

NATIONAL TRANSPORTATION SAFETY BOARD

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



June 26, 2015

MATERIALS LABORATORY FACTUAL REPORT

Report No. 15-070

A. ACCIDENT INFORMATION

Place : Greenville, Texas
Date : April 25, 2014
Vehicle : Flight Design GMBH CTLS, N106SF
NTSB No. : CEN14LA226
Investigator : Timothy Sorensen, AS-CEN

B. COMPONENTS EXAMINED

Engine components from a Rotax 912ULS2, s/n 6775304, including the camshaft assembly, #4 piston assembly, #4 cylinder and cylinder head, #4 valves (2) and #4 valve train hardware including hydraulic tappets and all other tappets (8 total). The oil filter and a small sample of the engine oil were also received.

C. DETAILS OF THE EXAMINATION

The received components from the #4 cylinder along with the camshaft are displayed in figure 1. Hydraulic valve tappets are displayed in figure 5.

Initial examinations of these components found the #4 exhaust valve was fractured just above the head. The piston crown and cylinder head dome were severely damaged by impacts consistent with the valve separation, as shown in figure 2. The #4 exhaust tappet was missing the retaining ring with the push rod seat and oil metering plate separate. The cam faces of several tappets showed spalling and the cam face of the #4 was severely worn. The #4 exhaust valve lobe was severely worn and damaged. Other components were unremarkable.

The exhaust valve was fractured through the exposed portion of the stem just above the head as shown in figure 3. The separated head was severely damaged consisted with continued engine rotation after separation. Both fracture faces were also extensively damaged with the stem side face almost entirely obliterated. The head side fracture face, shown in figure 4, was also extensively damaged but showed sufficient features to establish the fracture mode as bending fatigue. Macroscopic beach mark on the fracture indicated fatigue initiation on one side of the stem with progression directly across and through the remaining visible stem cross section. Scanning electron microscope (SEM) viewing found that the beach mark indicated fatigue origin region was obliterated and much of the fine fracture details were also damaged.

All of the hydraulic tappets are displayed in figure 5 in their as-received conditions. The tappets from the #1, #2, #3 cylinders and the intake side of the #4 were received intact and fully assembled. The #2 tappets were not individually identified as to their original positions. The #4 exhaust valve tappet was partially disassembled. As shown in the lower views of figure 5, the plunger cap and metering valve (plate) were separate from the tappet body and the plunger subassembly was displaced and partially exposed. The retaining snap ring was not received. Images from the engine teardown showed a large portion of the snap ring displaced but present in the tappet cavity. No further disassembly of the tappets was reported by the facility tearing down the engine.

Visually, the tappets from cylinders #1, #2 and #3 displayed moderate spalling of the cam faces with the exception of light spalling on the intake side of #1. The cam face of the #4 intake tappet also showed light spalling as seen in the upper right view of figure 7. The exhaust tappet in contrast displayed severe wear in a circular pattern as shown in the left view of figure 7. The wear had reduced the height of the tappet by more than 5 mm compared to the intake tappet as displayed in the lower view of figure 7. The intake tappet measured nominally 50.43 mm while the exhaust tappet measured nominally 45.22 mm.

When the tappets were disassembled, the disc (yellow in illustration) in the plunger check valve assembly of the #4 exhaust tappet was missing as shown in the upper view of figure 8. The disc was present in the #4 intake tappet shown in the lower view of figure 8 and in all other tappet as seen in figure 9.

Hardness measurements on the cam face of the #4 intake tappet averaged 59.12 HRC. Measurements on the cam face of the #4 exhaust tappet averaged 55.15 HRC. The engineering drawing specified a minimum cam face hardness of 55 HRC measured 1.54 mm off center.

The cam lobes for the #3 and #4 exhaust valves are displayed in figure 10. The #4 lobe was severely damaged with large spalls visible on both the opening and closing sides. The total lift of the lobe was also reduced, compared to other lobes, by about 0.6 mm.

The oil filter was cut apart and the filter paper removed as shown in figure 11. Residual oil in the filter cup and on the filter paper was heavily contaminated with metallic appearing particles. A sample of the particles was removed and washed in toluene and filtered. Visually the particles appeared as fine flakes of metal of various sizes as shown in the upper view of figure 12. A small portion, see lower view of figure 12, was analyzed by energy dispersive spectroscopy and was found to be iron base materials consistent with the material of the #4 tappet.

Joe Epperson
Senior Metallurgist

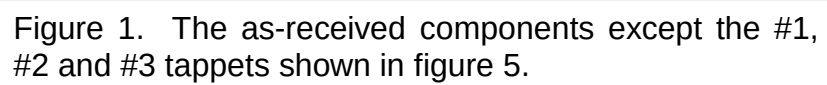




Figure 2. Views showing the impact damage to the cylinder crown and piston top.



Figure 3. At left, the intake and fractured exhaust valves. A closer side view of the fractured area of the exhaust valve is shown below.



