NATIONAL TRANSPORTATION SAFETY BOARD
Office of Research and Engineering
Materials Laboratory Division
Washington, D.C. 20594

September 22, 2009

MATERIALS LABORATORY FACTUAL REPORT Report No. 09-019

A. ACCIDENT

Place	:	Weaverville, California
Date	:	August 5, 2008
Vehicle	:	Sikorsky S-61N
NTSB No.	:	LAX08PA259
Investigator	:	Mike Hauf (AS-40)

B. COMPONENTS EXAMINED

Number 1 engine flow divider
Number 1 engine flow divider block
Number 1 engine pilot valve assembly
Number 2 engine flow divider
Number 2 engine pilot valve assembly

C. DETAILS OF THE EXAMINATION

The components were received by the Materials Laboratory in the condition shown in figures 1 and 2. The Number 1 engine flow divider and flow divider block are shown in figure 1a. The Number 2 engine flow divider is shown in figure 1b. Multiple fittings were attached to both flow dividers and insulated hoses were still attached to the Number 1 engine flow divider. The Number 1 and Number 2 engine pilot valve assemblies are shown in figures 2a and 2b respectively. The spring and piston were still attached to the Number 1 pilot valve assembly, while the Number 2 pilot valve had been partially disassembled and the piston already extracted. Charred residue was observed at the fuel return openings at the back of the pilot valve assembly housings.

C.1. FLOW DIVIDER AND FLOW DIVIDER BLOCK EXAMINATION

Each flow divider was held in a vice as-required to loosen fittings with a wrench, followed by disassembly over blue poster board. A fiber optic light was used to check for obstructions in elbows and other fittings that could not be inspected visually from end to end. Photographs of the disassembled Number 1 engine flow divider and Number 2 engine flow divider are shown in figures 3a and 3b, respectively. A photograph of the disassembled Number 1 engine flow divider block is shown in figure 4.

The o-rings and seals in both flow dividers were brittle and crumbled into small pieces during disassembly, a few pieces of which can be seen in figure 3b. There was a thin layer of charred residue at some of the fittings. Light from the fiber optic source was visible through all 90° elbow fittings, consistent with an open flow path. There were no signs of hard particulates, such as sand, metallic debris, or fibrous debris. The threads on one of the number 2 flow divider fittings seized while attempting to extract the fitting. Eventually the fitting itself sheared in half as indicated in figure 3b.

There were no signs of hard particulates on the Number 1 engine flow divider block. A brittle fragment of o-ring material had fallen into one of the ports on the block. Threads on a reducing coupler attached to the Number 1 engine flow divider block seized during removal, stripping the threads as indicated in figure 4. There were no obstructions in the 45° elbow or the reducing coupler.

C.2. PILOT VALVE EXAMINATION

The Number 1 engine pilot valve was disassembled as shown in figure 5. The piston would not slide out freely and was extracted from the sleeve with needle-nose pliers by pulling and using a back-and-forth twisting motion about the longitudinal axis. After the plug was removed, the sleeve slid freely out of the opposite end of the assembly. The o-rings were brittle, crumbled, and some were partially burned. A side view of the sleeve and piston is shown in figure 6. The stem and rectangular regions on the left and right piston valves had a dark brown/blue discoloration consistent with exposure to heat. The size and shape of the dark rectangular regions were consistent with the dimensions of the stator vane actuator ports on the sleeve.

The inner bore of the sleeve appeared smooth with regions of brown/blue discoloration, occasional fine longitudinal wear marks, and marks resulting from the disassembly process. A typical micrograph at the right end of the sleeve inner bore is shown in figure 7. Fine longitudinal wear marks were observed near the stator vane actuator port. Further down the sleeve were helical scratch marks consistent with the motion used to extract the piston. Occasional fine black residual particles of unknown origin were observed on the inner bore as indicated in figure 7. There was no resolvable metallic debris or fibrous debris.

The surface finish on the piston valves was marred by a small deformed region along the right valve edge, occasional fine longitudinal wear marks, and marks resulting from the disassembly process. Micrographs of the right and left port piston valves are shown in figures 8a and 8b, respectively. A deformed spot on the edge of the right valve is indicated in figure 8a. It measured 0.007 inch across. An examination of the inner bore of the sleeve did not find conclusive evidence of a corresponding mark. Fine longitudinal wear marks, indicated in 8a, were observed near a discolored rectangular region on the piston valve, believed to coincide with the location of a sleeve port. Markings on the left valve, indicated in figure 7b, had a metallic color and tracked across the surface at arbitrary

angles, consistent with formation after exposure to heat and after disassembly of the piston.

The deformed region along the edge of the right piston valve was examined by scanning electron microscopy (SEM). A backscatter electron detector operating in composition mode was used to discriminate between high and low atomic mass density regions. A higher magnification micrograph of the deformed edge in the same orientation as figure 8a is shown in figure 9. A raised edge of plastically deformed material surrounded an indentation. Small low atomic mass density particles in the 2 µm to 10 µm size range and formless low atomic mass density debris were observed in the indentation. Energy dispersive spectroscopy (EDS) was used to characterize the debris in the indentation. EDS spectra from five particles are shown in figures 10 a-e and the corresponding particles are labeled in figure 9. All five particles had a different composition. Detected elements consisted primarily of silicon, aluminum, carbon, oxygen, magnesium, and potassium.

The Number 2 engine pilot valve was disassembled as shown in figure 11. The piston had already been extracted from the sleeve in its as-received state and could be inserted and removed from the sleeve by hand. After the plug was removed, the sleeve would not slide out of the assembly. The sleeve was extracted from the housing by heating the assembly in an oven to 175 °C for 15 min, placing it in a vice, pressing a flat end punch against the back of the sleeve and tapping it out of the housing. The pressure of the vice caused some deformation to the housing. The o-rings were brittle, crumbled, and some were partially burned. A side view of the sleeve and piston is shown in figure 12. Metal transfer from the manual extraction process was observed on the outer diameter of the sleeve. The stem and rectangular regions on the left and right piston valves had a dark brown/blue discoloration consistent with exposure to heat. The size and shape of the dark rectangular regions were consistent with the dimensions of the stator vane actuator ports on the sleeve.

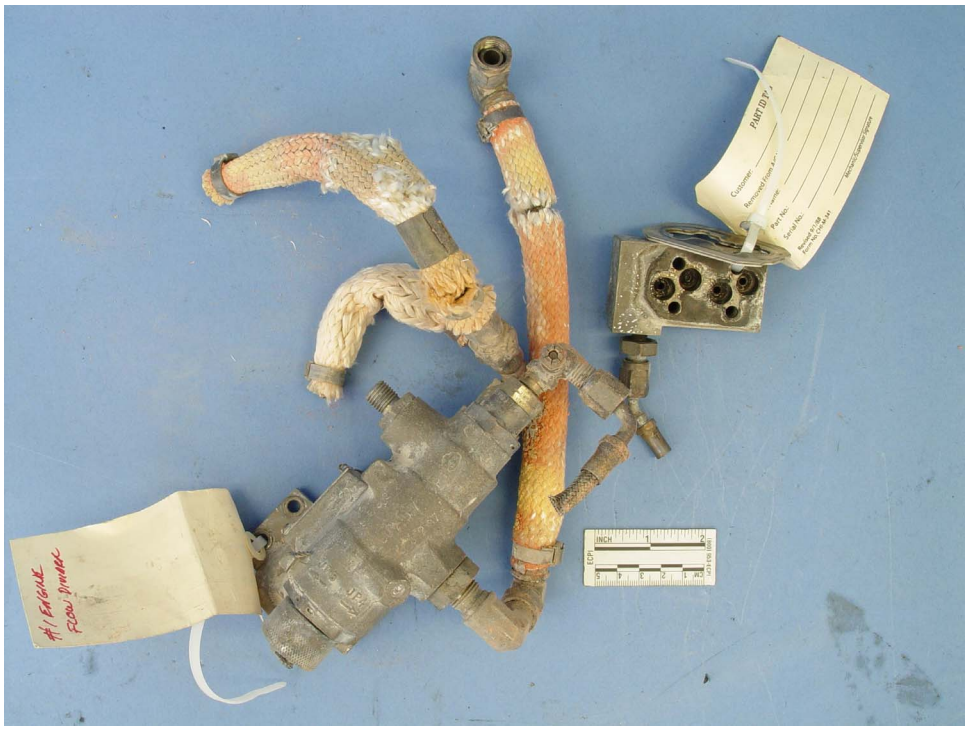
The inner bore of the sleeve appeared smooth with regions of brown/blue discoloration, occasional fine longitudinal wear marks, and marks resulting from the disassembly process. Fine longitudinal wear marks could be seen near the right stator vane actuator port as shown in figure 13a. Further down the bore were wear marks shown in figure 13b that had a metallic color, consistent with formation after exposure to heat. Occasional fine residual particles of unknown origin were observed on the inner bore of the sleeve similar to the sleeve in the Number 1 engine pilot valve. There was no resolvable metallic debris or fibrous debris.

