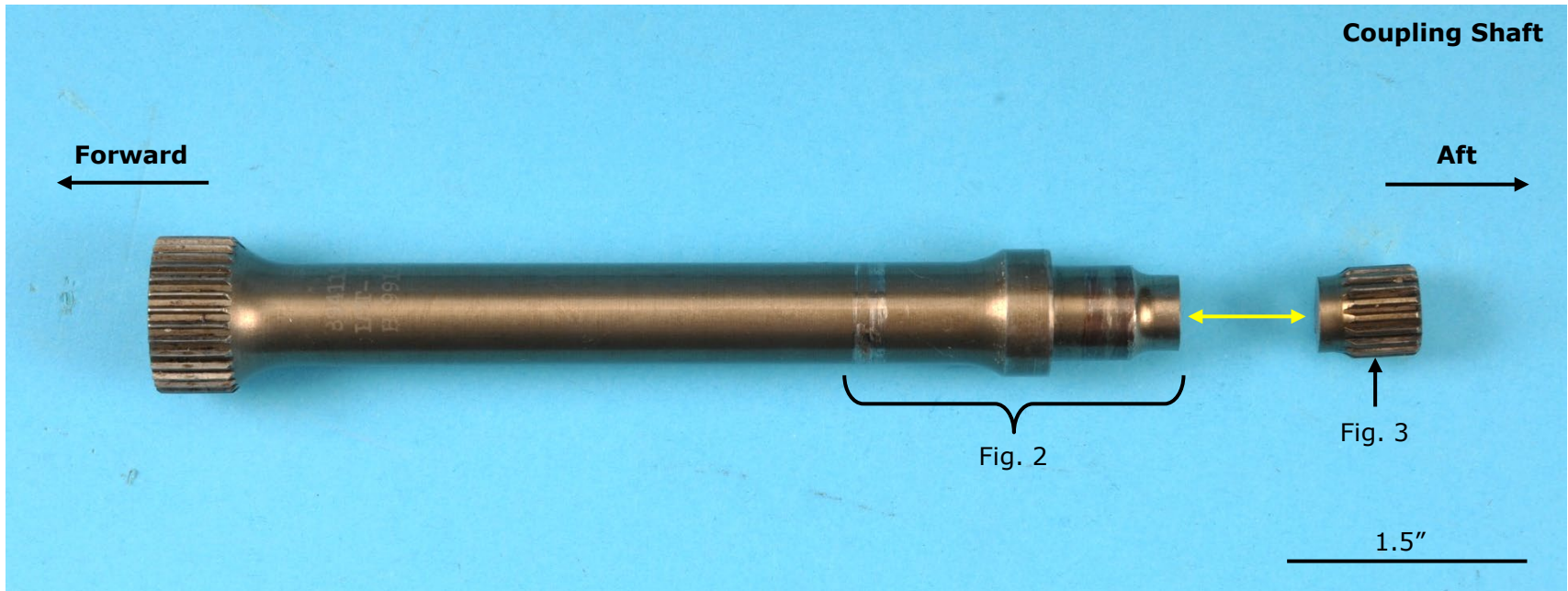
The as-received condition of the submitted magnetic plug from right engine S/N P36235C is shown in Figure 15A. The magnetic plug was flushed using Flash 142 mineral spirits and captured onto an 8 micron filter patch. The collected debris was cleaned with toluene and dried. The weight of the debris was measured to be 7 mg.

SEM analysis of the collected debris is shown in Figures 15B-C. EDX analysis generated from some of the metallic particles was suggestive of a steel similar to M50, the specified compressor bearing inner rings, outer ring, and rolling elements base material (Figure 16A). Other metallic particles were suggestive of an aluminum alloy (Figure 16B) and a steel similar to 4340 or 9310, as determined by EDX analysis (Figure 16C).

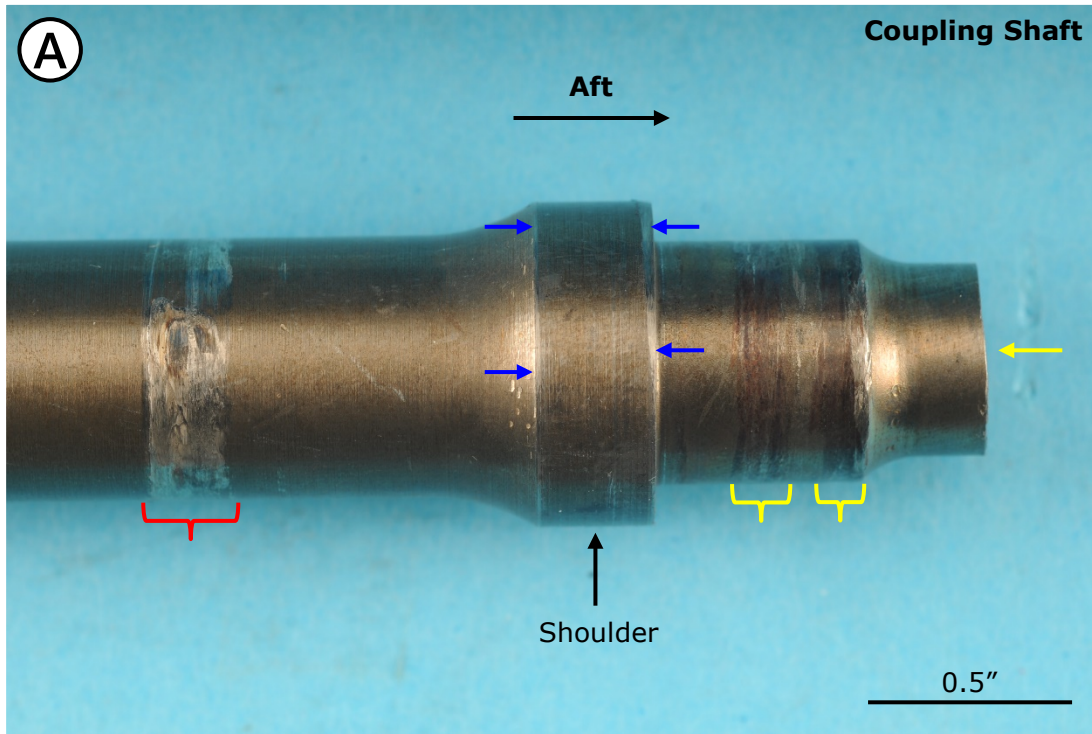
Debris was collected from the aft side of the compressor bearing carrier is shown in Figure 17A. The debris was suggestive of a steel similar to M50 (Figure 17B) and an aluminum alloy (Figure 17C), as determined by EDX analysis.

Debris was collected from the forward side of the compressor bearing carrier and is shown in Figure 18A. EDX analysis of some of the debris was rich in silver with concentrations in other elements (Figure 18B), and suggestive of an aluminum alloy (Figure 18C). Other debris was rich in magnesium and aluminum (Figure 18D) and rich in silicon, oxygen, aluminum, carbon, and traces of other elements (Figure 18E), as determined by EDX analysis.

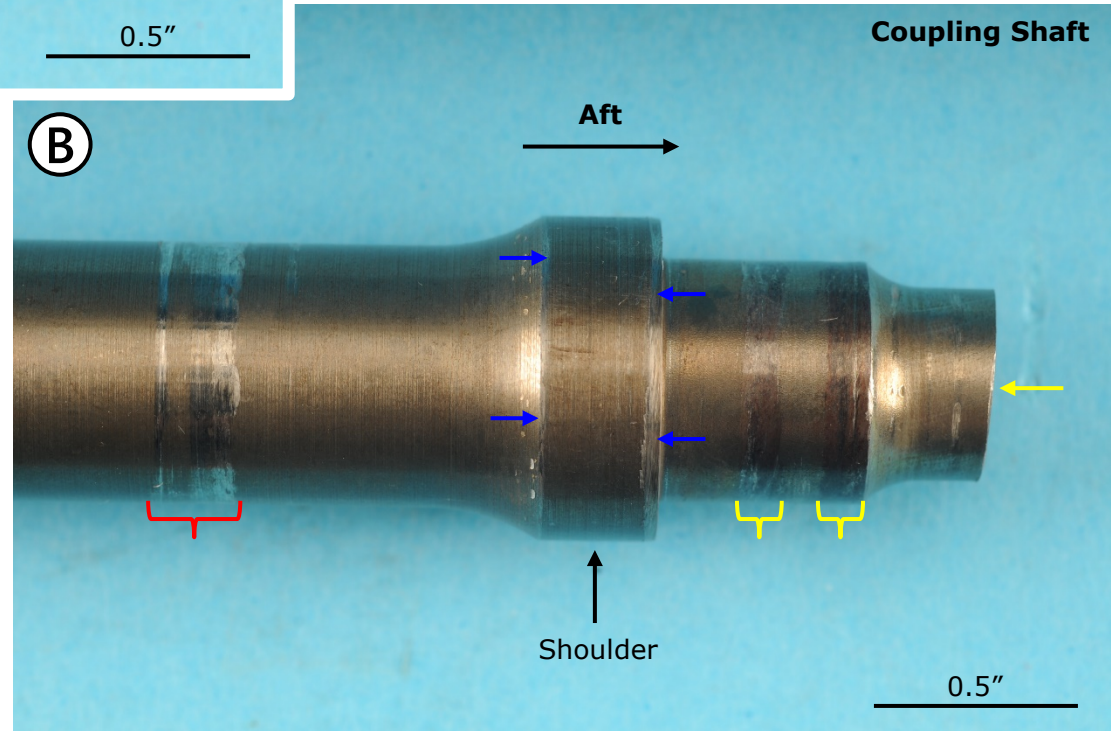
Debris was collected near the compressor bearing is shown in Figure 19A. EDX analysis of the large non-metallic particles were rich in carbon with concentrations in other elements, likely a piece of a carbon seal (Figure 19B). The smaller metallic particle was suggestive of an aluminum alloy, as determined by EDX analysis (Figure 19C).