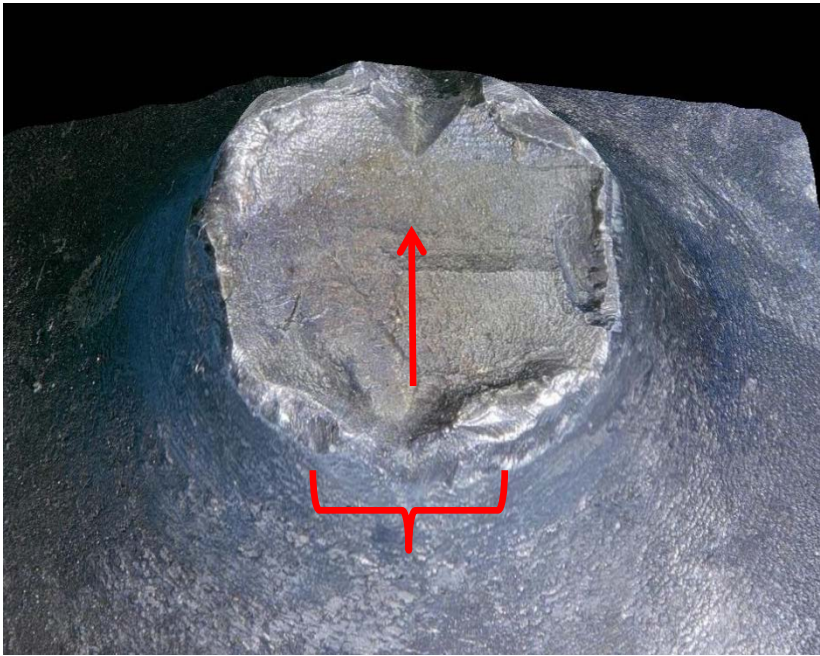
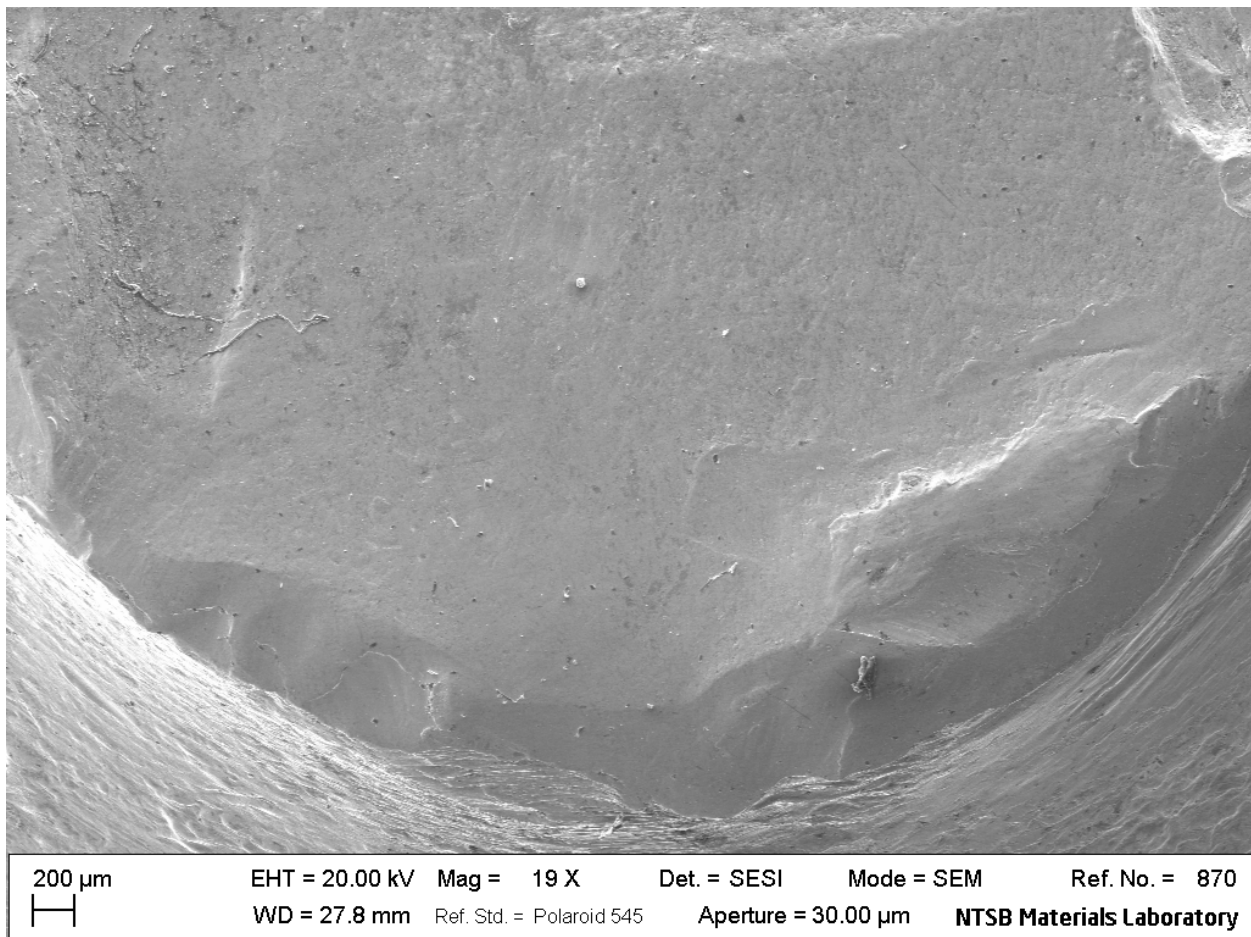


Figure 4. An optical view of the fatigue fracture of the exhaust valve, at left, with the damaged origin area denoted by the red bracket and progression direction indicated by the red arrow. An SEM view of the fatigue origin area, below, showing the extensive macro and microscopic damage.



