

# NATIONAL TRANSPORTATION SAFETY BOARD

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



August 31, 2022

## MATERIALS LABORATORY FACTUAL REPORT

Report No. 22-062

### A. ACCIDENT INFORMATION

Place : Laveen Village, Arizona  
Date : November 15, 2021  
Vehicle : Sonex Waix B, N535D  
NTSB No. : WPR22LA035  
Investigator : Andrew Swick, AS-WPR

### B. COMPONENTS EXAMINED

Rocker assembly for the number 3 and number 4 cylinders from an AeroVee engine.

### C. DETAILS OF THE EXAMINATION

An overall view of the submitted rocker assembly for the number 3 and number 4 cylinders is shown in figure 1. The adjuster for the number 4 exhaust valve was fractured at the outboard side of the swivel pad housing, and the inboard end of the adjuster with the swivel pad and housing was recovered loose in the rocker cover during the post-accident engine examination. The other three adjusters were intact, and the swivel pads moved freely within the housings.

As received, the flat side for the separated swivel pad faced the outboard (rocker arm) side of the housing. However, images of the separated swivel pad and housing from the engine examination summary showed the flat side facing the opposite direction (the valve side). The separated swivel pad moved with some resistance within the housing, and the flat side was repositioned by hand to face the inboard side of the housing. The remaining images of the separated swivel pad and housing in this report show the flat side facing the inboard side of the housing.

The threaded portion of the number 4 exhaust adjuster outboard of the fracture was retained within the rocker arm. A closer view of the outboard side of the fracture is shown in figure 2. The fracture surface was mostly rubbed and damaged by post-fracture recontact with the mating fracture surface and from contact with the valve tip after the swivel pad and housing had been displaced. A dashed line in figure 2 indicates a flat circular area that corresponded to contact with the exhaust valve tip. The center of the valve tip contact area was positioned slightly aft of the adjuster centerline. According to the AeroVee 2.1 Assembly and Installation Manual, the center of the swivel pad is offset from the valve tip center to facilitate proper valve rotation.

A bracket in figure 2 indicates an area of contact damage on the forward side of the fracture. Within the damaged area shown in figure 2, a smooth spherical impression was observed consistent with contact with the outboard side of the separated and displaced swivel pad. Corresponding contact damage was observed on the mating side of the fracture shown in figure 3. Overall, the corresponding contact damage was consistent with the separated swivel pad and housing being displaced forward following fracture from the threaded portion of the adjuster.

The inboard (valve) side of the separated portion of the adjuster is shown in figure 4. The flat valve contact face on the swivel pad had linear scratches that appeared to be machining marks, similar to those observed on the intact swivel pads as well. A faint circular pattern consistent with rotating valve contact was observed, but not as prominent as the patterns observed on the other three pads. Overall, the pad surface had a frosted appearance, and spalling damage was observed near the edges.

A side view of the separated pad and housing is shown in figure 5. The swivel pad was recessed within the housing, and the flat side was approximately flush with the inboard edge of the housing. One side of the housing inboard edge was worn and curled outward as indicated in figure 4, damage that was consistent with contact with the edge of the valve tip with the pad recessed within the housing. The inboard edge of the pad housing also showed a flattened area as indicated in figure 4, likely associated with contact with the valve tip after the swivel pad and housing displaced forward after fracture. The flattened area indicated in figure 4 was within the same quadrant as the contact damage on the outboard side (as indicated in figure 3).

Fracture features on the outboard side of the fracture were mostly obliterated by post-fracture damage. The fracture surface on the opposite side of the fracture as shown in figure 3 appeared to be less damaged. The thickness of the fractured section varied around the circumference. The remaining ligament was thickest in the lower left quadrant (in the orientation as viewed in figure 3) and was thinnest in the damaged area shown at the upper right quadrant.

The inboard side of the adjuster fracture surface was further examined using a scanning electron microscope (SEM). To clean the swivel pad and housing for SEM examination, the assembly was cleaned with an ultrasonic cleaner while immersed in acetone. The cleaned fracture was examined around the circumference. The fracture features were obscured with rubbing damage and oxidation, and no determination of fracture mechanism was made from the examination. An SEM image of a relatively thin portion of the fracture is shown in figure 4, where the thickness of the housing measured approximately 0.0012 inch thick.