**Figure 1.**

Overall image showing the as-received condition of the separated coupling shaft (Lot Number 1050) from TPE331 engine S/N P36235C (right engine). The coupling shaft had separated near the aft end (yellow double-sided arrow). Close up images of the shaft are shown in Figures 2-3, as indicated.

**Figure 2.**

(A-B) 180° views of the aft end of the coupling shaft (reference Figure 1). Non-uniform wear was observed on the shoulder (blue arrows), aft of the shoulder (yellow brackets), and forward of the shoulder (red brackets). The yellow arrows point to the fracture surface.



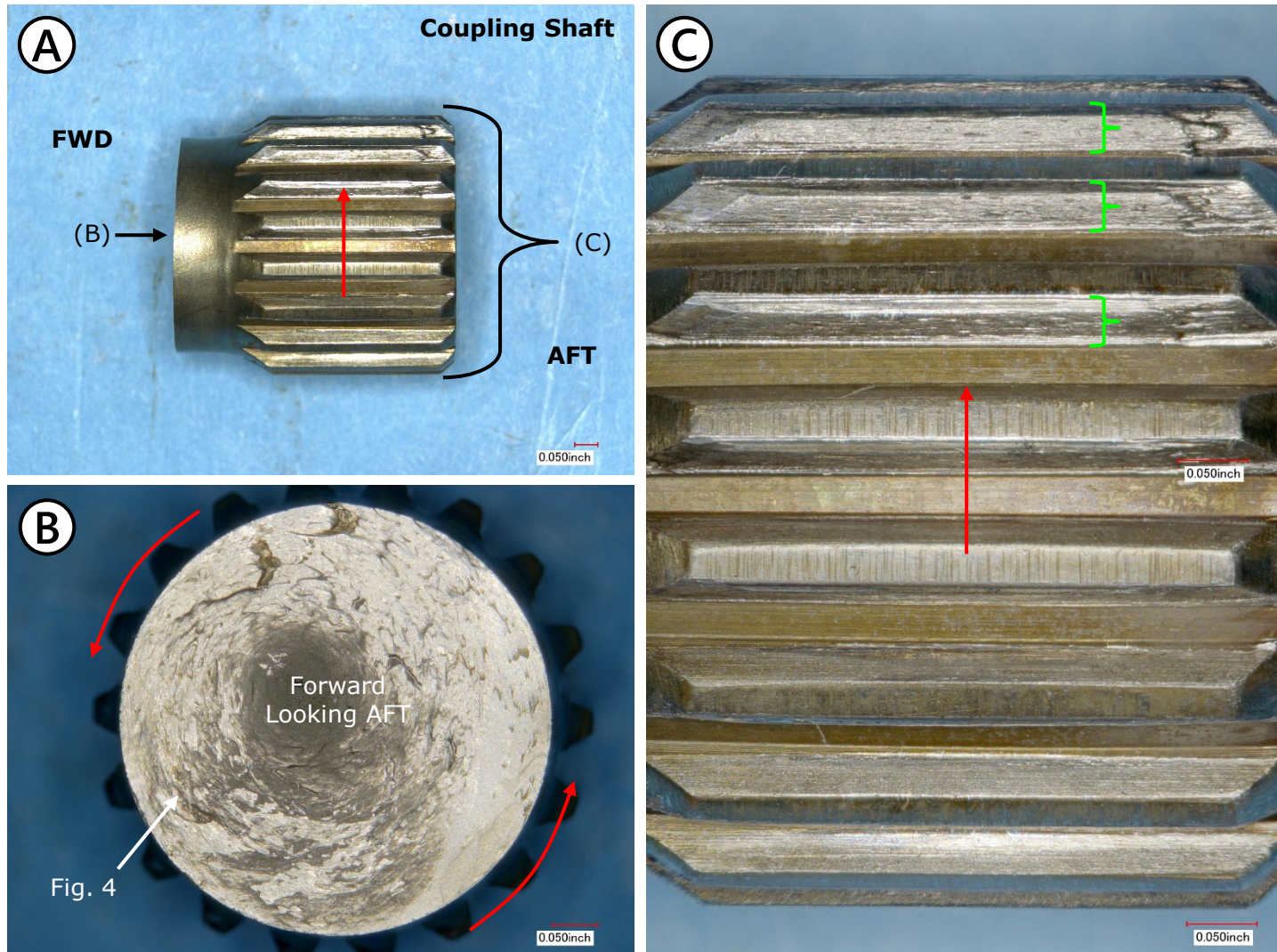
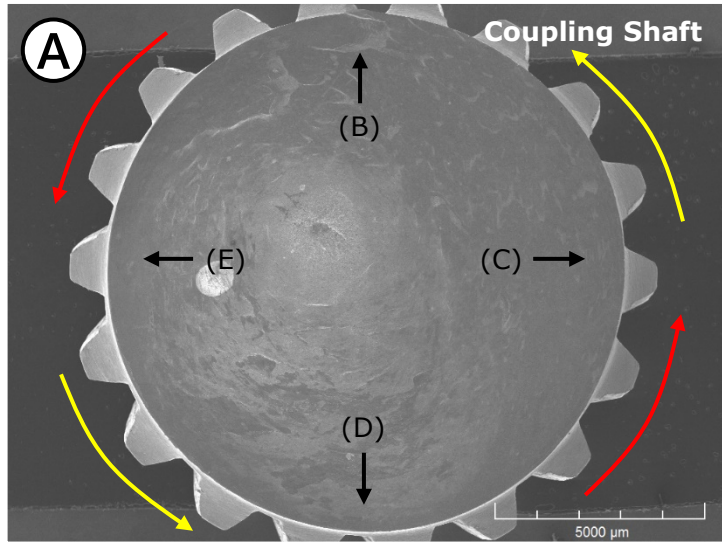
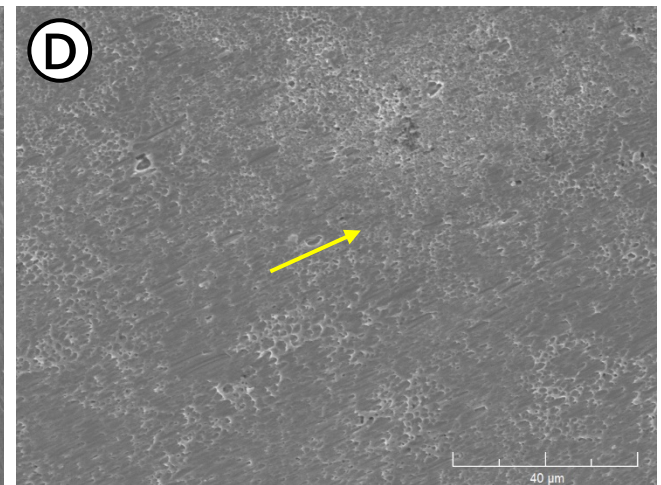
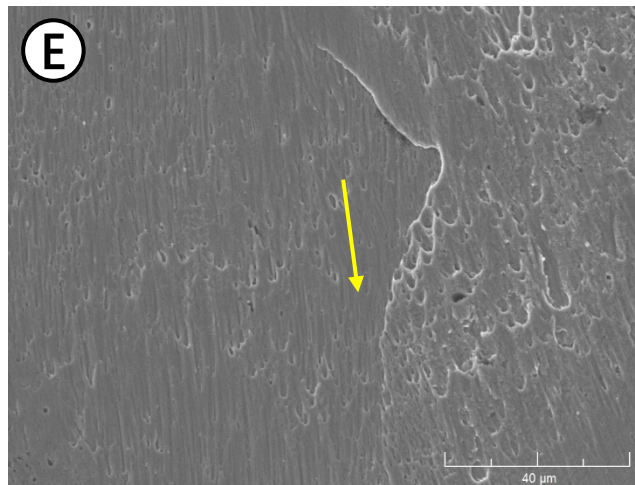
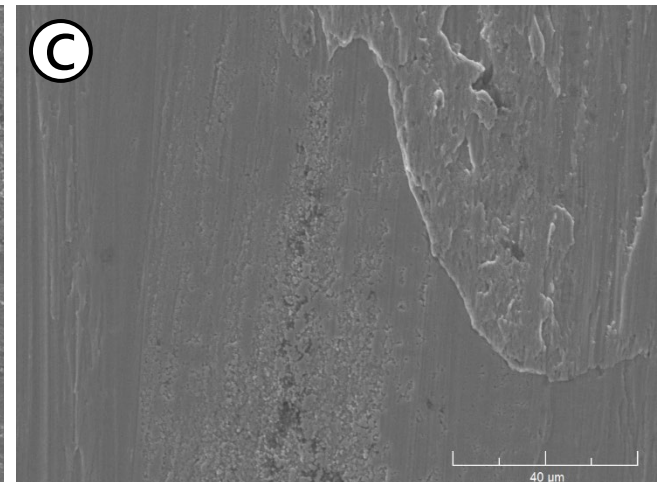
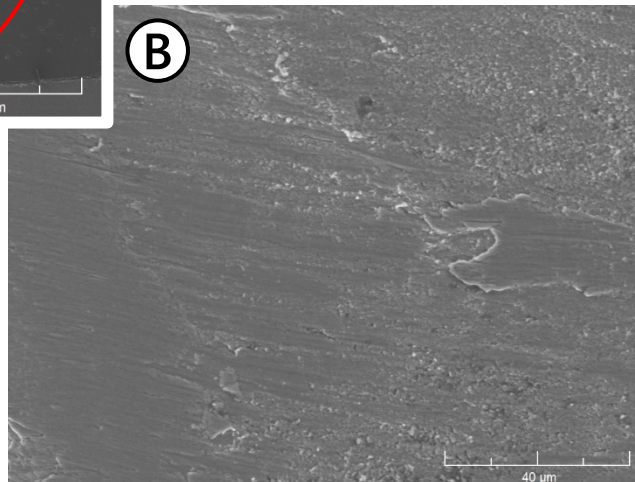


Figure 3.

