

NATIONAL TRANSPORTATION SAFETY BOARD

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



October 9, 2019

MATERIALS LABORATORY FACTUAL REPORT

Report No. 19-046

A. ACCIDENT INFORMATION

Place : Tampa, Florida
Date : April 4, 2019
Vehicle : Robinson R44 II, N4046J
NTSB No. : ERA19FA142
Investigator : Daniel Boggs, ASI-ERA

B. COMPONENTS EXAMINED

Air intake duct, P/N A785-31; manufactured by HBD/Thermoid, Inc., Manufacturer P/N: AD-1690-16-72-4, Lot Number: 1Q18.

C. DETAILS OF THE EXAMINATION

An air intake duct from the aircraft referenced above was submitted to the NTSB Materials Laboratory for examination as shown below in figure 1. The on-scene examination of the duct revealed that the inner rubberized fabric liner had partially collapsed, obstructing the interior volume of the duct.

1. Construction of the duct assembly

A schematic drawing of the duct assembly is shown in figure 2. It consisted of a tube section with an inner layer made from fiberglass cloth that was impregnated with a silicone rubber. A corrosion-resistant steel wire was wound in a helix over the top of the inner layer and an outer layer of rubberized silicone cloth was wrapped over the top of the wire, thereby embedding the wire in between two layers of rubberized cloth, as shown in the cross section view in figure 2. Two fiberglass cords were then wrapped around the outside of the tube, one cord on either side of the helical steel wire. Each end of the tube was terminated by a rubberized fiberglass cloth cuff.

The tube was manufactured by using partially cured sheets of rubberized cloth and assembling the tube components on a mandrel. The assembled tube was then cured in an oven thereby co-curing the inner and outer layers. According to product literature published by HBD/Thermoid, tubes of this design, referred to as SCEET tubing, are not recommended for negative pressure applications. According to an HBD/Thermoid representative, the tube inspection process did not include any steps to evaluate to co-cure between the inner and outer layers.

2. Examination of the accident vehicle duct

Examination of the accident duct revealed a region where the inner layer was protruding into the internal volume of the tube, as indicated in figures 1b and 3a. Further examination revealed internal surface wrinkles and smaller unbonded regions as shown in figures 3a – 3d.

The duct was dissected to examine the condition of the internal surfaces of the inner and outer layers and the steel wire. A utility knife was used to cut the outer fiberglass cords. They were then unwound and removed from the duct. The outer layer was then cut using the utility knife, first circumferentially, and then in each longitudinal direction. The coiled wire was cut in half and one half was detached from its anchor under the cuff to aid inspection of the rubber. The duct in its dissected condition is shown in figures 4a and 4b. There were few, if any, areas where the inner and outer layers were apparently bonded to one another.

During dissection, it was noted that the rubber layers were bonded to the internal wire in some regions but not in others. One area that was not bonded is shown in figures 5a and 5b, where the internal surface of the inner layer can be seen along with the helical wire and impressions left by the wire in the rubberized cloth. The region was tacky to the touch and when viewed at high magnification, a liquid residue was observed, as indicated in figure 5b. The residue was present as discrete droplets in some areas, a film in others, and was also present in the wire impressions.

The wooden shaft of a cotton-tip applicator was carved to a knife edge and used to collect a sample of the residue from the inner liner. The sample was analyzed using Fourier-transform infrared spectroscopy (FTIR) on an attenuated total reflectance (ATR) bench accessory equipped with a single bounce diamond/ZnSe crystal. The absorbance spectrum for the unknown substance is shown in figure 6a. A search for the spectrum identification using an online library of reference spectra returned best matches for several oxidized vegetable oils including castor oil.

A review by an HBD/Thermoid representative of their mandrel assembly area indicated that, in addition to materials used in the assembly and curing of SCEET tubing, castor oil and a water-based release agent were present in the mandrel assembly area. Samples of castor oil and the water-based release agent were provided to the lab for examination. The absorbance spectrum of the castor oil sample, as received, is shown in figure 6b. The castor oil spectrum was similar to the unknown substance with the exception of a small absorbance peak near $3,000\text{ cm}^{-1}$ and a reduction in the intensity and width of the peak at approximately $1,740\text{ cm}^{-1}$.

A few drops of the castor oil and of the water-based release agent were separately placed on a watch glass and placed in an oven at $140\text{ }^{\circ}\text{C}$ for two hours. The liquids were spread across the bottom of the glass to maximize the exposed surface area. After two hours the samples were air cooled and then examined by FTIR/ATR. The oven-exposed castor oil absorbance spectrum is shown in figure 6c and the water-based sample is shown in figure 6d.

The oven-exposed castor oil spectrum indicated that the oven exposure resulted in an attenuation of the small peak near $3,000\text{ cm}^{-1}$ and a broadening of the peak near $1,740\text{ cm}^{-1}$. The spectrum for the water-based material exhibited strong peaks near $1,020\text{ cm}^{-1}$ and 796 cm^{-1} and was not comparable to the residue spectrum.

3. Examination of exemplar ducts

Three exemplar ducts were submitted to the lab for examination. Two of the ducts had the same 1Q18 lot number as the accident duct and a third duct had a 1Q19 lot number. The two 1Q18 lot number ducts are shown in figure 7. The duct in the top part of the image was removed from aircraft serial number 14287 and the duct in the bottom part of the image was removed from aircraft serial number 14274. The 1Q19 duct was a new duct and had not been installed on an aircraft.

The 1Q18 ducts were dissected in a similar manner as the accident duct. The duct from S/N 14287 exhibited similar features as the accident duct and is shown in figures 8a and 8b. The inner and outer layers were not bonded to one another and droplets of the tacky residue were also present as shown in figure 8a. Traces of silicone rubber remained bonded to some of the helical wire after disassembly, as seen in figure 8b. The duct from S/N 14274 exhibited both bonding of the layers to the wire and some features consistent with co-curing of the inner and outer layer, as seen in figure 9. Visual and tactile examination did not reveal any apparent tacky residue on the internal surfaces.

A dissection of the 1Q19 duct was attempted but it was not possible to disassemble the duct in the same manner as the 1Q18 ducts. Images of the 1Q19 duct are shown in figures 10a and 10b. The outer fiberglass cords were removed and a circumferential cut was made, but when an attempt was made to peel the outer layer back, it could not be removed due to the co-curing between the inner and outer layers. Instead the cloth fibers on the outer layer tore while attempting to peel the outer layer. Instead, cuts were made on either side of a piece of wire and a small flap of the outer layer was removed as shown in figure 10b. The outer layer was bonded to the wire, which exhibited a copper color.

