

NATIONAL TRANSPORTATION SAFETY BOARD

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



August 19, 2019

MATERIALS LABORATORY FACTUAL REPORT

Report No. 19-049

1. ACCIDENT INFORMATION

Place : Prescott, Arizona
Date : August 29, 2018
Vehicle : Cessna P210N, N6500W
NTSB No. : WPR18FA245
Investigator : Zoë Keliher, AS-WPR

2. COMPONENTS EXAMINED

Remnants of exhaust system heat exchanger
Remnants of exhaust ducting
Exhaust manifold section

3. DETAILS OF THE EXAMINATION

On August 29, 2018, about 2035 mountain standard time, a Cessna P210N impacted terrain short of the runway in Prescott, AZ. The pilot, who was the registered owner and sole occupant, died. The airplane was substantially damaged. The aircraft had departed from the airport about five minutes prior to the accident. The wreckage was recovered and several components from the exhaust system of the airplane were sent to the NTSB Materials Laboratory for further examination.

Figure 1 shows the components from the exhaust system, as received. Of note was a cracked flange on the exhaust manifold tube. This crack was located along the flange on the side of the output port side of the primary manifold tube. This location is demonstrated in Figure 2 and Figure 3, as viewed from the top and side, respectively.

Figure 4 highlights the crack along the exhaust manifold flange, viewed from an angled position to demonstrate the size and gap in the material. The flange consisted of the outer metal sheet material having been bent outward and then back inward. The crack was located along this first outer bend. The linear length of the crack was approximately 1.81 inches. The maximum gap in the flange at the crack was approximately 0.20 inches wide.

Two areas on the flange adjacent to the crack were intentionally backcut and overstressed (laboratory opened) to facilitate examination of the crack faces. A typical

area of one of the mating crack faces is shown in Figure 5. Whereas the majority of the surface of the exhaust manifold exhibited a dull, black color, the crack faces exhibited a shiny, golden-yellow color. Visually, the crack faces exhibited three distinct regions—two outer layers with crack arrest marks and ratchet marks, and an inner layer with a rougher surface texture.

One of the crack faces was examined using a scanning electron microscope (SEM). Figure 6 shows a typical view of one of the crack faces. The two outer layers exhibited multiple individual thumbnail cracks. These cracks were separated by ratchet marks, which are jogs that form between cracks propagating on a fracture surface when multiple smaller cracks grow and eventually coalesce. These outer layers exhibited crack arrest marks and fatigue striations (see Figures 7 through 9). The orientation of these features was consistent with crack propagation from the surface inward. The striations shown in Figures 8 and 9 were consistent with fatigue crack propagation.

The middle region on the crack face consisted of rougher surface texture with different fracture features. Figure 10 shows a closer view of the middle region on the opened crack face. The middle region exhibited dimple rupture, consistent with subsequent overstress fracture.

All the above fracture features were consistent with reverse bending fatigue. This is a fatigue crack propagation mechanism whereby cracks initiate on opposite surfaces of a component that is being bent back and forth. The crack propagated inward from opposite surfaces until the remaining material cross section could no longer bear the stress, resulting in the middle remaining material fracturing from overstress (as exemplified by dimple rupture).

The crack faces exhibited multiple fatigue crack initiation sites. One such site is highlighted in Figure 11. None of the crack initiation sites exhibited material deficiencies much as inclusions, pits, or voids. As these edges were oxidized and damaged from post cracking damage, it could not be determined if there were any pre-cracking mechanical defects at the initiation sites.

Besides the main crack face that was laboratory opened, there were several secondary cracks observed in the SEM (see Figure 12). These cracks were located below the primary crack face. These cracks exhibited fatigue striations. However, these cracks had not propagated to the size of the main crack face.

A portion of the exhaust manifold tube flange was sectioned and examined using energy dispersive x-ray spectroscopy (EDS) for chemical composition. A typical EDS spectrum of the flange section is shown in Figure 13. The chemical composition was consistent with an austenitic stainless steel.

Erik M Mueller
Materials Research Engineer



Figure 1 – The components from the exhaust system, as received.



Figure 2 – The exhaust manifold, showing the location of the crack on the output flange.



