



Equipment Quality Analysis Report

Boeing Commercial Airplanes



EQA NUMBER: AS13704

DATE: April 12, 2024

MODEL NUMBER: 767-300F

AIRPLANE NUMBER: VT674, N287FE (current registry)

SUBJECT: *Left Engine Fire During Initial Climb*

IDENTIFICATION:

Part name:	Hose Assembly, Fuel
Boeing part number (P/N):	S332U280-11
Supplier part number:	AE706825-11
Serial number (S/N):	10628408-03
Supplier:	Eaton Aeroquip Inc.
FT, date code:	FT04/22, A04/22

REFERENCES:

- (a) National Transportation Safety Board (NTSB) incident number ENG24FA003
- (b) Sargent Industries Drawing CA-5465
- (c) Eaton Aeroquip Drawing AE706825-11

BACKGROUND:

On October 18, 2023, a Boeing 767-300F aircraft (VT674), operated by Federal Express (FED), experienced a left engine fire during initial climb from Memphis International Airport (MEM), Memphis, Tennessee. The flight crew reported that shortly after takeoff they heard a loud bang from the left side of the aircraft followed by an EICAS (engine indicating and crew alerting system) message and a left engine fire warning. The flight crew pulled the left engine fire handle, discharged both fire suppression bottles, and performed an in-flight turnback. The aircraft returned to MEM and performed an uneventful single engine landing. The subject event is under investigation by the US NTSB as documented in reference (a).



Ground inspection of the left engine with the cowl and thrust reversers opened revealed the engine had experienced an under-cowl fire and the main fuel pump (MFP) housing had fractured from the main fuel supply line.

The fuel hose assembly (P/N AE706825-11, S/N 10628408-03) was removed from the aircraft and sent to the fuel pump supplier, Collins. While at the supplier, the remaining fuel pump flange was removed from the hose. The hose assembly was then sent to the Boeing Equipment Quality Analysis (EQA) facility in Seattle, Washington for further examination and analysis.

SUMMARY:

The fuel hose assembly was examined at the EQA facility with Boeing Air Safety Investigation (ASI), Boeing Propulsion Engineering and Boeing Fluid Systems Standards (FSS) in attendance.

The following observations were noted during the examination of the hose assembly:

- The hose had a set curvature
- A portion of the fire sleeve outer coating was missing
- The fire sleeve was slightly pulled away from the tube end of the hose assembly
- The gasket was held onto the flanged end of the hose by one remaining bolt with an insert on the threads
- The gasket was notably warped

The gasket was sent to the Boeing Research & Technology (BR&T) Analytical Chemistry group for Fourier Transform Infrared Spectroscopy (FTIR) and Energy Dispersive X-ray Spectroscopy (EDS) analyses of the gasket surface. The results suggested that dark deposits in the groove and the on the surface of the gasket were carbon-rich pyrolysis residue of a seal material that was burnt away in the fire event. Fluorine was found in the residue, confirming that a fluorine-based seal had been present. See attachment A for complete BR&T chemical analysis report.

The gasket was then sent to the BR&T Fracture Analysis group. It was noted that a region of cracking and absent material was found in approximately 20 percent of the circumference of the groove. The cracked region was examined with a scanning electron microscope (SEM). The fractured region showed morphology indicating complete melting at the fracture surface; see attachment B for complete BR&T fracture analysis report.



EXAMINATION:

The hose assembly was received at the EQA facility on December 12, 2023. Images were taken of the container upon arrival. The exterior of the container was noted to be in good condition; see Figure 1 and Figure 2.



Figure 1: Container as received, top view



Figure 2: Container as received, side view

On December 15, 2023, prior to the examination date, Boeing ASI requested that EQA open the container to ensure that the gasket on flanged end of the hose was received. EQA opened the container and verified the presence of the gasket. It was secured to the hose by a bolt still engaged within a threaded insert, and a zip tie; see Figure 3 through Figure 5.



Figure 3: Container opened



Figure 4: Hose assembly as received



Figure 5: Flanged end of the hose with gasket and insert as received

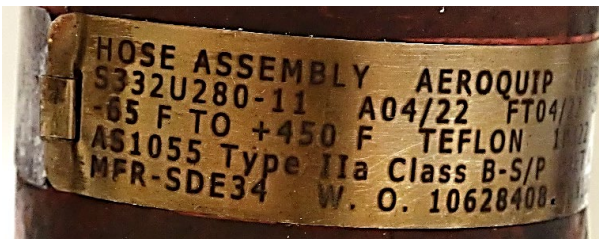
After verifying the presence of the gasket, the hose end was covered with a plastic bag and placed back in to the box.

The examination of the hose assembly was conducted on January 23, 2024 with Boeing Air Safety Investigation (ASI), Boeing Propulsion Engineering, and Boeing Fluid System Standards (FSS) in attendance.