The surface finish on the piston valves was marred by occasional fine longitudinal wear marks and marks resulting from the disassembly process. Micrographs of the right and left port piston valves are shown in figures 14a and 14b, respectively. Examples of typical fine wear marks are indicated in figures 14a and 14b. Other marks on the valves

had a metallic color and tracked across the surface at arbitrary angles as indicated, consistent with formation after exposure to heat and after disassembly of the piston.

Donald Kramer
Materials Engineer

a)



b)

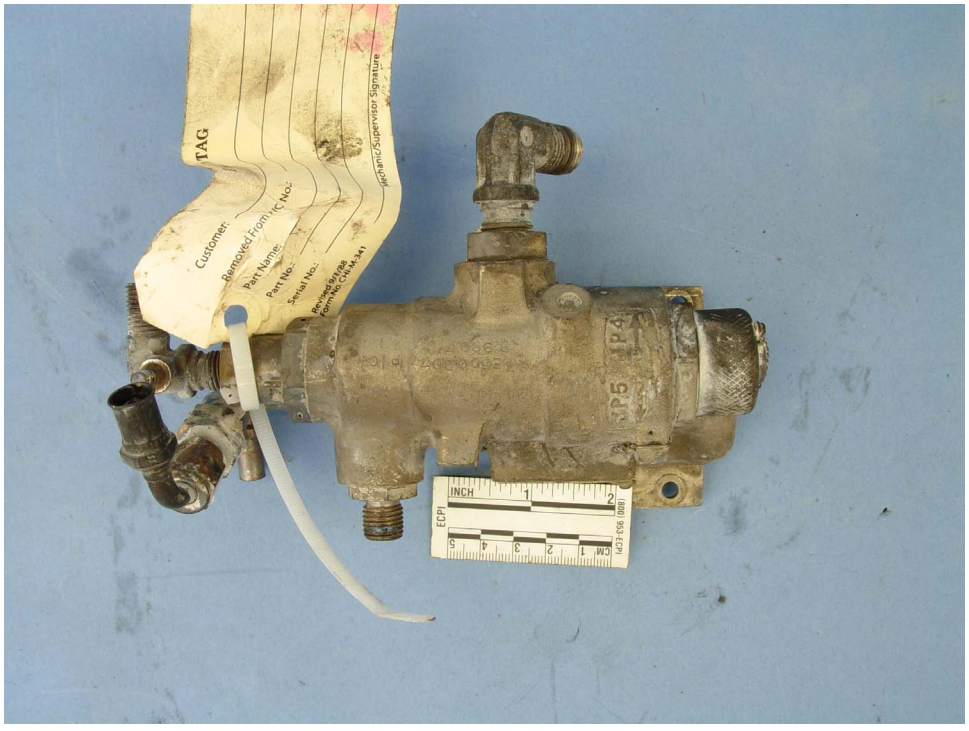


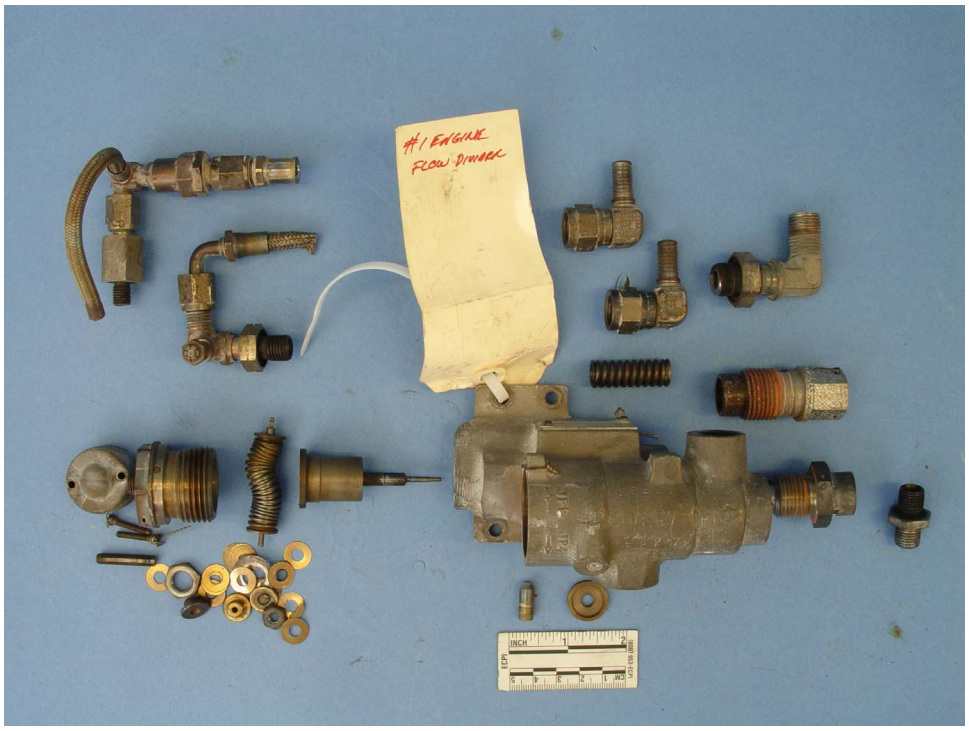
Figure 1: a) Number 1 engine flow divider and flow divider block as-received and b) Number 2 engine flow divider as-received.

a)

b)

Figure 2: a) Number 1 engine pilot valve assembly as-received and b) Number 2 engine pilot valve assembly as-received.

a)



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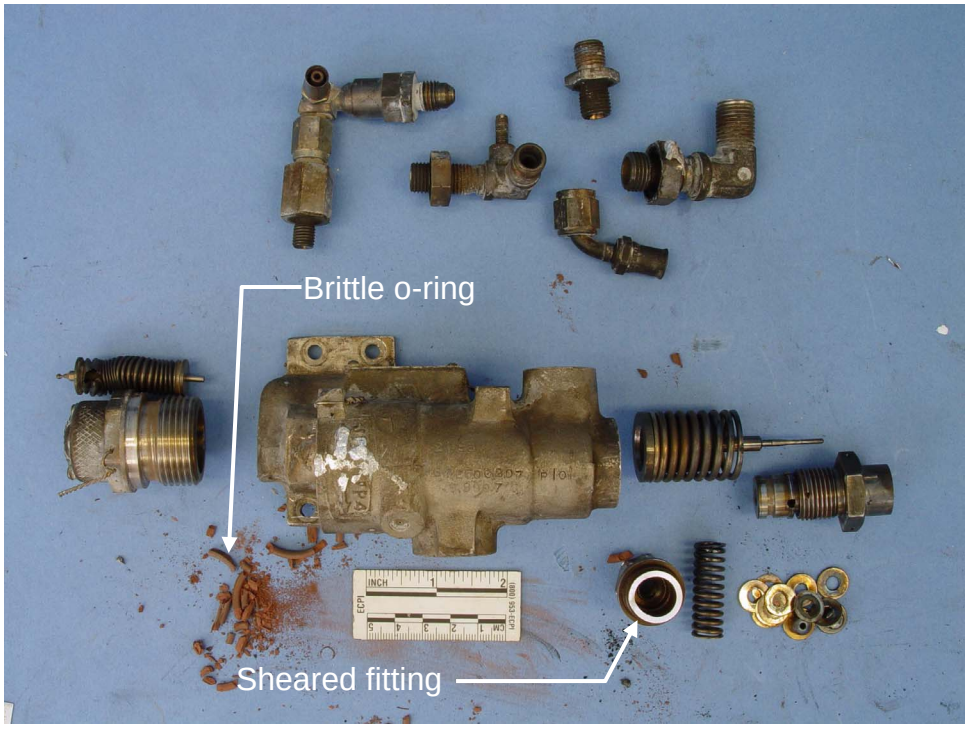


Figure 3: Photographs of flow dividers after disassembly; a) Number 1 engine flow divider; and b) Number 2 engine flow divider.

