

NATIONAL TRANSPORTATION SAFETY BOARD

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



June 15, 2020

MATERIALS LABORATORY FACTUAL REPORT

Report No. 20-015

A. ACCIDENT INFORMATION

Place : Melba, Idaho
Date : May 19, 2019
Vehicle : Beech C35, N1888D
NTSB No. : WPR19FA150
Investigator : Thomas Little, ASI-WPR

B. COMPONENTS EXAMINED

Beech Aircraft Series 215 propeller assembly with one attached blade and one separated blade.

C. DETAILS OF THE EXAMINATION

A Beech Aircraft Series 215 propeller assembly with one blade attached to the hub and one blade separated from the hub was submitted to the NTSB Materials Laboratory for examination as shown in figure 1a. An image of the hub portion of the assembly is shown in figure 1b. The propeller blades are attached to the hub by means of externally threaded blade retention nuts (figure 1a). The blade retention nuts mate with internal threads on either side of the hub. Thrust bearings (discussed below) are captured between a flange at the shank-end of the blade and the end face of the nut. In its as-manufactured condition, four lugs are brazed onto the outer surface of the hub. One of the lugs is indicated in figure 1b and the four lug positions are shown in figures 2a and 2b. The lugs serve as attachment points for two spinner attachment plates (figure 1b), one on either side of the hub, and four blade retention nut clips (figures 3a – d).

The propeller blades were both deformed, as shown in figure 1a. The separated blade exhibited an aft bend and clockwise twist of the blade tip so that the leading edge at the blade tip was rotated toward the aft direction, as shown in figure 1c. The retained blade also exhibited a clockwise twist mid span, but the tip was bent forward, as seen in figure 1a.

The as-received hub was missing one of the lugs as indicated in figure 1b, 2a, and 3b. The spinner attachment plate on the same side of the hub was also missing. The blade retention clips, in the as-manufactured condition, are attached to the end faces of the lugs with a bolt and lockwire and have teeth along one of their edges that interlock with mating teeth around the outer circumference of the blade retention nuts, as shown in figures 3c and 3d. With the clips installed in this manner, the blade retention nut would

be locked in place and would not rotate out of the hub. The retention clips were present on the three remaining lugs, however one of the clips, on the side of the hub with the separated blade, was bent (figure 3a), with the forward portion of the clip bent outward and aft.

The attachment pad for the missing lug is shown in figure 4a. There was a bronze-colored brazing material around the perimeter of the pad of unknown composition, while the interior was a dark brown/black color, typical of an iron oxide. The composition of the brazing material was examined using a scanning electron microscope (SEM) equipped with an energy dispersive x-ray spectrometer (EDS). In order to fit the pad in the SEM, the hub was first disassembled and an abrasive cutting saw was then used to cut a piece of material from the hub that contained the attachment pad as well as one of the intact lugs from the side of the hub that retained its propeller blade (figure 5a and 5b). The strip was then sectioned into smaller pieces using the same method and the intact lug was further cut so that its brazed joint could be viewed in cross section (figure 5c). The EDS spectrum from the brazing pad with the missing lug is shown in figure 4b. The spectrum exhibited primarily silver (Ag), cadmium (Cd), copper (Cu), and zinc (Zn), consistent with cadmium-containing silver brazing alloy. The EDS spectrum from the intact lug's brazed joint is shown in figure 5d. The spectrum exhibited primarily copper (Cu), which was consistent with the material and process used by the original manufacturer to braze the lugs to the hub.

The thrust bearing at the root of the propeller blade was examined for any notable features. The blade/bearing assembly is shown in figure 6a. The shank end of the blade has a support flange which backs the lower race. The blade retention nut serves as a support for the upper race. Thirty-one ball bearings are captured between the lower and upper races. During the original manufacture of the blade, the shank and blade are separate pieces. The races and blade retention nut are assembled over the shank and the blade is then joined to the shank. To examine the races and the blade retention nut, the blade was therefore cut from the shank using a band saw. The nut could then be examined separately as shown in figure 6b. For convenience, the circumference of the nut was labelled with clock positions with 12 o'clock starting at an existing black marking on the nut and the clock positions assigned as if viewing from the root of the blade toward the tip.

An examination of the lower race did not reveal any notable features. However, visual examination of the upper race revealed a crack located at a notch incorporated into the backside of the race located between the 7 o'clock and 8 o'clock positions, as indicated in figures 7a and 7b. The notches are intended to facilitate removal and replacement of the races if necessary. To examine the fracture surfaces, the race was sectioned using an abrasive cutting saw. One of the fracture faces is shown in figure 8a. The fracture surface exhibited a rough appearance with some apparent rubbing damage. A curvilinear crack progression mark was consistent with the crack starting at the center of the notch. The fracture surface was examined using a SEM (not shown) and the fracture surface exhibited dimple features that were consistent with an overstress fracture.

The ball bearings, shown in figure 8b, were covered in a black paste, consistent with a combination grease and dirt. The bearings and raceways were cleaned using solvents in a sonicating bath and examined visually. The surfaces exhibited superficial pitting, discoloration, and/or material transfer but no notable flats, gouges, brinelling marks, etc. were present.

Finally, the male threads on the blade retention nuts and the female threads on the hub were examined for any notable features. The nut from the separated blade exhibited non-uniform wear of the threads around the circumference of the nut, as shown in figures 9a – d, while the female threads on the hub exhibited little to no wear (not shown).

The depth of damage and wear of the threads was measured by using a silicone rubber molding material. The molding material was cast over the threads and allowed to cure. The cured pieces of rubber were lifted from the threads and cross-sectioned with a razor blade. The cross sections were then imaged on a digital optical microscope. The male threads on the blade retention nut were sampled at the 12, 3, 6, and 9 o'clock positions. The female threads on the hub were also sampled at 90° intervals: the forward position, aft position, and two locations 90° in between these two locations. One of these locations was near the disbonded lug and the other was near the intact lug.

For comparison, sample molds from the side of the hub with the retained blade were also taken and are shown in figures 10a and 10b. For the side with the retained blade, the thread depth on the blade retention nut measured 0.039 inch to 0.040 inch. Similarly, the thread depth on the hub female threads measured 0.038 inch to 0.040 inch.

The molds from the separated blade's blade retention nut are shown in figures 11a – d for the 12, 3, 6, and 9 o'clock positions, respectively. The first engagement thread (the first thread to gain purchase as the male and female threads engage) is labeled in each image. For the 12 and 3 o'clock positions, the thread cross-sections exhibited little to no wear at the first engagement thread and greater thread wear at greater depths. For the 12 o'clock position the thread depth started at 0.038 inch and decreased to 0.015 inch. Similarly, for the 3 o'clock position, the thread depth started at 0.037 inch and decreased to 0.015 inch. In contrast, the 6 o'clock position exhibited the greatest thread wear at the first engagement thread. The thread depth started at 0.023 inch at the first engagement thread and increased to 0.041 inch at the greatest depth. The 9 o'clock position exhibited wear at both ends of the cross-section. At the first engagement thread, the depth measured 0.032 inch. It increased to 0.039 inch before decreasing again to 0.027 inch.

The sample molds from the hub are shown in figures 12a – d for the disbonded lug position, the aft position, the intact lug position, and the forward position, respectively. Cross section depth measurement ranged from 0.038 inch to 0.044 inch across all four locations, compared to the 0.039-inch to 0.040-inch thread depth range measured on the opposite side of the hub as reported above.

