

NATIONAL TRANSPORTATION SAFETY BOARD

Office of Research and Engineering
Materials Laboratory Division
Washington, D.C. 20594



March 26, 2018

MATERIALS LABORATORY FACTUAL REPORT

Report No. 17-079

A. ACCIDENT INFORMATION

Place : Carbondale, Illinois
Date : August 28, 2017
Vehicle : Grumman AA-5B, N28005
NTSB No. : CEN17LA333
Investigator : Aaron Sauer, AS-CEN

B. COMPONENTS EXAMINED

McCauley 1A170/FFA propeller with attached doubler, forward bulkhead, spacer, and attachment bolt pieces.

C. DETAILS OF THE EXAMINATION

An overall view of the submitted components is shown in figure 1, and the components as depicted in the Illustrated Parts Catalog¹ for the Grumman AA-5 series airplanes are shown labeled in figure 2. The propeller was a McCauley 1A170/FFA propeller, serial number P80066. Pieces of the doubler and forward bulkhead were attached to the forward side of the propeller as indicated in figure 3, and a spacer was attached at the aft side of the propeller as shown in figure 4. Part number 5506011-3 was marked on the aft face of the doubler, consistent with the doubler part number included in the Globe spinner assembly listed in the type certificate data sheet for the accident airplane. The pieces of the spinner assembly and spacer were held in place with remnants of the attachment bolts, which are numbered for reference in this report by clock positions as viewed looking forward (see numbers in figures 3 and 4).

The propeller was fractured in the hub area, and 4 of the attachment bolts were fractured in the threaded portion of the shank. The numbers 3 and 11 attachment bolts were intact, and fractured lugs from the propeller flange on the crankshaft remained attached to the threaded ends of the bolts (see figure 4). The spacer was cracked through the dowel hole at the 4 o'clock position and was fractured through the numbers 7 and 9 bolt holes. The doubler and forward bulkhead were fractured in multiple locations with portions missing from each piece including the entire outer diameter of the forward bulkhead that had been attached to the spinner. The spinner and aft bulkhead were not recovered. (According to the airplane owner, the missing spinner on the airplane was

¹ Gulfstream Aerospace Corporation (1983).

painted white.) Fractures in the 4 attachment bolts and 2 propeller flange attachment lugs had rough, matte gray features consistent with ductile overstress fracture.

The propeller was fractured through the hub with fractures adjacent to and partially intersecting bolt holes 5 and 11. Photographs of the fracture surfaces on the piece labeled blade 2 are shown in figures 5 and 6. Both fractures were on relatively flat fracture planes with curving crack arrest marks, features consistent with fatigue. The fatigue features on each fracture surface emanated from multiple origins located at the forward face. Brackets in figures 5 and 6 indicate origin areas in each fracture.

The doubler, aft bulkhead, and spacer pieces were removed from the propeller to facilitate a closer examination of the fractures and adjacent surfaces. The fractured attachment bolts were bent and cut as needed to allow them to slide out of their corresponding holes in the propeller and spacer. The propeller flange lug pieces on bolts 3 and 11 were not able to be removed by unscrewing due to thread damage on the end of the bolt, so transverse cuts were made through the lug and the bolt to cut off the damaged portion, and the remaining forward piece of the lug was unscrewed from the cut end of the bolt. Views of the propeller hub after removal of the attached components are shown in figure 7.

1. Propeller

The locations of the origin areas for the two fatigue fractures in the hub are indicated in figure 7. The origins were located at the outer diameter of the annular rings associated with the underside of the attachment bolt heads at holes 5 and 11. At the number 5 attachment hole, a piece of the propeller adjacent to the hole was missing, and the missing piece included the blade 1 side of the origin area. The fracture at the blade 5 hole showed bending deformation as shown in figure 7, indicating the hub likely separated near hole 11 first. Fretting contact damage was also observed near many of the attachment holes as indicated with unlabeled arrows in figure 7. The area of fretting damage was largest adjacent to the fracture near hole 11.

Pink and red deposits were observed in the attachment and dowel holes for the propeller. The deposits can be seen clearly in figure 7 and on hole surfaces intersected by the fractures shown in figures 5 and 6. No pink or red deposits were observed on the surfaces of the holes in the spacer.

A portable bandsaw was used to cut through the hub at approximately the 12 o'clock position to separate the blade 2 side of the fracture near hole 11 for further examination. An overall view of the fracture surface after sectioning is shown in figure 8. The fatigue region extended across most of the fracture surface, ending near the inboard aft corner at the boundary indicated with a red dashed line. Near the origin, a portion of the fracture surface had a brown color, and the boundary of the brown region is indicated with a black dashed line. Adjacent to the brown region, a region with a bluish gray tint was observed, bounded by another black dashed line. A periodic pattern of crack arrest lines was observed between the bluish gray region and the fatigue boundary. Unlabeled

arrows in figure 8 indicate the locations of 17 crack arrest lines identified on the fracture surface between the bluish gray region and the fatigue boundary.

Views of the origin area and adjacent forward face of the blade are shown in figure 9. For reference, the forward bulkhead is shown in position at bolt hole 11 in figure 10. The fracture in the forward bulkhead curved around the outboard edge of the annular area of the bolt head, intersecting the propeller fracture near the middle of the origin area. Fretting contact damage was observed on the propeller surface along the line of fracture for the forward bulkhead and on the adjacent surface outboard of the bulkhead fracture.

The fracture surface shown in figure 8 was initially examined under a stereo microscope using a black light. The fracture surface was prepared for examination by blowing away loose debris with compressed air. No evidence of fluorescing dye was observed on the fracture surface.

Next, the fracture surface was examined in a scanning electron microscope (SEM) using energy dispersive x-ray spectroscopy (EDS) to analyze surface deposits. No cleaning with solvents was completed prior to the initial SEM examination and EDS analysis.

An accumulation of deposits in the dowel hole near the aft end of the fracture was analyzed using EDS, and the resulting spectrum is shown in figure 11. When viewed under an optical microscope, the deposits in the area analyzed appeared pink. For comparison, an EDS spectrum of the propeller fracture in an area relatively clean and free of deposits or oxidation is shown in figure 12 (lower spectrum). The pink deposits in the dowel hole had relatively higher peaks of carbon, oxygen, magnesium, silicon, chlorine, potassium, calcium, titanium, and iron compared to the spectrum from the relatively clean fracture surface.

EDS spectra were obtained from areas near the origin and within the discolored areas indicated with black dashed lines in figure 8, and the EDS spectra are shown in figure 12 (upper and middle spectrum, respectively). Compared to the spectrum obtained from a relatively clean area of the fracture further from the origin (lower spectrum in figure 12), the spectra near the origin and within the discolored region showed relatively higher peaks of oxygen. Closer to the origin, small peaks of silicon, chlorine, potassium and calcium were also detected.

The boundary of the discolored (oxidized) region was imaged in the SEM using a backscattered electron detector in composition mode,² and the resulting image is shown in figure 13. The oxidized region appears darker relative to the fracture surface aft of the boundary.

² SEM images produced using a backscattered electron detector in composition mode have contrast that is associated with atomic weight of the elements in the image. Areas with elements having higher atomic weights appear as a relatively lighter shade of gray compared to areas having elements with lower atomic weights.

Next, the fracture surface shown in figure 8 was submerged in acetone and cleaned using an ultrasonic cleaner. The pink and red deposits in the holes dissolved in the acetone during the cleaning. The cleaned fracture surface was then further examined using an SEM.

An overall view of the cleaned propeller fracture surface at the origin area near hole 11 is shown in figure 14. Several origins were noted as indicated with arrows in figure 14. Feathery fracture features with curving striations were observed emanating from the origin area, features consistent with fatigue. Figure 15 shows typical fracture features observed near the origin (upper image) and in an area outside the oxidized region (lower image).

Most of the fracture features emanated directly from the origin at the right in figure 14, which will be referenced as the primary origin. Closer SEM images of the primary origin are shown in figure 16. A relatively shallow pit was observed at the origin as indicated with an arrow in the upper image in figure 16. No evidence of material anomalies were observed as shown in the lower image in figure 16 obtained using the backscattered electron detector.

Oblique views of the primary origin are shown in figure 17. A relatively rough surface with oxide deposits were observed on the forward face of the propeller adjacent to the origin area. Additional views of the surface adjacent to the origin are shown in figure 18 as imaged using the secondary electron detector (upper image) and the backscattered electron detector (lower image). Scratches were observed on the surface mostly oriented at angles less than 45 degrees relative to the spanwise direction of propeller. Some scratches were also noted transverse to the spanwise direction such as those indicated in figure 18. However, the origin did not appear to coincide with any of the scratches. Particles of cadmium were observed scattered around the annular contact area around the bolt hole, and one of the particles is indicated in the lower image in figure 18. (The attachment bolts and doubler were coated with cadmium.) Accumulations of oxide particles were observed within approximately 0.008 inch (200 micrometers) of the fracture surface. No fretting contact damage was observed within the annular contact area located under the head of the attachment bolt.

2. Spacer

Fracture features in the spacer at the forward ends of hole 9 and the dowel hole at the 4 o'clock position had a faceted appearance with fracture on a plane perpendicular to the forward face, features consistent with fatigue in the aluminum alloy. Fatigue features emanated from the hole corners at each location. Beyond the fatigue boundaries, the spacer fractures were rough and matte gray consistent with ductile overstress fracture.

3. Doubler

Overall views of the doubler are shown in figure 19. The doubler had approximately radial fractures adjacent to holes 5 and 11 and through hole 9. A crack

was present around the outboard edge of the attachment bolt contact face at hole 1. A piece of the doubler between holes 9 and 11 was missing.

Portions of the doubler fracture surfaces had flat fractures perpendicular to the surface with curving boundaries, features consistent with fatigue. The fatigue features were located at the edges of the attachment bolt contact faces in the areas indicated with brackets in the upper image in figure 19. The fatigue propagated through the thickness of the doubler, initiating at the forward face in the fractures near holes 5 and 11 and initiating at the aft face near hole 1. The remaining fracture faces had matte gray fractures on slant planes, features consistent with ductile overstress fracture.

The thickness of the doubler was measured in a flat area between the holes, and the thickness measured 0.033 inch. The annular regions around the holes corresponding to the head contact area were recessed relative to the adjacent surfaces, and surfaces were smeared in the circumferential direction consistent with sliding contact with the underside of the attachment bolt heads. The thickness of the doubler in the recessed area around one of the holes measured 0.032 inch.

A piece of the doubler at the 12 o'clock position was cut from the rest of the piece, and the surface coating was ground away to reveal the underlying metal. The piece was analyzed using a Thermo Scientific Niton XL3t-980 x-ray fluorescence (XRF) alloy analyzer, and the metal was identified as AISI 4130 steel. Hardness tests were conducted on the sectioned piece, and results revealed a hardness of 92.8 HRB.

A representative from True Flight Holdings, the current owner of the type certificate for the accident airplane, indicated the part number 5506010-3 doubler is made of AISI 4130 steel in the normalized condition and has a thickness of 0.032 inch. According to Aerospace Materials Specification AMS6345D,³ normalized AISI (SAE) 4130 steel has a minimum tensile strength of 95,000 pounds per square inch. According to ASTM Standard A370-14,⁴ a nonaustenitic steel (such as AISI/SAE 4130) with a tensile strength of 95,000 pounds per square inch has a hardness of approximately 93 HRB.

4. Forward Bulkhead

Overall views of the forward bulkhead pieces are shown in figure 20. The forward bulkhead was fractured circumferentially outboard of the propeller attachment holes and approximately radially near holes 3 and 5 and through hole 9. Another fracture was present near hole 11 oriented approximately transverse to the propeller span direction. Pieces were missing including the entire outer circumference and segments between holes 3 and 5 and between holes 9 and 11.