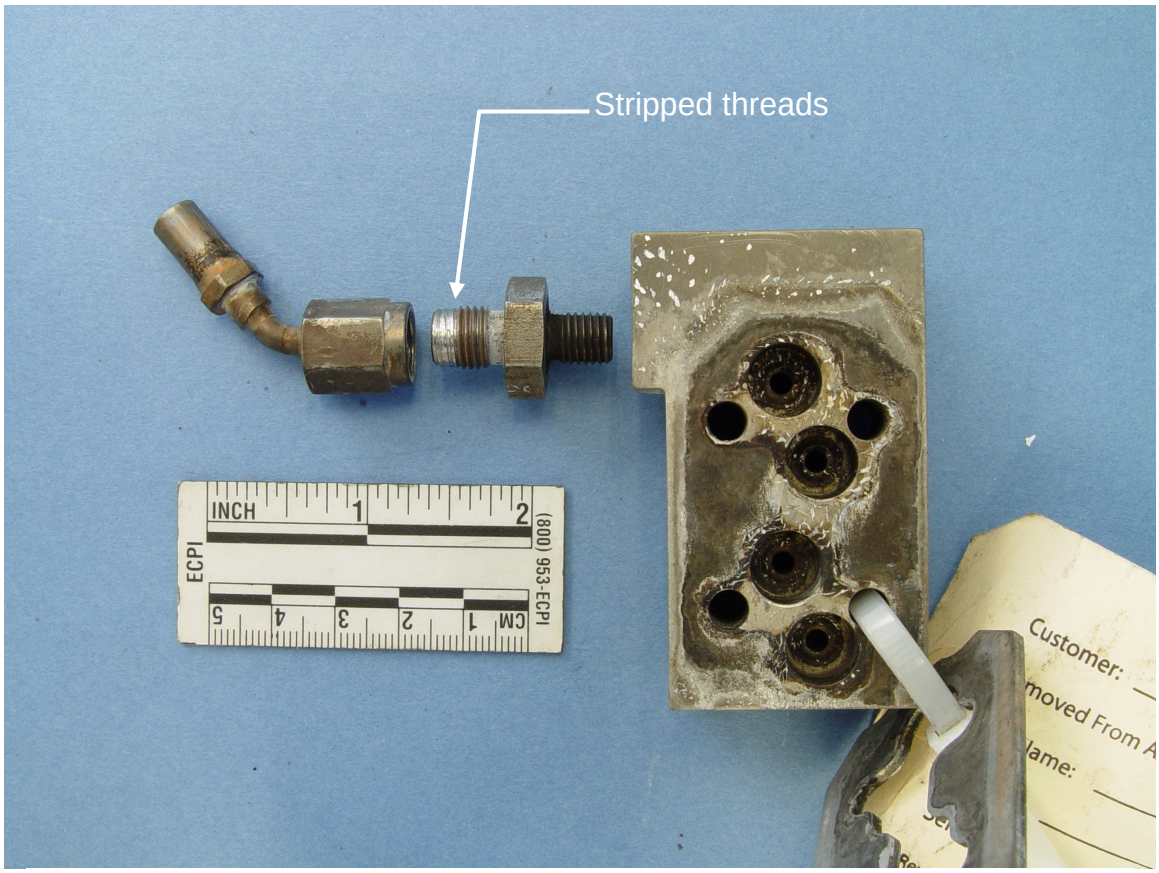


Figure 4: Number 1 engine flow divider block after disassembly.

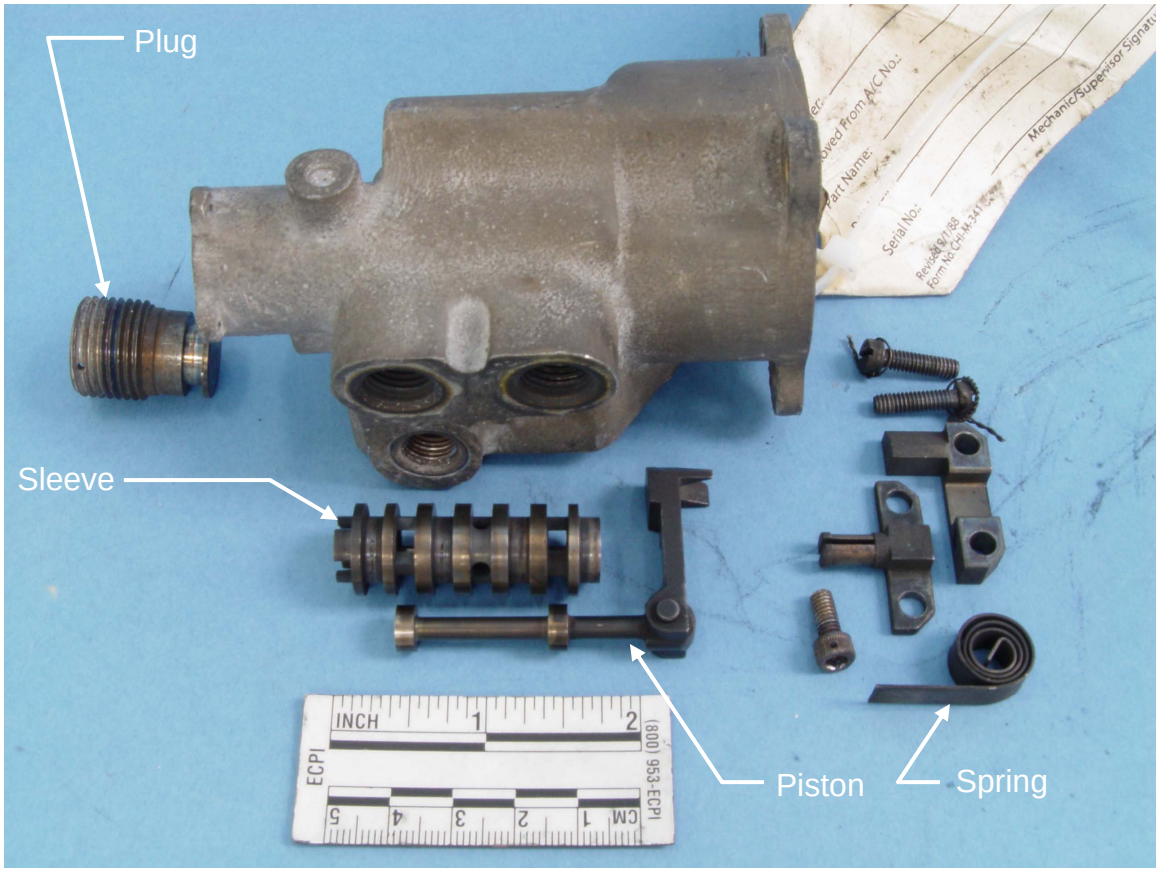


Figure 5: Number 1 engine pilot valve assembly after disassembly.