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Sr. Materials Engineer

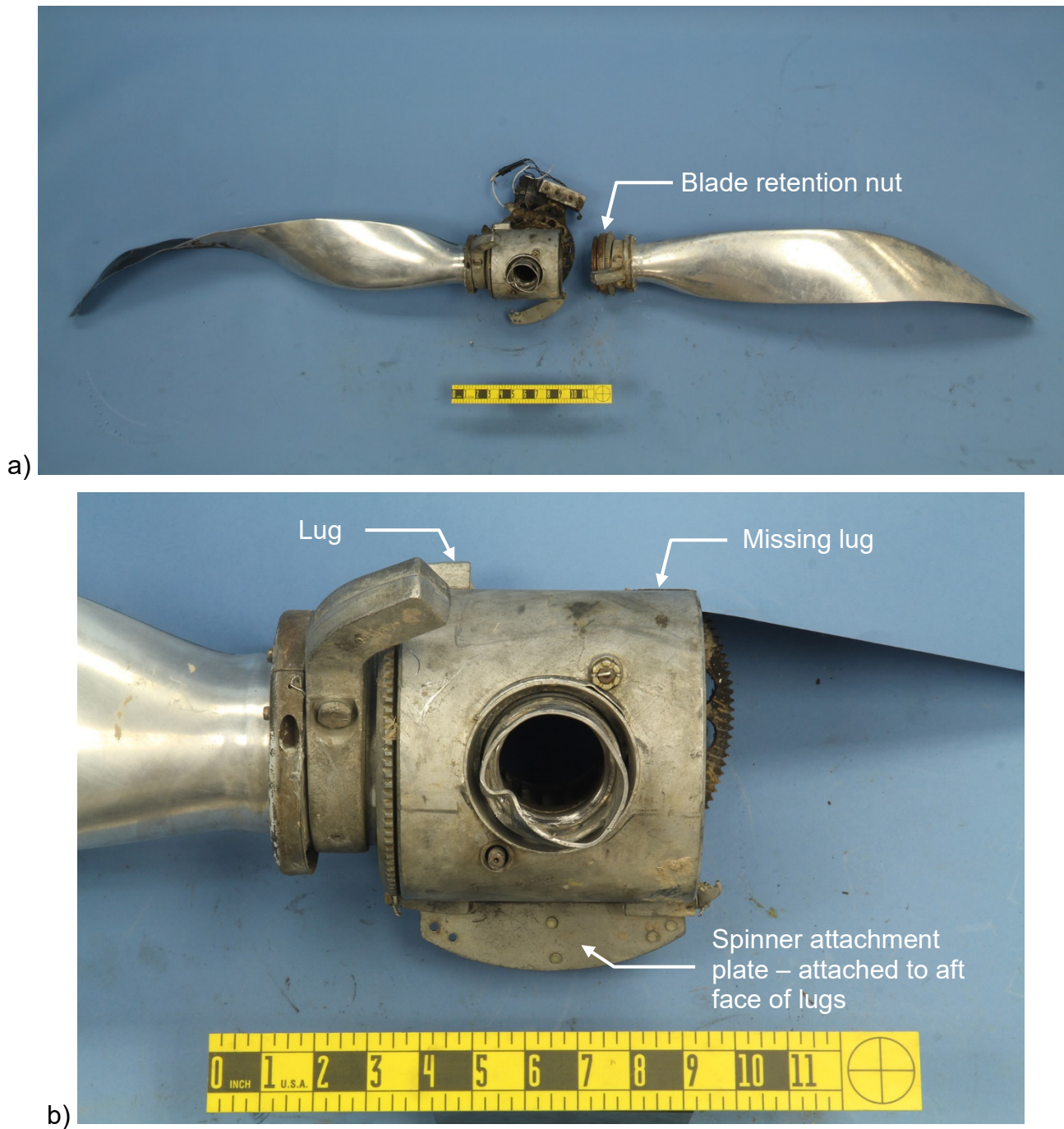
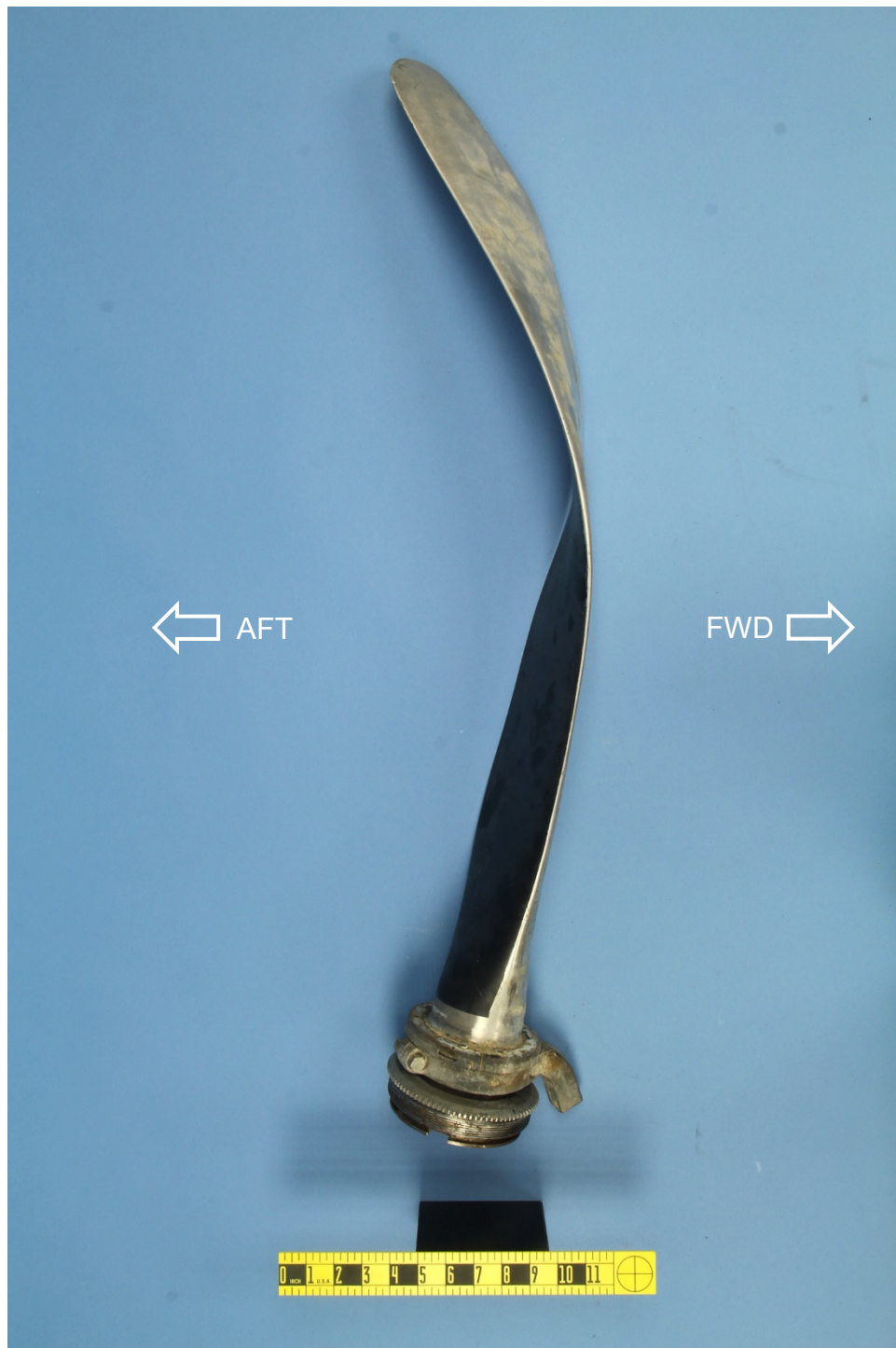


Figure 1: a) Overview image of the propeller hub assembly with one attached propeller blade, to the left of the hub in the image, and one separated propeller blade, set on the right side of the hub in the image and b) closer view of the hub with a missing lug in the upper right side of the image.



c)
Figure 1 (cont.): c) the separated blade viewed from the leading edge-side showing an aft bend and twist of the blade tip.



Figure 2: a) and b) Two images on opposite sides of the hub showing top-down views of the lugs.

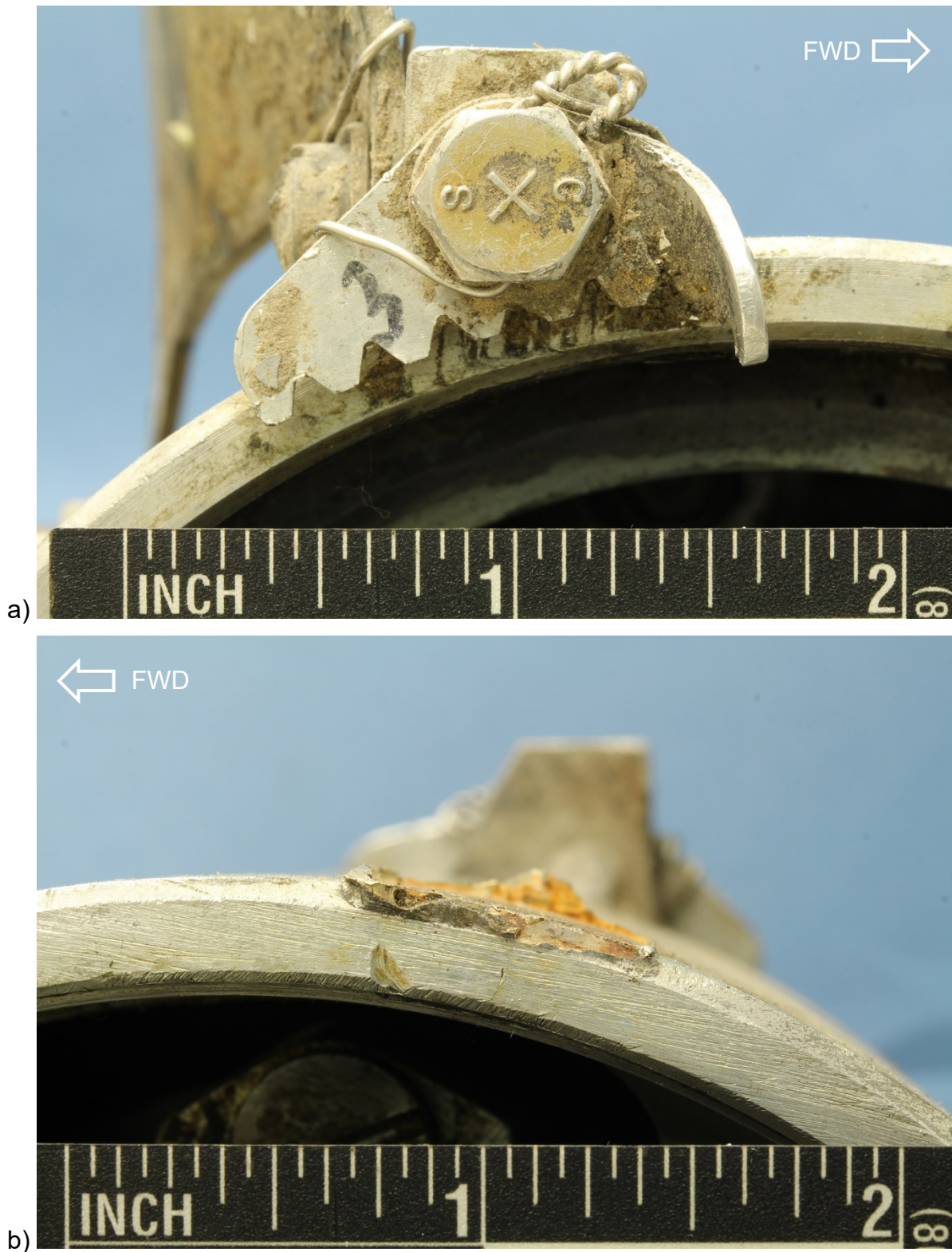


Figure 3: a) and b) Longitudinal views of the two lugs on the side with the separated propeller blade. The retention clip was bent on one lug and the other lug was missing.



c)



d)

Figure 3 (cont.): c) and d) Images of the two lugs and blade retention nut clips on the intact side of the hub.

