

National Transportation Safety Board

Office of Research and Engineering

Washington, DC 20594



ERA22LA410

MATERIALS LABORATORY

Factual Report 23-098

August 5, 2024

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A. ACCIDENT INFORMATION

Location: Buckland, Alaska
Date: September 9, 2022
Vehicle: Cessna U206, N8019Z
Investigator: Millicent Hill, AS-ERA

B. COMPONENTS EXAMINED

Valves, valve springs, valve spring seats, keepers, and intake valve stem seals from the numbers 1, 3, and 5 cylinders and intake and exhaust rocker arms from all 6 cylinders of a Continental IO-550-F-AP engine.

C. EXAMINATION PARTICIPANTS

Specialist Matthew R. Fox, Ph.D.
NTSB
Washington, DC

D. DETAILS OF THE EXAMINATION

An overall view of the submitted components are shown in figure 1. Most of the parts were received in bags labeled by cylinder number as indicated in figure 1. Exhaust rocker arms from cylinders 1 and 5 were associated with the cylinders as identified from photographs taken during the engine teardown examination. The remaining four exhaust rocker arms and the intake valve stem seals shown at the top of the upper image in figure 1 were not labeled to allow association with a particular cylinder. The intake rocker arms shown in the lower image were received in a later shipment and also were not labeled by cylinder number. For the components from cylinders 3 and 5, the exhaust valve is shown to the right of the intake valve, and the exhaust valve springs and seats are shown to the right of the intake valve springs and seats. For cylinder 1, the exhaust valve and exhaust valve springs are shown in figure 1 with the associated rocker arm.

The submitted components were from a Continental IO-550-F-AP engine. According to the engine service and maintenance log, the engine had been overhauled on September 10, 2021, when it was also converted from an IO-520-F engine in accordance with Vitatoe Aviation Supplemental Type Certification (STC) number SE03187AT. A deviation from the STC to install Continental cylinder and valve assemblies 658810A1 in place of assemblies 658592A1 was approved through Federal Aviation Administration Form 8110-3 dated September 20, 2021. The engine was installed on the airplane with zero time since overhaul on March 1, 2022, and the last log entry was on September 8, 2022, at which time the engine had accumulated 505 hours time in service (TIS) since overhaul. In that time, oil changes were performed at about 25-hour TIS intervals and the filter was changed at about

50-hour TIS intervals following the first two oil and filter changes that occurred after 11.5 hours and 32 hours TIS since overhaul.

A closer view of the cylinder 1 exhaust valve and rocker arm is shown in figure 2. The exhaust valve stem was bent, and the stem was fractured adjacent to the fillet radius transitioning to the head. A closer view of the fractured end of the valve stem is shown in figure 3. Fracture features were obliterated by post-fracture impact damage on both sides of the fracture, so a fracture mechanism was not identified. Longitudinally-oriented dark streaks and galling damage were observed on the valve stem near the fractured end as indicated with arrows in figure 3.

The tip end of the cylinder 1 exhaust valve was severely worn to a shape resembling a top hat, and any identifying marks on the tip were obliterated by the wear. The shoulder at the stem side of the keeper slot was also worn away to a cone-shaped slope transitioning from the stem diameter to the keeper slot diameter. The corresponding contact pad on the exhaust rocker arm was recessed from wear in a shape mirroring the valve tip wear as shown in figure 4. A portion of the arm adjacent to the pad was also worn consistent with contact with the valve spring seat. The pad end of the valve was tinted consistent with high heat exposure, and the worn areas of the pad were oxidized.

The number 3 cylinder intake valve was intact, and the valve tip had identifying markings that read "655868-C 19216G Z". The valve tip end face had a normal circular contact wear pattern. Isolated scuffs and longitudinal scratch marks were observed on the valve stem. Near the valve tip, multiple semicircular indents were observed on the stem as shown in figure 5.

A backlit image of the number 3 cylinder intake valve head outer edge is shown in figure 6. The valve seat face had a concave shape consistent with substantial valve seat face wear. The extent of wear appeared relatively uniform around the circumference.

The number 3 cylinder exhaust valve was intact, and the valve tip had identifying markings that read "655771-E 19119T Z". The valve tip end face was stained dark and had a normal circular wear pattern. Near the middle of the stem, the surface appeared burnished in 5 distinct longitudinally-oriented patches distributed around the circumference as indicated in figure 5.