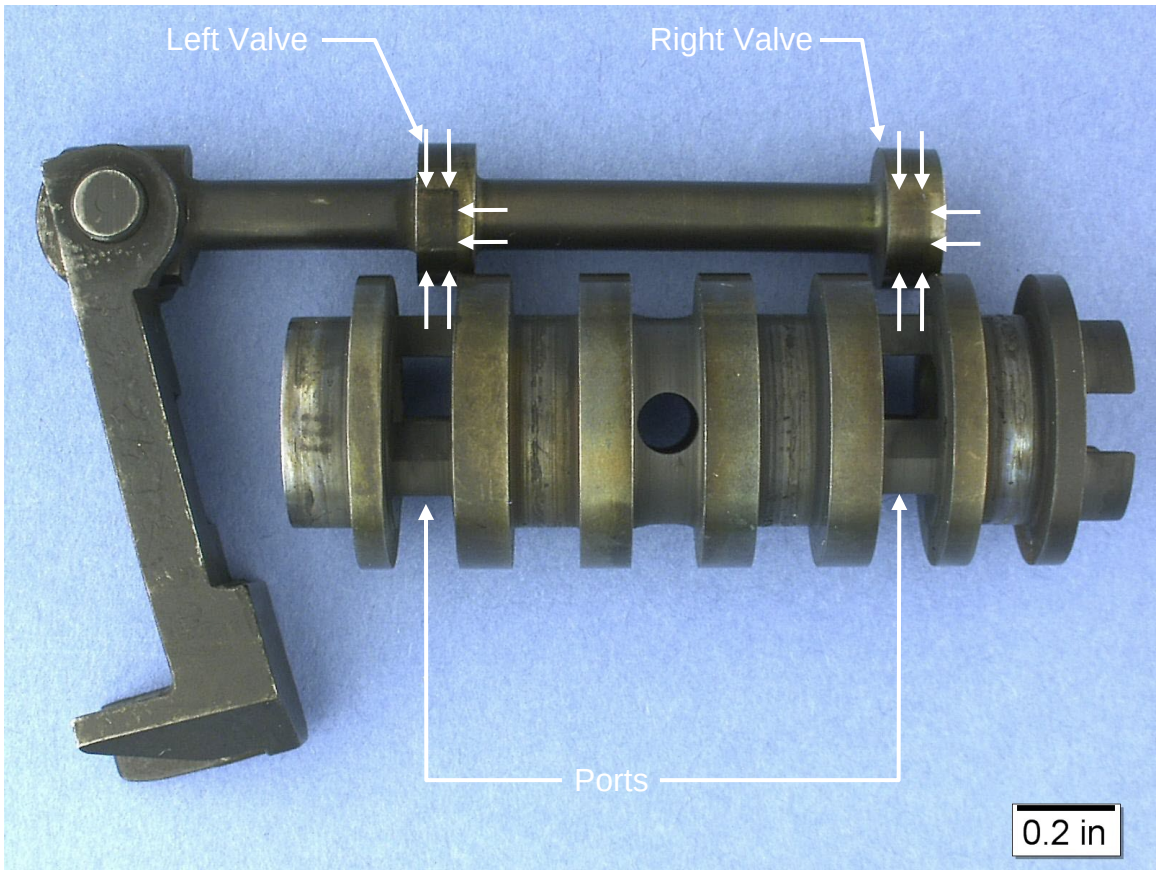


Figure 6: Photograph of the piston and sleeve from the Number 1 engine pilot valve. The valves on the piston have dark rectangular regions indicated by short arrows that are similar in size and shape to the stator vane actuator ports on the sleeve.

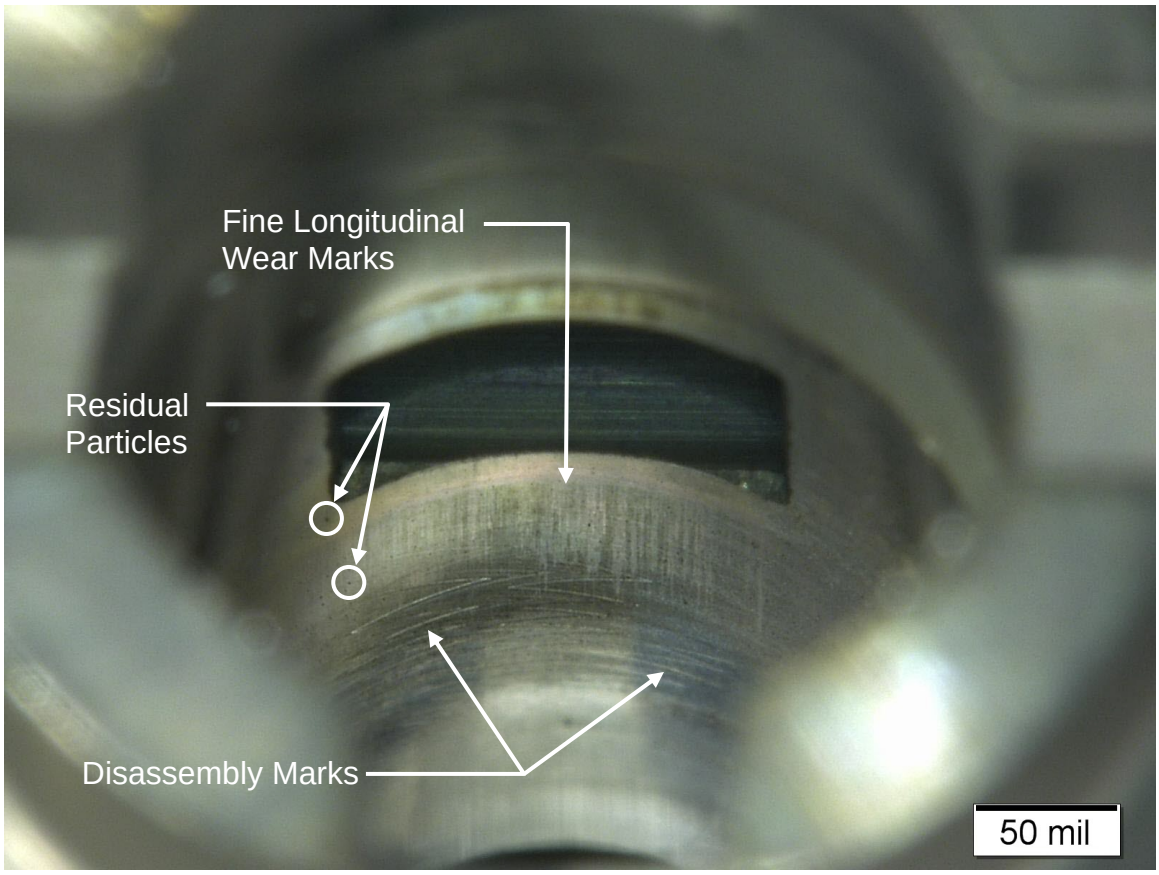
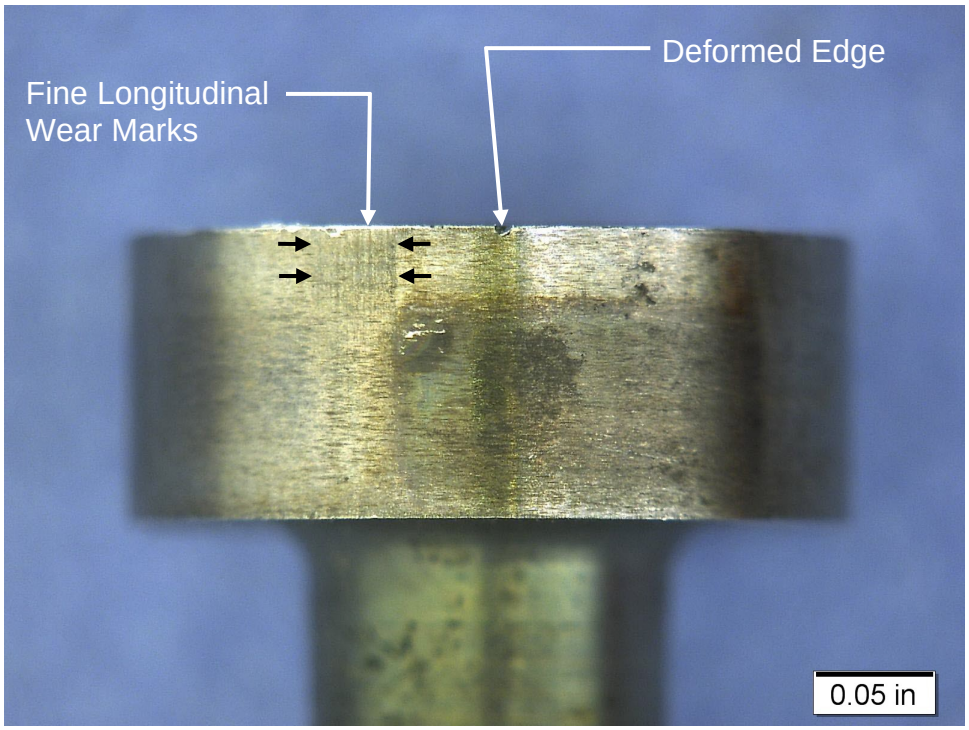