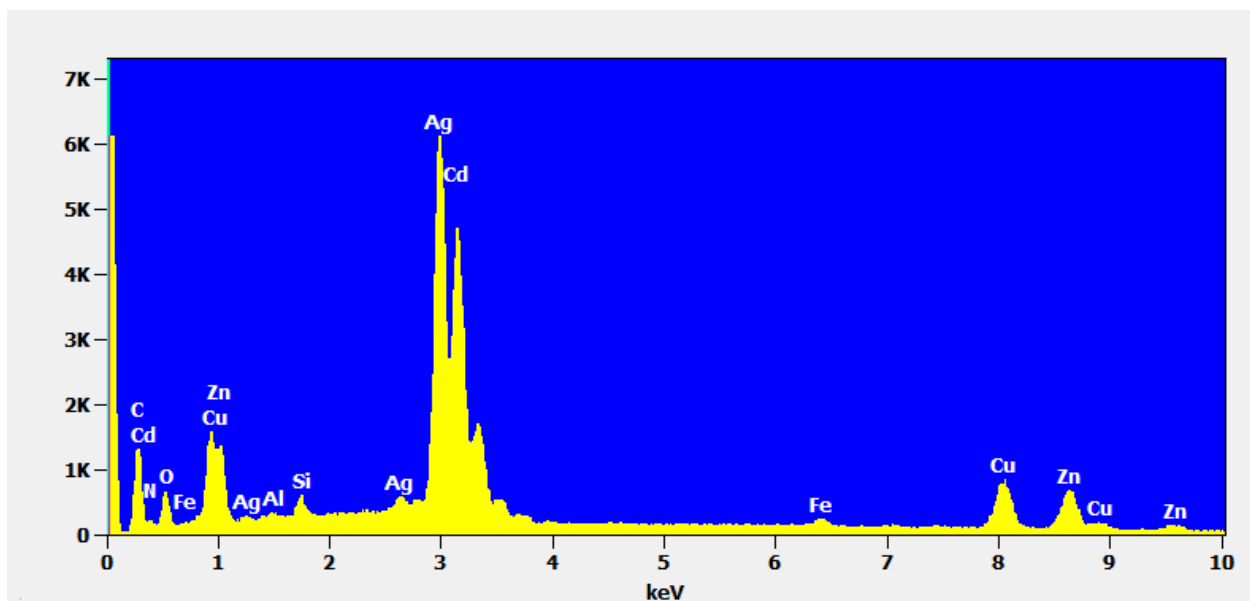
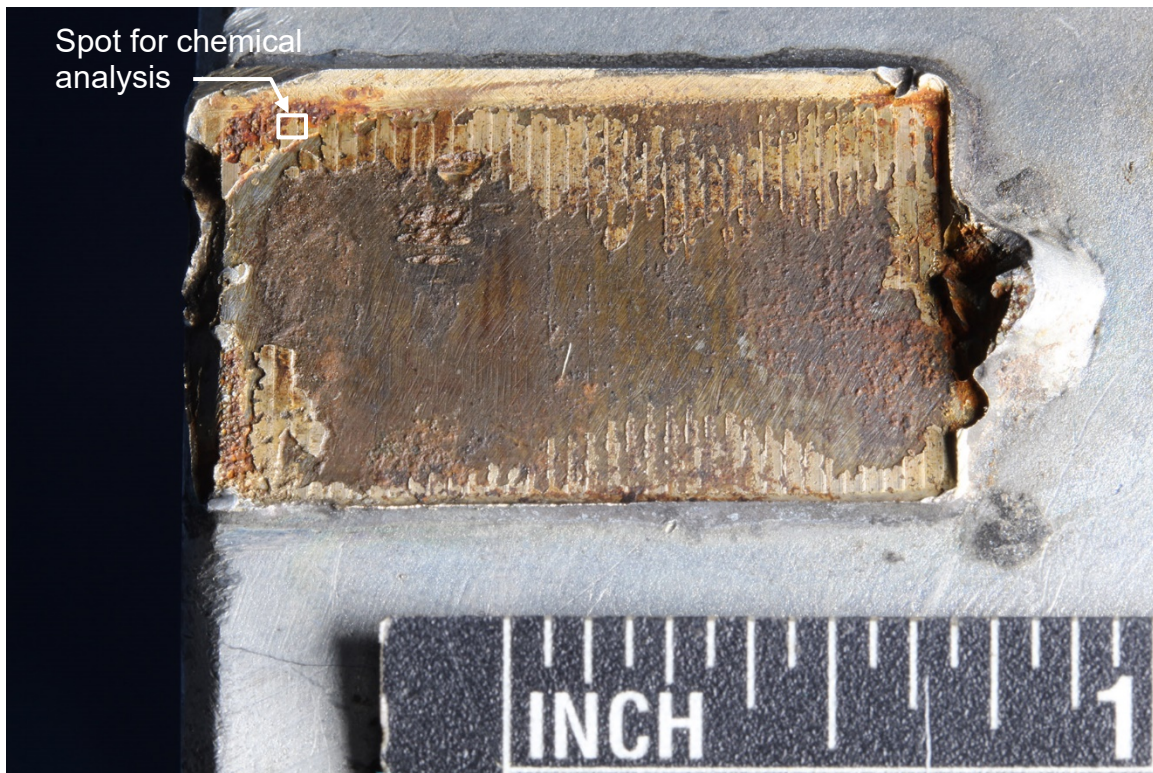


Figure 4: a) Image of the brazing pad for the disbonded lug and b) energy dispersive spectroscopy of the brazing compound indicating the presence of primarily silver (Ag), cadmium (Cd), copper (Cu), and zinc (Zn).

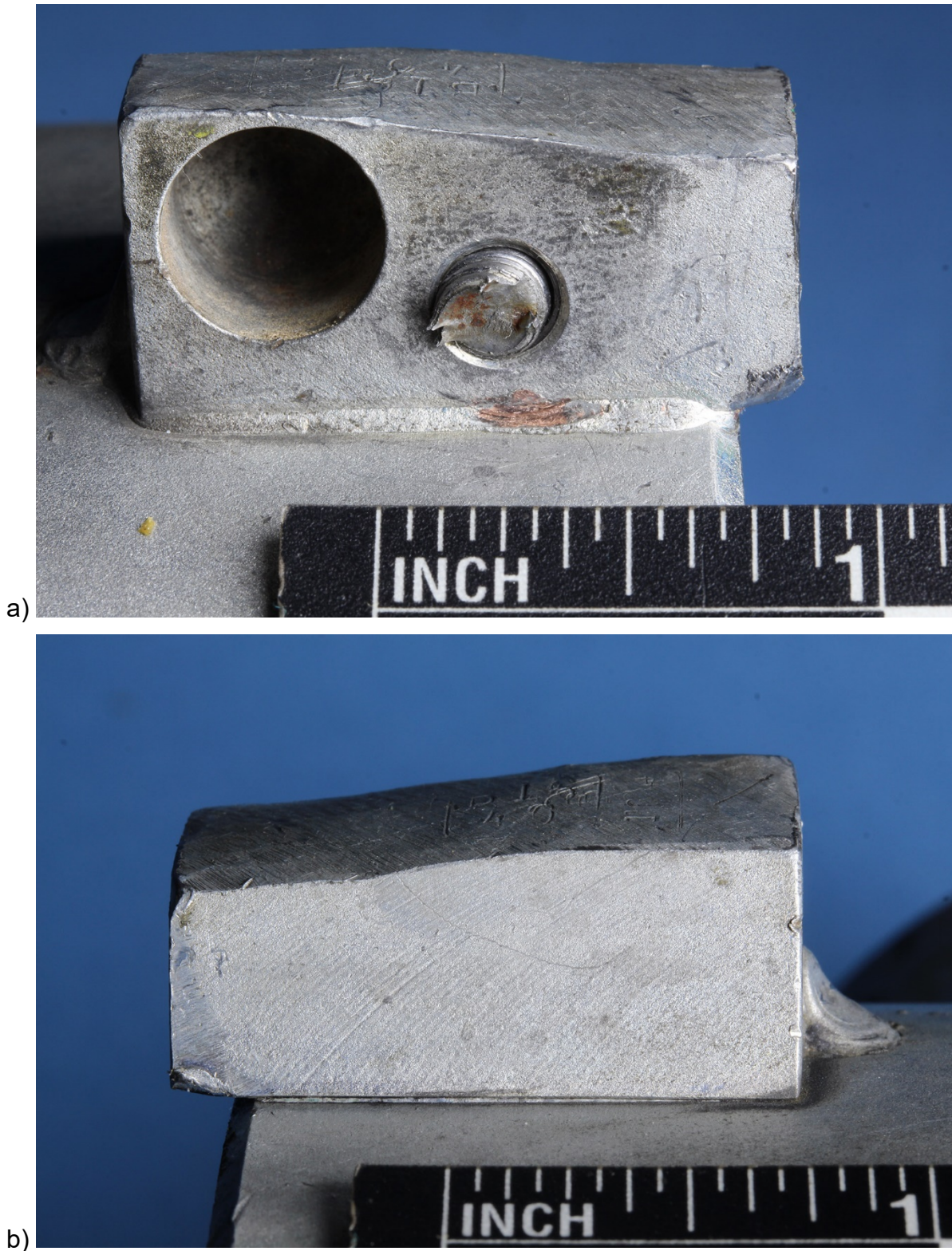


Figure 5: Images of an intact lug on the side of the hub with the retained propeller blade (see also figure 3d): a) aft face of the lug looking forward and b) forward face of the hub looking aft;

