

NATIONAL TRANSPORTATION SAFETY BOARD

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



August 4, 2020

MATERIALS LABORATORY FACTUAL REPORT

Report No. 20-039

A. ACCIDENT INFORMATION

Place : Hillsboro, Oregon
Date : April 6, 2020
Vehicle : Robinson R44 II, N725GT
NTSB No. : WPR20LA119
Investigator : Maja Smith, ASI-WPR

B. COMPONENTS EXAMINED

Air intake duct tube; Robinson P/N A785-31; manufactured by HBD/Thermoid, Inc.,
Manufacturer P/N: AD-1690-16-72-4, Lot Number: 3Q17.

C. DETAILS OF THE EXAMINATION

An air intake duct tube from the aircraft referenced above was sent to the NTSB Materials Laboratory for examination as shown below in figures 1a and 1b. The on-scene examination of the tube had revealed that the inner rubberized fabric liner collapsed, obstructing the interior volume of the tube. The tube was sent to Robinson Helicopters for an on-wing test to reproduce the collapse and subsequent shut down of the engine prior to being sent to the NTSB Materials Laboratory for examination.

1. Construction of the duct tube assembly

A schematic drawing of the duct tube assembly is shown in figure 2. It consists of a tube section with an inner layer made from fiberglass cloth that is impregnated with a silicone rubber. A corrosion-resistant steel wire is wound in a helix over the top of the inner layer and an outer layer of rubberized silicone cloth is 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 are then wrapped around the outside of the tube, one cord on either side of the helical steel wire. Each end of the tube is terminated by a rubberized fiberglass cloth cuff.

The tube is manufactured by using partially cured sheets of rubberized cloth and assembling the tube components on a mandrel. The assembled tube is 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 the co-cure between the inner and outer layers.

2. Examination of the accident vehicle duct tube

Examination of the accident tube revealed a region where the inner layer was protruding into the internal volume of the tube, as indicated in figures 1b and 3a. The region extended approximately 8.25 inch along the length of the tube starting near the cuff on one end. Further examination revealed internal surface wrinkles and smaller unbonded regions as shown in figures 3a – 3d.

The tube 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 tube. The outer layer was then cut using the utility knife, first circumferentially, and then in each longitudinal direction. The duct in its dissected condition is shown in figure 4.

Visual examination of the internal surfaces indicated that there were few, if any, areas where the inner and outer layers had apparently co-cured to one another. As the outer layer was peeled back, it appeared to be bonded primarily to the helical wire. Examination of the exposed wire surfaces indicated that there were areas where the silicone rubber separated in a cohesive manner, leaving remnants of rubber on the wire, as indicated in the higher magnification image in figure 5a. Conversely, in some areas the separation occurred at the rubber/wire interface, consistent with either no bond or a weak bond between the rubber and the wire. The outer and inner layers had not co-cured to one another as indicated by the smooth appearance of the internal surfaces shown in figures 5a through 5c.

The inner and outer layer internal surfaces were examined with the aid of a binocular stereomicroscope and two unidentified substances were observed. One substance consisted of discrete spots of gray particulates, several examples of which are indicated in figures 5a and 5b. The spots ranged in size and aspect ratio but were on the order of 0.1 inch in the longest direction and were distributed at random across the internal surfaces. A second friable translucent substance was observed in some areas, typically in steel wire impressions in the rubber layer and adjacent tented regions, an example of which is shown in figure 5c.

The chemical composition of the gray particulates was examined with the aid of a scanning electron microscope (SEM) equipped with an energy dispersive x-ray spectrometer (EDS). A piece of double-sided conductive carbon tape was applied to an aluminum disk and the disk/tape assembly was pressed against a sample of the gray particles. Some of the particles were lifted off the rubber layer and then examined using the SEM. A gray pollutant was also noted on the interior surface of the duct (the open interior of the tube, not shown) and a sample of that substance was collected in a similar manner. A backscatter SEM image and an EDS spectrum from the internal rubber surface sample are shown in figures 6a and 6b, respectively. Similarly, a backscatter image and two EDS spectra of the pollutant from the interior volume are shown in figures 7a through

7c, respectively. The spectrum of the gray particulate sample, shown in figure 6b consisted primarily of iron (Fe) with traces of manganese (Mn), consistent with the composition of a low carbon steel. The pollutant from the interior passage of the duct exhibited two different spectra; the first spectrum, as shown in figure 7b, consisted of bromine (Br), lead (Pb), and silicon (Si). The presence of bromine and lead was consistent with engine exhaust residue. The second spectrum, as shown in figure 7c, exhibited primarily aluminum (Al), silicon (Si), and calcium (Ca) with traces of iron (Fe), consistent with primarily silicate minerals. No traces of bromine, lead, aluminum, or calcium were observed on the intralayer gray particulate sample.

The friable translucent material was analyzed using Fourier-transform infrared spectroscopy (FTIR) on an attenuated total reflectance (ATR) bench accessory equipped with a single bounce diamond/ZnSe crystal. A metal blade was used to lift a sample of the translucent material from the rubber and transfer it to the crystal. The absorbance spectrum for the unknown substance is shown in figure 8a.¹ The spectrum was similar to that of a water-based mold release agent used by the manufacturer, as shown in figure 8b (NTSB, 2019). A spectral search using an online library of reference spectra returned matches for silicone-based materials.