200 μ m
H

EHT = 20.00 kV

Mag = 19 X

Det. = SESI

Mode = SEM

Ref. No. = 870

WD = 27.8 mm

Ref. Std. = Polaroid 545

Aperture = 30.00 μ m

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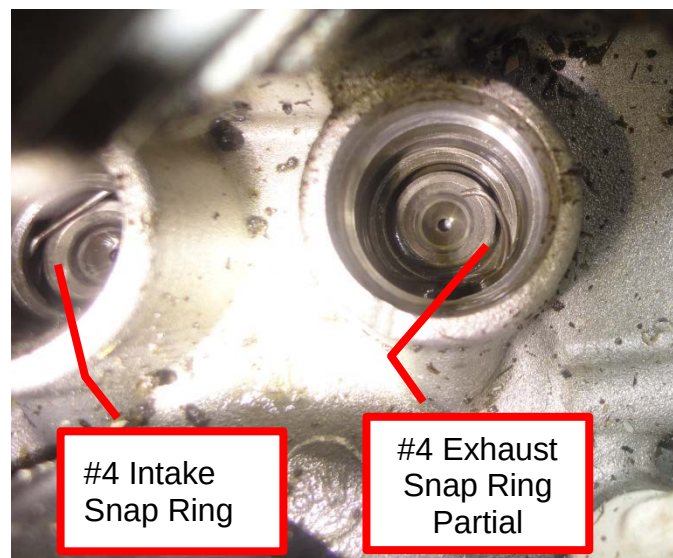
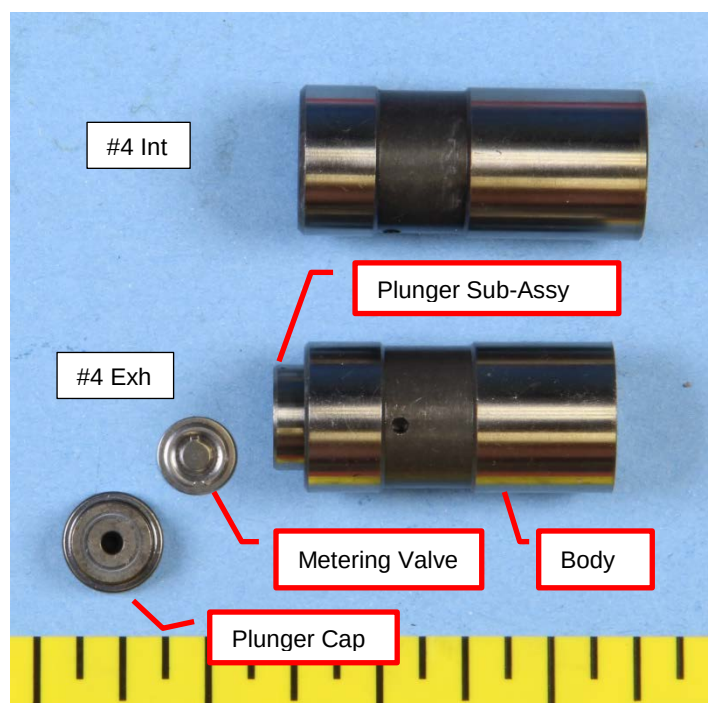
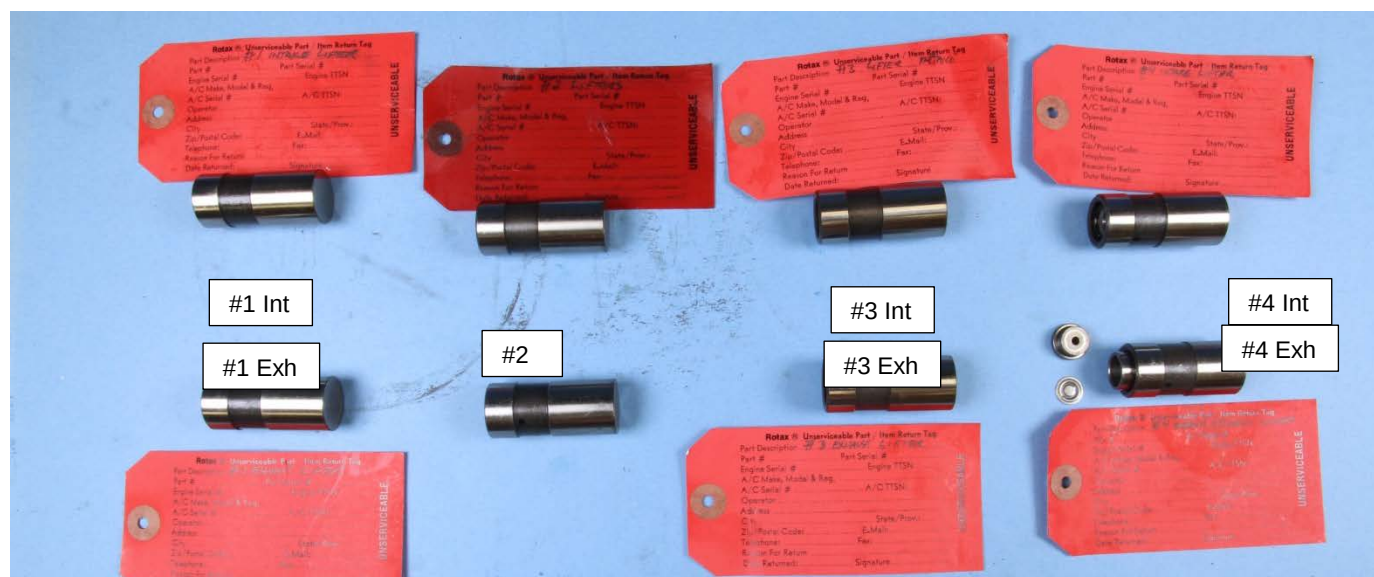
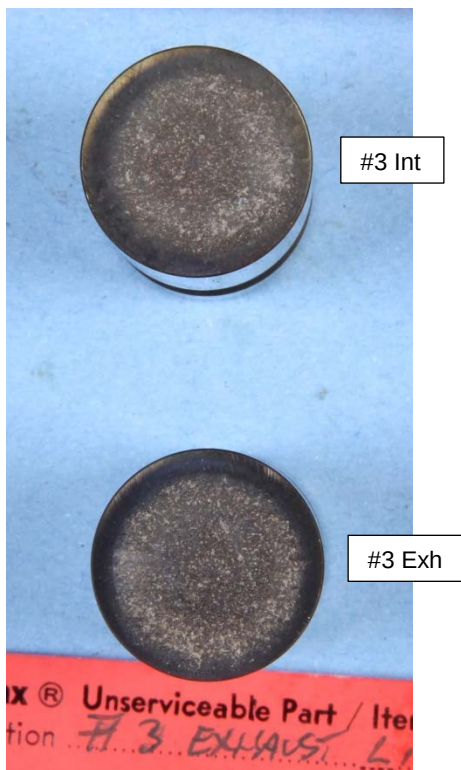