The hose assembly was removed from the container and images were taken capturing the overall condition. The hose had a set curvature, and both ends were sufficiently protected with absorbent pads, covered with plastic bags and secured with zip ties. It was also noted that slightly over half of the orange-colored, outer silicone rubber layer of the fire sleeve was missing. This exposed the woven fiberglass layer, which was covered in soot; see Figure 6.

**Figure 6:** Overview of hose assembly

Images of the identification (ID) band are shown in Figure 7 and Figure 8.

**Figure 7:** ID band**Figure 8:** ID band, slightly rotated from Figure 7

The fire sleeve was slightly pulled away from the tube end of the hose assembly. The fire sleeve was noted to be in an expected condition, following a heating event; see Figure 9.

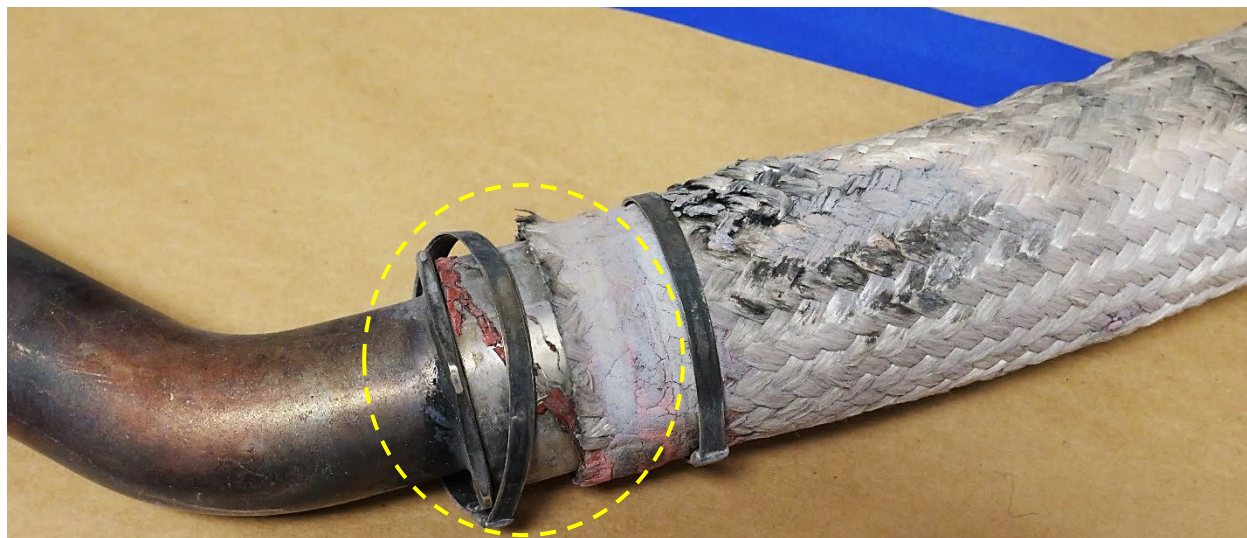


Figure 9: Fire shield at tube end of hose

The protective covering was removed from the flanged end of the hose, exposing the four-bolt flange and gasket; see Figure 10. The protective covering was removed from the quick disconnect end; see Figure 11.



Figure 10: Flanged end of hose with gasket



Figure 11: Quick disconnect end of the hose



The rag inside the tube and the zip-tie securing the gasket were removed. The holes were then marked as holes 1 through 4 for identification purposes only; see Figure 12.

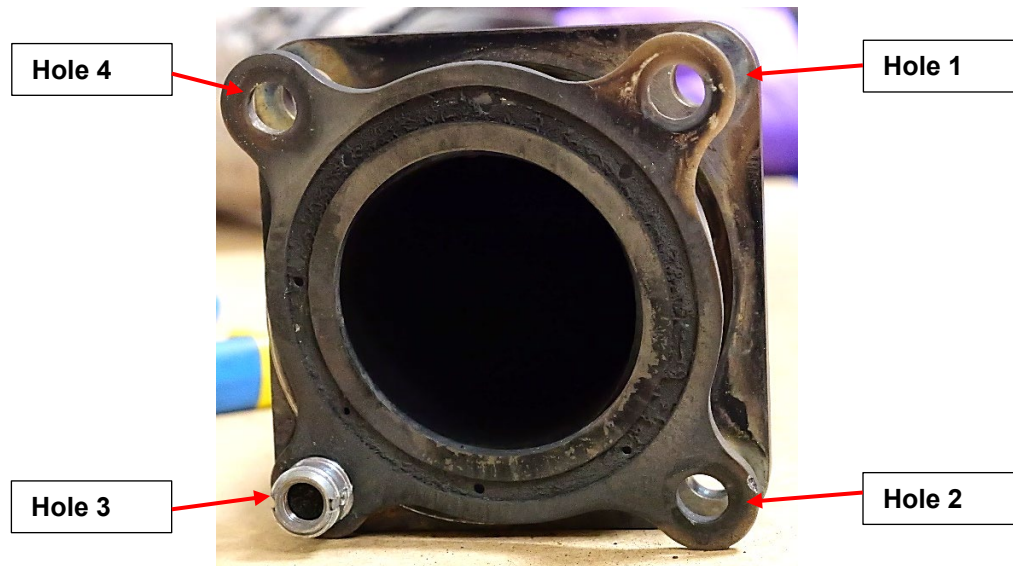


Figure 12: Flanged end of hose assembly

The gasket was held on by one remaining bolt still engaged within a threaded insert. The gasket was notably warped. Images were taken showing the warpage next to a scale as a visual aid only; see Figure 13 and Figure 14.