³ Aerospace Materials Specification AMS6345D, *Steel, Sheet, Strip, and Plate 0.95Cr - 0.20Mo (0.28 - 0.33C) (SAE 4130) Normalized or Otherwise Heat Treated*, SAE International, Warrendale, Pennsylvania (2015).

⁴ ASTM International Standard A 370 – 14, *Standard Test Methods and Definitions for Mechanical Testing of Steel Products*, Annual Book of ASTM Standards, ASTM International, West Conshohocken, Pennsylvania (2014).

Portions of the fracture surfaces had flat fractures perpendicular to the surface with curving boundaries, features consistent with fatigue. Brackets in the upper image in figure 20 indicate locations with fatigue features. Unlabeled arrows indicate directions of fatigue propagation. Brackets without arrows or brackets with arrows near the end of the bracket had fatigue cracks that propagated through the thickness.

Fatigue regions were present outboard of each of the propeller attachment holes. The origins were located adjacent to the annular area associated with the attachment bolt heads, initiating at both the forward and aft sides of the bulkhead at each of the locations. The remaining fatigue regions had fracture features that generally propagated radially inboard or outboard as shown with arrows in figure 20 and were located between attachment holes that corresponded to the propeller fracture locations.

The forward bulkhead was cut between the 11 o'clock and 12 o'clock positions to facilitate a further examination of the fatigue region outboard of hole 11 and to examine the forward and aft surfaces adjacent to hole 11. An overall SEM image of the fatigue region at the outboard side of the hole is shown in figure 21. Brackets in figure 21 indicate approximate locations of fatigue origins at the forward and aft sides of the bulkhead, and a dashed line indicates the approximate boundary associated with the fatigue features emanating from each of the origin areas.

The aft surface of the forward bulkhead in the area mating to the primary fatigue origin for the propeller is shown in figure 22. A linear imprint corresponding to the propeller fracture was visible on the surface as indicated. Accumulations of oxides were present adjacent to the fracture line, and fretting contact damage was observed on the surface only to the tip side of the fracture line. Isolated shallow pits were observed inboard of the propeller fracture location.

The thickness of the forward bulkhead measured in a flat area near the inner diameter was 0.048 inch. Around each of the attachment holes, the forward bulkhead was deformed and was slightly dished with the concave side facing toward the forward direction.

A section of the forward bulkhead was cut from the 12 o'clock position to facilitate composition analysis, hardness testing, and conductivity measurement. The surface of the sectioned piece was first ground to remove surface contamination and oxidation. Using the XRF alloy tester, the metal was identified as aluminum alloy 6061. The hardness measured 99 BHN (58.4 HR30Tw),⁵ and conductivity measured 44.6% IACS.

The representative from True Flight Holdings indicated the part number 5506010-503 forward bulkhead is made of aluminum alloy 6061 heat treated to a T6 condition. An engineering drawing of the propeller assembly provided by a

⁵ Hardness conversion using ASTM International Standard E-140-12be1, *Standard Hardness Conversion Tables for Metals Relationship Among Brinell Hardness, Vickers Hardness, Rockwell Hardness, Superficial Hardness, Knoop Hardness, Scleroscope Hardness, and Leeb Hardness*, Annual Book of ASTM Standards, ASTM International, West Conshohocken, Pennsylvania (2012).

representative from McCauley Propeller Systems shows the forward doubler has a reference thickness of 0.045 inch to 0.050 inch. According to the ASM Handbook Volume 2,⁶ typical hardness and conductivity values for aluminum alloy 6061 in the T6 condition are 95 BHN and 43% IACS, respectively.

5. Propeller Flange Lugs

During removal of the attachment bolts from the propeller as described near the beginning of this report, transverse cuts were made through bolts 3 and 11 and the attached propeller flange lugs. The forward ends of the lugs were then unscrewed off the cut ends of the bolts. After the lugs were removed, black deposits with silver flakes were observed in the threads and around the inner circumference of the lugs forward of the threads. A sample of the deposits from lug 3 was placed in the SEM for EDS analysis. Results showed the black deposits had high peaks of carbon and cadmium while the silver flakes had high peaks of iron.

The black deposits from lug 3 were further examined using a Fourier Transform Infrared (FTIR) spectrometer with a diamond attenuated total reflectance (ATR) accessory in accordance to ASTM E1252-98.⁷ The spectrometer was used to collect and process infrared wavelength absorbance spectra of the sample. The spectrum for the sample contained the following combination of spectral peaks corresponding to particular functional groups found within molecular structure of the material. The presence of a low, broad peak at $\sim 3450\text{ cm}^{-1}$ was indicative of an oxygen-hydrogen bond (O-H). The presence of a strong doublet peak between $\sim 2920\text{ cm}^{-1}$ and $\sim 2850\text{ cm}^{-1}$ was indicative of a carbon-hydrogen (C-H) single stretching bond. The presence of a broad peak at $\sim 2100\text{ cm}^{-1}$ was indicative of a carbon-carbon bond and indicated the presence of elemental carbon (soot) within the sample. The presence of a single peak at $\sim 1730\text{ cm}^{-1}$ was indicative of a carbon-oxygen (C=O) double bond. The presence of a single peak at $\sim 1400\text{ cm}^{-1}$ was indicative of a carbon-double hydrogen (C-H₂) bending bond. Peaks at $\sim 1160\text{ cm}^{-1}$ and 1070 cm^{-1} were indicative of a carbon-oxygen (C-O) stretching bond. The presence of a single peak at $\sim 720\text{ cm}^{-1}$ was indicative of multiple carbon-double hydrogen (C-H₂) bending bonds. Based on peak heights and peak resolution, the sample was present in a very small amount and/or was degraded. Overall, the spectrum was consistent with a carboxylic acid. A spectral library search was performed on the obtained material spectrum, and no strong matches were identified. However, there were some similarities to the spectra of several surfactants. Carboxylic acids are used in the production of several classes of surfactants. Carboxylic acids, as well as surfactants, can be found as components or additives to lubricants, greases, and fuels. According to the McCauley Propeller Systems Owner/Operator Information Manual,⁸ the torque specifications for propeller attachment bolts on fixed pitch propellers are for bolts installed dry.

⁶ ASM Handbook Volume 2: Properties and Selection: Nonferrous Alloys and Special-Purpose Materials, ASM International, Materials Park, Ohio (1990).

⁷ American Society for Testing Materials E1252-98: Standard Practice for General Techniques for Obtaining Infrared Spectra for Qualitative Analysis, ASTM International, West Conshohocken, Pennsylvania (2013).

⁸ McCauley Propeller Systems, Wichita, Kansas (2014).

The forward end of the propeller flange lug from bolt 11 was sectioned longitudinally and was subsequently cleaned by submerging the pieces in acetone in an ultrasonic cleaner. The threads of both the propeller flange lug and the attachment bolt were found to be intact with no evidence of general deformation of the thread profiles.

6. Propeller Maintenance Instructions

The McCauley model 1A170/FFA propeller is subject to repetitive inspections in accordance with Airworthiness Directive (AD) 82-27-01. The inspections are to be accomplished at intervals of 200 hours time in service (TIS). The inspections include removal of paint from the hub area followed by dye penetrant inspection of the attachment holes, center bore, and entire hub area. The last inspection per the AD was completed on March 20, 2015 at a tachometer time of approximately 1,429.35 hours. At the time of the accident, the tachometer read 1,506.71 hours, a difference of 77.36 hours. According to the mechanic that performed the last recorded inspection, the shop does not use red dye penetrant, and inspections are performed with a fluorescent dye penetrant for higher sensitivity and easier clean-up.

The McCauley Propeller Systems Owner/Operator Information Manual refers to AD 82-27-01 and indicates the McCauley model 1A170/FFA propeller should be inspected with fluorescent dye penetrant. In Section 15: Non-Destructive Procedures of the Information Manual, the inspection procedure for fluorescent dye penetrant inspection includes a note that states in part,

The use of visible dye penetrants (Type II) is not recommended for the inspection of the propeller and propeller hardware. While Type II visible dye penetrants do have limited crack detection capability, the constituents of visible dye penetrants are likely to deposit residue in crack voids. The residue can be extremely difficult to remove from cracks, regardless of the cleaning method employed. Cracks can become fully or partially masked by the remaining residue. Due to these characteristics, visible dye penetrants can make follow-on detection of existing cracks virtually impossible when using other NDI penetrant methods, specifically Fluorescent Penetrant Inspection (FPI).

The McCauley Propeller Systems Owner/Operator Information Manual also indicates fixed pitch propellers such as the model 1A170/FFA propeller should be overhauled after 2,000 hours TIS or 72 calendar months, whichever occurs first.⁹ The overhaul process includes removal and reapplication of paint to the propeller to facilitate dimensional and FPI inspections. According to the representative from McCauley Propeller Systems, the design of the logos on the accident propeller (see figure 1) was discontinued from use at McCauley in 1998.

⁹ The time limits for overhaul listed in the owner's manual are not a requirement for airplanes such as the accident airplane operated under 14 *Code of Federal Regulations* Part 91.

7. Flight Information

Data from the accident airplane flight log is shown plotted in figure 23. According to the flight log data, the airplane accumulated 28 flight cycles and 89.9 hours TIS since the last propeller inspection per AD 82-27-01. (The accumulated TIS includes a ground run engine cycle where the engine was run for 0.2 hours 13 calendar days before flight cycle 13.) According to the data, no flight cycles were accumulated for more than 100 calendar days on several occasions, including between cycles 7 and 8, cycles 10 and 11, cycles 12 and 13, and cycles 19 and 20. The longest calendar time between cycles occurred between cycles 10 and 11, which was 17 flight cycles prior to the accident.

Matthew R. Fox, Ph.D.
Senior Materials Engineer

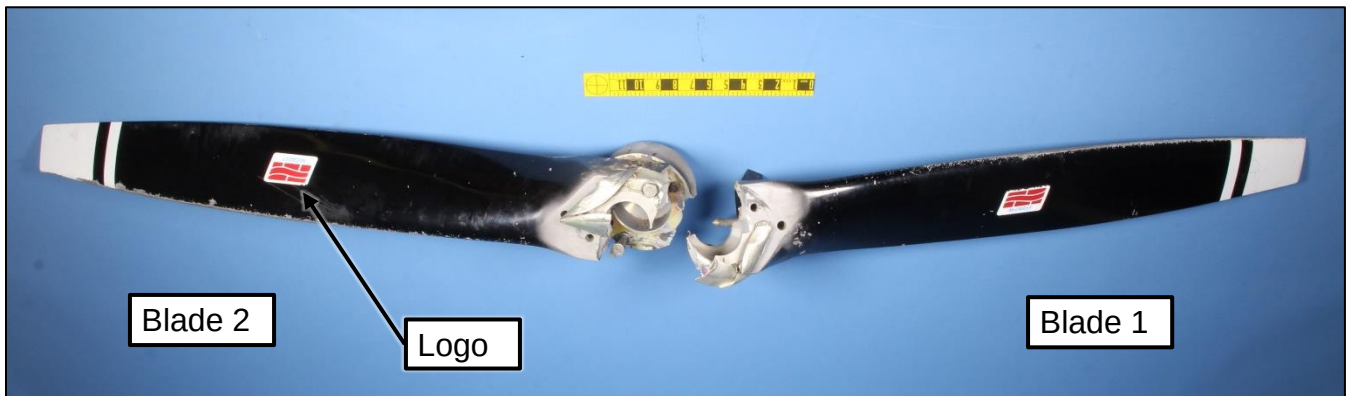


Figure 1. Overall view of the submitted components.