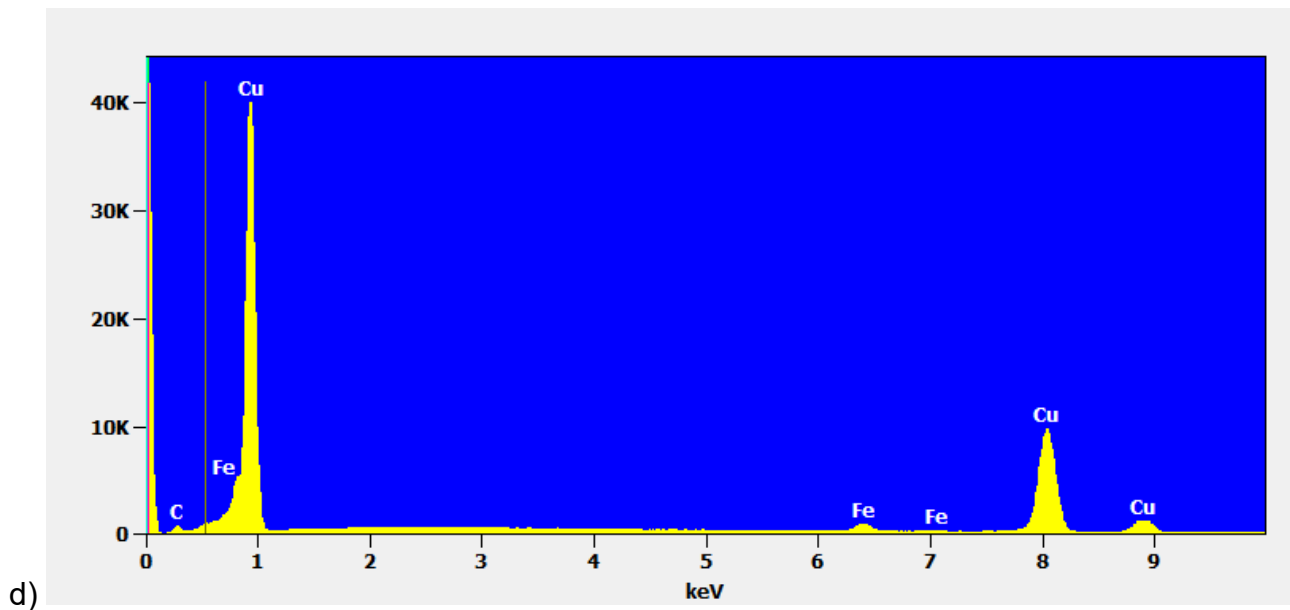


Figure 5 (cont.): c) Image of a sectioned piece of the lug and hub joined by a brazing material. The view is of the aft piece looking in the aft direction; and d) energy dispersive spectroscopy of the brazing compound indicating the presence of copper (Cu).

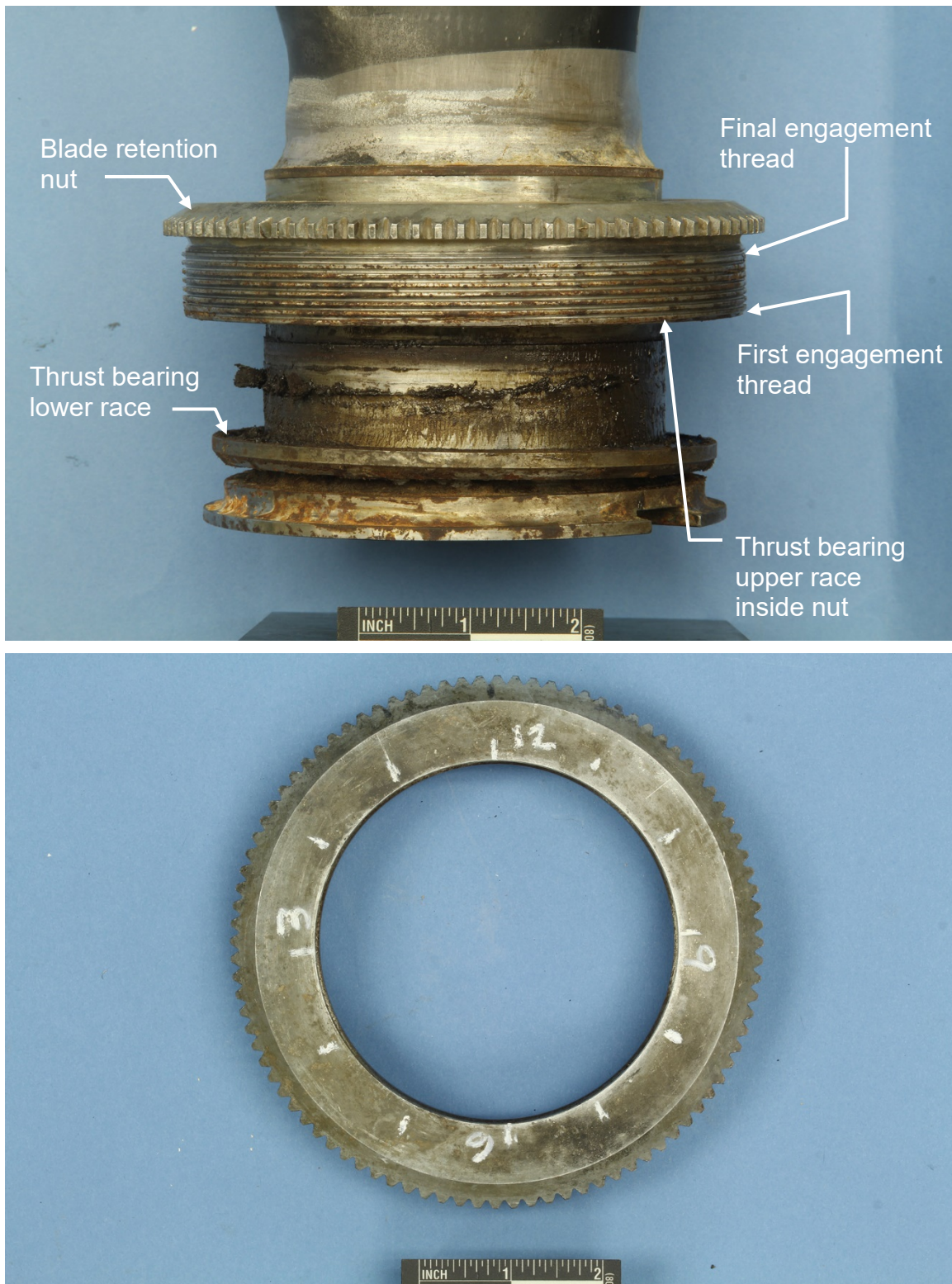


Figure 6: a) Image of the separated propeller blade showing the shank-end with the blade retention nut and bearing races still attached and b) image of the blade retention nut after the blade was cut and the nut removed. The perimeter of the nut was labelled with clock positions starting with 12 o'clock at a preexisting black mark on the nut.