(A-C) Digital microscope images of the separated coupling shaft (reference Figure 1). The red arrows indicate the specified direction of shaft rotation within the engine (counterclockwise forward looking aft (FLA)). Wear was observed on the loaded side of the gear teeth (green brackets in (C)). Scanning electron microscope (SEM) images of the coupling shaft fracture surface are shown in Figure 4.

**Figure 4.**

(A-E) Secondary electron (SE) SEM images showing the fracture surface on the aft section of the separated coupling shaft (reference Figure 3B). Fracture features indicative of torsional overload were observed in some locations, as indicated by the elongated dimples in the counterclockwise direction as shown in views (D-E); however, most of the fracture features were obscured by smearing and secondary damage (reference views (B-C)). The yellow arrows in (A) and (D-E) indicate the direction of rotation with respect to the mating fracture surface. The red arrows in (A) indicate the specified direction of the shaft rotation within the engine (counterclockwise FLA).



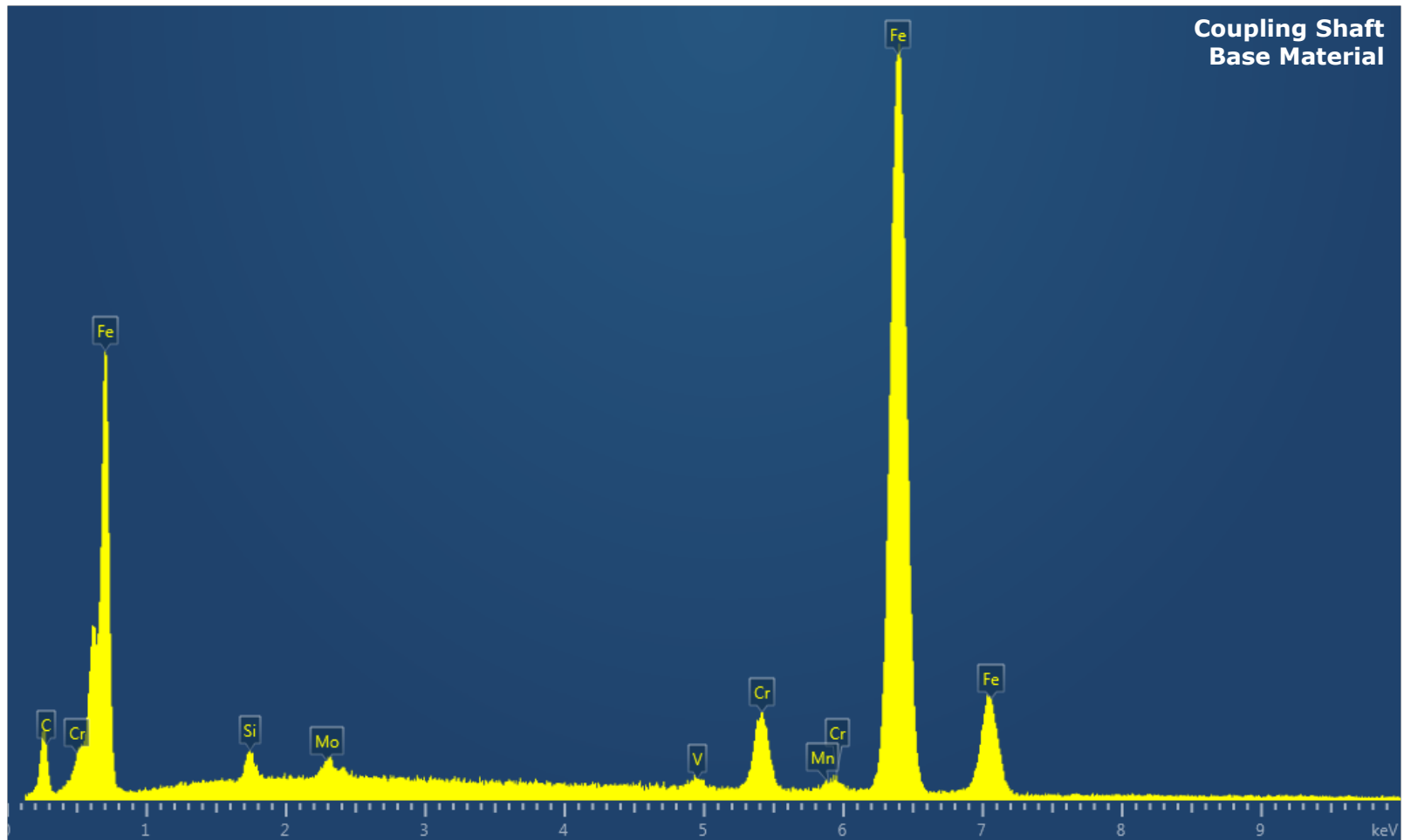


Figure 5.

Representative energy dispersive X-ray (EDX) spectrum generated from analysis of the coupling shaft base material. The spectrum was indicative of the specified H11 material.

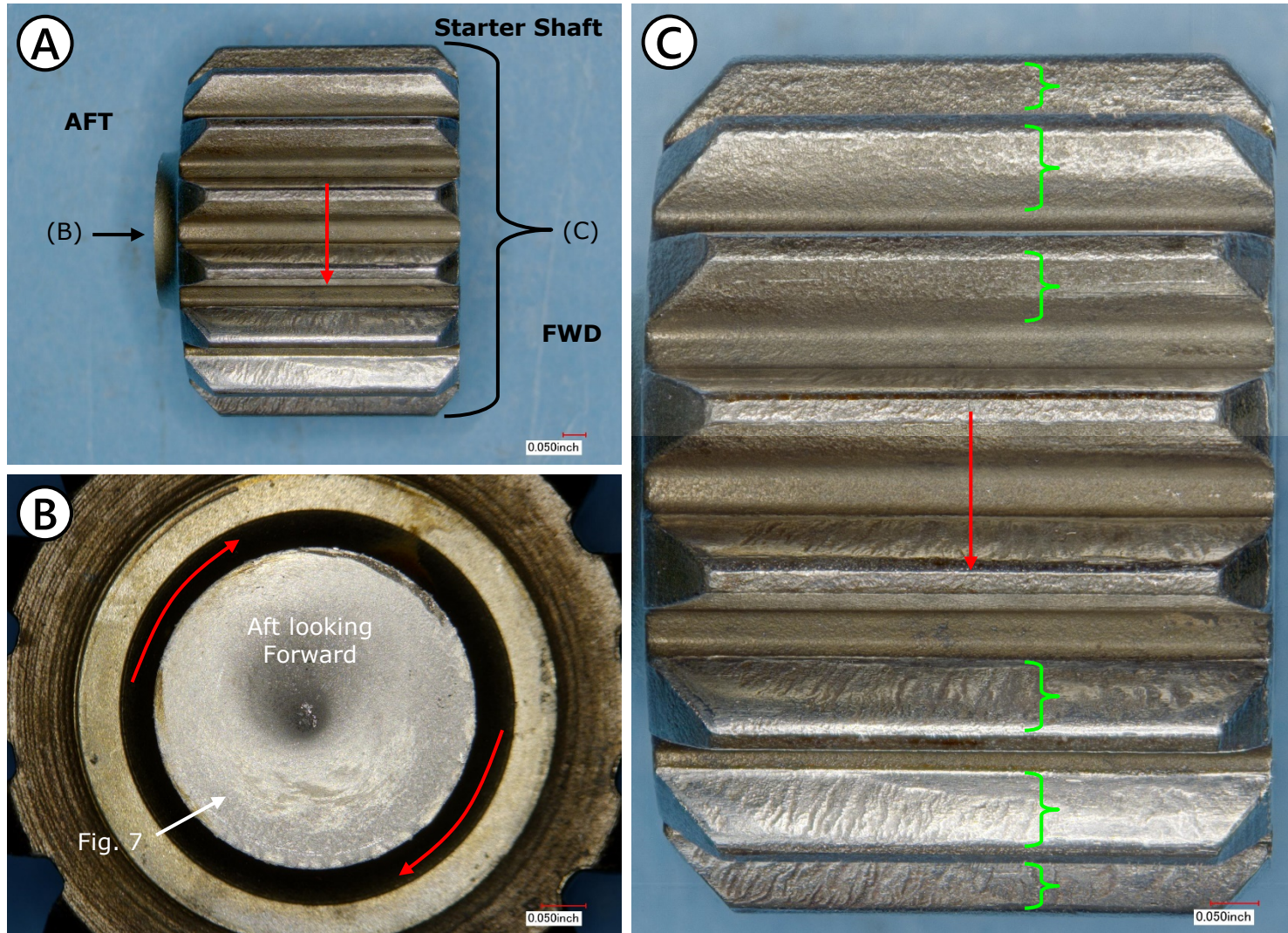


Figure 6.

(A-C) Digital microscope images of the separated starter shaft (P/N not provided). The red arrows indicate the specified direction of the shaft rotation within the engine (clockwise aft looking forward (ALF)). Wear was observed on both sides of the gear teeth (green brackets in (C)). SEM images of the starter shaft fracture surface are shown in Figure 7.