D. REFERENCE

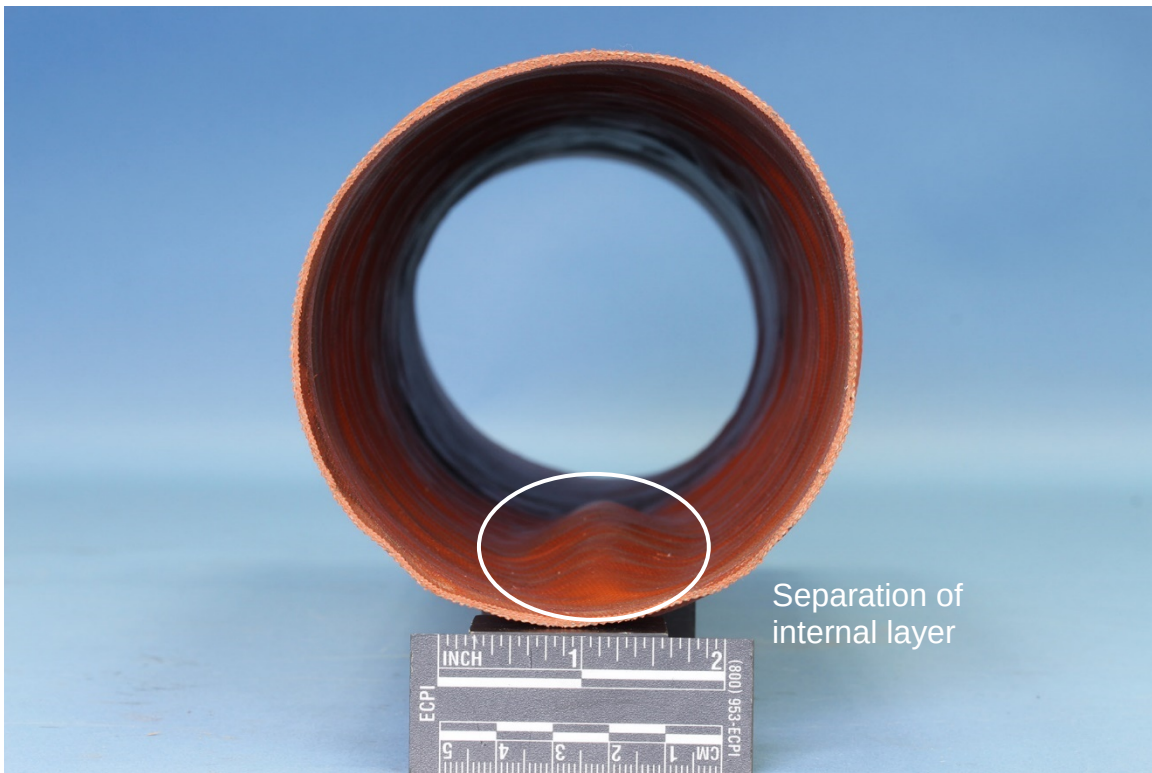
NTSB (2019). "Materials Laboratory Factual Report 19-046", dated October 9, 2019, downloaded from accident docket ERA19FA142 at <https://dms.nts.gov/pubdms/search/>.

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¹ To aid the comparison of spectra, atmospheric carbon dioxide peaks at 2340 cm⁻¹ and 2360 cm⁻¹ were subtracted from the spectrum in figure 8a.



a)



b)

Separation of
internal layer

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

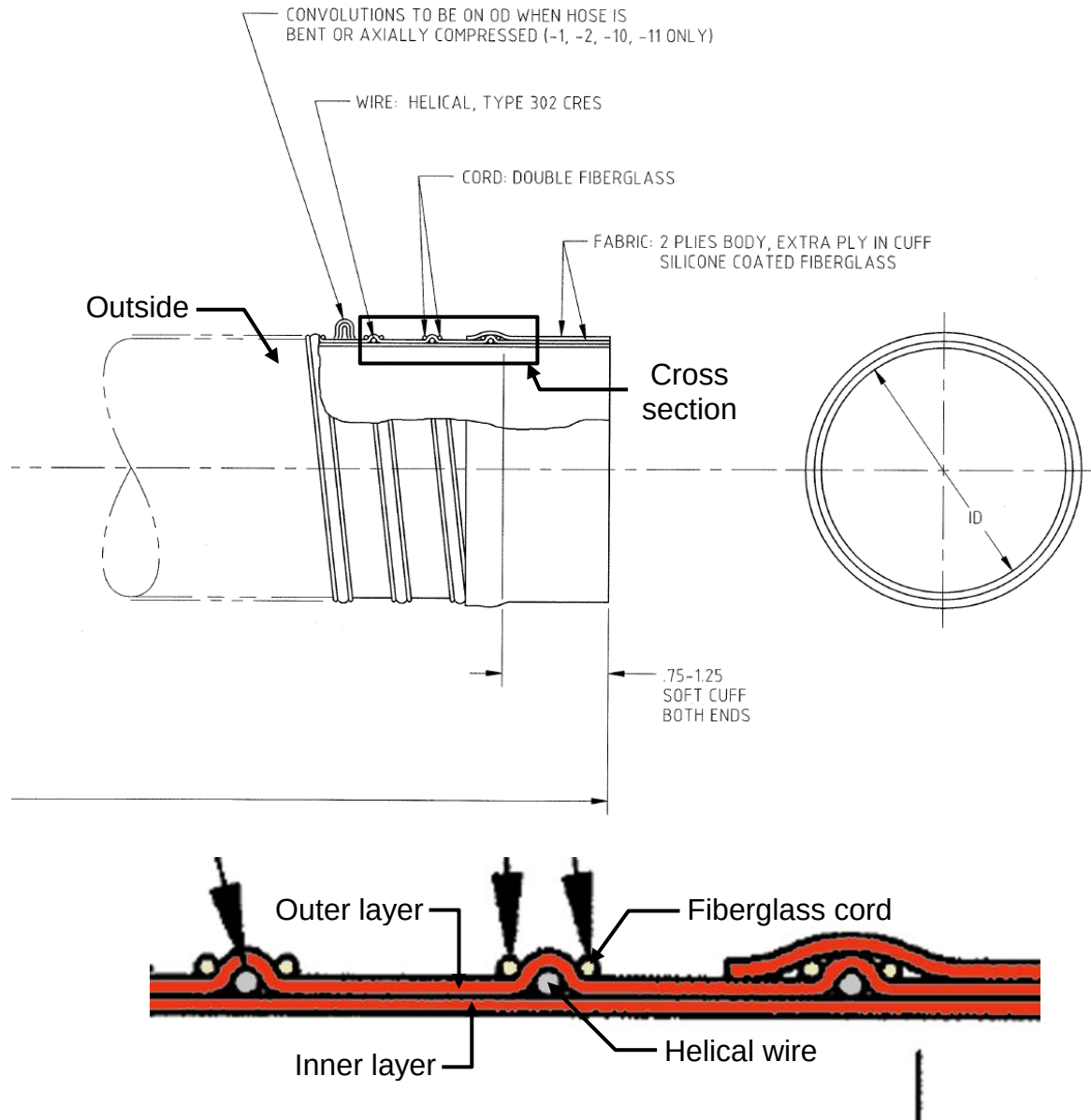


Figure 2: Schematic drawing of the SCEET duct tube. The upper image shows the side view and axial view. The lower image shows a close up view of the cross section with labels for the individual components that make up the tube. Color has been added to the lower image for visualization purposes.