A backlit image of the number 3 exhaust valve head outer edge is shown in figure 7. The valve seat face had a relatively flat face that showed limited wear. The extent of wear appeared relatively uniform around the circumference.

An overall view of the valve head faces from the number 3 cylinder is shown in figure 8 (left side). The valve heads had a uniform heat signature pattern around the circumference. A light coating of gray combustion deposits was observed on the

intake valve head face, and the exhaust valve had a thicker layer of reddish orange deposits.

The number 5 cylinder intake valve was intact, and identification marks on the tip read "655868-C 19216F Z". Extensive longitudinally-oriented dark streaks and galling damage were observed on the valve stem as shown in figure 9. The valve tip end face is also shown in figure 9. Multiple rocker arm impact marks were observed on the end face as indicated in figure 9. Oxidation and pits were also observed across the surface as indicated.

A backlit image of the number 5 cylinder intake valve head outer edge is shown in figure 10. The valve seat face had a concave shape consistent with substantial valve seat face wear. The extent of wear appeared relatively uniform around the circumference.

The number 5 cylinder exhaust valve and rocker arm are shown in figure 11. Extensive longitudinally-oriented dark streaks and galling damage were observed on the valve stem as indicated in figure 11. The tip of the exhaust valve was worn to a shape resembling a top hat, and any identifying marks were obliterated by the wear. The corresponding contact pad on the exhaust rocker arm was recessed from wear in a shape mirroring the valve tip wear as shown in the upper image in figure 11. A portion of the arm adjacent to the pad was also worn consistent with contact with the valve spring seat. The pad end of the valve was tinted consistent with high heat exposure, and the worn areas of the pad were oxidized.

A backlit image of the number 5 exhaust valve head outer edge is shown in figure 12. The valve seat face had a relatively flat face that showed limited wear. The extent of wear appeared relatively uniform around the circumference.

An overall view of the valve head faces from the number 5 cylinder is shown in figure 8. The valve heads had a uniform heat signature pattern around the circumference. Both valve faces had limited deposits of combustion products.

Two of the exhaust rocker arms that were not associated with a particular cylinder number are shown in figures 13 and 14. The rocker pads for both rocker arms were tinted dark consistent with high heat exposure, and coked oil deposits were observed on the rocker arm shown in the lower half of figure 13. A depression was observed in each pad consistent with impact and wear damage from contact with the corresponding valve tip. Pits were also observed on the pad surfaces within the contact areas.

Procedures for rocker arm inspection and bushing replacement for the accident engine are described in the Continental Standard Practice Maintenance Manual (SPMM), and a copy of relevant pages from the SPMM revision dated January 6, 2023, was provided by a representative from Continental Aerospace

Technologies. A table in the SPMM lists exhaust and intake rocker arm assembly part numbers 652130 and 652131, respectively, for use in engines including the Continental IO-550-A, B, and C engines.¹ A drawing of these rocker arms as illustrated in the SPMM is shown in figure 15. Since part numbers can fade or become illegible over time, the SPMM provides diagrams for identifying distinguishing features associated with parts currently in use. The drawing for the intake rocker arm (part number 652131) notes a “bump” on the inboard side of the valve arm as noted in figure 15. In contrast, the drawing for the exhaust rocker arm (part number 652130) does not show a bump.

The SPMM notes that rocker arm bushings must be replaced at engine overhaul. The SPMM includes a warning that dual bushing rocker arms have been discontinued for engines including the IO-550-series engines, and dual bushings for installation in these older rocker arms are no longer available. The obsolete rocker arms (rocker arms with a smooth rocker arm bore designed for use with the dual bushings) should be discarded and replaced with rocker arms that have an oil feed groove machined into the rocker arm bore for use with the current single bushing installation. The warning in the SPMM further states, “Installation of single piece rocker bushings in rocker arms designed for two piece bushings may restrict or block oil flow to the rocker shaft and valve guides, resulting in possible engine failure.”

The single bushings for the part numbers 652130 and 652131 intake and exhaust rocker arms contained two oil passage holes. As shown in figure 15, the bushings are to be installed with the oil passage holes located at the inboard side of the rocker arm at specific angles relative to the transverse plane. Additionally, the hole centers are offset from the midpoint between the two end faces of the bushing, and the SPMM provides a diagram of the rocker arms viewed looking inboard showing correct positioning of the offset relative to each rocker arm’s longitudinal axis. A warning in the SPMM states, “Incorrectly positioned bushing oil passages will result in a loss of rocker arm shaft lubrication, severe wear of the rocker arm bushing, shaft, and valve guide and possible engine failure.”