Figure 5. The as-received tappets at top. The #4 cylinder tappets are at left with sub-components labeled. At right, images (from teardown) showing the dislodged partial snap ring in the exhaust tappet and the in-place full snap ring in the intake tappet.



Figure 6. Views of the cam faces of the tappets showing various amounts and types of damage.



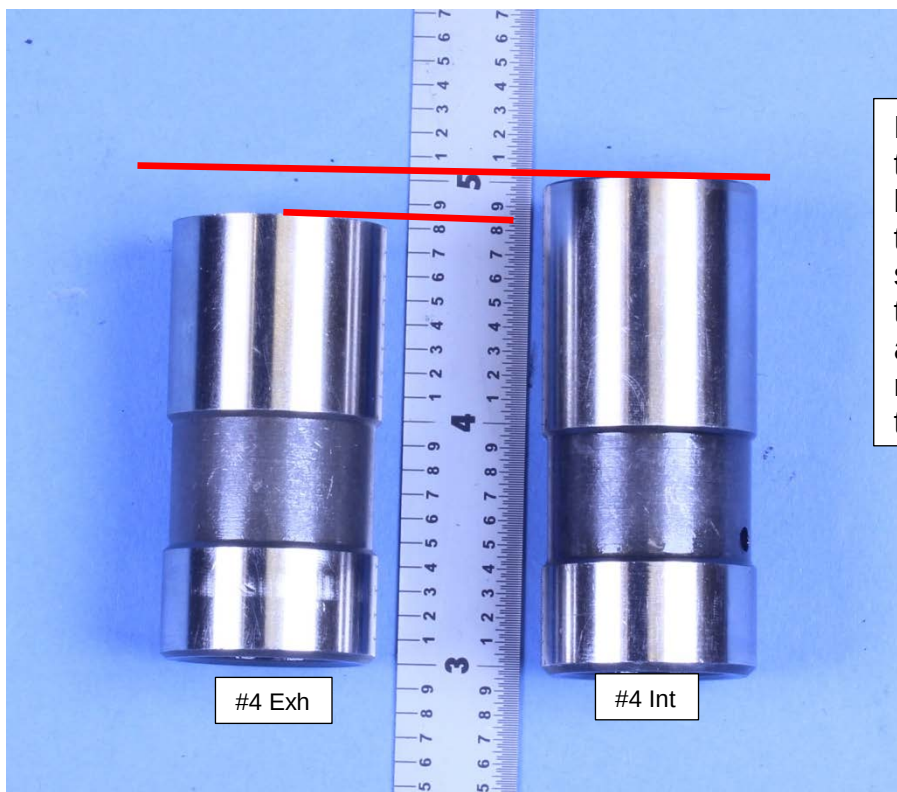


Figure 7. Closer views (top) of the cam faces of the #4 tappets, heavy circular wear pattern on the exhaust tappet and light surface spalling on the intake tappet. Left view illustrates the amount of wear and material removed from the exhaust tappet.