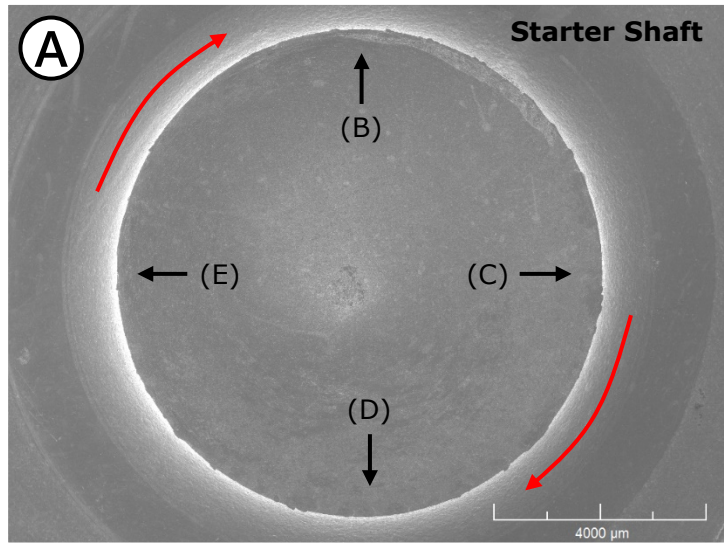
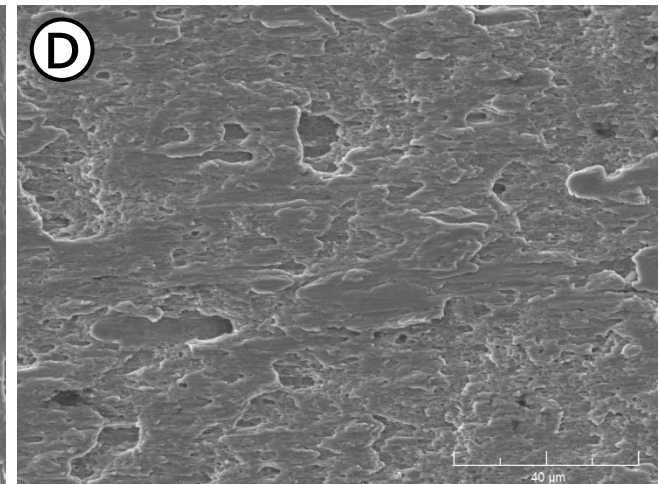
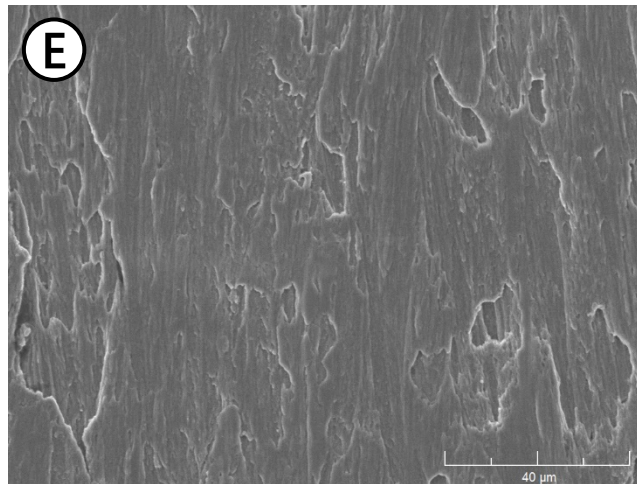
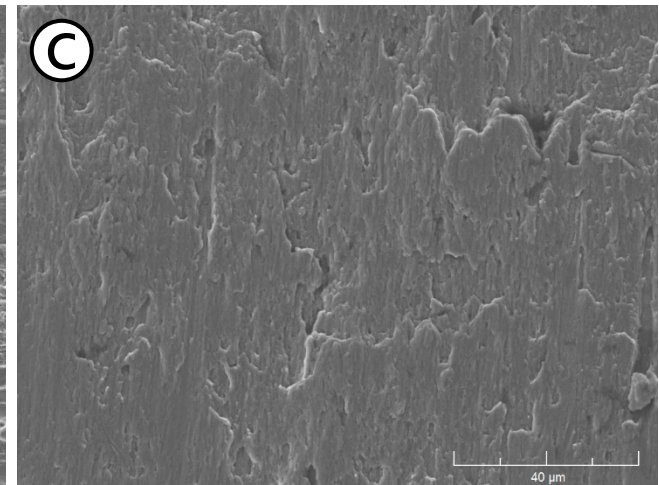
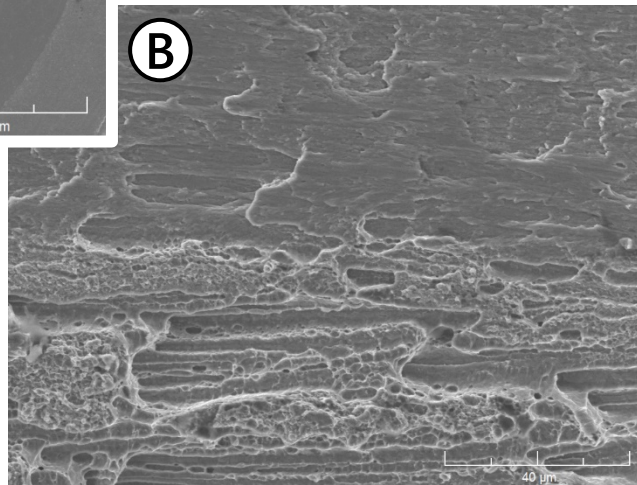


Figure 7.

(A-E) SE SEM images of the starter shaft fracture surface (reference Figure 6B). Fracture features indicative of overload were observed in some locations (reference view (B)); however, most of the finer fracture features were obscured by smearing and secondary damage (reference views (C-E)). The red arrows in (A) indicate the specified direction of the shaft rotation within the engine (clockwise ALF).



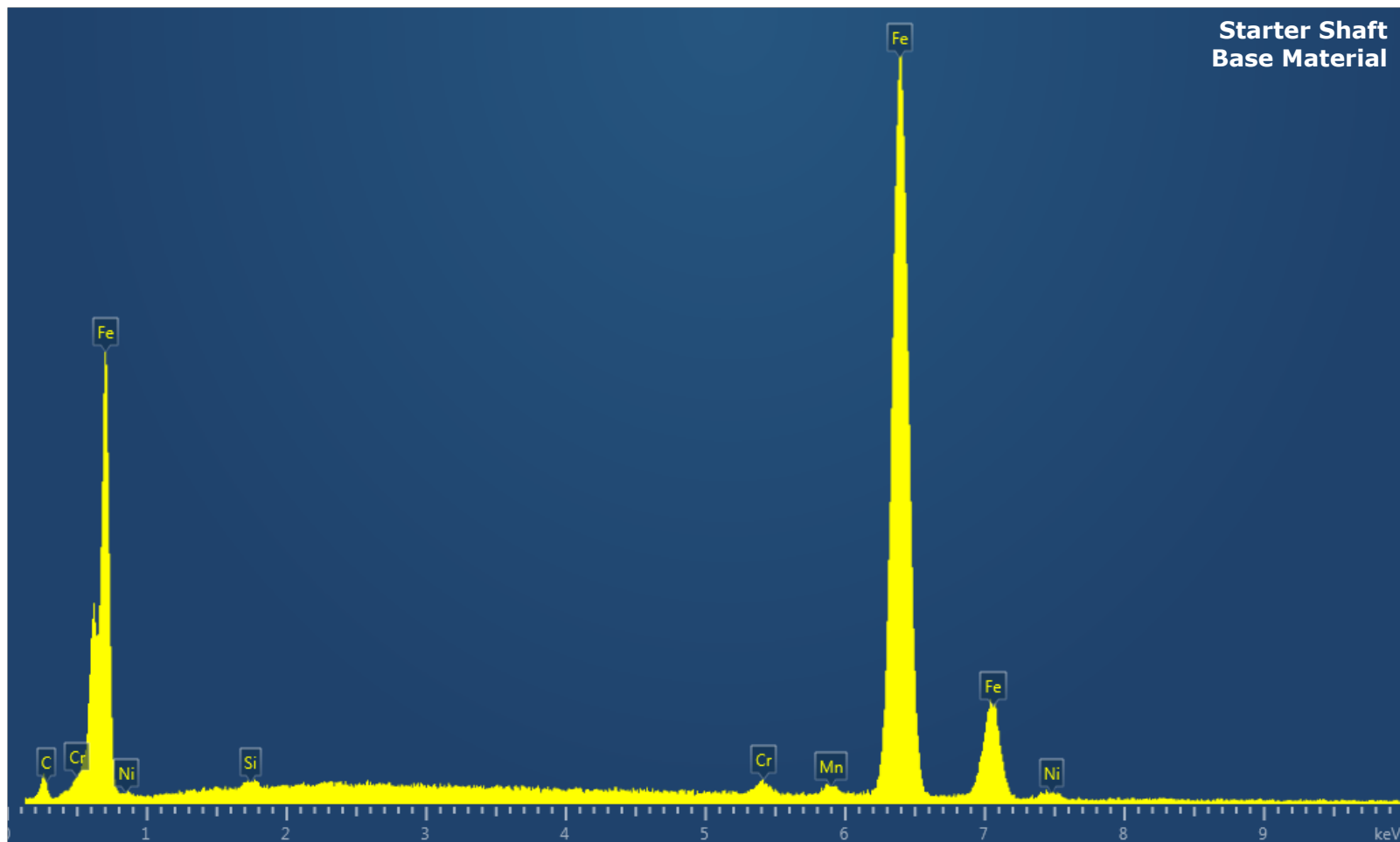


Figure 8.