Next, the swivel pad was separated from the housing by using a water-cooled abrasive saw to section through the housing on two sides. A view of the swivel pad after sectioning is shown in figure 7. The spherical outboard half of the swivel pad had a rough surface consistent with scoring and galling damage. The damage pattern had circular

patterns on two sides with linear features in between consistent with rotating contact within the housing.

On the interior surfaces of the swivel pad housing, the outboard portion had scoring and galling that mirrored the damage patterns observed on the swivel pad with a circular pattern on two sides and linear scratches between. The scoring and galling damage was concentrated at the outboard side of the housing as shown in figure 8, and material on the outboard side of the housing had worn away, producing space for the swivel pad to be recessed within the housing. The normal seat surface for the swivel pad was inboard of the worn area as shown in figure 8 and was darkened from time in service with the swivel pad recessed in the worn housing.

The galled and scored surfaces on the swivel pad and housing were examined using backscattered electron imaging,<sup>1</sup> and areas that contrasted from the background were analyzed using energy dispersive x-ray spectroscopy (EDS). In addition to background elements composing the pad and housing steel, EDS spectra of deposits and particles generally showed high peaks associated with carbon, oxygen, lead, and bromine, elements associated with oil and combustion deposits. No evidence of embedded hard particles was observed on the scored surfaces.

The three intact adjusters had swivel pads that appeared to be positioned normally in the housing and did not appear to be recessed. The swivel pads for the two intake valves had nominal contact patterns on the valve contact faces. However, the number 3 exhaust swivel pad contact face was spalled in a circle around the center of the pad as shown in figure 9. The swivel pads were rotated within the housing to look for any evidence of damage or wear. The swivel pads for the two intake valve adjusters had smooth oiled surfaces with no evidence of degradation. However, the number 3 exhaust swivel pad had areas of pitting damage on the spherical portion of the surface such as the area shown in figure 10. The optical image in figure 10 was obtained using a Keyence VHX-7000 in depth mode with enhanced shadow imaging.

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<sup>1</sup> SEM images produced using a backscattered electron detector in composition mode have contrast that is associated with atomic number of the elements in the image. Areas with elements having higher atomic numbers appear as a relatively lighter shade of gray compared to areas having elements with lower atomic numbers.

The outboard ends of the adjusters are shown in figure 11. The screwdriver slots at the outboard ends were deformed on each of the adjusters, including the number 4 exhaust valve adjuster shown at higher magnification in the detail image in figure 11. The distance from the outboard face of the locking nut to the outboard end of the adjuster was measured on each rocker arm. The distances measured 0.227 inch, 0.191 inch, 0.217 inch, and 0.247 inch for the number 3 intake, number 3 exhaust, number 4 intake, and number 4 exhaust adjusters, respectively.