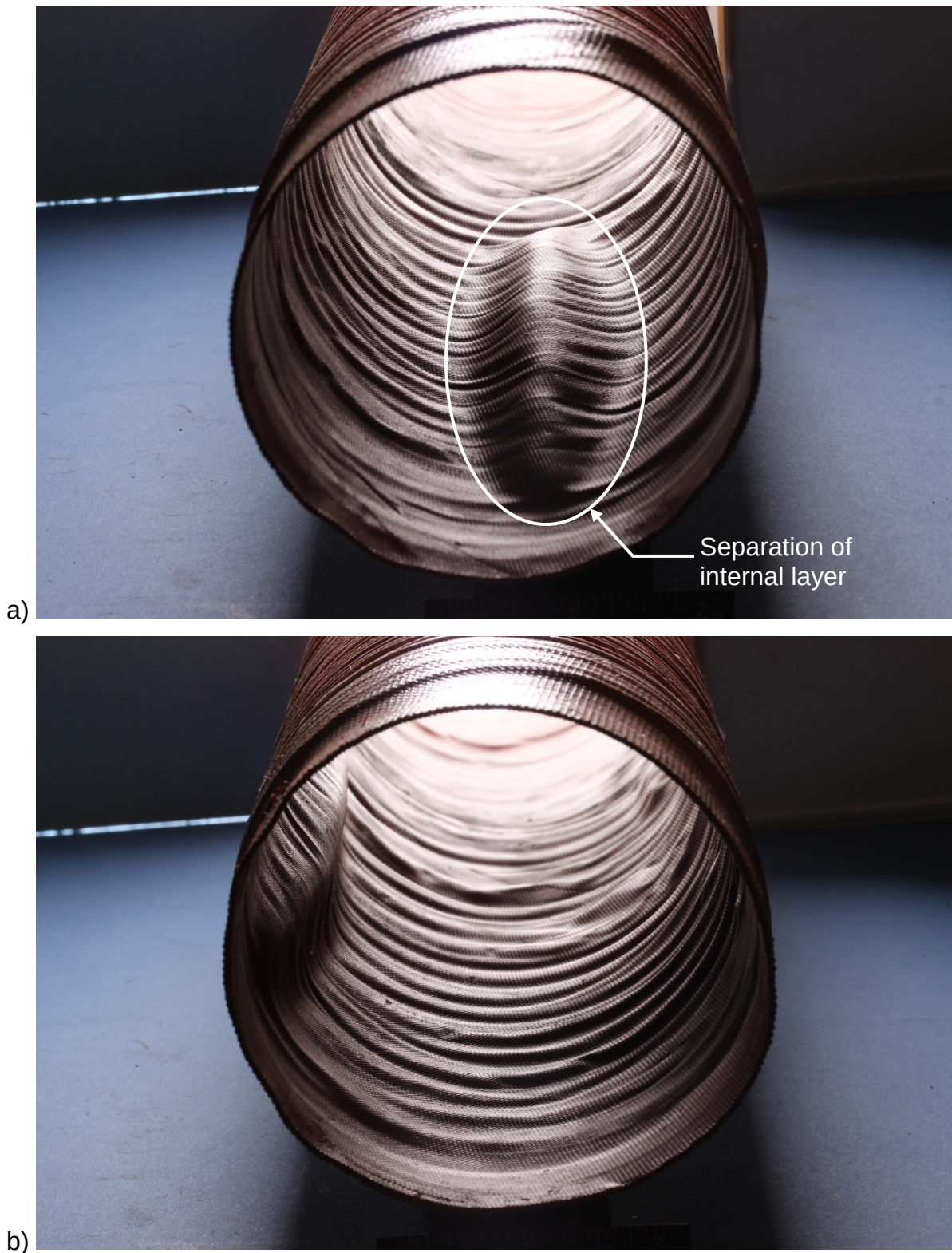
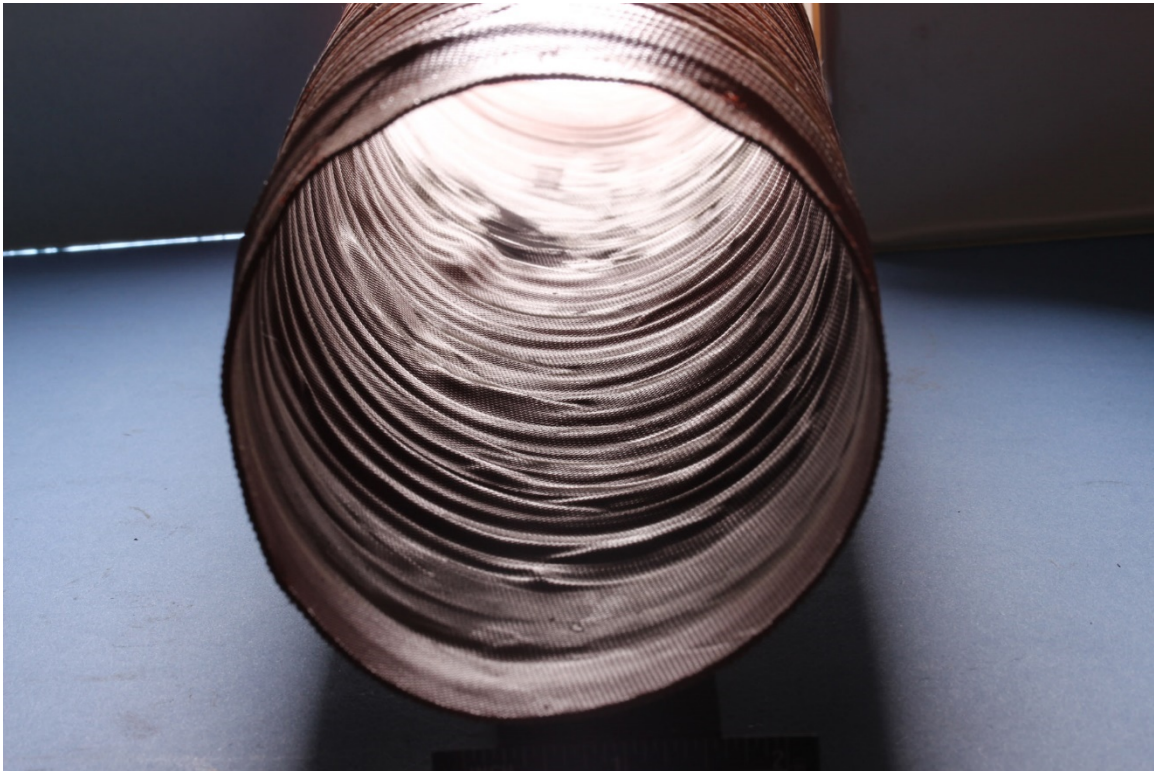