Figure 3 – View of the exhaust manifold, rotated 90° from Figure 2, with the crack location labeled.

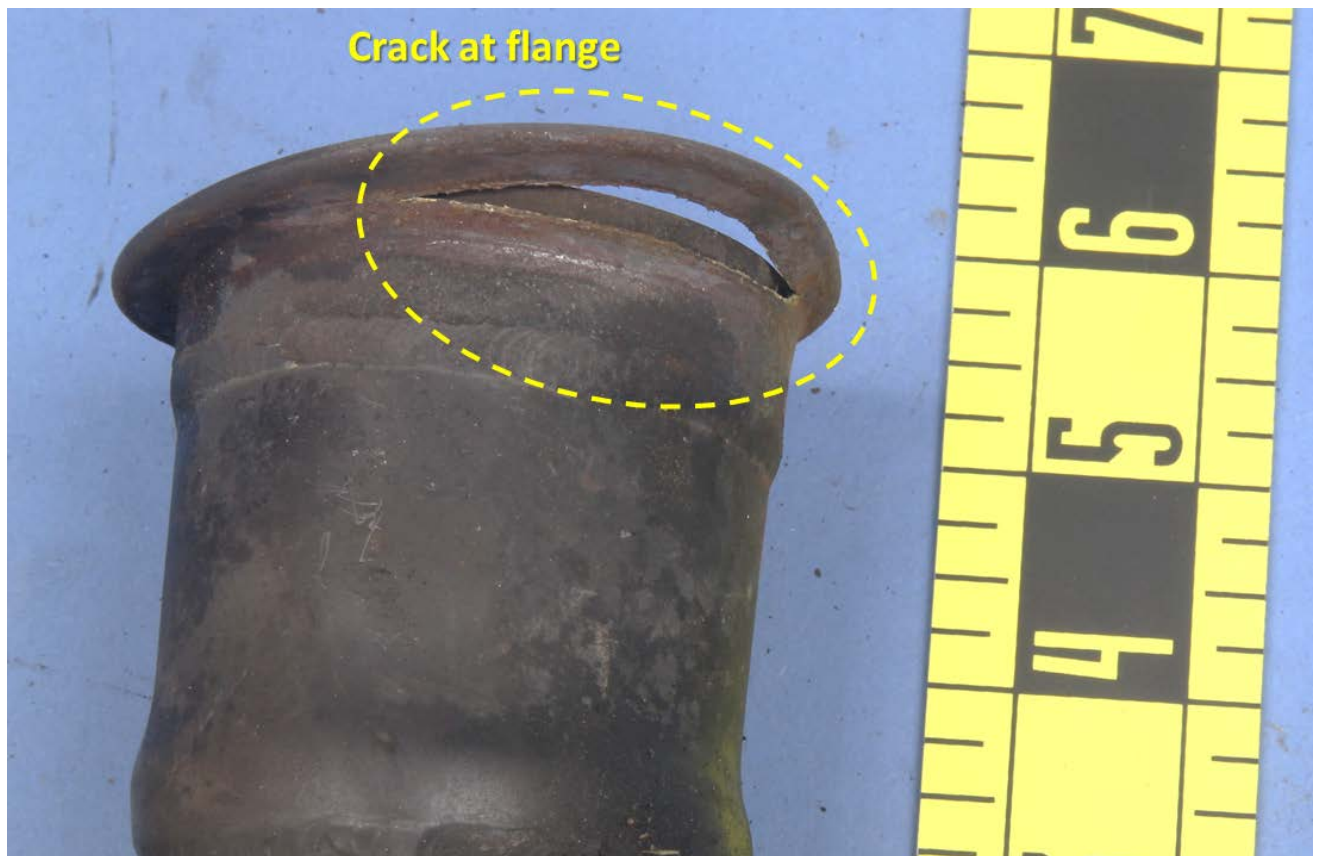


Figure 4 – Closer view of the flange crack on the output port of the manifold, as received.



Figure 5 – Closer view of a portion of the opened crack, showing multiple thumbnail cracks and ratchet marks.