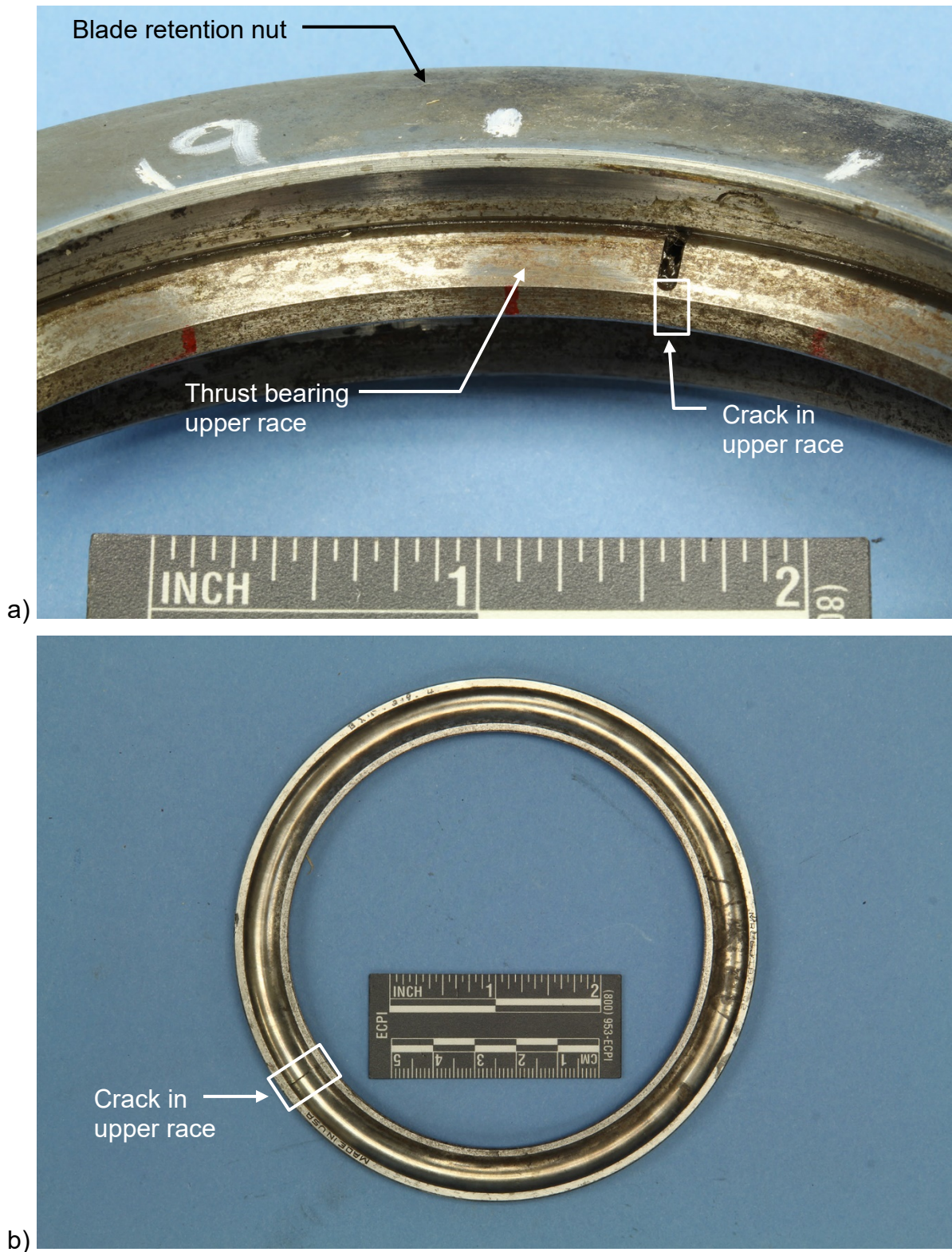


Figure 7: a) and b) Images of the the thrust bearing upper race showing the location of a crack at a manufactured notch on the backside of the race.

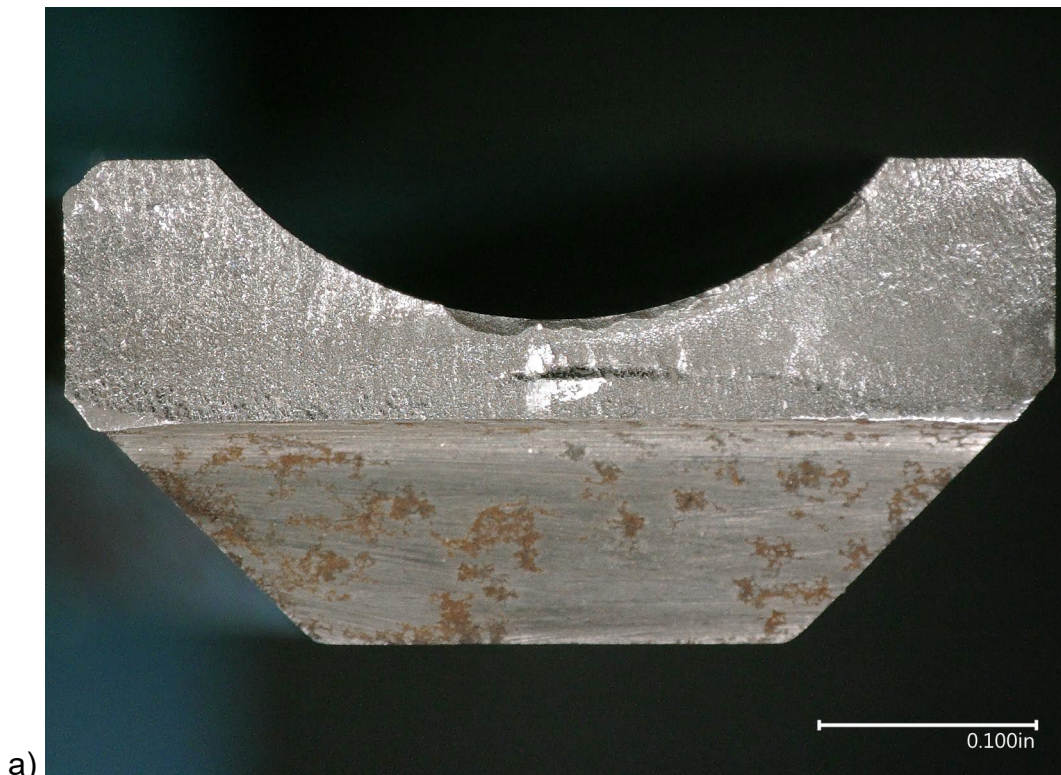


Figure 8: a) Image of one of the thrust bearing upper race fracture surfaces and b) image of the thrust bearings (31 total) in their as-received condition.

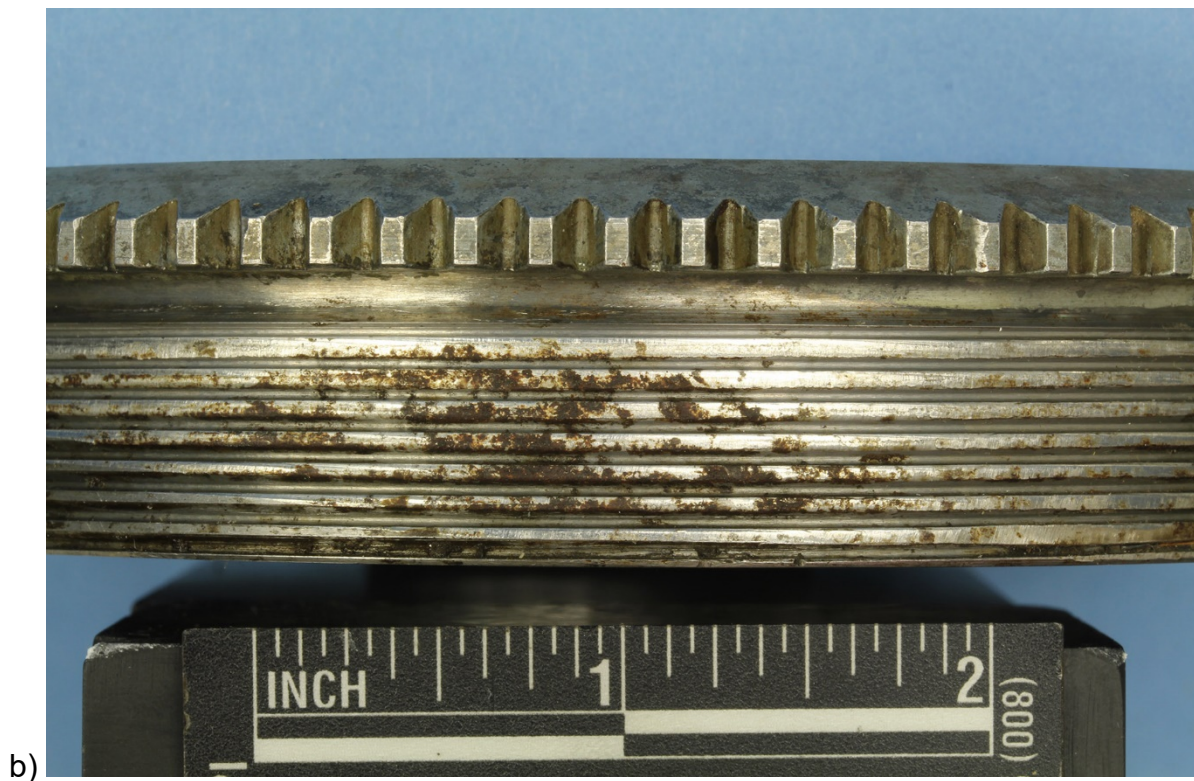
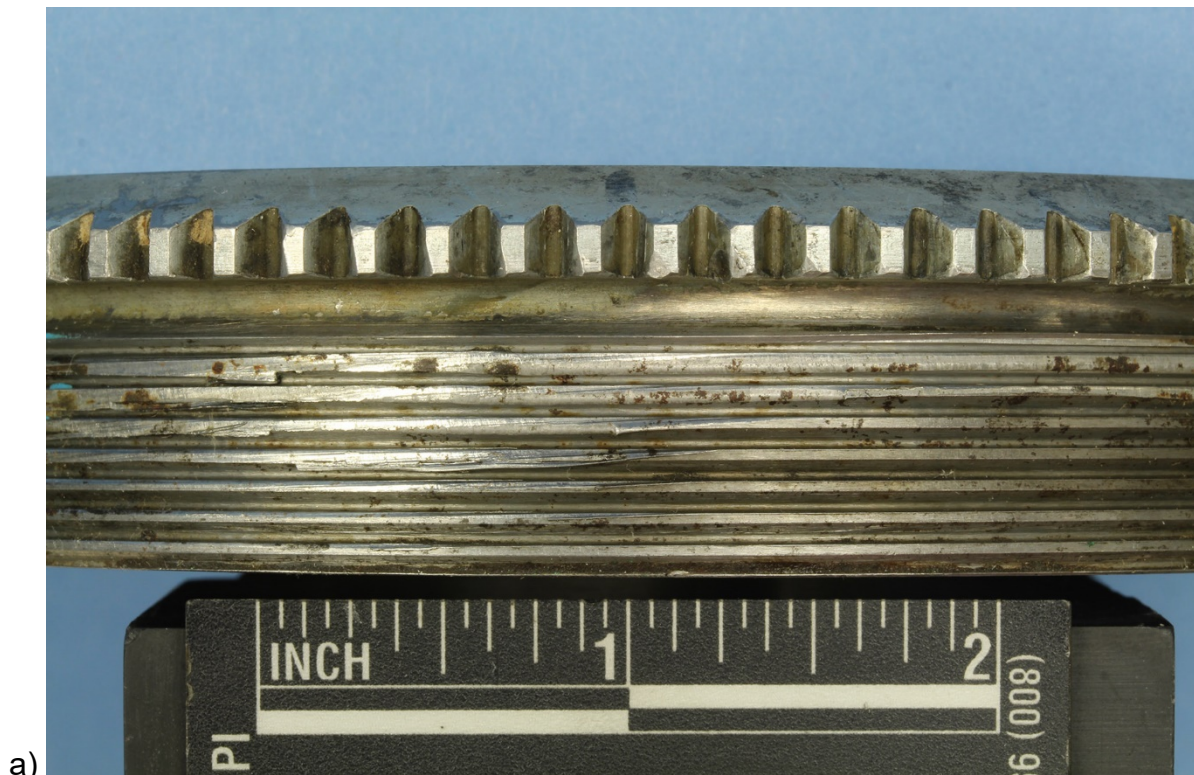