Figure 13: Gasket warped (between holes 1-4)

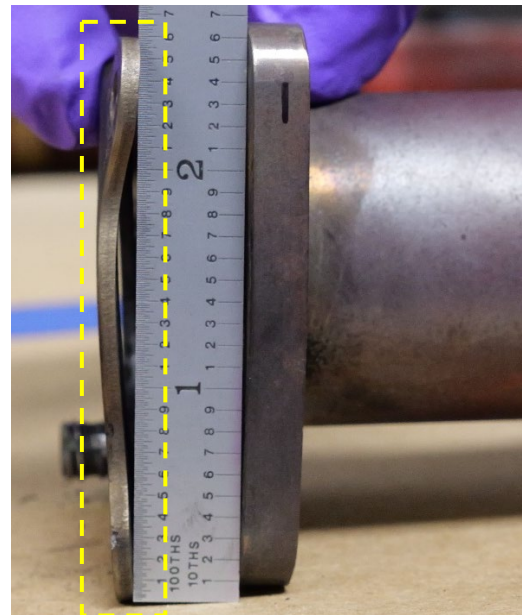


Figure 14: Gasket warped (between holes 1-2)



The threaded insert on the remaining bolt measured 0.375 inch in length; see Figure 15.



Figure 15: Threaded insert length measured

The bolt had approximately 0.25 inch of thread engagement within the insert. No evidence of tooling, or witness marks were found on the surface of the insert.

The gasket and flange bolt holes were measured using a digital caliper; see Table 1 and Table 2.

The inner diameter (ID) of the gasket bolt holes should be 0.256 to 0.276 inch and the distance between the holes should be 2.052 to 2.072 inch per reference (b).

The distance between the flange bolt holes should be 2.062 +/- 0.010 inches per reference (c). The flange bolt hole ID was not called out in the reference (c) drawing.

Table 1: Gasket bolt hole measurements (units: inches)

Hole	Gasket bolt hole inner diameter (ID)	Distance between holes
1	0.262	2.074
2	0.260 - 0.265, ovalized	
3	Bolt was inserted	2.082
4	0.261 – 0.263 ovalized	

Table 2: Flange bolt hole measurements (units: inches)

Hole	Flange bolt hole ID	Distance between holes
1	0.284	2.079
2	0.284	
3	Bolt was inserted	
4	0.286	2.076 (between bolt holes 1-4)



The bolt and insert were removed from the flange using a wrench and vise grip pliers; see Figure 16 and Figure 17. Excessive rotational force was needed to remove the bolt.



Figure 16 Gasket, bolt and insert



Figure 17: Bolt and insert after removal

Following the bolt removal, measurements were taken of hole 3 of the gasket and flange; see Table 3 and Table 4.

The inner diameter (ID) of the gasket bolt holes should be 0.256 to 0.276 inch and the distance between the holes should be 2.052 to 2.072 inch per reference (b).

The distance between the flange bolt holes should be 2.062 +/- 0.010 inches per reference (c). The flange bolt hole ID was not called out in the reference (c) drawing.

Table 3: Gasket bolt hole measurements (units: inches)

Hole	Gasket bolt hole ID	Distance between holes
3	0.264 - 0.266	2.071 (between bolt holes 2-3)
		2.064 (between bolt holes 3-4)

Table 4: Flange bolt hole measurements (units: inches)

Flange bolt hole	Distance between holes
2-3	2.074
3-4	2.074

The hose assembly was examined with a borescope, beginning at the flanged end, towards the quick disconnect end of the hose. It was noted that the interior of hose was clean, with some discoloration noted approximately 4-18 inches from the flanged end. The discoloration was noted to be in the proximity to the damage on the outer fire sleeve. The spring tangs were noted to be intact on both ends of the convoluted portion of the hose.



The hose assembly measured approximately 69.75 inches in length using a tape measure as shown in Figure 18 and Figure 19. The hose assembly should measure 69.770 +/- 0.500 inches in length, per the reference (b) drawing.



Figure 18: Measurement of hose assembly



Figure 19: End measurement of hose assembly

The damaged portion of the fire sleeve was pulled back from the flanged end of the hose to examine the braided stainless-steel area of the hose; see Figure 20. No notable findings were observed.



