NATIONAL TRANSPORTATION SAFETY BOARD

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

6/30/2017

MATERIALS LABORATORY FACTUAL REPORT Report No. 17-053

A. ACCIDENT INFORMATION

Place	:	San Juan, Puerto Rico
Date	:	August 17, 2016
Vehicle	:	Passenger RO/RO vessel *Caribbean Fantasy*
NTSB No.	:	DCA16FM052
Investigator	:	Adam Tucker, IIC MS-10 Luke Wisniewski, MS-10

B. COMPONENTS EXAMINED

Fuel line gaskets from main port and starboard engines

C. REFERENCE

Jordi Laboratories-Job Number: J12285, Report date May 16, 2017

D. DETAILS OF THE EXAMINATION

1. Fourier Transform Infrared Spectroscopy examination

a. Port supply (accident) flange

The port engine fuel supply line gasket was removed from the supply line flange during a group laboratory examination in the NTSB Materials Laboratory[1]. The gasket broke off in several pieces when the fuel pipe flange was disassembled. The gasket material was rigid and brittle. Exposed interior edges were heavily deteriorated.

A piece of the gasket material was examined using a Fourier Transform Infrared (FTIR) spectrometer with a diamond attenuated total reflectance (ATR) accessory in accordance to American Society for Testing Materials E1252-98: *Standard Practice for General Techniques for Obtaining Infrared Spectra for Qualitative Analysis*.

The spectrum contained spectral peaks that corresponded to particular functional groups found within molecular structure of the gasket material. The presence of a triplet peak at ~2961 cm^{-1}, ~2920 cm^{-1} and ~2851 cm^{-1} corresponds to carbon-hydrogen stretching bonds. A broad, weak single peak at ~2112 cm^{-1} is indicative of a silicon-hydrogen bond. A strong single peak at ~1259 cm^{-1} is indicative of a carbon-hydrogen (CH_3) bending bond. A broad doublet at ~1079 cm^{-1} and ~1010 cm^{-1} is indicative of a silicon-oxygen stretching bond.

[1] For information on this examination, see NTSB Materials Laboratory Report 17-008

A weak single peak at ~865 cm^{-1} is indicative of a carbon-hydrogen (CH_3) bond. A strong peak at ~791 cm^{-1} is indicative a silicon-carbon bond and a weak peak at ~687 cm^{-1} is indicative of a silicon-carbon/hydrogen (CH_3) functional group.

The spectrum from the gasket material suggested that the material was a siloxane. A spectral library search found a strong match to polydimethylsiloxane also known as silicone rubber. It was not possible to determine the filler material using FTIR since the siloxane signatures were strong enough to mask the signatures of mineral fillers commonly used in silicone rubber. Silicone rubber is considered an unsuitable gasket material for use is fuel systems[2]. Exposure to fuel degrades silicone rubber.

A piece of the gasket was sent to an independent third-party laboratory to determine the filler material used in the gasket. This testing is described in Section 2 below.

b. Starboard engine supply and return line gaskets

The starboard engine fuel supply and return line gaskets were removed from the respective flanges by a representative of the ship's owner and the gaskets were shipped to the NTSB Materials Laboratory. A small section of each of the gaskets was examined using a Fourier Transform Infrared (FTIR) spectrometer[3].

Both spectra contained the following spectral peaks that corresponded to particular functional groups found within molecular structure of the gasket material. The presence of three peaks at ~3670 cm^{-1}, ~3390 cm^{-1} and ~3310 cm^{-1} corresponds to nitrogen-hydrogen stretching bonds. A strong doublet peak at ~2920 cm^{-1} and 2850 cm^{-1} is indicative of a carbon-hydrogen stretching single bond. A broad weak peak at ~2320 cm^{-1} is indicative of a carbon-nitrogen (C≡N nitrile) triple bond. A broad medium peak at ~1640 cm^{-1} can be indicative of a nitrogen-hydrogen (N-H) bond or a carbon-carbon (C=C) double bond. A weak doublet peak ~1450 cm^{-1} and ~1400 cm^{-1} is indicative of a carbon-hydrogen (C-H) bending bond. A single peak at ~660 cm^{-1} is indicative of a nitrogen-hydrogen ($N\text{-}H_3$) functional group.

The supply line gasket and return line gasket spectra were a good match to each other except for a peak at ~1006 cm^{-1} in the supply line spectrum. The FTIR spectrum for the starboard engine supply line exhibited a strong single at this location where the starboard engine return line spectrum had a broader, less intense peak in this location. This peak is usually indicative of a silicon-oxygen (Si-O) bond.

The spectra from the both gaskets suggested that the gasket material was a straight-chained alkene with an attached nitrile group. A spectral library search found a strong spectral match to acrylonitrile/butadiene copolymer also known as nitrile rubber.

Pieces of both gaskets were sent to an independent third-party laboratory to determine the filler material used in the gaskets. This testing is described in Section 2 below.

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[2] See Appendix A for compatibility chart.
[3] This spectroscopic analysis was done using the same method as the port fuel supply line gasket.

2. Third Party Laboratory Testing

Pieces of the three fuel line gaskets were submitted to an independent third-party laboratory for analysis of the gasket filler materials, proportions and chemistry. The results were presented in the referenced report and summarized below.

The following tests were performed:

1. Thermogravimetric Analysis (TGA)
2. Scanning Electron Microscopy with Energy Dispersive X-Ray Spectroscopy (SEM-EDX)

The TGA analysis results are listed below.

1. Port engine supply line was reported to have an average of 59.06% of residual filler.
2. Starboard engine supply line was found to comprise an average of 53.18% of residual filler.
3. Starboard engine return line was found to comprise an average of 66.86% of residual filler.

On examining the filler by EDX, the samples port engine supply line and starboard engine return line were found to contain significant amounts of magnesium (Mg), silicon (Si), and oxygen (O). The laboratory determined, that while a mixture of minerals may be present in the samples, the results do not rule out the presence of chrysotile, one of the minerals found in asbestos.

The sample starboard engine supply line did not contain a significant amount of magnesium; which does not suggest the presence of chrysotile in the sample and was therefore not consistent with the other samples.

A copy of the report with a complete list of findings for these samples is attached as Appendix B to this report.

The FTIR spectrum for the starboard engine supply line exhibited a strong single at ~1006 cm^{-1}. This peak is indicative of a silicon-oxygen (Si-O) bond. The strong presence of silicon in the EDS and FTIR spectra is consistent with a silica (glass) filler.

Nancy B. McAtee
Chemist

Appendix A

Elastomer Compatibility Chart

Elastomer and Fuels Compatibility Chart

Fairchild Industrial Products Company
3920 West Point Boulevard • Winston-Salem, NC 27103
phone: 336-659-3400 • fax: 336-659-9323
sales@specontransmission.com www.specontransmission.com

ELASTOMERS				
FUELS	General Purpse Fluoroelastomer (FKM)	Nitrile	Silicone	Specification
Kerosene	1	1	4	
Gasoline	1	1-2	4	
Soddard Solvent	1	1	4	ASTM D-484-52
Diesel	1	1	4	
Bio-Diesel (Ethyl Stearate)	3	3	X	
JP-3	1	1	4	JP-3 (Mil-T-5624)
JP-4	1	1	4	JP-4 (Mil-T-5624)
JP-5	1	1	4	JP-5 (Mil-T-5624)
JP-8	1	1	4	JP-8 (Mil-T-83133)
JP-10	1	1	4	
Fuel Oil, 1 and 2	1	1	4	
Fuel Oil, #6	1	1	2	
Ethanol	2	3*	1	
Methanol	4	3*	1	
E10	2	2-3	4	
E85	2	2-3	4	

* In Dynamic Applications

COMPOUND COMPATIBILITY RATING
1 - SATISFACTORY
2 - FAIR
3 - DOUBTFUL
4 - NOT RECOMMENDED
X - INSUFFICIENT DATA

Approximate Service Temperature Ranges
Fluorocarbon (Viton): -15°F to 400°F
Nitrile: -30°F to 250°F
Silicone: -65°F to 450°F

Data from Dupont Performance Elastomers Database, Chemical Resistance Guide for Elastomers III, 2005 and Dow Corning Chemical Resistance Guide for Silastic Materials.

For additional information please contact a Fairchild Applications Engineer at 336-659-3400.

Appendix B

Laboratory Testing Report

Nancy McAtee
National Transportation Safety Board

Released by:

Mark Jordi, Ph.D.
President

Job Number: J12285

CONFIDENTIAL

Jordi Labs
MATERIAL SOLUTIONS. UNCOMPROMISING INTEGRITY.

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May 16, 2017

Nancy McAtee
National Transportation Safety Board
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Washington, DC 20594

P: 202-314-6509
E: MCATEEN@ntsb.gov

Dear Nancy,

Please find enclosed the test results for your samples described as:

1. Starboard Engine Supply Line
2. Starboard Engine Return Line
3. Port Engine Supply Line

The following tests were performed:

1. Thermogravimetric Analysis (TGA)
2. Scanning Electron Microscopy with Energy Dispersive X-Ray Spectroscopy (SEM-EDX)

Objective

Three (3) fuel line gaskets were submitted for chemical analysis. The gaskets had been previously analyzed by FTIR and found to be consistent with a nitrile rubber. The filler of the gaskets are of interest as the engine manufacturer recommends a non-asbestos filled gasket. The goal of this analysis was to determine the filler content and investigate the chemistry of the filler, specifically in relation to asbestos.

Summary of Results

The samples *Starboard Engine Supply Line, Port Engine Supply Line,* and *Starboard Engine Return Line* were found to comprise an average of 53.18, 59.06, and 66.86% of residual filler respectively following TGA. On examining the filler by EDX, the samples *Port Engine Supply Line* and *Starboard Engine Return Line* were found to contain significant amounts of Mg, Si, and O. While a mixture of minerals may be present in the samples, the results do not rule out the presence of chrysotile, one of the minerals found in asbestos. The sample *Starboard Engine Supply Line* did not contain a significant amount of Mg; which is more suggesting of a lack of chrysotile in the sample and was therefore not consistent with the other samples.

Individual Test Results

A summary of the individual test results is provided below. All accompanying data, including spectra, has been included in the data section of this report.

Recommended Next Steps

The possibility of multiple minerals existing in a single sample prevents definitive determination of any one mineral being present, such as chrysotile. To try an determine the individual minerals present in the sample, Powder X-Ray Diffraction (pXRD) could be used to identify whether specific minerals related to asbestos may be present. Polarized light microscopy (PLM) or Transmission Electron Microscopy (TEM) may also allow for more definitive identification of the minerals present.

<u>Sample Preparation</u>

The samples were received as shown in **Figure 1**. It was noted that the *Starboard Engine Supply Line* sample contained a metal mesh which ran through the middle of the sample. This metal mesh was not sampled when portioning the sample for TGA analysis.