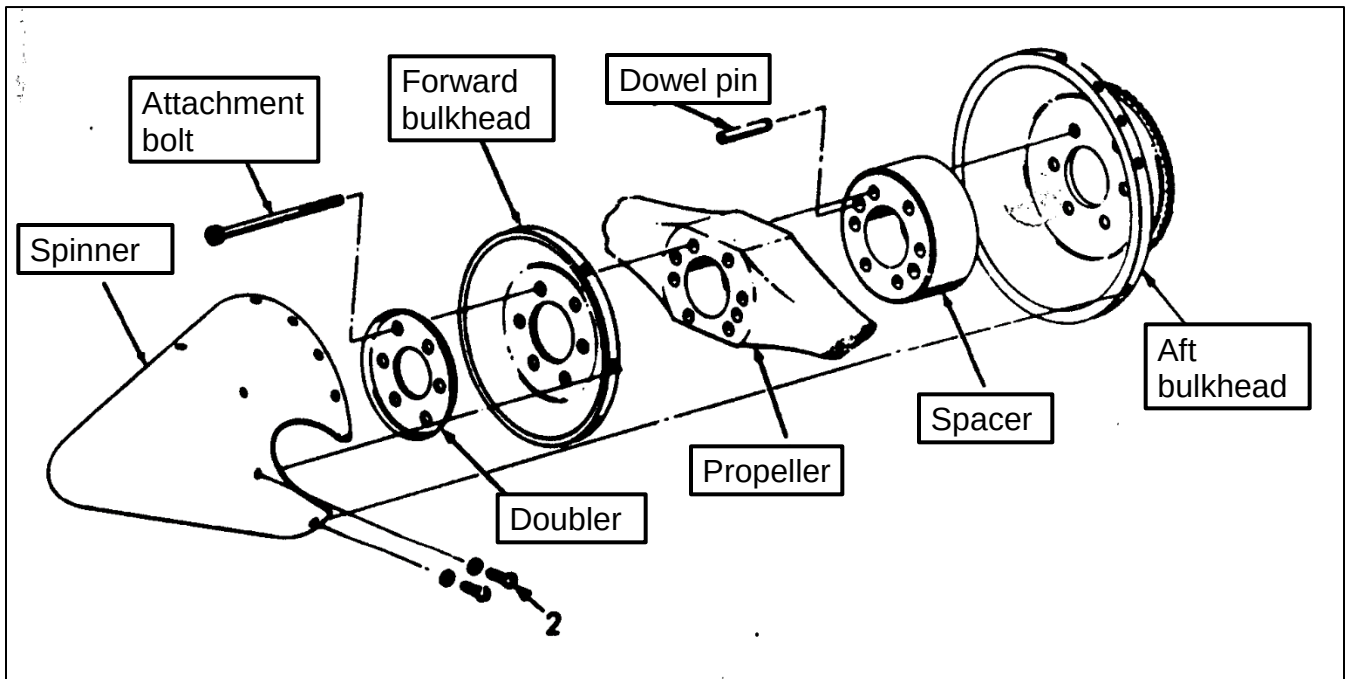


Figure 2. Propeller and spinner assemblies as depicted in the Grumman AA-5 series Illustrated Parts Catalog.

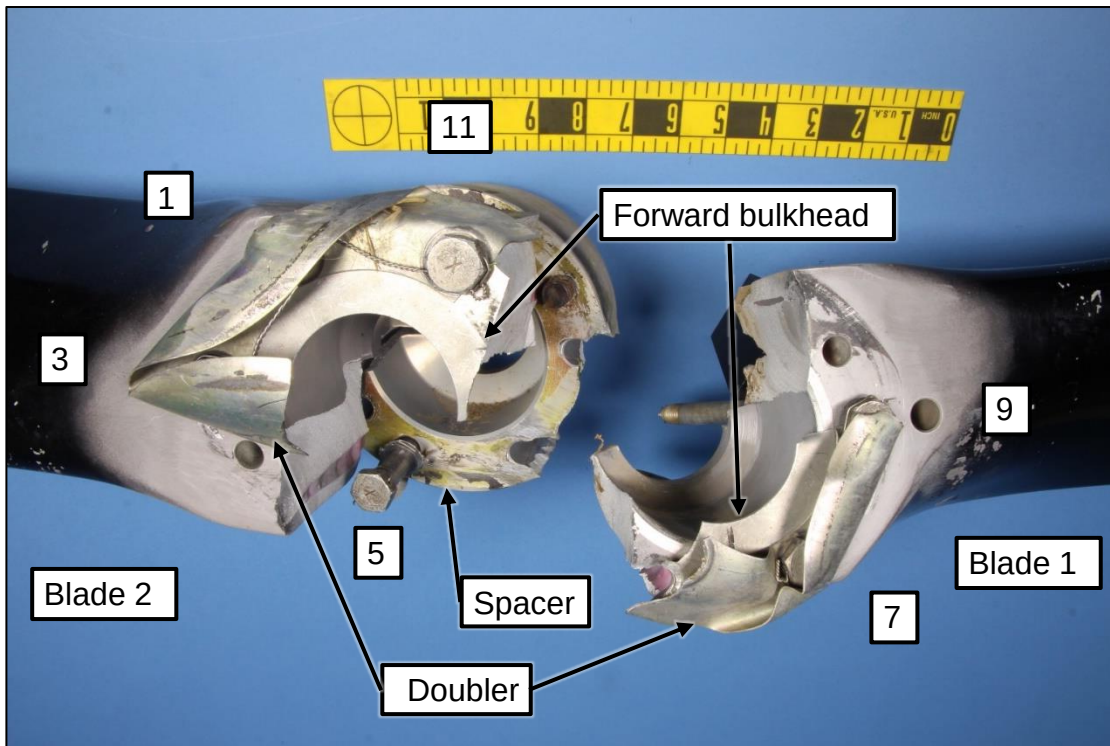


Figure 3. Closer view of the forward face of the propeller hub area.

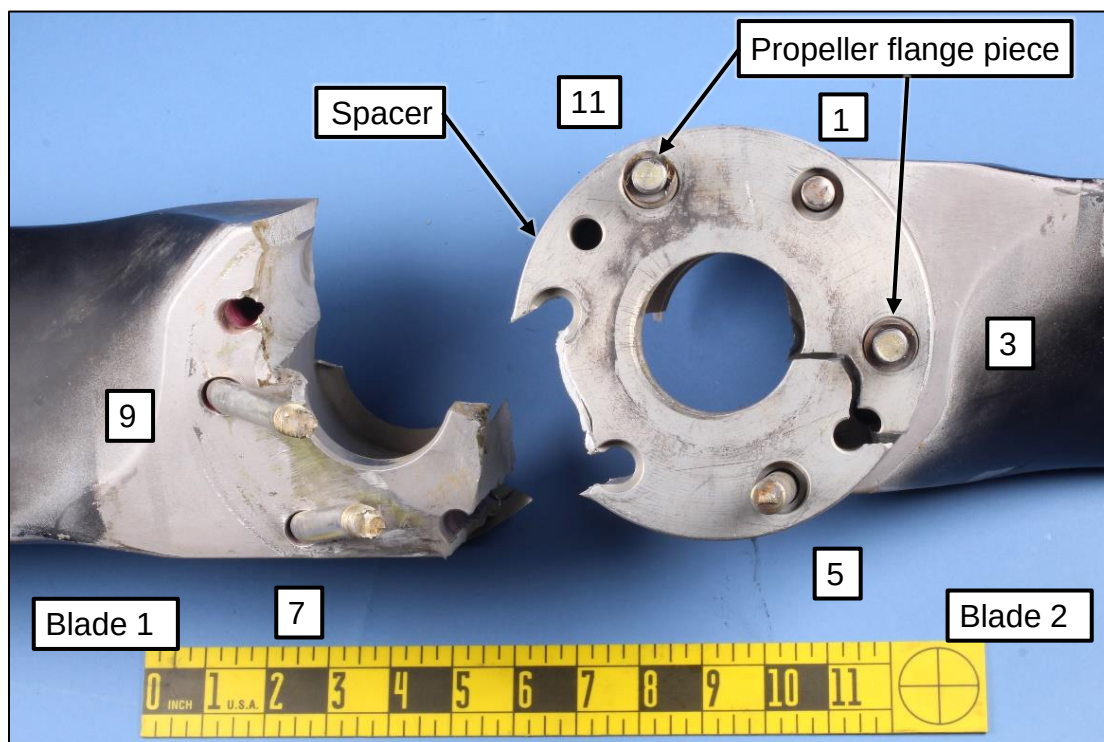


Figure 4. View of the aft faces of the propeller hub and spacer.

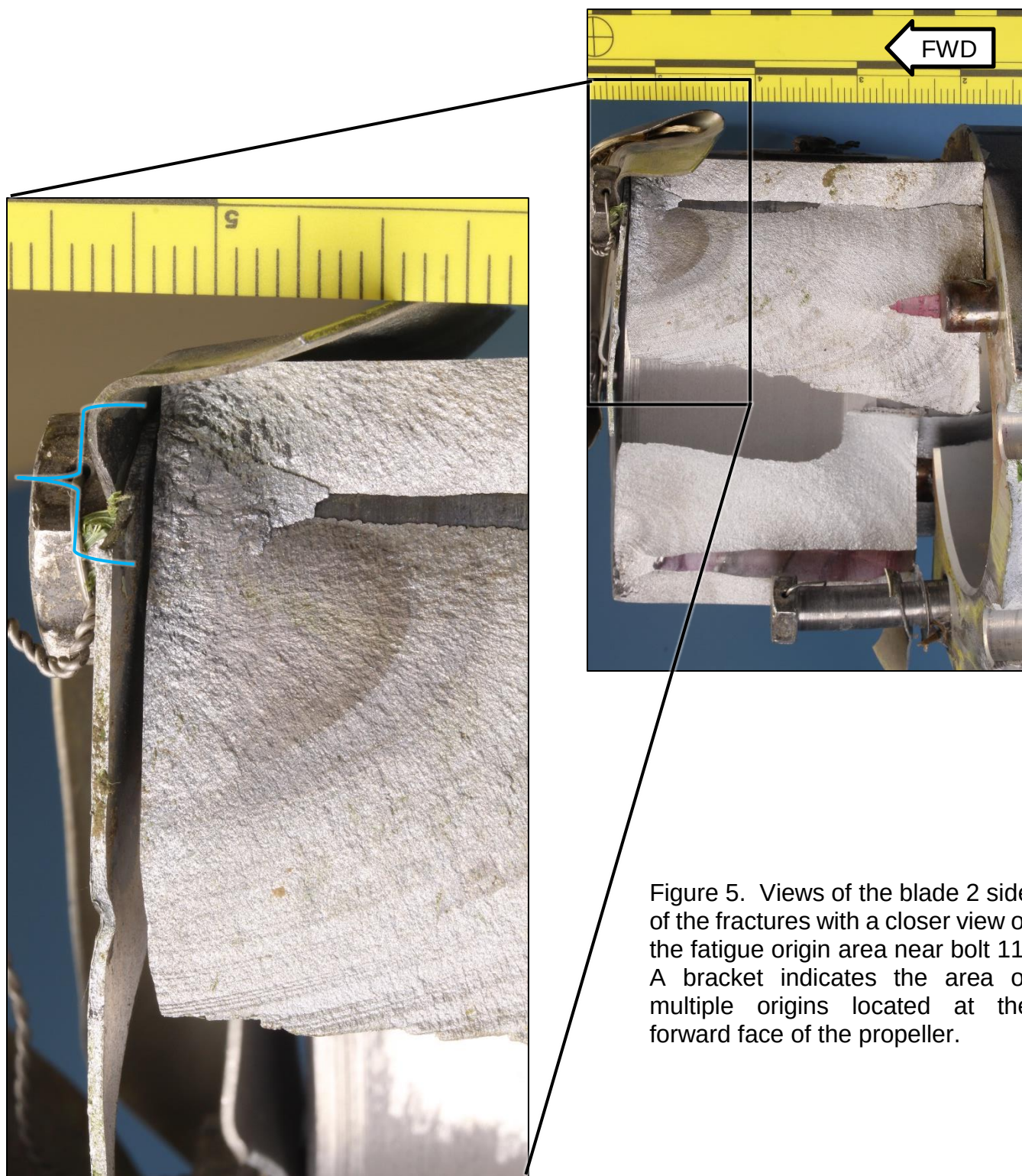


Figure 5. Views of the blade 2 side of the fractures with a closer view of the fatigue origin area near bolt 11. A bracket indicates the area of multiple origins located at the forward face of the propeller.



