

NATIONAL TRANSPORTATION SAFETY BOARD

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



September 14, 2022

MATERIALS LABORATORY FACTUAL REPORT

Report No. 22-068

A. ACCIDENT INFORMATION

Place : Coalinga, California
Date : August 19, 2020
Vehicle : UH-1H, N711GH
NTSB No. : WPR20LA280
Investigator : Van McKenny (AS-40)

B. COMPONENTS EXAMINED

Hydraulic irreversible valve assembly for the right lateral servo.

C. DETAILS OF THE EXAMINATION

1.0 Irreversible Valve for the Right Lateral Servo

The irreversible valve assembly contained several internal valves (sequence; thermal relief; differential pressure relief; check valves "A" and "B; and an accumulator valve). Appendix 1A shows a cross section diagram of the irreversible valve assembly and Appendix 1B shows a reconstructed X-ray computed tomography (CT) image of the same valve.¹ The internal valves were disassembled from their respective ports with the exception of the thermal relief and accumulator valves. The inner and outer surfaces of the servo assembly were dry and contained no evidence of hydraulic fluid (liquid).

2.1 Sequence Valve

The cover for the sequence valve was attached by three screws to the body of the irreversible valve assembly. The screws were secured by safety wire and, in turn, the safety wires were intact. The cover showed bending deformation damage that was oriented away from the body of the irreversible valve assembly, see Appendices 2A and 2B. The outer face of the cover exhibited evidence of an oxide layer (tint color was brown) and micro-cracks within the oxide layer that followed the bending contours adjacent to the holes for the screw, see Appendix 2C.

The sequence valve contained an internal spring, as shown in Appendix 1B. This spring applies tension stress to the inner surface of the cover. Prior to removing the cover from the

¹ Reconstructed X-ray CT images in this report are from the NTSB Computed Tomography Specialist's Factual Report, dated April 13, 2022, or those obtained during the same work.

sequence valve, the irreversible valve assembly was placed on the table frame of a hydraulic shop press and the ram portion was positioned against the outer face of the cover. The three screws and safety wires were disassembled from the cover while the ram was positioned above the cover. After removing the three screws, the ram was raised with the cover, allowing the piston head and portion of the spool² and sleeve to be exposed. Appendix 2D shows a photograph of the inner face of the deformed cover after disassembly. The inner face of the deformed cover exhibited evidence of an oxide layer (tint color was brown). The oxide layer contained micro-cracks in areas following the bending contours adjacent to the screw holes. The inner face of the cover also contained deformation that coincided with that on the deformed head of the piston (see Appendix 2G).

Appendices 2E and 2F show photographs of the exposed piston head. Appendix 2F shows a portion of the exposed spool and sleeve. The piston head and sleeve contained ring seals. As the piston head and sleeve were removed from the port, fractured pieces of the ring seals fell out of the port. Appendix 2G shows a side view of the spool and sleeve and fractured pieces of the ring seals. All the ring seals within this port fractured into multiple pieces (none of them were intact). The extracted parts of the sequence valve were examined (Appendices 2G through 2I). With the exception of the ring seals, the internal parts of the sequence valve were intact and showed no evidence of fracture, corrosion, or wear damage. An attempt was made to manually pull (with needle-nose pliers) the spool out of the sleeve. The needle-nose pliers was secured to one end of the stem (rod portion) of the spool. This action was repeated for the opposite end of the spool. The spool could not be removed from the sleeve by using pliers.

2.2 Check Valves “A” and “B”

Check valves “A” and “B” and the differential pressure relief valve shared one cover. The cover was attached by four screws to the body of the irreversible valve assembly. The screws were secured by safety wires and, in turn, the safety wires were intact. The wires were cut in the laboratory to facilitate removal of the screws. Because these valves contained an internal spring, the cover was removed in a manner that was similar to the sequence valve (utilizing the shop hydraulic press). With the differential pressure relief valve partially covered, check valves “A” and “B” were removed from its respective port.

As parts of check valves “A” and “B” were removed from the port, fractured pieces of the ring seals fell out of the port, see Appendix 3A. All the ring seals fractured into multiple pieces (none of them were intact). With the exception of the ring seals, the internal parts of the valve were intact (see Appendix 3B). The seat portions from check valves “A” and “B” are shown in Appendix 3C. Each seat has an inner reduced diameter portion and an inner larger diameter portion. A flat step is located in the transition region between the reduced and larger inner diameter portions. In the assembled condition, the spring is in contact with the reduced inner diameter portion. The outer diameter portion of the poppet valve is installed within the larger inner diameter portion of the seat. The bottom of the poppet valve sits on the step portion. The step portion for the seat in check valve “B” showed no evidence of

² Spool is also referred to as a slide.

wear but the step portion for the seat of check valve “A” showed evidence of wear damage that extended all around its circumference. The step portion contained an outer radius corner that intersected the reduced inner diameter portion and an inner radius corner that intersected the larger inner diameter portion. Examination of check valve “A” revealed outer radius corner in many areas were fractured and portions of the fractured corners remained attached to the seat. The fractured corners that remained attached to the seat showed evidence of deformation. The amount of material that separated from the outer radius corner was not determined.

2.3 Differential Pressure Relief Valve

The differential pressure relief valve was removed from the irreversible valve assembly in the same manner as in check valves “A” and “B”. The piston portion and spring located under the piston were removed from the assembly. The ring seal for the piston was intact and it contained several micro-cracks, see Attachments 4A and 4B.

As the differential pressure relief valve parts were removed from the port, fractured pieces of the ring seals fell out of the port, see Attachment 4C and 4D. The other two ring seals fractured into multiple pieces. The other extracted parts of the valve were intact and showed no evidence of wear damage, see Attachments 4E and 4F.

4.0 Materials Analysis

Various pieces of the valves were analyzed with an Olympus Vanta X-ray fluorescence (XRF) portable alloy analyzer to determine their material grade. Appendix 5 shows the materials that were identified by the portable alloy analyzer.

TM55-1520-210-23P, titled “Technical Manual, Aviation Unit and Intermediate Maintenance, Repair Parts and Special Tool List, (Including Depot Maintenance Repair Parts and Special Tools), For Helicopter – Utility – Tactical Transport UH-1B, UH1C, UH-1H, UH-1M, EH-1H (Bell), UH-1V”, dated 27 Feb 1981, provides illustrations (parts breakdown) and parts lists for the respective helicopters. The part’s name and part number, and national stock number (NSN) are listed and they refer back to an item number in an illustration within the manual. The ring seals in this lab report are referred to in the TM55 technical manual as packing preform. Most of the packing preforms for the irreversible valve assembly were listed as conforming to specification MS28775, titled Packing, Preformed, Hydraulic, +275°F (“O” Ring). According to MS28775, the packing preform materials are procured to MIL-P-25732 specification, titled Performance Specification, Packing, Preformed, Petroleum Hydraulic Fluid Resistant, Limited Service at 250 °F (121 °C). The MIL specification covers an Acrylonitrile-Butadiene (NBR) rubber in the form of molding rings, compression seals, O-ring cord, and molded-in-place gaskets for aeronautical and aerospace applications.

The ring seal for the piston head of the sequence valve was black and the outer surface exhibited a smooth texture. The sample of the ring seal for the piston head was tested to see whether it was a magnetic material. A magnet was placed next to a fractured piece of

the ring seal. It was not attracted to a magnet. To determine whether this piece was flexible or brittle, it was intentionally bent with a needle-nose pliers. This piece fractured easily and showed no evidence of flexibility. The fracture face of this piece exhibited a brittle fracture feature. The XRF alloy analyzer cannot detect the element carbon, so the ring seal for the piston was analyzed by other analytical methods. Energy dispersive spectroscopy (EDS) analysis of the ring seal produced a spectrum that contained one major elemental peak of carbon. Fourier Transform Infrared (FTIR) analysis of the same sample showed a spectrum that contained no evidence of hydrocarbon peaks and each contained only a single peak ($\sim 2100\text{ cm}^{-1}$) consistent with carbon.³ This type of FTIR spectrum is indicative of either a carbon-based material such as graphite or the material was significantly heat damaged leaving only carbonize⁴ residue (Appendix 6 shows a typical FTIR spectrum).

Particles were extracted from inside of the valve assembly for material analysis. Most of the particles were extracted from areas of the valve assembly that corresponded to particles referred to as “high density” particles in NTSB Computed Tomography (CT) Specialist’s Factual Report, dated April 13, 2022. Refer to NTSB CT Specialist’s Factual Report for reconstructed CT images of the valves and location of the respective “high density” particles. More than one particle was found in an area identified by the NTSB CT Specialist Factual Report as having a “high density” particle. Therefore, multiple particles were extracted from those specific areas for materials analysis. Appendix 7 shows a list of particles that were examined. Appendices 7A through 7S show SEM images of particles that were extracted from the valve assembly; their respective EDS spectrum; approximate weight percent of each element found in the spectrum; and approximate size of the particle.⁵ The thickness of a sample was estimated when samples appeared to have a nearly uniform thickness. Color and luster of the particles were determined by binocular microscope examination.

Prepared by

Frank Zakar
Senior Metallurgist

³ FTIR analysis was by performed Nancy McAtee, NTSB Fire and Explosion Specialist.

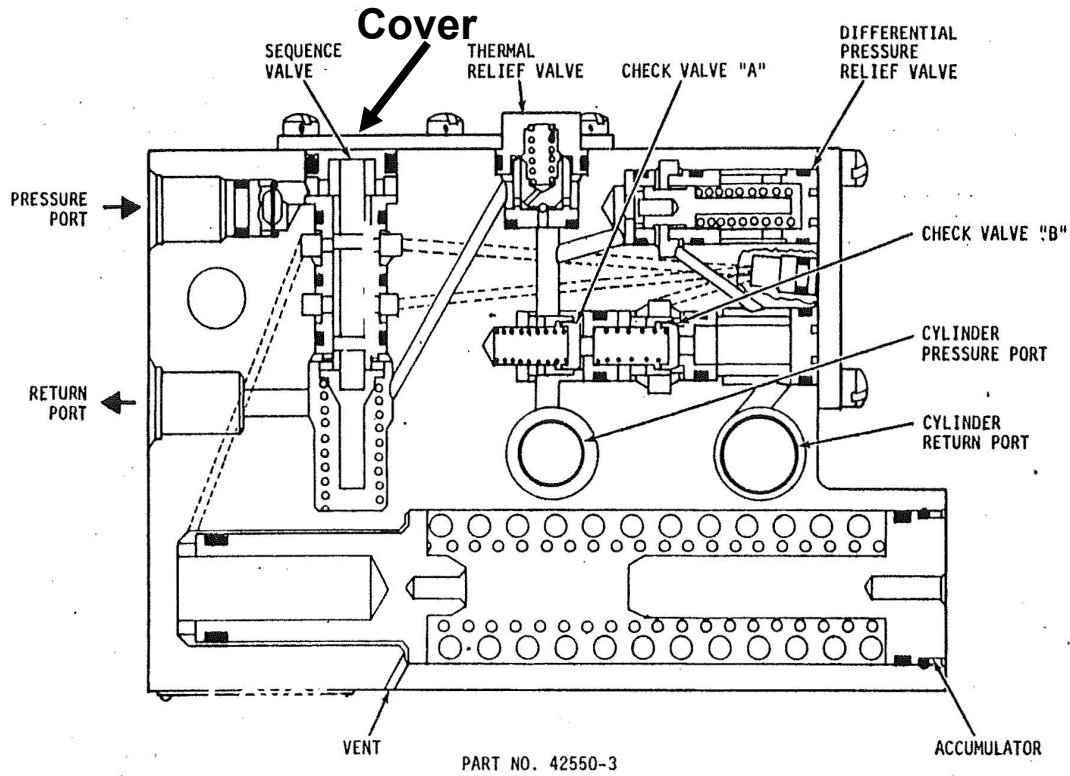
⁴ Carbonize – when a carbon containing material is converted into carbon, typically by heating or burning.

⁵ SEM and EDS analysis of particle was performed by Edward Komarnicki, NTSB Engineering Technician. Particle sizes are reported in millimeters and inches. The scale in many of the SEM images are in micrometers (μm). For reference purpose 1,000 μm is equal to 1 millimeter (mm).

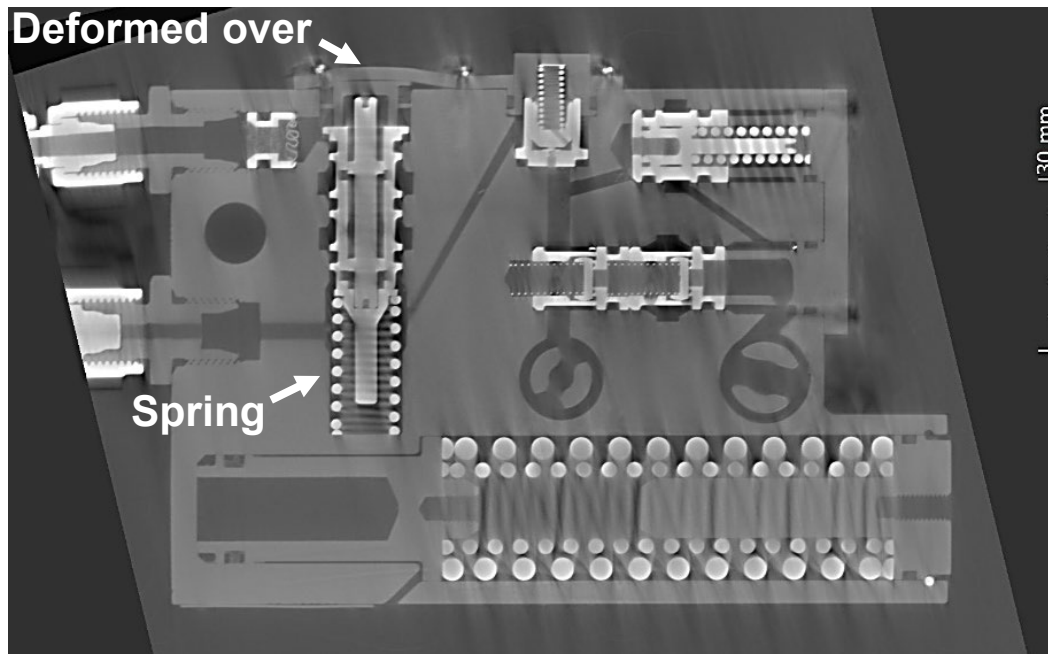
APPENDICES

APPENDIX 1

Irreversible Servo



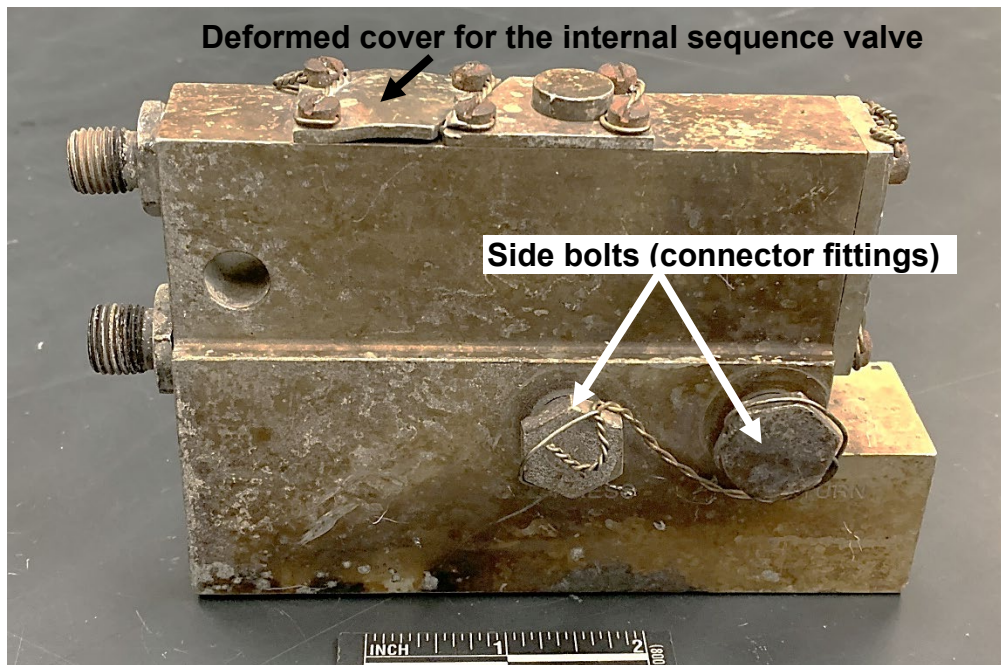
Appendix 1A. Cross section diagram of the hydraulic irreversible valve assembly.