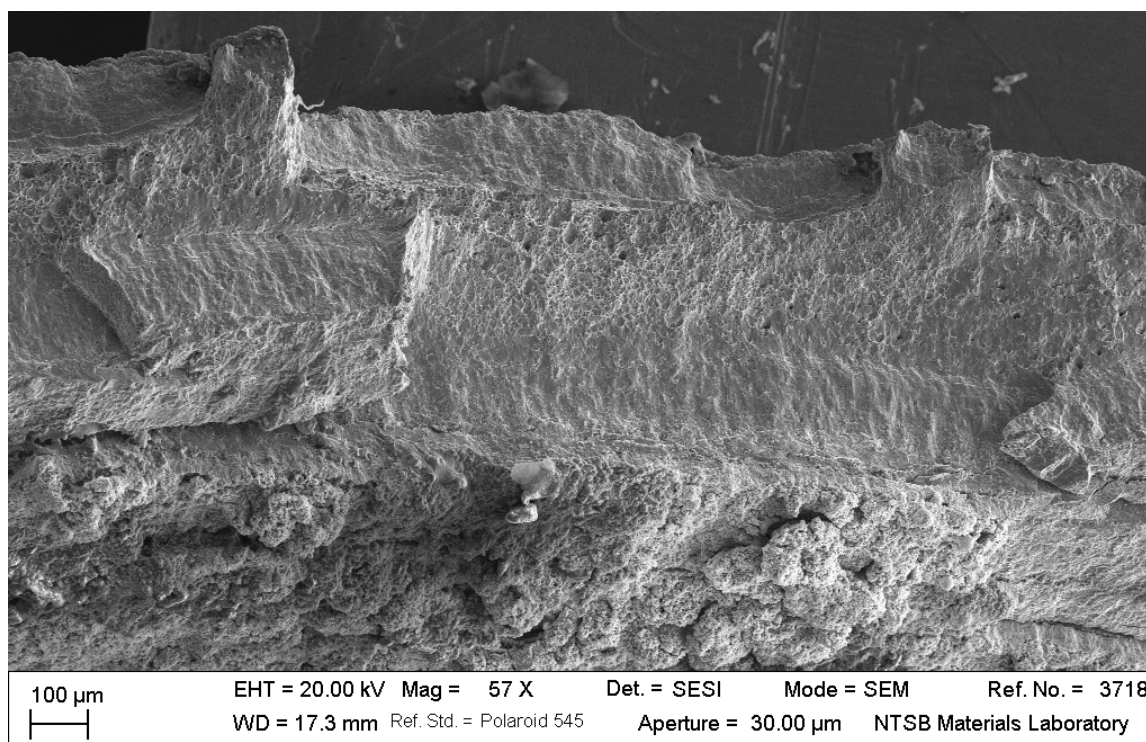


Figure 6 – Secondary electron micrograph of part of the opened crack, showing multiple individual smaller cracks that propagated inward.