Donald Kramer, Ph.D.
Sr. Materials Engineer

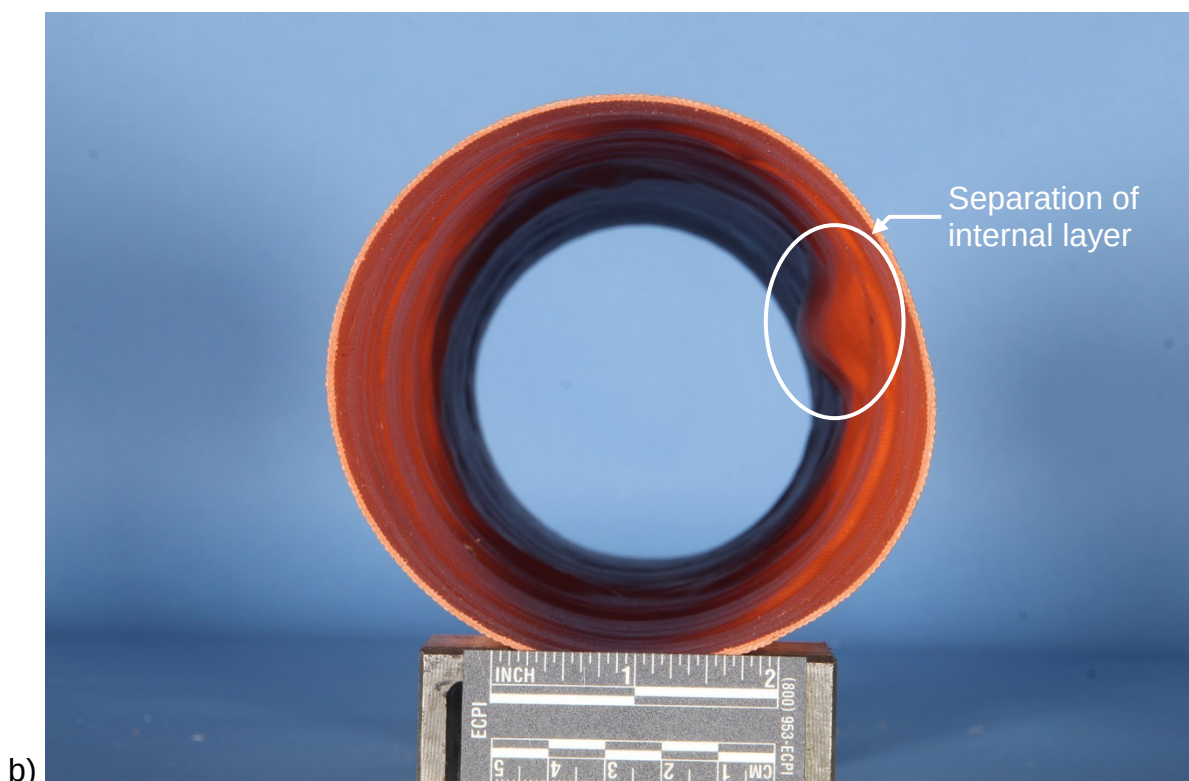


Figure 1: Images of the air intake duct as received: a) side view and b) axial view.

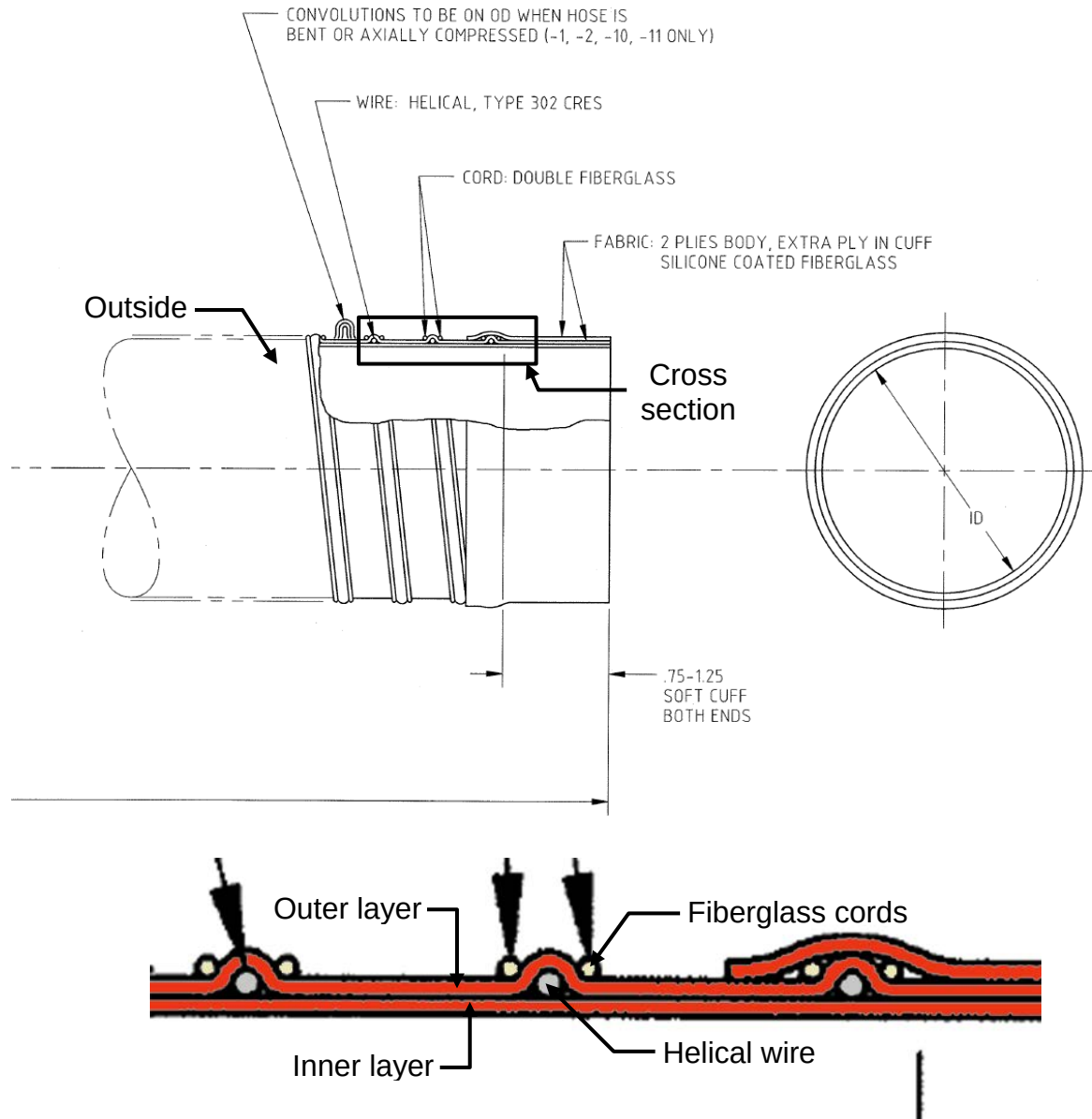


Figure 2: Schematic drawing of the SCEET duct tube. The upper image shows the side view and axial view. The lower image shows a close up view of the cross section with labels for the individual components that make up the tube. Color has been added to the lower image for visualization purposes.