Figure 7: Micrograph of the Number 1 engine pilot valve sleeve inner cylinder. The micrograph was taken at the right end of the sleeve.

a)



b)

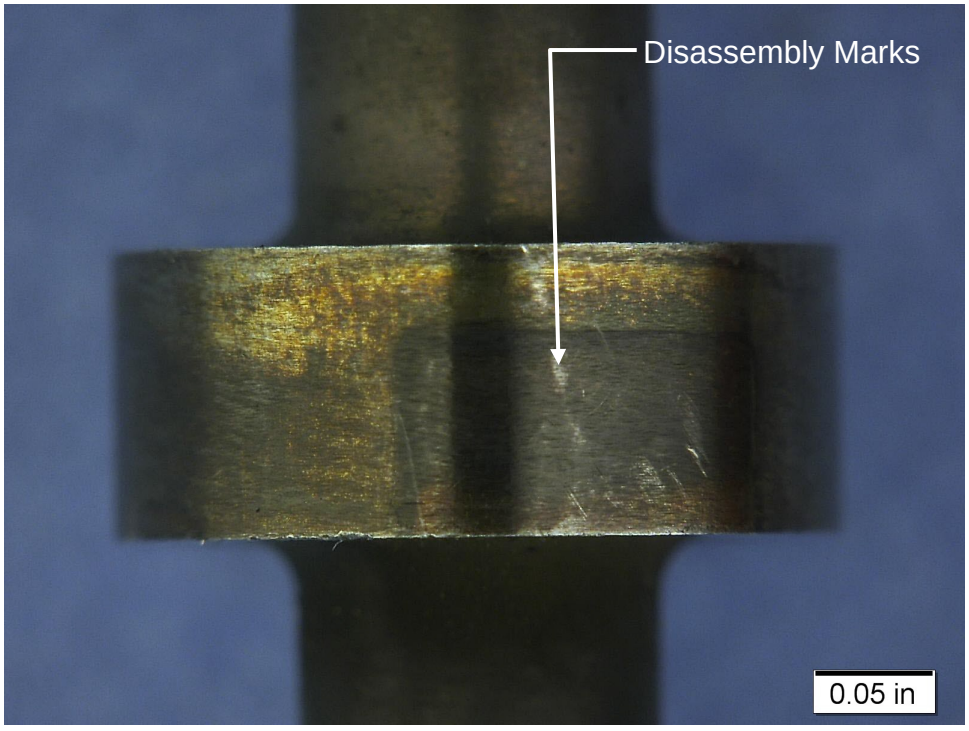


Figure 8: Micrographs of the piston from the Number 1 engine pilot valve assembly; a) right piston valve and b) left piston valve (see Figure 6).

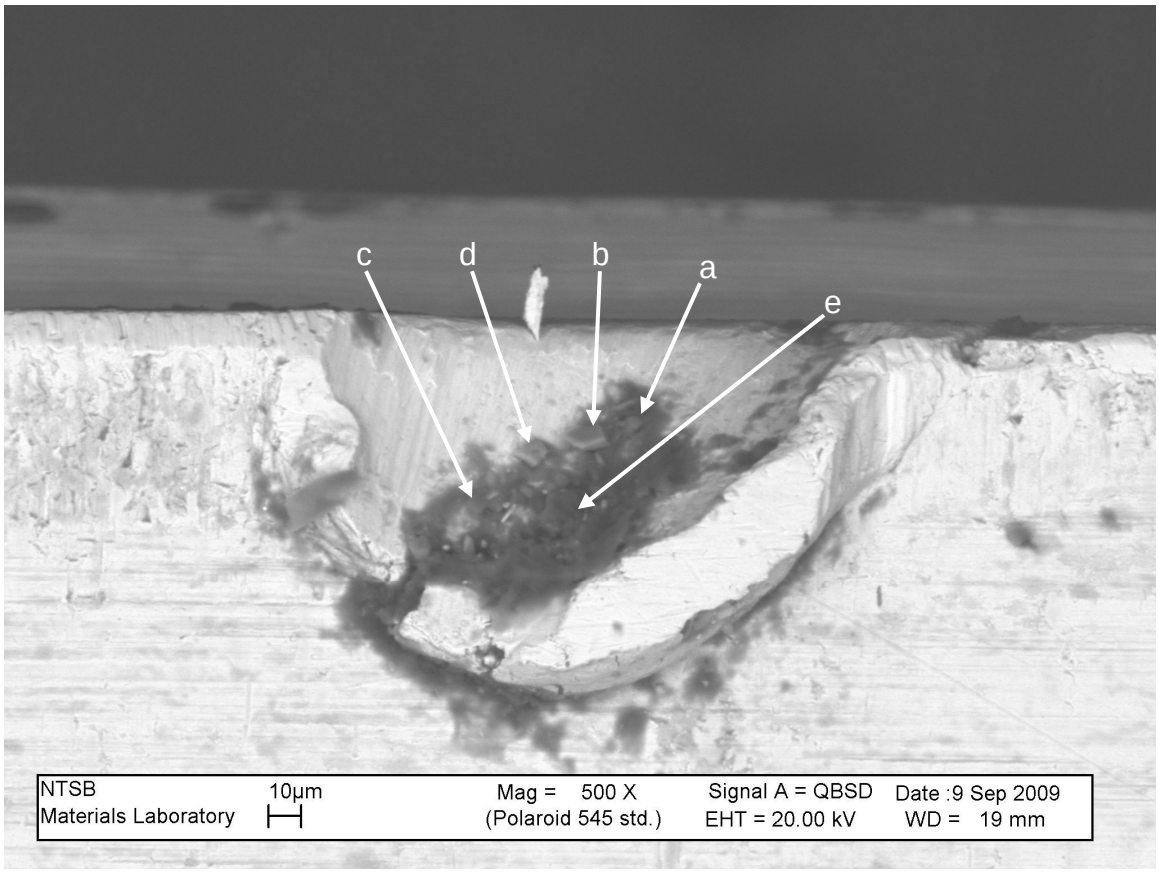
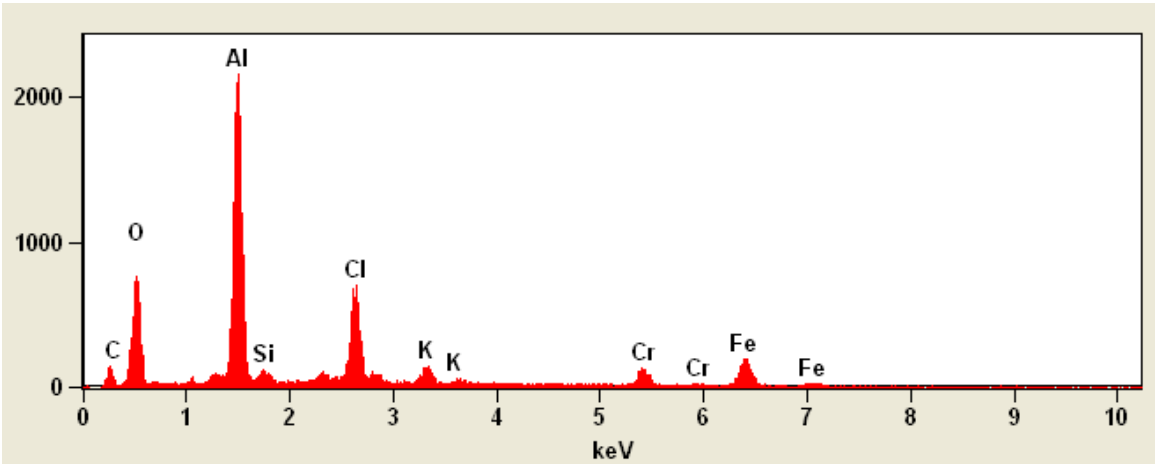