Figure 6. Blade 2 side of the fracture at bolt 5. A bracket indicates the area of multiple origins located at the forward face of the propeller.

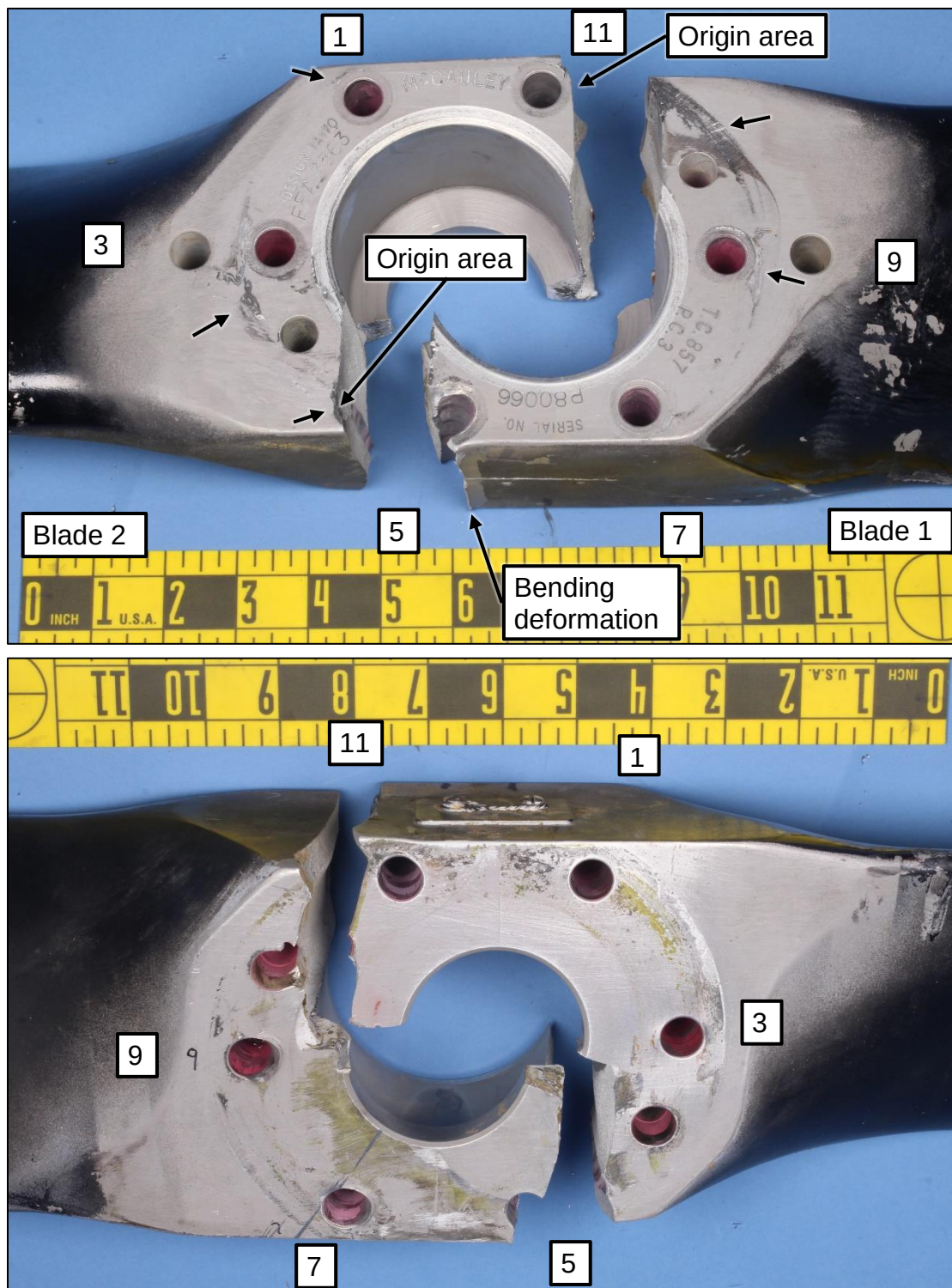


Figure 7. Overall views of the forward (upper image) and aft (lower image) faces of the propeller hub area after removing the attached components. Unlabeled arrows indicate areas of fretting contact damage. Note pink and red deposits in the holes.

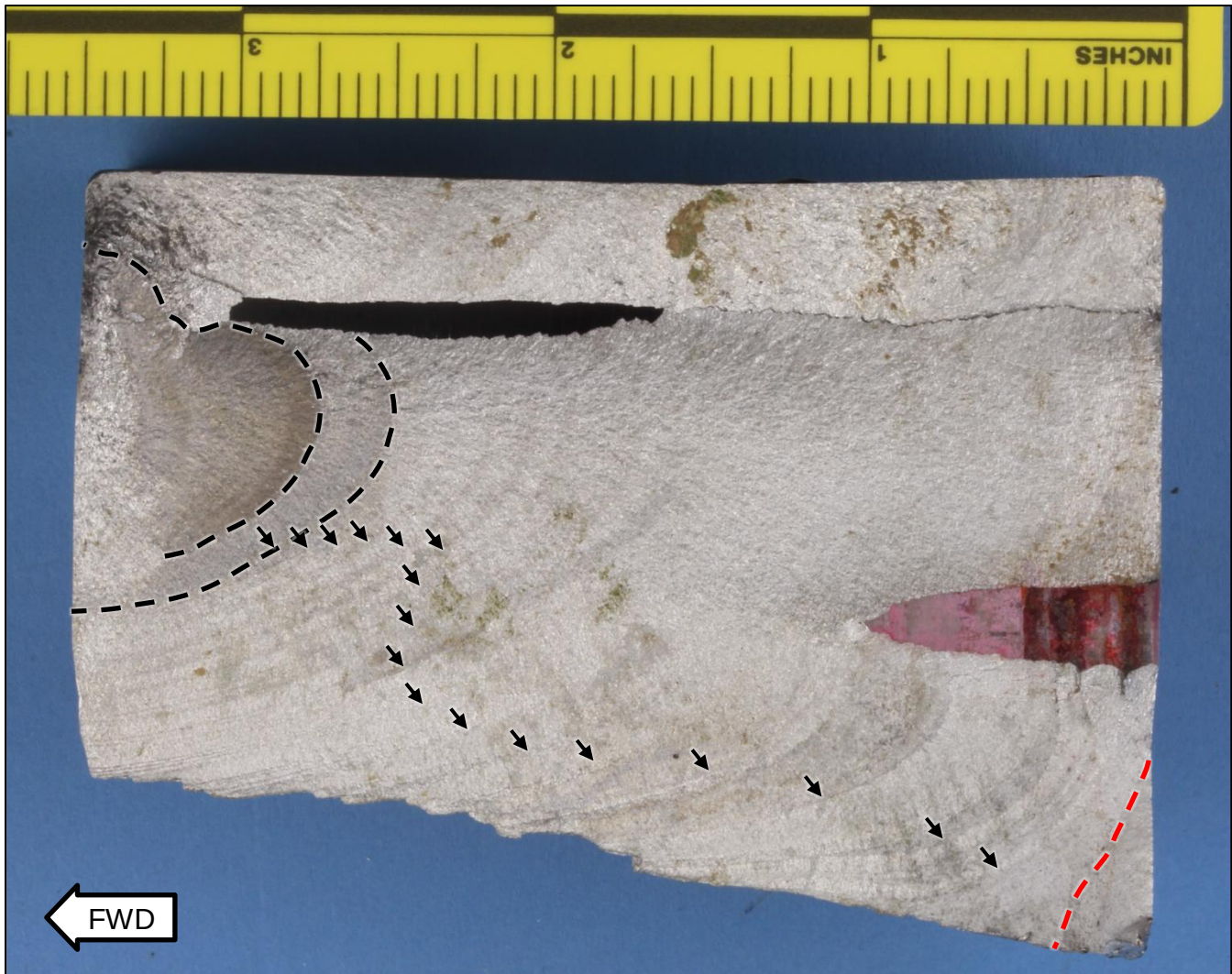


Figure 8. Overall view of the blade 2 side of the fracture near bolt hole 11 after disassembly and sectioning from the rest of the propeller. Black dashed lines indicate boundaries associated with surface oxidation near the origin area, and a red dashed line indicates the fatigue boundary. Arrows indicate 17 crack arrest lines identified on the fracture surface between the outermost oxidized region and the fatigue boundary.