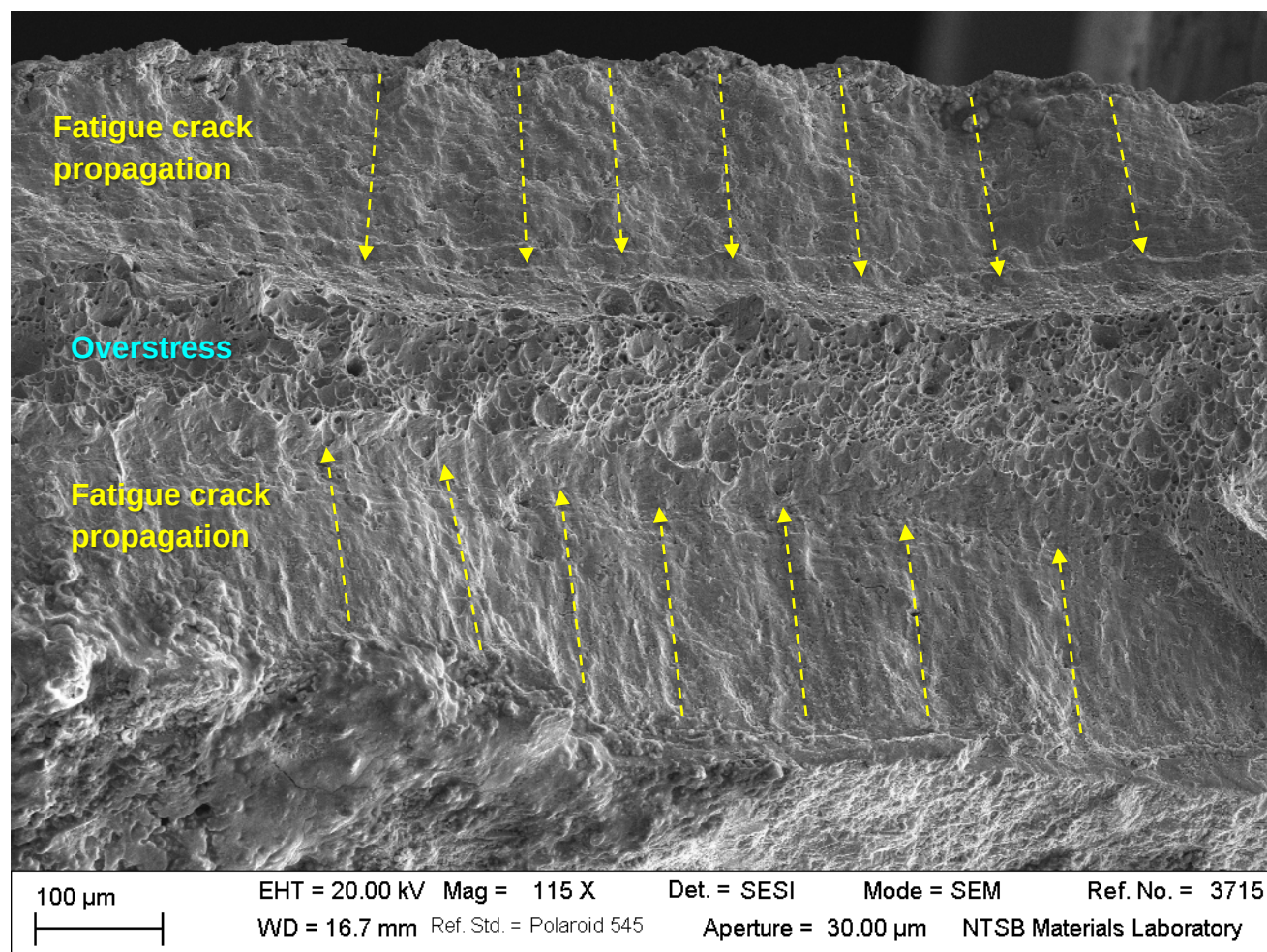


Figure 7 – SE micrograph of the opened crack showing opposite fatigue cracks propagating inward, with a middle region of dimple rupture (overstress).