Figure 9: Images showing the appearance of the blade retention nut threads at the following positions: a) 12 o'clock; b) 3 o'clock;

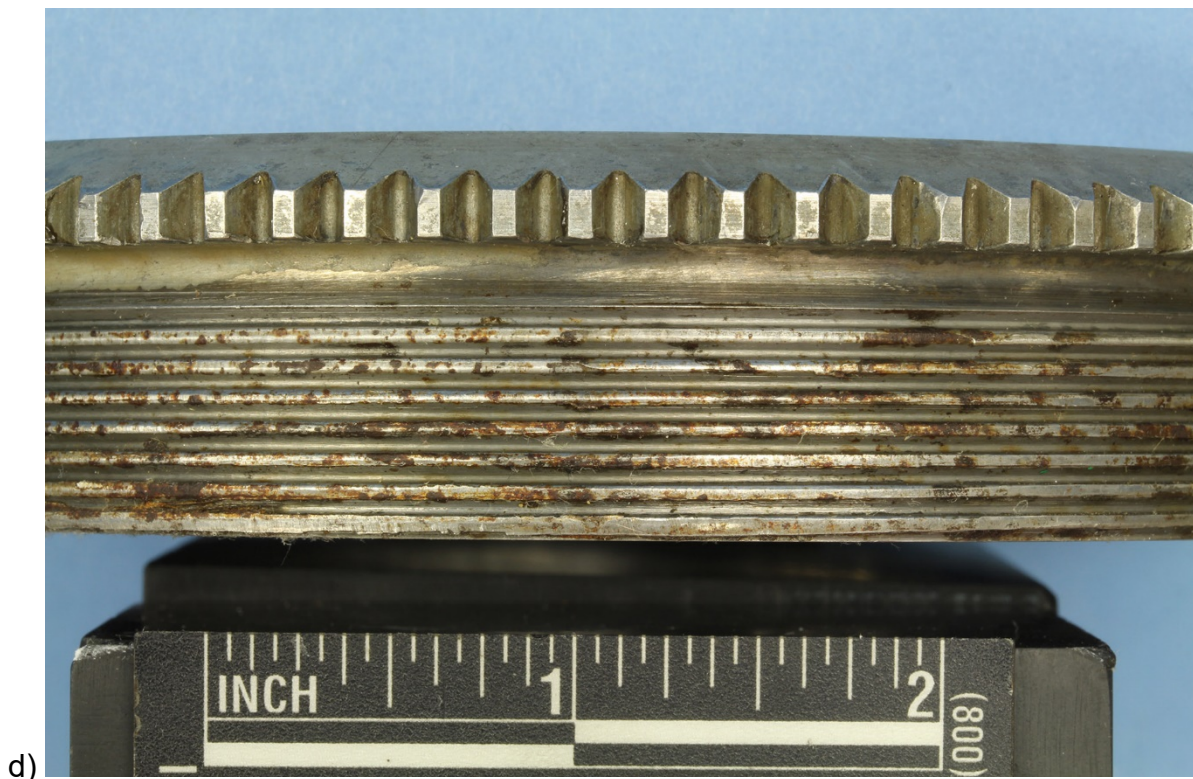
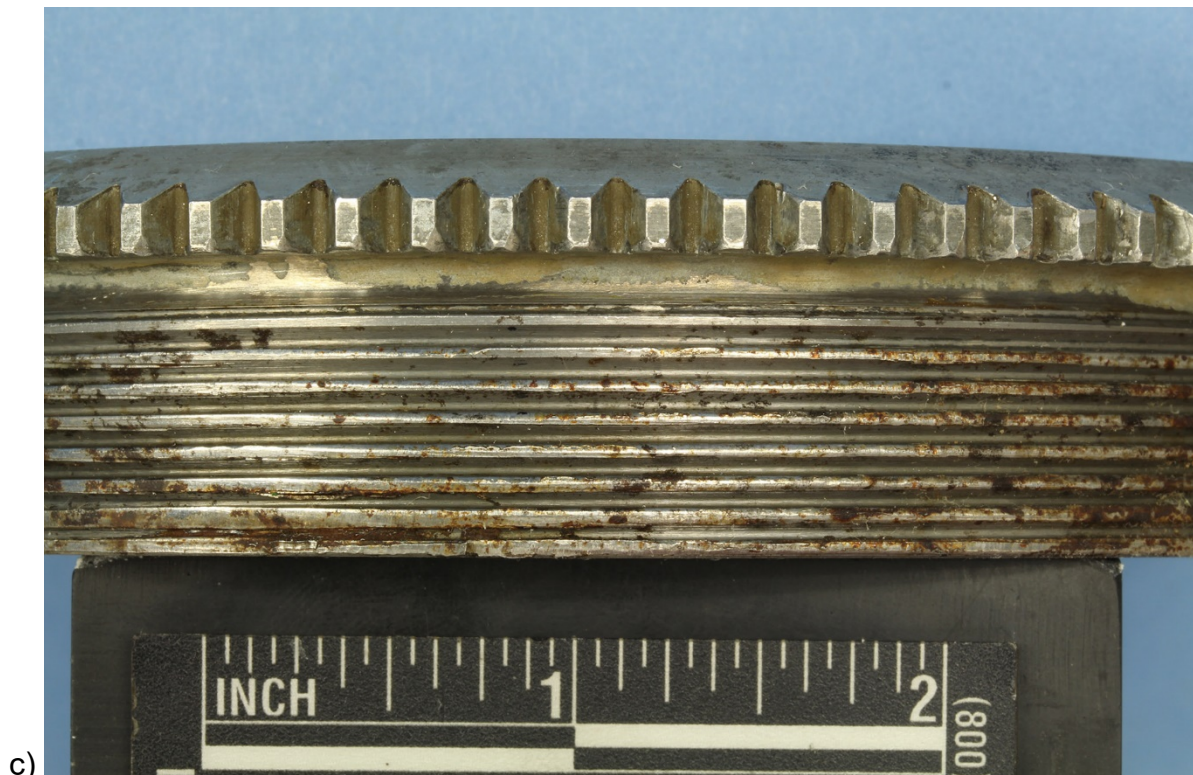


Figure 9 (cont): c) 6 o'clock; and d) 9 o'clock.