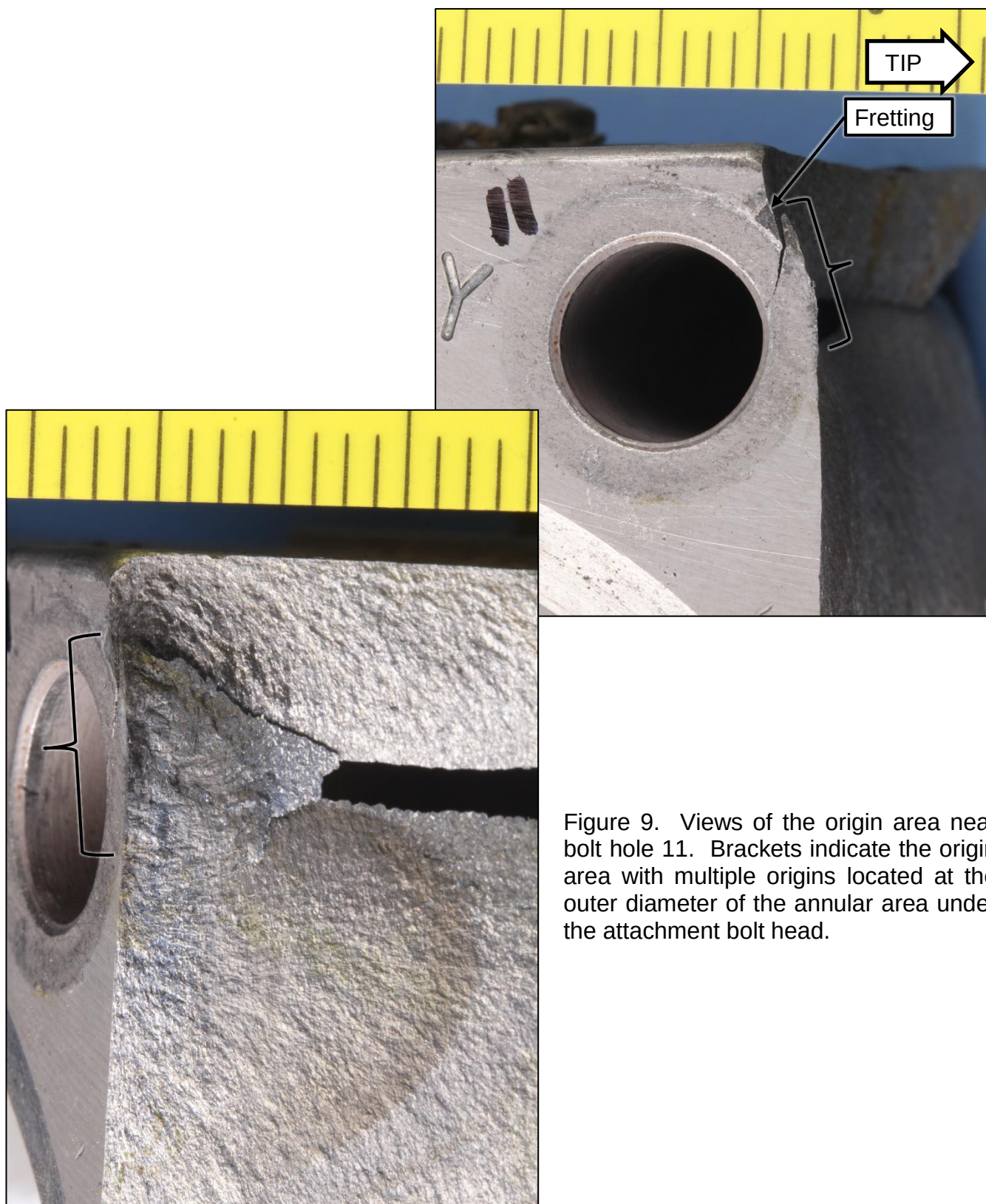


Figure 9. Views of the origin area near bolt hole 11. Brackets indicate the origin area with multiple origins located at the outer diameter of the annular area under the attachment bolt head.

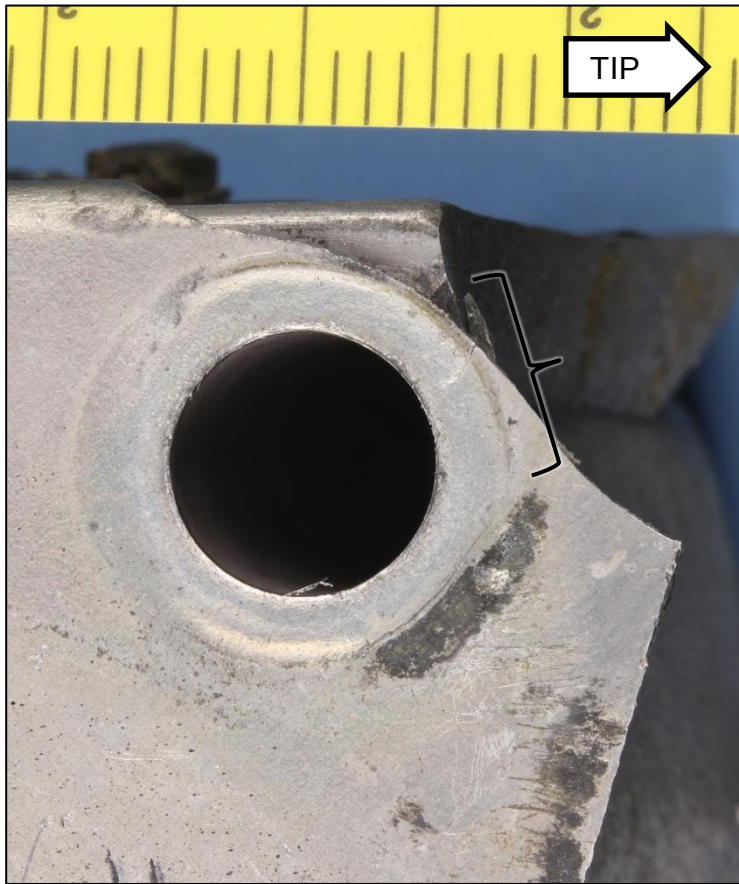


Figure 10. View of the origin area near bolt hole 11 with the forward bulkhead in position. The bracket indicates the location of the underlying origin area on the propeller.

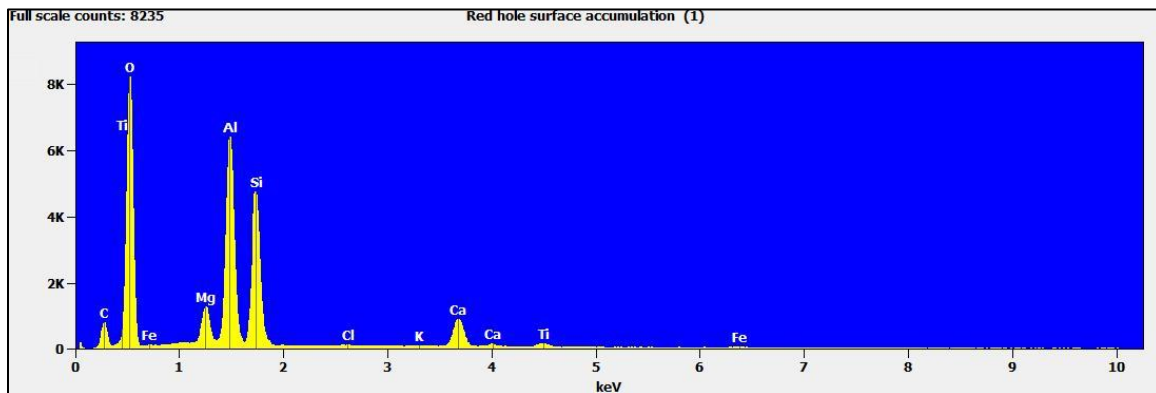


Figure 11. EDS spectrum of an accumulation of deposits (appearing pink or red in optical images) in the dowel hole near the aft end of the fracture shown in figure 8.

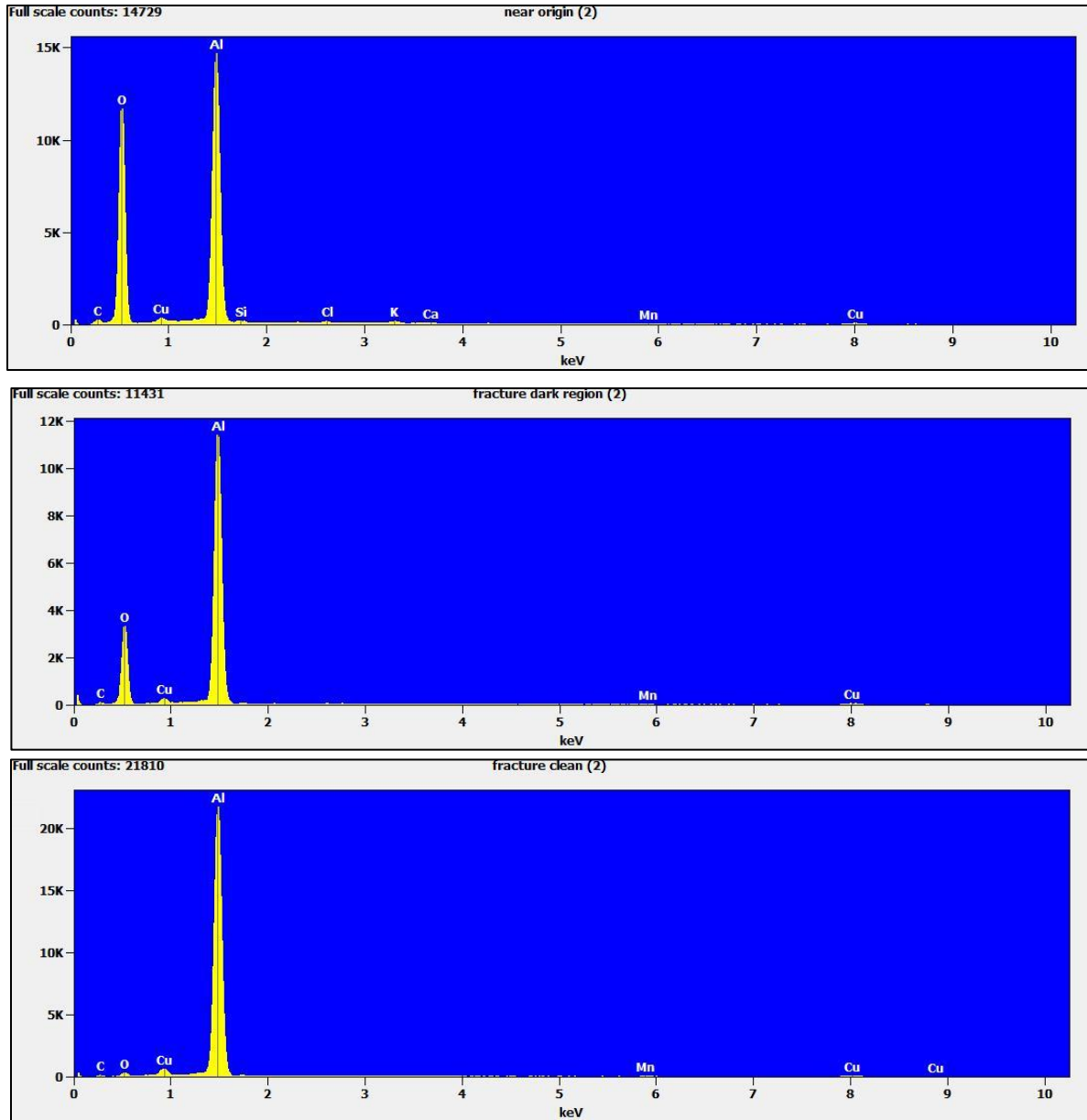


Figure 12. EDS spectra of areas of the fracture surface near the fatigue origin (upper spectrum), in the oxidized region near the boundary of the oxidized region (middle spectrum), and in an area outside of the oxidized region relatively free of surface deposits (lower spectrum). See figure 13 for an SEM image of the oxidized region boundary.

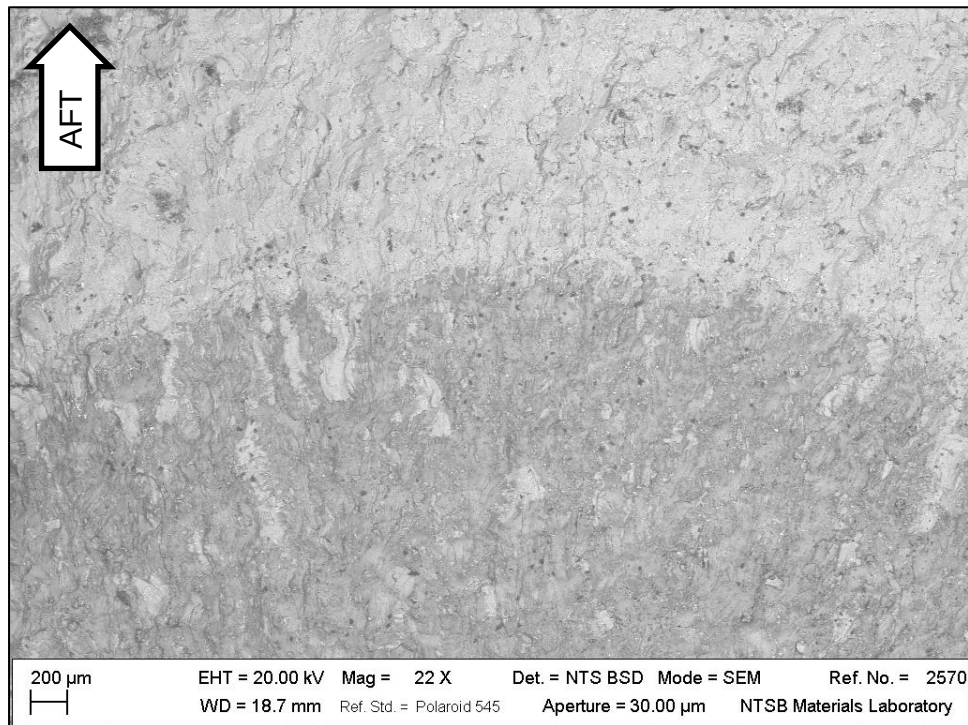


Figure 13. SEM image using a backscatter detector showing the boundary of the oxidized region. The oxidized region appears darker due to the presence of oxygen, which has an atomic weight lower than that of aluminum.