Matthew R. Fox, Ph.D.  
National Resource Specialist - Materials

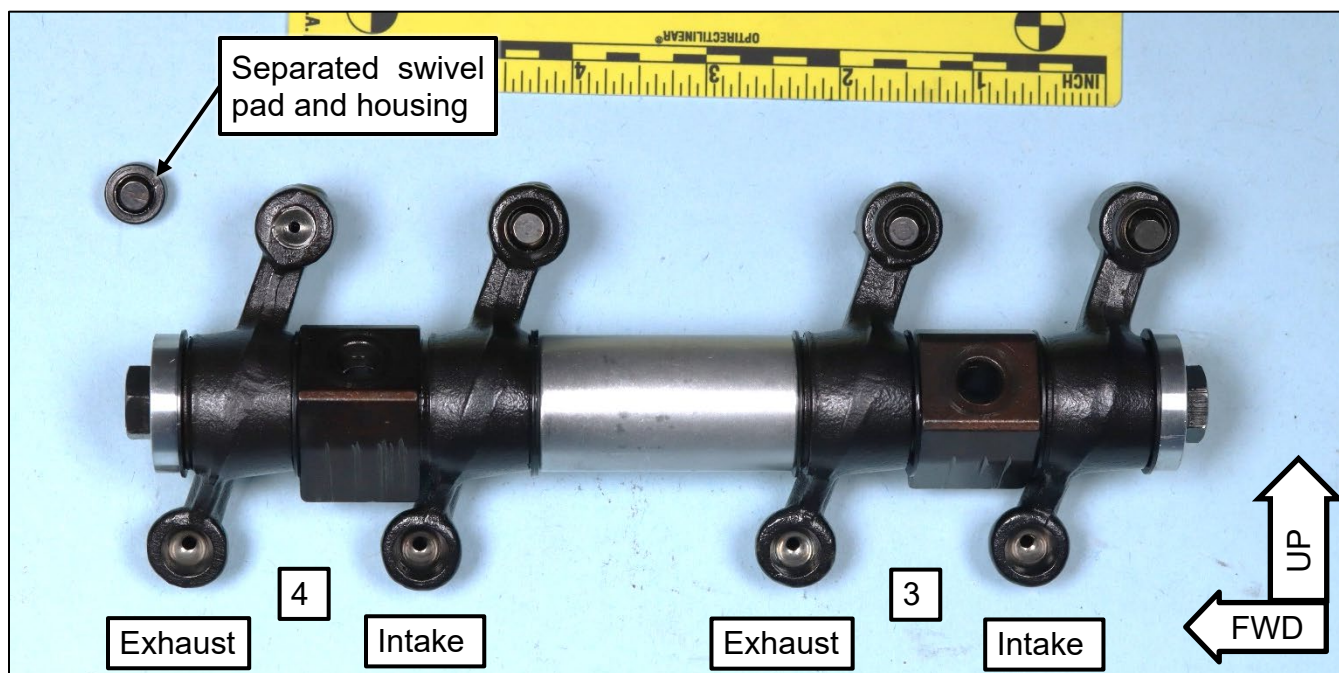


Figure 1. Overall view of the rocker assembly showing the inboard side of the rocker arms including the fractured number 4 exhaust valve adjuster.

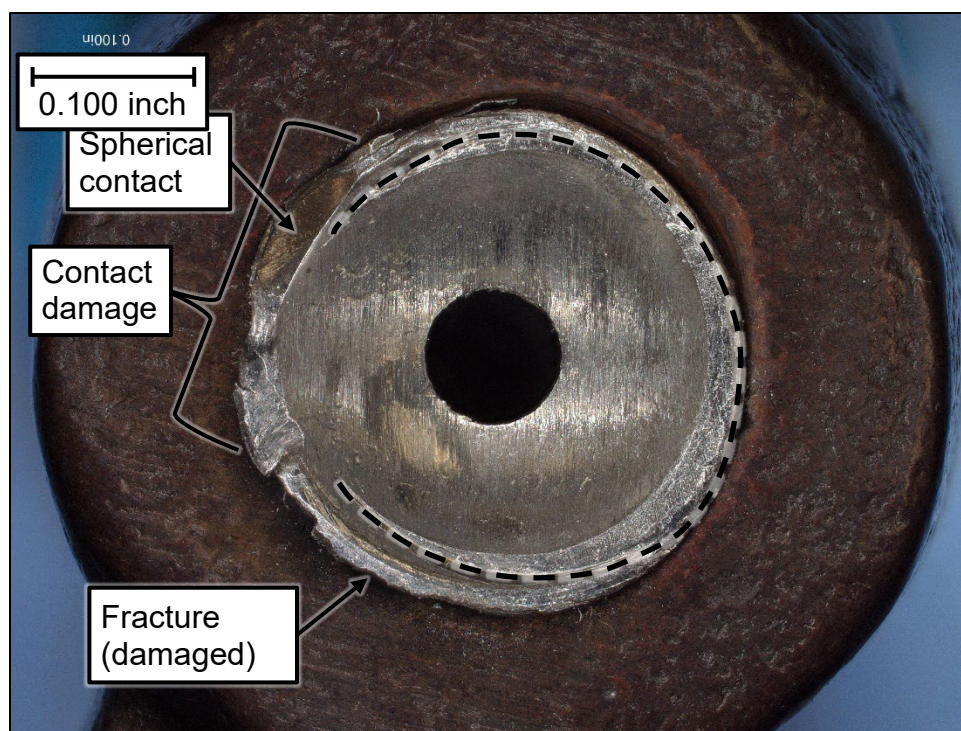


Figure 2. Outboard (rocker arm) side of the valve adjuster fracture. A dashed line indicates an area corresponding to contact with the valve tip, and a bracket indicates contact damage corresponding to contact with the displaced mating side of the fractured adjuster.