Figure 20: Fire sleeve pulled back

Several features of the hose were dimensionally measured for reference only as they are not listed in the reference (c) drawing; see Table 5.

Table 5: Hose dimensional measurements (units: inches)

Hose feature	Results
Tube outer diameter (OD) at the fitting junction	1.745
Crimp OD at the tube end	2.333
Fire sleeve band ID	2.70 and 2.57
OD of intact portion of the fire sleeve	2.583



It was requested by engineering that the gasket be analyzed for any signs of external contaminants.

The gasket was sent to the Boeing Research & Technology (BR&T) Analytical Chemistry group to perform FTIR and EDS analyses of the gasket surface. Refer to the analysis section of this report for results. Upon completion of the analysis, the gasket was returned to the EQA facility.

EQA examined the gasket under magnification, and observed traces of what appeared to be melted seal material within the groove; see Figure 21

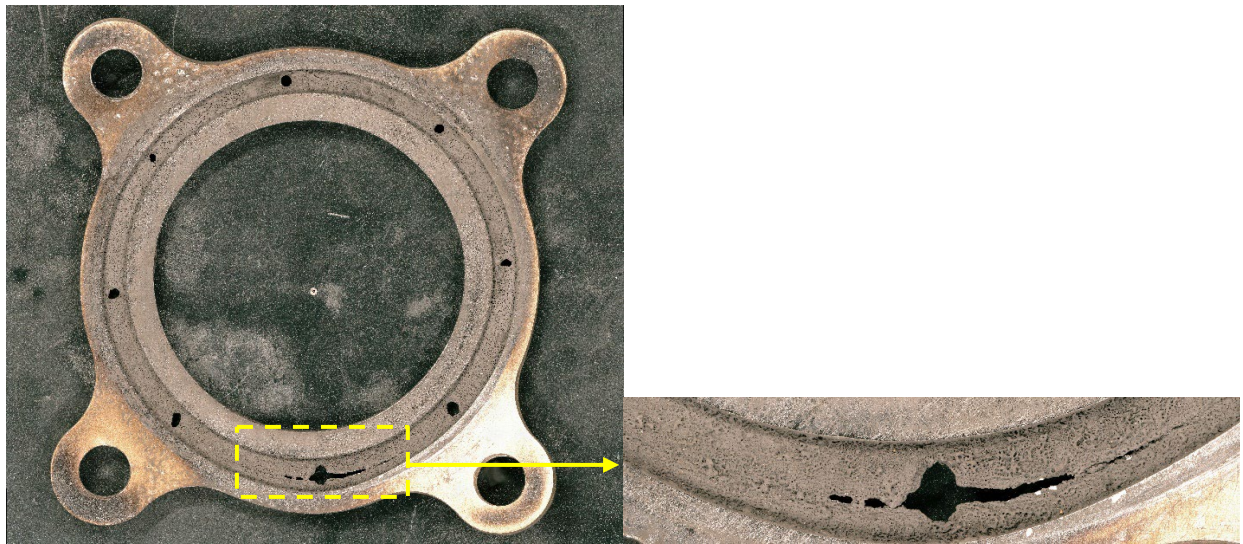


Figure 21: Gasket groove under magnification

It was also noted that the metallic gasket material, initially noted as missing, appeared to be fractured. This was verified with an X-ray examination of the gasket; see Figure 22.