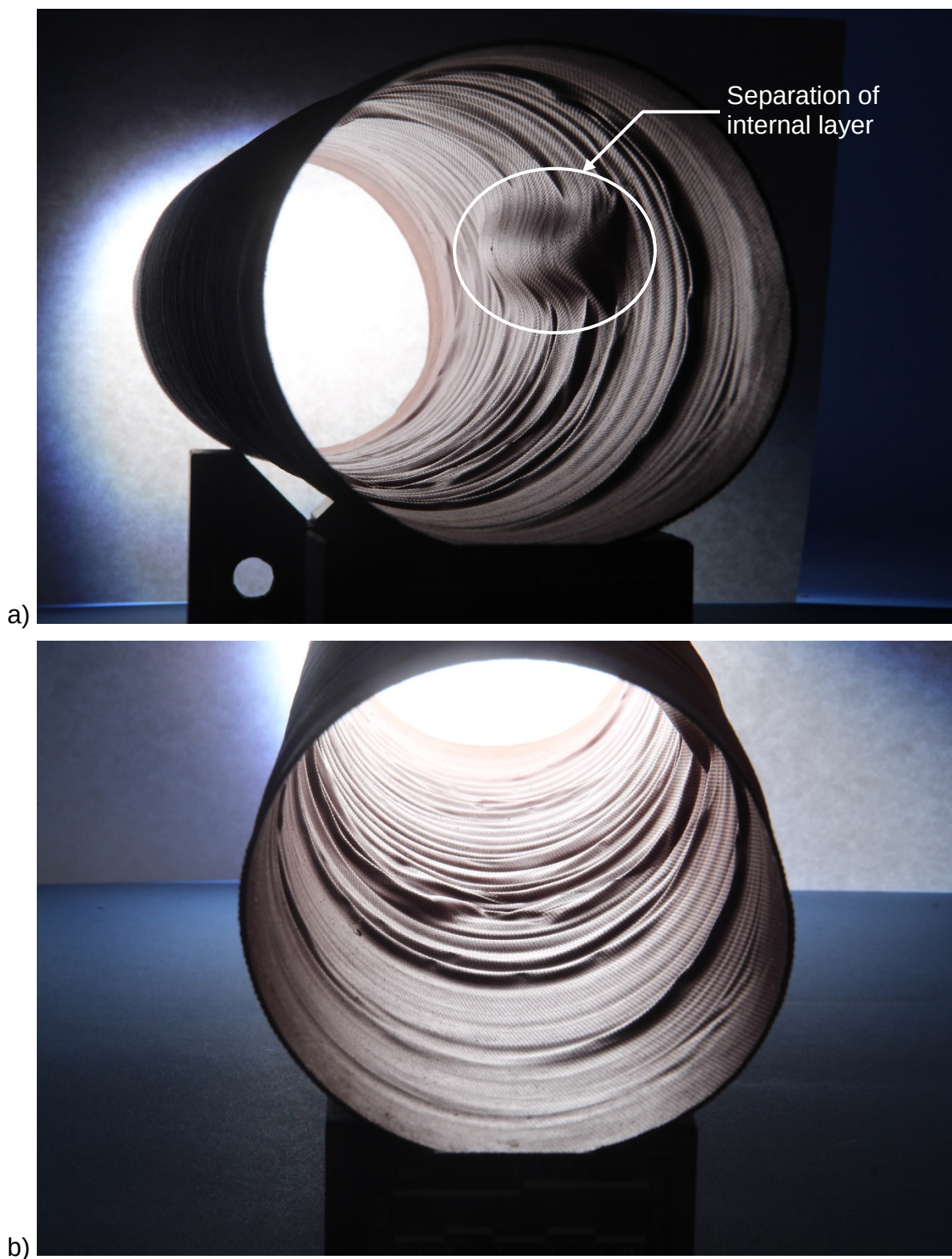


Figure 3: Images of the internal volume of the duct backlit to highlight separations and wrinkles: a) right side as oriented; b) lower side as oriented;

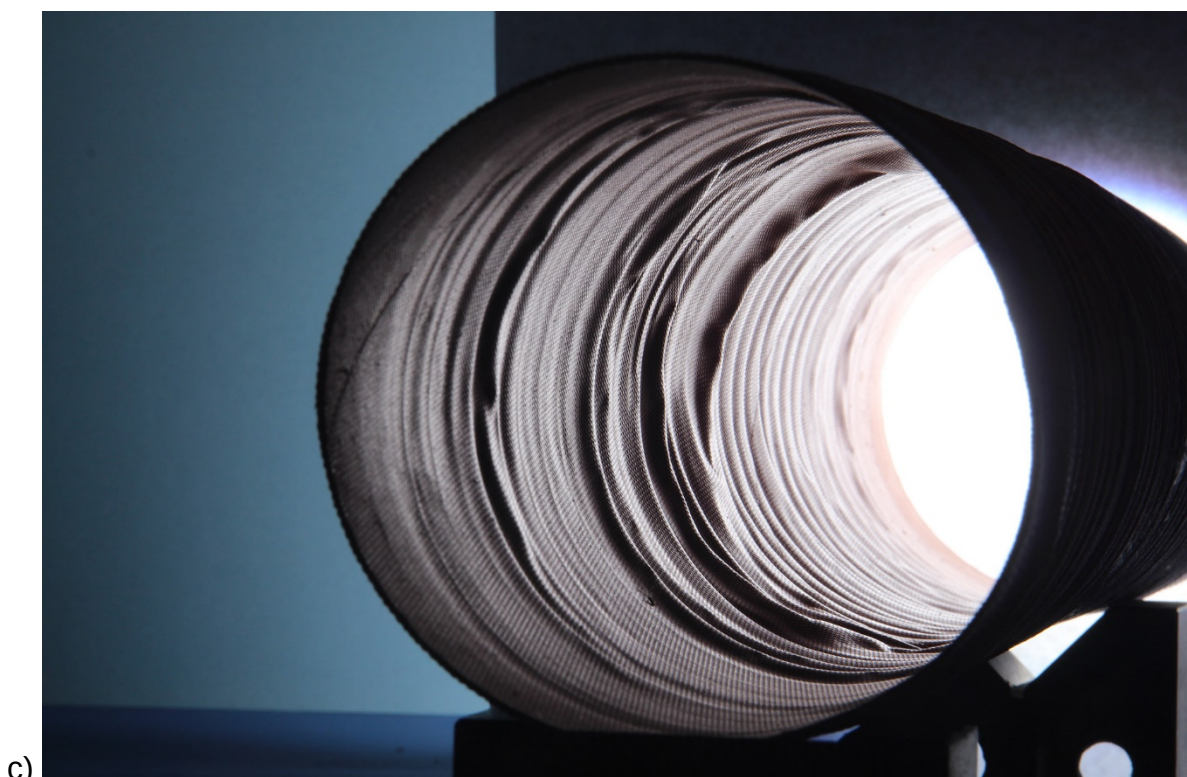


Figure 3 (cont.): c) left side as oriented; and d) upper side as oriented.



a)



b)

Figure 4: Images of the SCEET tube from the accident vehicle after dissection: a) side view from one direction and b) side view from the opposing direction.