Representative EDX spectrum generated from analysis of the starter shaft base material. The spectrum was suggestive of a steel similar to 4340. Note that the specified base material of the start shaft was not reported.

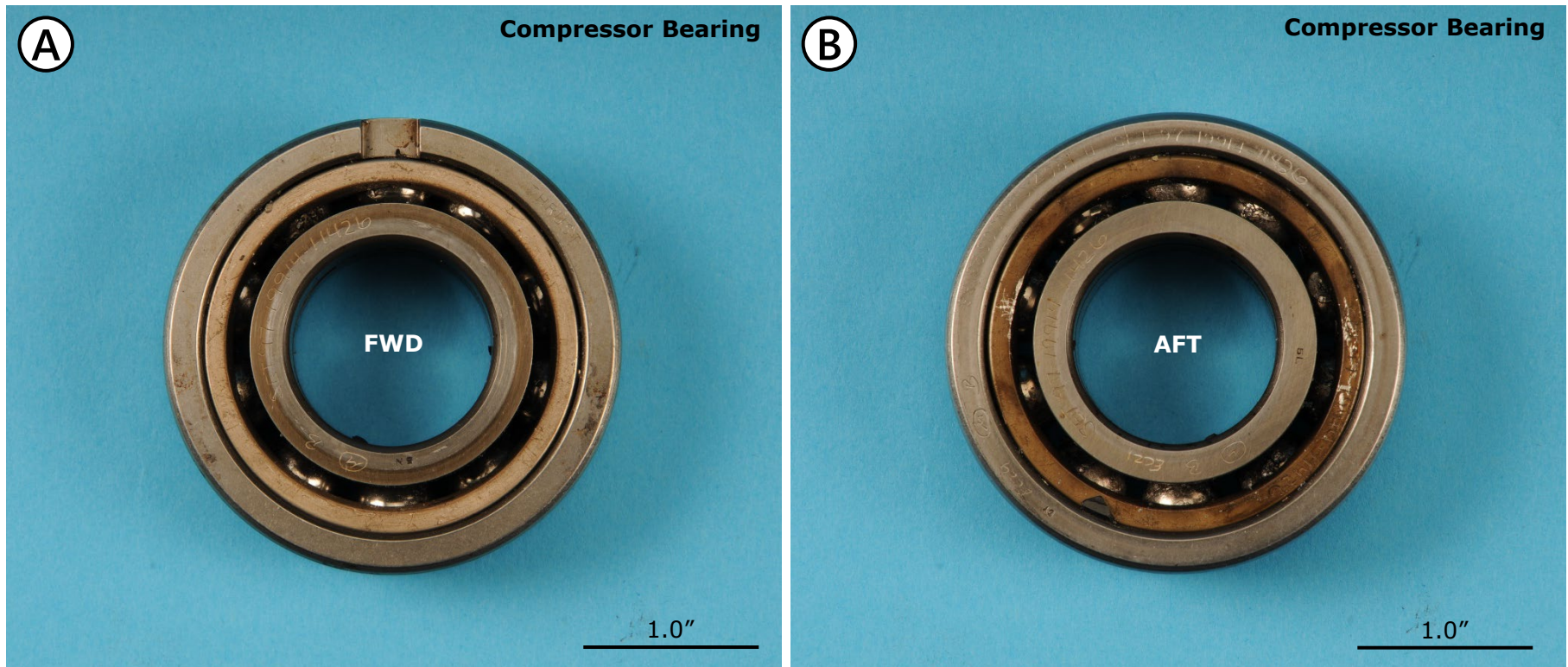


Figure 9.

Overall images showing the as-received condition of the (A) forward and (B) aft sides of the compressor bearing (S/N 97-19914-11426). An image of the bearing after disassembly is shown in Figure 10.



Figure 10.

Overall image showing the compressor bearing after disassembly. Close up images of the bearing components are shown in Figures 11-14, as indicated.

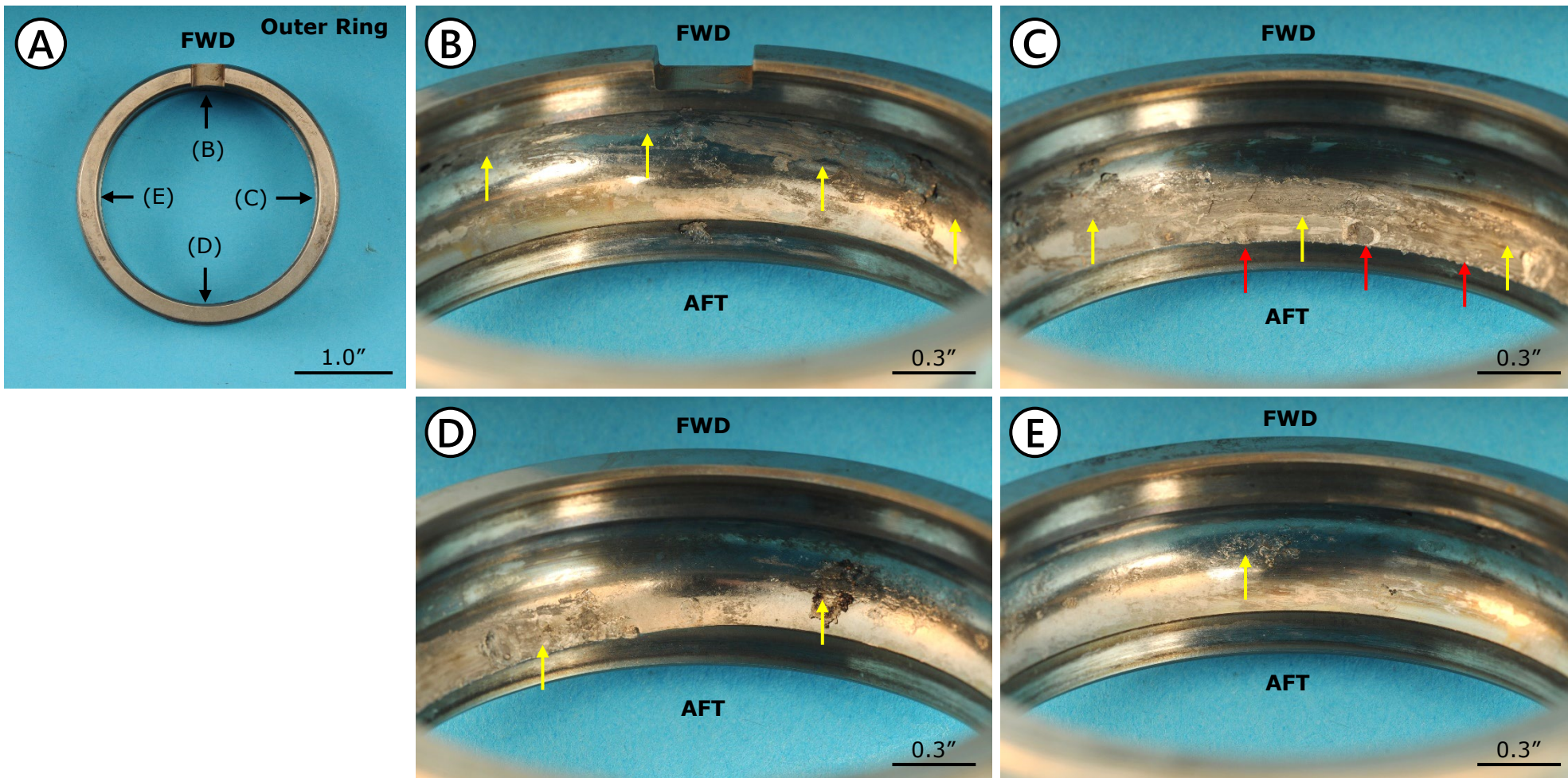


Figure 11.

(A) Overall and (B-E) close up images showing the compressor bearing outer ring (reference Figures 9-10). Damage and non-uniform wear were observed on the outer ring raceway (yellow arrows). Deformed material from the outer ring raceway onto the aft shoulder was observed in some locations (red arrows in (C)).

