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

November 8, 2017

MATERIALS LABORATORY FACTUAL REPORT Report No. 17-067

A. ACCIDENT INFORMATION

Place	:	McKinleyville, California
Date	:	July 29, 2016
Vehicle	:	Piper PA31T
NTSB No.	:	WPR16FA153
Investigator	:	Brice Banning IIC/AS-ANC
		Nancy McAtee Fire Group Chairman RE-30

B. COMPONENTS EXAMINED

High voltage wiring sections attached to the main bus tie circuit breaker panel located in floor of cockpit; hydraulic lines co-located in area under main bus tie circuit breaker; fuel cross-feed valve and attached fuel lines.

C. DETAILS OF THE EXAMINATION

The following components were submitted to the Materials Laboratory for examination. All electrical components were examined for electrical arcing and related signatures. The hydraulic and fuel components were submitted to determine the cause of the fractures in the lines.

Wire Examination

Wires that were connected to the high-power circuit breaker panel were identified and removed from the aircraft for further examination. For system identifications and description of individual wires, see the WPR16FA153 System Group Chairman's factual report.

Wire Name	Recovered Length (inches)	Notes	Figure Number
L MAIN 2	35	A portion of the circuit breaker remained attached to the wire. In addition, the wire was trapped inside a section of structure. Approximately 11 inches of wire insulation were missing from the fractured end of the wire. The remaining insulation exhibited thermal discoloration and shrinking. Signs of heat damage reduced in severity moving away from the circuit breaker panel end. The fractured end was frayed, and the exposed conductor showed notching consistent with mechanical rubbing. The fractured end was examined using a scanning electron microscope (SEM). No obvious signs of arcing on exposed sections of conductor were found. Several areas of the cross diameter on several conductors were flattened and appeared to have missing material. The end was also examined using electron dispersive spectroscopy (EDS) to look for the presence of foreign materials present on the wire conductors. No foreign material was found.	1,2,3
L MAIN 1	31	The wire insulation exhibited limited thermal discoloration. A section approximately 2.5 inches from the pressure seal had lost the outer insulation layer but the inner braided layer was still present. In addition, there were several small scattered areas of damaged outer insulation.	4
ICE L (Section 1)	26	This section was cut just below pressure seal for removal. Approximately 10.5 inches of insulation were missing from fractured end, followed by approximately 10 inches of thermal discolored insulation. No obvious signs of arcing on exposed conductors.	5
ICE L (Section 2)	~48	Approximately 20 inches of thermal insulation from the fractured end were discolored. The other end was disconnected directly from the circuit breaker panel. A small section of pressure bulk head seal was present.	6
STC Fuse to Bus Bar	13.5	The entire length was missing insulation. The fractured end showed signs of welding and beading. There were some signs of mid-conductor damage approximately 10 inches from fractured end. There were small areas of beading/welding also present in this area.	7

NON-ESS	74	This wire section was still attached (tied together) to the ICE R section. The section from the fractured end to pressure seal was 49.5 inches in length. The remaining section from pressure seal to the circuit breaker panel connector (Yellow) was 24.5 inches in length. There were approximately 8 inches of bare conductor at the fractured end. The remaining insulation was thermally damaged the entire length to the pressure seal. There was some scattered tearing and slippage of the insulation. No obvious thermal damage above the pressure seal to the connection. No obvious signs of arcing (beading or welding)	8
ICE R	97.5	This wire section was still attached to the NON-ESS section. The section from the fractured end to pressure seal was 47.5 inches in length and 20 inches from pressure seal to circuit breaker connector (Yellow). There were approximately 9 inches of bare conductor at the fractured end. The remaining insulation was thermally damaged the entire to the pressure seal. There was some scattered tearing and slippage of the insulation. No obvious thermal damage above the pressure seal to the connection. No obvious signs of arcing (beading or welding).	8
R MAIN2 (Section 1)	53	The section from the fractured end to the cut was 38 inches in length. The fractured end was frayed. The section from the cut to the pressure seal was 15 inches in length. There were approximately 5.5 inches of missing insulation at the fractured end. There were two areas of missing insulation located 1.5 and 3.5 inches from beginning edge of the insulation. There was approximately 1 inch of exposed conductor at pressure seal. The remaining insulation was numerous areas of thermal discoloration and sooting. There were also some small scattered areas of missing insulation. The pressure seal had thermal damage. There was some structure still attached with bare conductors leading up to the structure. No obvious signs of arcing (beading or welding) on the exposed conductors.	9