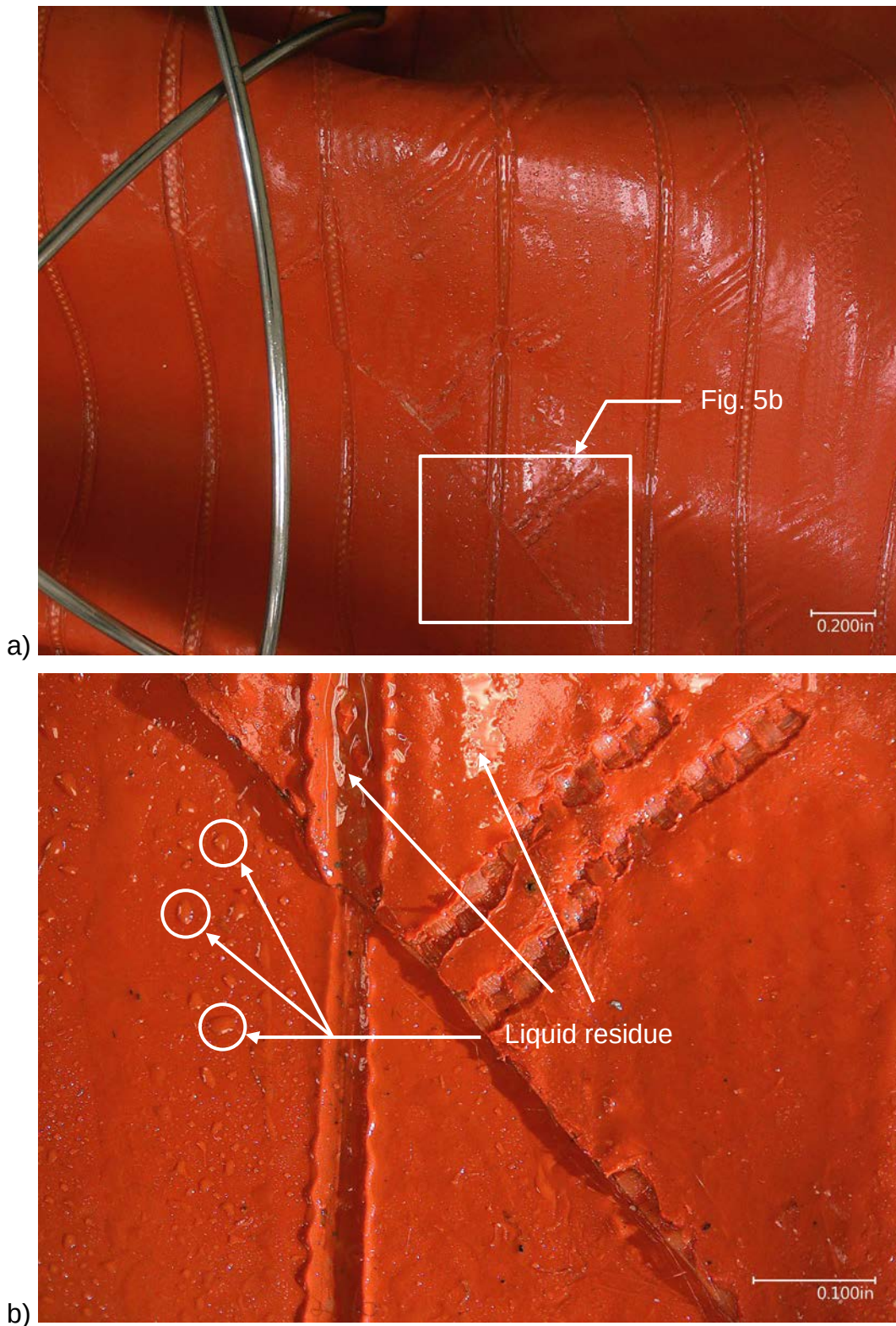
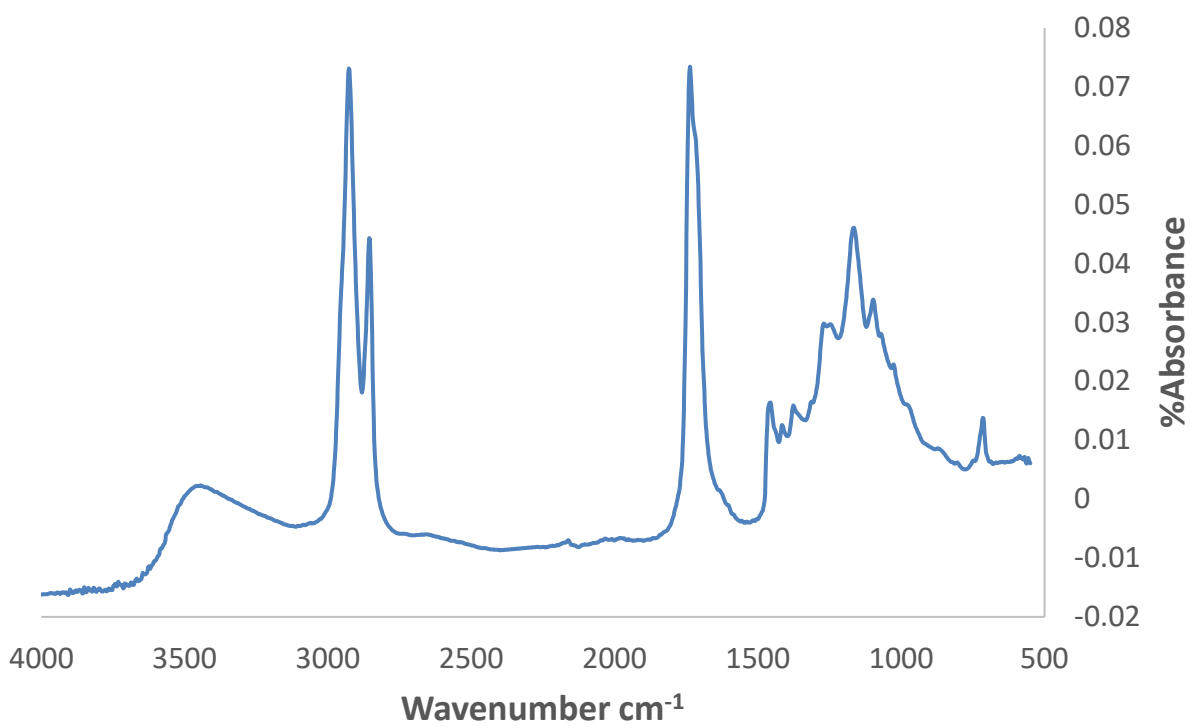
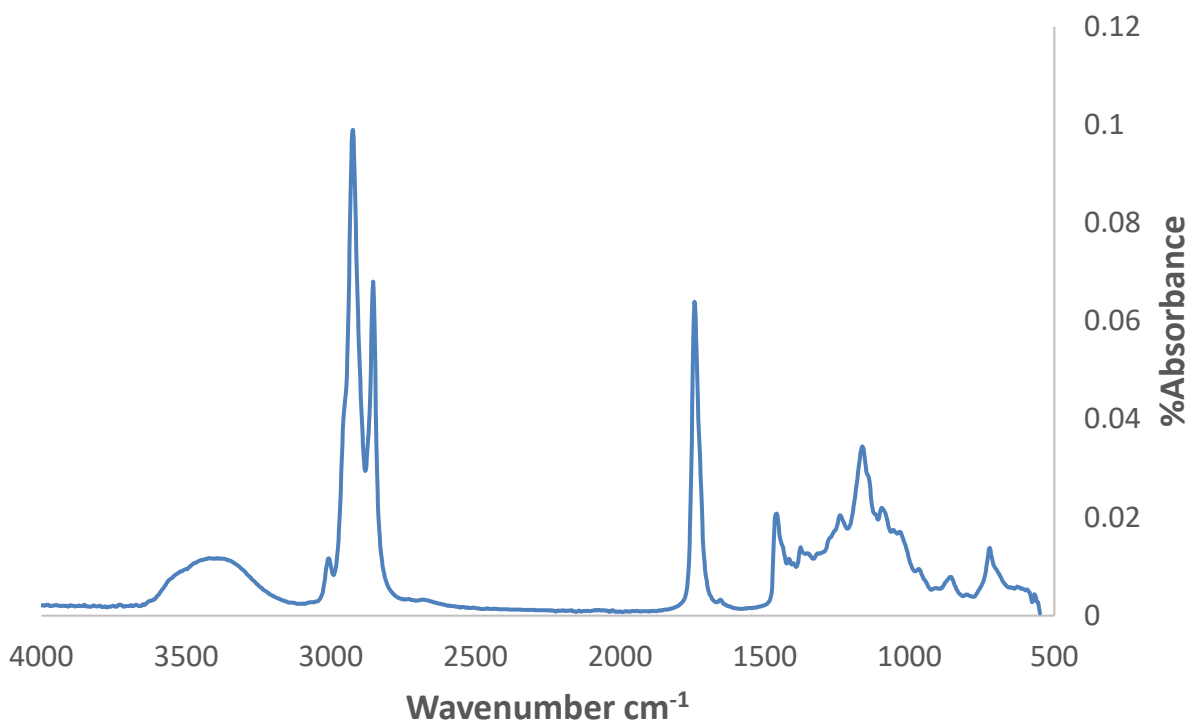