Appendix 1B. Reconstructed X-ray computed tomography image of the irreversible valve assembly showing the deformed cover for the internal sequence valve. The sequence valve and other internal valves each contain at least one spring (appear similar to lined up spheres).

APPENDIX 2

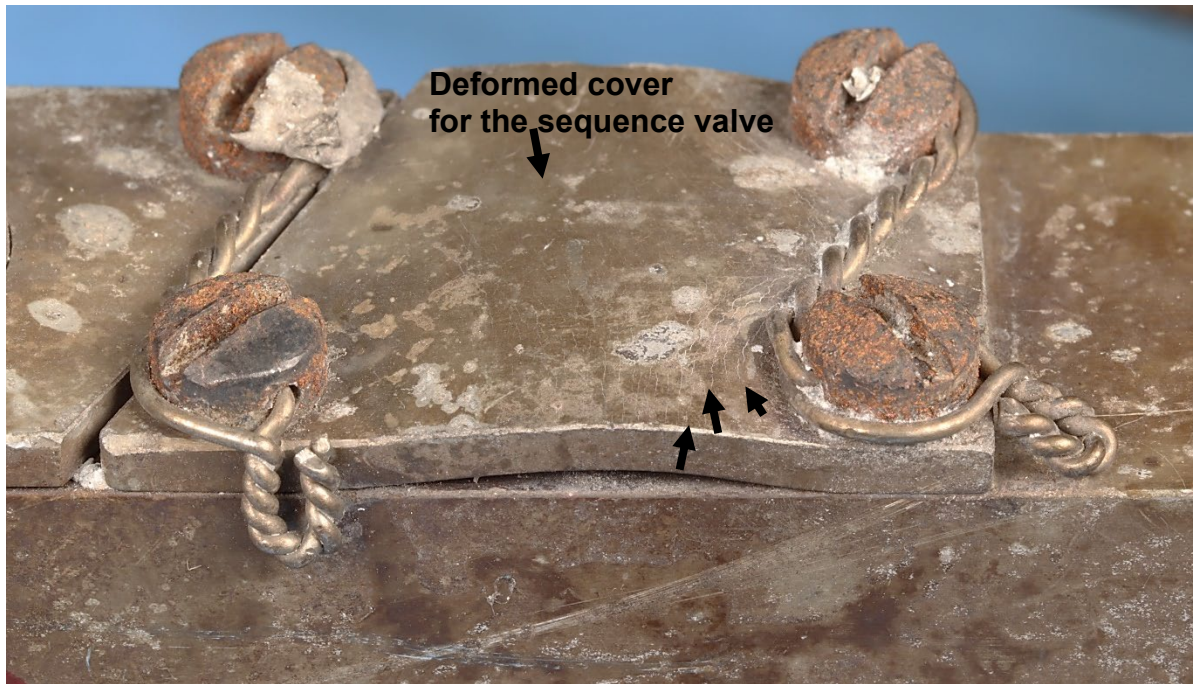
Sequence Valve



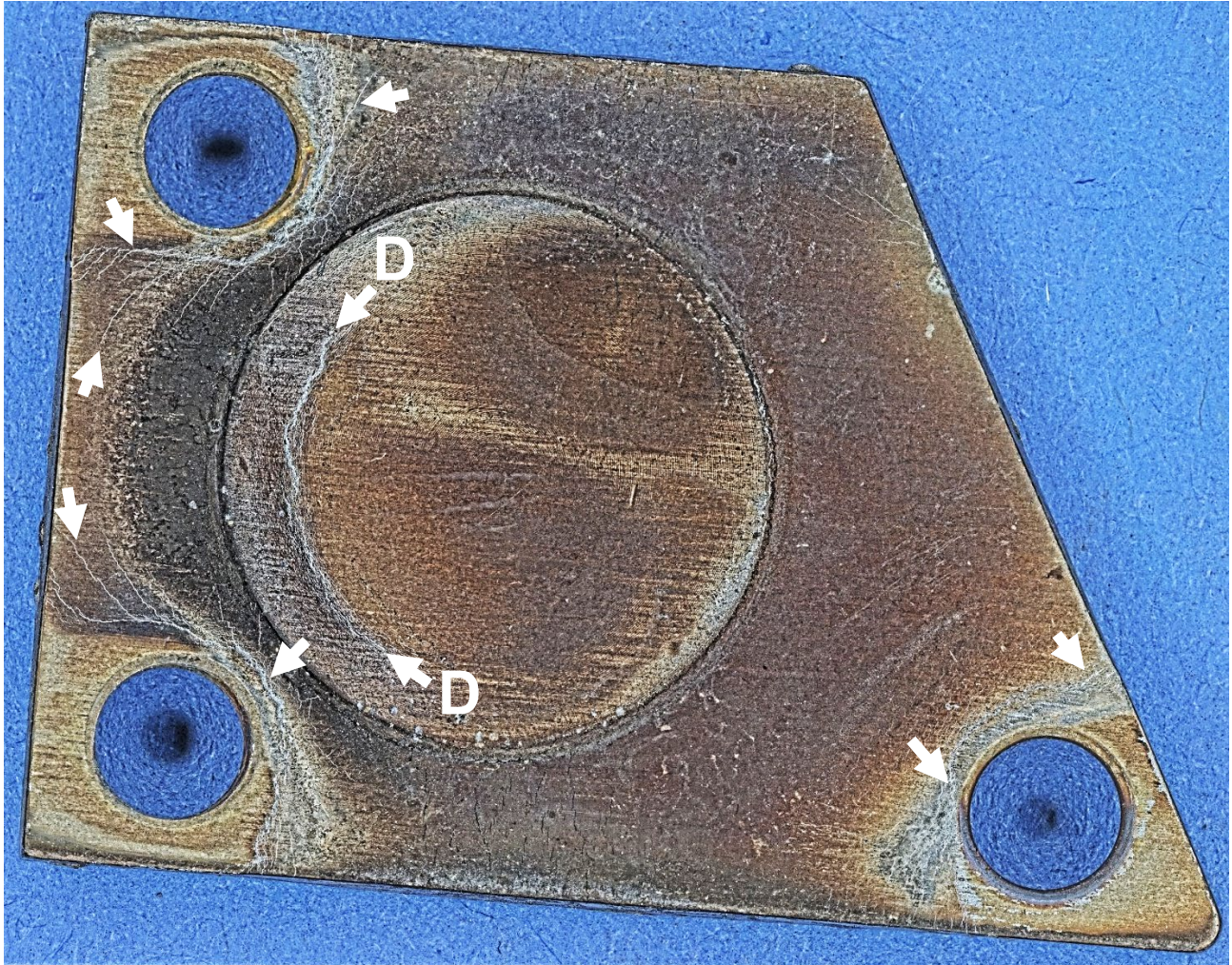
Appendix 2A. Overall view of the irreversible valve assembly showing the deformed cover for the internal sequence valve.



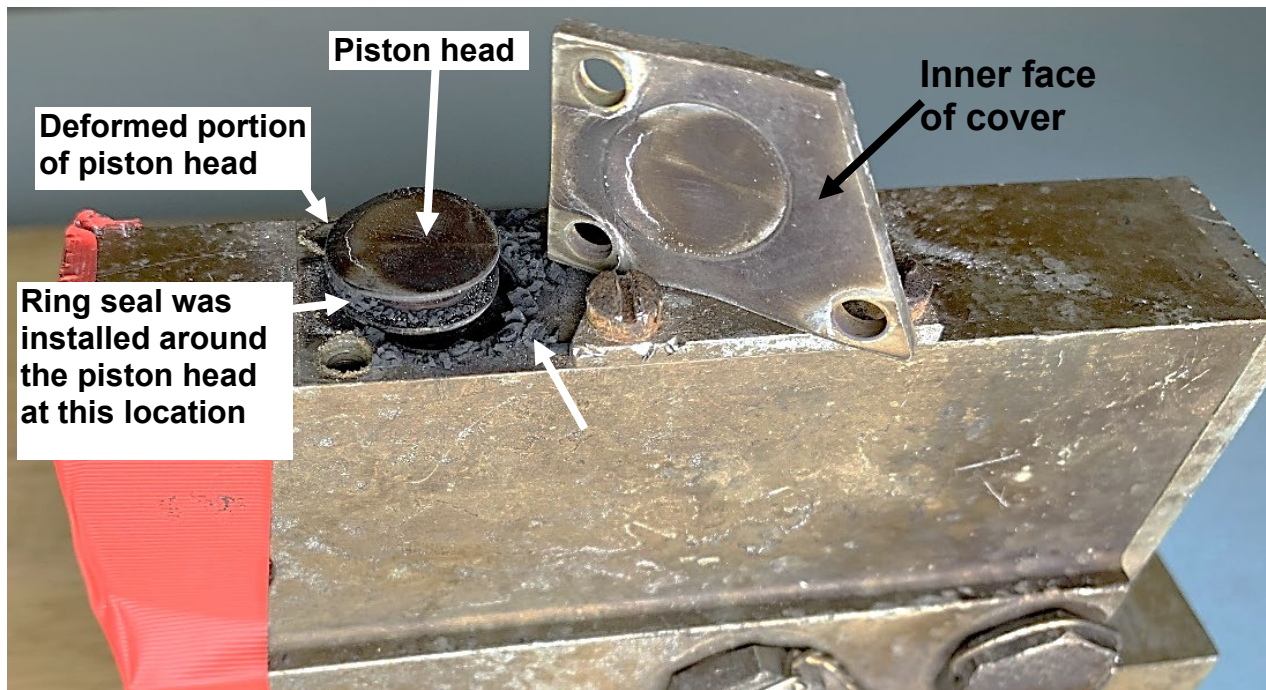
Appendix 2B. Side view of the deformed cover for the internal sequence valve.



Appendix 2C. Views of the outer face of the deformed cover for the sequence valve showing micro-cracks in the oxide layer (areas indicated by black arrows).



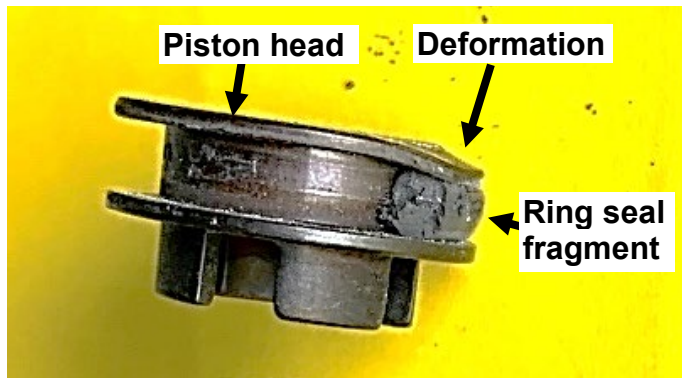
Appendix 2D. Inner face of the deformed cover for the sequence valve showing micro-cracks in the oxide layer in the areas around the bolt holes, indicated by unmarked arrows, and an area corresponding to the deformed head of the piston, between arrows "D".



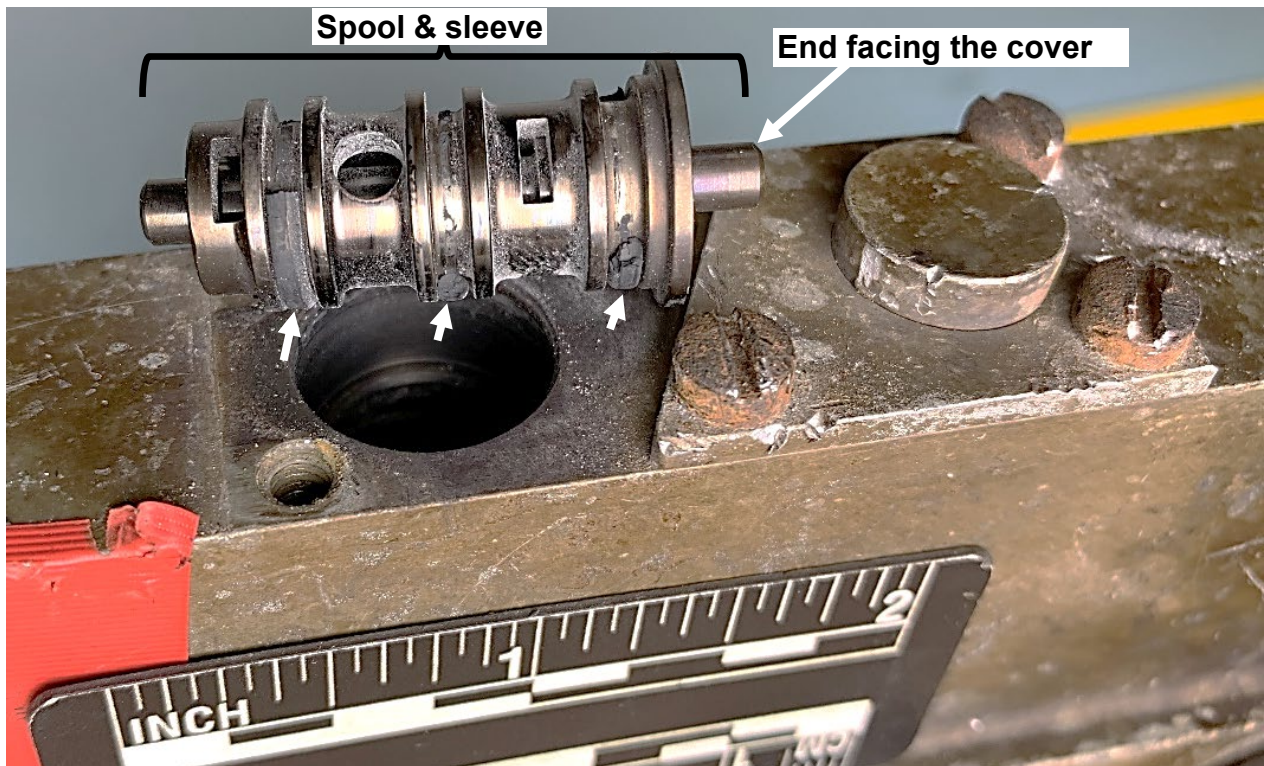
Appendix 2E. Disassembled cover for the sequence valve port showing exposed piston head. White arrow indicates fractured fragments of the ring seal. In this stage of disassembly, the hydraulic lines were removed from the irreversible valve assembly (left side of page) and their respective ports were covered with red adhesive tape. The tape was applied to prevent particles from entering or departing the ports.