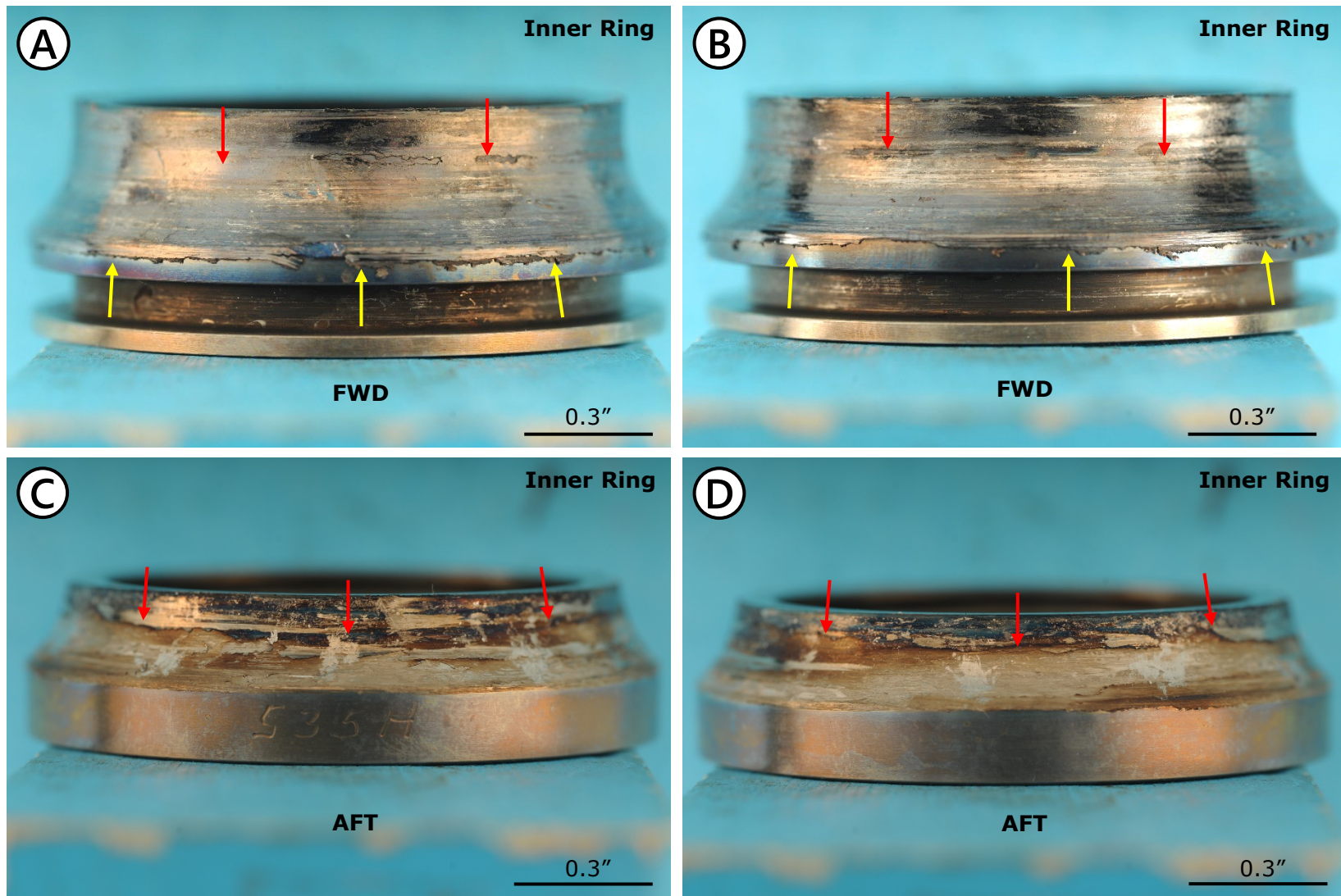


Figure 12.

Views showing the (A-B) forward and (C-D) aft sides of the split inner rings (reference Figures 9-10). Rolled over material was observed at the OD shoulder of the forward side of the split inner ring (yellow arrows in (A-B)). Damage was observed on the split inner ring raceways (red arrows).

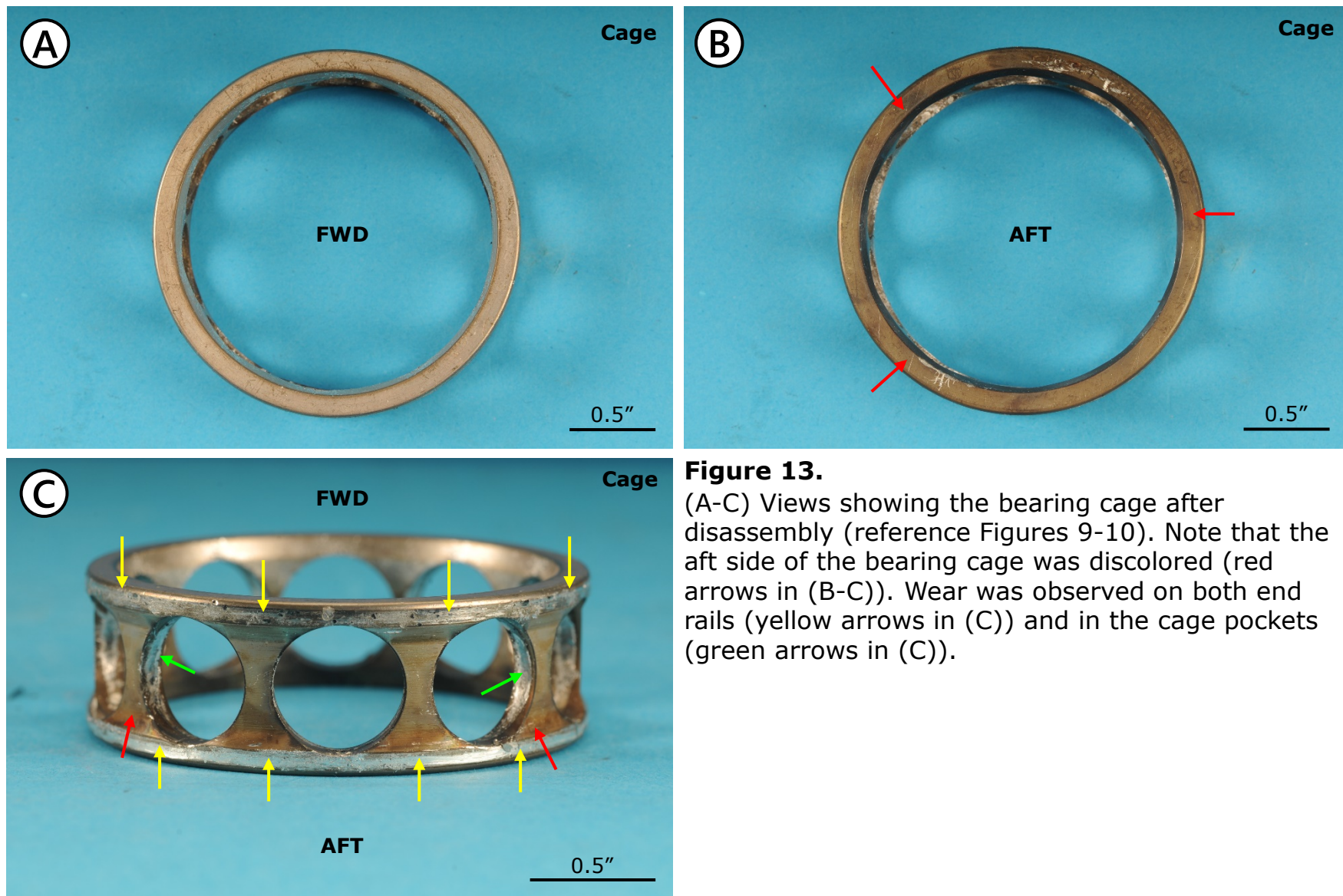


Figure 13.

(A-C) Views showing the bearing cage after disassembly (reference Figures 9-10). Note that the aft side of the bearing cage was discolored (red arrows in (B-C)). Wear was observed on both end rails (yellow arrows in (C)) and in the cage pockets (green arrows in (C)).



Figure 14.

View showing the rolling elements (reference Figures 9-10). All the rolling elements exhibited damage and discoloration (yellow arrows).

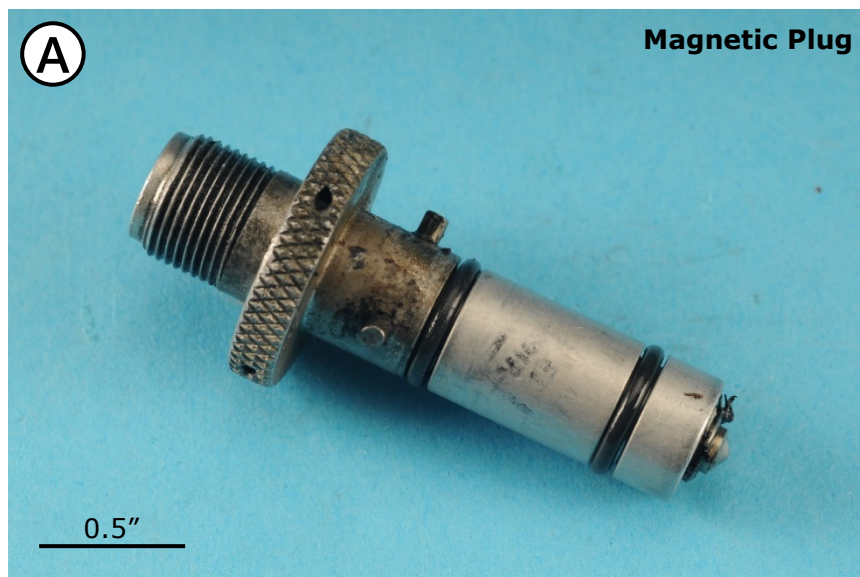
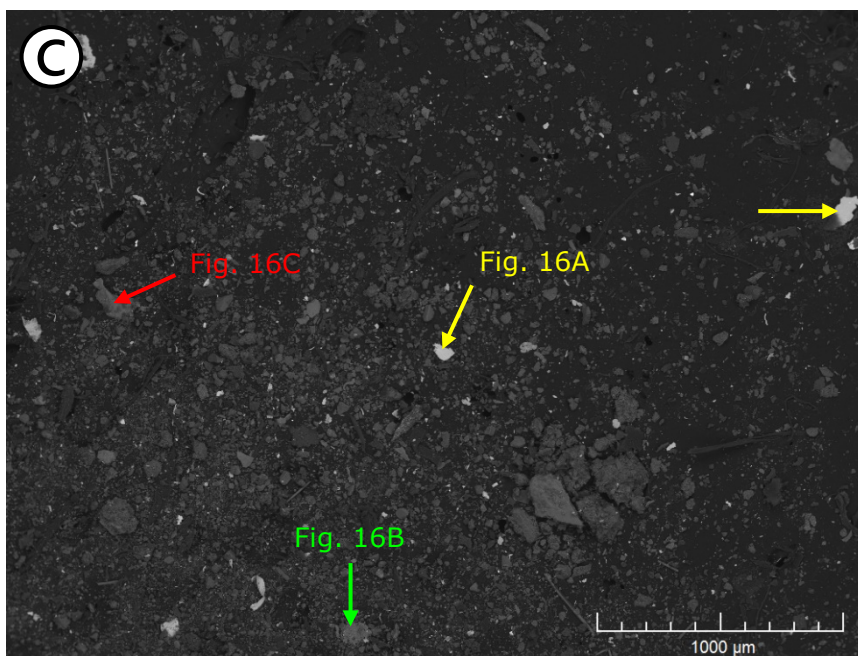
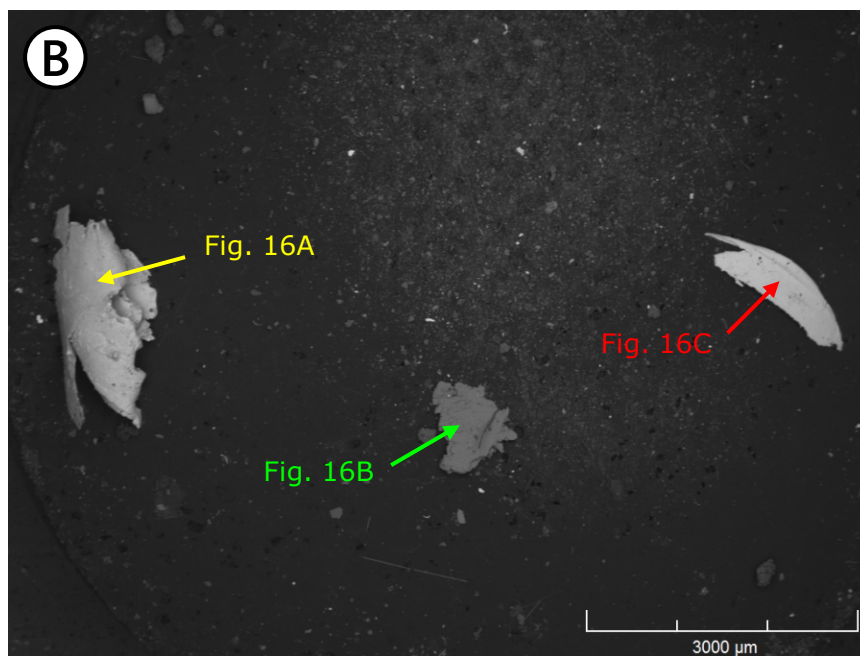