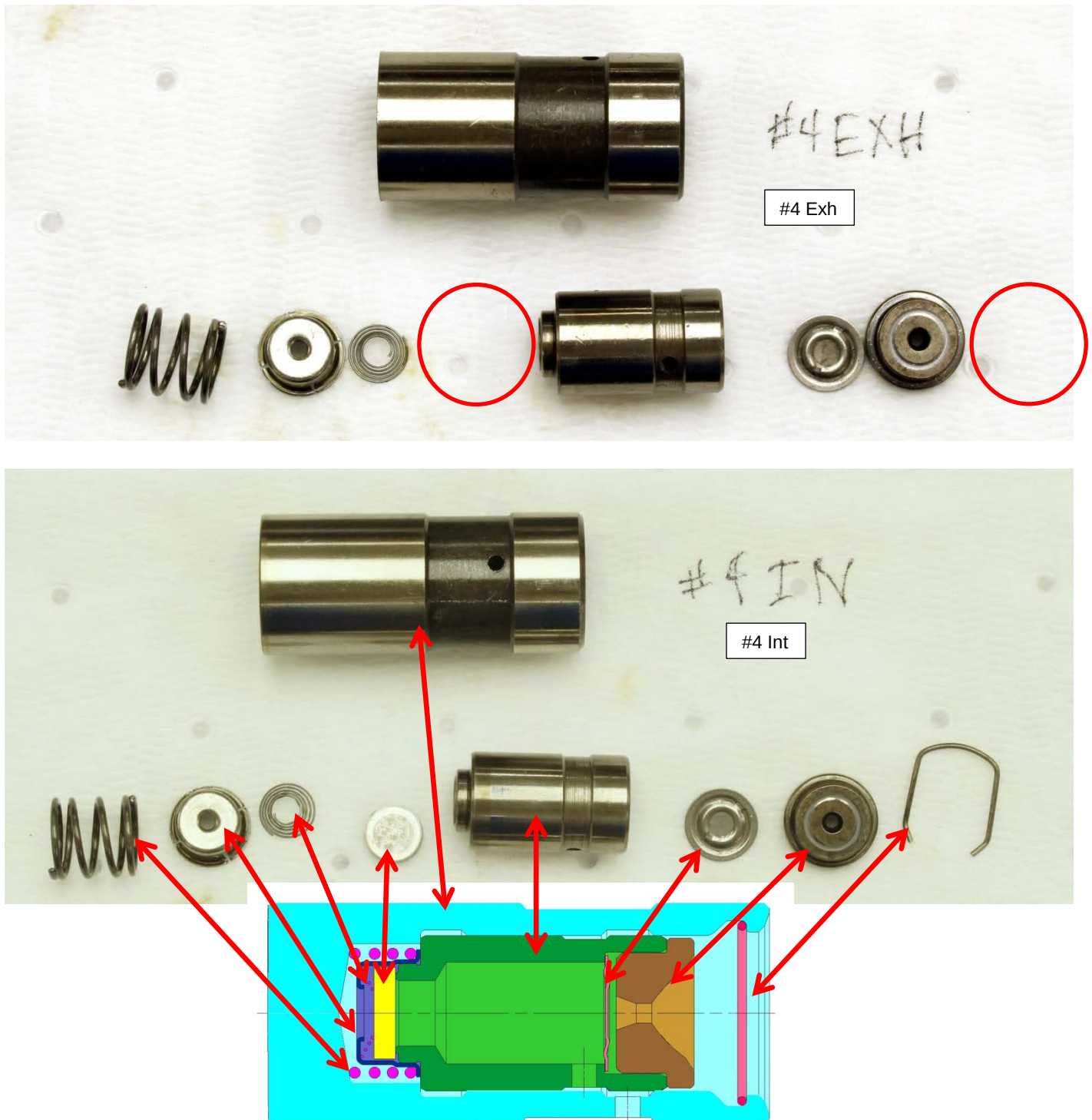


Figure 8. Views of the disassembled #4 exhaust valve tappet (top) showing the missing components (red circles) and the #4 intake valve tappet (middle). A cross sectional illustration is shown at the bottom with arrows to the related component of the intake tappet. Components from the left to right are: plunger spring, check valve cap, check valve spring, check valve disc, tappet body, plunger, metering valve, plunger cap and snap ring.