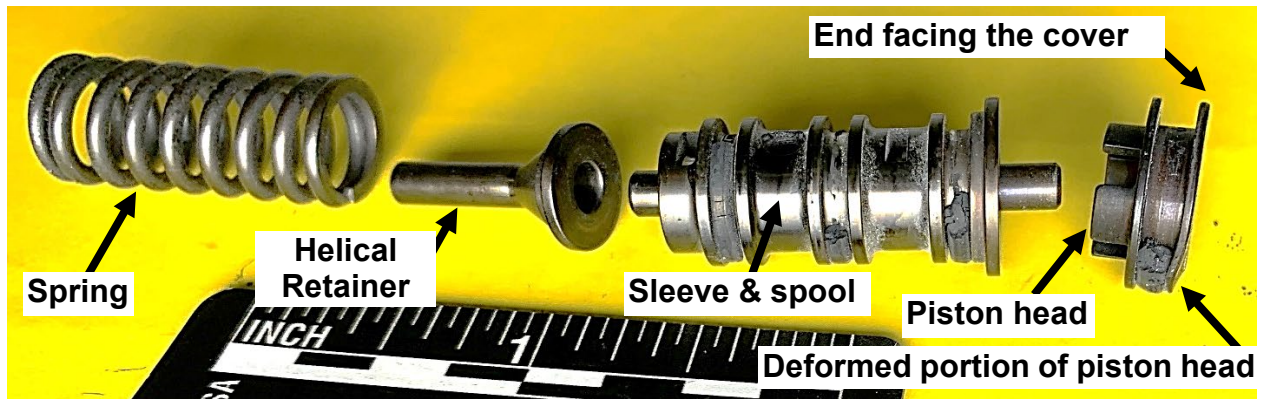
Appendix 2F. Piston head that was extracted from the sequence valve port and exposed top portion of the spool and sleeve.



Appendix 2G. Side view of the piston head that was extracted from the sequence valve showing deformation at the upper end of the head. A small fragment of the ring seal remained attached to the piston head.



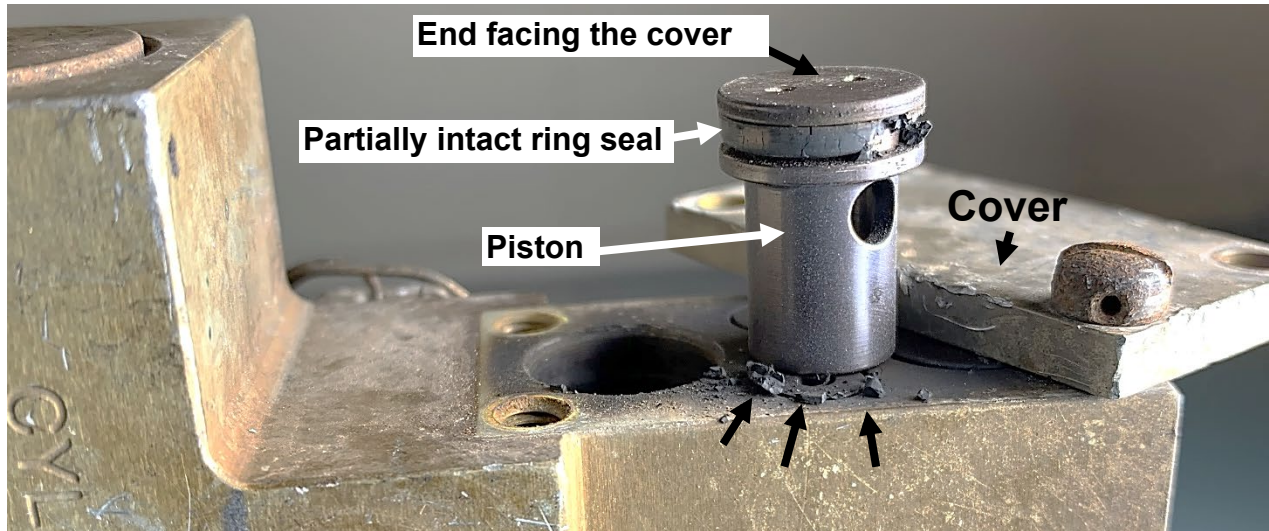
Appendix 2H. Spool and sleeve assembly that were extracted from the sequence valve port. Fractured portions of the ring seals are indicated by arrows.



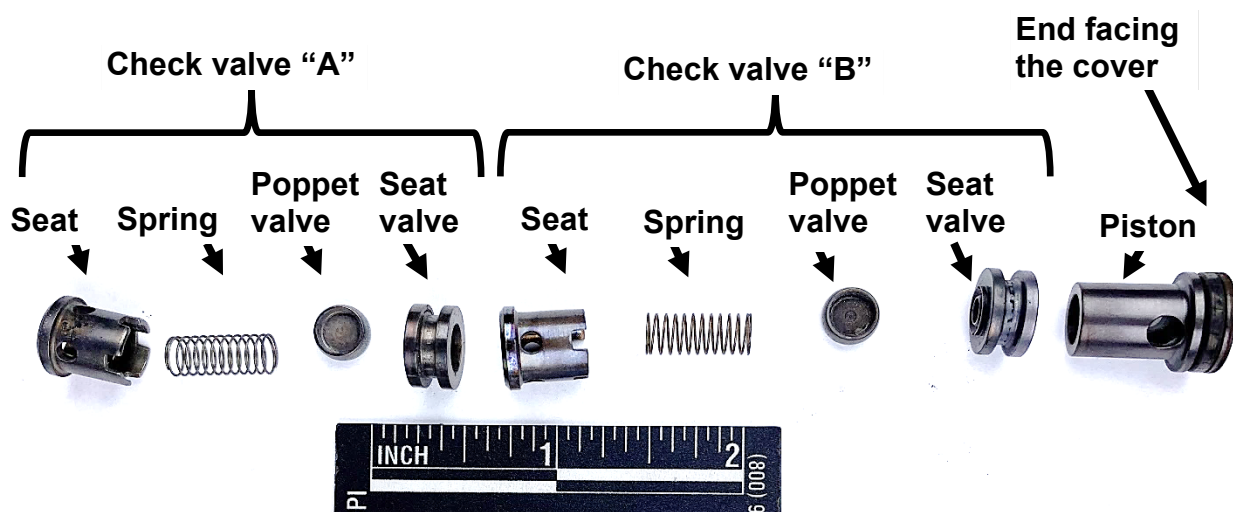
Appendix 2I. Disassembled pieces of the sequence valve.

APPENDIX 3

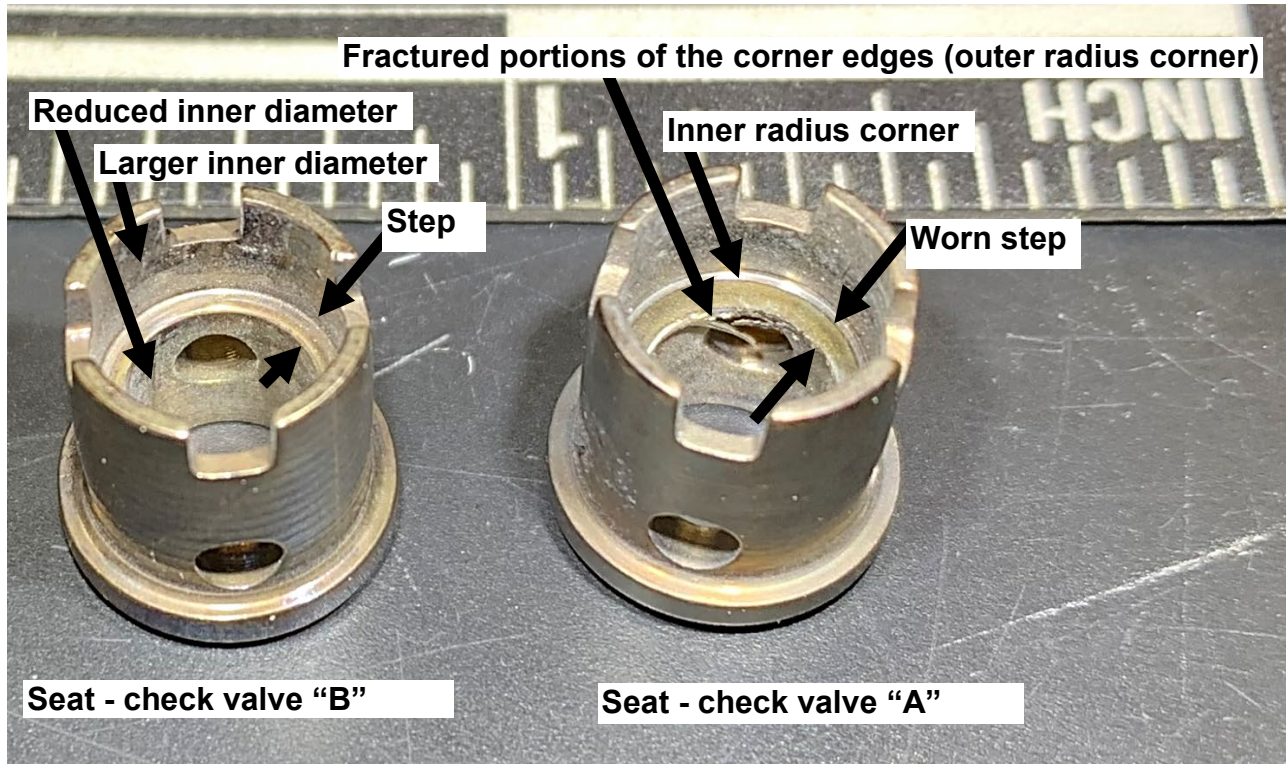
Check Valves “A” and “B”



Appendix 3A. Piston that was extracted from the check valve "A" and "B" port. Partially intact portion of the ring seal remained attached to the piston. Fractured pieces of the ring seals are indicated by black arrows.



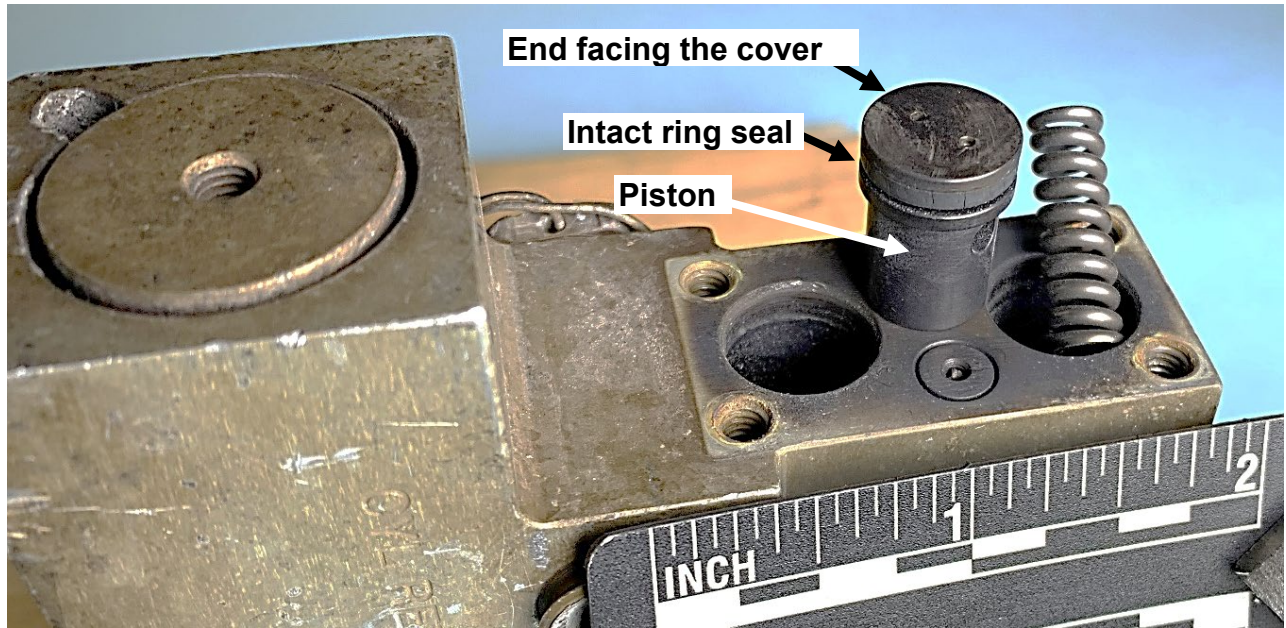
Appendix 3B. Disassembled check valve "A" and "B" portions.



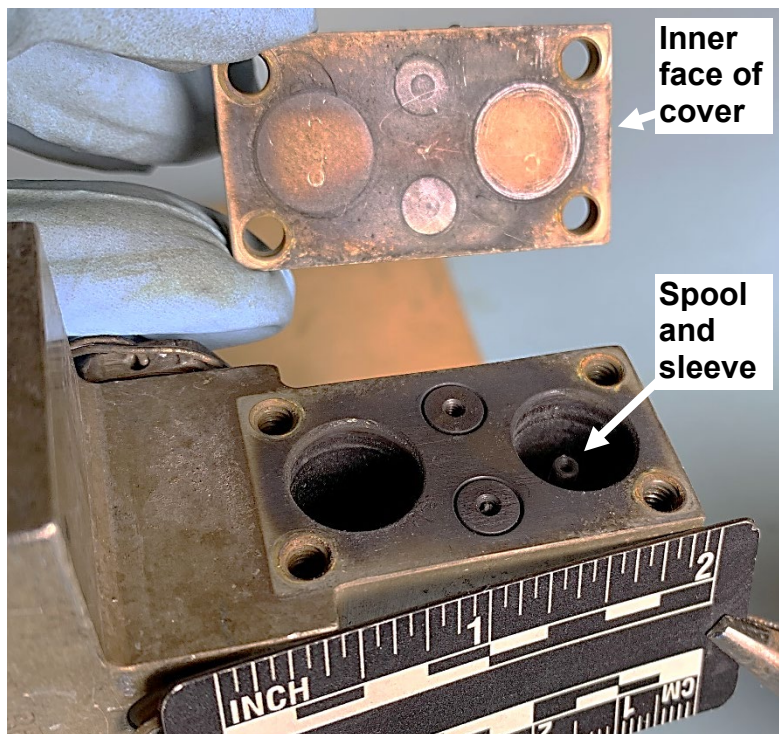
Appendix 3C. Seat portions from check valves "B" and "A".