Figure 5: Higher magnification images of the accident duct inner layer internal surface: a) reference image of inner layer and b) higher magnification image at the location indicated showing droplets and a film of a tacky liquid residue.

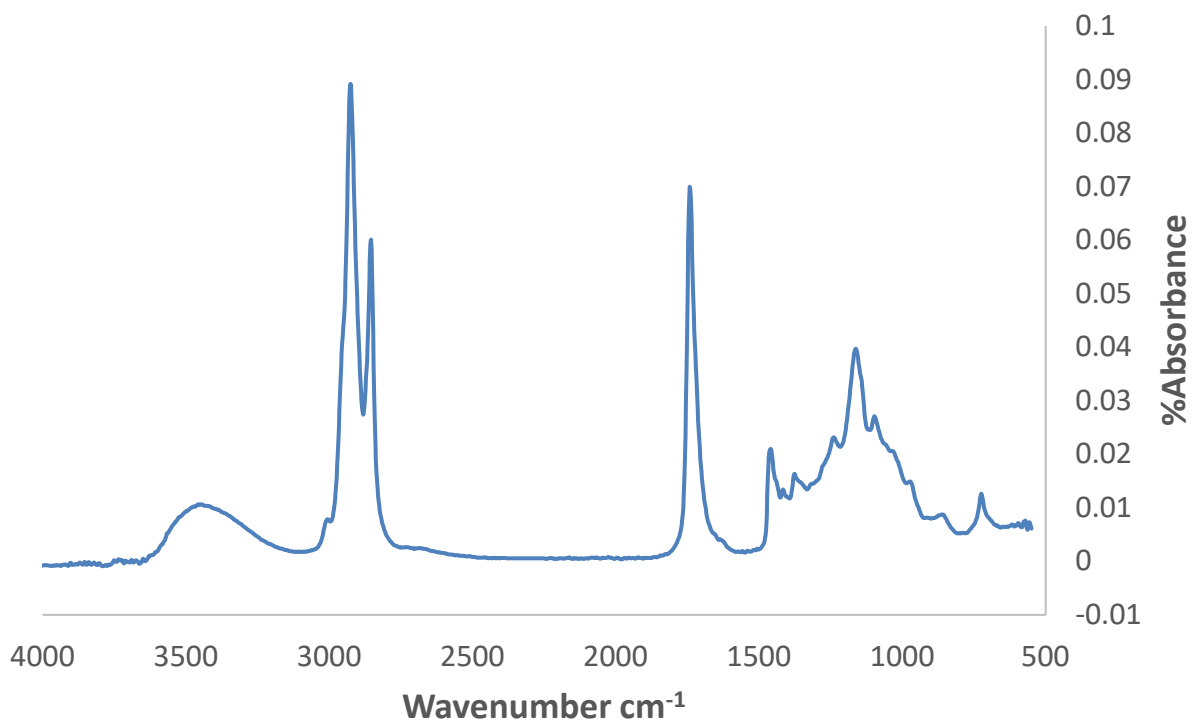


a)