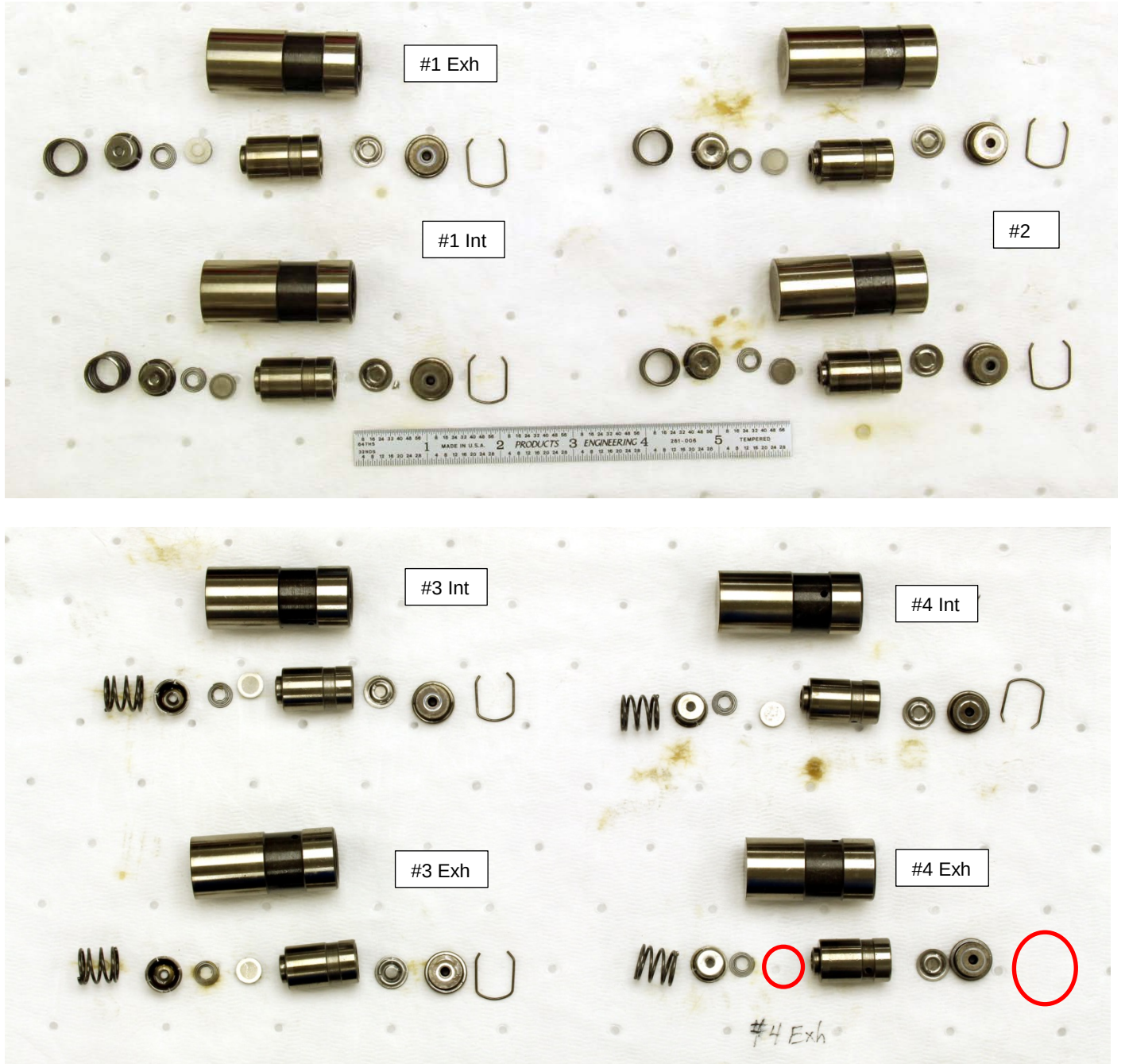


Figure 9. All disassembled tappets. Red circles denote missing components.

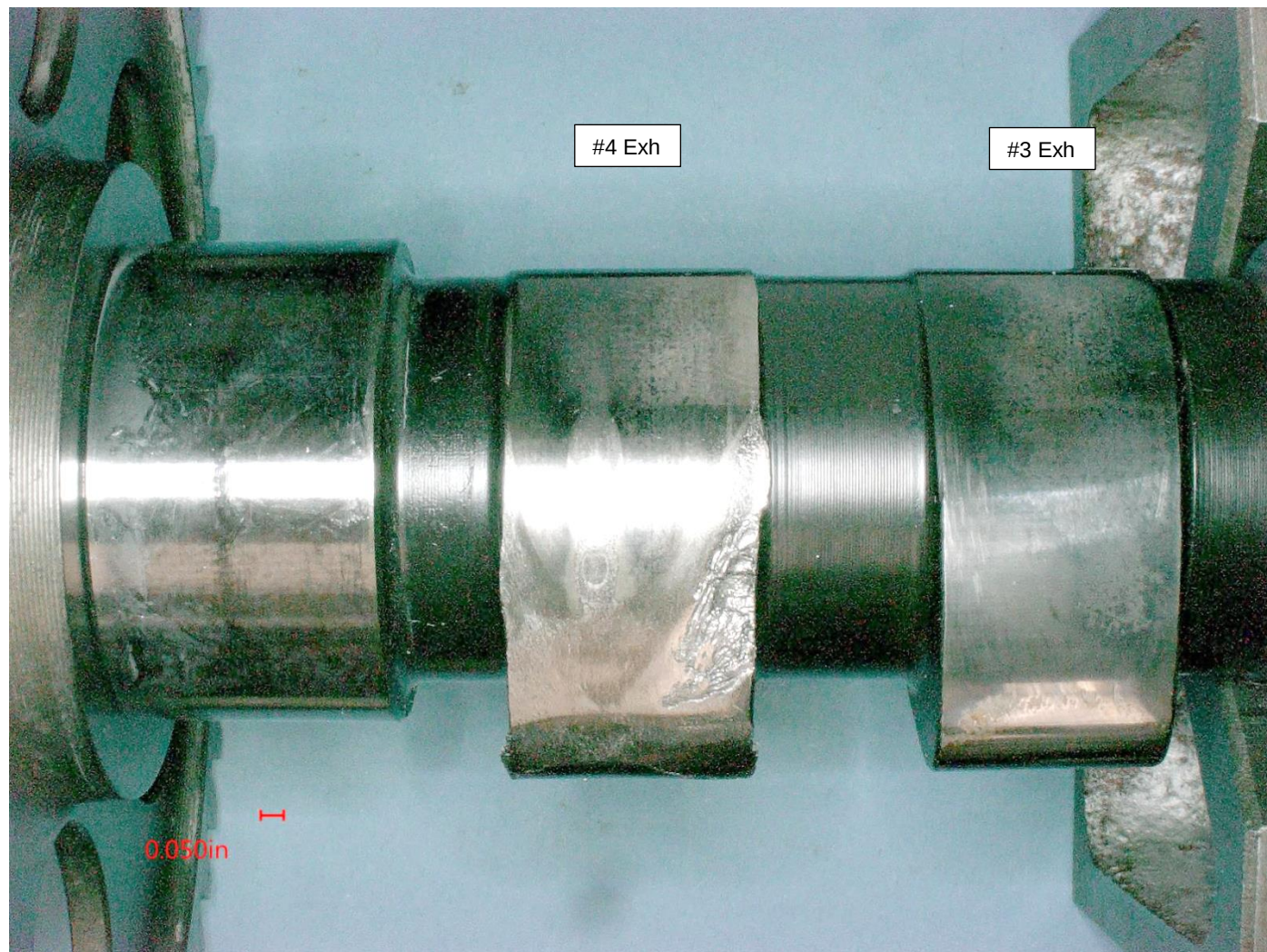


Figure 10. A view of the #4 exhaust cam lobe showing damage.