Figure 9: Backscatter electron micrograph of the deformed edge region on the Number 1 engine pilot valve piston indicated in figure 8a.

a)



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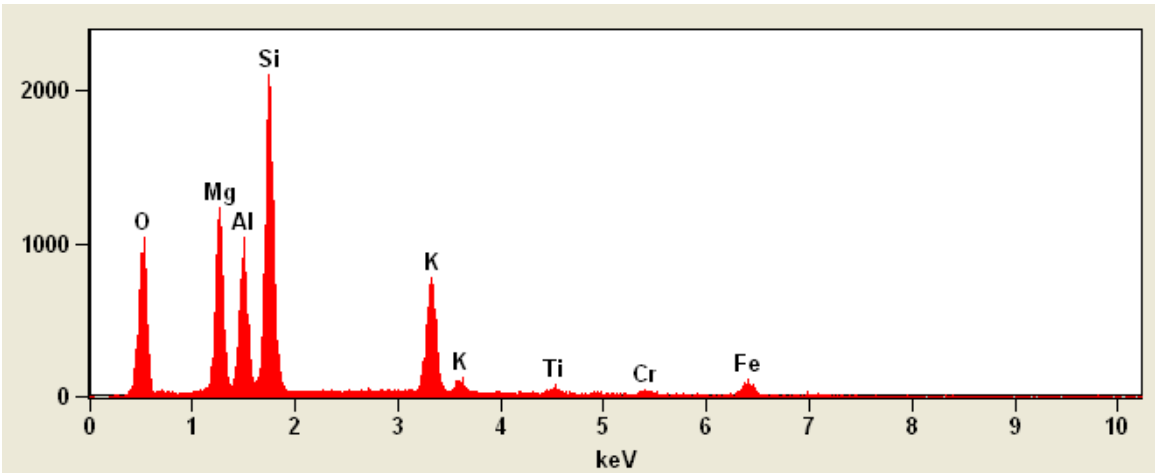

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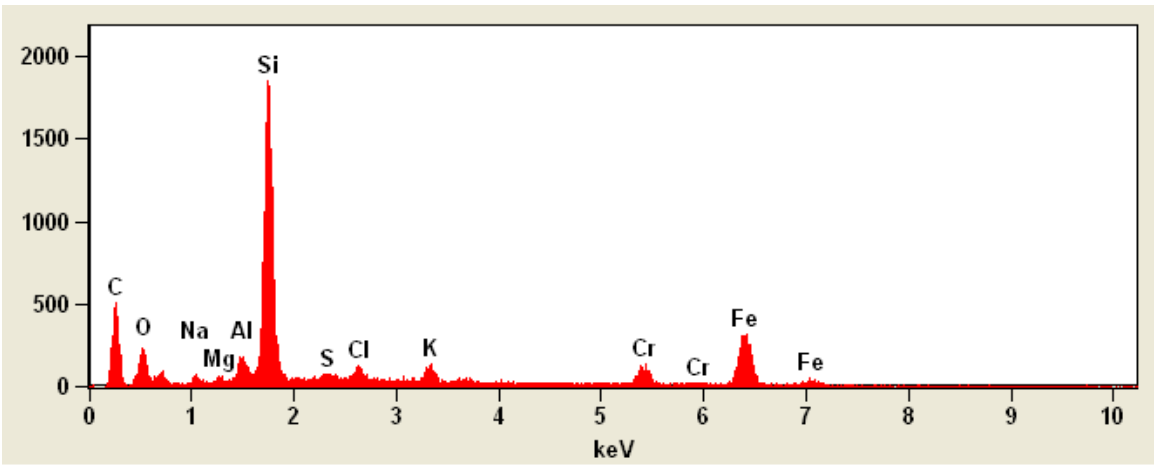
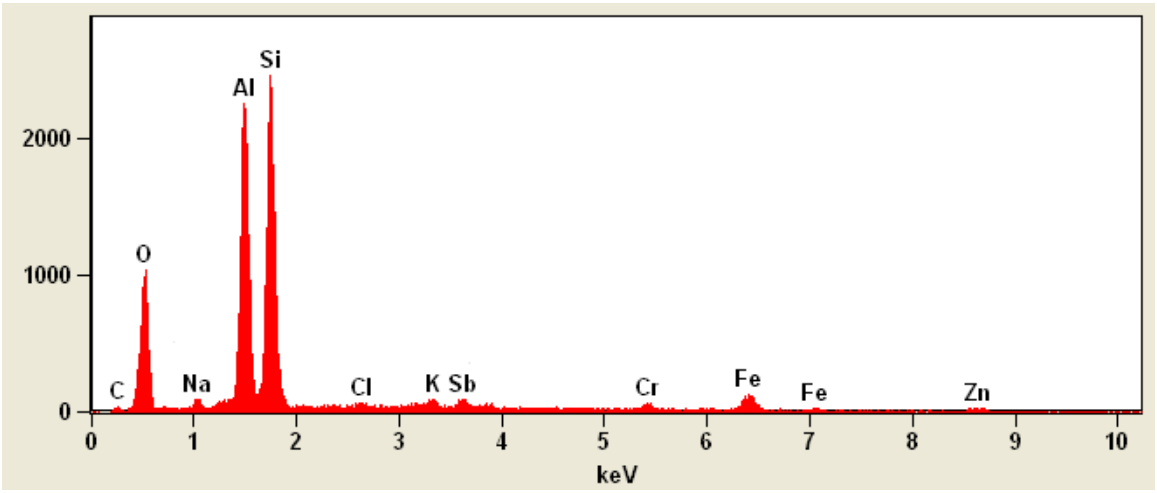


Figure 10: EDS spectra of embedded particles found in the deformed edge region of the Number 1 engine pilot valve piston. The locations of spectra a,b, and c are labeled in figure 9.

d)



e)

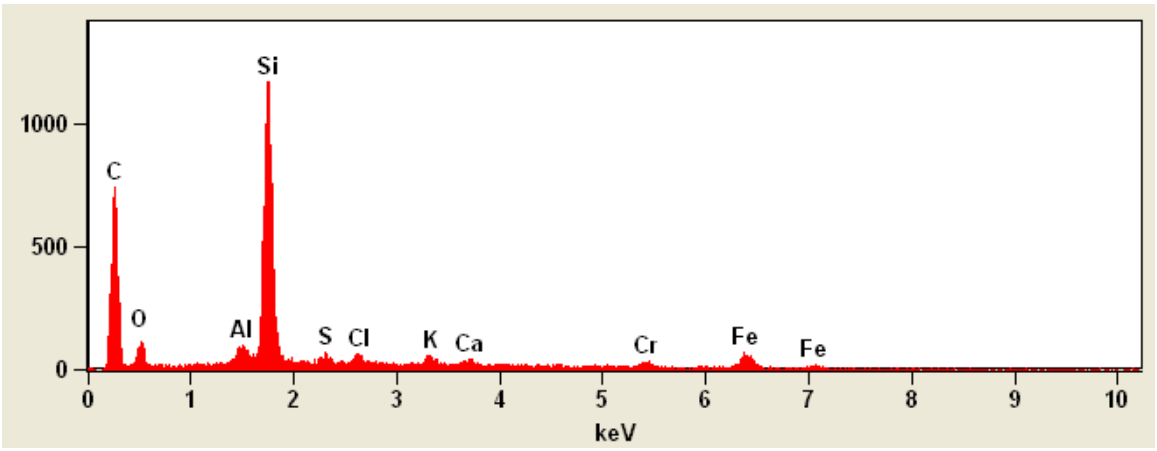


Figure 10 (cont.): The locations of spectra d and e are labeled in figure 9.