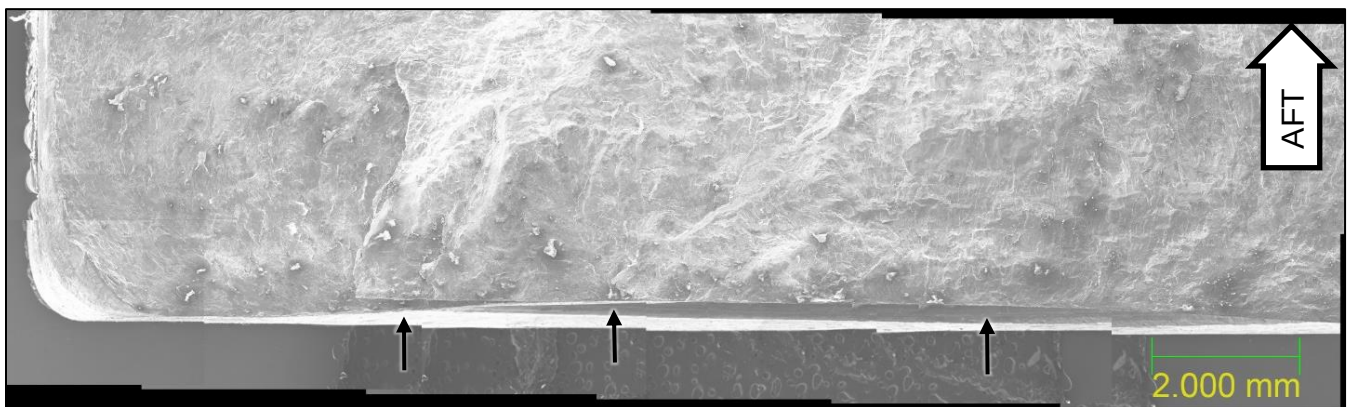


Figure 14. SEM image of the origin area at hole 11 after cleaning with solvent. Arrows indicate locations of fatigue origins. stitched together into one image. The image was created from individual SEM images that were stitched together.

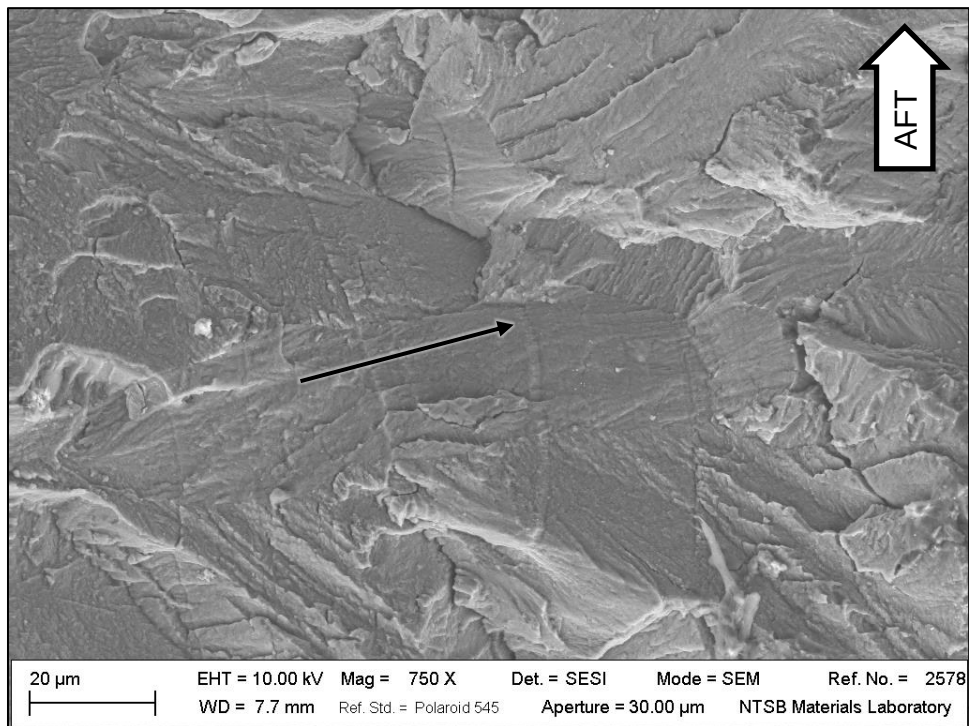
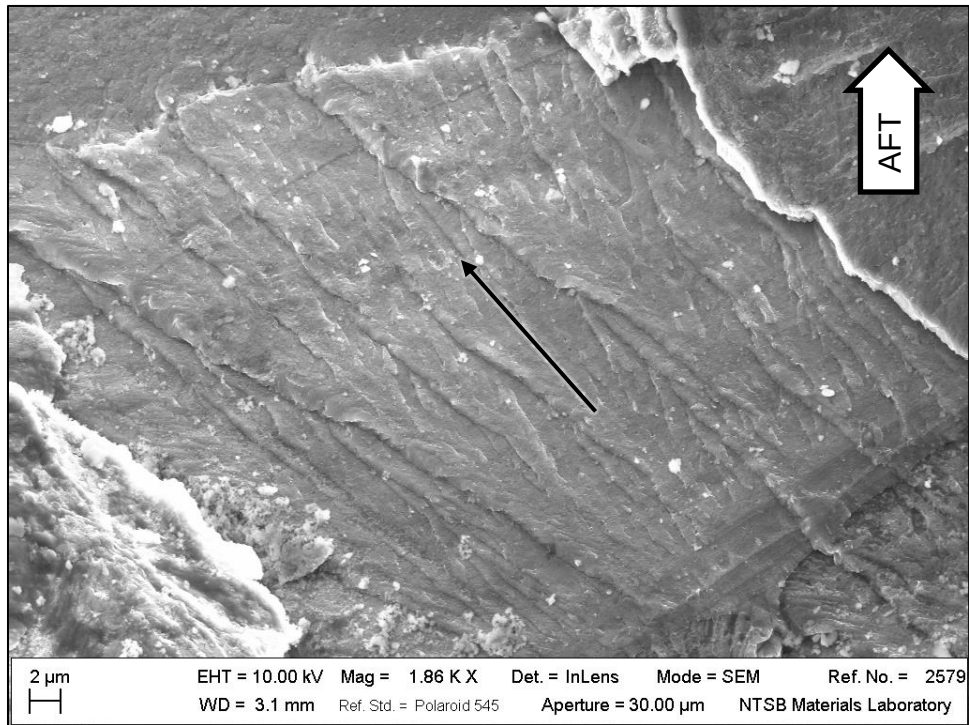


Figure 15. SEM images of typical fatigue fracture features near the origin (upper image) and at a location outside the oxidized region (lower image). Arrows indicate crack propagation directions.

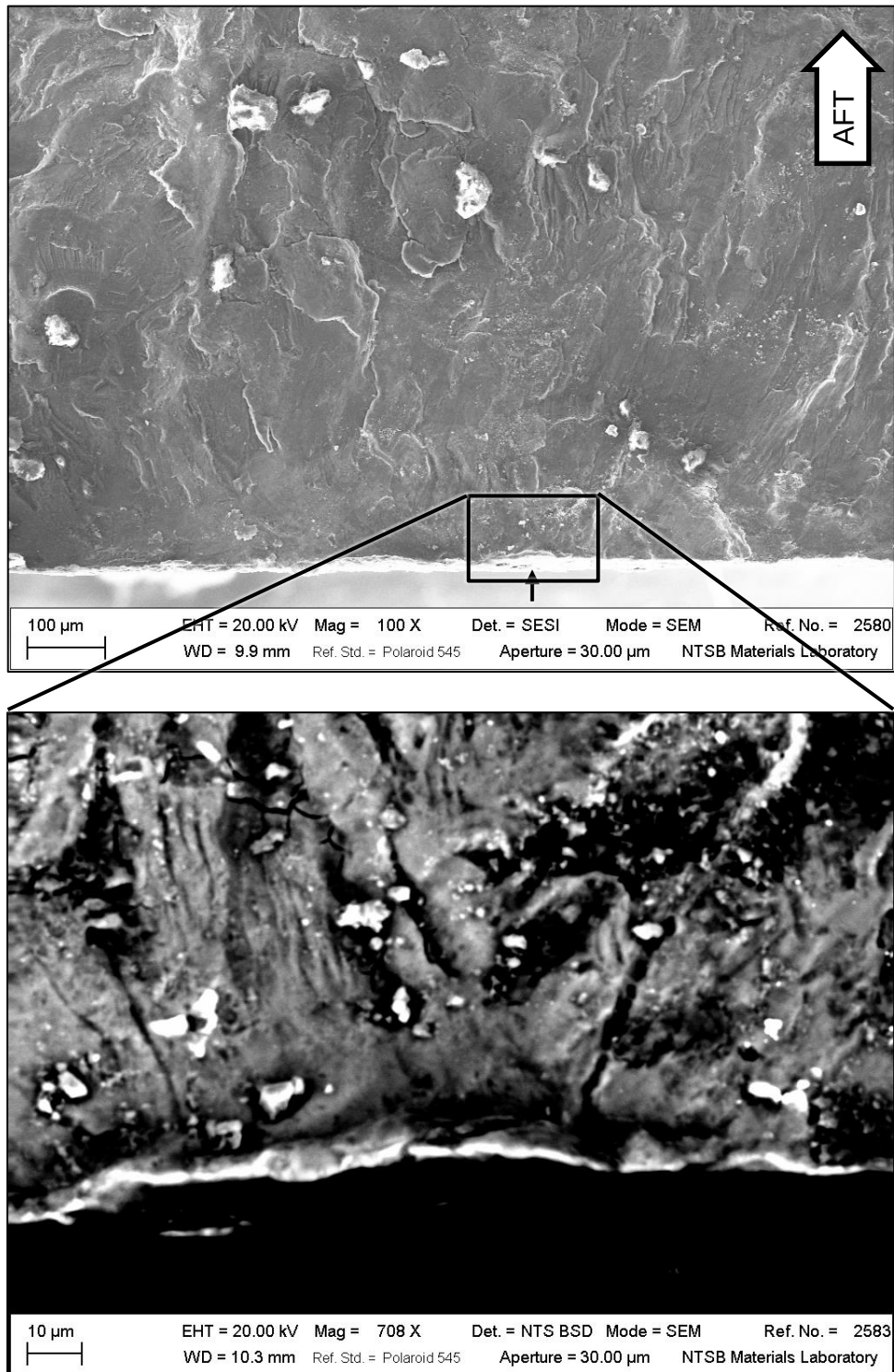


Figure 16. SEM images of the origin area. The upper image shows the area as viewed using the secondary electron detector, and the lower image shows a closer view of the origin using a backscattered electron detector.