R MAIN2 (Section 2)	18	The section was still attached to the circuit breaker panel. The total recovered length ran from the cut end to the circuit breaker panel. The diode was still present. There were approximately 7 inches of exterior thermal damage to insulation, but the insulation was still intact.	10
RBUS 1	34	The section was still attached to the circuit breaker panel. The total recovered length ran from the cut end to the circuit breaker panel. No obvious signs of thermal damage.	10
RBUS 2	32	The section was still attached to the circuit breaker panel. The total recovered length ran from the cut end to the circuit breaker panel. No obvious signs of thermal damage.	10
R MAIN1	65	A portion of circuit breaker post was attached on the fractured end. The length from the fractured end to the pressure seal was 32.5 inches in length. The wire section from pressure seal to circuit breaker was 32.5 inches in length. There were approximately 9.5 inches of bare conductor on the fractured end. No obvious signs of arcing (beading or welding) on the exposed section. The remaining insulation exhibited thermal damage up to the pressure seal and continued to approximately 12.5 inches past the pressure seal. This section was x-rayed to look for conductor damage underneath the insulation. No anomalies were found in radiograph.	11
P3H	7	The wire section contains both terminal ends. The entire wire section was missing insulation. A large area of welded conductors/arcing was present approximately 2 inches and 4.5 inches from terminal ends.	12, 13, 14
P2B	6.5	The wire contained both terminal ends. The insulation was intact over the entire length with some scattered areas of thermal damage.	15
P3B to Battery	6	The insulation was missing over the entire length of the wire section. There were multiple small areas of welding conductors and some areas of mid-conductor beading.	15

RAD ½ (wire A)	68	There were 8.5 inches of bare conductor starting from the fractured end. There were approximately 6 inches of thermal damage to the surface of the wire insulation starting at the edge of intact insulation and approximately 7.5 inches of thermal discoloration past the damaged insulation. There were no obvious signs of arcing (beading or welding).	16
RAD ½ (wire B)	65	There were 5 inches of bare conductor starting from the fractured end. There were approximately 3 inches of thermal damage to the surface of the wire insulation starting at the edge of intact insulation and bubbling of the inner layer of insulation. There was approximately 15 inches of thermal discoloration past the damaged insulation. There were no obvious signs of arcing (beading or welding).	17
EMS INV PWR	66	There was a 27-inch section of bare conductor starting at the fractured end. There were areas of slippage and tearing of the intact insulation. There was a small area of mid conductor that exhibited some beading but no large areas of welding or beading.	18
EMS PWR	61	There was a 23-inch section of bare conductor starting at the fractured end. Some nicks in the intact wire insulation as well as some slippage and areas of light sooting. There were a few random areas of small beading but no large area of welding or beading.	19
P2E	60	The bus bar was still attached to one end. with 13.5 inches of bare conductor on this end of the wire. There was approximately 6 inches of bare conductor on the fractured end. There was also scattered nicks and slippage and melting of insulation adjacent to the exposed conductor areas. There were no obvious signs of arcing (beading or welding). There was heavy sooting on the outer wire insulation in the area of the right wing (RW) disconnect.	20

P2K	58	The starter solenoid was still attached on one end. There were 7 inches of bare conductor on the fractured end and 14 inches of bare conductor exposed at the RW disconnect end. The intact insulation near RW disconnect end was melted. There was slippage and melting of intact insulation adjacent to exposed conductors. There were scattered areas of small beading in areas where there was mechanical damage to the conductor. There was heavy sooting in area of RW disconnect.	21
P1K	73	A section of the insulation from P1E and P1K had melted together. The wires were separated for examination. There were approximately 10 inches of bare conductor at starter end. There were small areas beading and broken conductor mid-width. There were scattered tears and nicks in the remaining insulation as well as slippage, thermal puckering and melting in the insulation adjacent to the exposed conductors.	22
P1E	121	A section of the insulation from P1E and P1K had melted together. The shunt was present on one end. There was some beading and welding approximately 7 inches from fractured end. There were two areas along the length of the wire section with approximately 12 inches exposed conductors. There were several broken conductor strands in both exposed areas. The intact insulation adjacent to areas of bare conductor was melted.	23
Unidentified		There was approximately a 3-inch section of exposed conductor at the end of the section opposite the cut. There was slippage and melting of the insulation adjacent to this exposed area. There was some welding and beading at the very ends of the conductors on the bare end consistent with the conductor ends being pulled out of a connection.	24

Hydraulic lines

The remaining sections of the following hydraulic tubes were removed from the accident aircraft: 1) GEAR UP, 2) GEAR DOWN, 3) DOOR OPEN, and 4) DOOR CLOSED as shown in Figure 25. The hydraulic lines were constructed of 5050-0 aluminum tubing. All the

remaining lines displayed visible signs of heat exposure (material melting and changes in surface finish) and several inches of material were missing each of the lines.

The fractured ends on all the lines were examined. All the line ends exhibited patterns consistent with overstress fracture; some fractures exhibited features consistent with elevated temperature exposure as a contributing factor. On one of the fractured tubes, the GEAR UP line, intergranular fracture features were found as shown in Figure 26. A cross-section of fracture area showed severe grain separation along the grain boundaries, along with missing grains and intergranular voids. These features were consistent with incipient melting, where one of the solid phases (the interdendritic Zn/Mg-heavy phases) melt while the primary matrix (Al-rich) phase does not[1]. This suggests that the temperature was above the solidus temperature for the alloy, but below the liquidus (complete melting) temperature[2]. There were no indications of microstructural features consistent with stress corrosion cracking or embrittlement.