APPENDIX 4

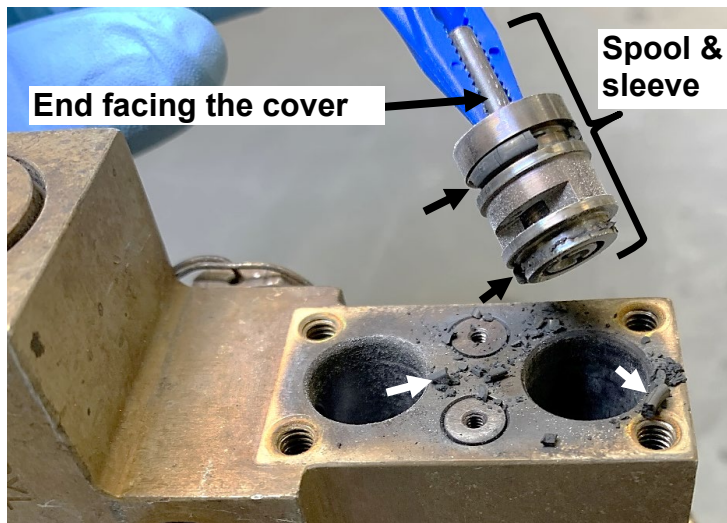
Differential Pressure Relief Valve



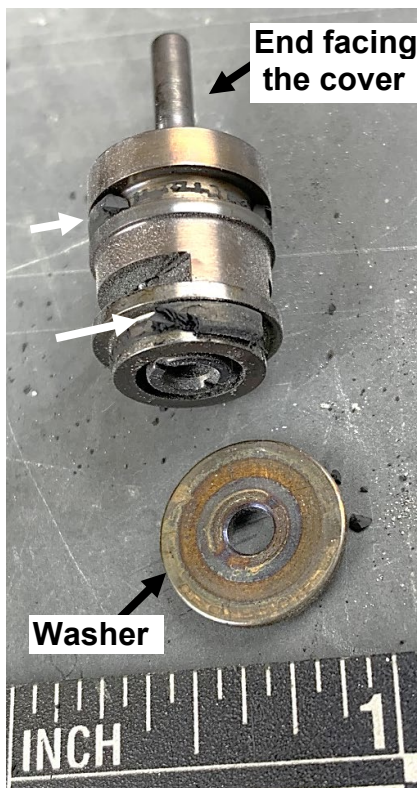
Appendix 4A. Piston and spring that were extracted from the differential pressure relief valve (port located on the right side of the page).



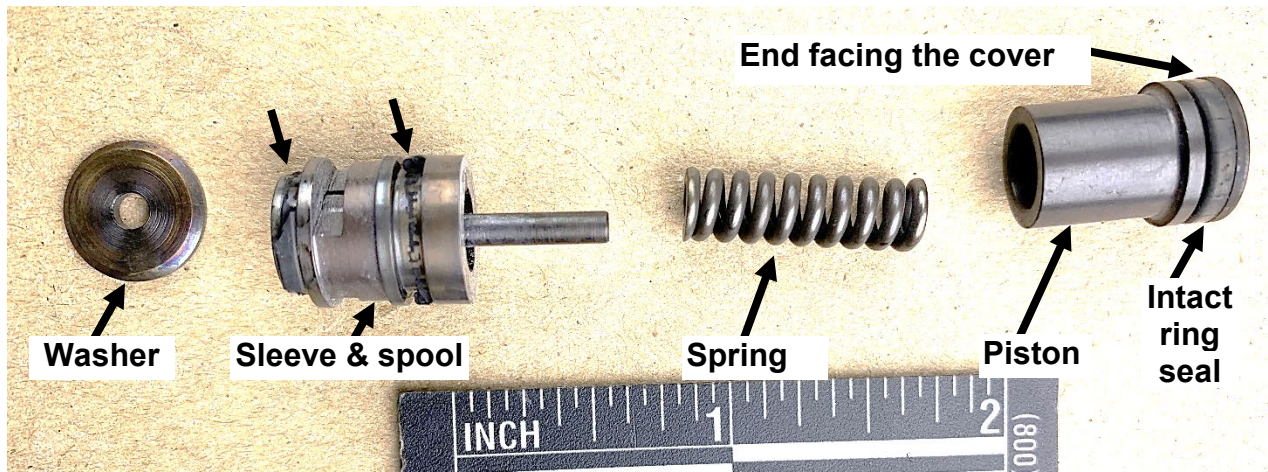
Appendix 4B. Cover that was disassembled from the differential pressure relief valve.



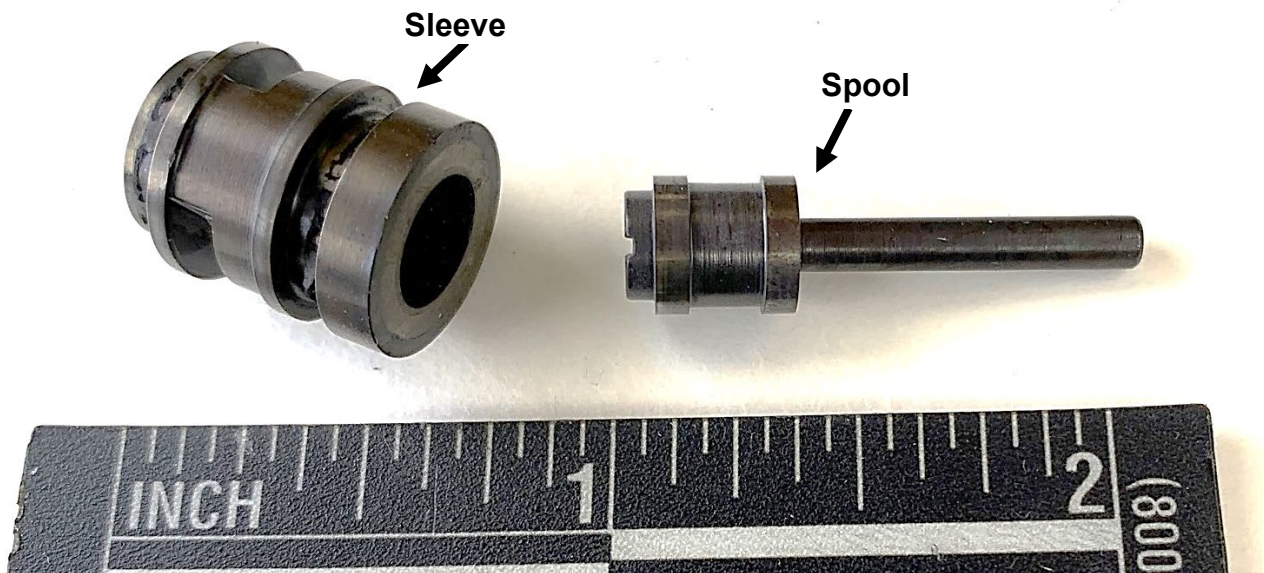
Appendix 4C. Spool and sleeve that were removed from the differential pressure relief valve port showing ring seal fragments that remained attached to the sleeve (indicated by black arrows); and pieces of the ring seal that fell off the sleeve (indicated by white arrows).



Appendix 4D. Spool and sleeve, and washer, that were removed from the differential pressure relief valve. Fractured ring seals are indicated by white arrows.



Appendix 4E. Pieces removed from the differential pressure relief valve. Fractured ring seals pieces that remained attached to the sleeve and spool are indicated by arrows.



Appendix 4F. Disassembled sleeve (left) and spool (right) from the differential pressure relief valve.

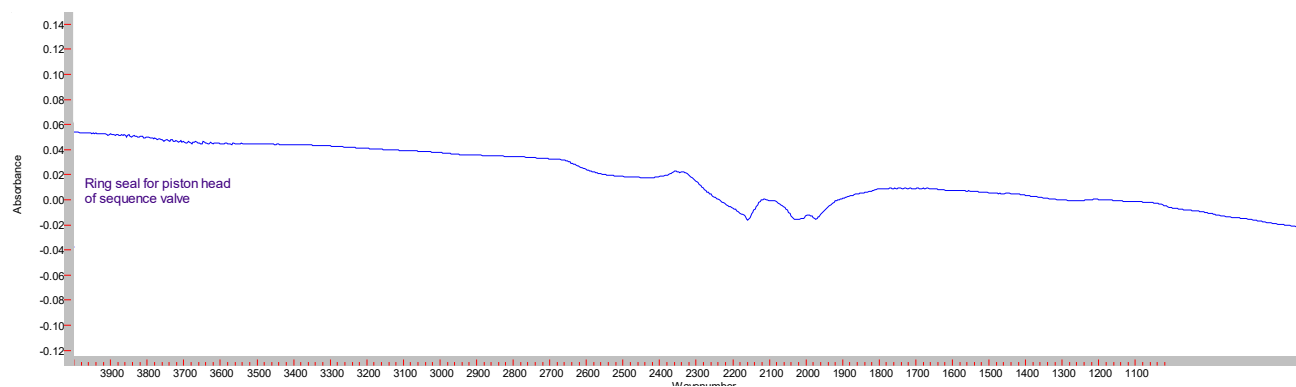
APPENDIX 5

Materials Identified by the Alloy Analyzer

Appendix 5 Materials Identified by the Alloy Analyzer	
Part	Identified Material
Housing and covers for the irreversible valve assembly	2014 aluminum alloy
Piston; and piston head	2014 aluminum alloy
Seat for “A” and “B” valve	17-4 PH steel
Spool for sequence valve	430 stainless steel
Sleeve for sequence valve	430 stainless steel
Spring	303 stainless steel
Poppet valve	430 stainless steel

APPENDIX 6

FTIR Spectra



Appendix 6. FTIR spectrum (Absorbance vs. Wavenumber [cm^{-1}]) of a sample from the ring seal for the piston head of the sequence valve.

APPENDIX 7

EDS Spectra of Particles

Appendix 7 List of Small Particles that were Analyzed by EDS and SEM			
Arbitrary Sample Number Assigned to Particle by NTSB Materials Lab	Appendix Number Containing SEM image, EDS Spectrum, and Size of Particle	Valve Where Particle was Found; Color of Particle	Specific Location Where Particles were Found Within the Valve
7A	7A	Differential pressure relief valve; white	Particles 7A through 7G were extracted from the general area referred to as containing high density particle 14 identified in NTSB Computed Tomography (CT) Specialist's Factual Report; page 109, figure 102; see Note (*).
7B	7B	Differential pressure relief valve; shiny black	
7C	7C	Differential pressure relief valve; brown	
7D	7D	Differential pressure relief valve; black matte	
7E	7E	Differential pressure relief valve; grey-white	
7F	7F	Differential pressure relief valve; black-grey	
7G	7G	Differential pressure relief valve; black-matte	
7H	7H	Entrance to check valve B; grey	Particle 7H was extracted from the general area referred to as containing high density particle 15 identified in NTSB CT Specialist's Factual Report; page 110, figure 103; see Note (*).
7I	7I	Sequence Valve; black	Bottom of Spool **
7J	7J	Sequence Valve; black	Spool top seal **
7K	7K	Connector Fitting – Cylinder Return Port; grey	Particles 7K through 7N were extracted from the general area referred to as containing high density
7L	7L	Connector Fitting – Cylinder Return Port; green	

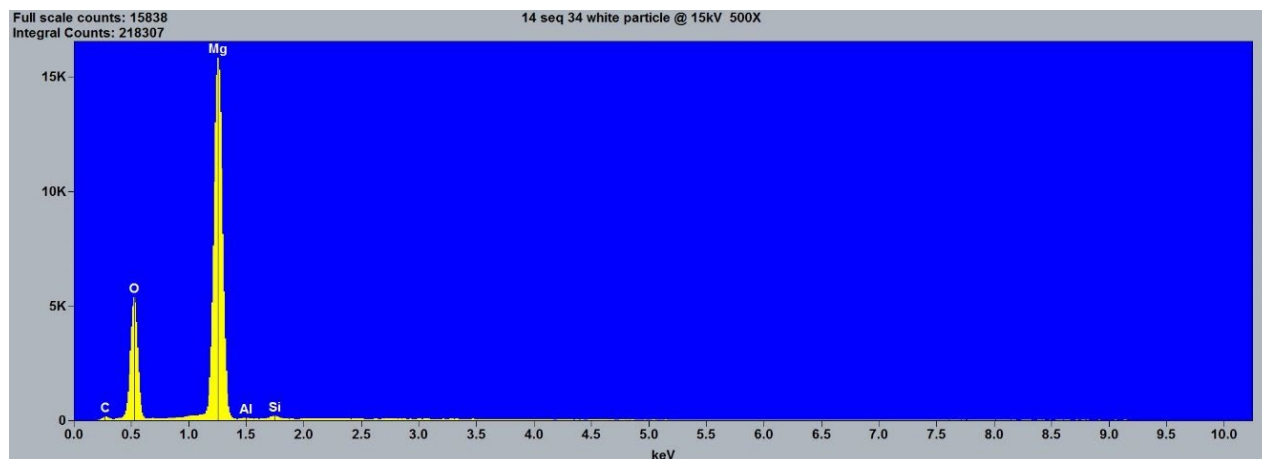
7M	7M	Connector Fitting – Cylinder Return Port; brown	particles 18 and 19 identified in NTSB CT Specialist's Factual Report; pages 113 and 114; figures 106 and 107; respectively; see Note (*).
7N	7N	Connector Fitting) – Cylinder Return Port; shiny black	
7O	7O	Connector Fitting – Cylinder Pressure Port; grey	Particles 7O through 7S were extracted from the general area referred to as containing high density particles 5, 6, 7; pages 100, 101, 102; figures 93, 94, 95; respectively; see Note (*)
7P	7P	Connector Fitting – Pressure Side; brown	
7Q	7Q	Connector Fitting – Cylinder Pressure Port; black	
7R	7R	Connector Fitting) – Cylinder Pressure Port; silver-like	
7S	7S	Connector Fitting – Cylinder Pressure Port; shiny metallic	

Notes:

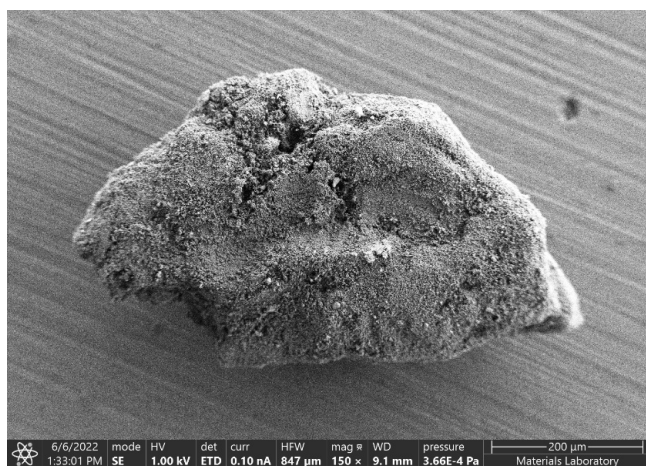
(*) Refer to NTSB Computed Tomography (CT) Specialist's Factual Report, dated April 13, 2022, for reconstructed CT images of the valves and location of the specific "high density" particles.