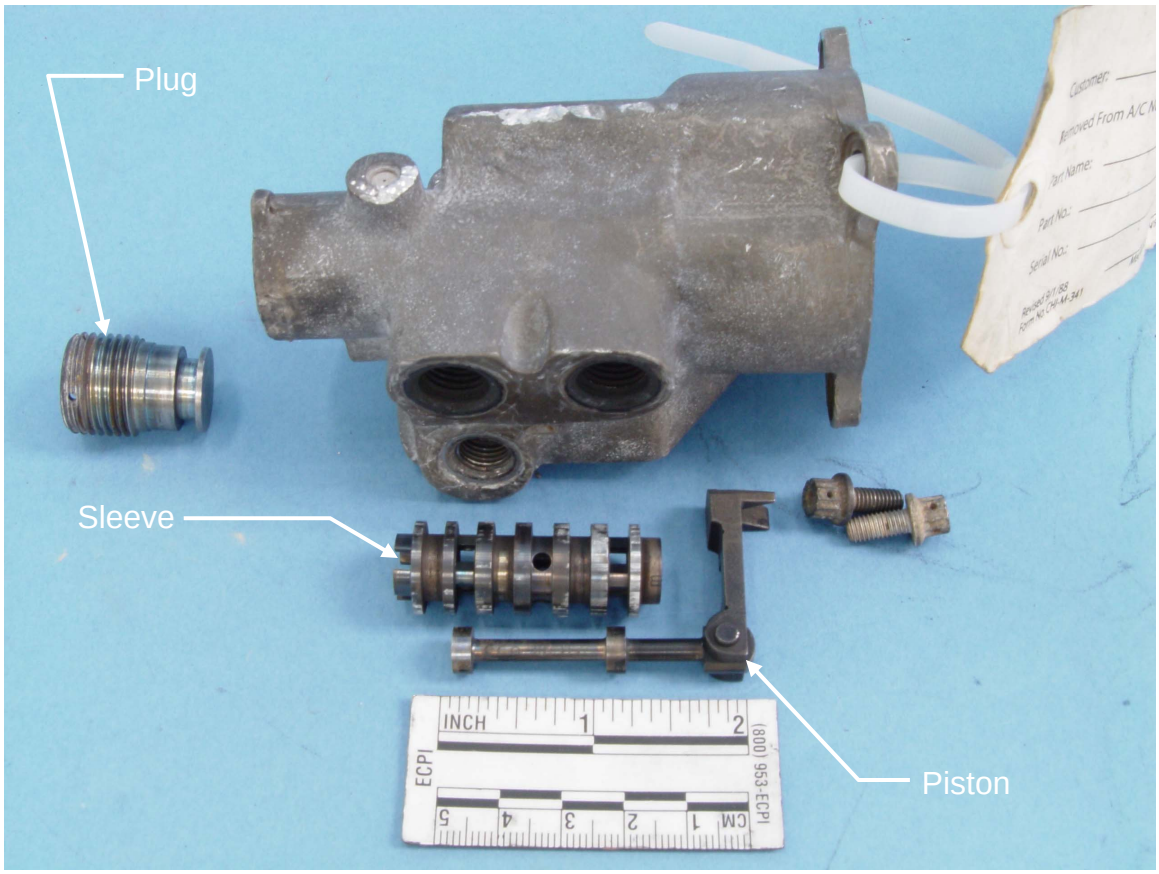


Figure 11: Number 2 engine pilot valve assembly after disassembly.

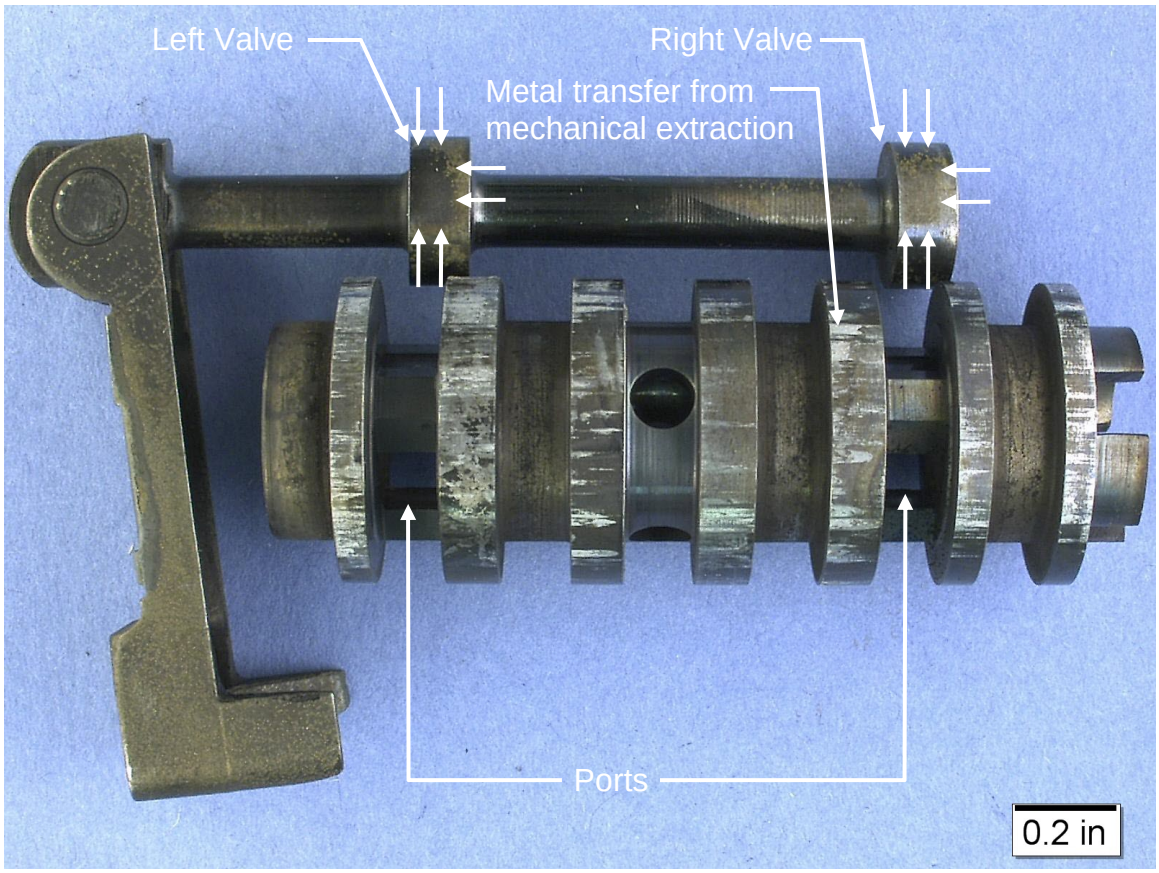
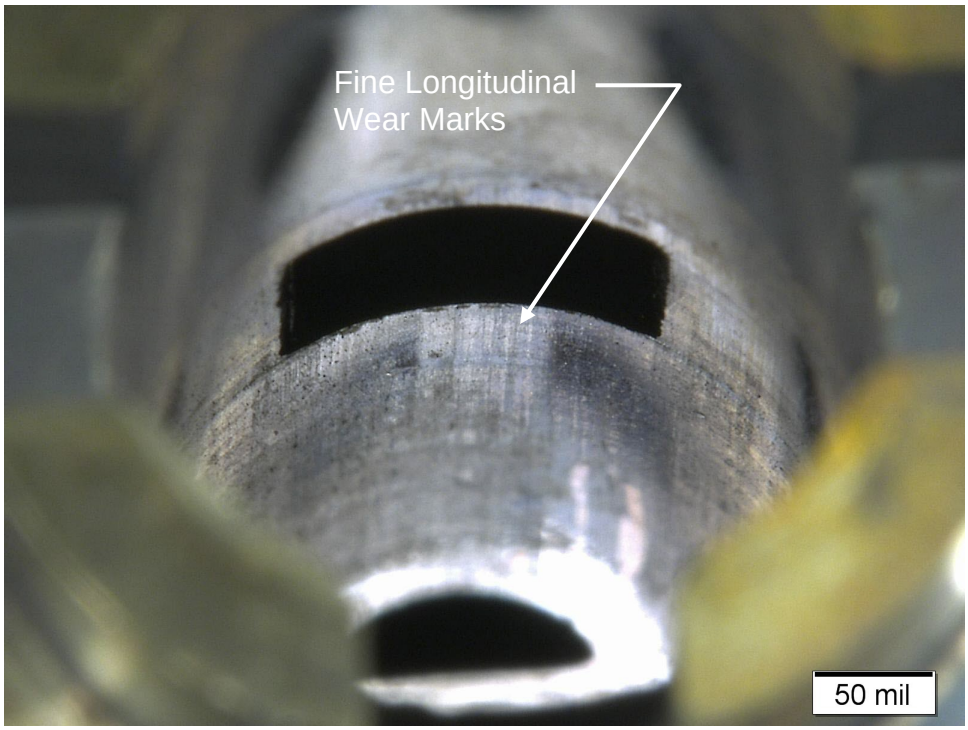