Fuel system components

The cross-feed valve and several sections of associated fuel lines were submitted for examination. The components are shown in Figure 27. The left side line was intact to the fitting. A section of the right side was still present however the fitting was separated from the rest of the line. The fractured end of the right fitting shown fracture features consistent with overstress. The fracture end of the section still attached to the valve showed signs of melting and sagging consistent with thermal exposure.

Residue analysis

A brown residue was found on the back of the circuit breaker panel. A small piece was removed from the surface of the panel as well as a sample of a black foam sealant material from another area of the circuit breaker panel. These two samples were examined using a Fourier Transform Infrared (FTIR) spectrometer with a diamond attenuated total reflectance (ATR) accessory in accordance to ASTM E1252-98 (American Society for Testing Materials E1252-98: Standard Practice for General Techniques for Obtaining Infrared Spectra for Qualitative Analysis and American Society for Testing Materials). The spectrometer was used to collect and process infrared wavelength absorbance spectra of the two samples.

The two spectra were a strong match. Both spectra contained spectral peaks that corresponded with specific molecular functional groups. A triplet peak at ~3692-3619 cm^{-1} corresponds to an oxygen-hydrogen bond (non-stretching). The presence of a broad peak between 3600-3050 cm^{-1} is indicative of a nitrogen-hydrogen bond. A doublet peak at ~2926 cm^{-1} and ~2855 cm^{-1} corresponds to a carbon-hydrogen stretching bond. A single peak at ~1735 cm^{-1} is indicative of a carbon-oxygen double bond (carbonyl). A single medium peak at ~1549 cm^{-1} is indicative of a nitrogen-hydrogen bond. A single medium peak at ~1457 cm^{-1} is indicative of a carbon-carbon double bond. A single peak at ~1245 cm^{-1} is indicative of

[1] Interdendritic is between dendrites of a crystal or metal.
[2] Solidus temperature is the highest temperature at which an alloy is solid.

a carbon-oxygen-carbon bond. A set of peaks at ~1089, 1030 cm^{-1} and ~1006 cm^{-1} are consistent with the presence of a carbon-nitrogen bond, a carbon-carbon (single) bond and a carbon-oxygen bond. These functional groups are consistent with an aromatic compound with an amide or carbamic functional group like a polyurethane.

A spectral library search for both samples was performed. The spectra from the materials removed from the circuit breaker panel had strong matches to several foam-type sealants.

Nancy B McAtee
Fire and Explosion Specialist

Figure 1. Overall photograph of L MAIN 2.

Figure 2. Closeup photograph of fractured end of L MAIN 2.

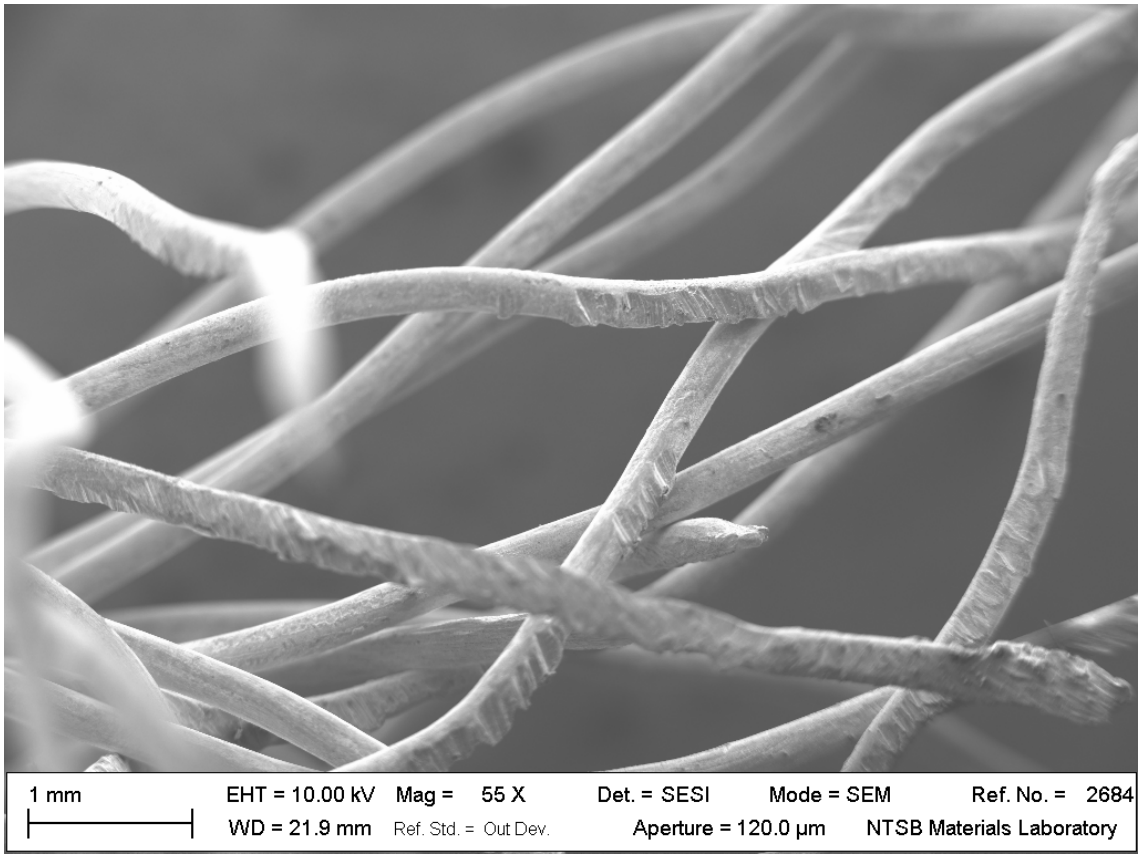

Figure 3. Micrograph of notching on conductor surface of L MAIN 2.