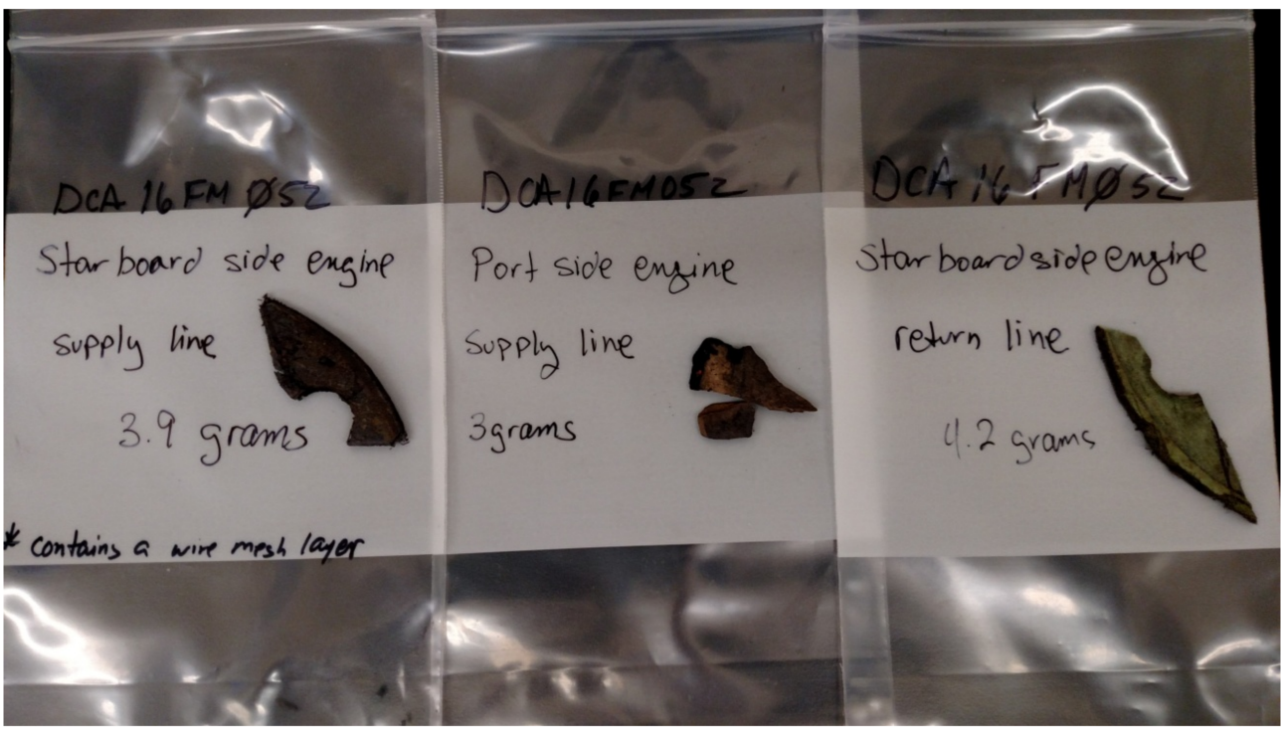


Figure 1: The samples *Starboard Engine Supply Line, Port Engine Supply Line,* and *Starboard Engine Return Line*

TGA

Approximately 30mg of each sample was portioned using a scalpel and placed into a platinum weigh boat for under a nitrogen atmosphere and heated from ambient to 1000 °C at a rate of 20 °C per minute. On reaching 1000 °C, the atmosphere was switched to oxygen and held isothermally for 3 minutes. Each sample was run in duplicate.

Analysis results are shown in **Table 1**. The samples were found to have complex temperature profiles, with many small weight loss steps which did not return to a baseline to allow for accurate measurement. However, in each sample two major weight loss steps could be discerned. Notably, this initial weight loss step occurred at a significantly lower temperature in the *Starboard Engine Return Line* sample compared to the other samples.

Notably, the *Starboard Engine Supply Line* sample was found to experience the most weight loss upon switching the atmosphere to oxygen, which may suggest a larger amount of carbon black filler in the sample. The *Port Engine Supply Line* was found to have a large degree of inconsistency between the duplicate runs, which may suggest a certain degree of inhomogeneity in the sample. Contrary, the *Starboard Engine Return Line* was the most consistent of the samples.

Table 1
TGA Weight Loss

Sample Name	Run	Weight Loss Step	Weight Loss (%)	Total Weight Loss Under Nitrogen (%)	Total Weight Loss Under Oxygen (%)	Total Weight Loss	Average Total Weight Loss (%)	Average Percent Residuals (%)
Port Engine Supply Line	1	1	14.82	48.68	0.933	49.61	40.94	59.06
		2	33.86					
	2	1	12.68	30.77	1.504	32.27		
		2	18.09					
Starboard Engine Supply Line	1	1	17.78	27.42	17.31	44.73	46.82	53.18
		2	9.635					
	2	1	19.53	34.20	14.89	48.91		
		2	14.67					
Starboard Engine Return Line	1	1	8.568	31.68	1.723	33.40	33.14	66.86
		2	23.11					
	2	1	8.719	31.18	1.690	32.87		
		2	22.46					

SEM-EDX

The residues remaining from TGA analysis of the samples were transferred to SEM carbon tape and mounted for analysis by SEM-EDX. **Figures 2-4** show the secondary electron (SE) and backscattered electron (BSE) images of each sample. **Figures 5-18** show the SEM-EDX images and the elemental composition of each sampling location is summarized in **Tables 2-12**. It should be noted that all three samples had the appearance of a fibrous material mixed with larger fragments of some other compound. A mixture of asbestos fibers and other fillers may have a similar appearance, although a control asbestos sample could allow for a more direct comparison.

The samples *Starboard Engine Return Line* and *Port Engine Supply Line* were found to contain significant amounts of C, O, Na, Mg, Al, Si, Ca, and Fe. Of particular interest are the elements Mg, Si, and O, as these components are observed in the asbestos mineral chrysotile. While EDX as performed in this analysis is not a highly quantitative method, the ratios of the these elements observed in the two samples is not inconsistent with the presence of chrysotile. However, the abundance of other elements indicates that a mixture of other minerals may be present. By contrast, the *Starboard Engine Supply Line* sample was found to have very low levels of Mg, with the elements C, O, Na, Al, Si, K, and Fe in significant abundance. This result is more suggestive of a lack of chrysotile in the sample, or if so it is a minor component, and the sample is more consistent with silicate glass fiber and aluminum oxide as a filler.

Table 2: Elemental concentration at area 1 on *Starboard Engine Return Line*

Element	Atomic Number	Series	Weight %	Mole %	% Error
Carbon	6	K	1.42	2.50	42.16
Oxygen	8	K	48.99	64.44	9.04
Sodium	11	K	1.88	1.72	12.18
Magnesium	12	K	2.70	2.34	7.72
Aluminum	13	K	2.93	2.28	6.41
Silicon	14	K	20.97	15.71	3.81
Sulfur	16	K	0.11	0.07	63.98
Potassium	19	K	0.10	0.05	65.92
Calcium	20	K	20.22	10.62	2.94
Iron	26	K	0.68	0.26	57.76

Table 3: Elemental concentration at area 2 on *Starboard Engine Return Line*

Element	Atomic Number	Series	Weight %	Mole %	% Error
Carbon	6	K	1.26	2.13	18.90
Oxygen	8	K	48.46	61.51	7.69
Sodium	11	K	5.36	4.73	7.84
Magnesium	12	K	5.91	4.94	6.12
Aluminum	13	K	8.09	6.09	5.07
Silicon	14	K	23.10	16.70	4.10
Potassium	19	K	0.21	0.11	60.79
Calcium	20	K	7.01	3.55	4.73
Titanium	22	K	0.24	0.10	59.80
Iron	26	K	0.37	0.13	61.12

Table 4: Elemental concentration at area 3 on *Starboard Engine Return Line*					
Element	Atomic Number	Series	Weight %	Mole %	% Error
Carbon	6	K	3.44	5.72	14.58
Oxygen	8	K	47.07	58.82	7.47
Sodium	11	K	4.33	3.76	7.88
Magnesium	12	K	8.67	7.13	5.61
Aluminum	13	K	7.20	5.33	5.19
Silicon	14	K	22.91	16.31	4.10
Potassium	19	K	0.46	0.24	21.45
Calcium	20	K	3.70	1.85	5.64
Titanium	22	K	0.83	0.35	19.75
Iron	26	K	1.41	0.51	22.26

Table 5: Elemental concentration at area 4 on *Starboard Engine Return Line*					
Element	Atomic Number	Series	Weight %	Mole %	% Error
Carbon	6	K	2.55	4.38	16.58
Oxygen	8	K	46.46	59.96	8.33
Sodium	11	K	3.26	2.93	9.15
Magnesium	12	K	5.41	4.59	6.26
Aluminum	13	K	5.67	4.34	5.53
Silicon	14	K	23.56	17.32	3.95
Potassium	19	K	0.49	0.26	23.61
Calcium	20	K	10.34	5.33	3.69
Titanium	22	K	0.84	0.36	25.90
Iron	26	K	1.41	0.52	27.65

Table 6: Elemental concentration at area 1 on *Port Engine Supply Line*					
Element	Atomic Number	Series	Weight %	Mole %	% Error
Carbon	6	K	1.44	2.39	41.25
Oxygen	8	K	44.60	55.67	6.52
Sodium	11	K	2.60	2.26	8.34
Magnesium	12	K	30.94	25.42	4.47
Aluminum	13	K	0.52	0.39	16.52
Silicon	14	K	18.60	13.22	4.70
Potassium	19	K	0.49	0.25	24.32
Calcium	20	K	0.81	0.41	19.67

Table 7: Elemental concentration at area 2 on *Port Engine Supply Line*					
Element	Atomic Number	Series	Weight %	Mole %	% Error
Carbon	6	K	1.56	3.18	99.99
Oxygen	8	K	35.46	54.36	10.35
Iron	26	L	0.93	0.41	34.85
Sodium	11	K	2.26	2.42	10.53
Magnesium	12	K	4.08	4.11	7.04
Aluminum	13	K	0.21	0.19	34.34
Silicon	14	K	4.37	3.82	4.96
Sulfur	16	K	1.49	1.14	8.37
Potassium	19	K	0.35	0.22	23.86
Calcium	20	K	49.29	30.16	2.10

Table 8: Elemental concentration at area 3 on *Port Engine Supply Line*					
Element	Atomic Number	Series	Weight %	Mole %	% Error
Carbon	6	K	4.42	7.97	14.52
Oxygen	8	K	39.78	53.86	8.66
Sodium	11	K	7.74	7.29	8.59
Magnesium	12	K	7.32	6.52	7.01
Aluminum	13	K	3.58	2.87	7.29
Silicon	14	K	13.04	10.05	4.86
Potassium	19	K	0.46	0.25	31.16
Calcium	20	K	12.28	6.64	3.79
Titanium	22	K	1.87	0.85	14.78
Iron	26	K	9.53	3.70	7.13

Table 9: Elemental concentration at area 1 on *Starboard Engine Supply Line*					
Element	Atomic Number	Series	Weight %	Mole %	% Error
Carbon	6	K	2.48	4.33	15.72
Oxygen	8	K	47.70	62.64	7.02
Iron	26	L	11.63	4.38	8.75
Sodium	11	K	1.65	1.51	12.04
Aluminum	13	K	13.12	10.22	4.65
Silicon	14	K	20.74	15.52	4.36
Potassium	19	K	1.26	0.68	11.98
Calcium	20	K	1.24	0.65	11.54
Titanium	22	K	0.18	0.08	59.77