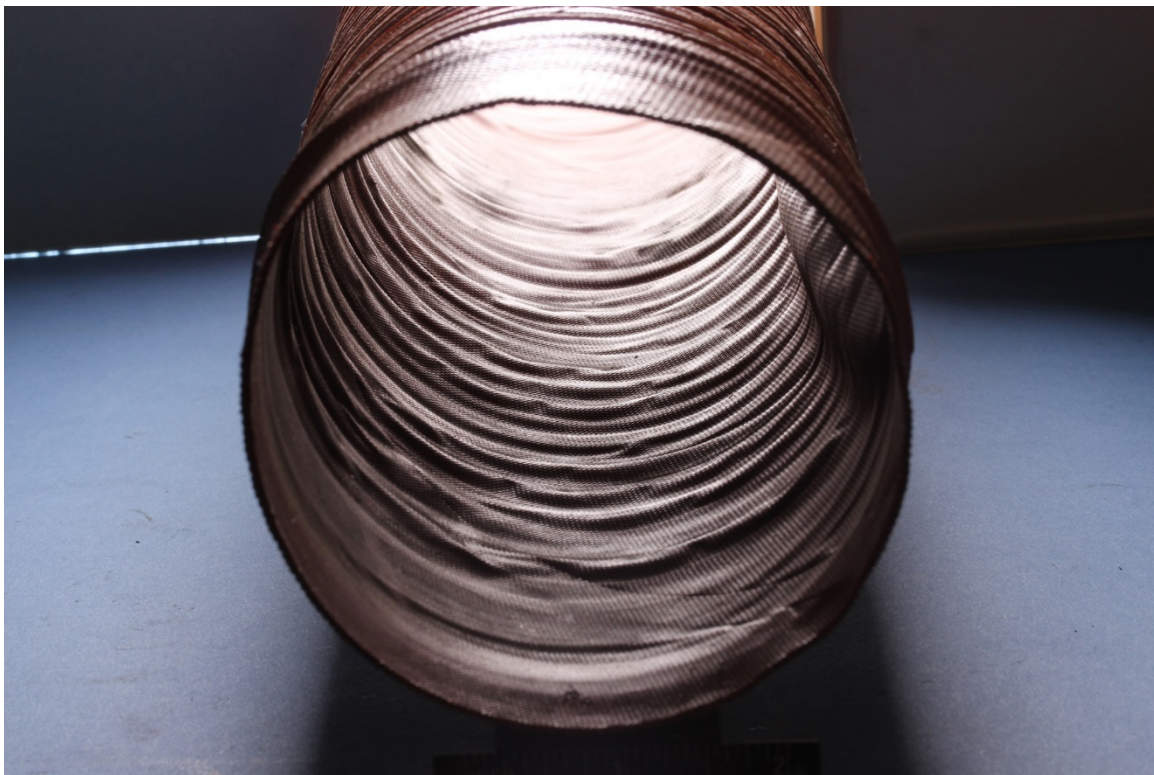