Views of the exhaust rocker arms are shown in figure 16. As noted in the upper image in figure 16, 5 of the 6 exhaust rocker arms had a bump on the inboard side of the valve arm, which was inconsistent with the drawing for the current exhaust rocker arm for the Continental IO-550-series engine as illustrated in the SPMM. Unlabeled arrows in figure 16 point to locations of oil passage holes in the installed bushings. None of the oil holes were located in the positions described in the SPMM or as shown in figure 15. In 5 of the 6 exhaust rocker arms including those from cylinders 1 and 5, both oil holes were located outboard of the bushing centerline. In the remaining exhaust rocker arm (shown at the lower right in figure 16), one hole was

¹ The cylinder assemblies installed on the engine were Continental cylinder assemblies (part number 658810A1), which according to a Continental application guide, are installed on multiple (TS)IO-520-series engines and IO-550-A, B, and C engines.

located outboard of the bushing centerline, and the other hole was located directly inboard of the bushing centerline. In one of the rocker arms removed from a cylinder other than number 1 or 5, the bushing was also installed with the oil holes offset to the incorrect side relative to the arm's longitudinal axis.

Bushings were pressed out of the rocker bore in each of the exhaust rocker arms, and representative results are shown in figure 17. Smooth rocker bores were observed in 5 of 6 exhaust rocker arms, including those from the number 1 and number 5 cylinders after the bushings were pressed out. For comparison, an oil feed groove was observed in the rocker bore of the exhaust rocker arm that did not have a "bump" as indicated in the lower image in figure 17.

An overall view of the intake rocker arms is shown again for reference in figure 18. Unlabeled arrows in figure 18 point to locations of oil passage holes in the installed bushings. None of the oil holes were located in the positions described in the SPMM or as shown in figure 15. The oil holes in all 6 intake rocker arms were similarly located outboard of the bushing centerline. Additionally, the oil hole positions were offset to the incorrect side of the longitudinal centerline in 4 of the 6 arms.

Bushings were pressed out of the rocker bore in each of the intake rocker arms. Two of the six intake rocker arms had a machined oil feed groove in the rocker bore while the remaining four intake rocker arms, including the representative arm shown in figure 19, had a smooth rocker bore.

Submitted by:

Matthew R. Fox, Ph.D.
Chief Technical Advisor - Materials

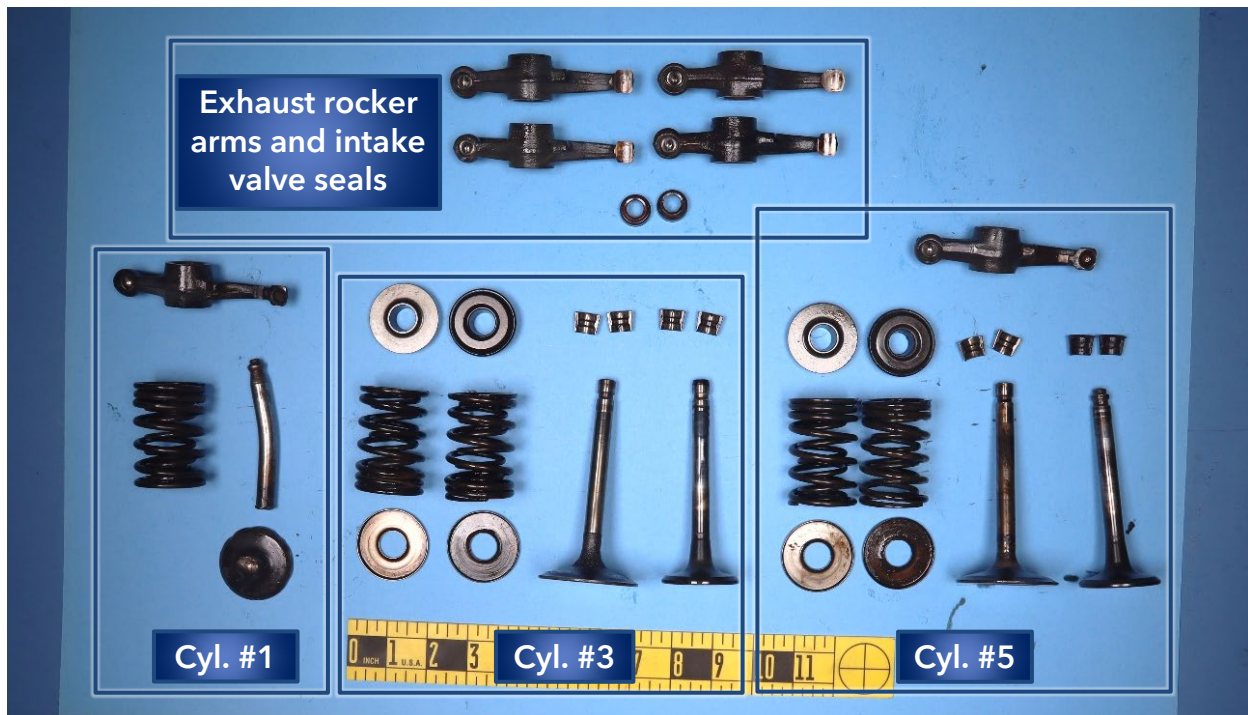


Figure 1. Overall view of the submitted components from cylinder numbers 1, 3, and 5 and exhaust rocker arms from all 6 cylinders as received (upper image) and a view of the 6 intake rocker arms as received in a subsequent shipment (lower image).



Figure 2. Closer view of the exhaust valve and associated rocker arm from cylinder number 1.

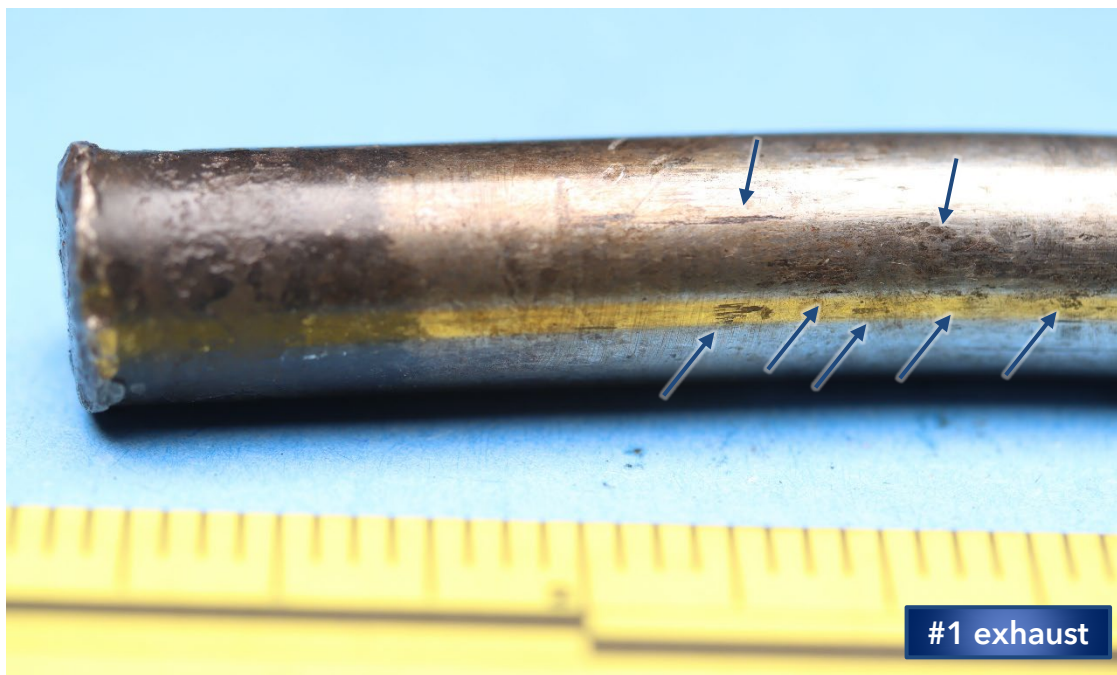


Figure 3. Fractured end of the number 1 cylinder exhaust valve stem. Longitudinally-oriented dark streaks and galling damage such as those indicated with unlabeled arrows were observed consistent with valve sticking.