Table 10: Elemental concentration at area 2 on *Starboard Engine Supply Line*					
Element	Atomic Number	Series	Weight %	Mole %	% Error
Carbon	6	K	3.26	5.51	18.88
Oxygen	8	K	45.72	58.00	7.78
Sodium	11	K	1.05	0.92	14.48
Magnesium	12	K	0.20	0.17	52.29
Aluminum	13	K	17.30	13.02	3.96
Silicon	14	K	27.82	20.11	4.16
Sulfur	16	K	0.16	0.10	62.45
Potassium	19	K	2.23	1.16	11.50
Calcium	20	K	1.20	0.61	15.08
Titanium	22	K	0.21	0.09	59.90
Iron	26	K	0.82	0.30	57.41

Table 11: Elemental concentration at area 3 on *Starboard Engine Supply Line*					
Element	Atomic Number	Series	Weight %	Mole %	% Error
Carbon	6	K	2.09	3.63	16.54
Oxygen	8	K	46.60	60.67	7.38
Sodium	11	K	1.25	1.13	12.37
Magnesium	12	K	0.08	0.07	64.17
Aluminum	13	K	15.65	12.08	4.23
Silicon	14	K	24.87	18.44	4.23
Potassium	19	K	1.42	0.76	12.99
Calcium	20	K	1.23	0.64	14.64
Titanium	22	K	0.75	0.33	24.42
Iron	26	K	6.05	2.26	8.24

Table 12: Elemental concentration at area 4 on *Starboard Engine Supply Line*					
Element	Atomic Number	Series	Weight %	Mole %	% Error
Carbon	6	K	4.15	7.51	15.88
Oxygen	8	K	40.55	55.11	7.83
Sodium	11	K	1.21	1.15	16.83
Magnesium	12	K	0.14	0.12	65.68
Aluminum	13	K	14.38	11.59	4.97
Silicon	14	K	22.18	17.17	4.68
Sulfur	16	K	0.21	0.14	61.47
Potassium	19	K	1.50	0.84	14.38
Calcium	20	K	1.58	0.86	15.45
Titanium	22	K	0.28	0.13	60.06
Iron	26	K	13.81	5.38	6.87