Figure 3: Images of the internal volume of the tube backlit to highlight separations and wrinkles: a) lower side as oriented in figure 1b; b) tube rotated clockwise 90° from part (a);



c)



d)

Figure 3 (cont.): c) tube rotated clockwise 90° from part (b); and d) tube rotated clockwise 90° from part (c).



Figure 4: Image of the duct tube after dissection.

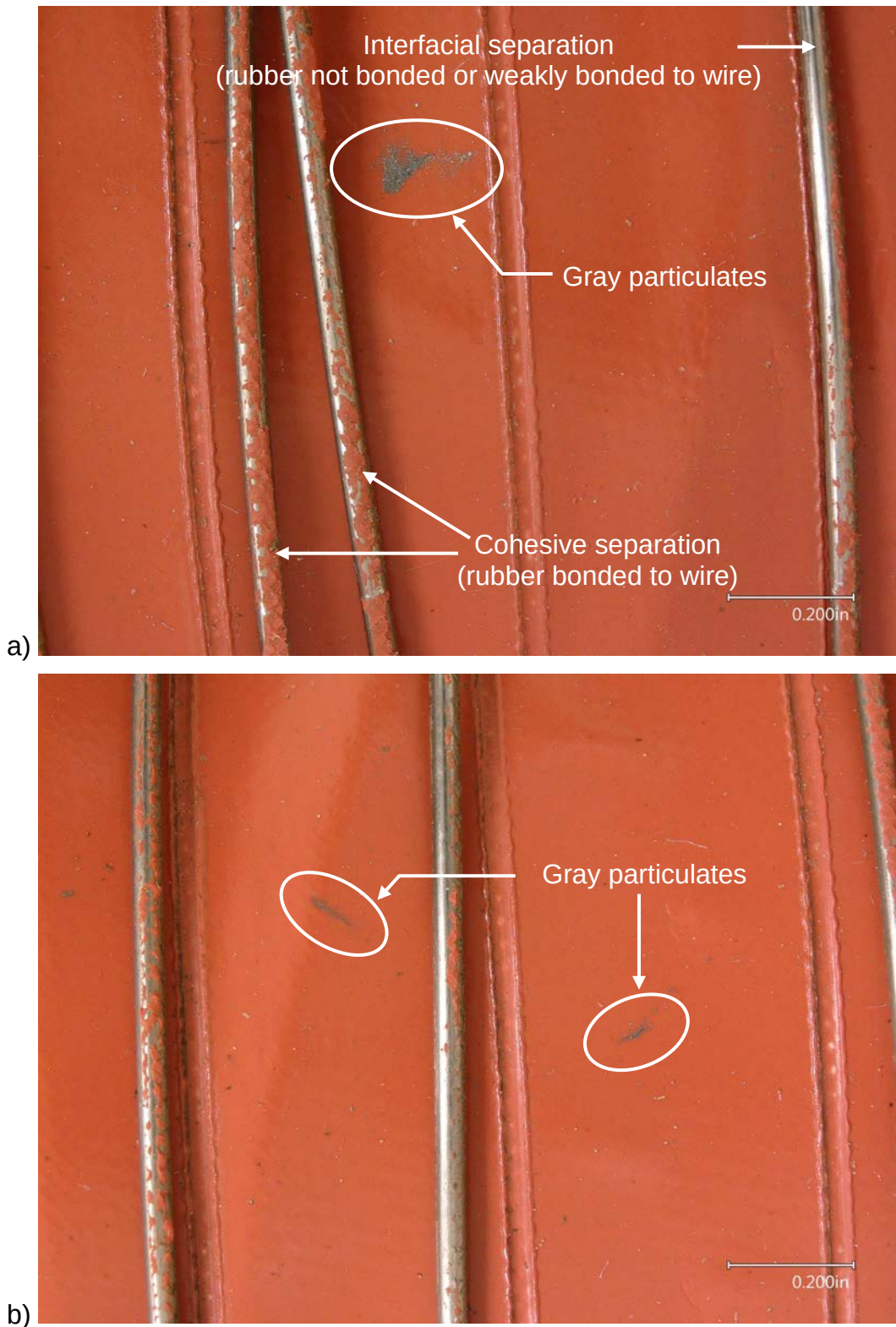


Figure 5: Images of the inner layer internal surface and steel wire: a) indicated areas of cohesive separation where pieces of rubber remained attached to the wire, interfacial separation between rubber and wire, and a discrete area of gray particulates; b) a second image showing additional areas of particulates;

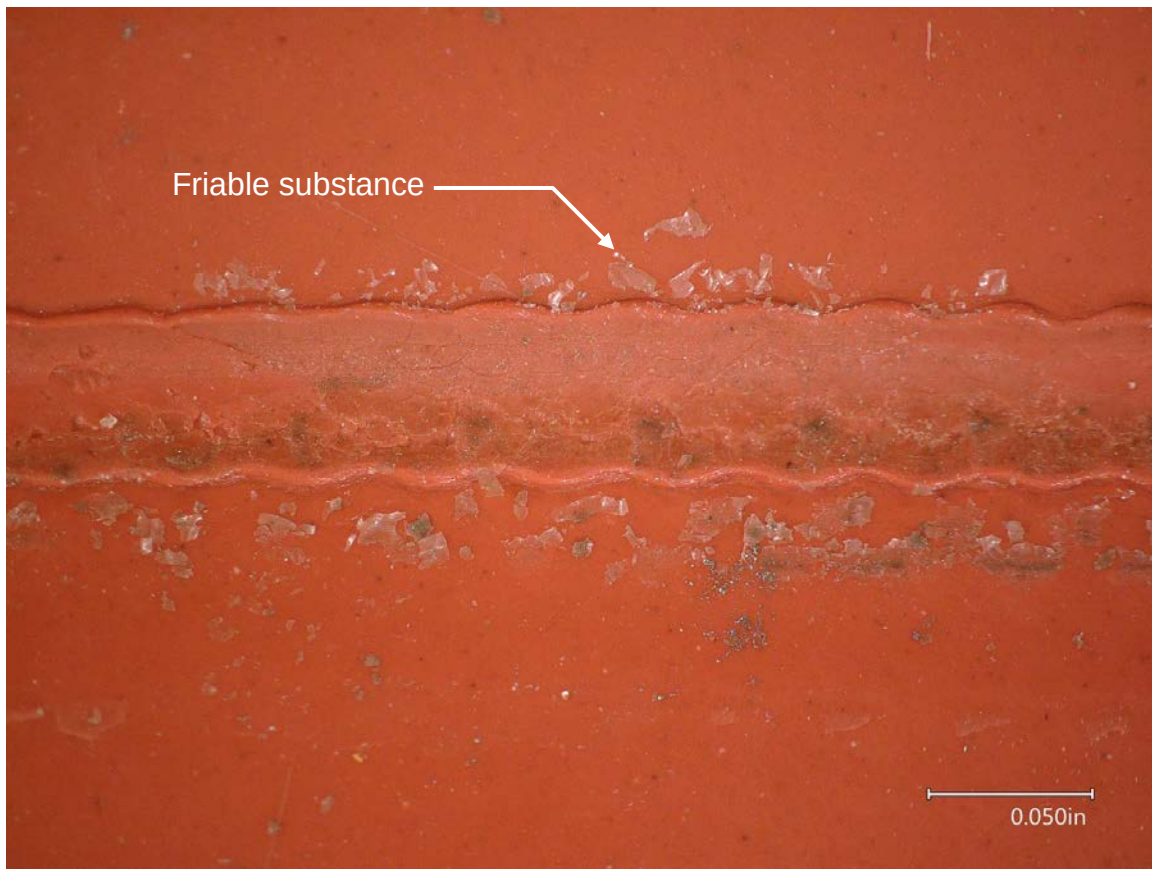


Figure 5 (cont.): and c) outer layer internal surface showing a friable translucent material in the wire impression and adjacent tented area.