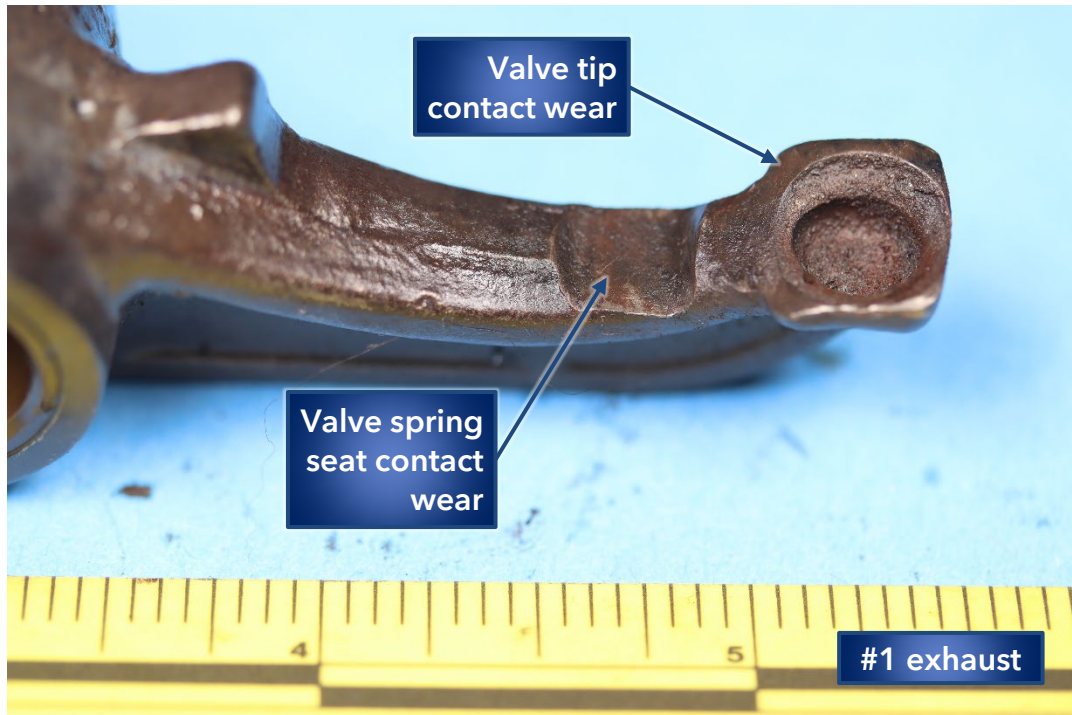


Figure 4. Valve contact pad for the number 1 cylinder exhaust rocker arm.