Figure 4. Overall photograph of L MAIN 1.

Figure 5. Overall photograph of L ICE (Section 1).

Figure 6. Overall photograph of ICE L (Section 2).

Figure 7. Overall photograph of STC fuse to bus bar.

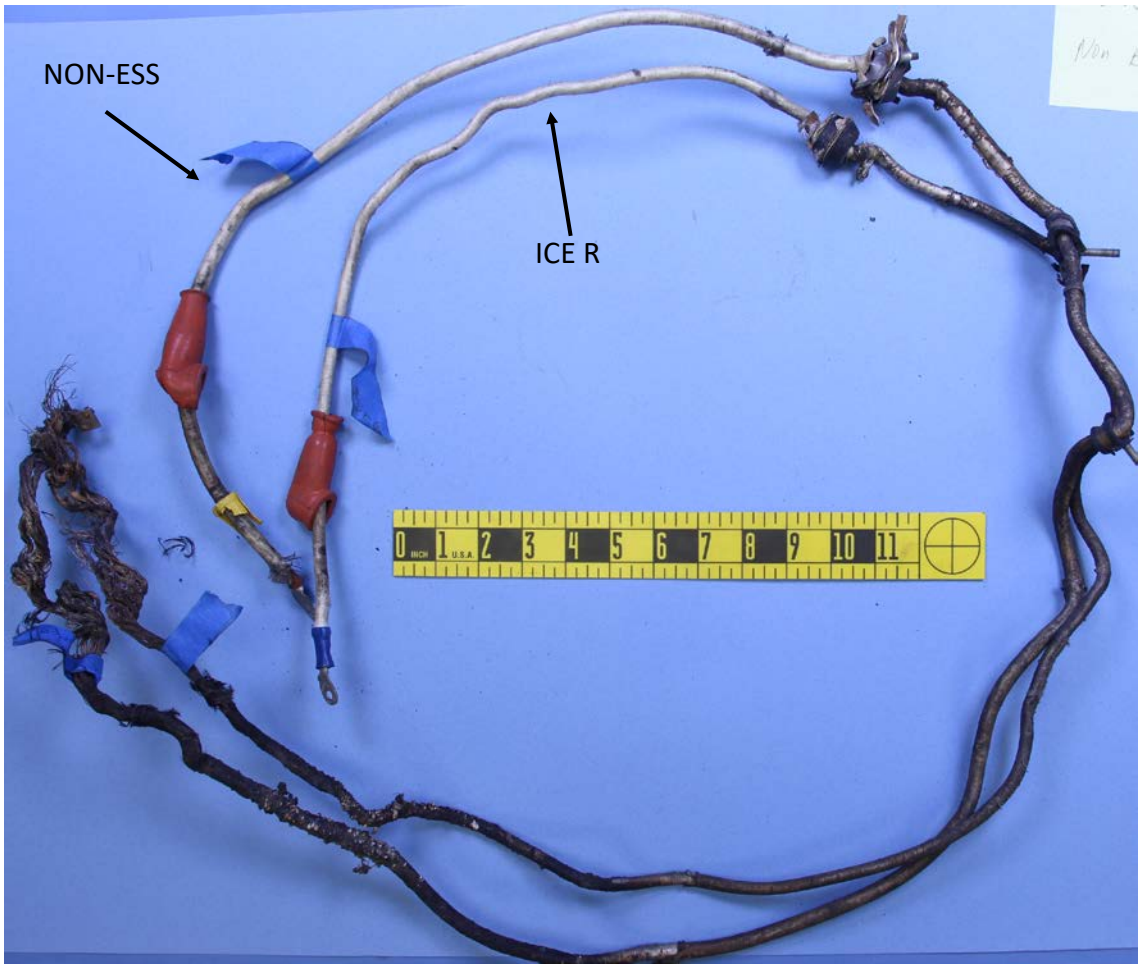

Figure 8. Overall photograph of NON-ESS and ICE R.

Figure 9. Overall photograph of R MAIN 2 (Section 1).