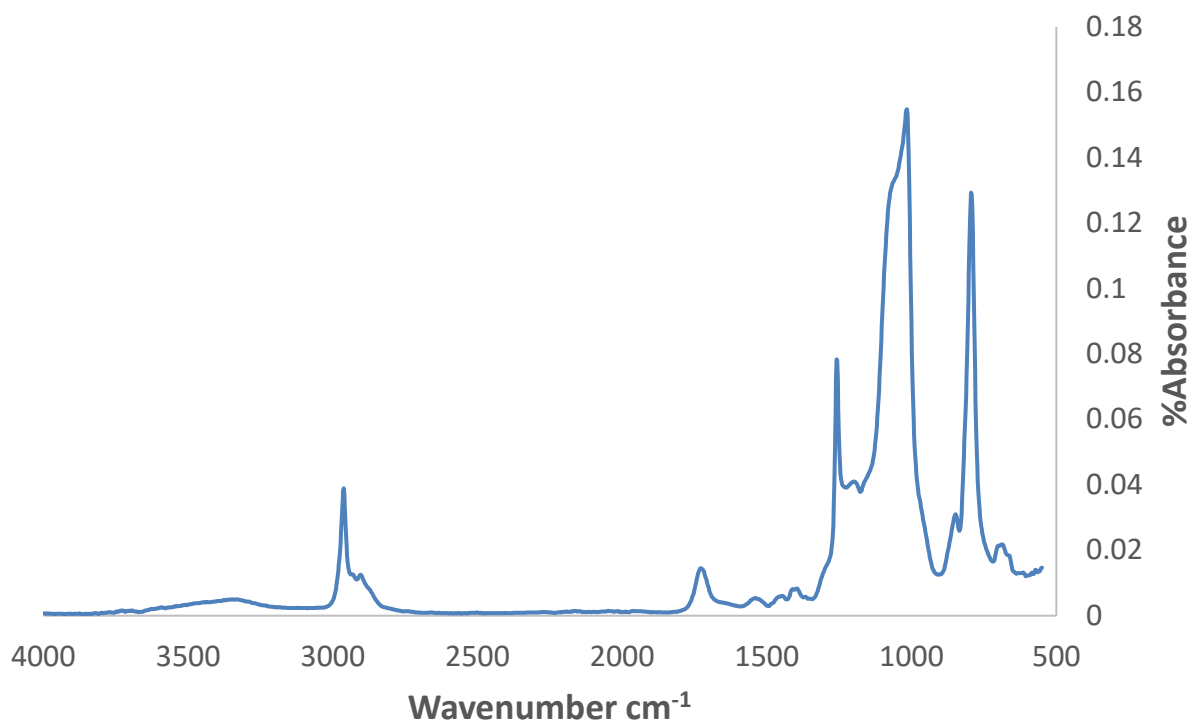


b)

Figure 6: FTIR/ATR spectra as follows: a) residue from accident duct; b) castor oil as received;



c)



d)

Figure 6 (cont.): c) castor oil after 2 hr at 140 °C; and d) water-based release agent.

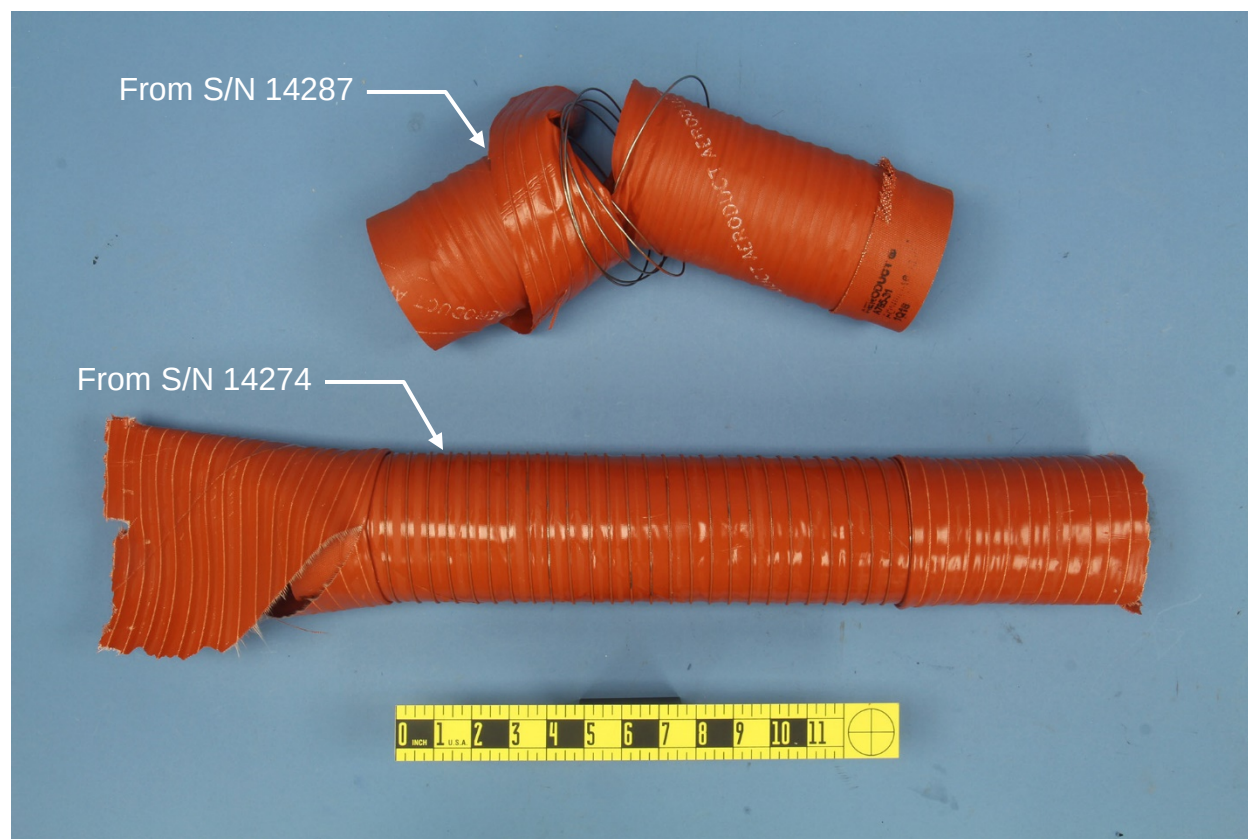


Figure 7: Image of exemplar ducts from aircraft serial numbers 14287 and 14274.