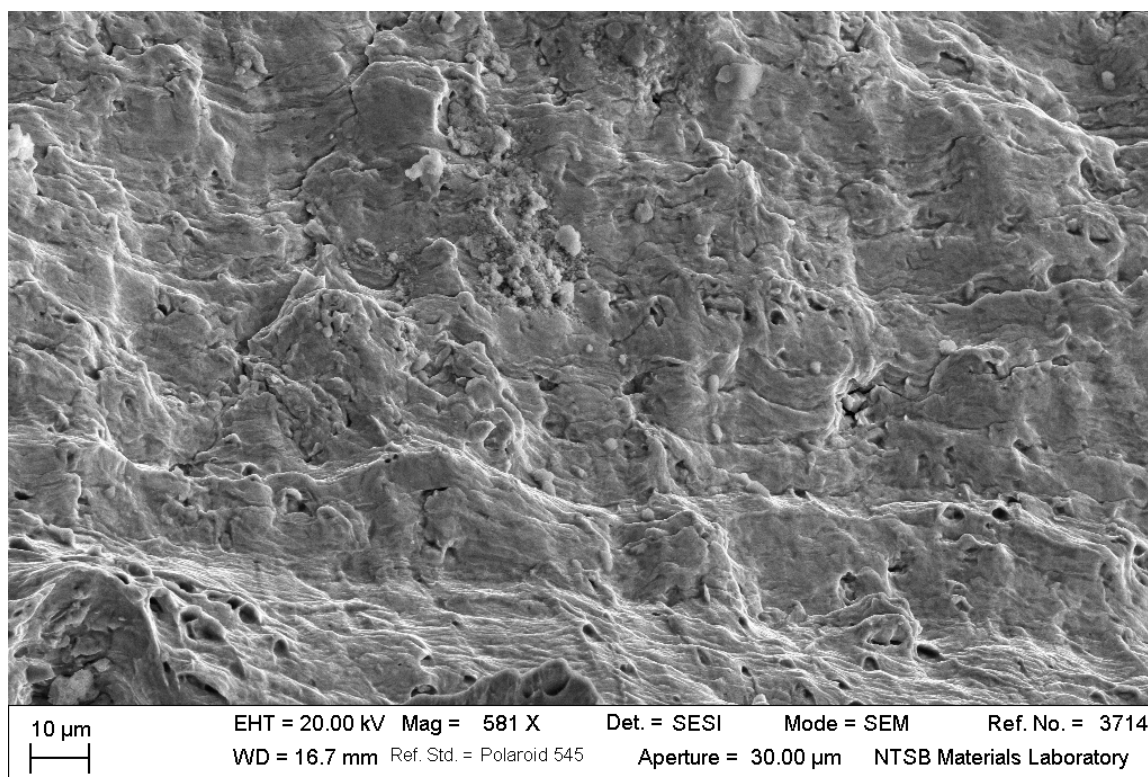


Figure 8 – SE micrograph of a typical area of fatigue striations on the crack.

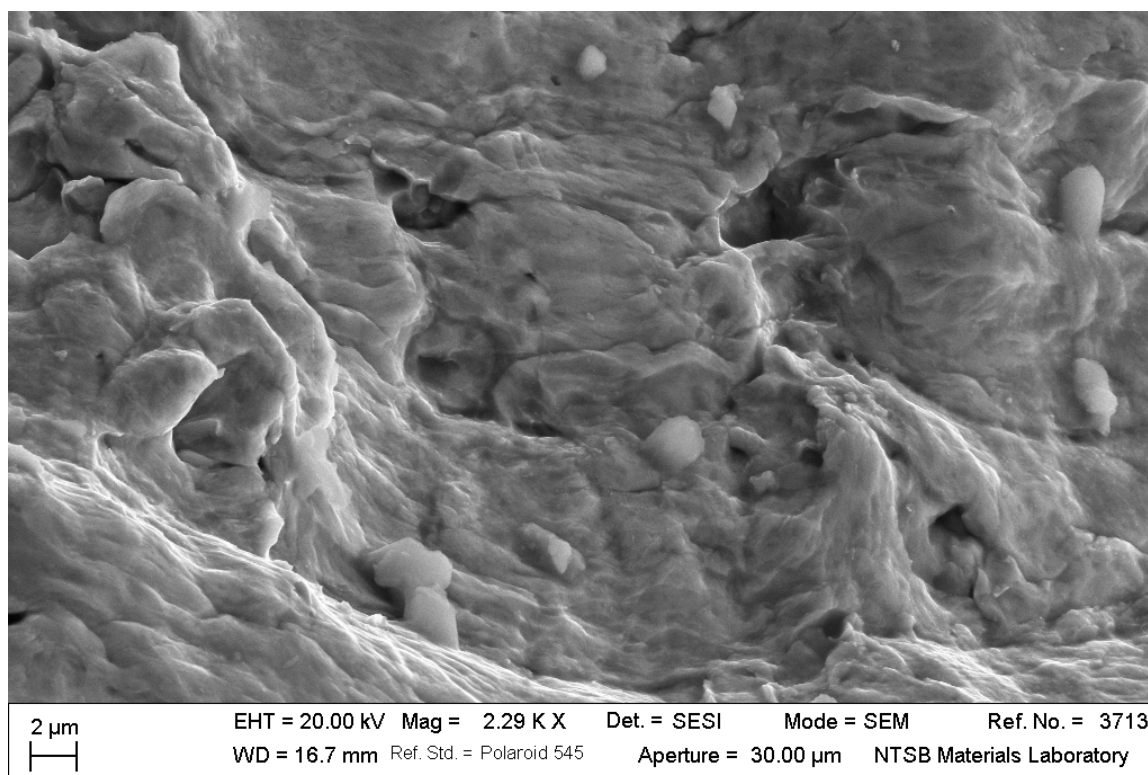


Figure 9 – SE micrograph showing a closer view of the striations in Figure 8.