Figure 12: Photograph of the piston and sleeve from the Number 2 engine pilot valve. The valves on the piston have dark rectangular regions indicated by short arrows that are similar in size and shape to the stator vane actuator ports on the sleeve. The outside of the sleeve showed metal transfer marks consistent with the mechanical force required to extract it from the aluminum housing.

a)



b)

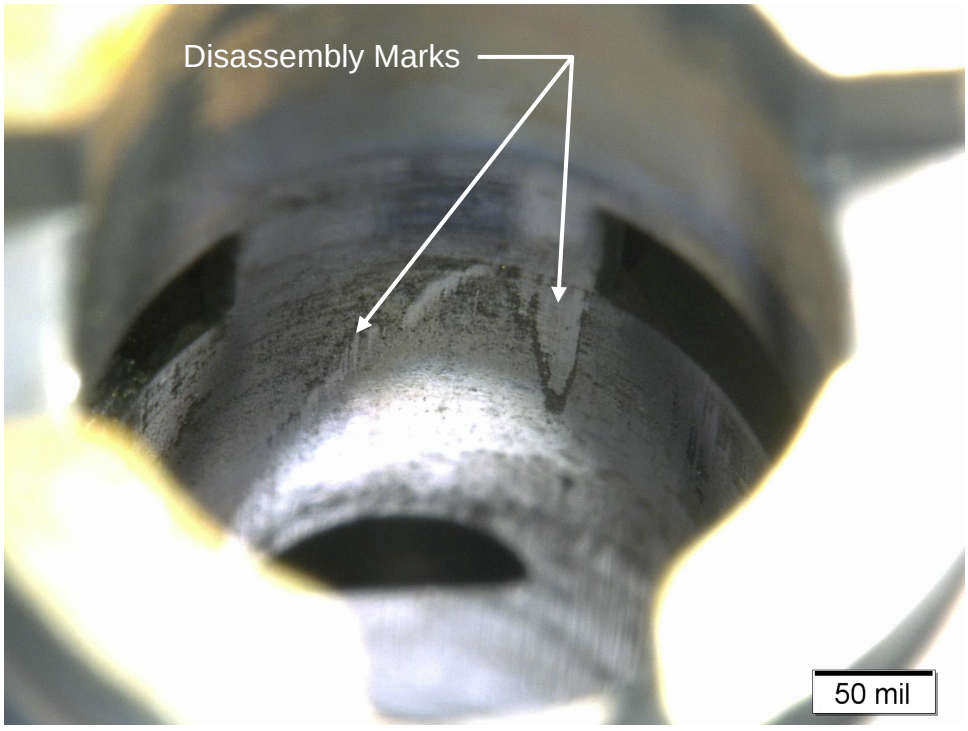
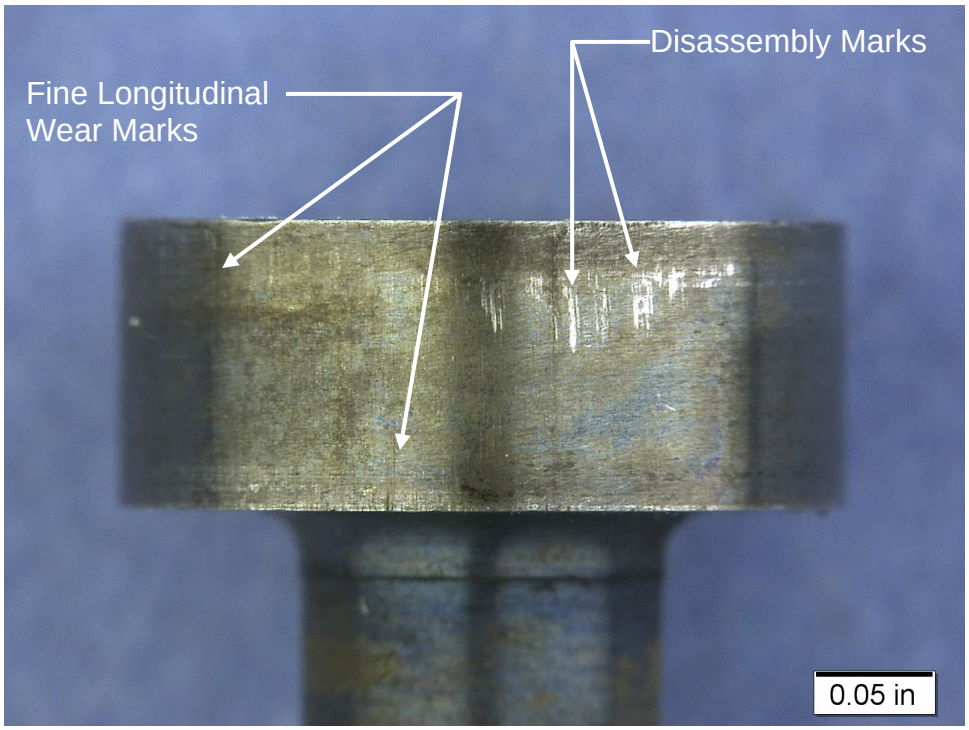


Figure 13: Micrographs of the Number 2 engine pilot valve sleeve inner cylinder. The micrographs were taken at the right end of the sleeve; a) fine longitudinal wear marks and b) disassembly marks.

a)



b)

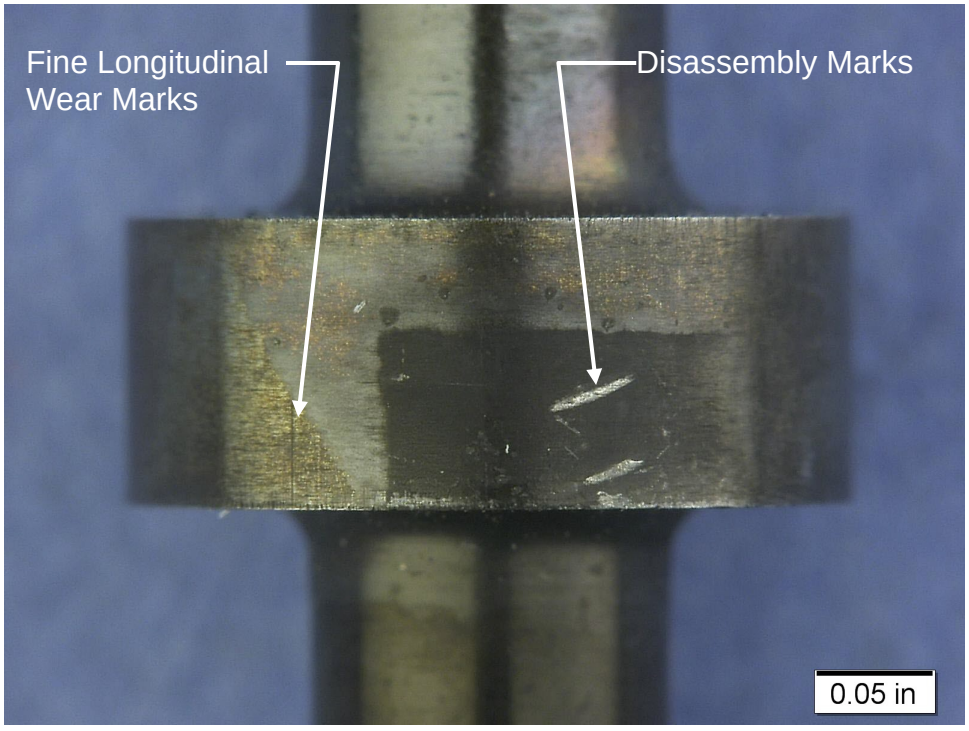


Figure 14: Micrographs of the piston from the Number 2 engine pilot valve assembly; a) right piston valve and b) left piston valve (see figure 10).