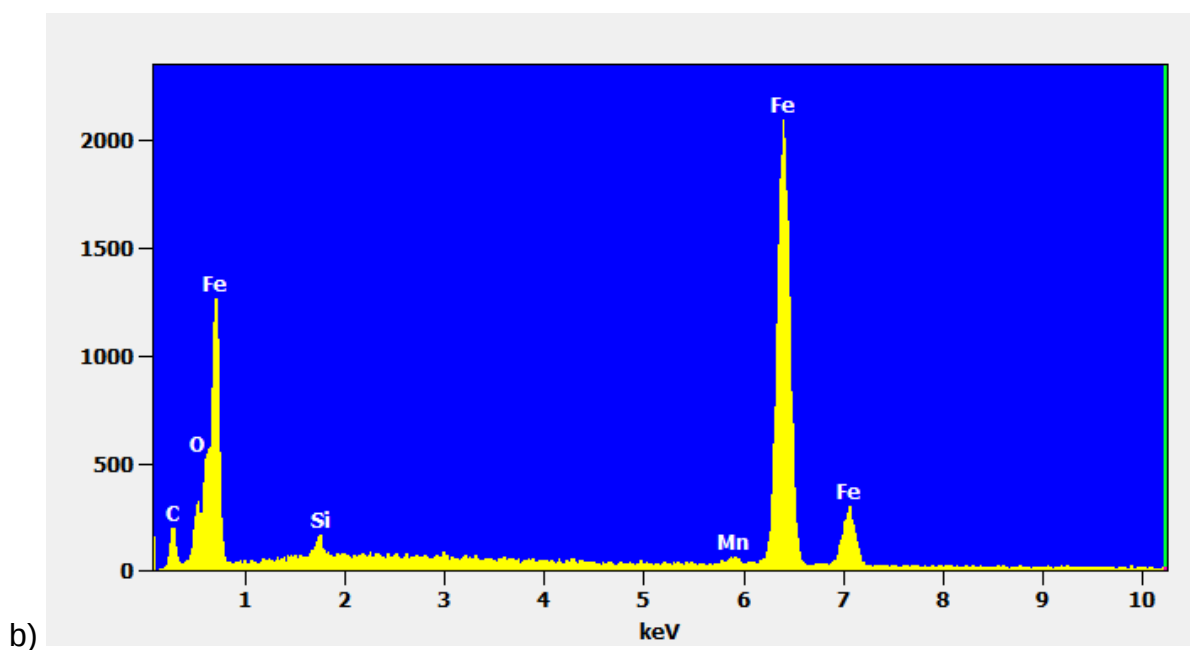
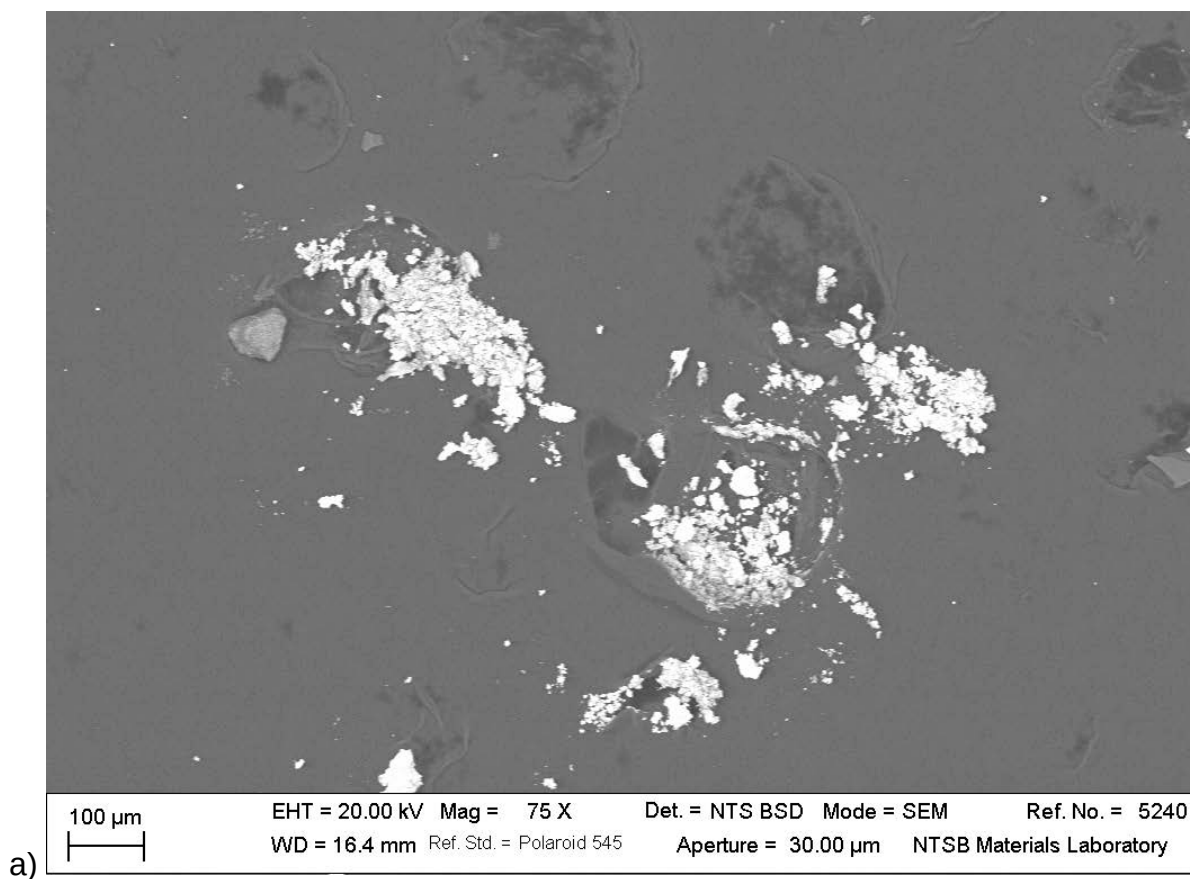


Figure 6: a) SEM backscatter image of a sample of gray particulate residue taken from between the inner and outer layers and b) EDS spectrum of the particles indicating the presence of iron (Fe) and manganese (Mn), consistent with a low-carbon steel.