(**) Arbitrarily selected by NTSB Materials Lab for analysis – no correlation to a high density particle in NTSB CT Specialist's Factual Report.

Appendix 7A (Sample 7A)



Element	14 seq 34 white particle @ 15kV 500X	
	Line Type	Weight %
C K	K	2.04
O K	K	37.93
Mg K	K	59.10
Al K	K	0.19
Si K	K	0.74
		100.00

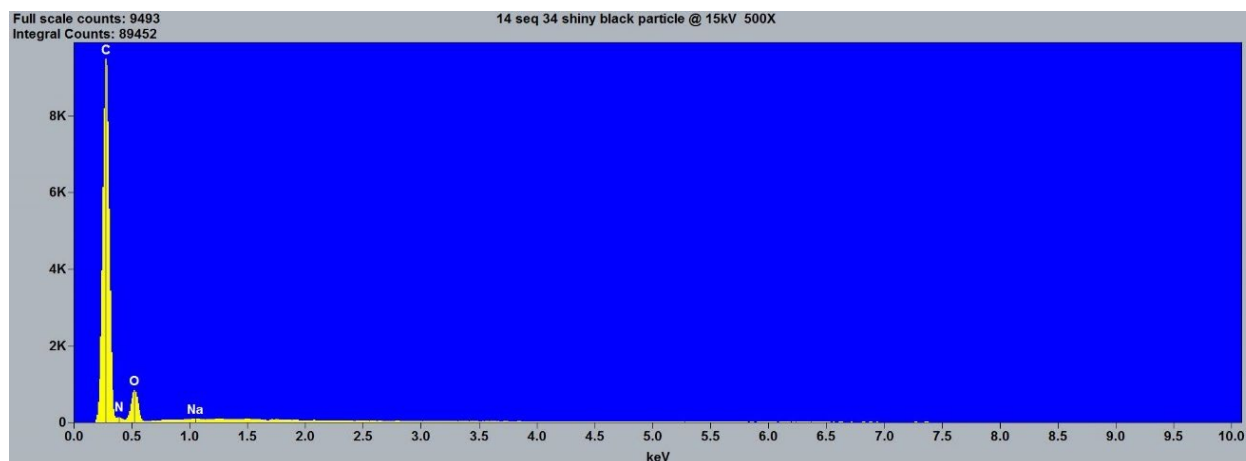


Length = 0.7 mm (0.028 in)

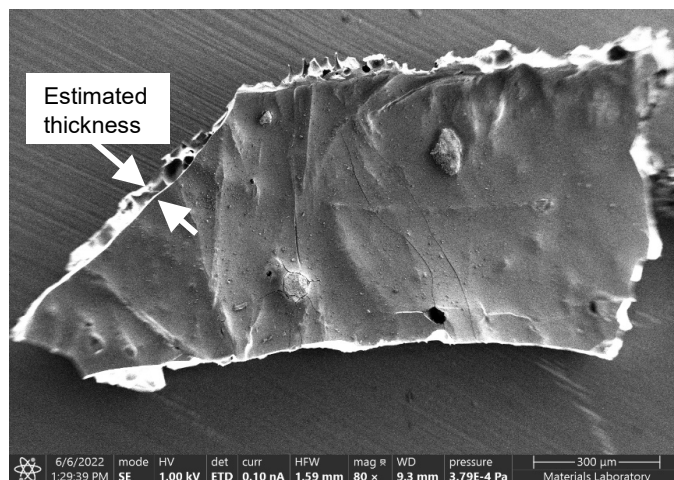
Width = 0.4 mm (0.016 in)

Thickness = not measured;
appeared less than width

Appendix 7B (Sample 7B)



Element	14 seq 34 shiny black particle @ 15kV 500X	
	Line Type	Weight %
C K	K	55.68
N K	K	11.74
O K	K	32.31
Na K	K	0.28
		100.00

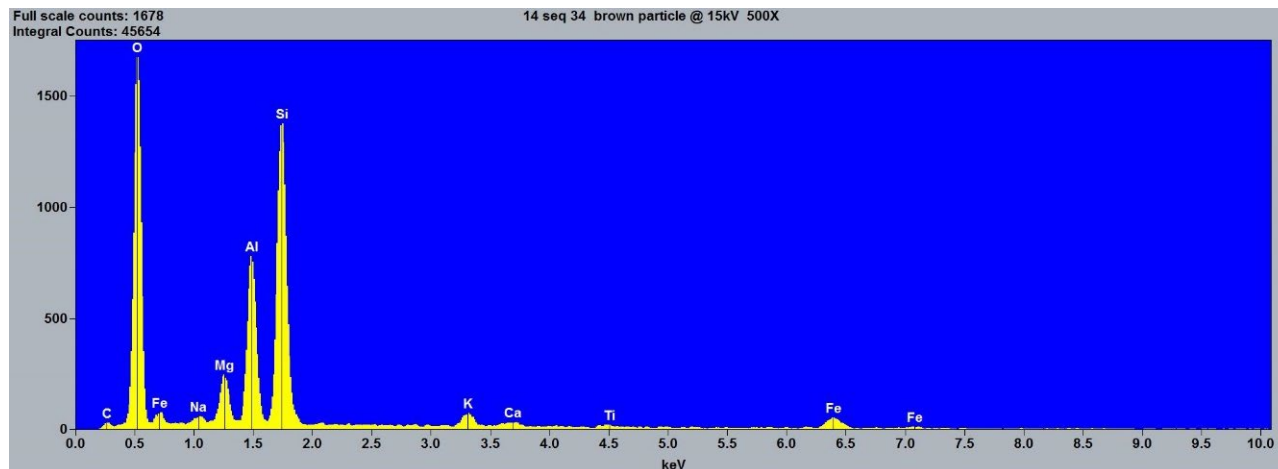


Length = 1.5 mm (0.059 in)

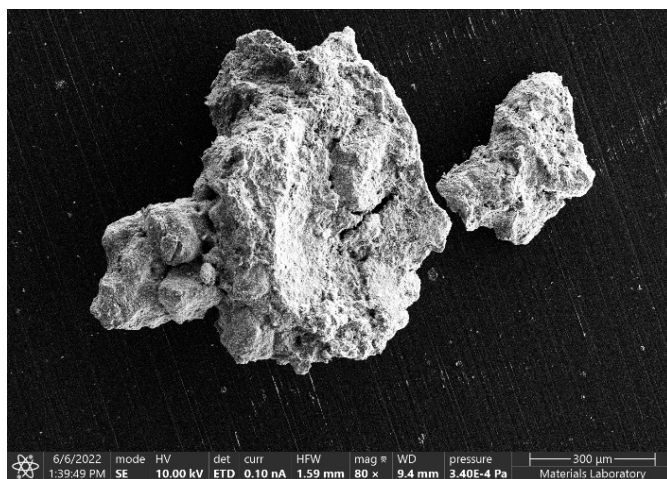
Width = 0.6 mm (0.024 in)

Thickness = 0.06 mm (0.002 in) estimated;
based on appearance of
fractured edge

Appendix 7C (Sample 7C)



Element	14 seq 34 brown particle @ 15kV 500X	
	Line Type	Weight %
C K	K	1.23
O K	K	49.42
Na K	K	0.83
Mg K	K	3.50
Al K	K	11.31
Si K	K	24.15
K K	K	1.88
Ca K	K	0.80
Ti K	K	0.49
Fe K	K	6.42
		100.00

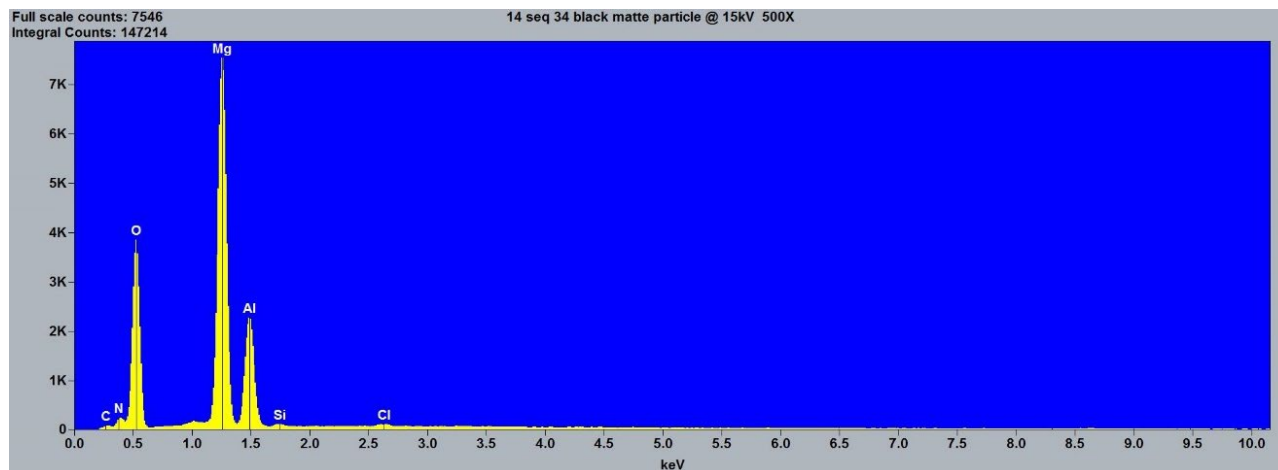


Length = 1.2 mm (0.047 in)

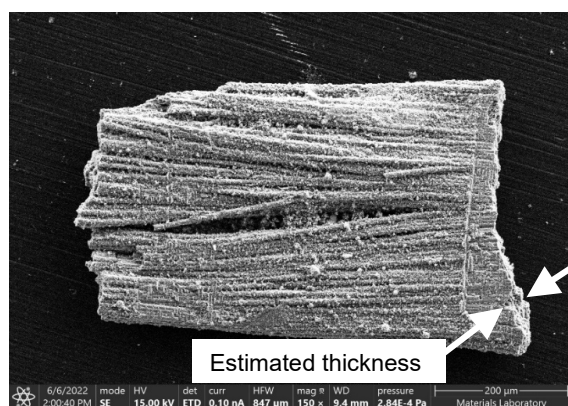
Width = 0.8 mm (0.031 in)

Thickness = not measured;
appears less than width

Appendix 7D (Sample 7D)



Element	14 seq 34 black matte particle @ 15kV 500X	
	Line Type	Weight %
C K	K	1.29
N K	K	2.95
O K	K	39.77
Mg K	K	38.28
Al K	K	16.92
Si K	K	0.41
Cl K	K	0.38
		100.00

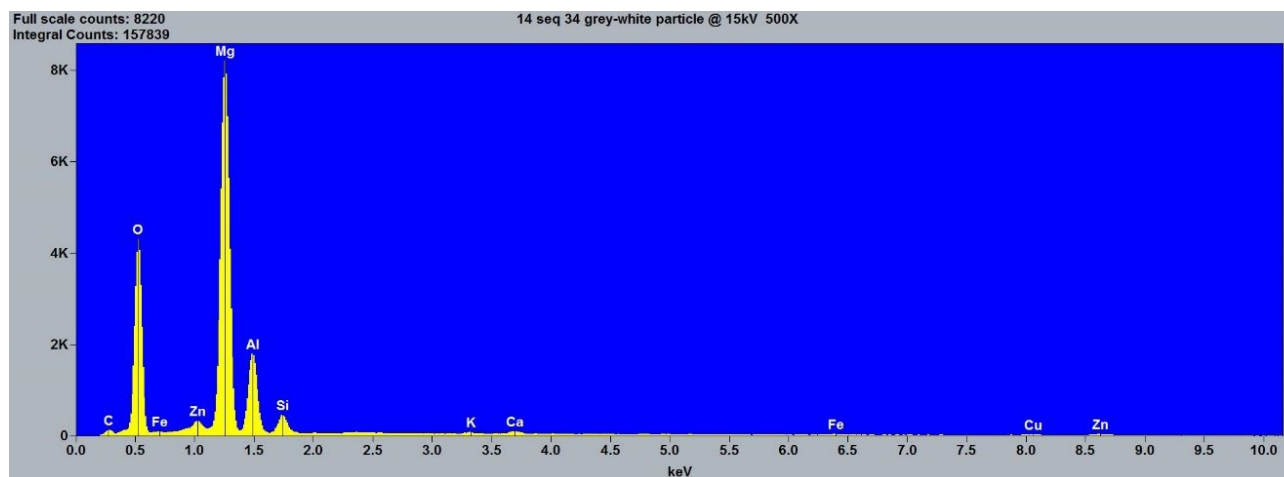


Length = 0.7 mm (0.028 in)

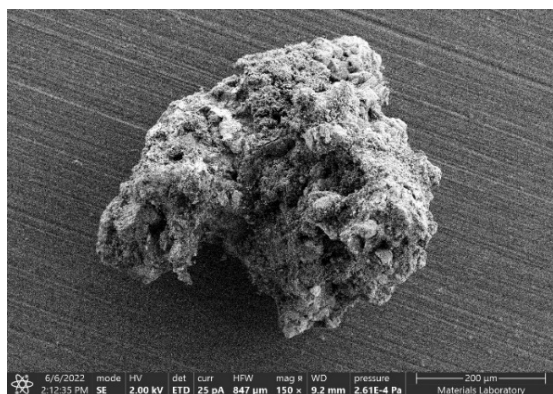
Width = 0.4 mm (0.016 in)

Thickness = 0.04 mm (0.002 in) estimated;
based on appearance of fractured edge

Appendix 7E (Sample 7E)



Element	14 seq 34 grey-white particle @ 15kV 500X	
	Line Type	Weight %
C K	K	1.68
O K	K	36.97
Mg K	K	39.79
Al K	K	11.84
Si K	K	2.87
K K	K	0.24
Ca K	K	0.55
Fe K	K	0.69
Cu K	K	1.58
Zn K	K	3.80
		100.00

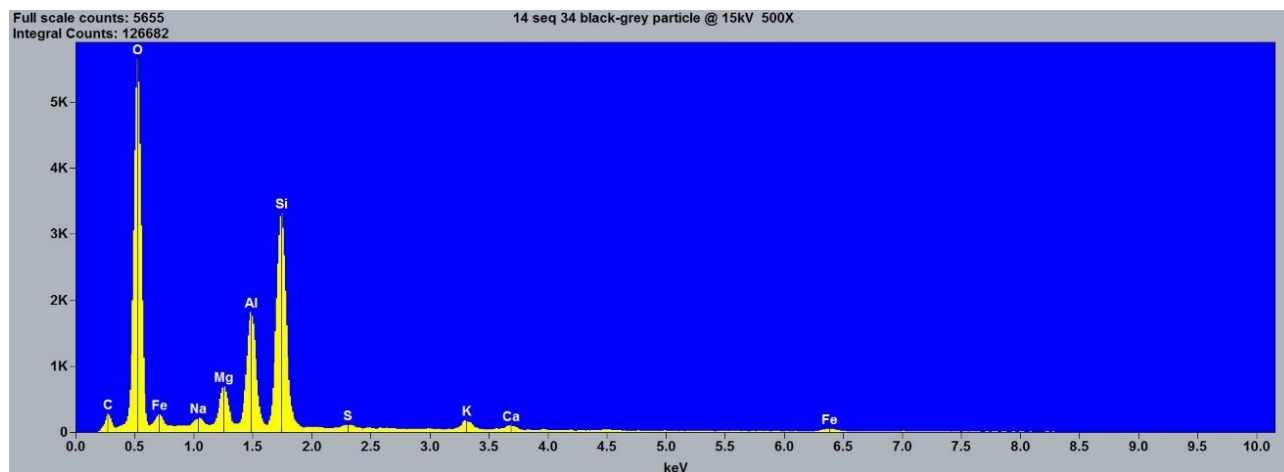


Length = 0.5 mm (0.020 in)