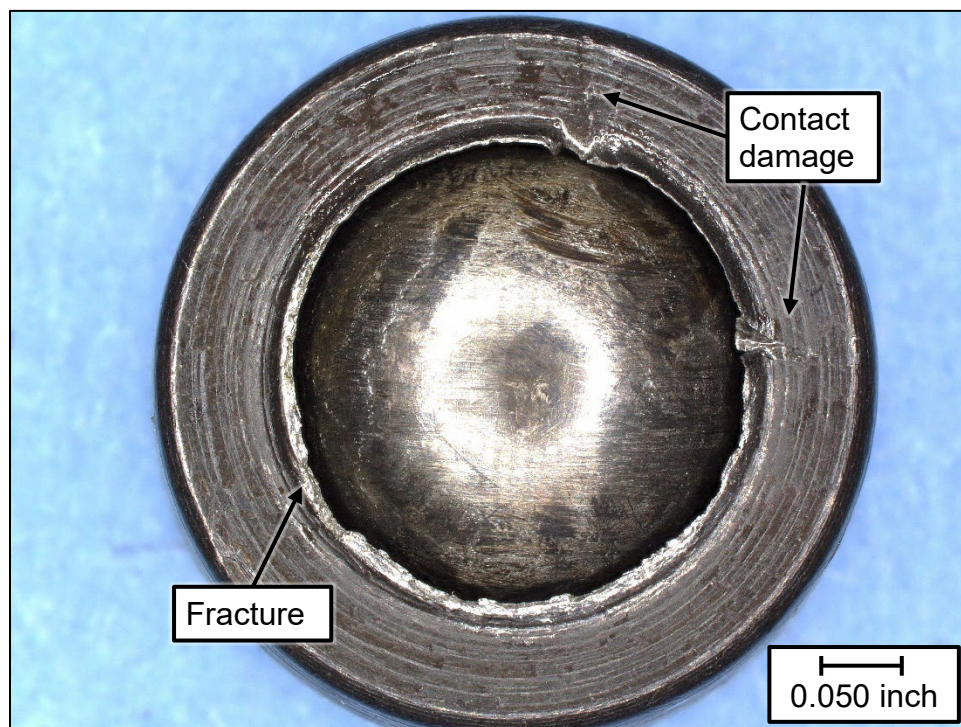


Figure 3. Inboard (valve) side of the valve adjuster fracture.