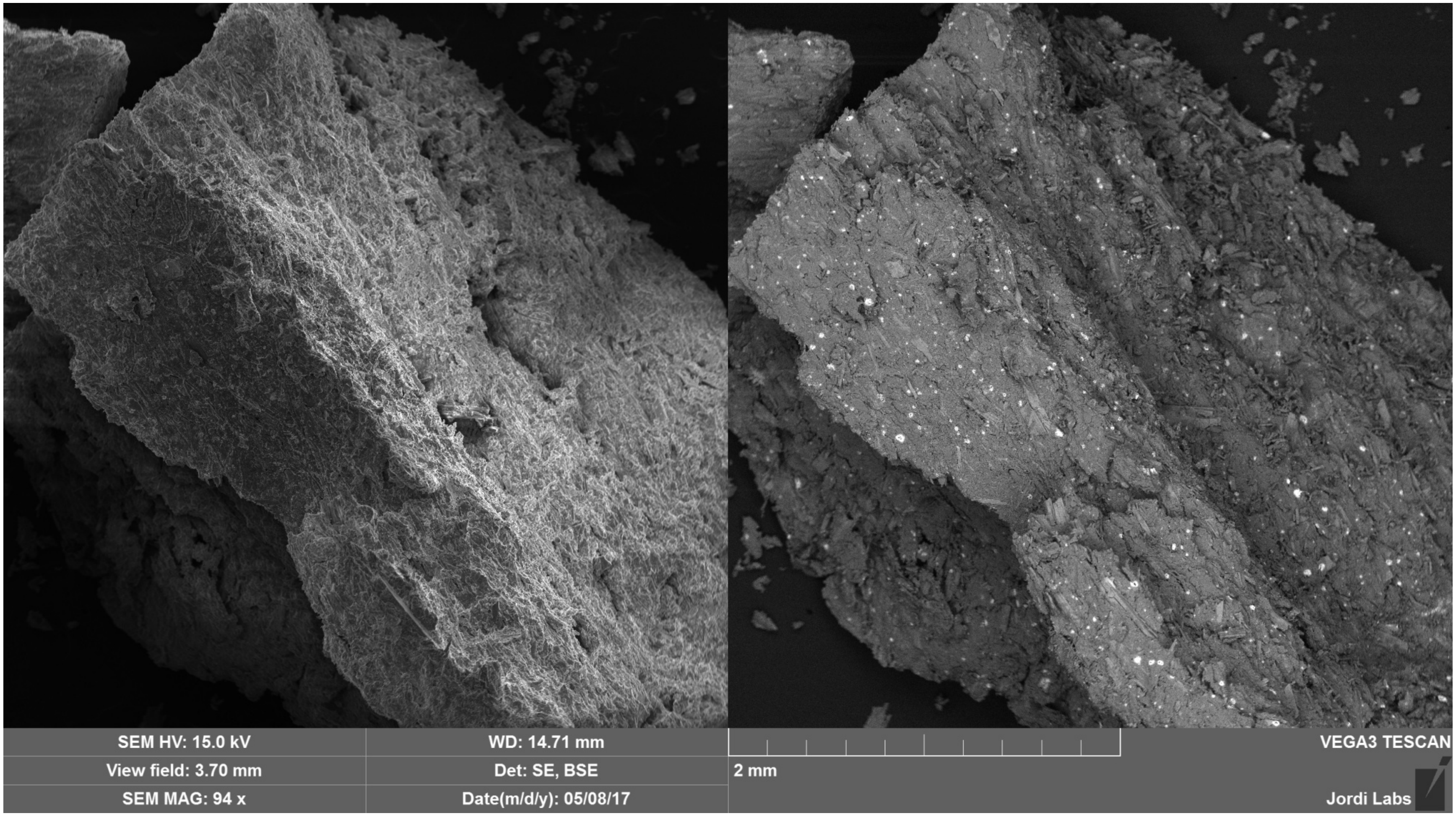


Figure 2: SEM SE (left) and BSE (right) images of *Starboard Engine Return Line*

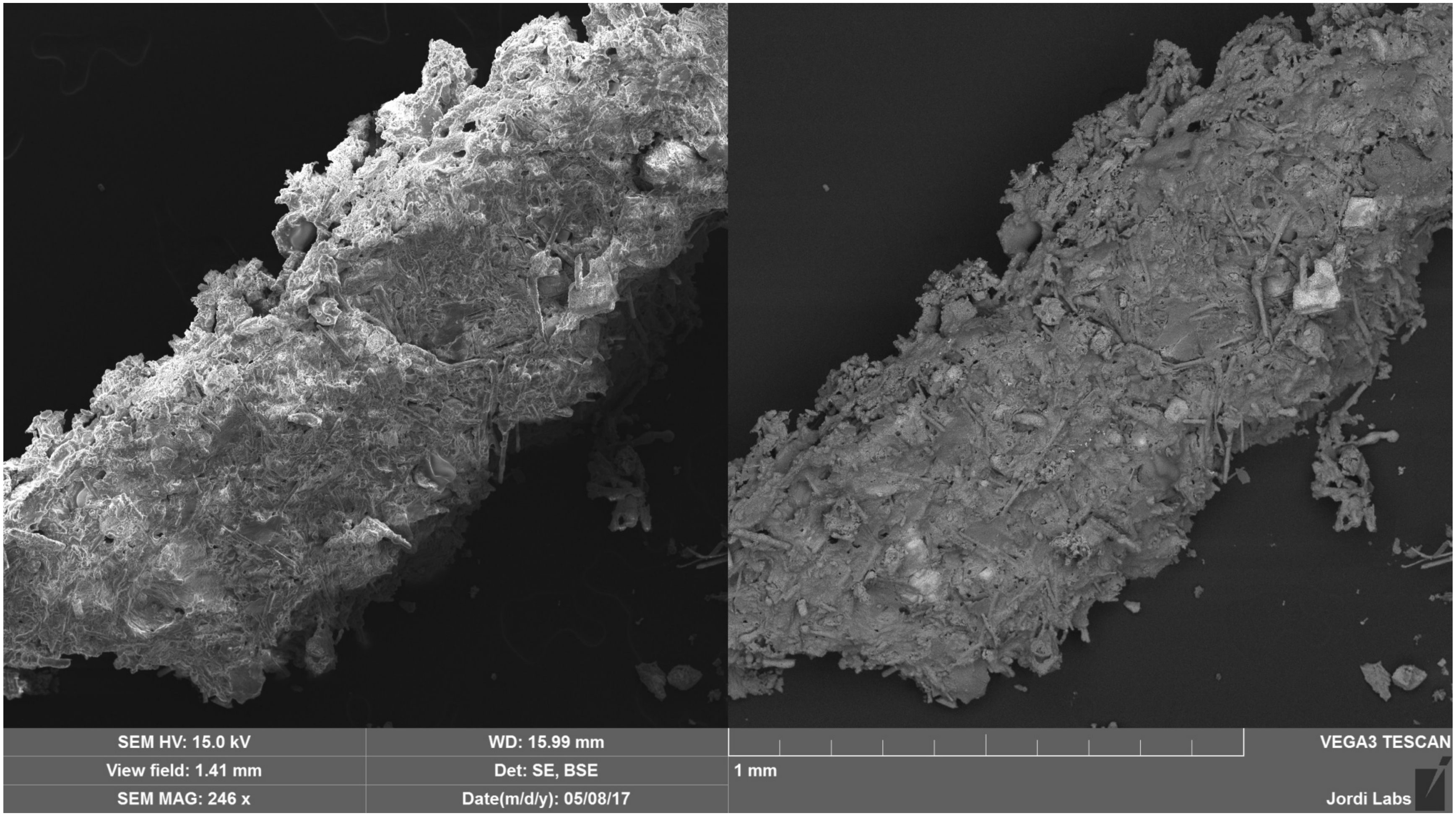


Figure 3: SEM SE (left) and BSE (right) images of *Port Engine Supply Line*

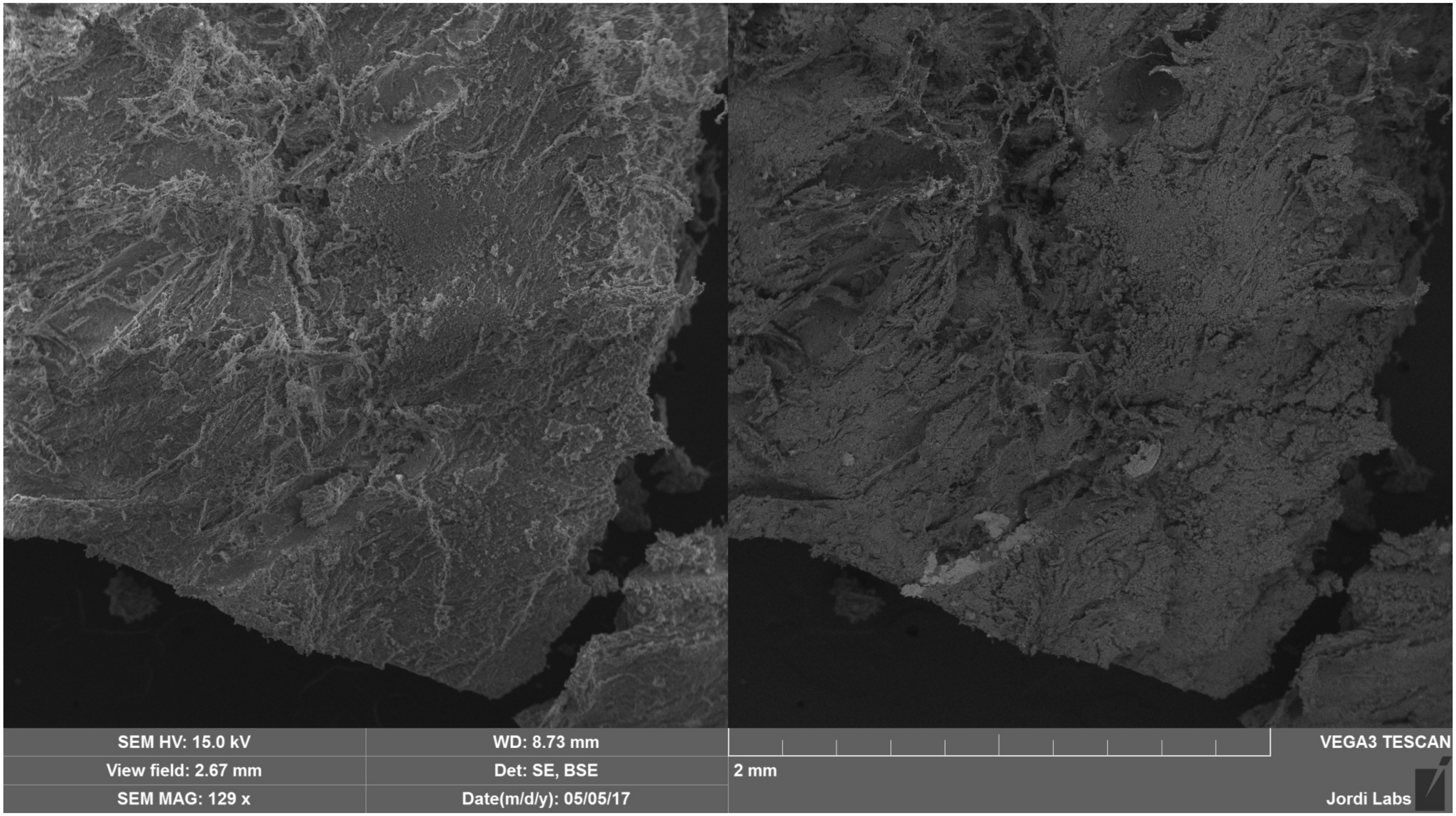


Figure 4: SEM SE (left) and BSE (right) images of *Starboard Engine Supply Line*

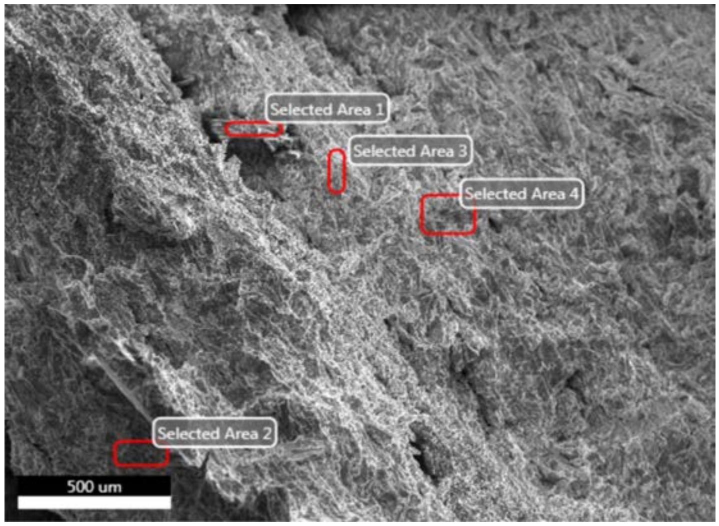


Figure 5: SEM-EDX image of all sampling locations analyzed of *Starboard Engine Return Line*

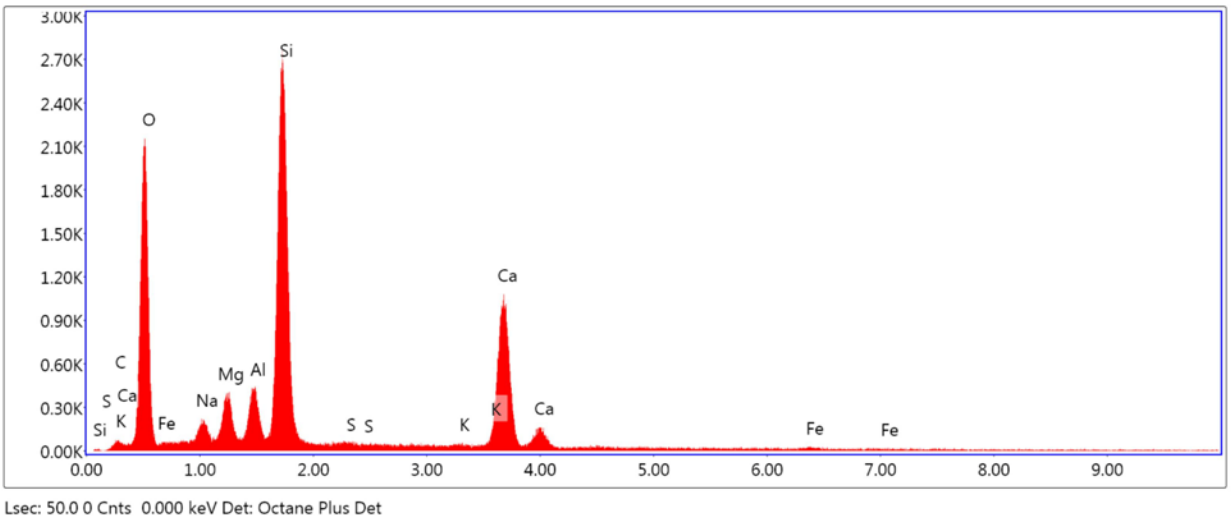


Figure 6: SEM-EDX elemental abundance of area 1 analyzed of *Starboard Engine Return Line*

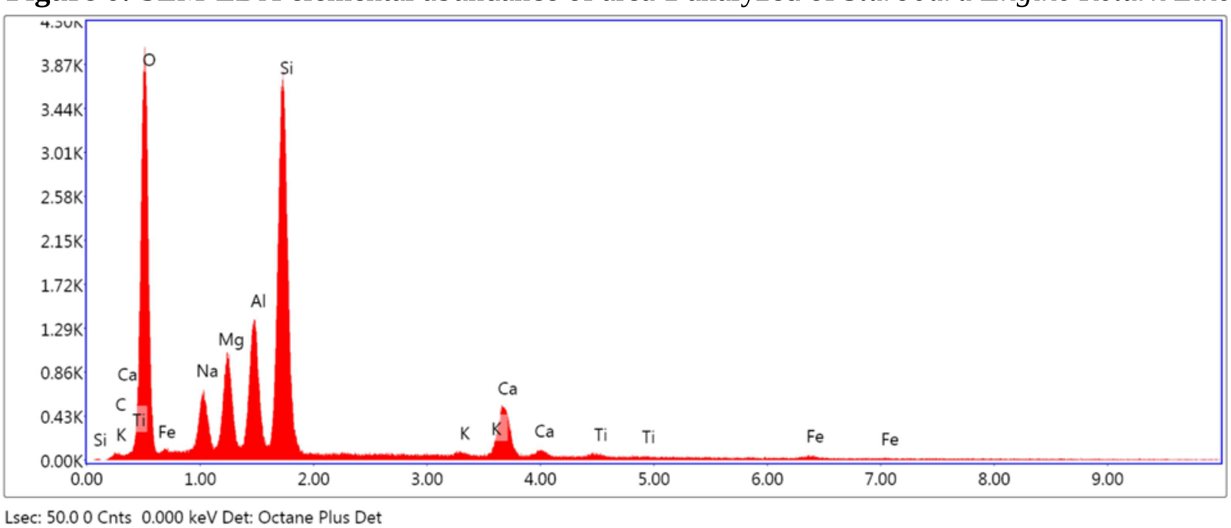


Figure 7: SEM-EDX elemental abundance of area 2 analyzed of *Starboard Engine Return Line*

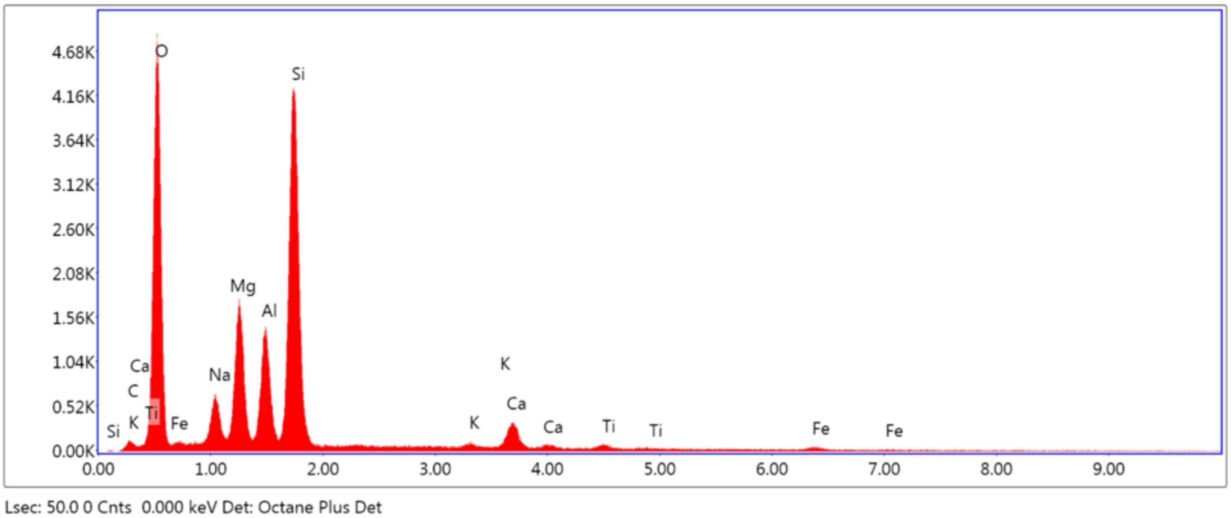


Figure 8: SEM-EDX elemental abundance of area 3 analyzed of *Starboard Engine Return Line*

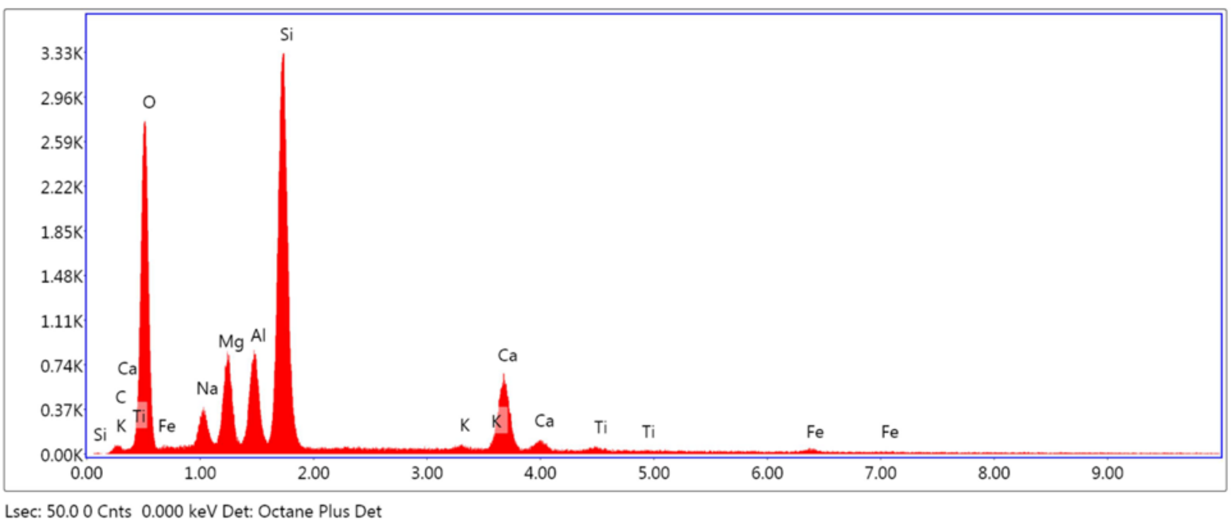


Figure 9: SEM-EDX elemental abundance of area 4 analyzed of *Starboard Engine Return Line*