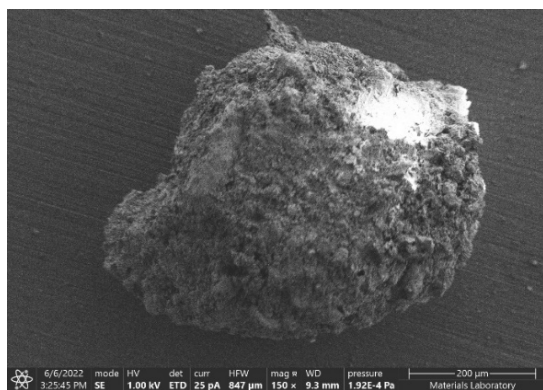
Width = 0.5 mm (0.020 in)

Thickness = not determined

Appendix 7F (Sample 7F)



Element	14 seq 34 black-grey particle @ 15kV 500X	
	Line Type	Weight %
C K	K	3.93
O K	K	56.80
Na K	K	1.03
Mg K	K	3.47
Al K	K	9.51
Si K	K	20.40
S K	K	0.64
K K	K	1.50
Ca K	K	0.66
Fe K	K	2.08
		100.00

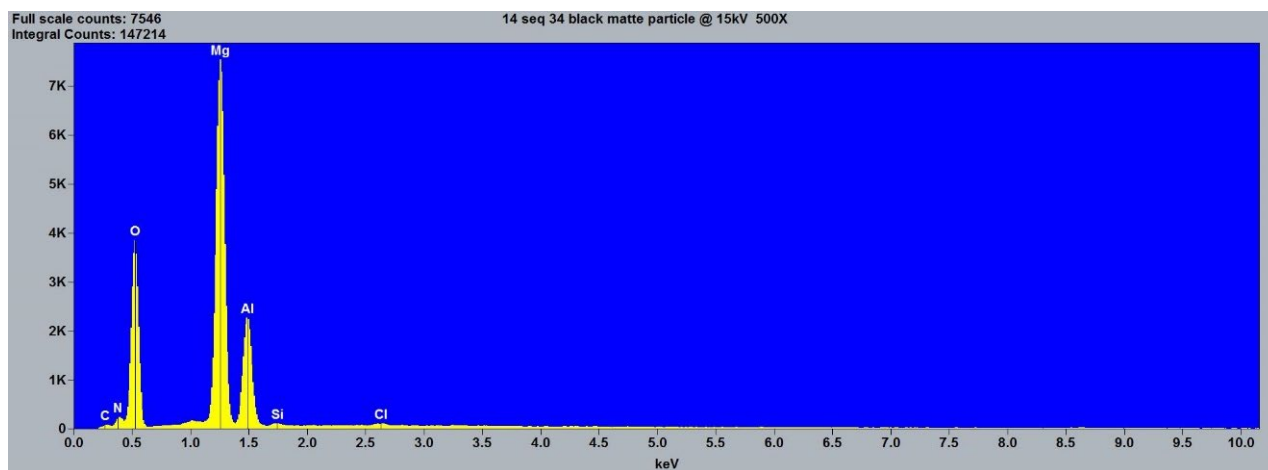


Length = 0.6 mm (0.024 in)

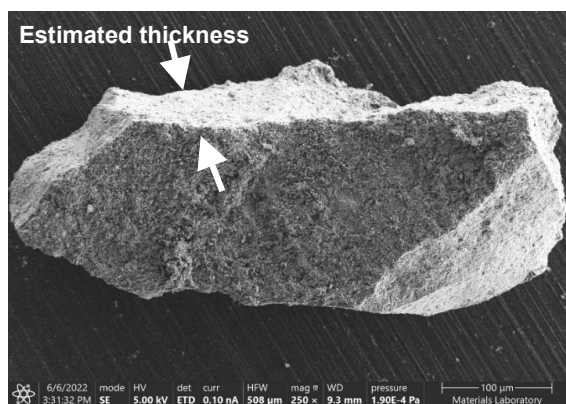
Width = 0.5 mm (0.020 in)

Thickness = not determined

Appendix 7G (Sample 7G)



Element	14 seq 34 black matte particle @ 15kV 500X	
	Line Type	Weight %
C K	K	1.29
N K	K	2.95
O K	K	39.77
Mg K	K	38.28
Al K	K	16.92
Si K	K	0.41
Cl K	K	0.38
		100.00

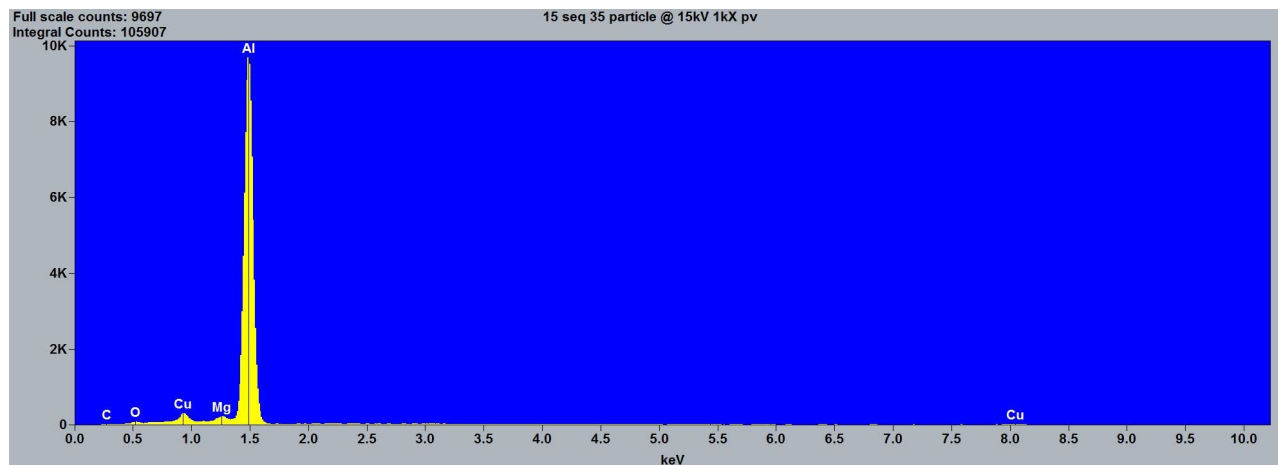


Length = 0.5 mm (0.020 in)

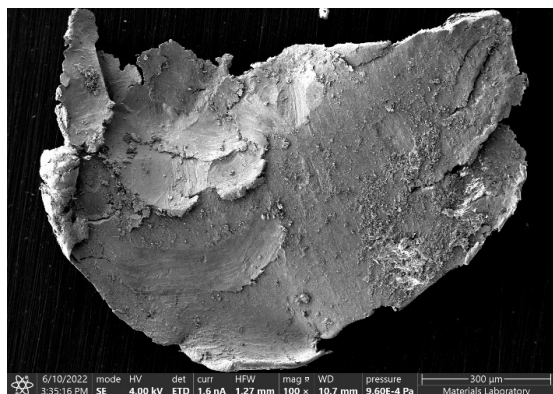
Width = 0.2 mm (0.008 in)

Thickness = 0.05 mm (0.002 in) estimated;
based on appearance of fractured edge

Appendix 7H (Sample 7H)



Element	15 seq 35 particle @ 15kV 1kX pv	
	Line Type	Weight %
C K	K	1.49
O K	K	1.04
Mg K	K	1.17
Al K	K	91.34
Cu K	K	4.96
		100.00

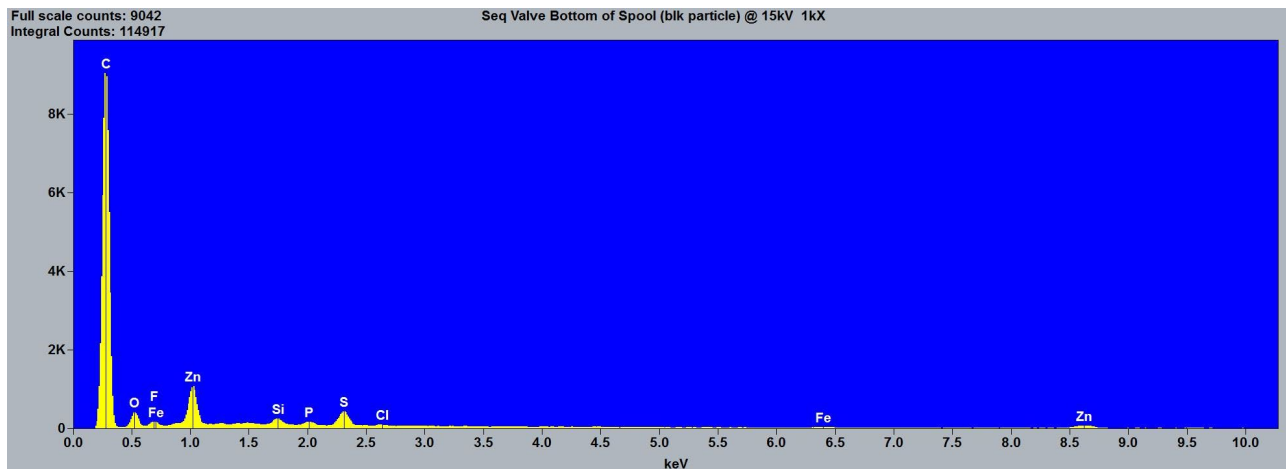


Length = 1.2 mm (0.047 in)

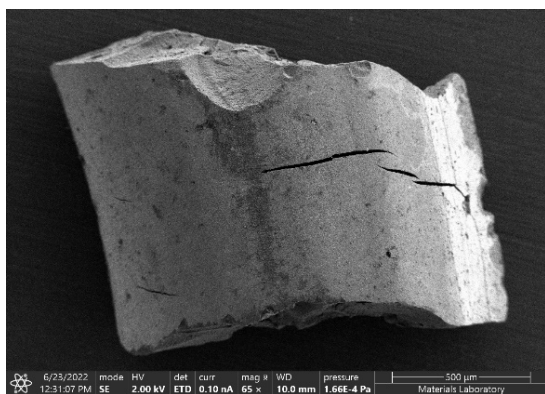
Width = 0.7 mm (0.028 in)

Thickness = not measured;
appeared less than width

Appendix 7I (Sample 7I)



Element	Seq Valve Bottom of Spool (blk particle) @ 15kV 1kX	
	Line Type	Weight %
C K	K	72.58
O K	K	8.65
F K	K	1.36
Si K	K	0.91
P K	K	0.55
S K	K	2.58
Cl K	K	0.38
Fe K	K	0.80
Zn K	K	12.20
		100.00

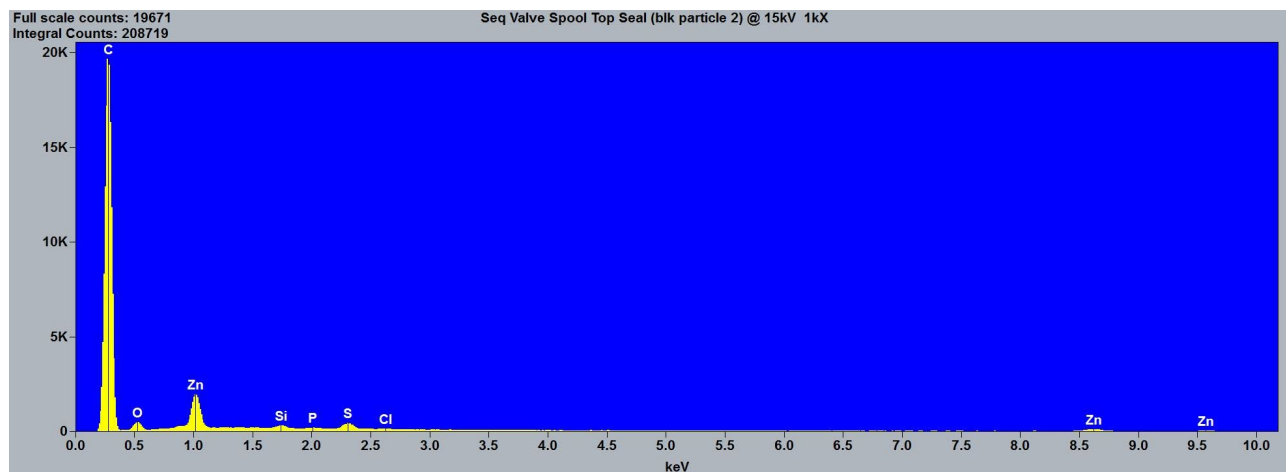


Length = 1.4 mm (0.055 in)

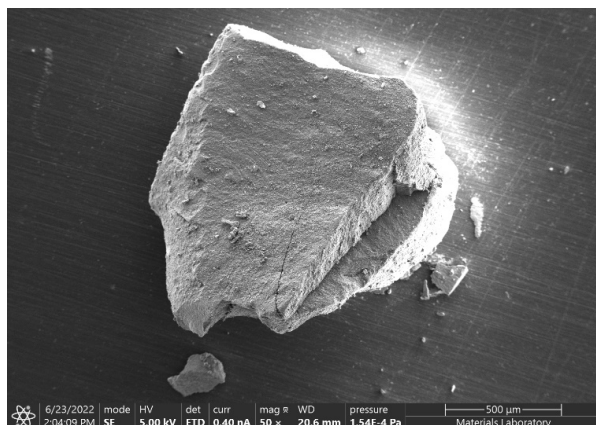
Width = 1.1 mm (0.043 in)

Thickness = not measured;
appeared less than width

Appendix 7J (Sample 7J)



Element	Seq Valve Spool Top Seal (blk particle 2) @ 15kV 1kX	
	Line Type	Weight %
C K	K	80.16
O K	K	6.25
Si K	K	0.59
P K	K	0.25
S K	K	1.51
Cl K	K	0.23
Zn K	K	11.02
		100.00