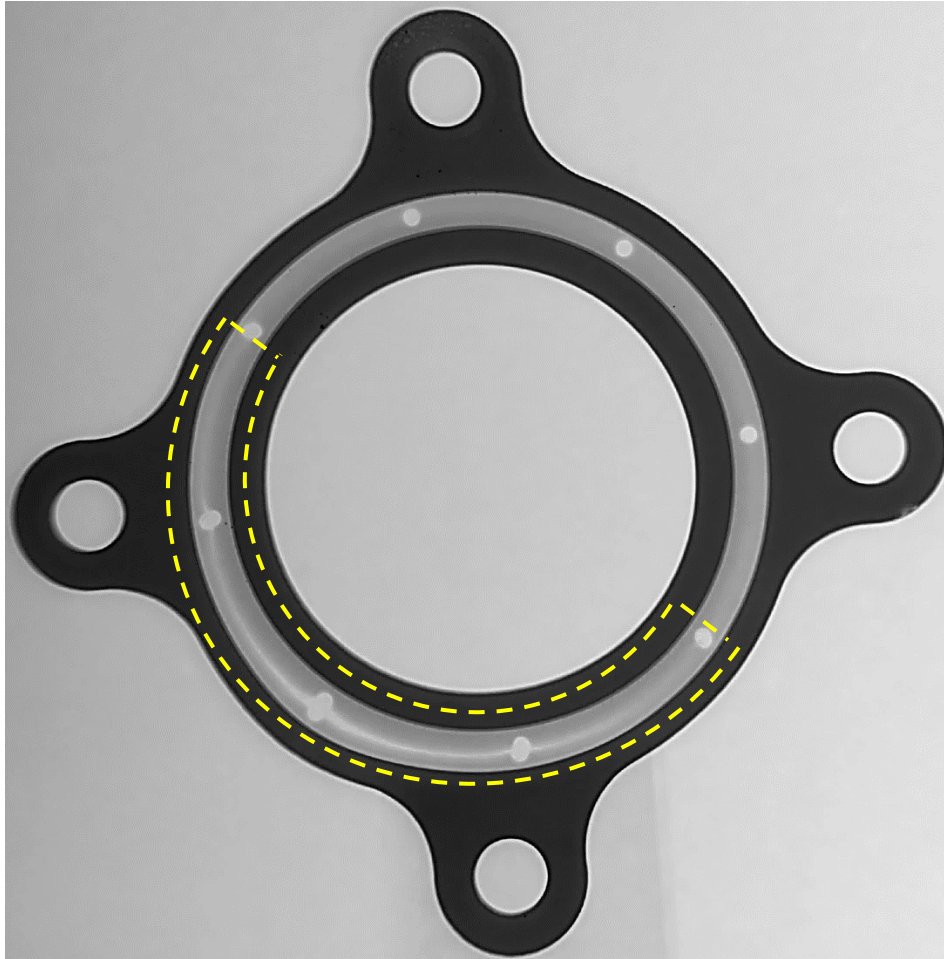


Figure 22: X-ray image of gasket showing fracture within the dashed yellow lines

Due to the level of deformation of the gasket, EQA was not able to obtain a flatness measurement.

ASI and engineering requested that the fracture within the gasket be analyzed. The gasket was then sent to the BR&T Fracture Analysis group for examination.

ANALYSIS:

BR&T Analytical Chemistry performed FTIR and EDS analyses of the gasket surface. Attachment A reports that the data suggests that the dark deposits in the groove and the on the surface of the gasket are the carbon rich pyrolysis residue of the O-ring material that was burnt away in the fire event. Fluorine was found in the residue confirming a fluorine-based O-ring was present.; see attachment A for the completed report.

BR&T fracture analysis noted that a region of cracking and absent material was found in approximately 20 percent of the circumference of the groove. The cracked region was excised for a detailed SEM examination. The fractured region showed morphology



indicating complete melting at the fracture surface; see attachment B for complete report.

DISPOSITION:

The subject hose assembly will be conveyed per instruction from ASI after completion of this analysis.

The preceding information is being submitted for information purposes.

ATTACHMENTS:

- A. BR&T analytical chemistry report _Gasket
- B. BR&T Seal Gasket Fracture Analysis summary



BOEING RESEARCH & TECHNOLOGY
Chemical Technology
Analytical Chemistry / Fluids and Lubricants

Date: March 7, 2024

Analytical Chemistry Lab

BLIS job 005-2024-03-07-00096

Subject

767 Engine fuel hose gasket

Background

Gasket was involved in an engine fire. Please analyze the black material in the O-ring groove and the black surface of the gasket using.

Summary

The data suggests that the dark deposits in the groove and the on the surface of the gasket are the carbon rich pyrolysis residue of the O-ring material that was burnt away in the fire event. Fluorine was detected in the residue confirming a fluorine based O-ring was present.

Experimental

Samples were analyzed by sampling "as is."

Fourier Transform Infrared Spectroscopy (FTIR) was performed using a Thermo Scientific model iS-50 spectrophotometer equipped with a Continuum microscope and scanned from 4000 to 750 cm^{-1} at 4 cm^{-1} resolution.

Elemental composition analysis was performed by Energy Dispersive X-ray Spectroscopy analysis (EDS) using a JEOL electron probe microanalyzer (EPMA) model JXA-8530F Hyperprobe.

Results and Discussion

The O-ring called out in the drawing is Mil-R-83248, a fluorosilicone.

No IR spectra of the dark deposits in the groove and the on the surface of the gasket were able to be acquired. This suggests that the organic fraction of gasket material was burnt away leaving carbon pyrolysis products.

EDX detected carbon with a traces of fluorine, magnesium and calcium (Figure 1).