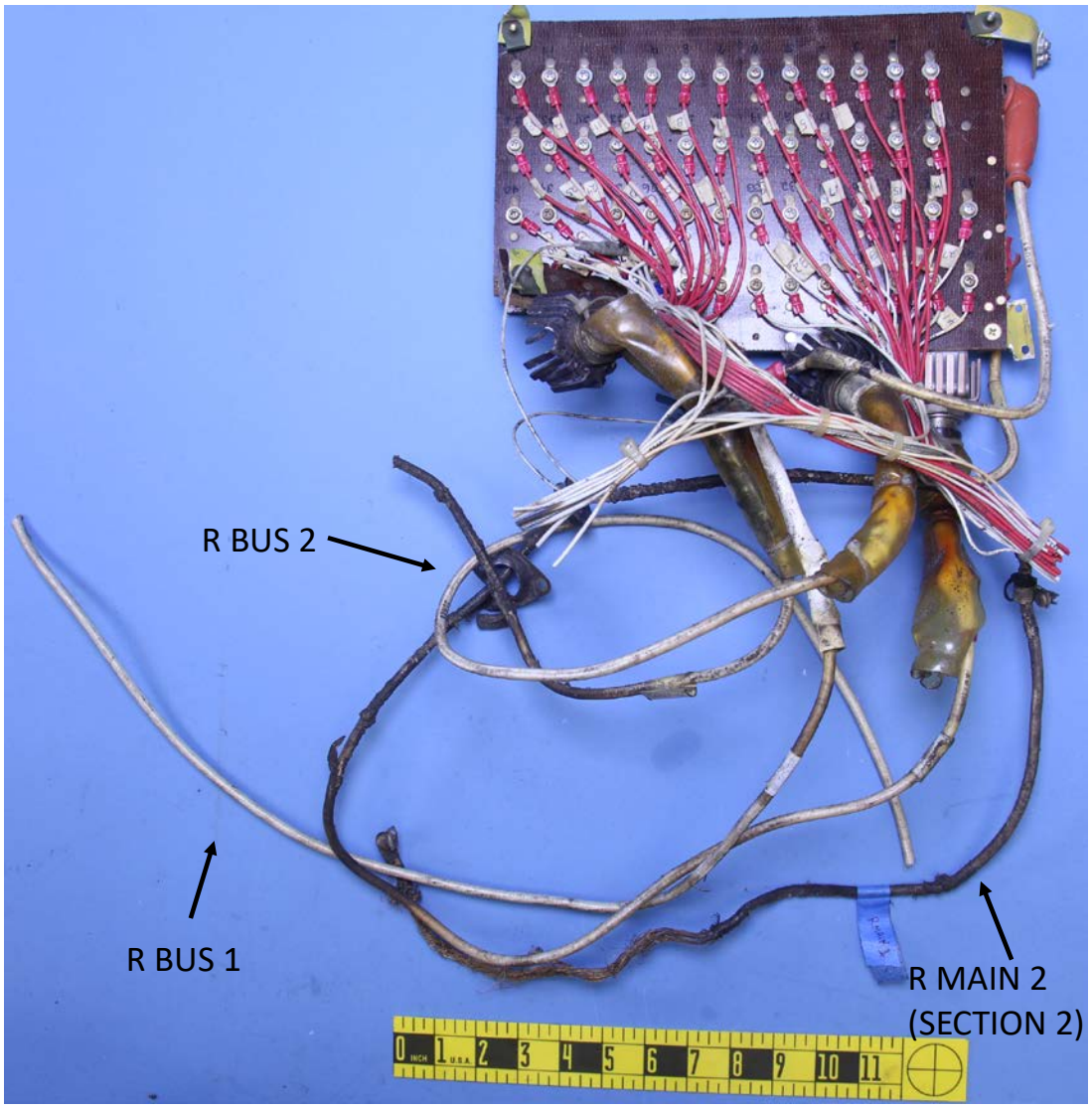

Figure 10. Overall photograph of circuit breaker panel with R BUS 1, R BUS 2, and R MAIN 2 (section 2) connected.

Figure 11. Overall photograph of R MAIN 1.

Figure 12. Overall photograph of P3H.