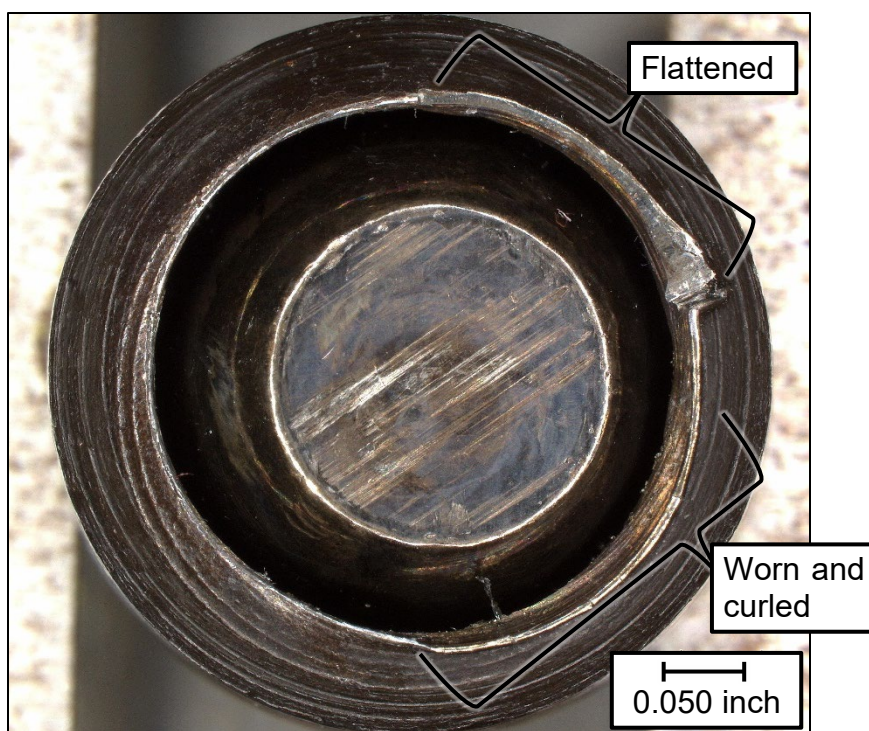


Figure 4. Valve side of the swivel pad showing valve tip contact damage at the edge of the pad housing.

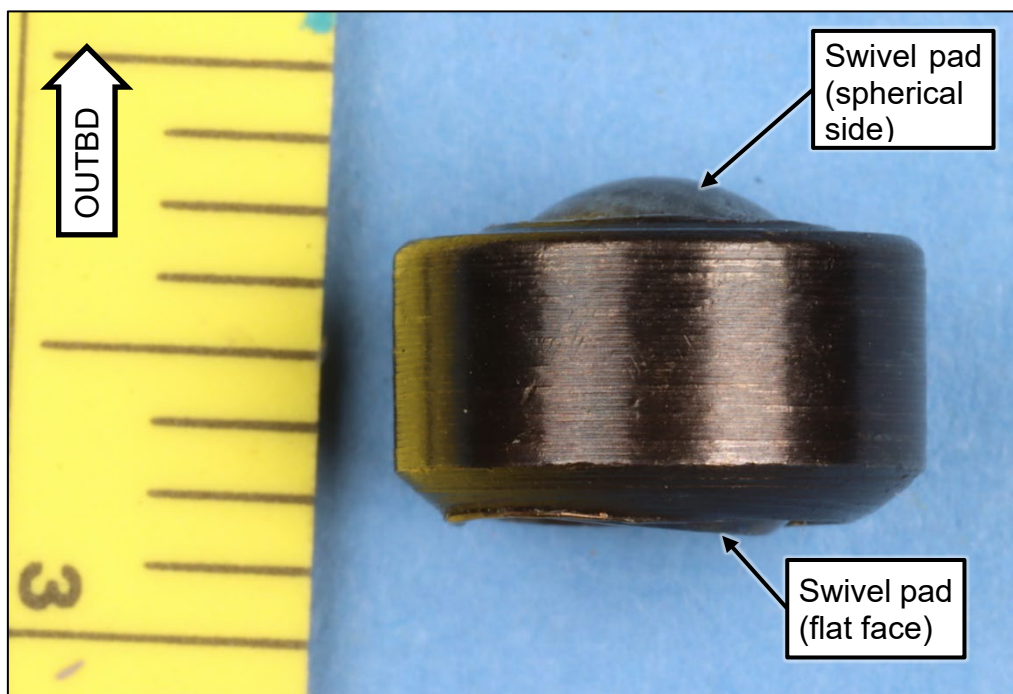


Figure 5. Side view of the swivel pad housing showing the pad recessed within the housing.