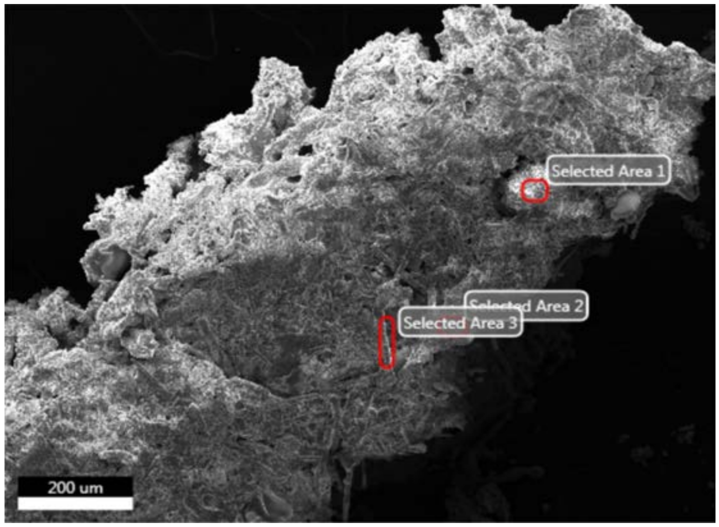


Figure 10: SEM-EDX image of all sampling locations analyzed of *Port Engine Supply Line*

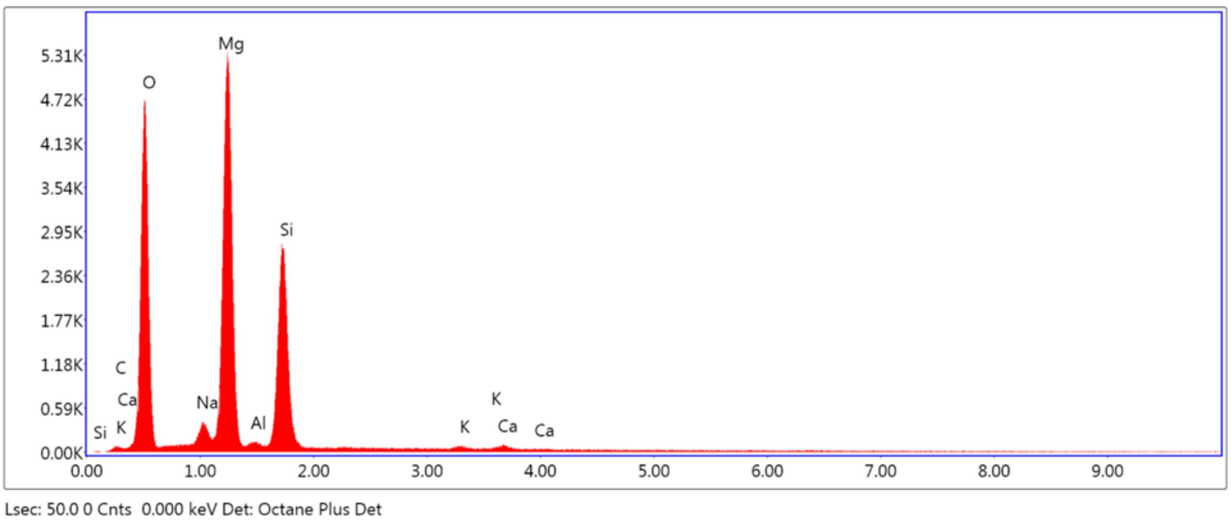


Figure 11: SEM-EDX elemental abundance of area 1 analyzed of *Port Engine Supply Line*

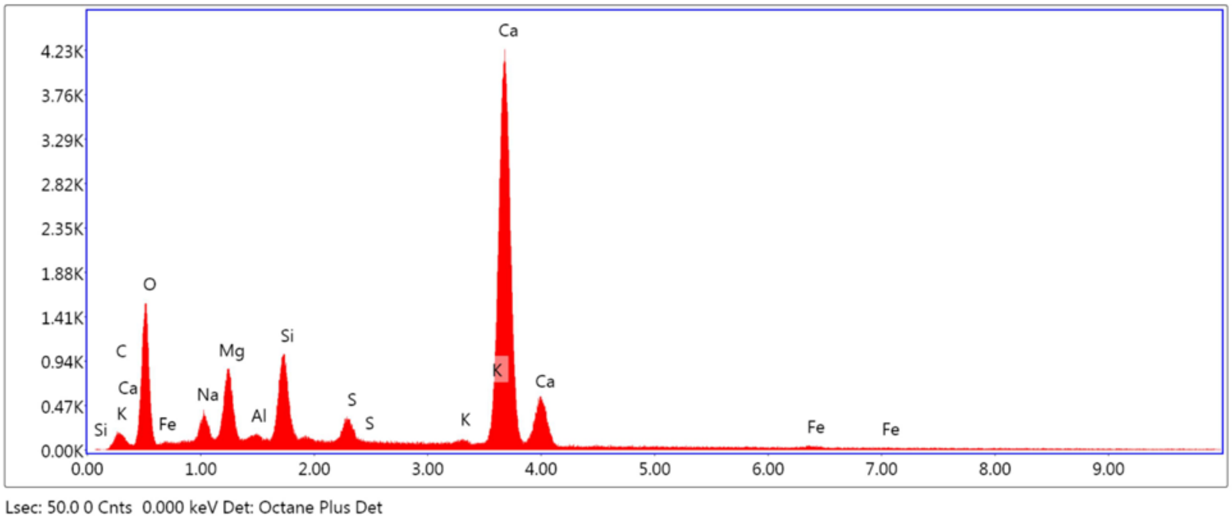


Figure 12: SEM-EDX elemental abundance of area 2 analyzed of *Port Engine Supply Line*

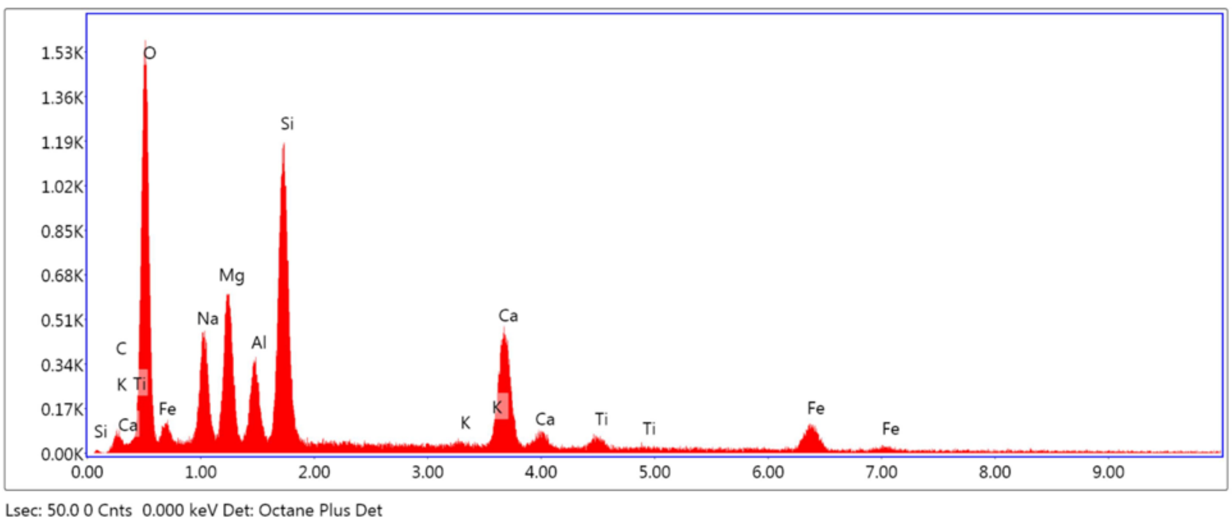


Figure 13: SEM-EDX elemental abundance of area 3 analyzed of *Port Engine Supply Line*

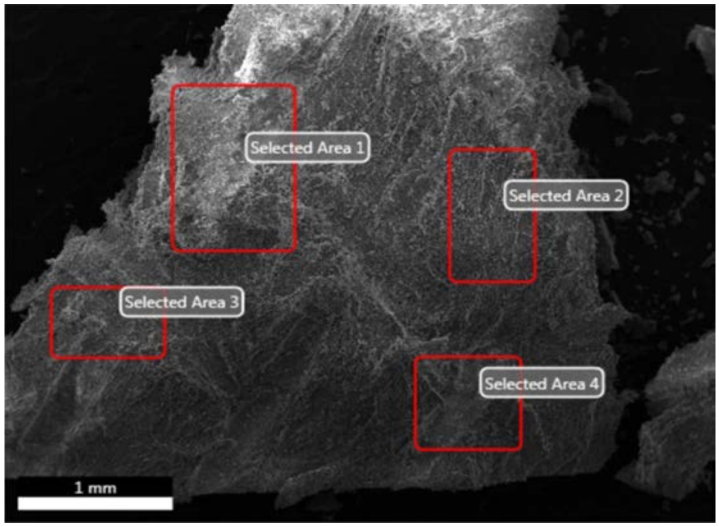


Figure 14: SEM-EDX image of sampling locations analyzed of *Starboard Engine Supply Line*