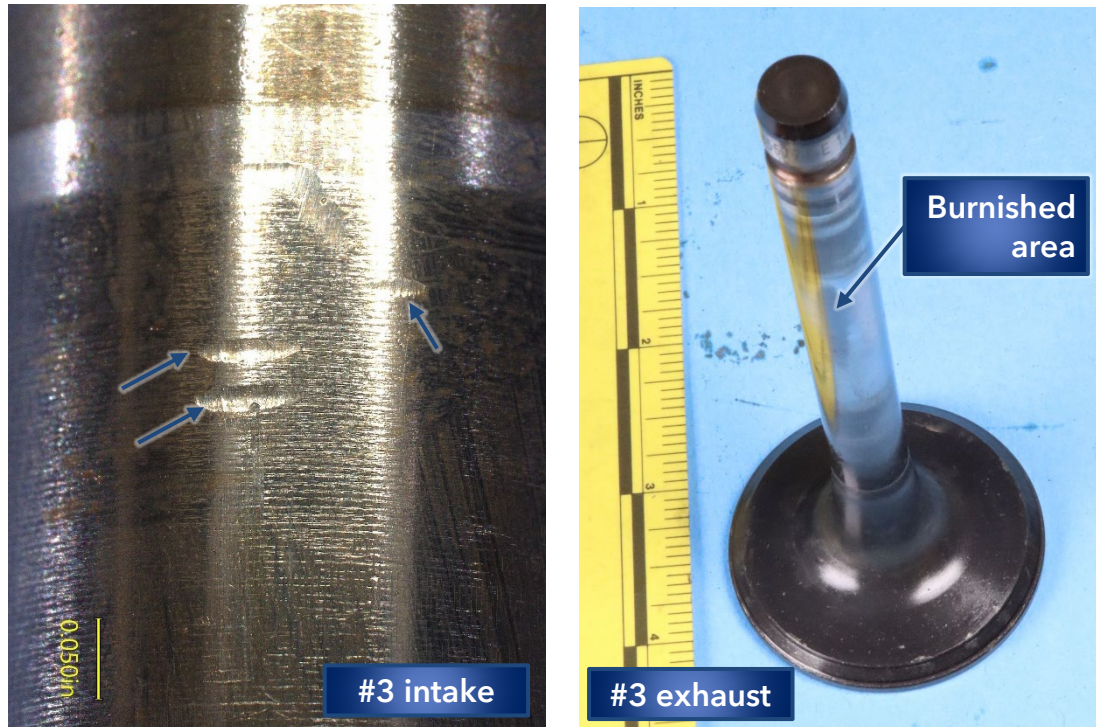


Figure 5. Semicircular contact marks near the tip of the number 3 cylinder intake valve stem (left image) and view of burnishing marks on the number 3 cylinder exhaust valve stem (right image).

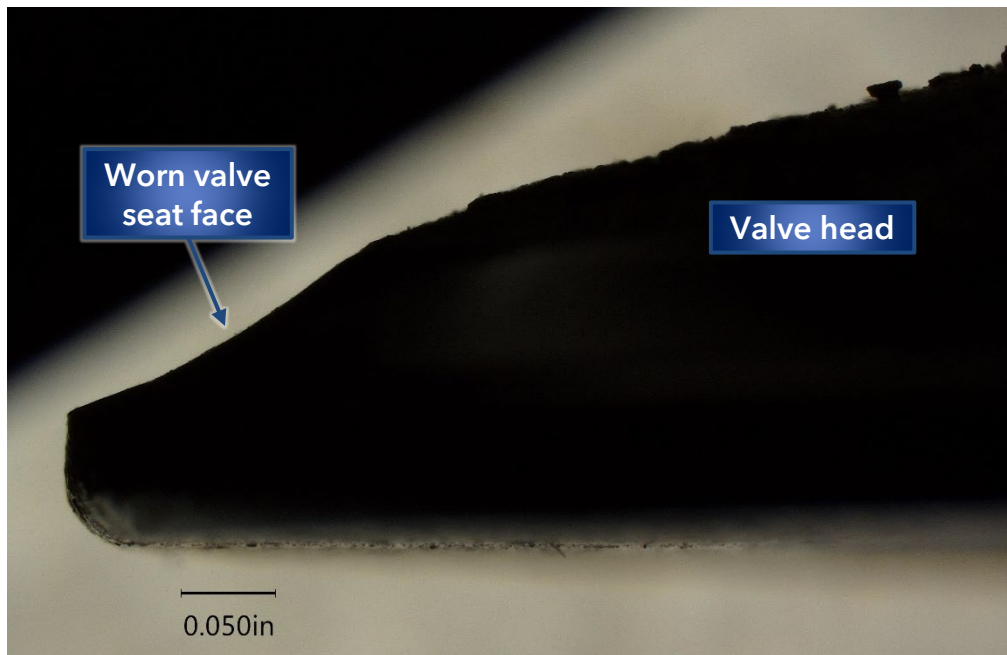


Figure 6. Backlit image of the number 3 cylinder intake valve head outer edge.