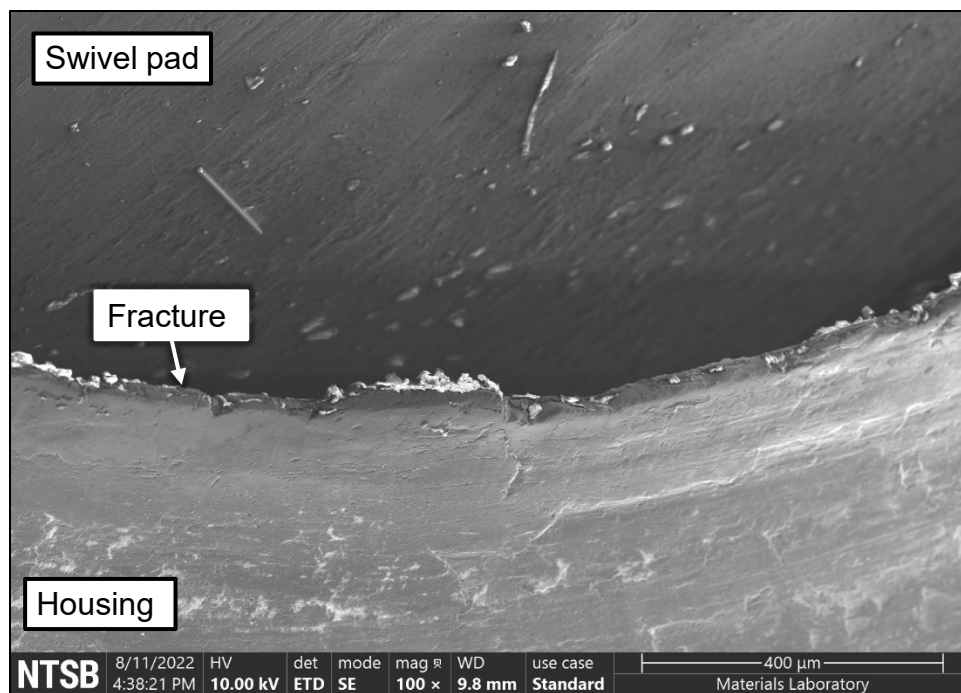


Figure 6. SEM image of the adjuster fracture where the thickness of the housing was relatively thin.

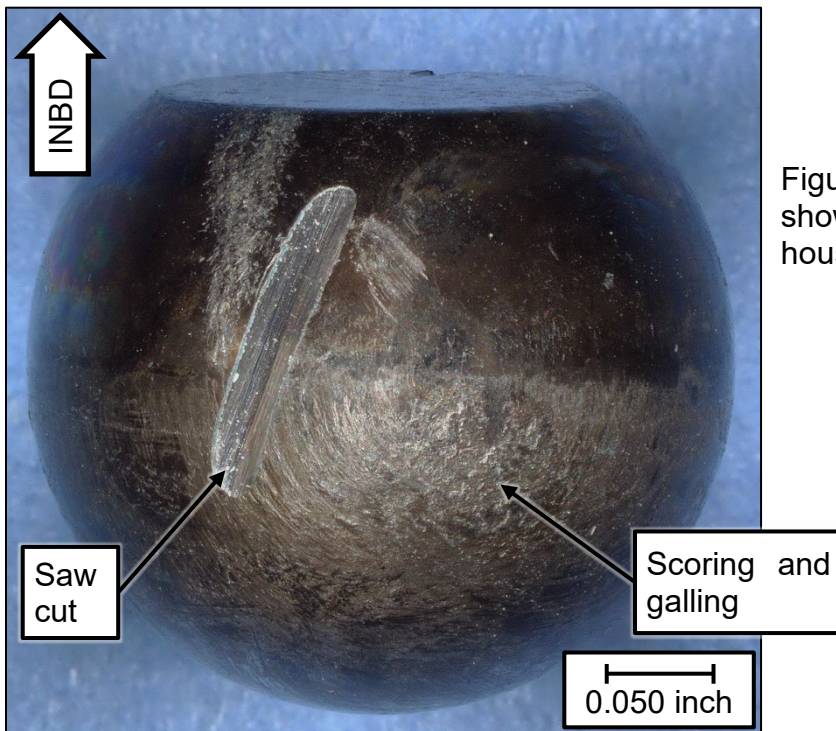


Figure 7. Swivel pad after sectioning showing scoring and galling on the housing contact faces.