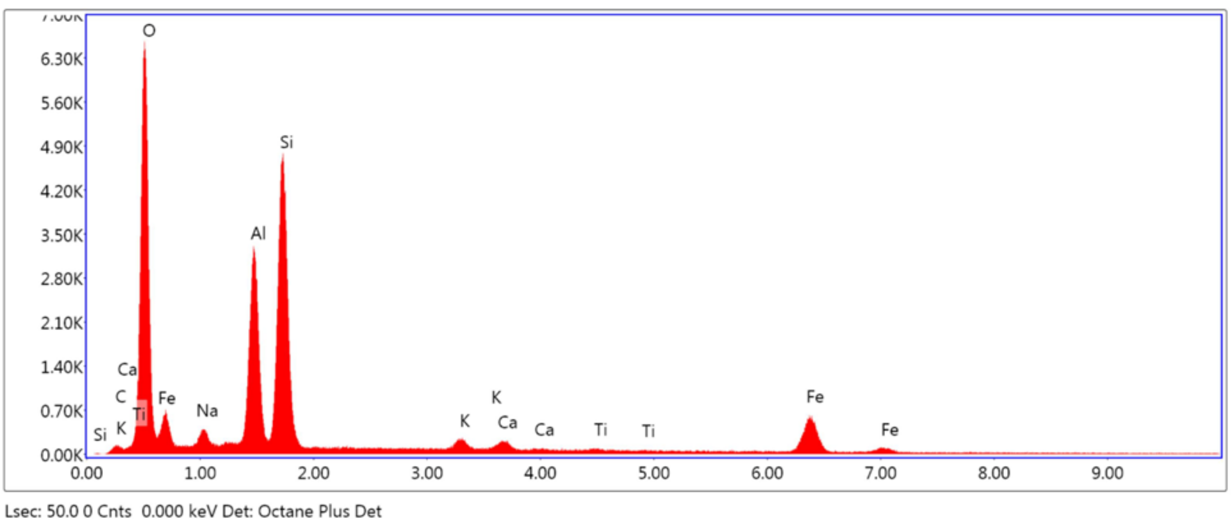
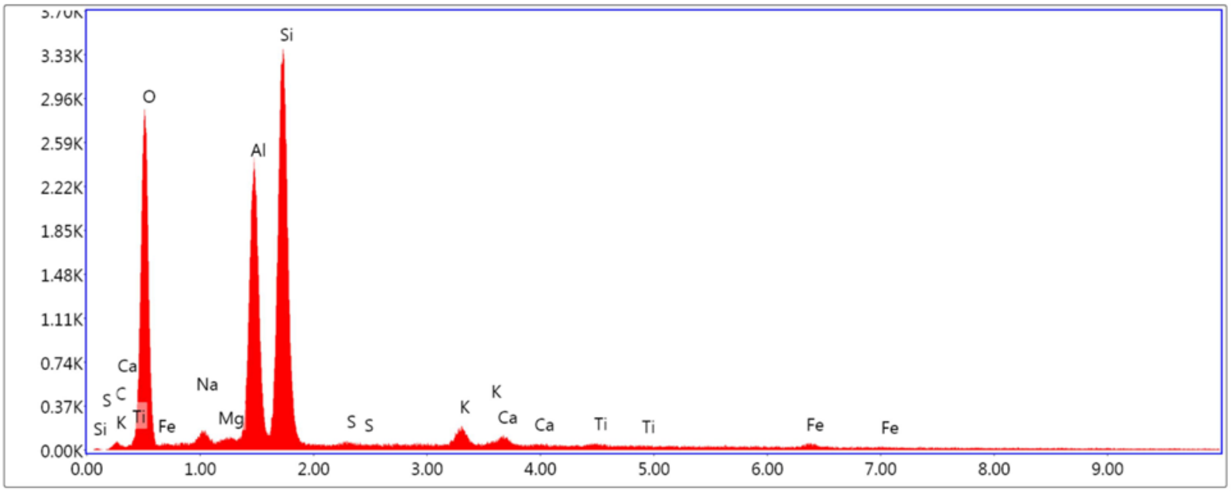
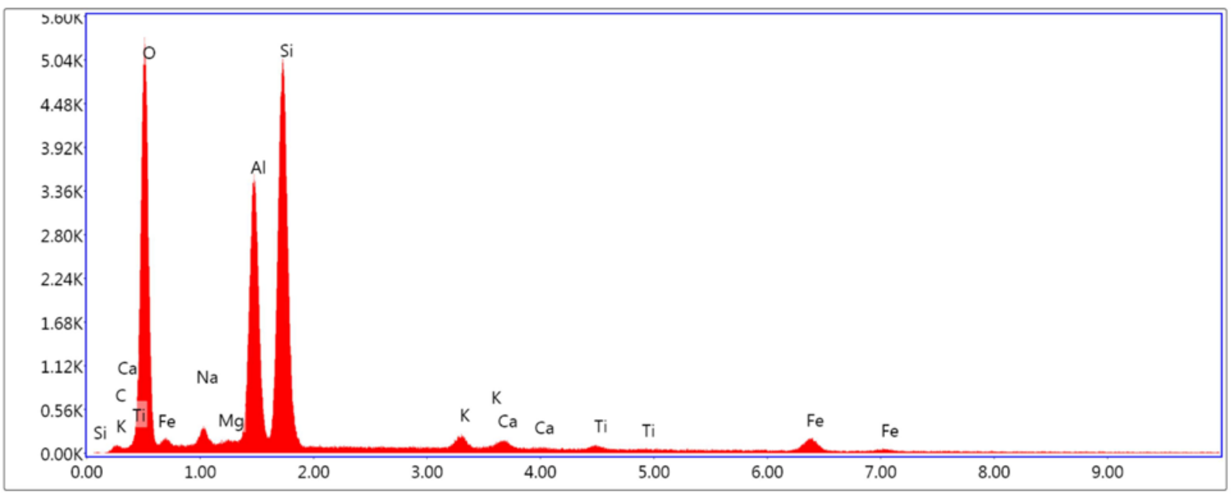


Figure 15: SEM-EDX elemental abundance of area 1 analyzed of *Starboard Engine Supply Line*



Lsec: 50.0 0 Cnts 0.000 keV Det: Octane Plus Det

Figure 16: SEM-EDX elemental abundance of area 2 analyzed of *Starboard Engine Supply Line*



Lsec: 50.0 0 Cnts 0.000 keV Det: Octane Plus Det

Figure 17: SEM-EDX elemental abundance of area 3 analyzed of *Starboard Engine Supply Line*

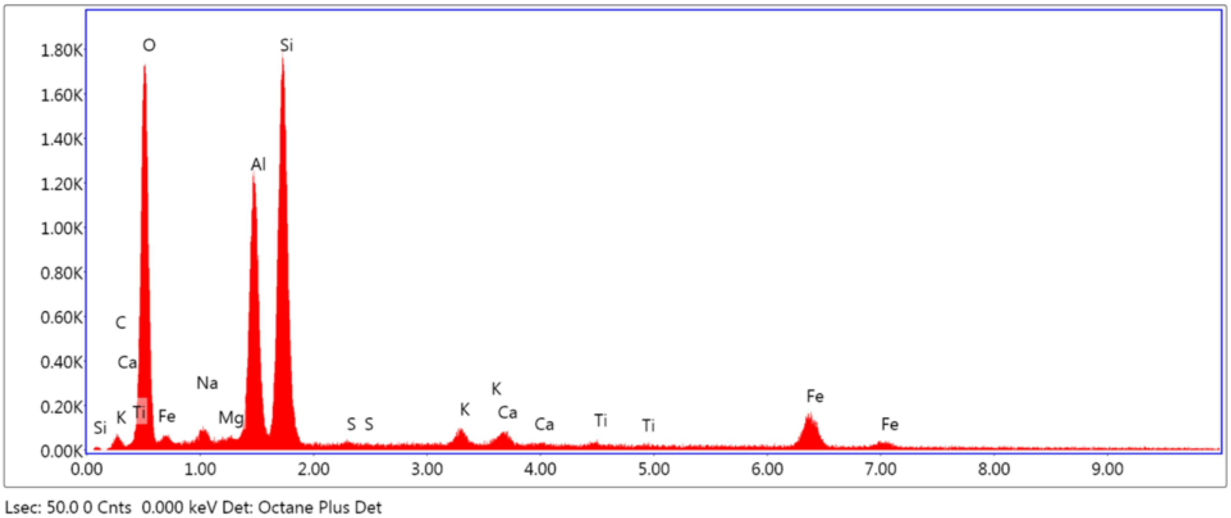


Figure 18: SEM-EDX elemental abundance of area 4 analyzed of *Starboard Engine Supply Line*

Analysis Conditions

TGA

Analysis of samples was accomplished using a TA 500 Thermogravimetric Analyzer in combination with TA Universal Analysis software. Approximately 30mg of the sample was weighed into a platinum weigh boat for each analysis. Samples were run under a nitrogen atmosphere and heated from ambient to 1000°C at a rate of 20°C per minute. On reaching 1000 °C, the atmosphere was switched to oxygen and held isothermally for 3 minutes.

SEM-EDX

The sample was dispersed onto a SEM sample substrate. Multiple spots and/or areas were analyzed by EDX in spot and area mode.

Instrument:	Tescan Vega S 3 LMU with EDAX Octane Plus EDX detector
Electron Beam Conditions:	15 kV, Beam intensity 14

Closing Comments

Jordi Labs' reports are issued solely for the use of the clients to whom they are addressed. No quotations from reports or use of the Jordi name is permitted except as authorized in writing. The liability of Jordi Labs with respect to the services rendered shall be limited to the amount of consideration paid for such services and do not include any consequential damages.

Jordi Labs specializes in polymer testing and has 30 years experience doing complete polymer deformulations. We are one of the few labs in the country specialized in this type of testing. We will work closely with you to help explain your test results and <u>solve your problem</u>. We appreciate your business and are looking forward to speaking with you concerning these results.

Sincerely,

Leland Martin

Leland Martin, M.S.
Senior Chemist
Jordi Labs LLC

Mark Jordi

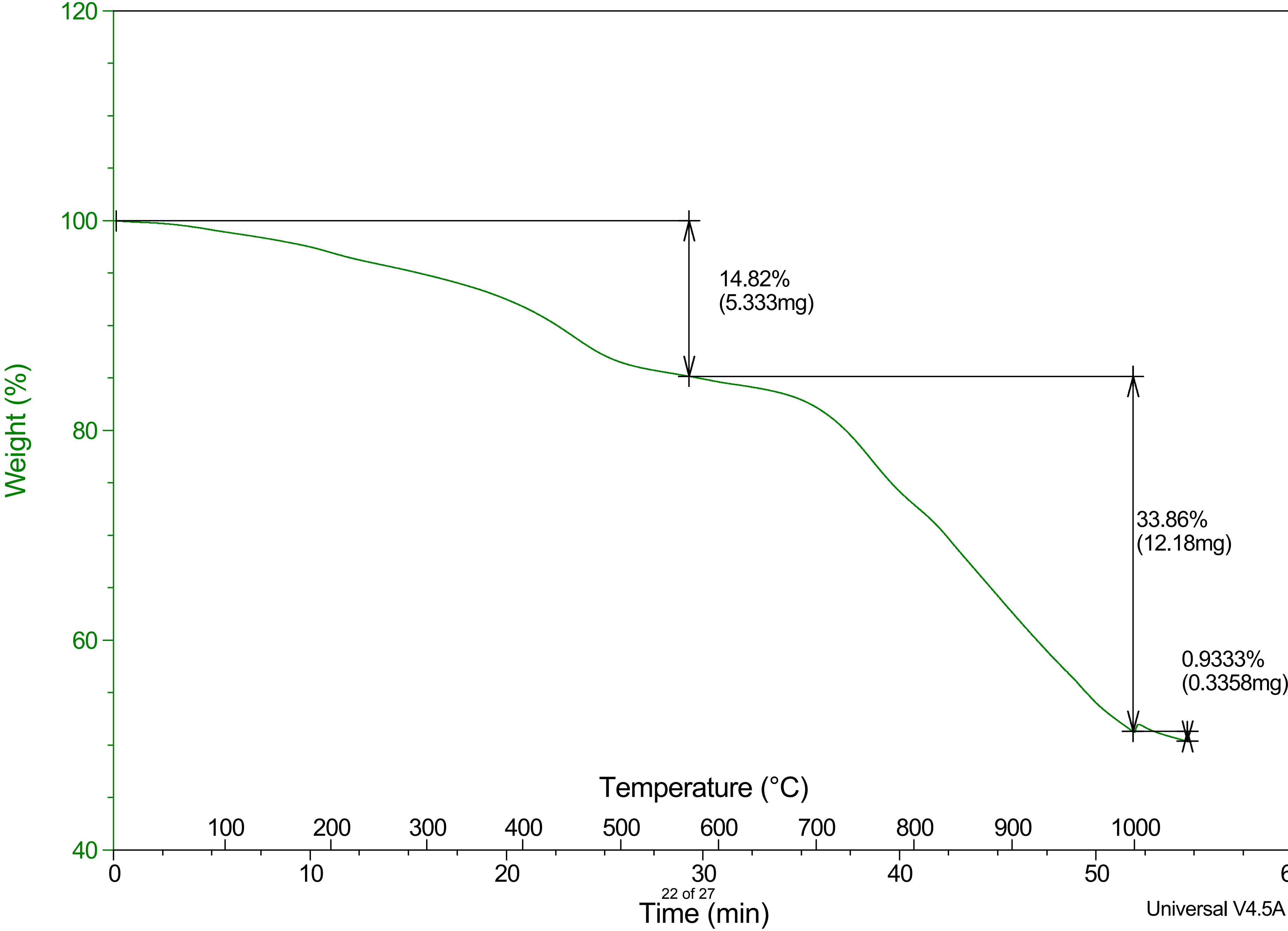
Mark Jordi, Ph. D.
President
Jordi Labs LLC