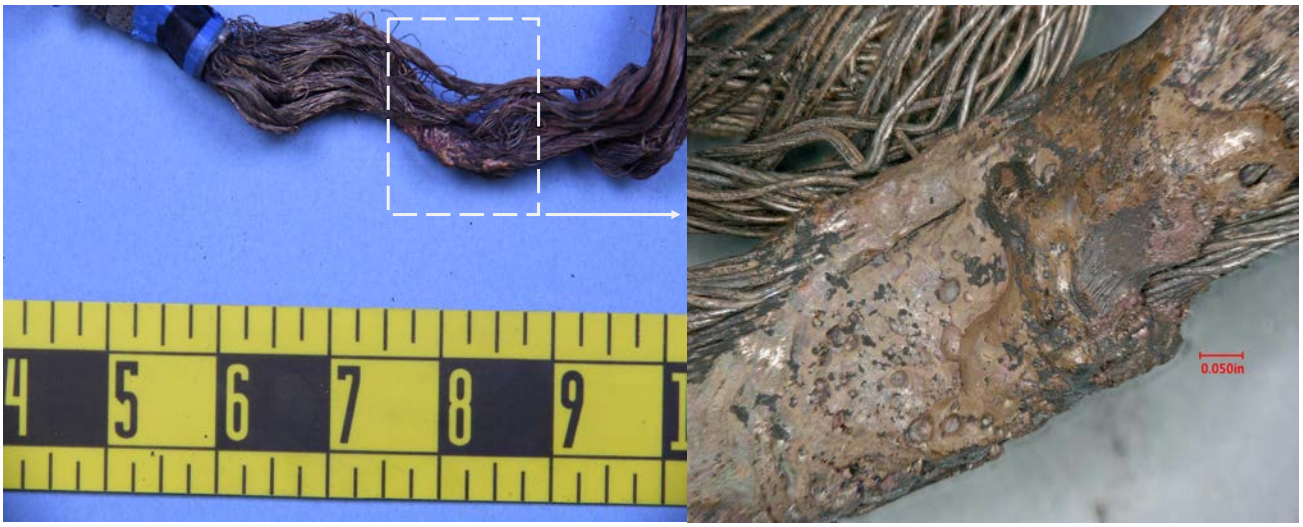

Figure 13. Closeup photograph of welded area on P3H.

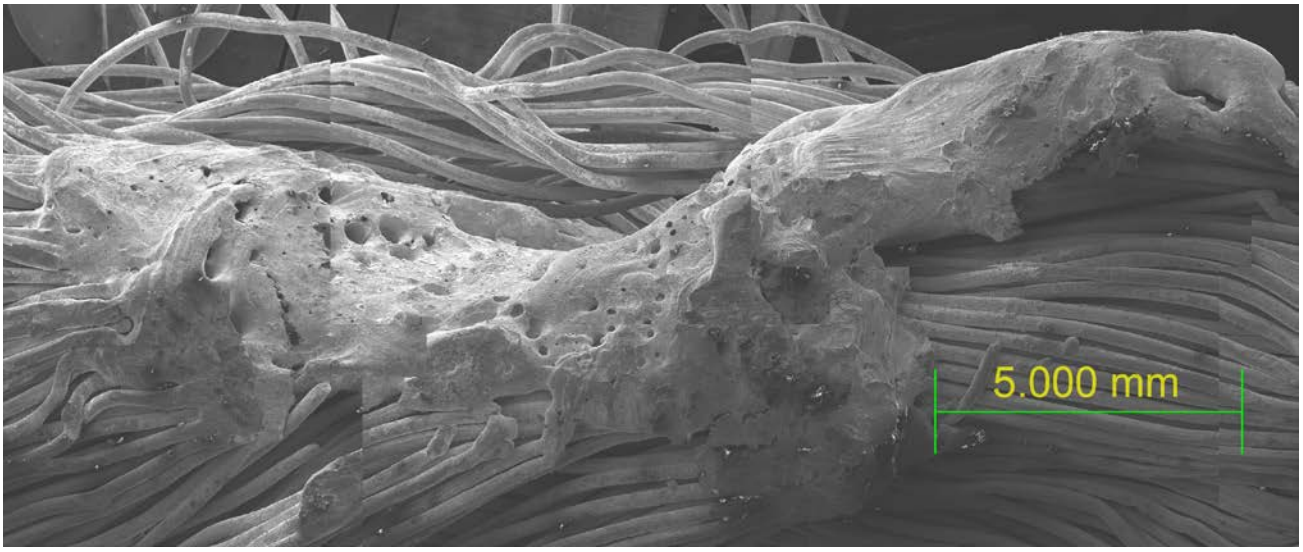

Figure 14. Micrograph of welded area on P3H.

Figure 15. Overall photograph of P2B connected to P3B to Battery.