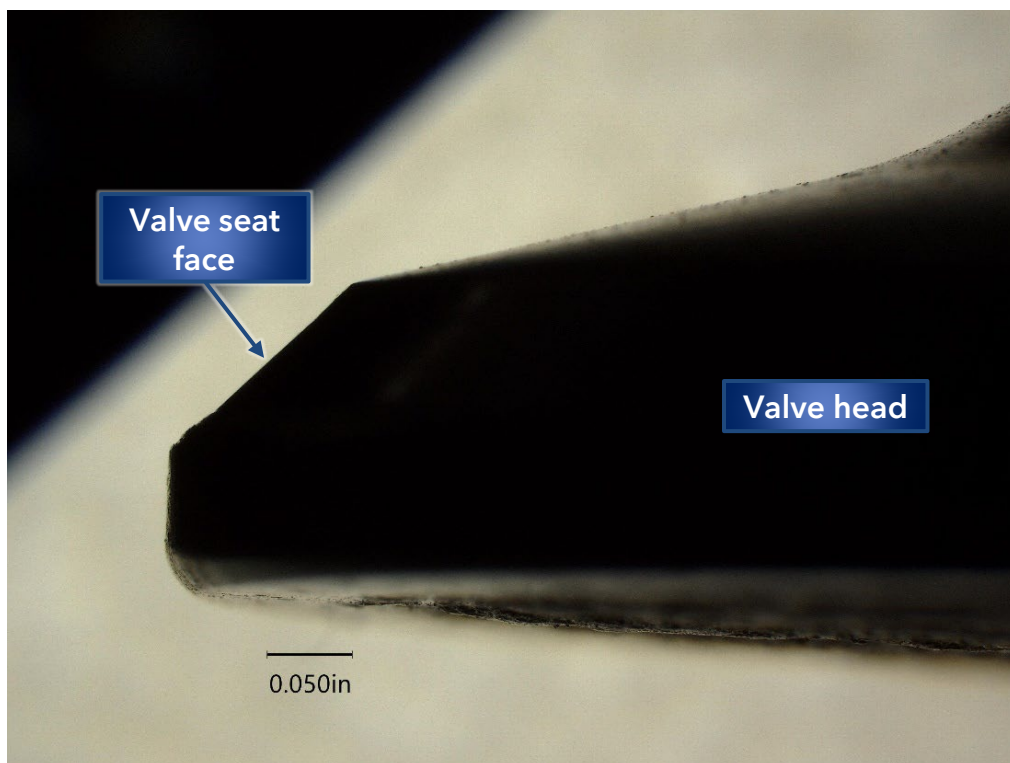


Figure 7. Backlit image of the number 3 cylinder exhaust valve head outer edge.



Figure 8. Valve head faces from the number 3 and number 5 cylinders.



Figure 9. Overall view of the number 5 cylinder intake valve (left image) with a closer view of the tip end face (right image). Longitudinally-oriented dark streaks and galling damage were observed on the stem, and impact marks were observed on the tip end face.

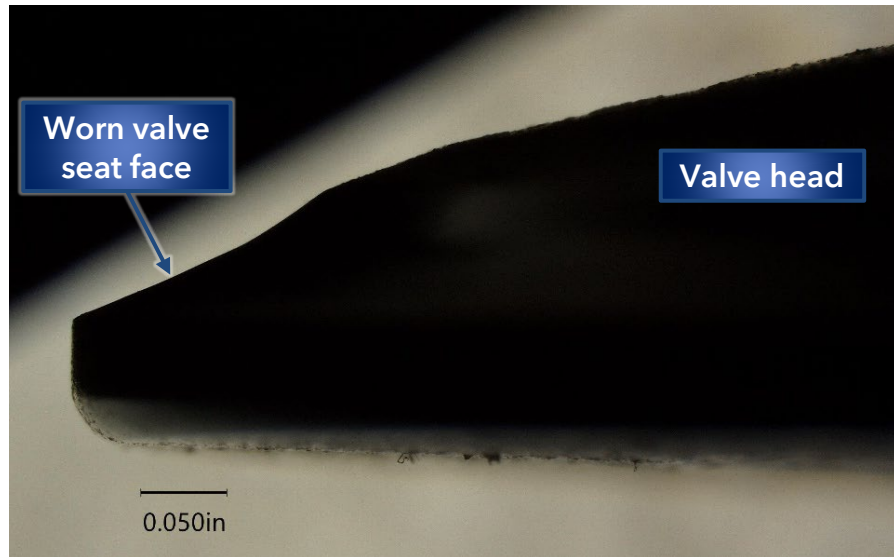


Figure 10. Backlit image of the number 5 cylinder intake valve head outer edge.



Figure 11. Overall view of the number 5 cylinder exhaust valve and rocker arm (lower image) with a closer view of the valve contact pad on the rocker arm (upper image).