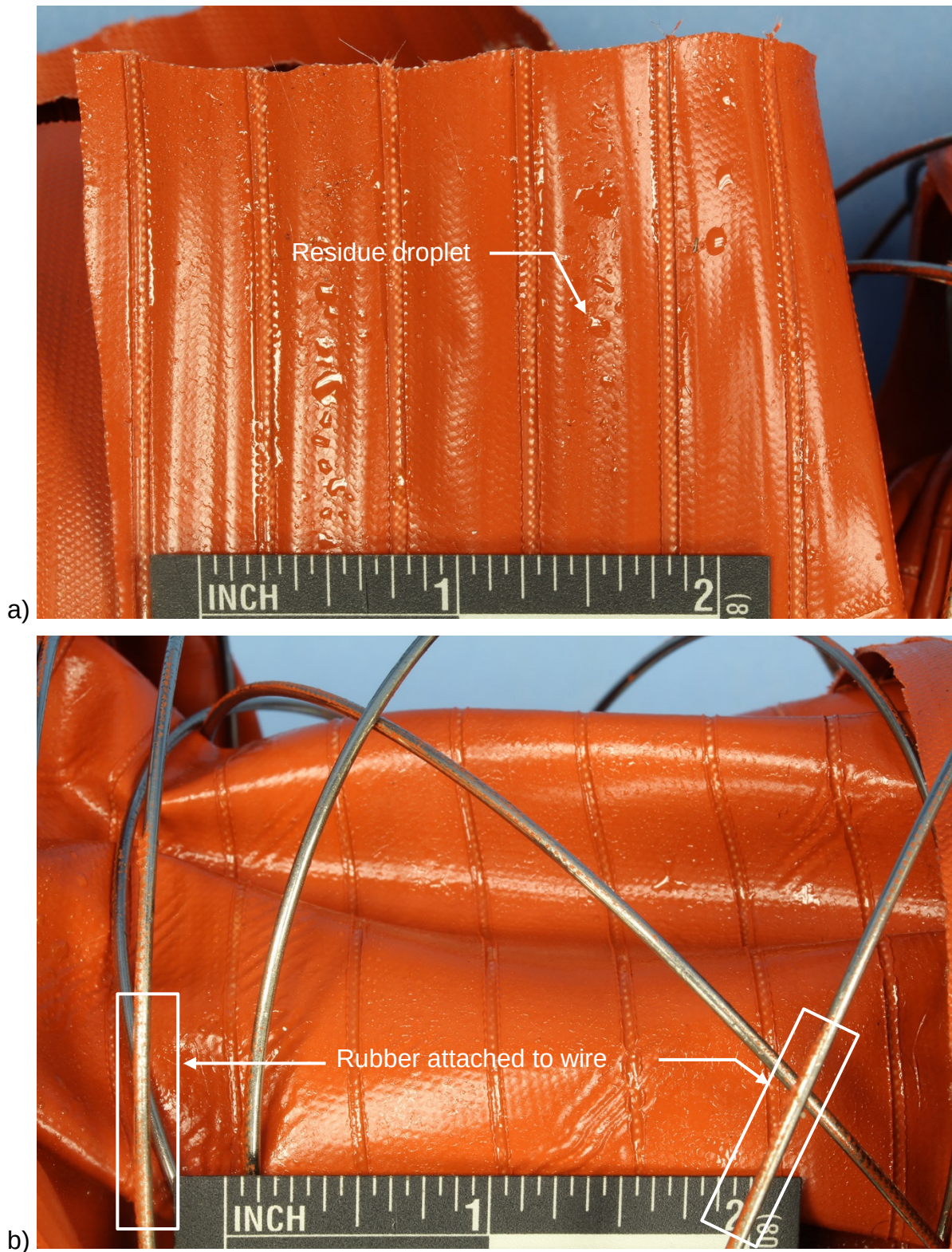


Figure 8: Images of the exemplar duct from aircraft serial number 14287: a) outer layer internal surface showing droplets of residue and b) inner layer and helical wire showing pieces of rubber attached to the wire.

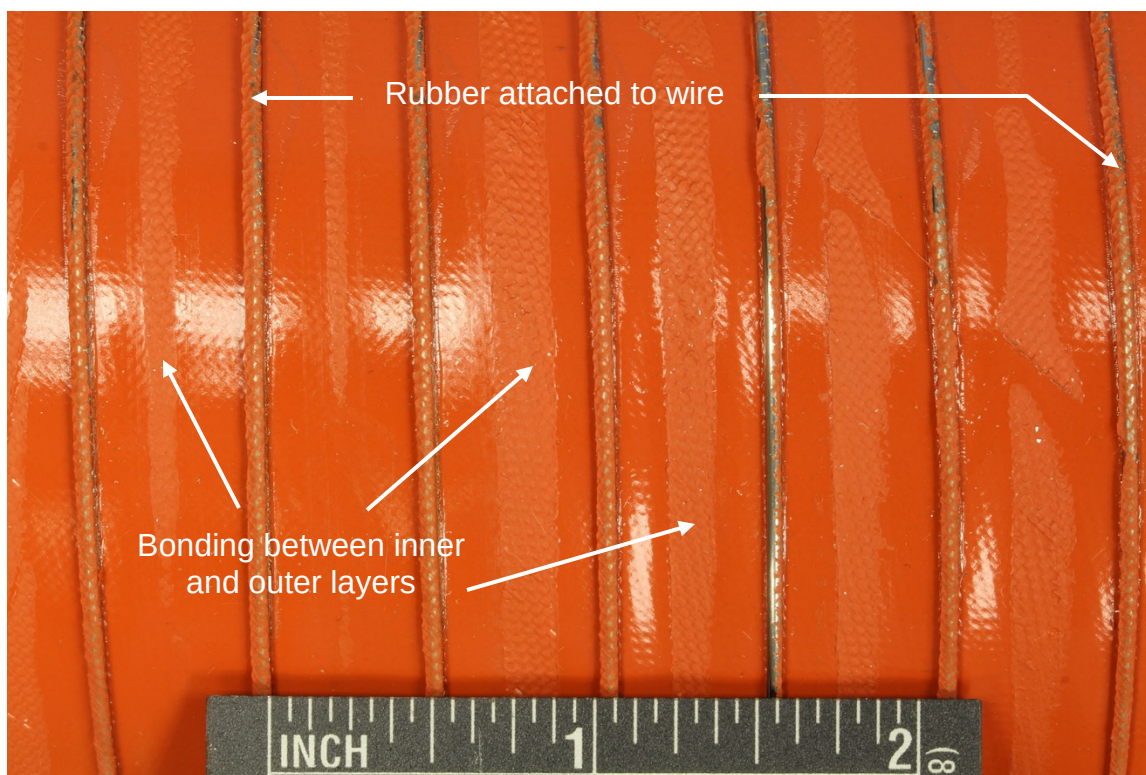
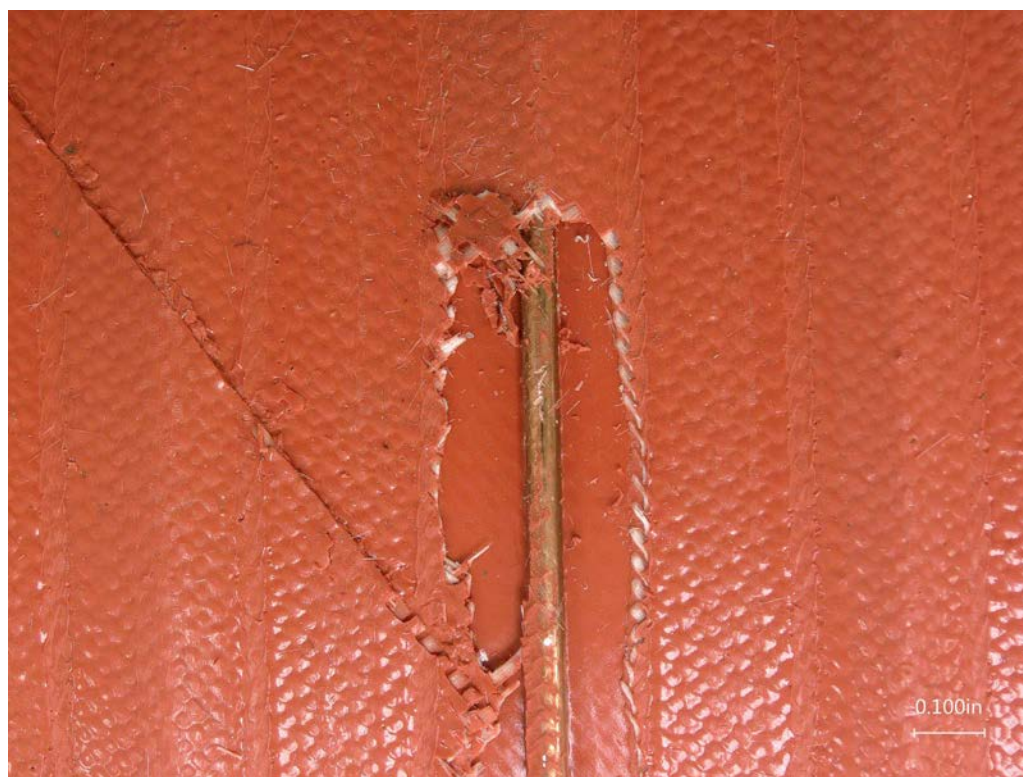