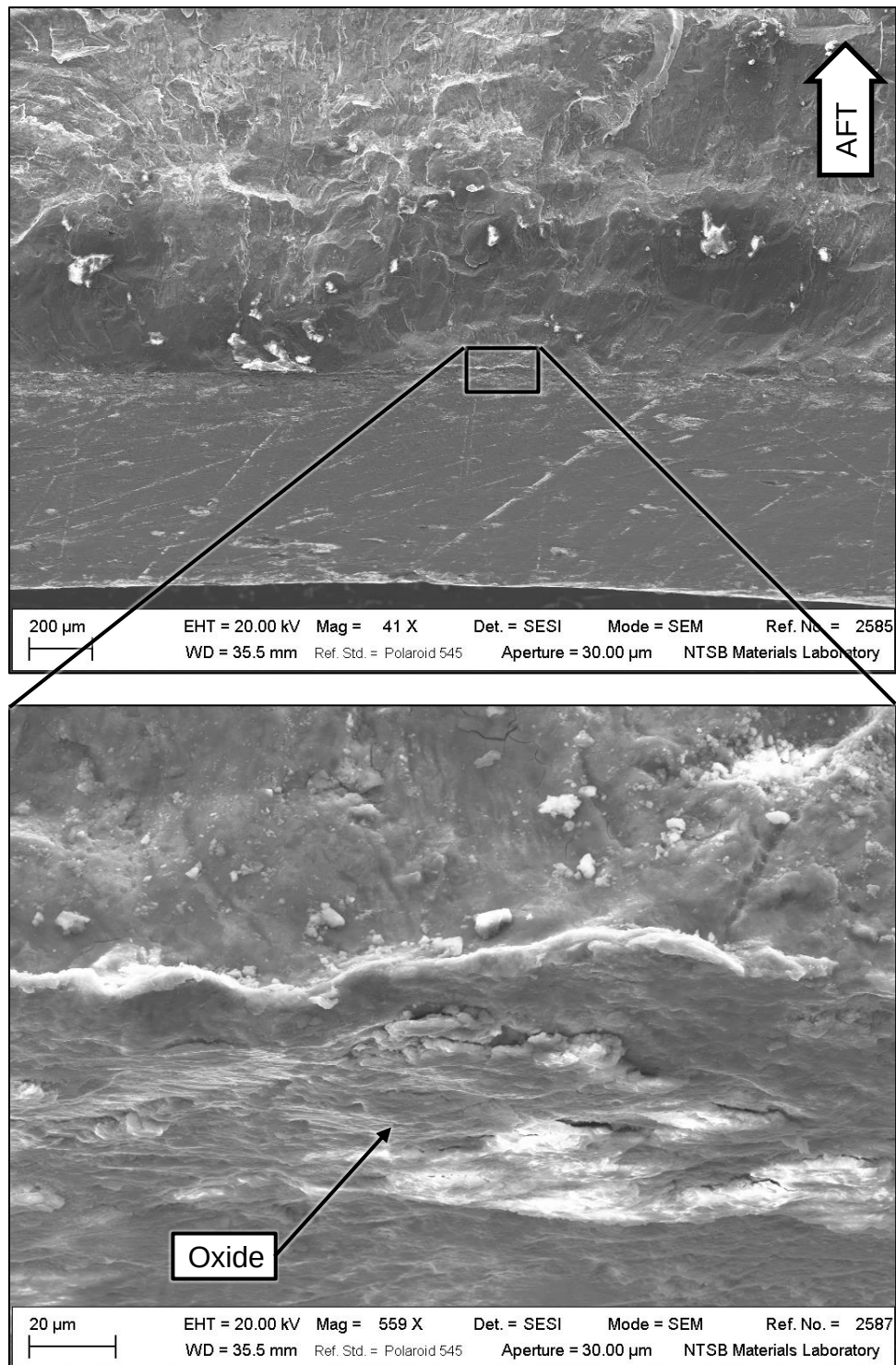


Figure 17. SEM images of the origin area at an oblique angle showing both the fracture surface and the adjacent forward face of the propeller.

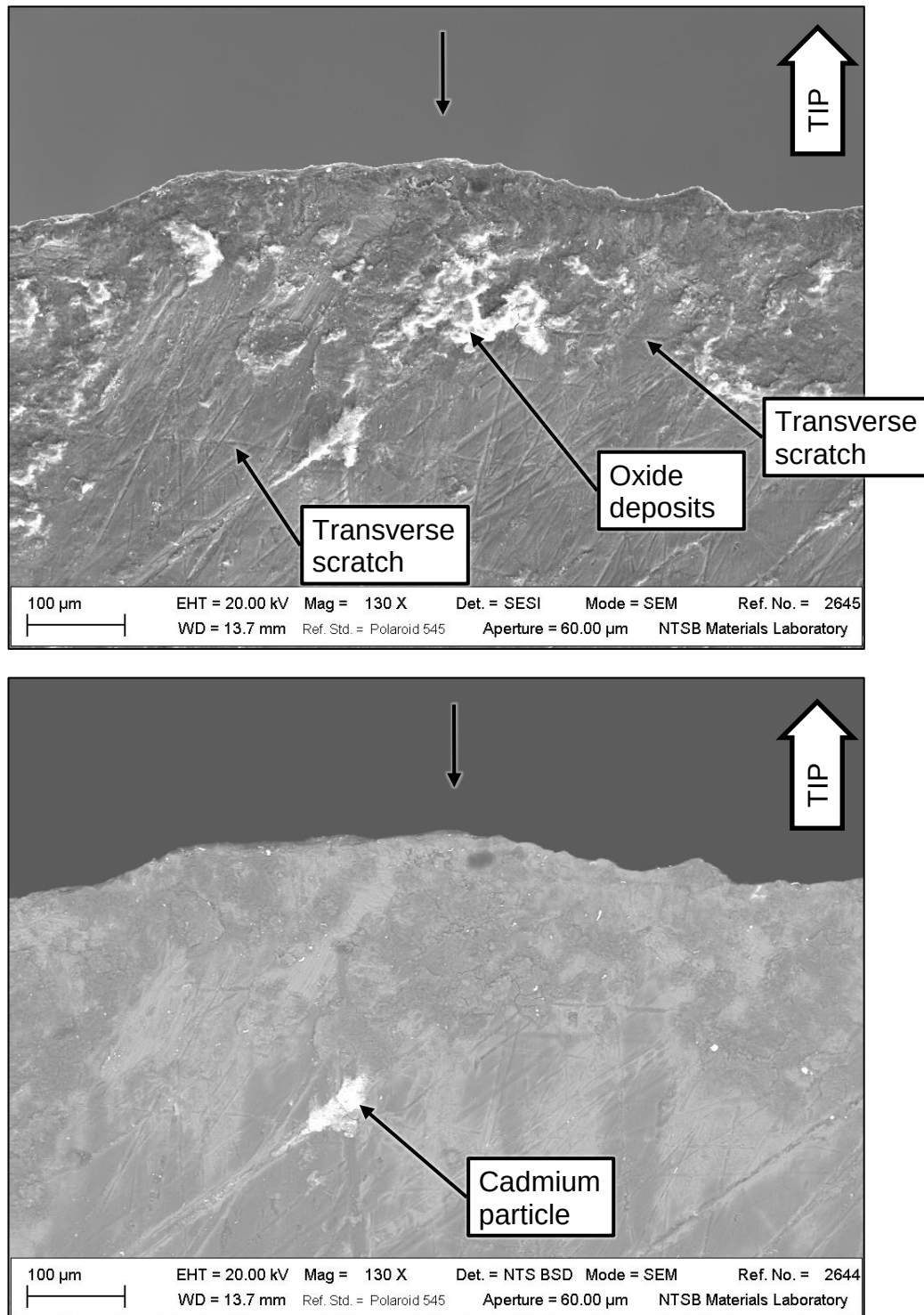


Figure 18. Forward face of the propeller adjacent to the fatigue origin as viewed in an SEM using the secondary electron detector (upper image) and the backscatter detector (lower image). An arrow in each image indicates the origin location.

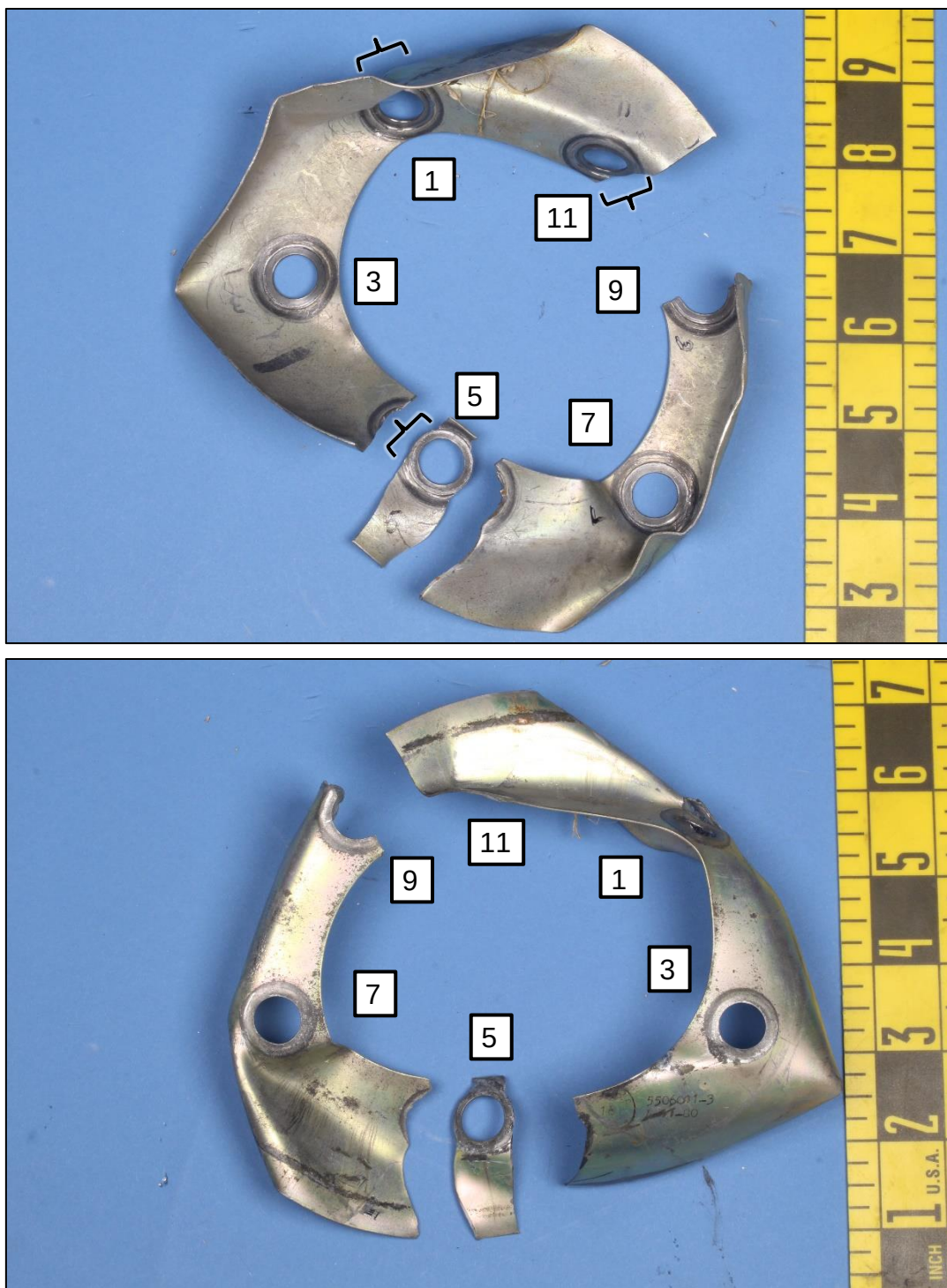


Figure 19. Forward (upper image) and aft (lower image) faces of the doubler. Brackets in the upper image indicate locations with fatigue features.