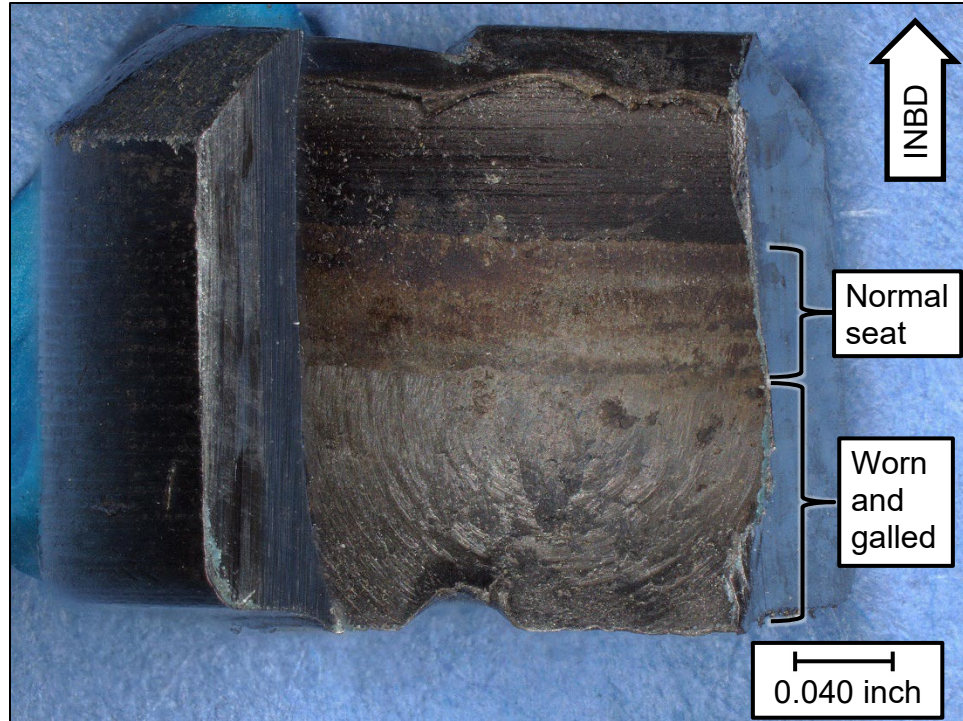


Figure 8. Sectioned half of the swivel pad housing showing galling and wear on the interior surface.



Figure 9. Number 3 exhaust valve adjuster showing spalling damage on the swivel pad face.

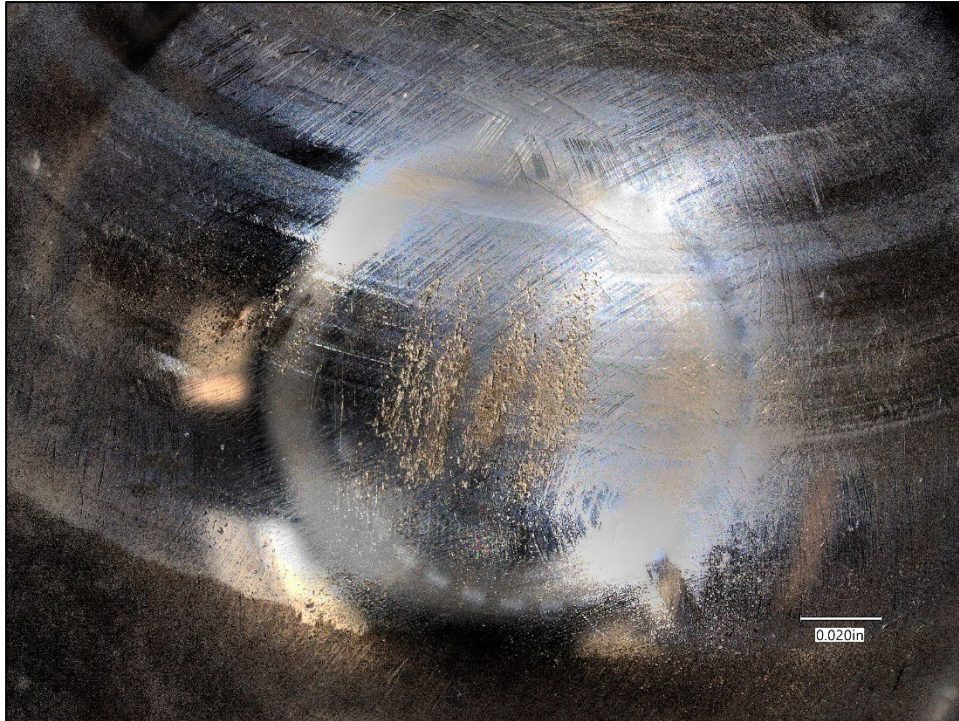


Figure 10. Optical image obtained using a Keyence VHX-7000 in depth mode with enhanced shadow imaging showing pitting on the spherical surface of the number 3 exhaust swivel pad.

Figure 11. Outboard side of the rocker arms on the rocker assembly. The deformed slot edges on the adjuster for the number 4 exhaust valve is shown in the detail image at the right.