TGA Data

Sample: Port Supply Line
Size: 35.9800 mg
Method: Ramp
Comment: 34.5

TGA

File: R:...\TGA\Port Supply Line.001
Operator: JNW
Run Date: 05-May-2017 08:47
Instrument: TGA Q500 V20.13 Build 39

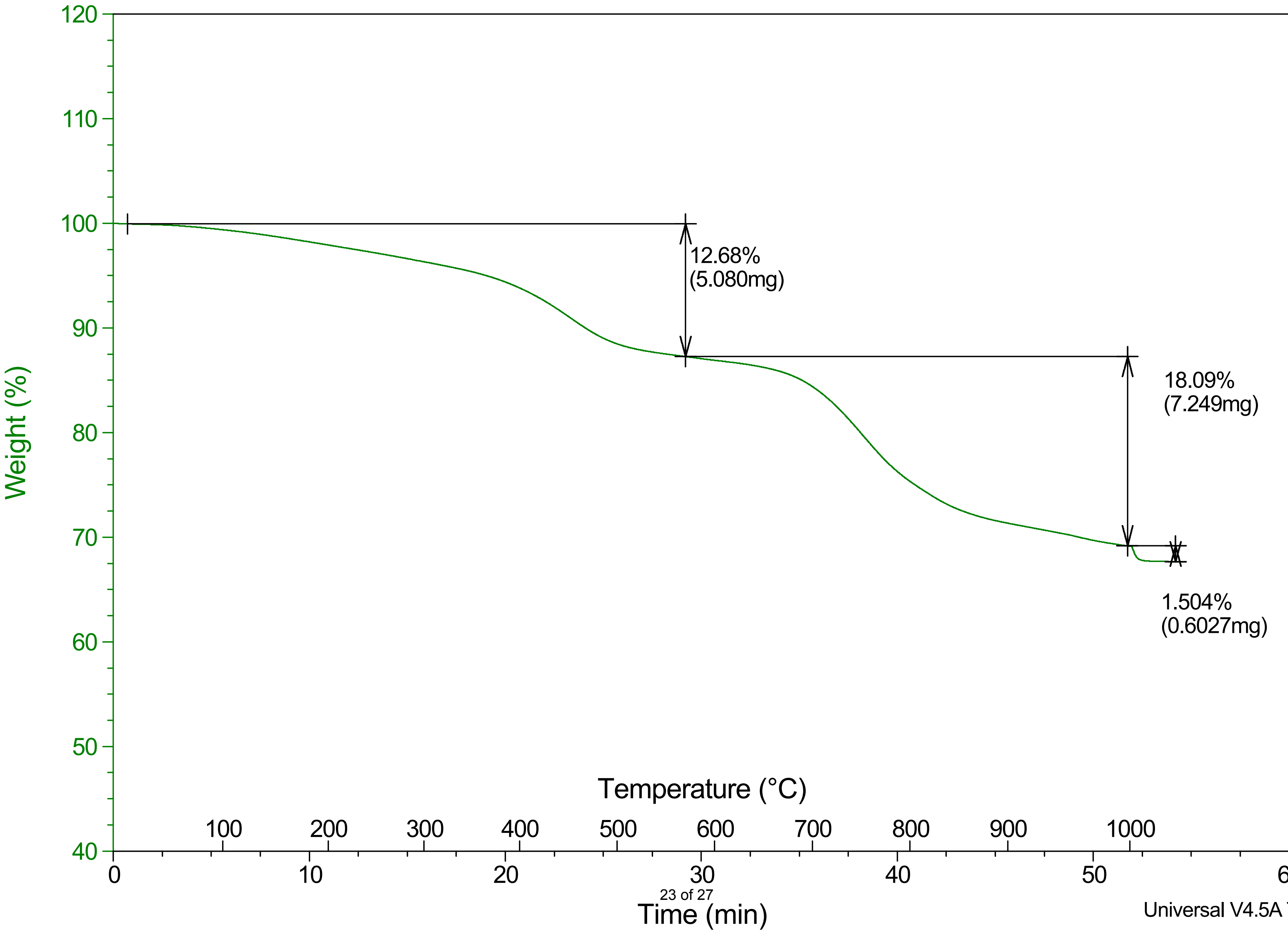


Universal V4.5A TA Instruments

Sample: Port Supply Line
Size: 40.0610 mg
Method: Ramp
Comment: 35.1

TGA

File: R:...\TGA\Port Supply Line.002
Operator: JNW
Run Date: 04-May-2017 16:48
Instrument: TGA Q500 V20.13 Build 39

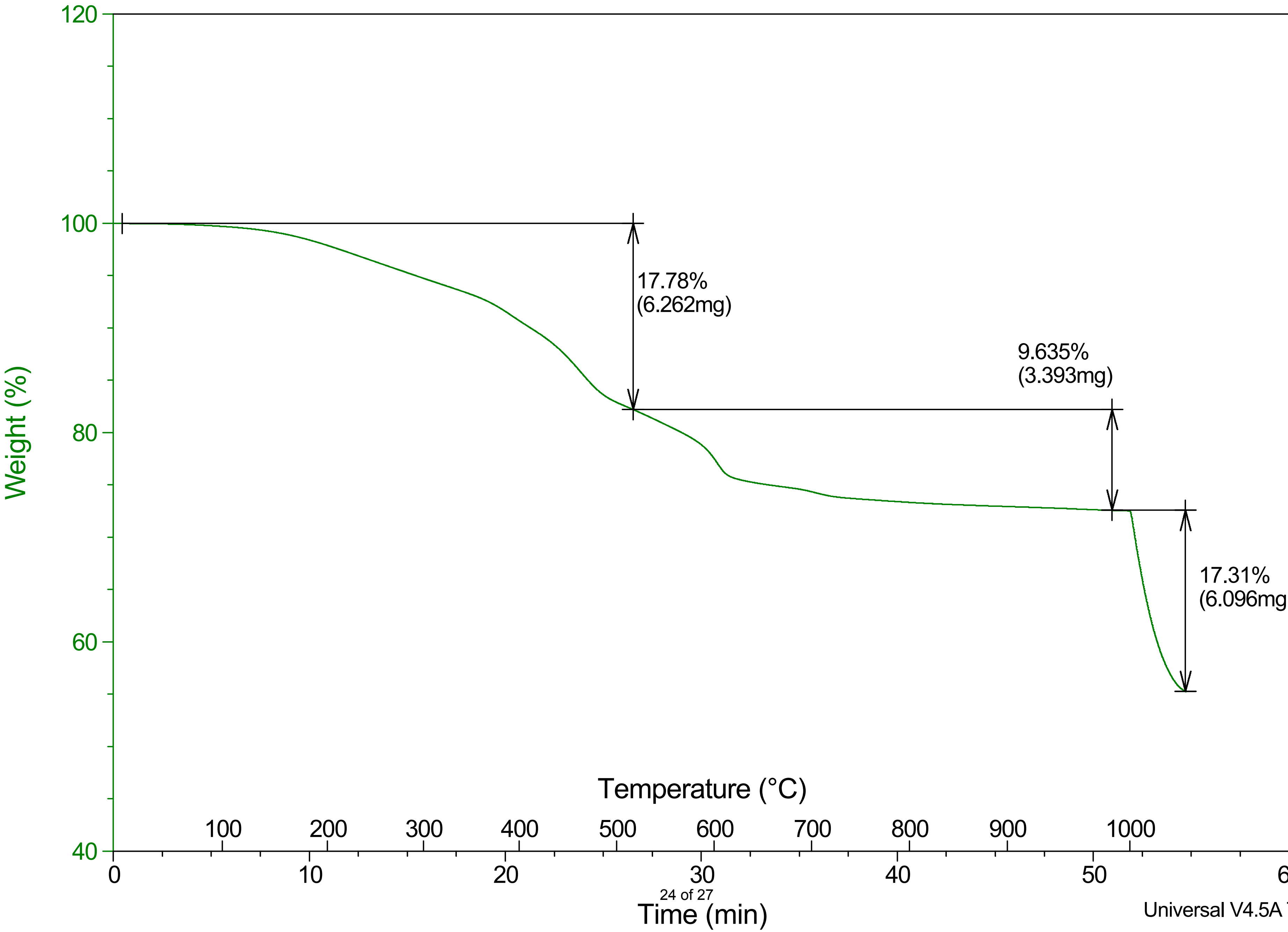


Universal V4.5A TA Instruments

Sample: Starboard Supply Line
Size: 35.2200 mg
Method: Ramp
Comment: 35.3

TGA

File: R:...\TGA\Starboard Supply Line.001
Operator: JNW
Run Date: 04-May-2017 18:43
Instrument: TGA Q500 V20.13 Build 39