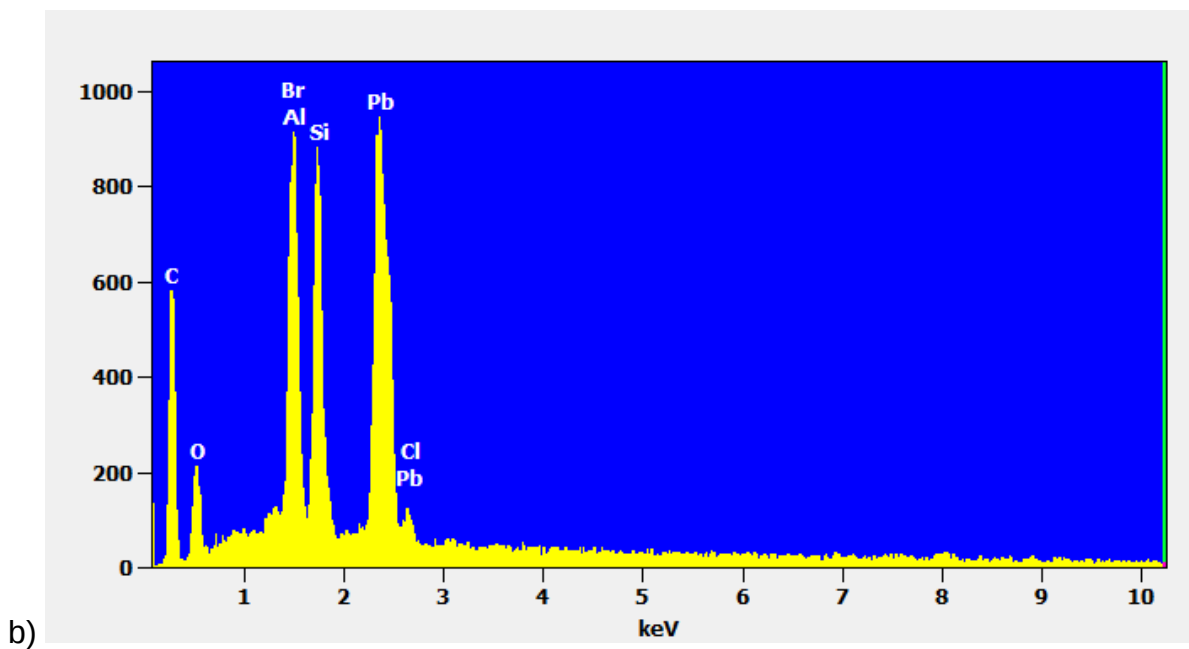
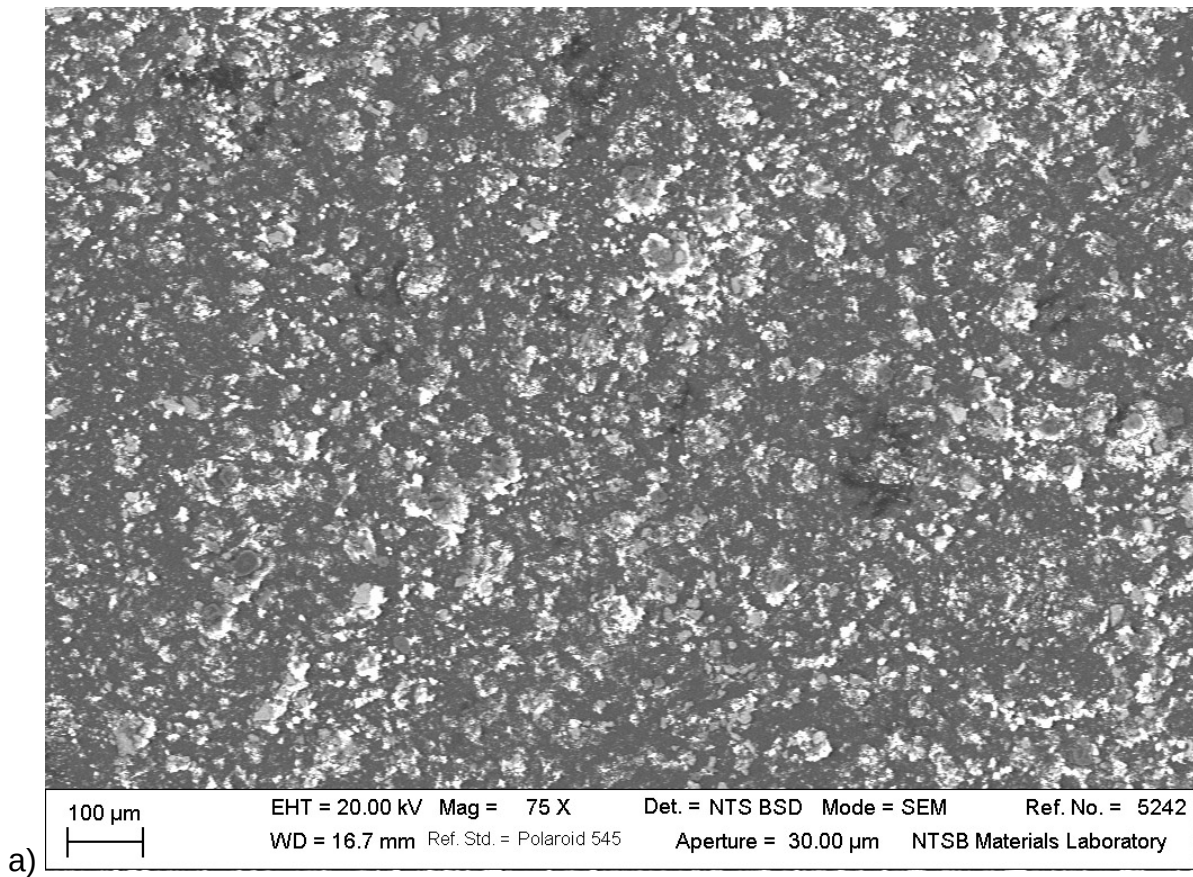


Figure 7: a) SEM backscatter image of a sample of pollution taken from the internal volume of the duct tube; b) EDS spectrum of one type of particle showing the presence of lead (Pb), bromine, (Br), aluminum (Al), and silicon (Si);