Figure 9: Image of the exemplar duct from aircraft serial number 14274 showing rubber attached to the wire and bonding between inner and outer layers.



a)



b)

Figure 10: Images of an exemplar duct from lot 1Q19: a) overview image and b) image of exposed steel wire and adjacent internal surface of inner layer after cutting away a section of the outer layer.

APPENDIX A: EXERPT FROM AERODUCT CATALOG

Aeroduct®

**A TRADITION OF EXCELLENCE IN PRODUCING
FLEXIBLE HOSE AND DUCTING FOR THE
AVIATION INDUSTRY**



HBD/Thermoid, Inc.

SUBSIDIARY OF HBD INDUSTRIES, INC.

GENERAL AVIATION PRODUCTS

Aeroduct Ducting

Aeroduct wire-supported ducting, in its various forms and constructions, provides the most versatile type of ducting in the industry. It's suitable for permanent or temporary installations to meet many different applications. Aeroduct aircraft ducting is manufactured with fiberglass fabrics, impregnated with neoprene or silicone rubber compounds, that's developed for flame resistance and high temperature applications.

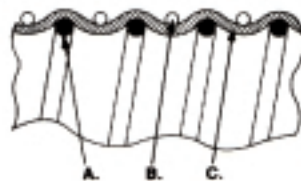


SCAT

SCAT ducting is recommended for use in conducting extremely cold or hot air where temperatures range from -65°F to $+550^{\circ}\text{F}$. It is lightweight and extremely flexible. This ducting minimizes waste since short sections, which are normally unusable, can be joined together to form a continuous length. It is not recommended for negative pressure applications.

Construction:

- A. Support - Copper-coated or bronze-plated spring-steel-wire helix.
- B. Cover - Woven fiberglass fabric impregnated with silicone rubber. Standard length - 11 feet.
- C. Cord - Fiberglass cord coated with silicone.



SCAT DUCTING (Red)

TECHNICAL DATA

Inside Diameter (inches)*	2	3	4	5	6
Weight (pounds per foot)	.19	.29	.38	.48	.58
Inside Bend Radius (inches)	.50	.75	1.0	1.25	1.50
Length Required for 180° Bend (inches)	8	12	16	20	24
Minimum Burst Pressure (psig)	102	88	69	57	41
Internal Working Pressure (psig)	26	22	17	14	10
Maximum Leakage (cfm/ft. at working pressure)	.010	.015	.020	.025	.030
Crush Resistance (pounds per foot)	400	320	290	240	200
Axial Tensile Strength (pounds)	375	535	660	870	900
Retracted Length (inches per foot)	3.5	3.5	2.8	2.1	2.0
Operating Temperature Range	-65°F to $+550^{\circ}\text{F}$				

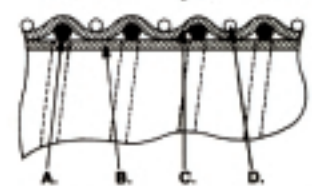
SCEET

SCEET ducting is ideal for use in conducting extremely cold or hot air at temperatures ranging from -80°F to $+550^{\circ}\text{F}$, and for conveying fumes. This ducting is highly flexible and can be easily installed around obstructions and sharp bends. It has less air friction loss than similar nonlined ducting. SCEET ducting is not recommended for applications involving liquids or highly abrasive materials, or for negative pressure applications.

Construction:

- A. Support - Copper-coated or bronze-plated spring-steel-wire helix bonded between the liner and cover material.
- B. Liner - Fiberglass fabric impregnated and coated with silicone rubber.
- C. Cover - Fiberglass fabric impregnated and coated with silicone rubber.

- D. Cord - Fiberglass cord coated with silicone. Standard length - 11 feet.



SCEET DUCTING (Red)

TECHNICAL DATA

Inside Diameter (inches)*	2	3	4	5	6
Weight (pounds per foot)	.20	.33	.44	.55	.66
Inside Bend Radius (inches)	.75	1.0	1.25	1.50	1.75
Length Required for 180° Bend (inches)	10	14	19	24	28
Minimum Burst Pressure (psig)	165	142	125	76	68
Internal Working Pressure (psig)	42	35	31	19	17
Maximum Leakage (cfm/ft. at working pressure)	.016	.024	.032	.040	.048
Crush Resistance (pounds per foot)	400	320	290	240	200
Axial Tensile Strength (pounds)	525	680	860	900+	900+
Retracted Length (inches per foot)	4.5	4.5	4	3.5	3.5
Operating Temperature Range	-80°F to $+550^{\circ}\text{F}$				