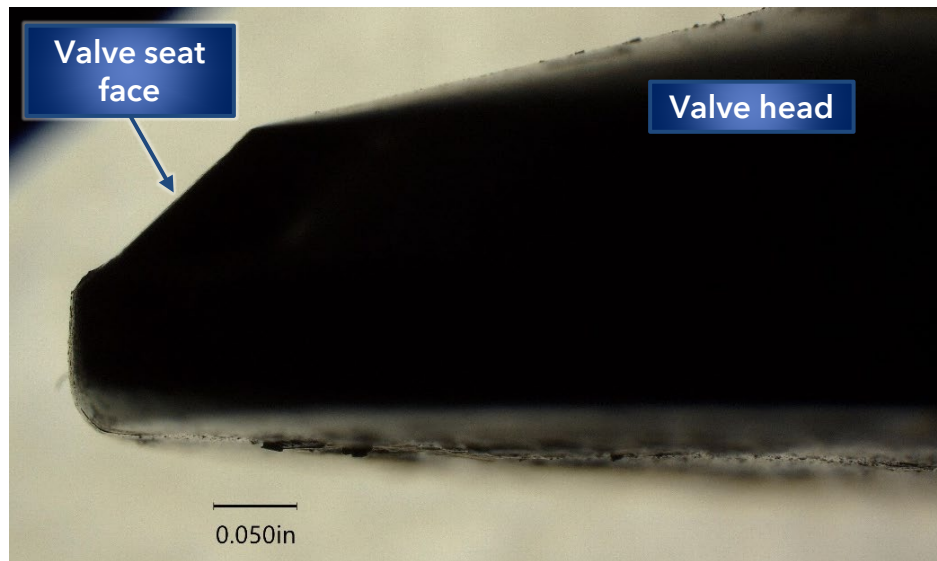


Figure 12. Backlit image of the number 5 cylinder exhaust valve head outer edge.



Figure 13. View of an unlabeled exhaust rocker arm (upper image) with a closer view of the valve contact pad (lower image).



Figure 14. View of an unlabeled exhaust rocker arm (upper image) with a closer view of the valve contact pad (lower image).

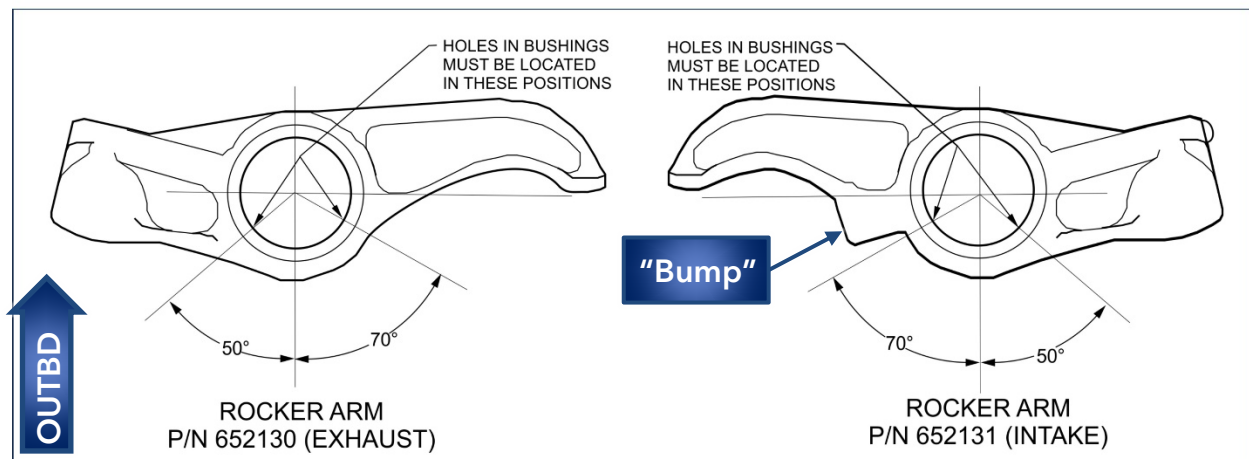


Figure 15. Rocker assembly drawings for the intake and exhaust rocker arms for engines including the Continental IO-550-A, -B, and -C engines as shown in the Continental Standard Practice Maintenance Manual. (Courtesy Continental Aerospace Technologies)



Figure 16. Views of the exhaust rocker arms. Unlabeled arrows point to locations of oil passage holes in the rocker bushings.



Figure 17. Number 1 exhaust rocker arm (upper image), number 5 exhaust rocker arm (middle image), and unlabeled exhaust rocker arm that did not have a “bump” (lower image) after pressing the bushings from the respective rocker bore. A circumferential oil groove was present in the exhaust rocker arm without a bump as indicated in the lower image, and no oil groove was observed in the rocker bore for other exhaust rocker arms including from the number 1 and number 5 cylinders as shown.



Figure 18. Intake rocker arms with unlabeled arrows pointing to oil passage holes in the bushings.



Figure 19. Intake rocker arm with the bushing partially removed. No circumferential oil groove was observed in the rocker bore in 4 of the 6 intake rocker arms including the representative rocker arm shown here.