Figure 15.

(A) Macro image showing the magnetic plug in the as-received condition. (B-C) Backscattered electron (BSE) SEM images showing representative debris collected from the magnetic plug. EDX analysis of the debris identified by yellow, green, and red arrows are shown in Figure 16.



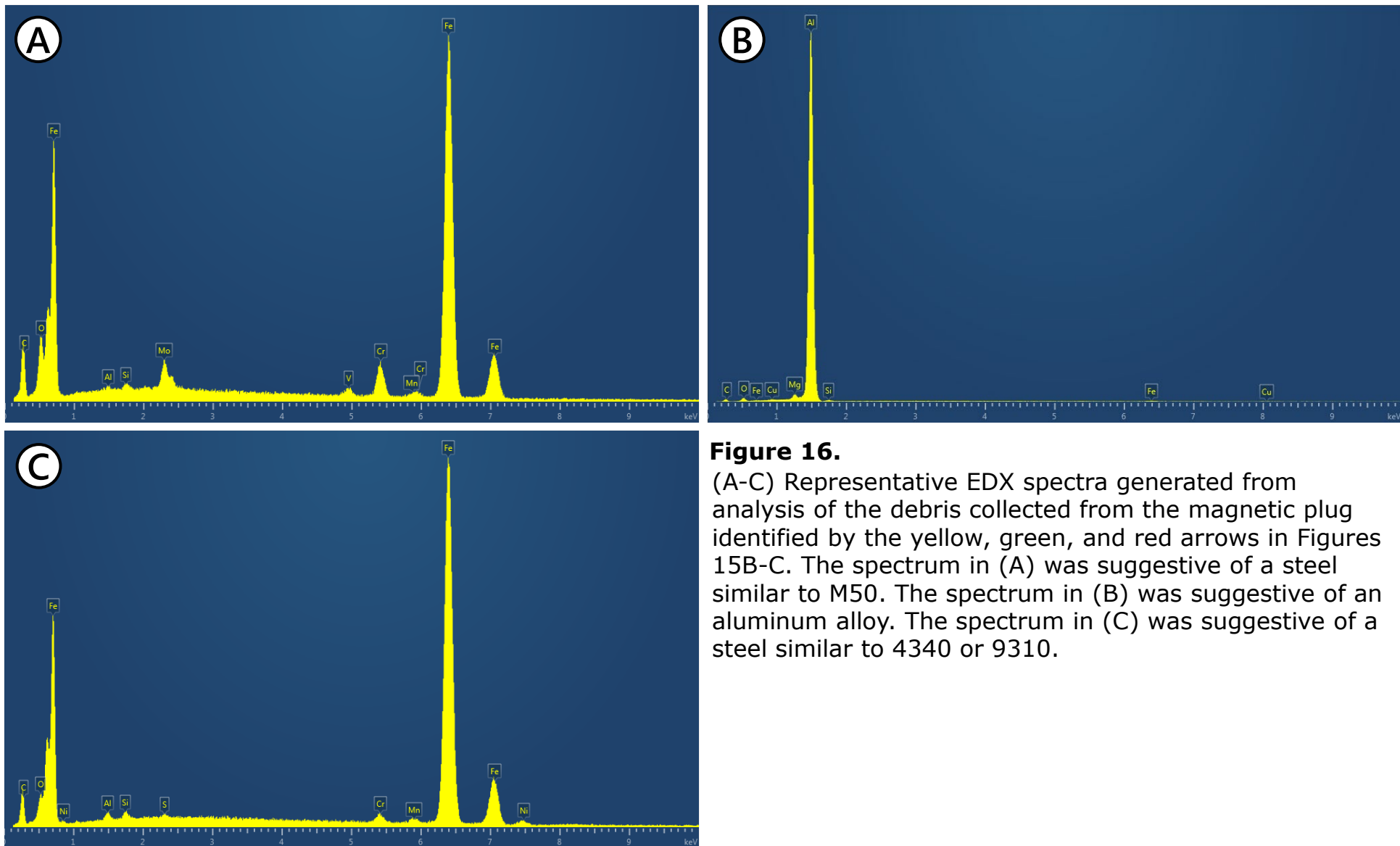


Figure 16.

(A-C) Representative EDX spectra generated from analysis of the debris collected from the magnetic plug identified by the yellow, green, and red arrows in Figures 15B-C. The spectrum in (A) was suggestive of a steel similar to M50. The spectrum in (B) was suggestive of an aluminum alloy. The spectrum in (C) was suggestive of a steel similar to 4340 or 9310.