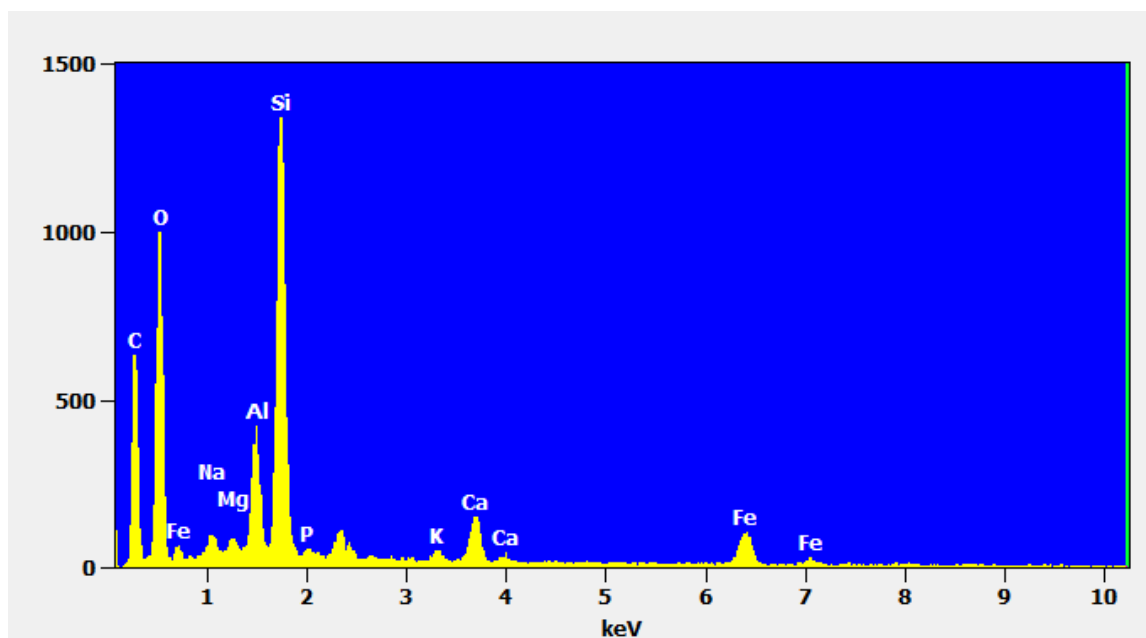
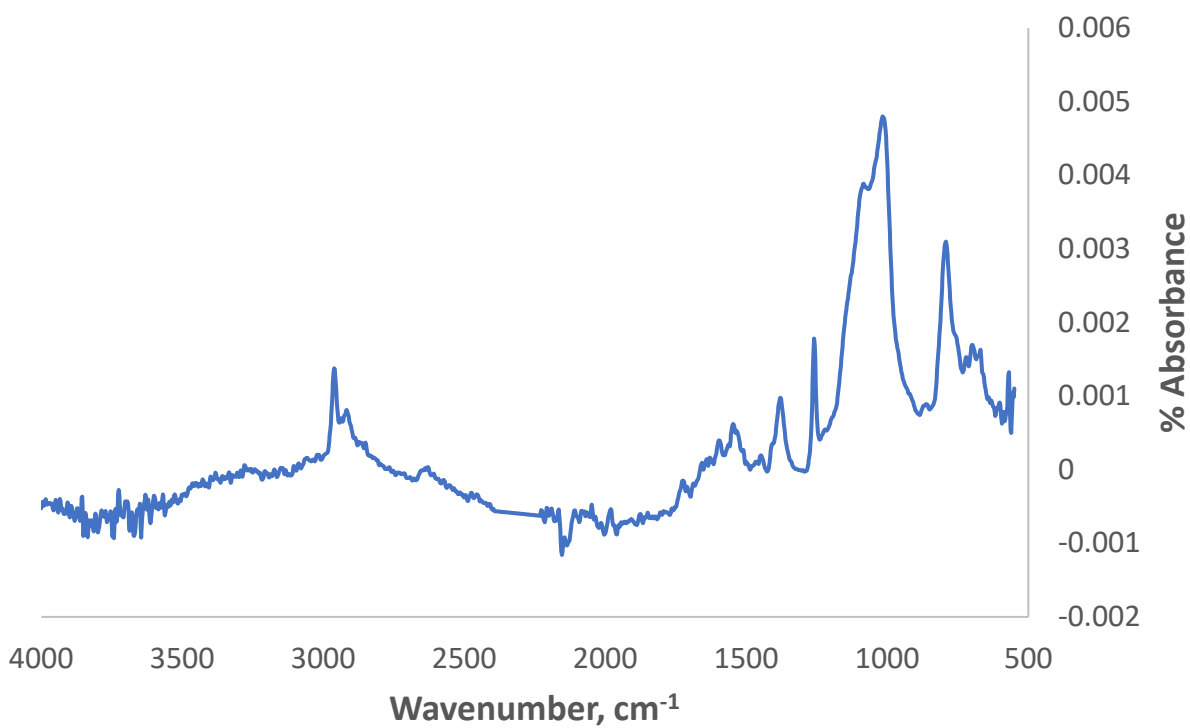
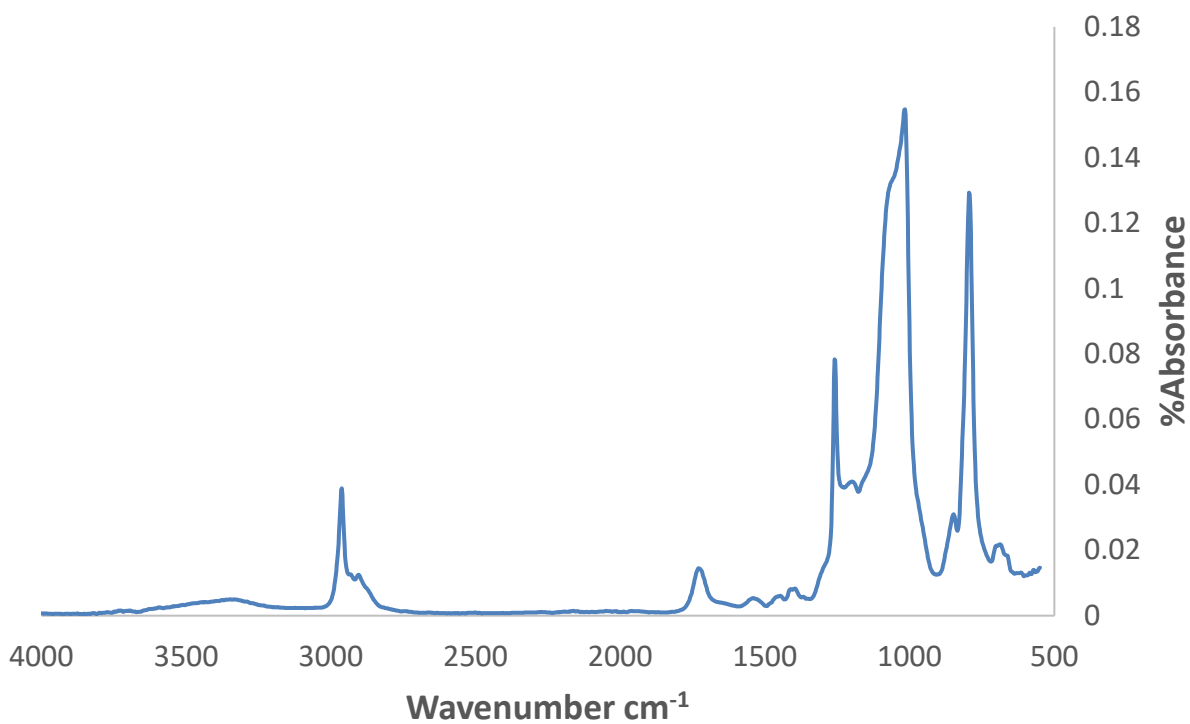


Figure 7 (cont.): and c) EDS spectrum of a second type of particle showing primarily the presence of aluminum (Al), silicon (Si), and calcium (Ca) with traces of iron (Fe).



a)



b)

Figure 8: FTIR/ATR spectra as follows: a) friable residue from accident duct and b) a sample of a water-based mold release agent used by the duct tube manufacturer.