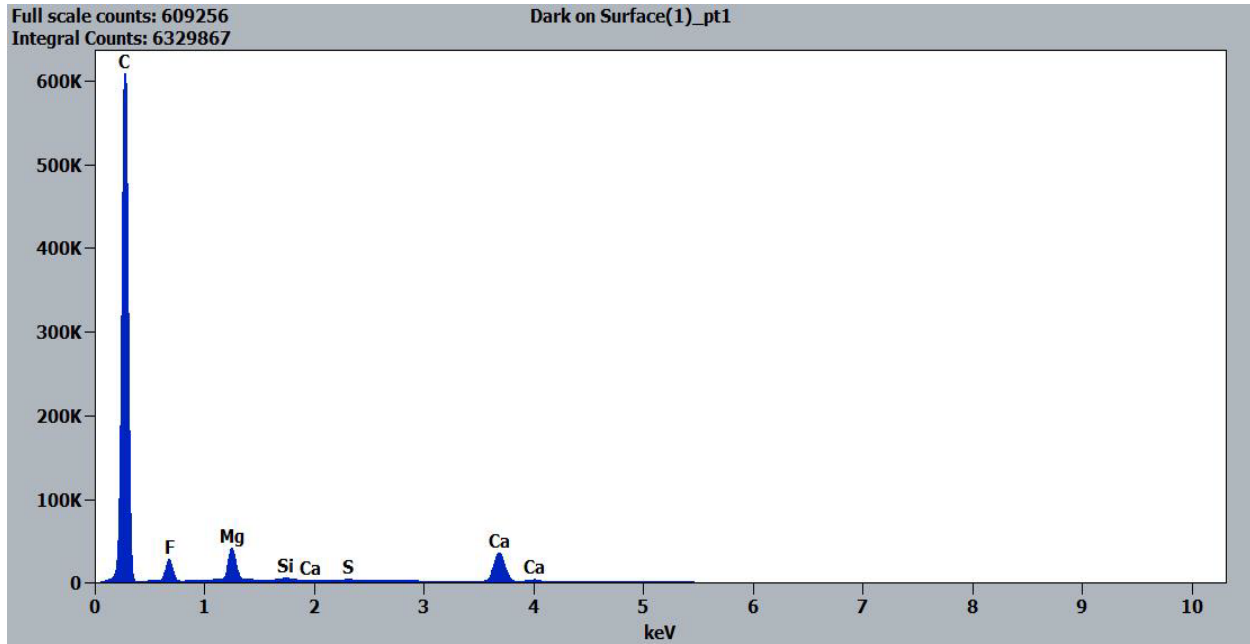


Figure 1: EDS representative elemental spectrum of dark O-ring and surface deposits.

BR&T Seal Gasket Fracture Analysis Summary

After a thermal event on a 767 a seal gasket (Sargent P/N CA-5465-0X) was submitted for fracture analysis (Figure 1). A region of cracking and absent material was found in approximately 20 percent of the circumference of the groove (Figure 2). The cracked region was excised for detailed examination with a scanning electron microscope (SEM). Figures 3 through 5 show SEM images of the fracture surface. The fractured region showed morphology indicating complete melting at the fracture surface.



Figure 1. EQA photograph of the as received seal gasket (Sargent P/N CA-5465-0X)

BR&T Seal Gasket Fracture Analysis Summary



Figure 2. Optical photograph showing the region of the gasket with cracking and material absent.