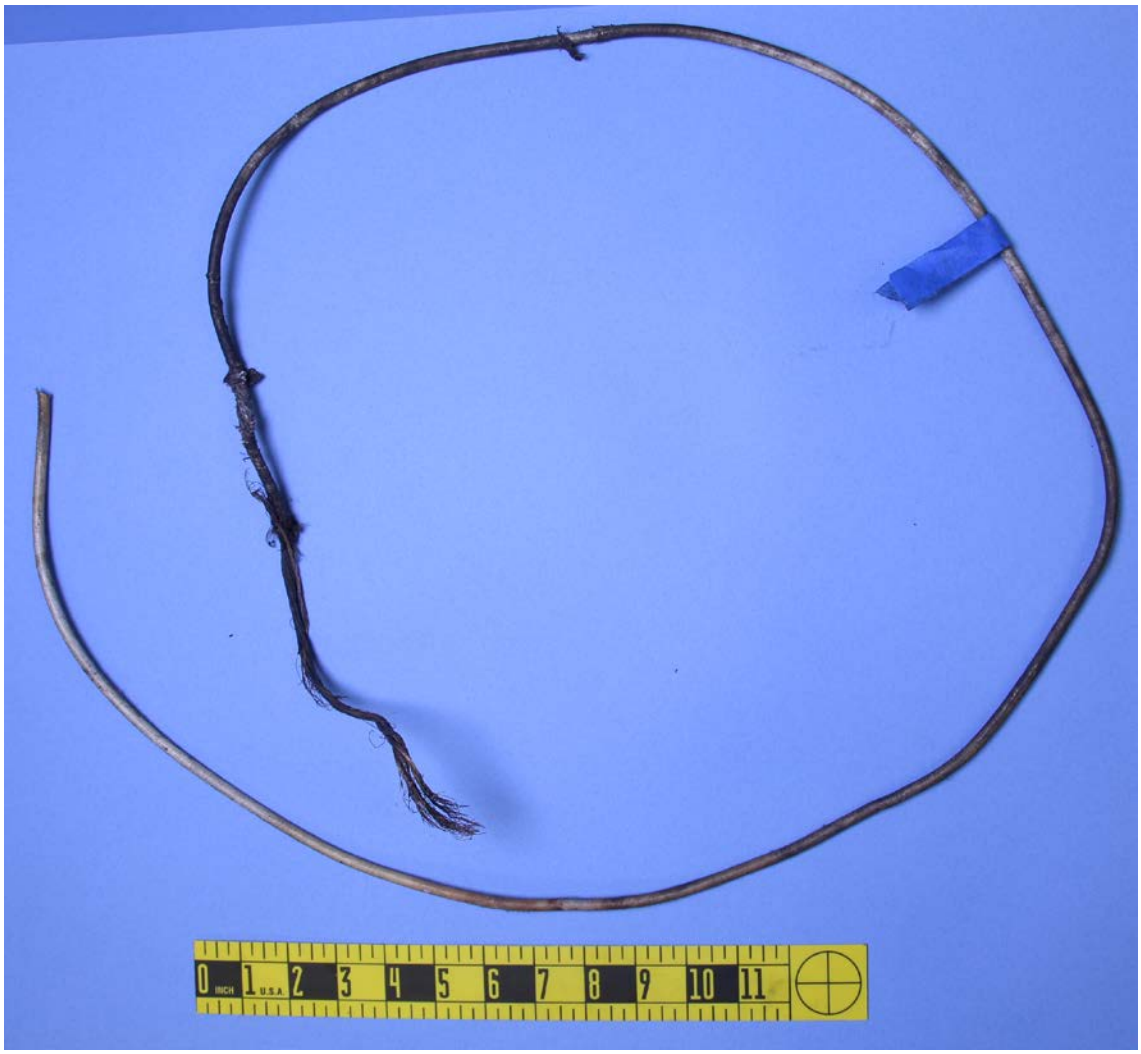

Figure 16. Overall photograph of RAD 1/2 (wire A).

Figure 17. Overall photograph of RAD 1/2 (wire B).

Figure 18. Overall photograph of EMS INV PWR.

Figure 19. Overall photograph of EMS PWR.

Figure 20. Overall photograph of P2E.

Figure 21. Overall photograph P2K.

Figure 22. Overall photograph of P1K.

Figure 23. Overall photograph P1E.

Figure 24. Closeup photograph of welding and arcing damage on end of unidentified wire.

Figure 25. Overall photograph of hydraulic line as received in the laboratory.