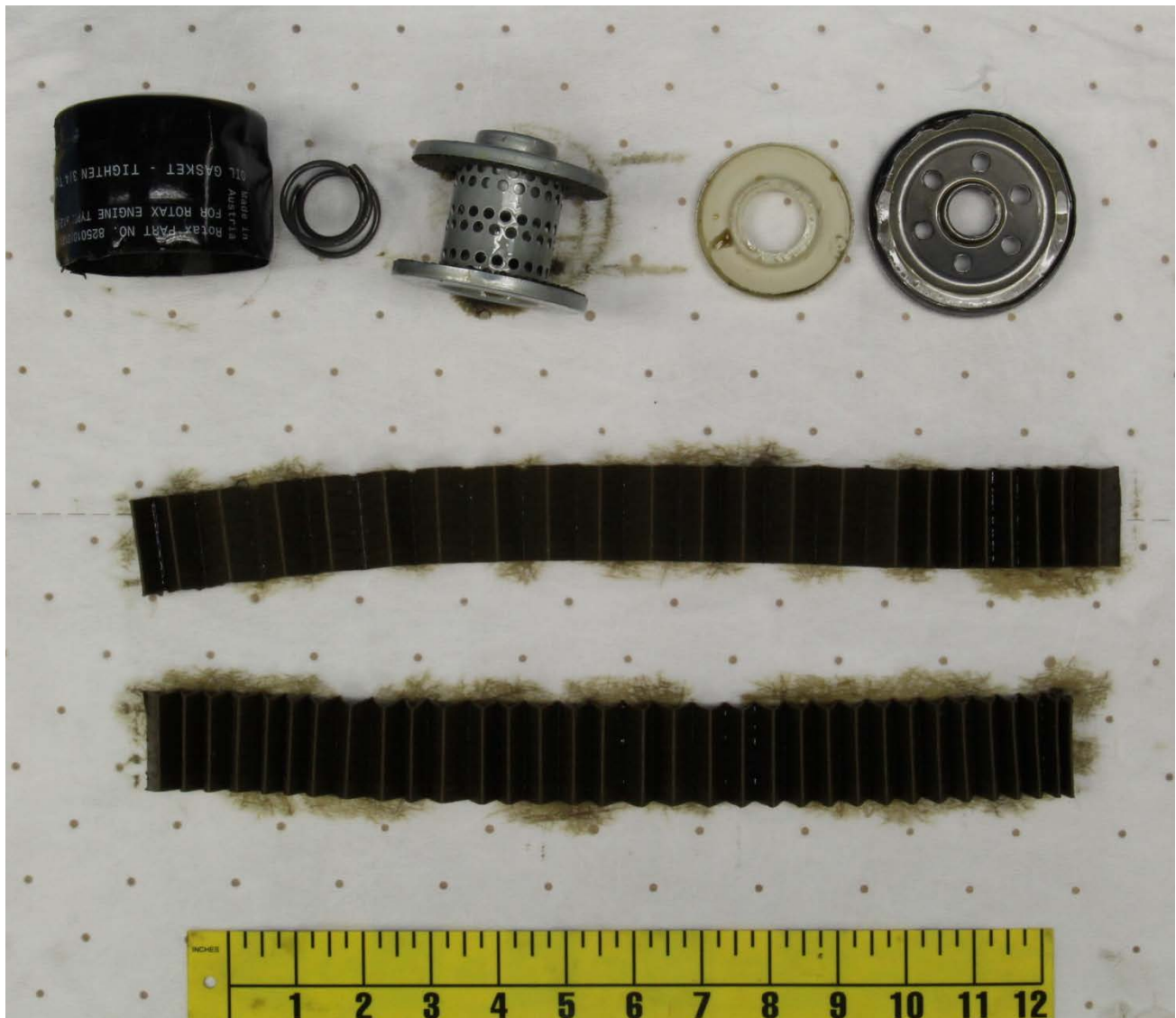


Figure 11. The disassembled oil filter with the filter paper removed and expanded.