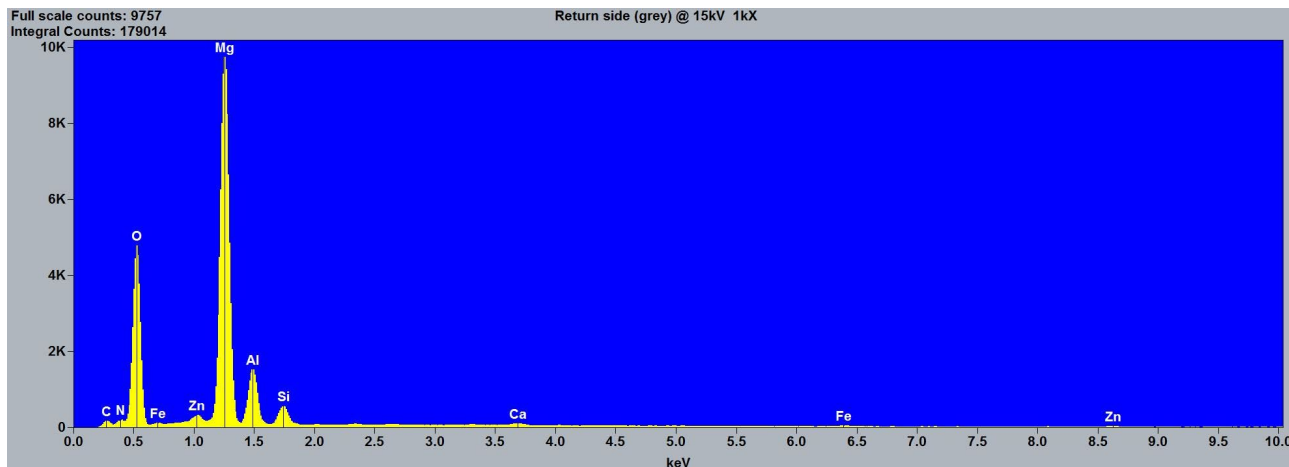


Length = 1.4 mm (0.055 in)

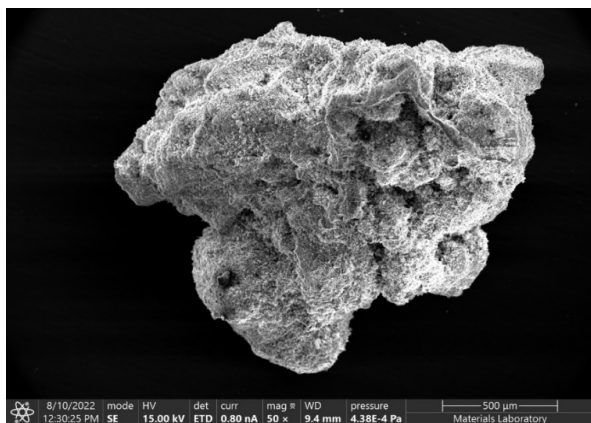
Width = 1.2 mm (0.047 in)

Thickness = not measured;
appeared less than width

Appendix 7K (Sample 7K)



Element	Return side (grey) @ 15kV 1kX	
	Line Type	Weight %
C K	K	2.07
N K	K	2.26
O K	K	36.89
Mg K	K	41.77
Al K	K	8.85
Si K	K	3.23
Ca K	K	0.60
Fe K	K	1.13
Zn K	K	3.20
		100.00

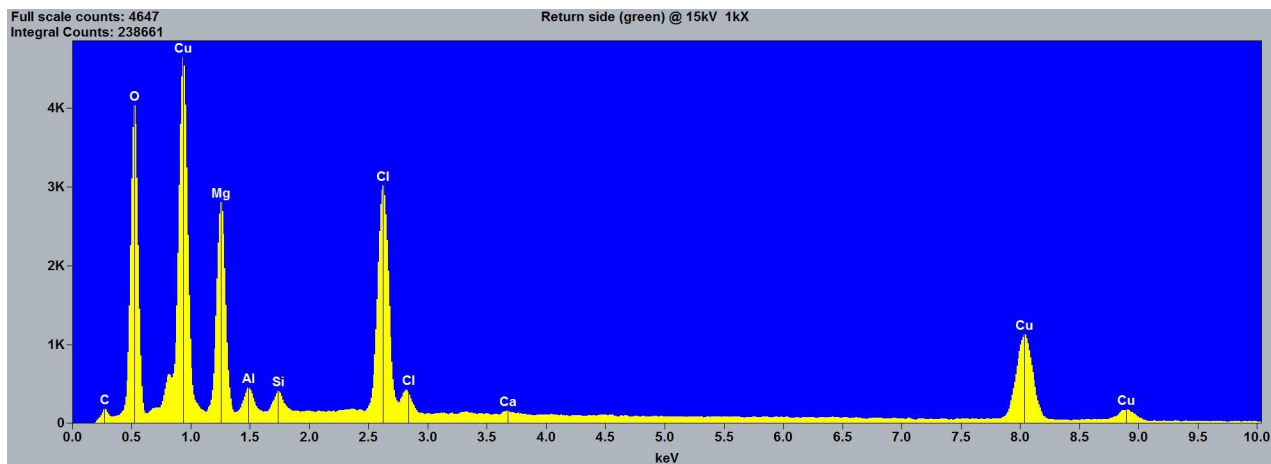


Length = 1.9 mm (0.075 in)

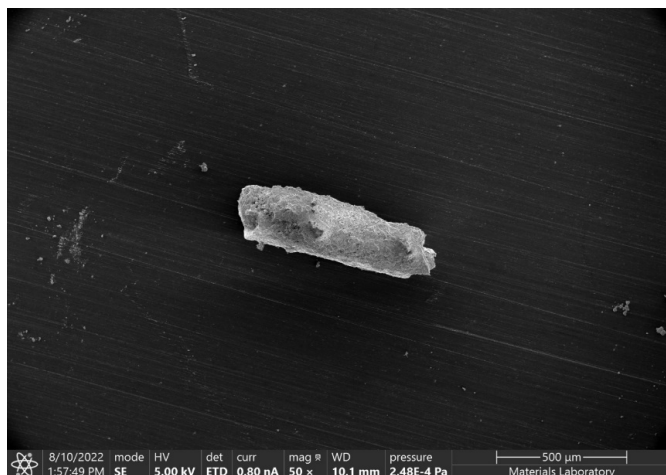
Width = 1.5 mm (0.059 in)

Thickness = not measured;
appeared less than width

Appendix 7L (Sample 7L)



Element	Return side (green) @ 15kV 1kX	
	Line Type	Weight %
C K	K	1.26
O K	K	20.33
Mg K	K	11.31
Al K	K	1.25
Si K	K	0.89
Cl K	K	11.38
Ca K	K	0.21
Cu K	K	53.36
		100.00

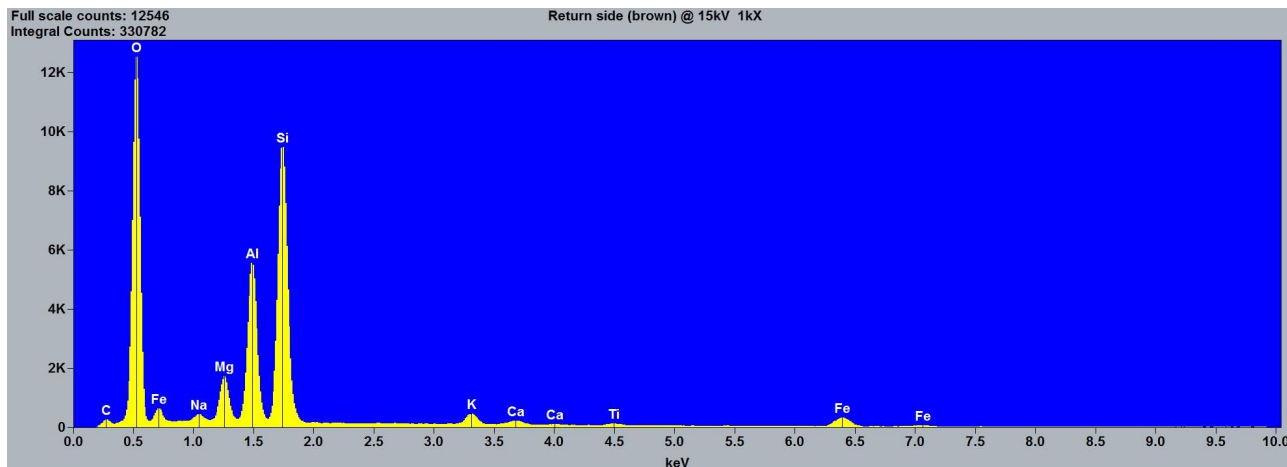


Length = 0.79 mm (0.031 in)

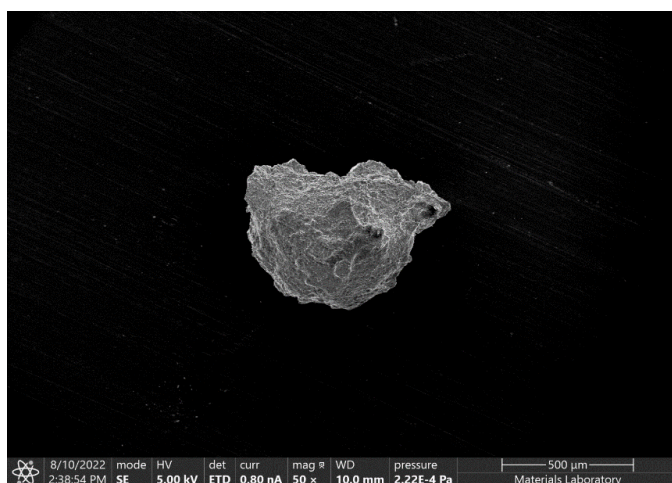
Width = 0.23 mm (0.009 in)

Thickness = not measured;

Appendix 7M (Sample 7M)



Element	Return side (brown) @ 15kV 1kX	
	Line Type	Weight %
C K	K	1.45
O K	K	50.73
Na K	K	0.71
Mg K	K	3.41
Al K	K	11.48
Si K	K	23.26
K K	K	1.57
Ca K	K	0.82
Ti K	K	0.45
Fe K	K	6.12
		100.00

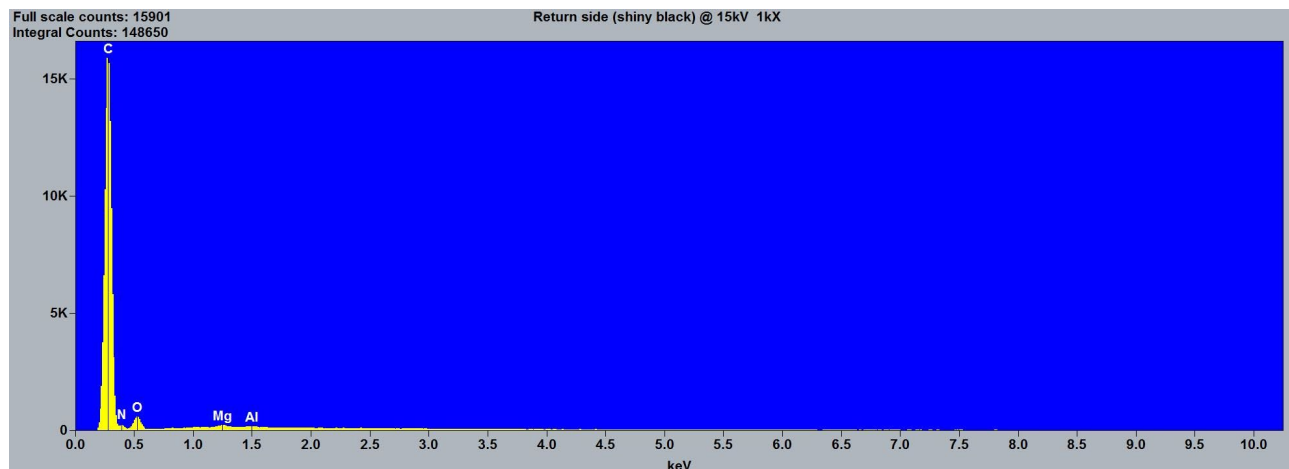


Length = 0.77 mm (0.030 in)

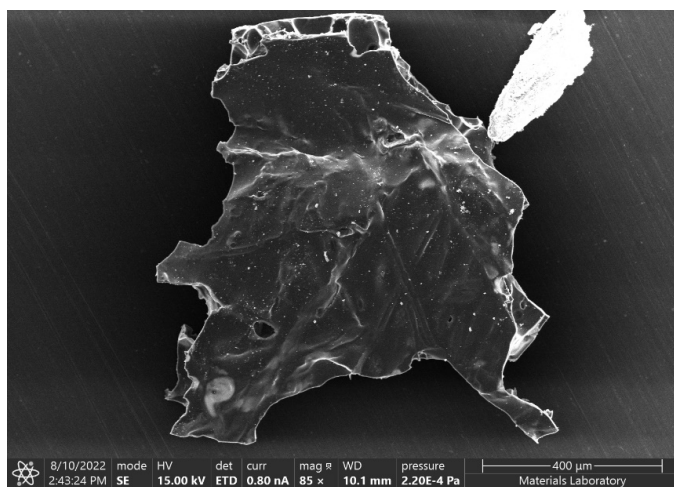
Width = 0.5 mm (0.02 in)

Thickness = not measured;
appeared less than width

Appendix 7N (Sample 7N)



Element	Return side (shiny black) @ 15kV 1kX		
	Line Type		Weight %
C K	K		64.46
N K	K		13.91
O K	K		20.93
Mg K	K		0.46
Al K	K		0.23
			100.00

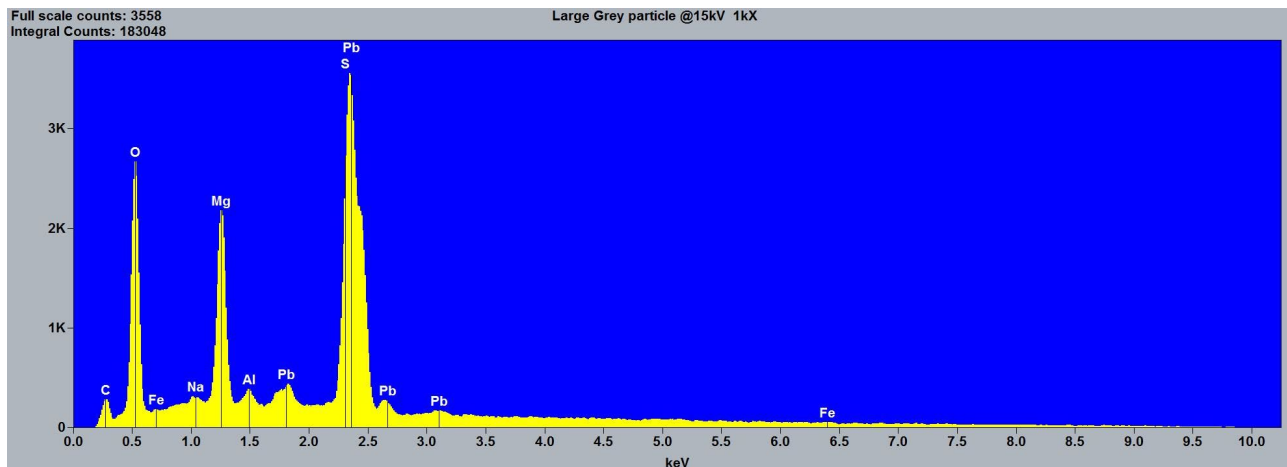


Length = 0.81 mm (0.032 in)