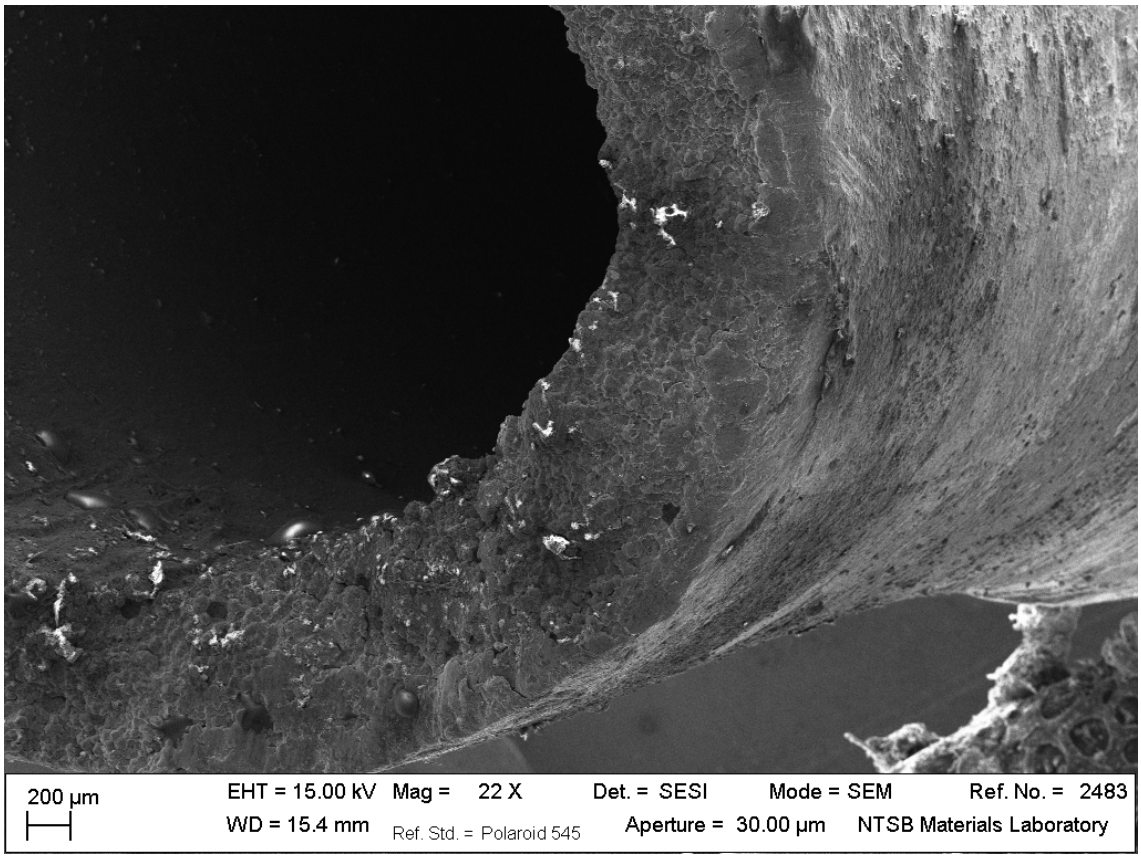

Figure 26. Micrograph of fracture surface of GEAR UP line showing intergranular features.

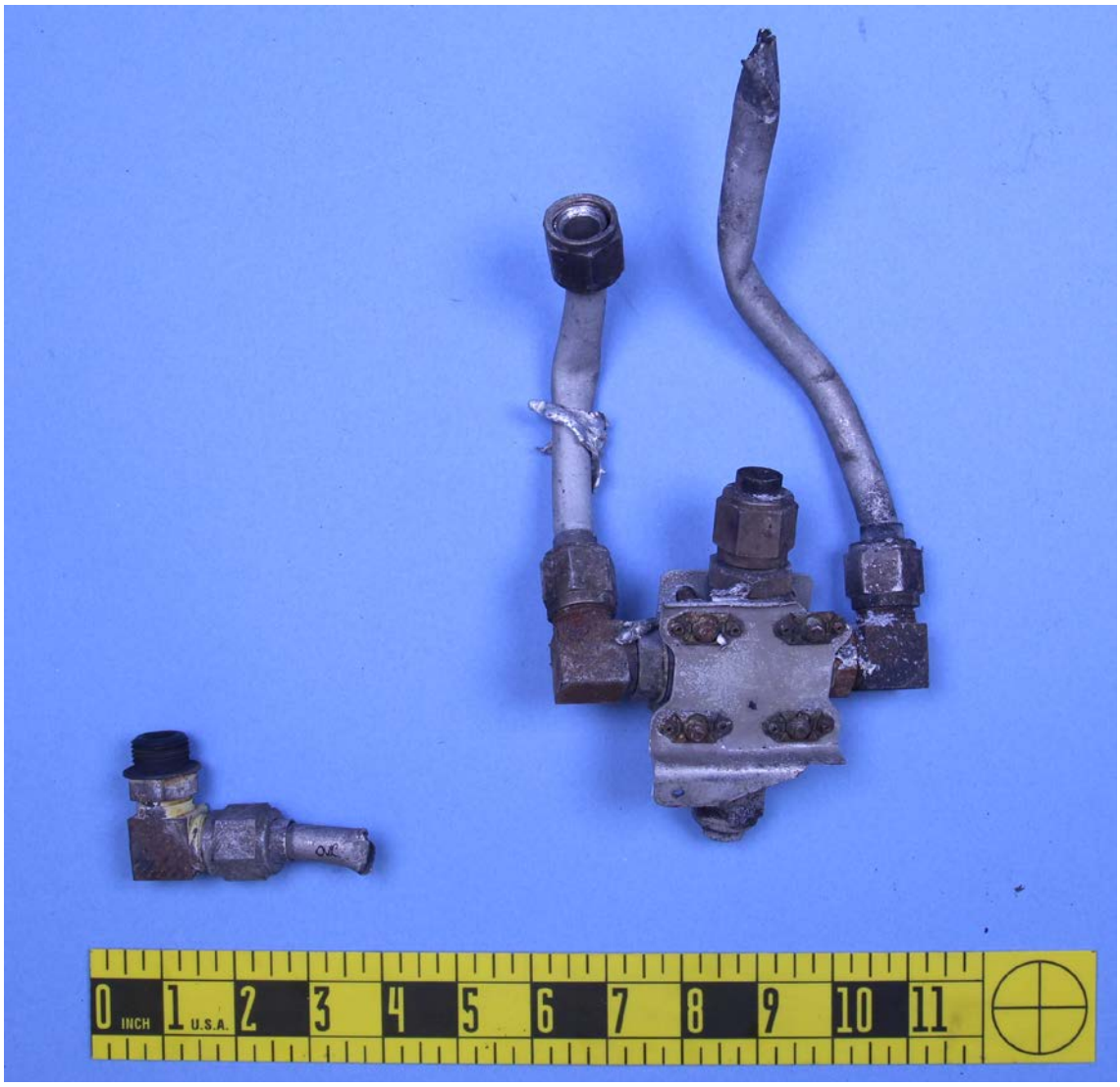

Figure 27. Overall photograph of fuel system components as received in the laboratory.