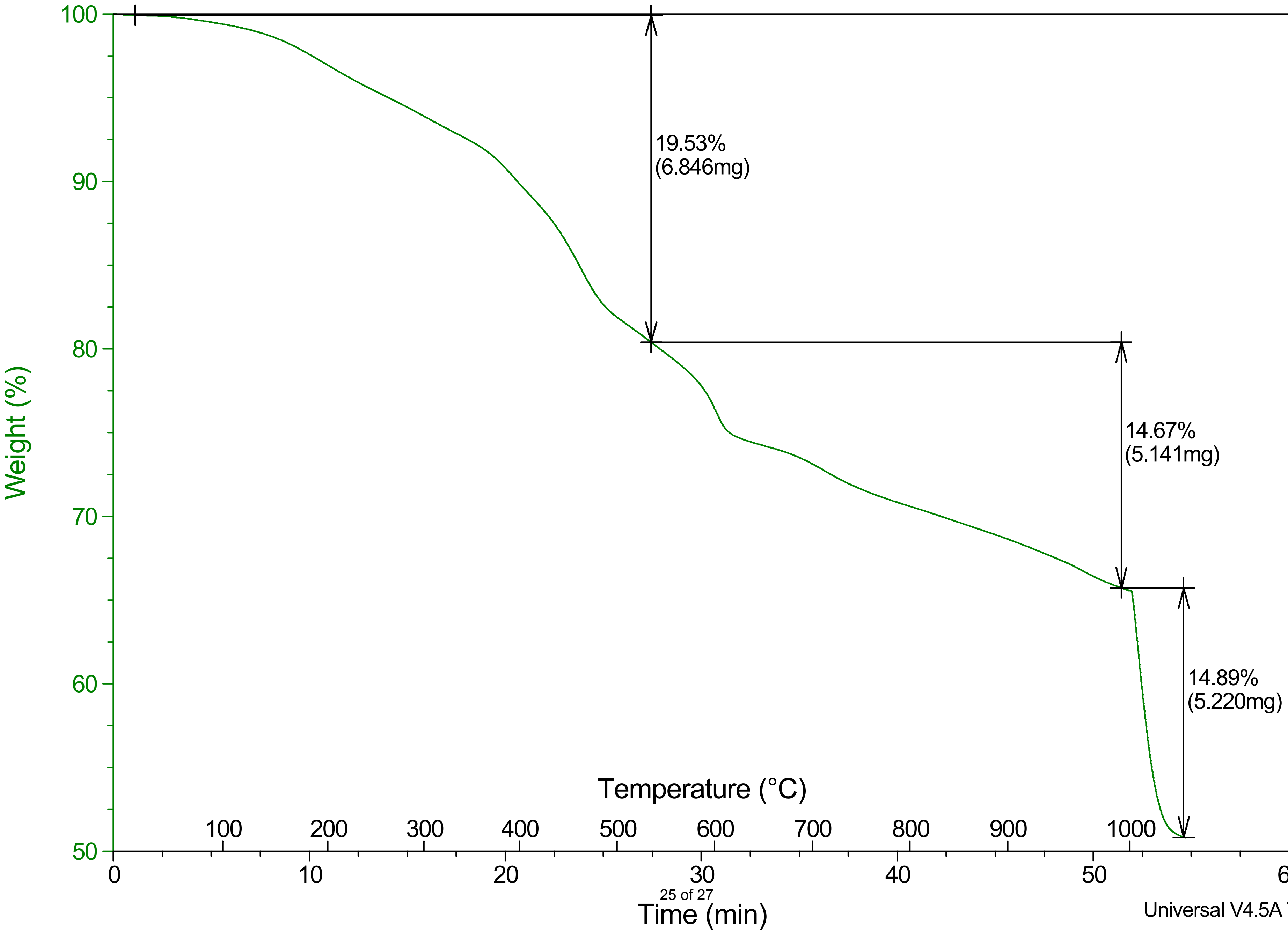


Universal V4.5A TA Instruments

Sample: Starboard Supply Line
Size: 35.0480 mg
Method: Ramp
Comment: 34.6

TGA

File: R:...\TGA\Starboard Supply Line.002
Operator: JNW
Run Date: 04-May-2017 20:38
Instrument: TGA Q500 V20.13 Build 39

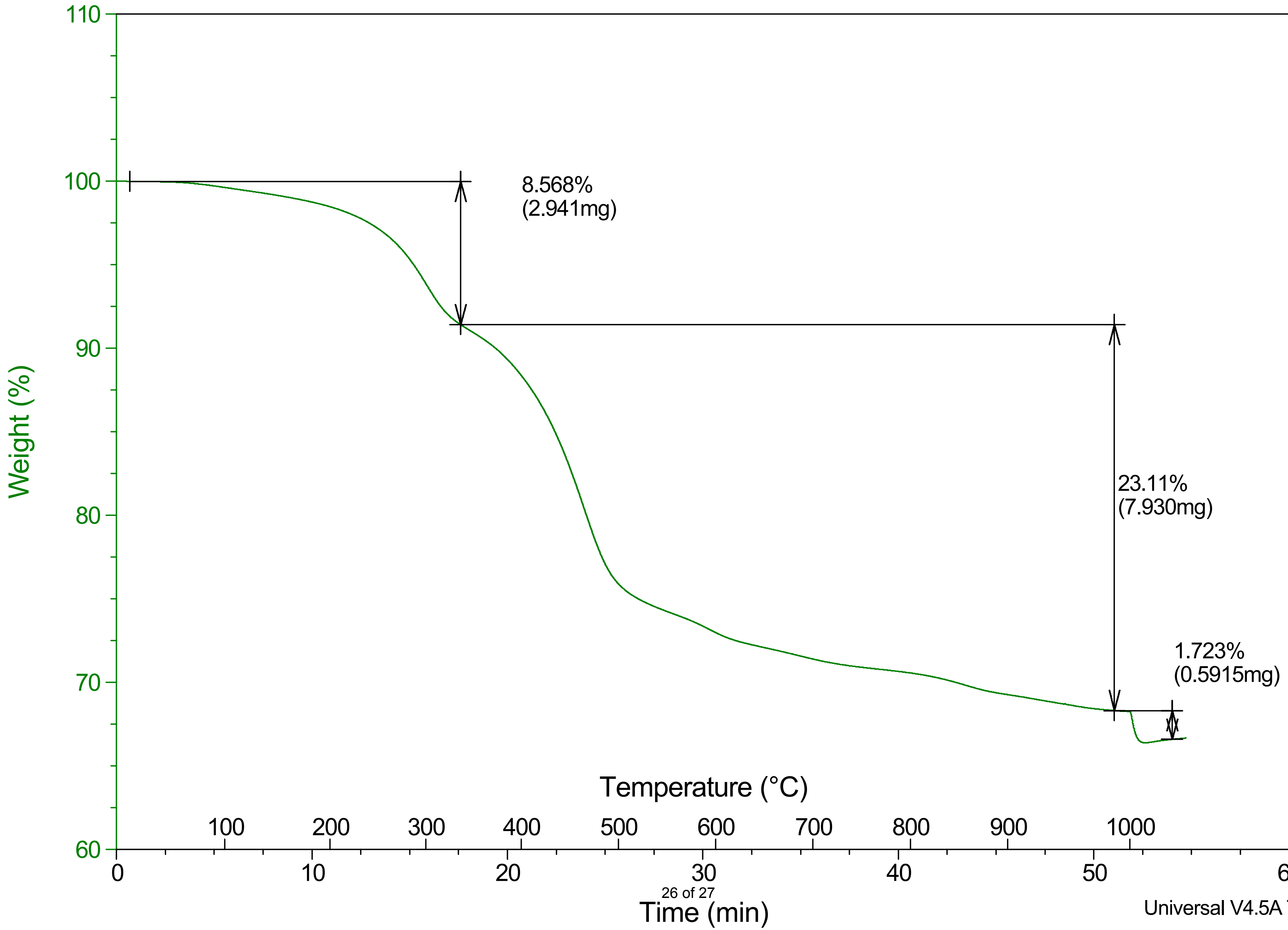


Universal V4.5A TA Instruments

Sample: Starboard Return Line
Size: 34.3210 mg
Method: Ramp
Comment: 34.8

TGA

File: R:...\TGA\Starboard Return Line.001
Operator: JNW
Run Date: 04-May-2017 12:56
Instrument: TGA Q500 V20.13 Build 39

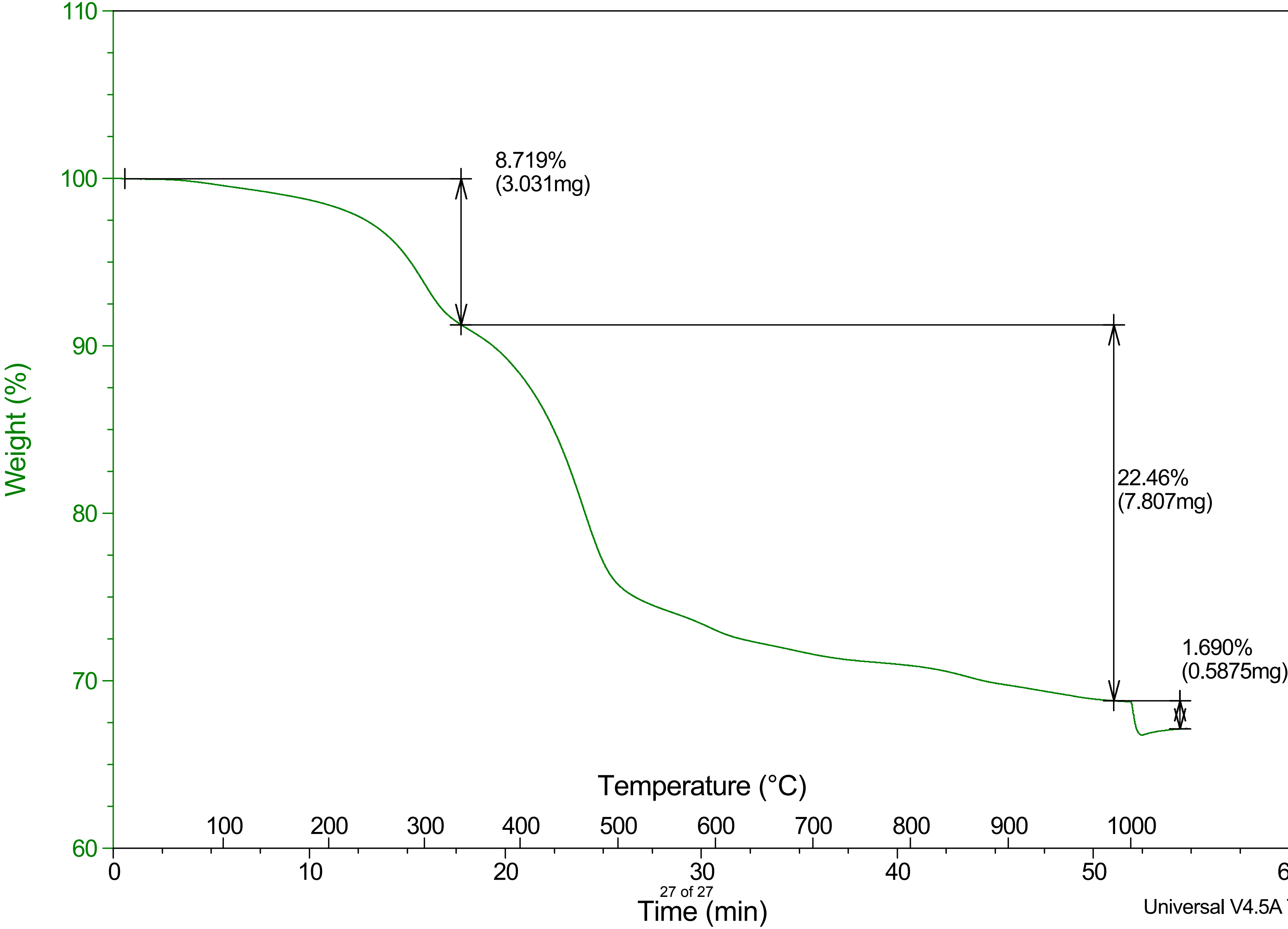


Universal V4.5A TA Instruments

Sample: Starboard Return Line
Size: 34.7660 mg
Method: Ramp
Comment: 34.9

TGA

File: R:...\TGA\Starboard Return Line.002
Operator: JNW
Run Date: 04-May-2017 14:51
Instrument: TGA Q500 V20.13 Build 39



Universal V4.5A TA Instruments