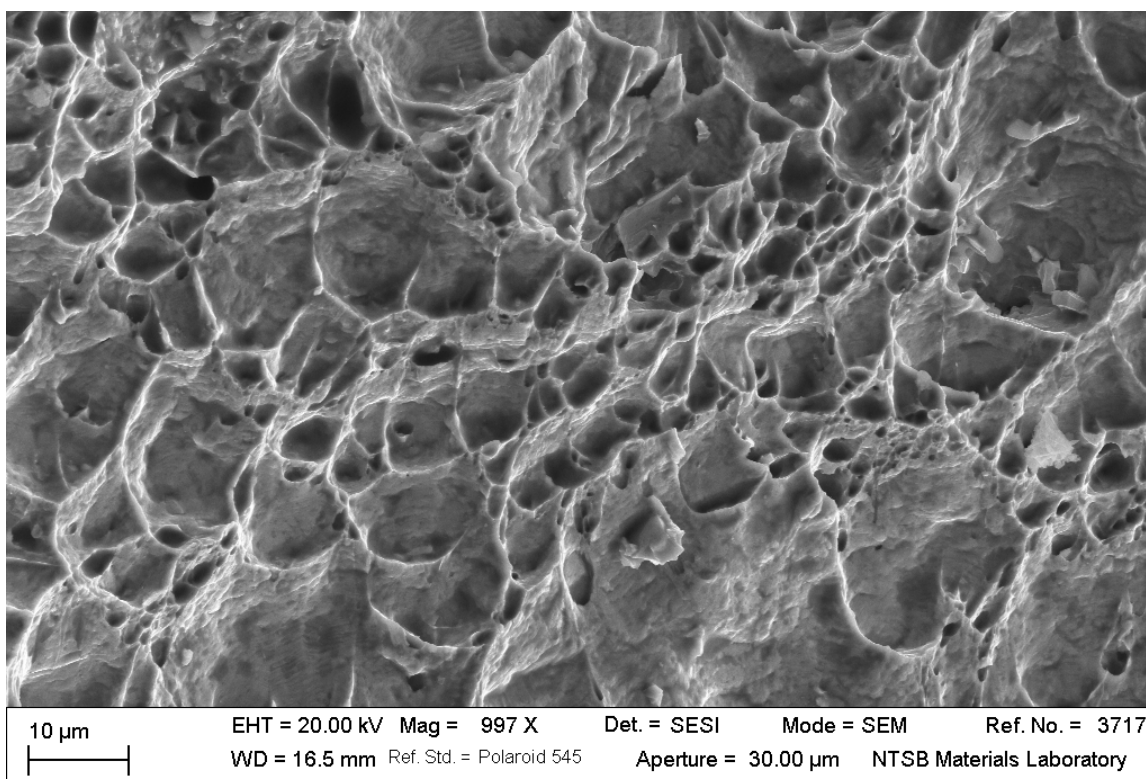


Figure 10 – SE micrograph of dimple rupture in the middle region of the crack.