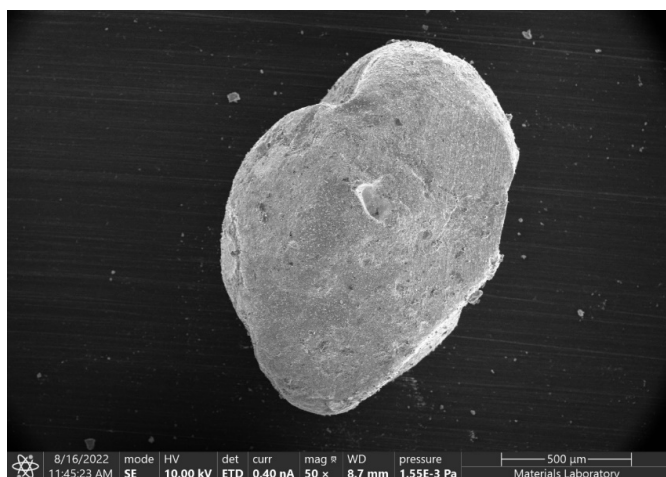
Width = 0.7 mm (0.028 in)

Thickness = not measured;
appeared less than width

Appendix 7O (Sample 7O)



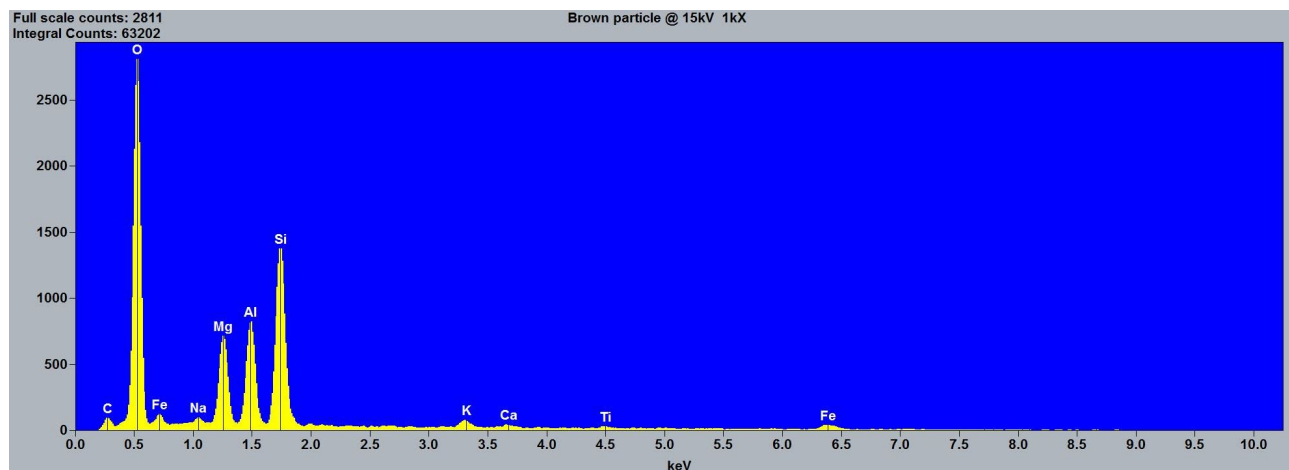
Large Grey particle @15kV 1kX		
Element	Line Type	Weight %
C K	K	1.03
O K	K	17.97
Na K	K	0.30
Mg K	K	8.11
Al K	K	0.60
S K	K	2.63
Fe K	K	1.80
Pb M	M	67.57
		100.00



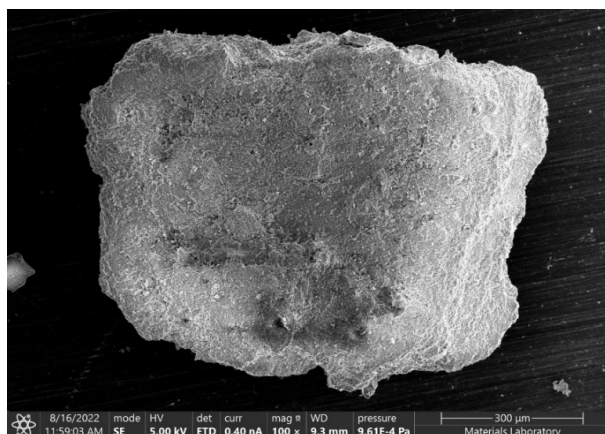
Length = 1.5 mm (0.059 in)

Width = 1.0 mm (0.039 in)

Thickness = not measured;
appeared less than width

Appendix 7P (Sample 7P)

Brown particle @ 15kV 1kX		
Element	Line Type	Weight %
C K	K	1.55
O K	K	41.23
Na K	K	0.55
Mg K	K	7.97
Al K	K	9.61
Si K	K	20.00
K K	K	1.96
Ca K	K	0.90
Ti K	K	1.06
Fe K	K	15.16
		100.00

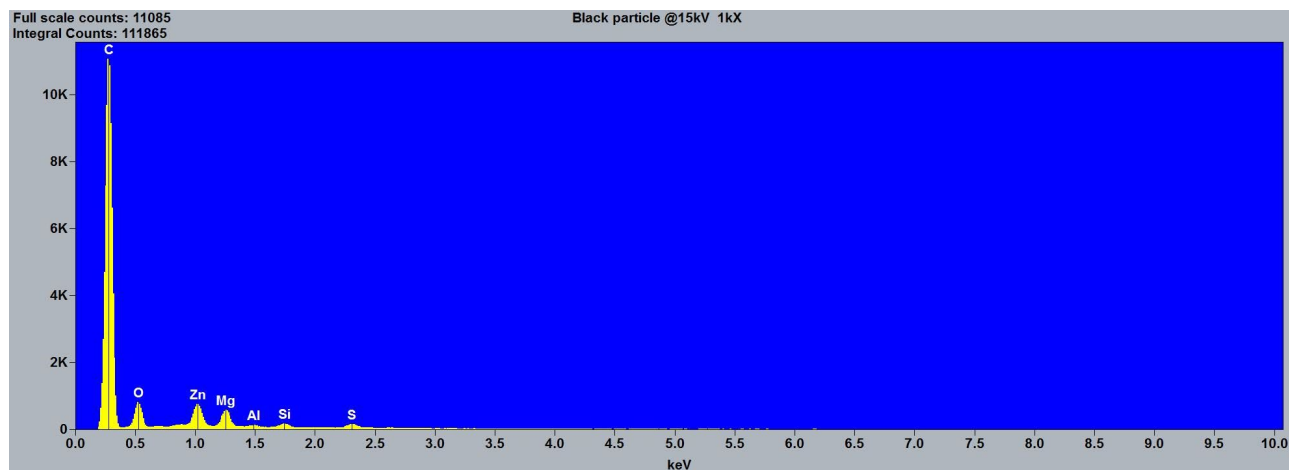


Length = 0.9 mm (0.0 in)

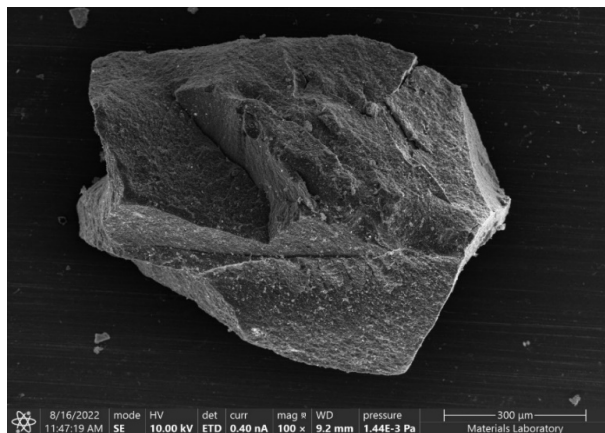
Width = 0.71 mm (0.028 in)

Thickness = not measured;
appeared less than width

Appendix 7Q (Sample 7Q)



Element	Black particle @15kV 1kX	
	Line Type	Weight %
C K	K	68.21
O K	K	14.11
Mg K	K	4.07
Al K	K	0.37
Si K	K	1.06
S K	K	1.62
Zn L	L	10.57
		100.00

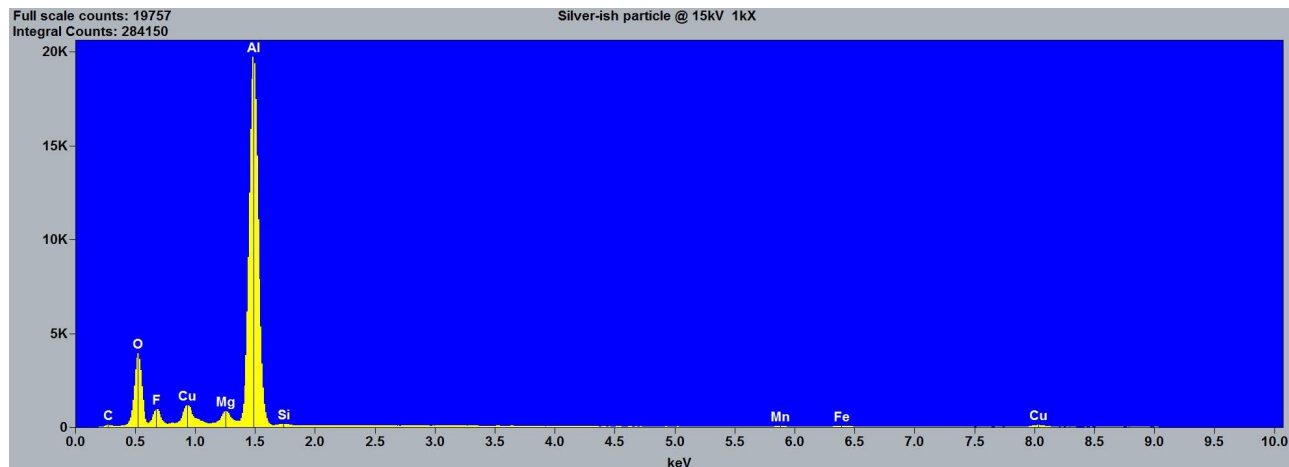


Length = 0.92 mm (0.036 in)

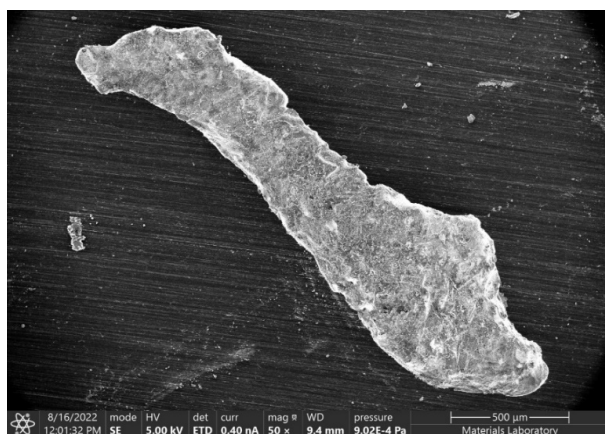
Width = 0.71 mm (0.028 in)

Thickness = not measured;
appeared less than width

Appendix 7R (Sample 7R)



Silver-ish particle @ 15kV 1kX		
Element	Line Type	Weight %
C K	K	1.23
O K	K	24.42
F K	K	7.62
Mg K	K	1.68
Al K	K	56.53
Si K	K	0.38
Mn K	K	0.62
Fe K	K	1.55
Cu K	K	5.97
		100.00

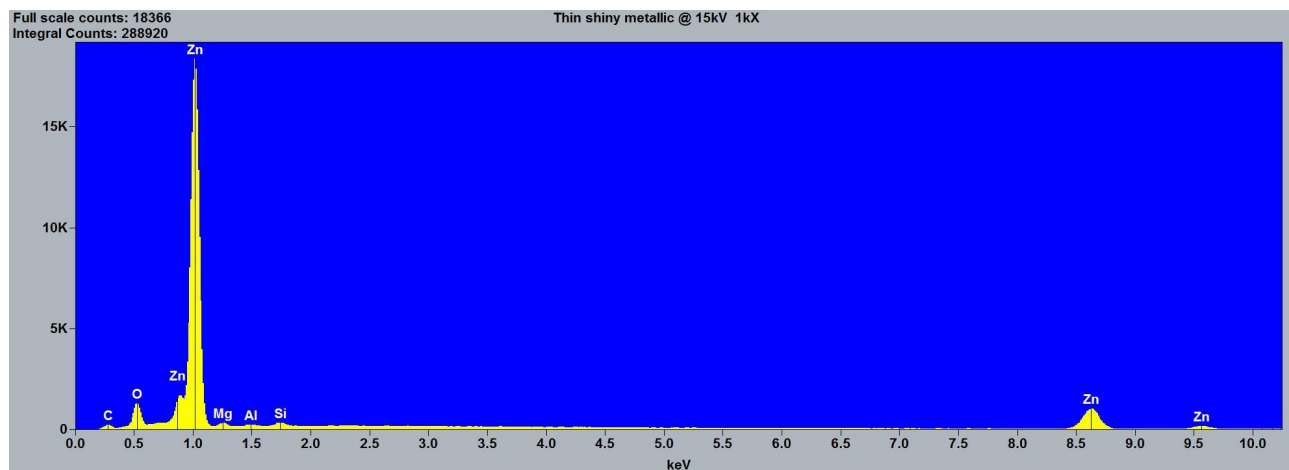


Length = 2.29 mm (0.090 in)

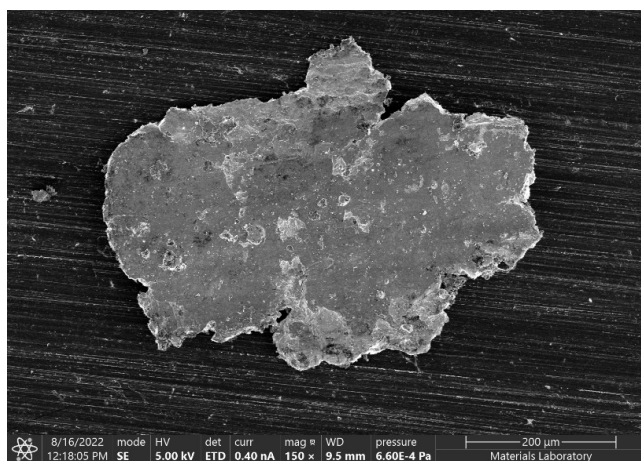
Width = 0.47 mm (0.019 in)

Thickness = not measured;
appeared less than width

Appendix 7S (Sample 7S)



Element	Thin shiny metallic @ 15kV 1kX	
	Line Type	Weight %
C K	K	2.30
O K	K	7.97
Mg K	K	1.17
Al K	K	0.53
Si K	K	0.97
Zn K	K	87.06
		100.00



Length = 0.57 mm (0.022 in)

Width = 0.38 mm (0.015 in)

Thickness = not measured;
appeared less than width