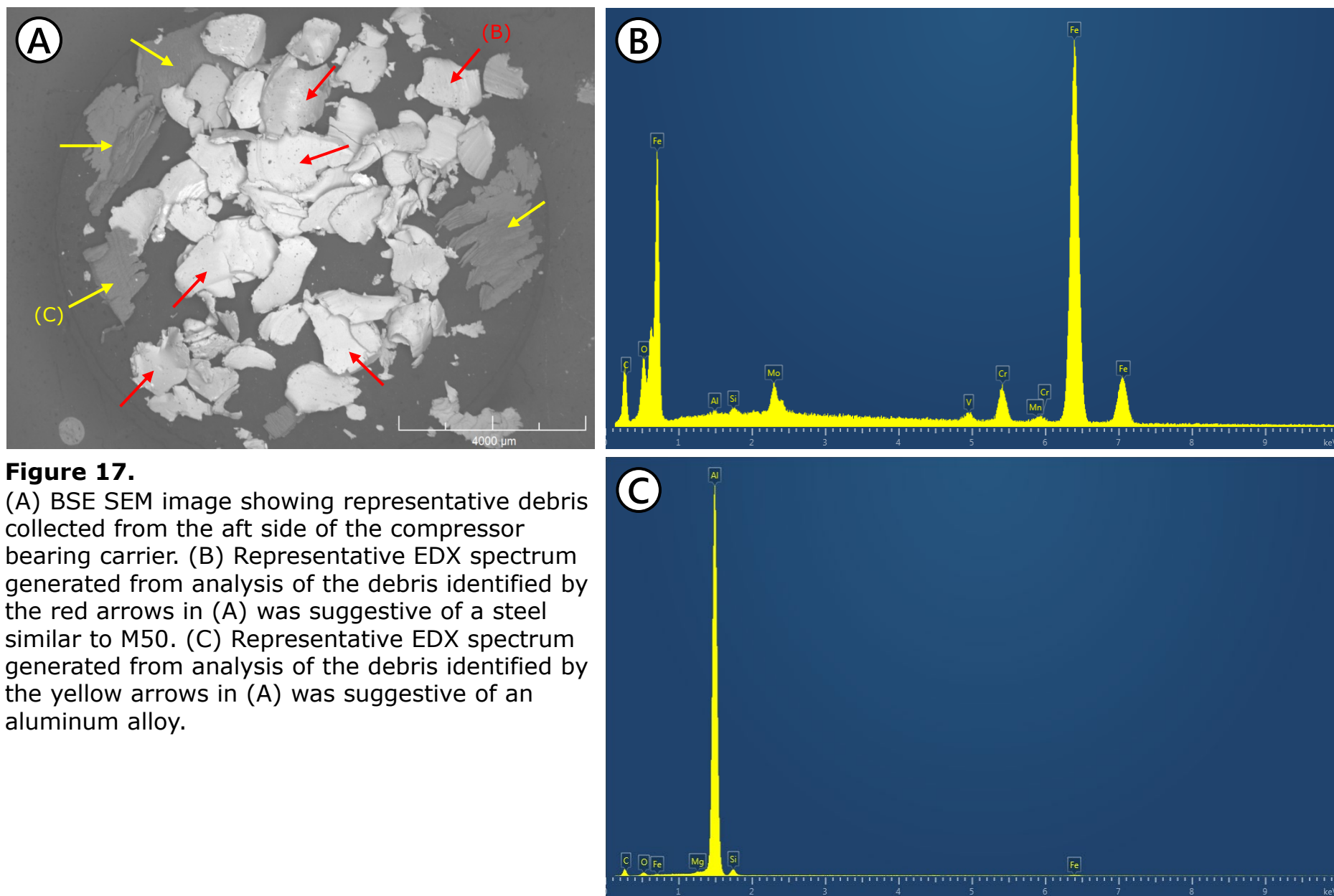
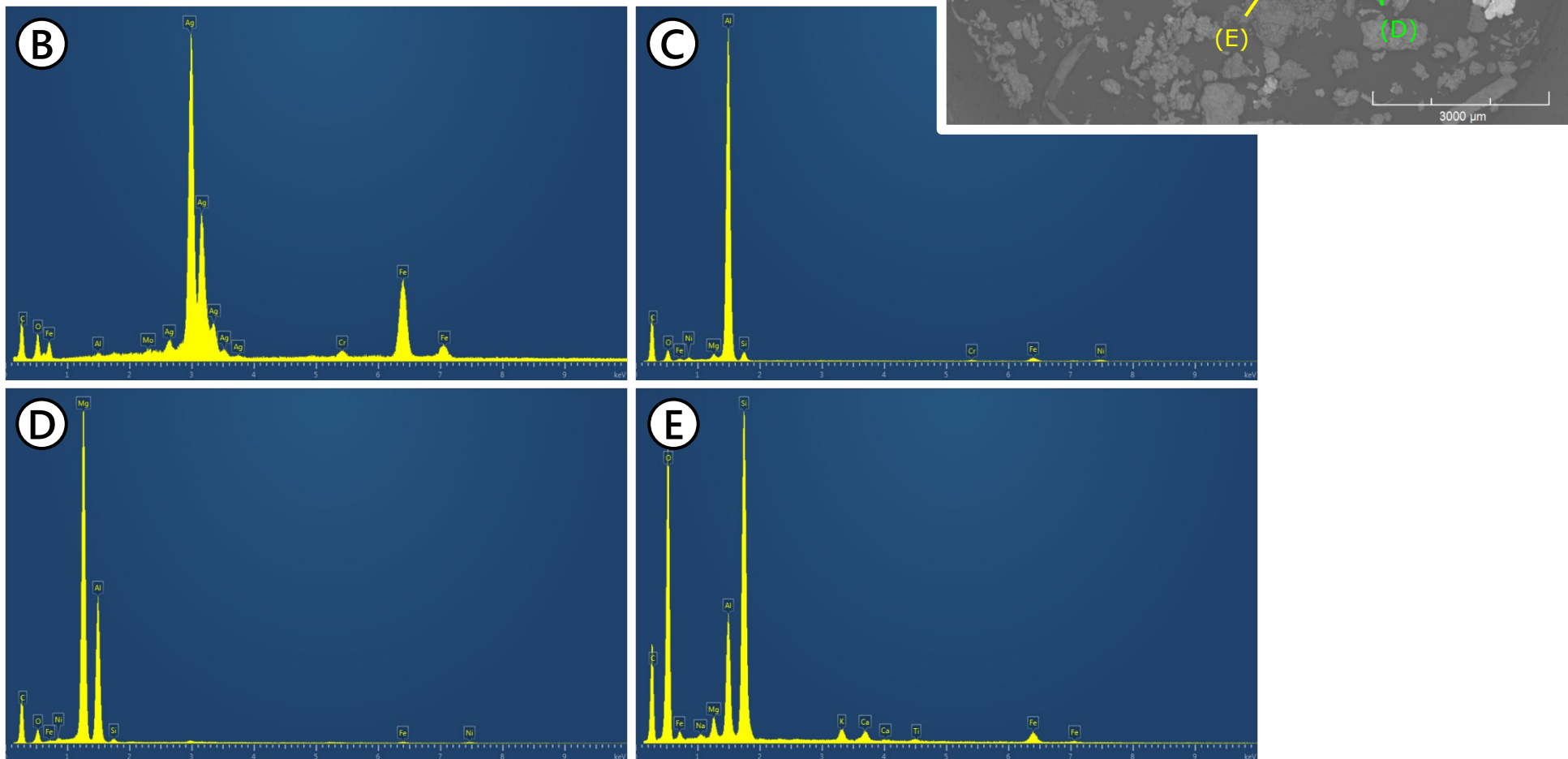


Figure 17.

(A) BSE SEM image showing representative debris collected from the aft side of the compressor bearing carrier. (B) Representative EDX spectrum generated from analysis of the debris identified by the red arrows in (A) was suggestive of a steel similar to M50. (C) Representative EDX spectrum generated from analysis of the debris identified by the yellow arrows in (A) was suggestive of an aluminum alloy.

Figure 18.

(A) BSE SEM image showing representative debris collected from the forward side of the compressor bearing carrier. (B-E) Representative EDX spectra generated from analysis of the debris identified by the red, blue, green, and yellow arrows in (A). The spectrum in (B) was indicative of silver with concentrations in other elements. The spectrum in (C) was suggestive of an aluminum alloy. The spectrum in (D) was rich in magnesium and aluminum. The spectrum in (E) was rich in silicon, oxygen, aluminum, carbon, with traces of other elements.



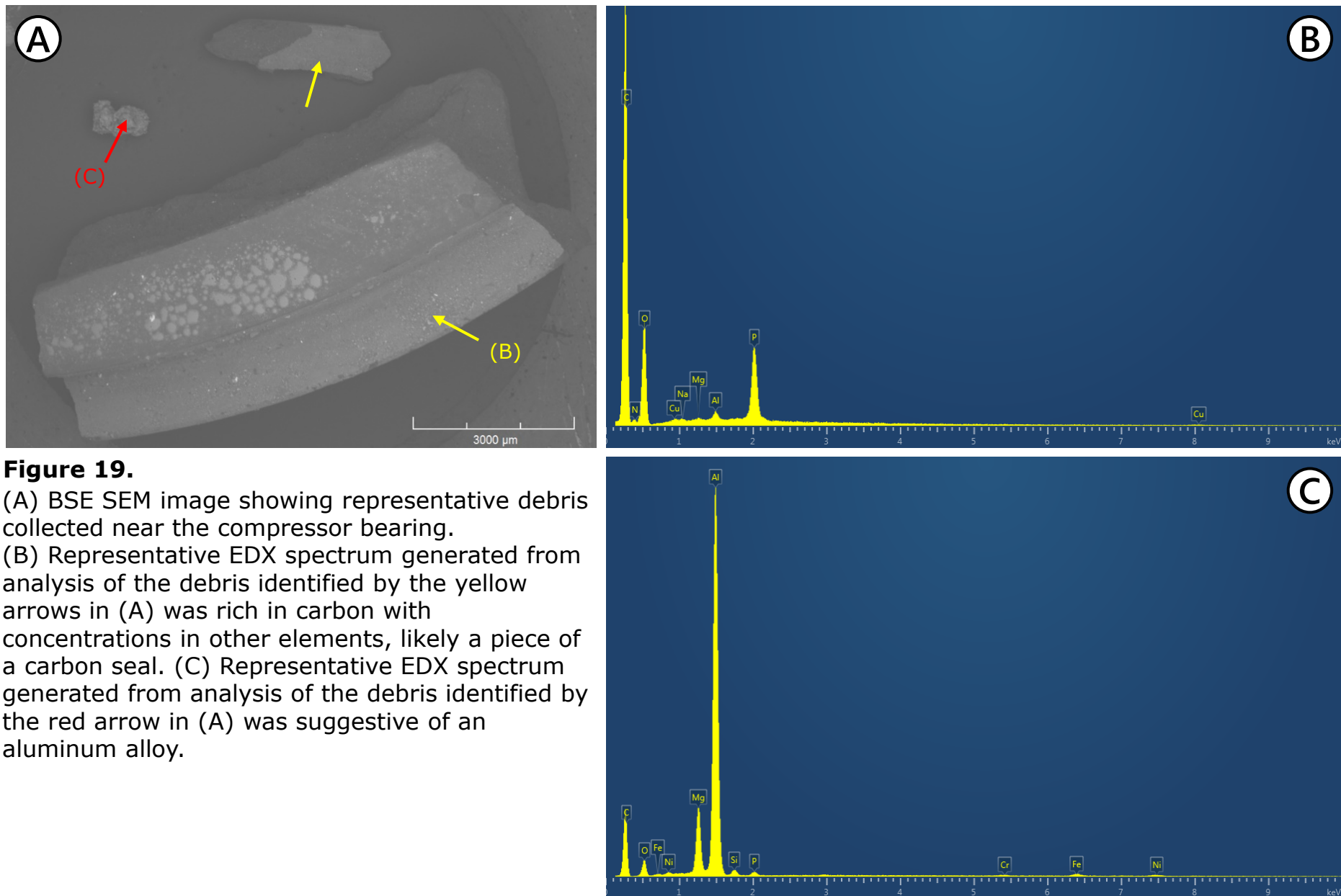


Figure 19.

(A) BSE SEM image showing representative debris collected near the compressor bearing.

(B) Representative EDX spectrum generated from analysis of the debris identified by the yellow arrows in (A) was rich in carbon with concentrations in other elements, likely a piece of a carbon seal. (C) Representative EDX spectrum generated from analysis of the debris identified by the red arrow in (A) was suggestive of an aluminum alloy.