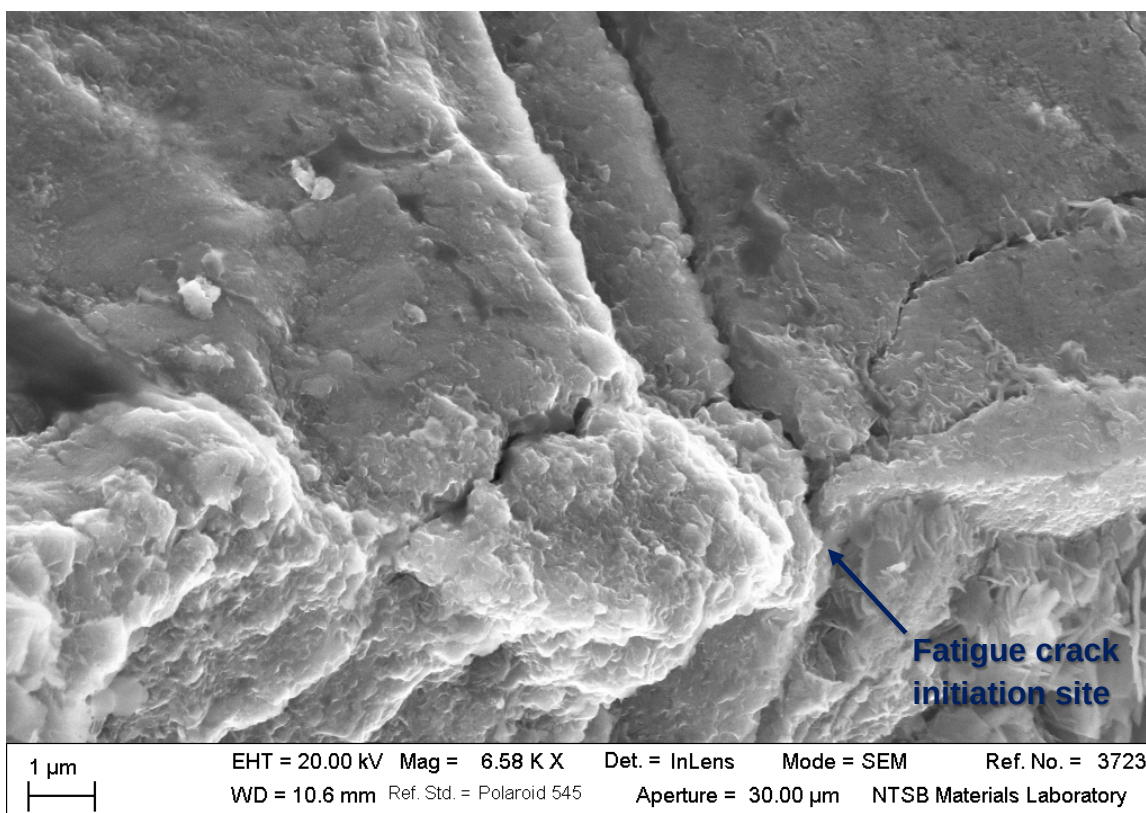


Figure 11 – SE micrograph of a fatigue crack initiation site on the crack.