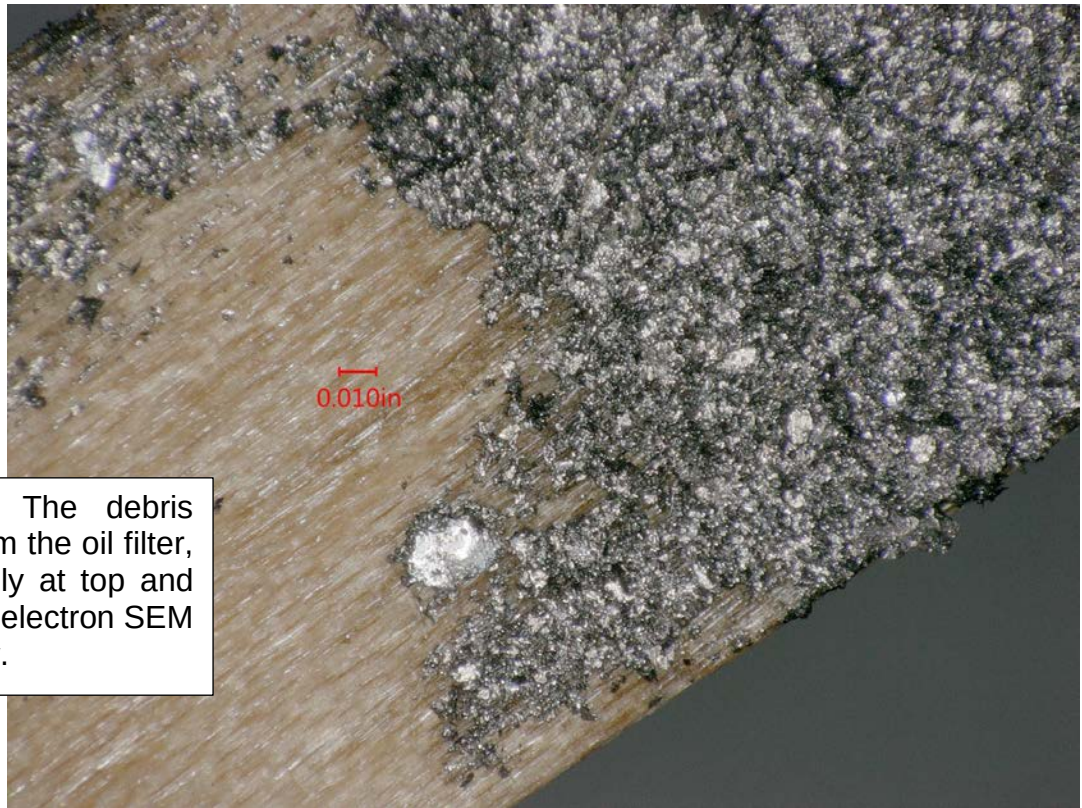
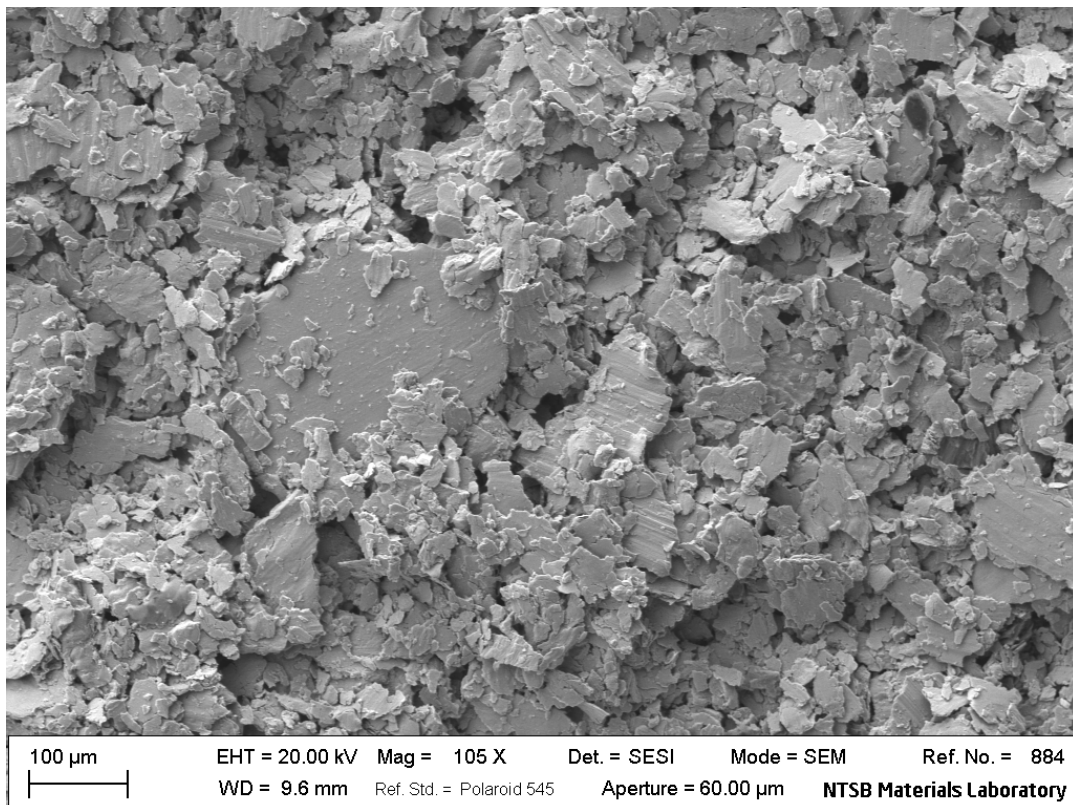


Figure 12. The debris recovered from the oil filter, shown optically at top and by secondary electron SEM viewing below.



100 μm

EHT = 20.00 kV

Mag = 105 X

Det. = SESI

Mode = SEM

Ref. No. = 884

WD = 9.6 mm

Ref. Std. = Polaroid 545

Aperture = 60.00 μm

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