BR&T Seal Gasket Fracture Analysis Summary

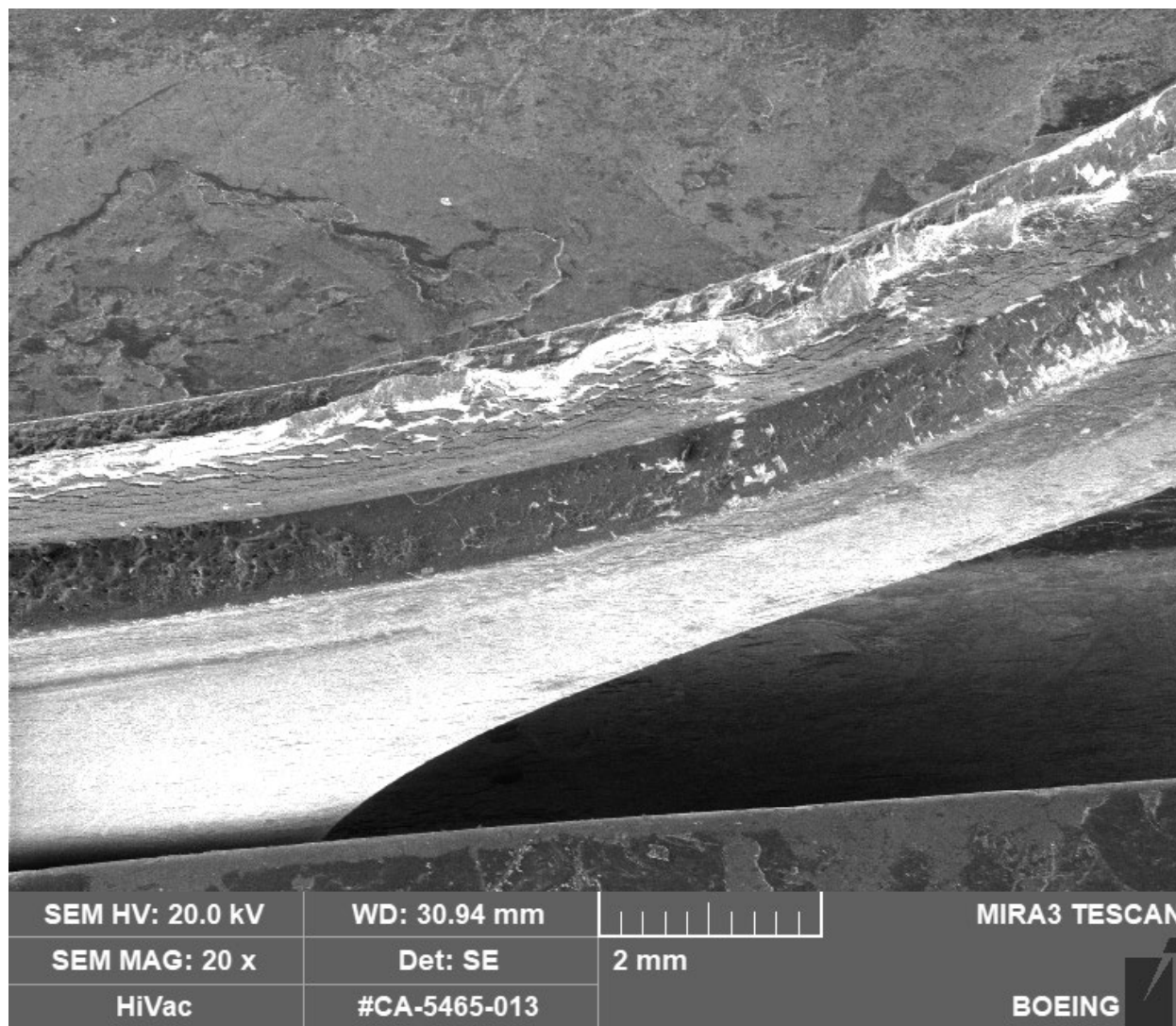


Figure 3. 20X magnification image of the fractured region on the gasket.