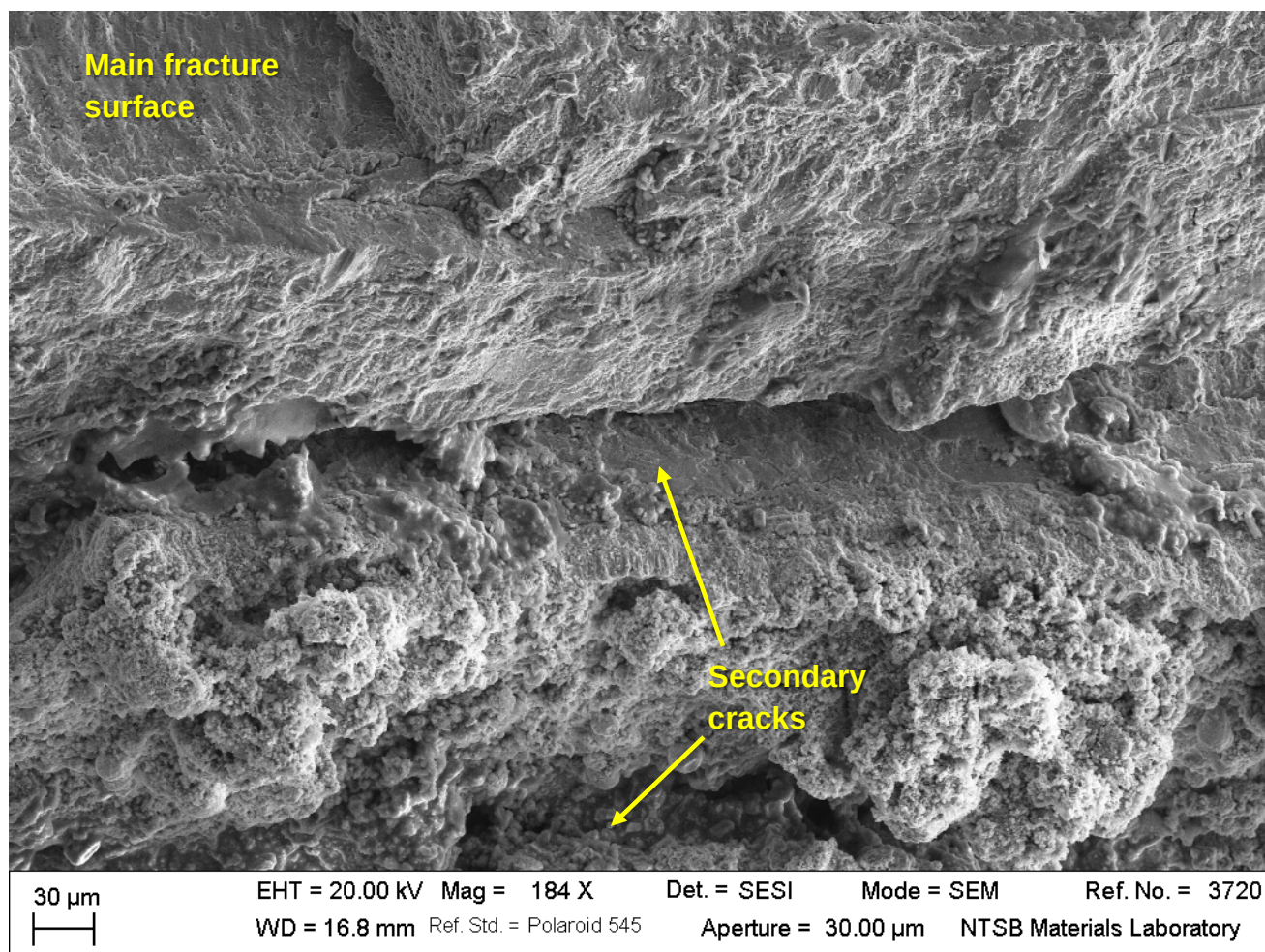


Figure 12 – SE micrograph showing smaller, secondary fatigue cracks below the main crack.

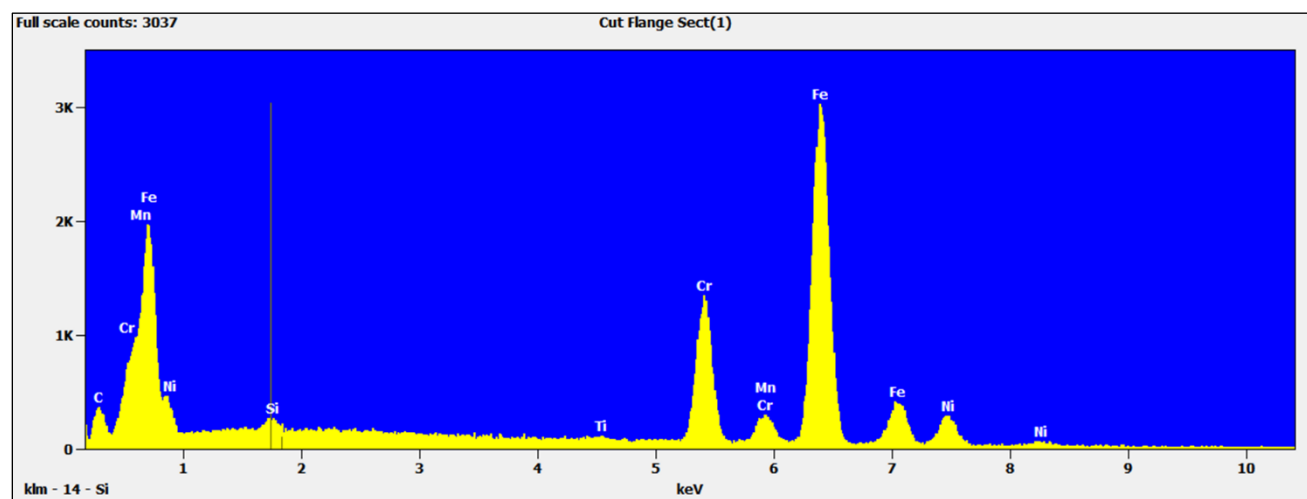


Figure 13 – EDS spectrum of a typical sectioned area of the exhaust manifold flange.