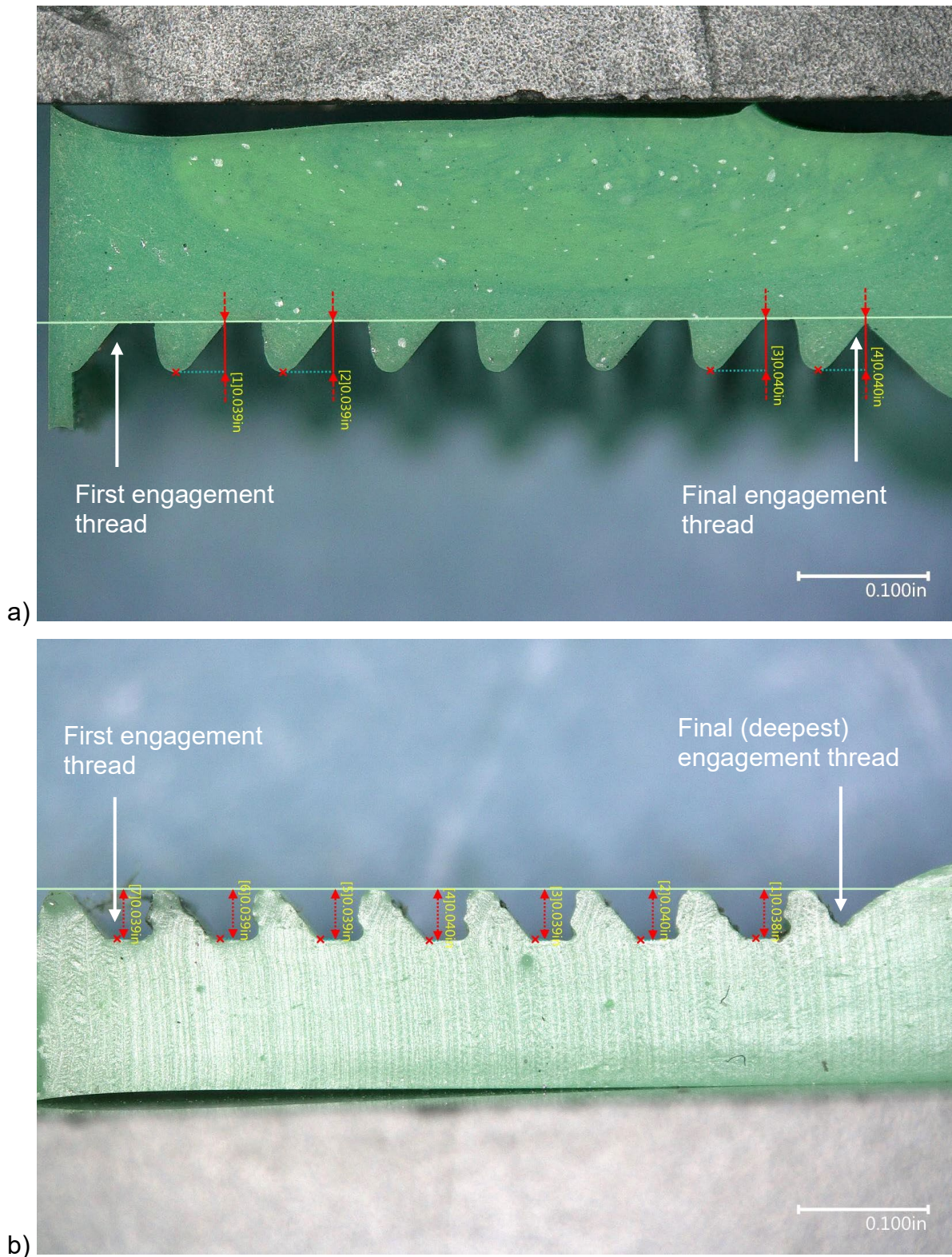


Figure 10: Comparison rubber molds of the threads from the side of the hub with the retained blade: a) external thread profile of the retained blade retention nut and b) the internal thread profile on the hub.

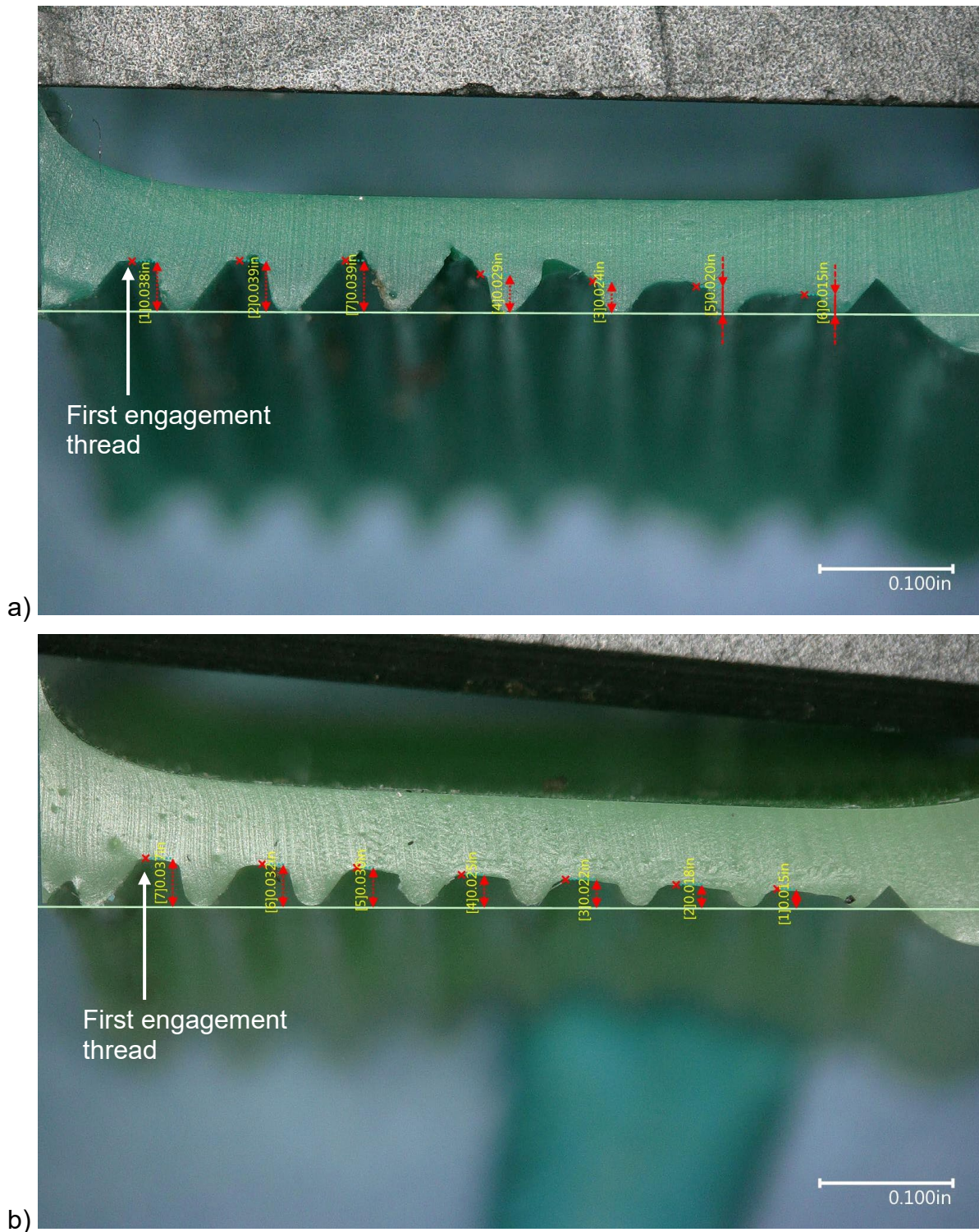
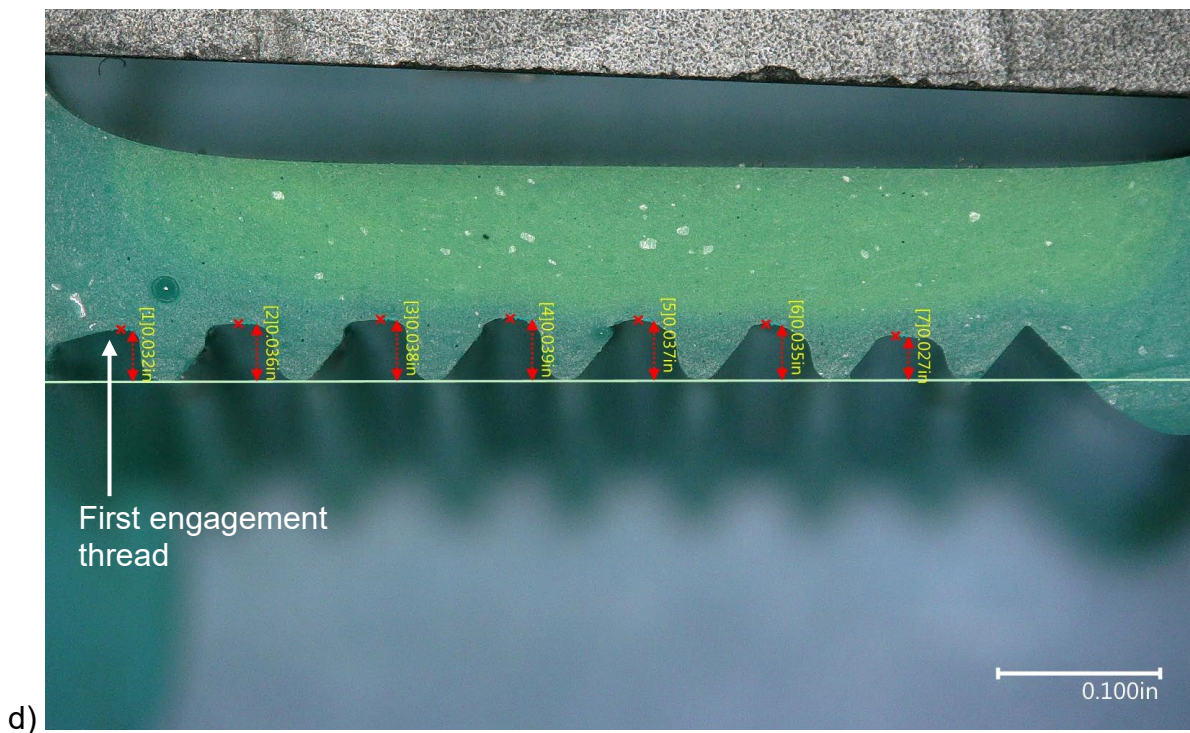
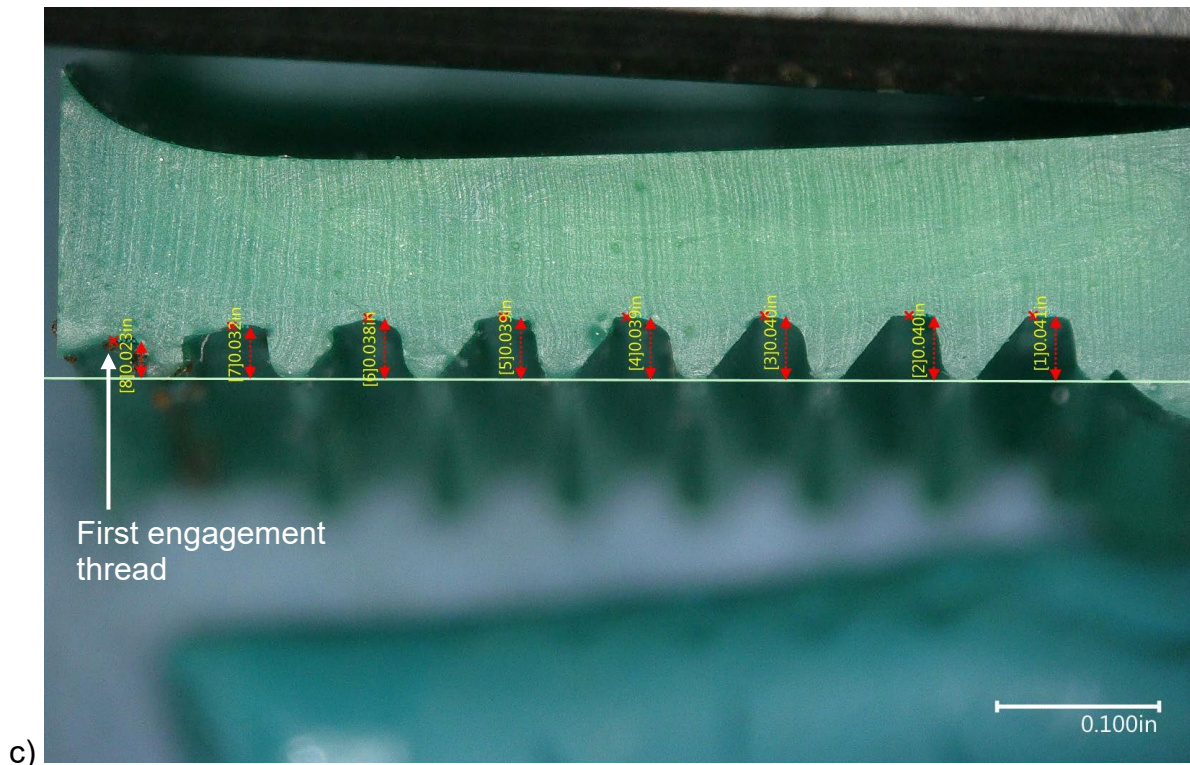