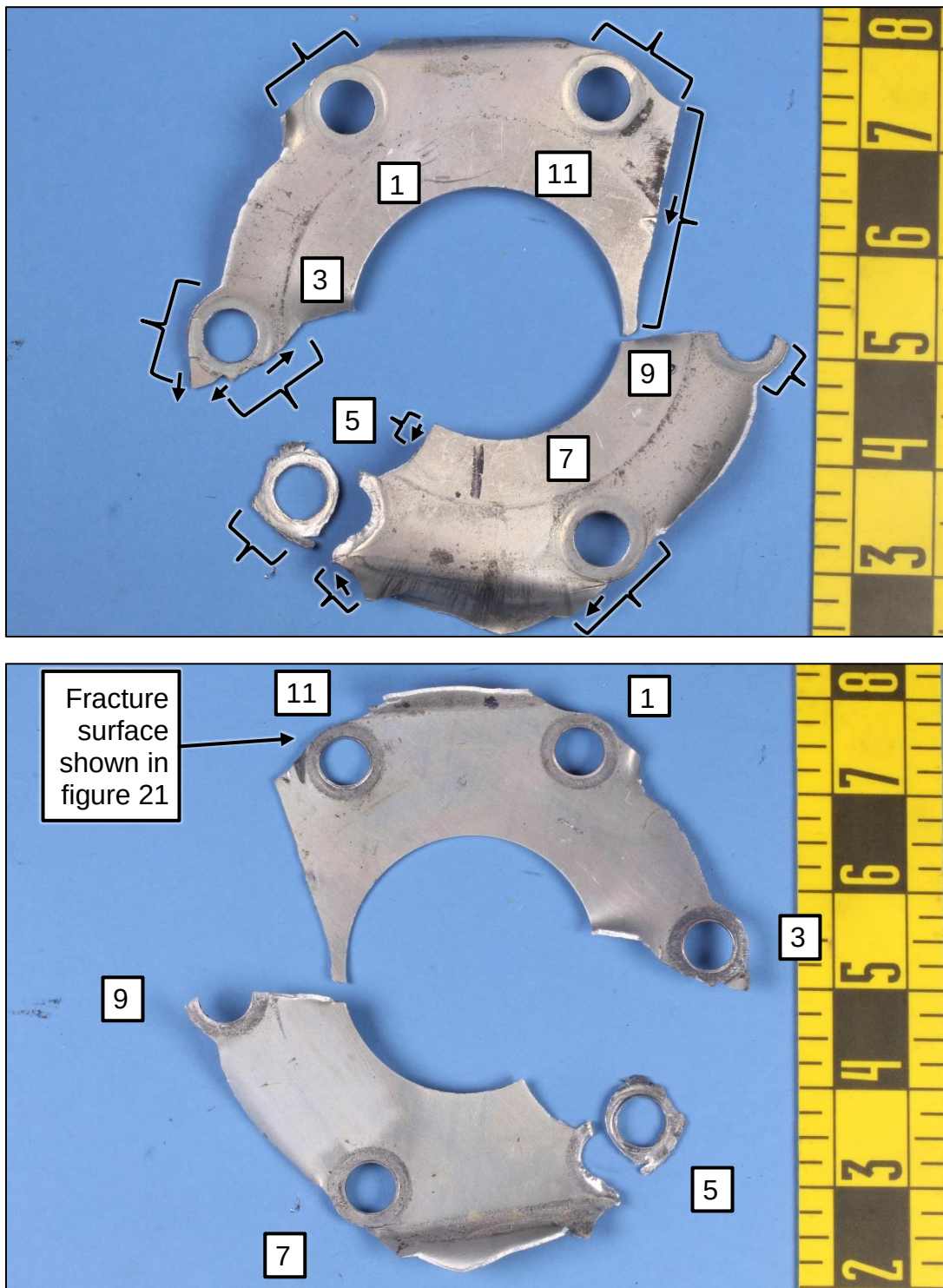


Figure 20. Forward (upper image) and aft (lower image) faces of the forward bulkhead. Brackets in the upper image indicate areas of fatigue fracture, and arrows indicate directions of crack propagation.

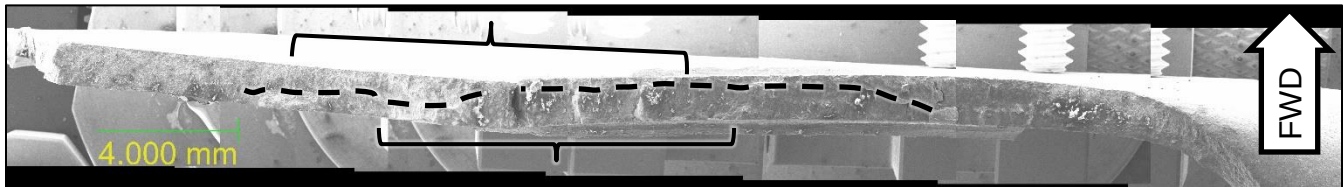


Figure 21. Fracture surface through the forward bulkhead at the outboard edge of the hole 11 annular area under the attachment bolt head (location indicated in figure 20). The image is a series of SEM images stitched together to produce a single image. Brackets indicate fatigue origin areas at the forward and aft sides of the fracture, and a dashed line indicates the boundary associated with fatigue features emanating from each origin area.

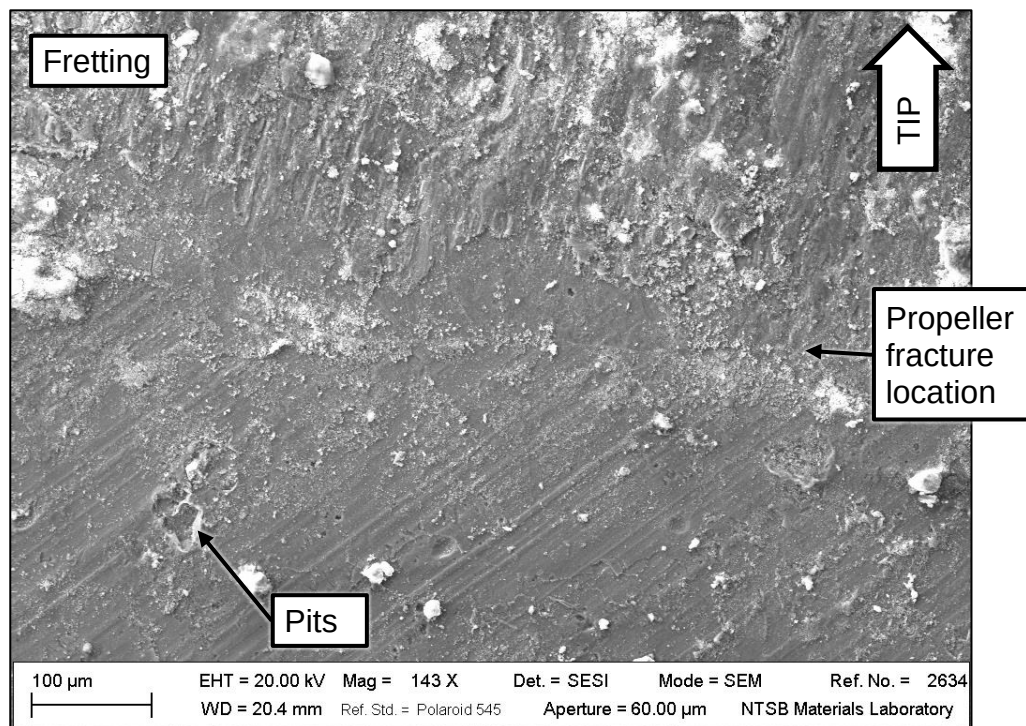


Figure 22. SEM image of the aft surface of the forward bulkhead near the fatigue origin. Accumulations of oxides are present at the fracture location. Fretting damage is present on the surface outboard (toward the blade tip) of the fracture.

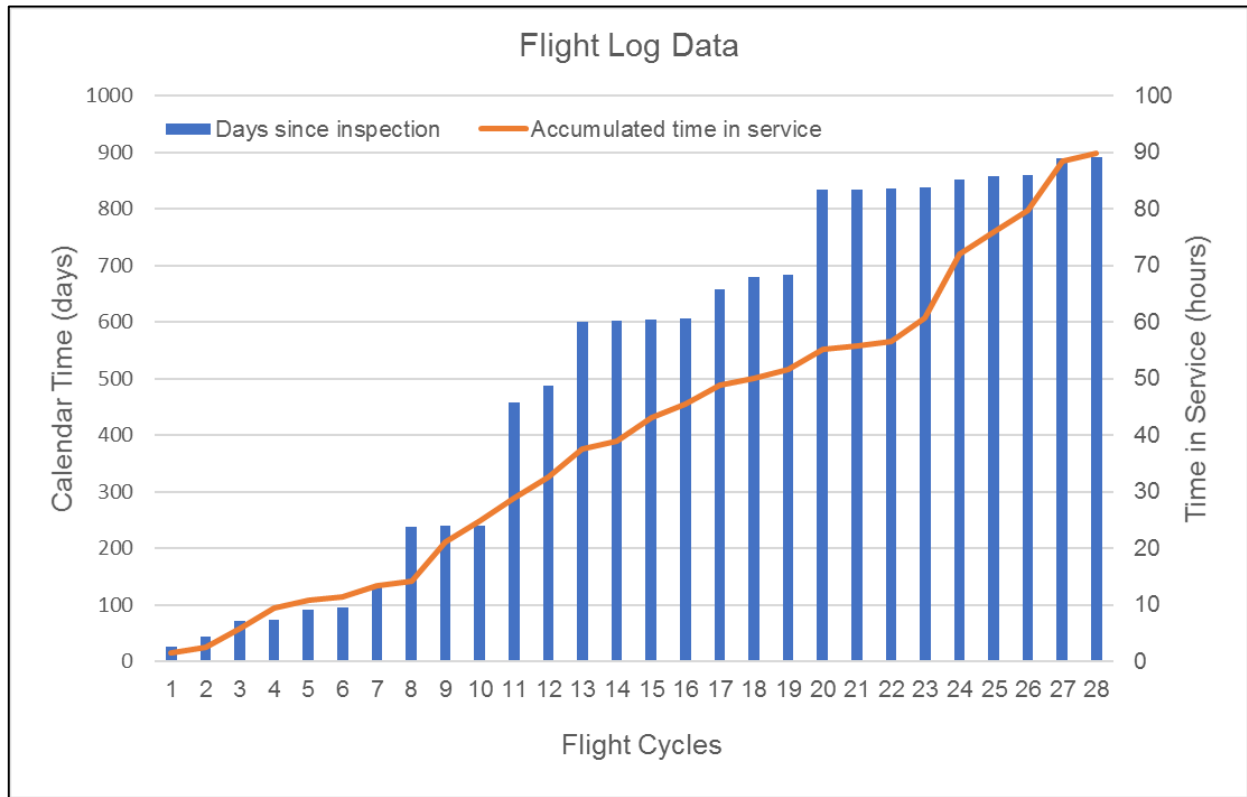


Figure 23. Accumulated calendar days, flight cycles, and powerplant TIS since the last propeller inspection per AD 82-27-01 as reported in the flight log for the accident airplane. The accumulated TIS includes a ground run engine cycle where the engine was run for 0.2 hours 13 calendar days before flight cycle 13.