BR&T Seal Gasket Fracture Analysis Summary

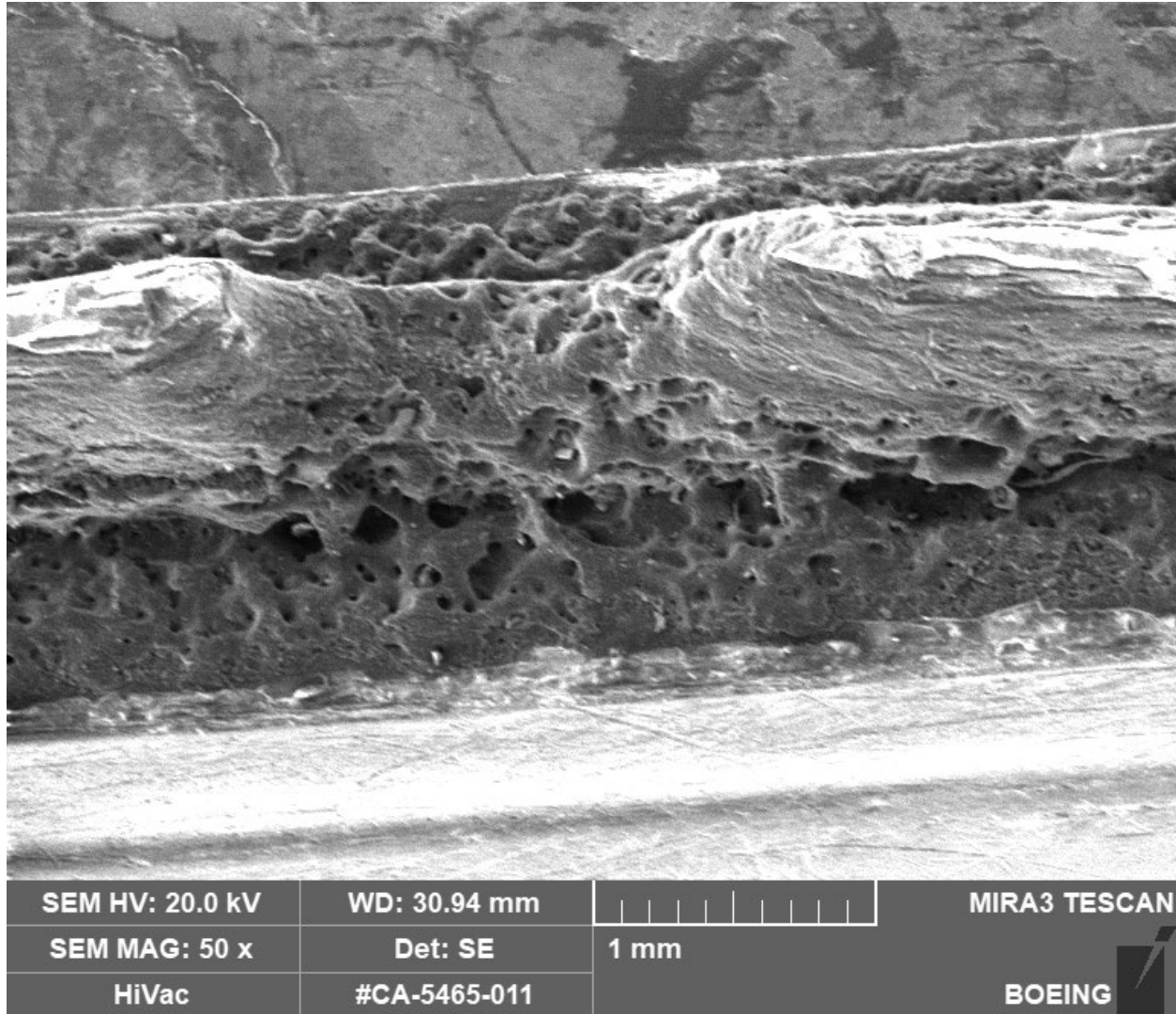


Figure 4. 50X magnification image of the fractured region on the gasket.

BR&T Seal Gasket Fracture Analysis Summary

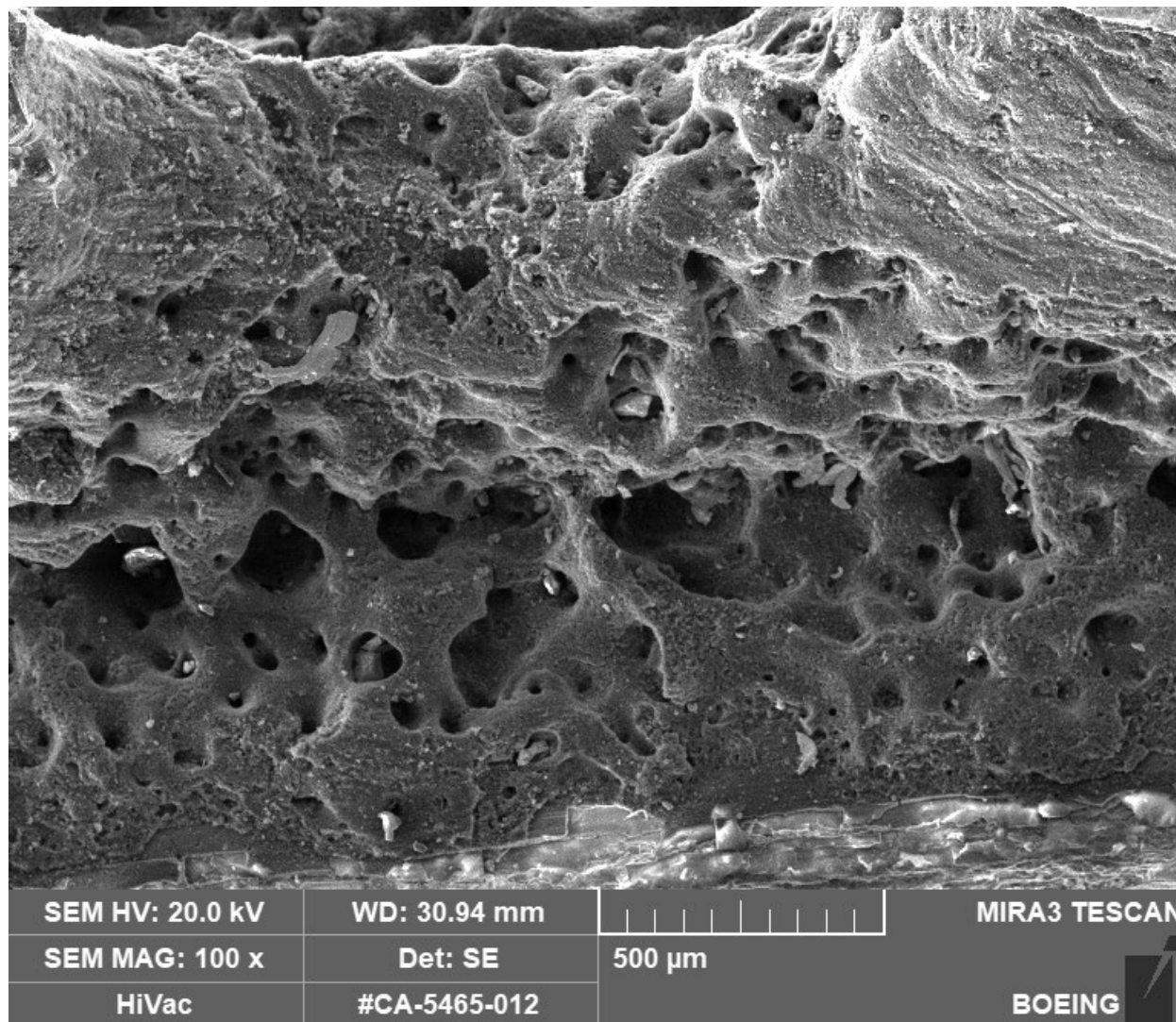


Figure 5. Higher magnification image of the region shown in Figure 4, the morphology shows complete melting of the edge of the fracture.