Figure 11: Images of the cross-section thread profiles from the blade retention nut on the separated blade: a) 12 o'clock; b) 3 o'clock;



c) 6 o'clock; and d) 9 o'clock.

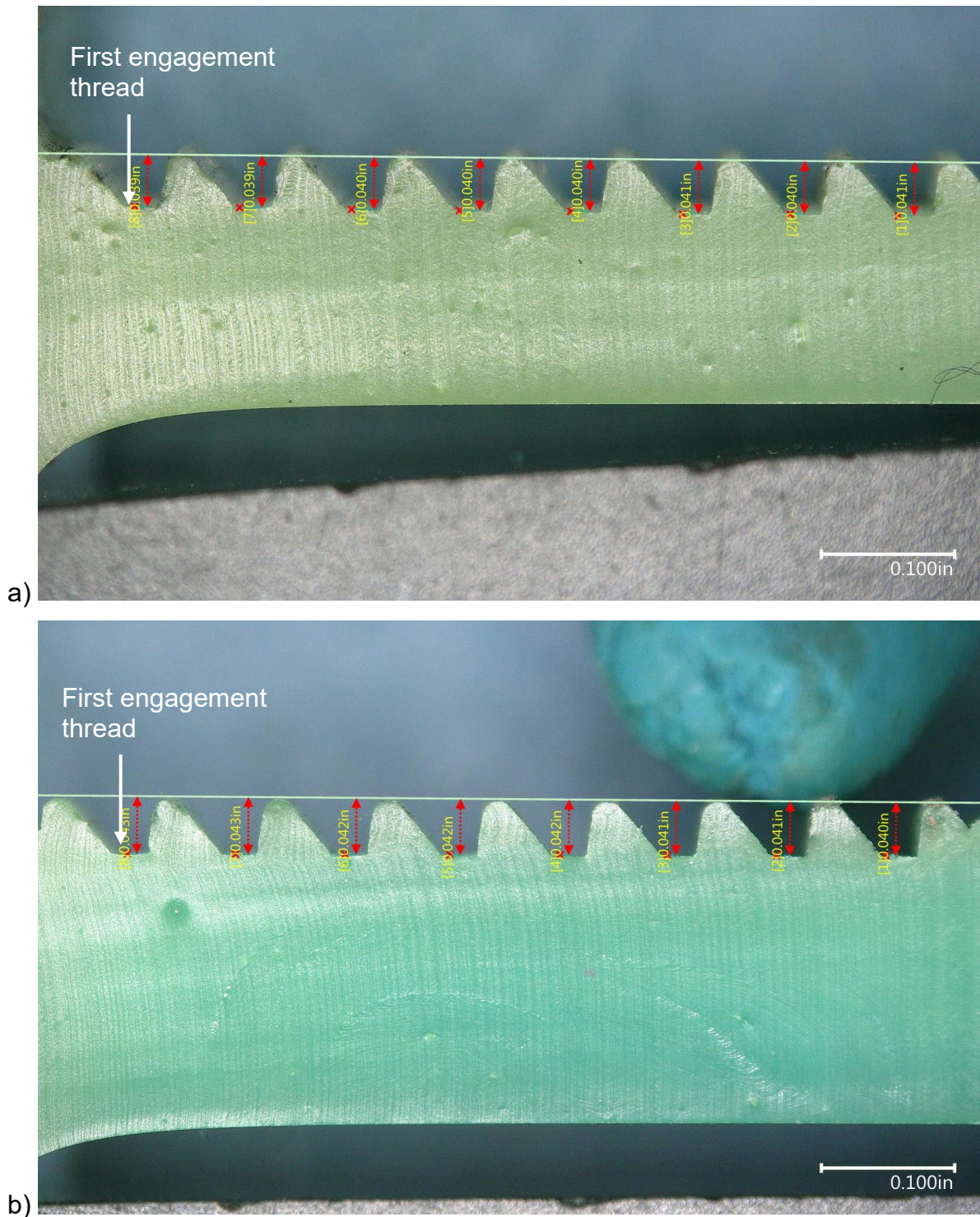


Figure 12: Images of the cross-section thread profiles from the hub internal threads on the side with the separated blade: a) near the disbonded lug; b) at the aft side of hub;

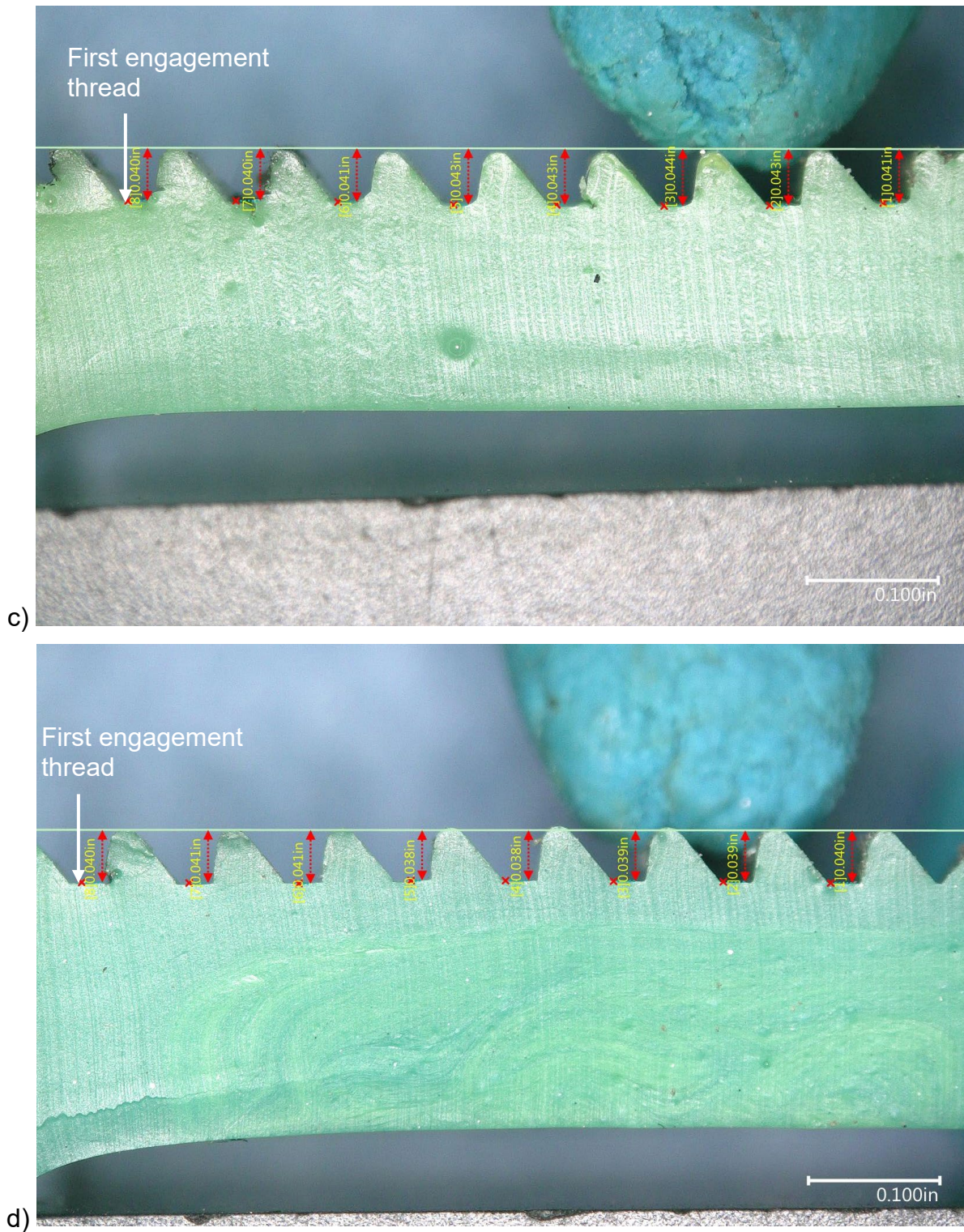


Figure 12 (cont.): c) near the intact lug; and d) at the forward side of the hub.