NATIONAL TRANSPORTATION SAFETY BOARD
Office of Research and Engineering
Materials Laboratory Division
Washington, D.C. 20594

March 6, 2009

MATERIALS LABORATORY FACTUAL REPORT Report No. 09-013

A. ACCIDENT

Place	:	Weaverville, California
Date	:	August 5, 2008
Vehicle	:	S-61N Firefighting Helicopter
NTSB No.	:	LAX08PA259
Investigator	:	Mike Hauf (AS-40)

B. COMPONENTS EXAMINED

1st and 2nd stage turbine wheels and 2nd Stage turbine nozzle assembly with casing from engine #1.

1st stage turbine wheel, 1st stage nozzle, turbine forward shaft, and stationary seal from engine #2.

Both engines were General Electric CT58 turbo-shafts.

C. DETAILS OF THE EXAMINATION

The various received components from the #1 and #2 engines are displayed in figure 1. Components of the two engines will be discussed separately below.

Engine #1

The 1st and 2nd stage turbine wheel assemblies are displayed in figure 2 (a). The first stage disk was identified with part number (p/n) 99207-4002T17P06, serial number (s/n) GATHA9JG. The second stage disc was marked with p/n 99207-4002T96P02, s/n GATCWM4L. The 1st stage blades were reported to be made from coated R80[1] material and were marked with FKN16WAH on the bottom of the root.

The blades of the 1st stage turbine were all fractured at approximately 2/3 span as shown in figures 2 (b) and (c). The airfoil surfaces of all blades were all dark tan in color with areas of lighter tan material. Figure 3 (a) shows a typical fractured 1st stage blade from the #1 engine and compares it to an unfractured one from the #2 engine. Magnified optical examinations found that the tan color was a deposit on the surfaces of the blade,

[1] Rene' 80, a nickel based super alloy nominally containing cobalt, chromium, aluminum, titanium, tungsten, and molybdenum.

covering the original blade coating. In many instances, the tan deposits extended onto the fracture surfaces. The tan coating was significantly reduced but not fully removed by brushing the surfaces with soap and water, as shown in figure 3 (b).

Close magnified examinations revealed similar features on all blades. Typical features included irregular chordwise fractures with rough dark fracture surfaces having a pronounced interdendritic pattern and multiple secondary cracks adjacent to the fractures. The fracture surfaces appeared typical of high temperature stress rupture separations on all blades with no indications of progressive cracking such as fatigue.

Examinations of many blades found that, typically, the original blade coating was intact on most of the blade surfaces but was typically partially spalled from the blade adjacent to portions of the fracture, in the vicinity of the secondary cracking and at the trailing edge on the concave side, as shown in figure 4 (a). Figure 4 (b) shows a closer view of the blade at the leading edge showing the secondary cracking with the attendant spalled coating, areas of intact original coating and areas of remaining tan deposits after cleaning. Elemental maps by energy dispersive x-ray spectrography of these areas, contained in figure 5, clearly showed the various constituents as the base metal elements (exemplified by chromium) in the spall coating area, predominantly aluminum where the coating was intact and mixture of elements that were mostly silicon and magnesium (silicon shown) in the tan deposit area.

A longitudinal metallographic section was cut through a typical 1st stage blade at about ¼ chord. The unetched section displayed extensive secondary cracking in the immediate vicinity of the fracture as displayed in figure 6. When etched with Kalling's reagent[2], the cross section displayed significant microstructure variations from the base of the blade to the airfoil fracture area. In the base, figures 7 (a) and (b), the microstructure was typical of a solution treated and aged nickel based superalloy containing gamma prime participates in a gamma matrix with dispersed intermetallics and clearly defined grain boundaries. However, near the fracture, figure 7 (c) and (d), the microstructure showed intermetallic particles in a dendritic structure with little or no gamma prime participates and poorly defined grain boundaries. The microstructure was typical of high temperature exposure and partial resolutioning of the gamma prime. Along the airfoil length, the coating showed increasing oxidation toward the fracture and spalling adjacent to the fracture, as shown in figure 8.

Knoop microhardness measurements on the polished cross section were taken in the base region, near mid span and adjacent to the fracture (tip) and showed decreasing hardness as indicated in the table below and shown on figure 9. Values for the #2 engine are also shown.

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[2] Kalling's Reagent contains 40ml distilled water, 2g Copper chloride ($CuCl_2$), 40ml Hydrochloric acid and 40 ml Ethanol.

Table 1st Stage Turbine Blade Hardness Profile
Knoop Indentor
500g Load (gf)

	Base		Mid Span		Tip	
	HK_{500}	HRC	HK_{500}	HRC	HK_{500}	HRC
#1 Eng	427	44	327	33	327	33
#2 Eng	465	47	438	44	366	37.5

HRC approximate conversion
per ASTM E140

The inner diameter of the turbine wheel bore measured between 0.7995 inch and 0.8005 inch. The bore diameter was reportedly specified as between 0.792 inch and 0.802 inch.

The 2nd stage turbine nozzle assembly is displayed in figure 10. No identifying markings were found on the assembly or attached turbine case. The assembly was generally intact but had large quantities of deposited material on the air seal segments inline with the 1st stage turbine disk. In locations, the built up deposits were nearly 0.1 inch thick. The nozzle, case and air seals were additionally covered with tan deposits previous identified on the 1st stage turbine. A portion of the deposited material was chipped / peeled from the air seals. The deposit was longitudinally sectioned mounted in phenolic material and lightly polished. The deposit cross section showed internal voids but otherwise appeared to be homogenous material through its thickness, as shown in figure 11 (a). An energy dispersive x-ray line scan, figures 11 (b) and (c), through the thickness of the material also showed a uniform composition except at discreet aluminum-containing intersected particles.

Engine #2

The 1st stage turbine assembly is displayed in figure 12. The assembly appeared intact with little or no visible mechanical damage. The turbine blades were intact showing a dark brown coloration as shown in figure 3. The blade coating appeared intact with no visible cracking or peeling or indications of thermal distress.

A longitudinal metallographic section was cut in the same plane as the sample from the #1 engine. In the polished but unetched condition, a dark transverse feature was noted at about 2/3 span, as shown in figure 13 (a). The feature appeared to be a line of oxides containing a few small pores.

When etched with Kalling’s reagent, the revealed microstructure varied from base to tip as seen in the #1 engine blade. The base, figure 13 (b), and mid span, figure 13 (c) locations both showed gamma prime precipitates in a gamma matrix along with dispersed intermetallic particles. However, the gamma prime was coarser at the mid span. At the tip region of the blade the gamma prime appeared to have been partially resolutioned leaving gamma prime remnants and intermetallics. Hardness (see table above) showed a decrease from base to tip but not to the extent of the blades from the #1 engine.

The inner diameter of the turbine wheel bore measured between 0.7990 inch and 0.8000 inch. The bore diameter was reportedly specified as between 0.792 inch and 0.802 inch.

The 1st stage turbine nozzle assembly, shown in figure 14 (a), was generally intact and appeared undamaged. The nozzle vanes surfaces showed some spatter on the convex sides near the trailing edges, see figure 14 (b). EDS of the spatter established that it was predominately aluminum in composition.

The forward turbine shaft and stationary seal are displayed in figure 15. The seal surfaces contained grooves in the abradable coating from contact with the knife edges on the turbine shaft. The grooves appeared deeper toward one side of the seal indicative of a slight axial misalignment between the shaft and seal.

Joe Epperson
Senior Metallurgist

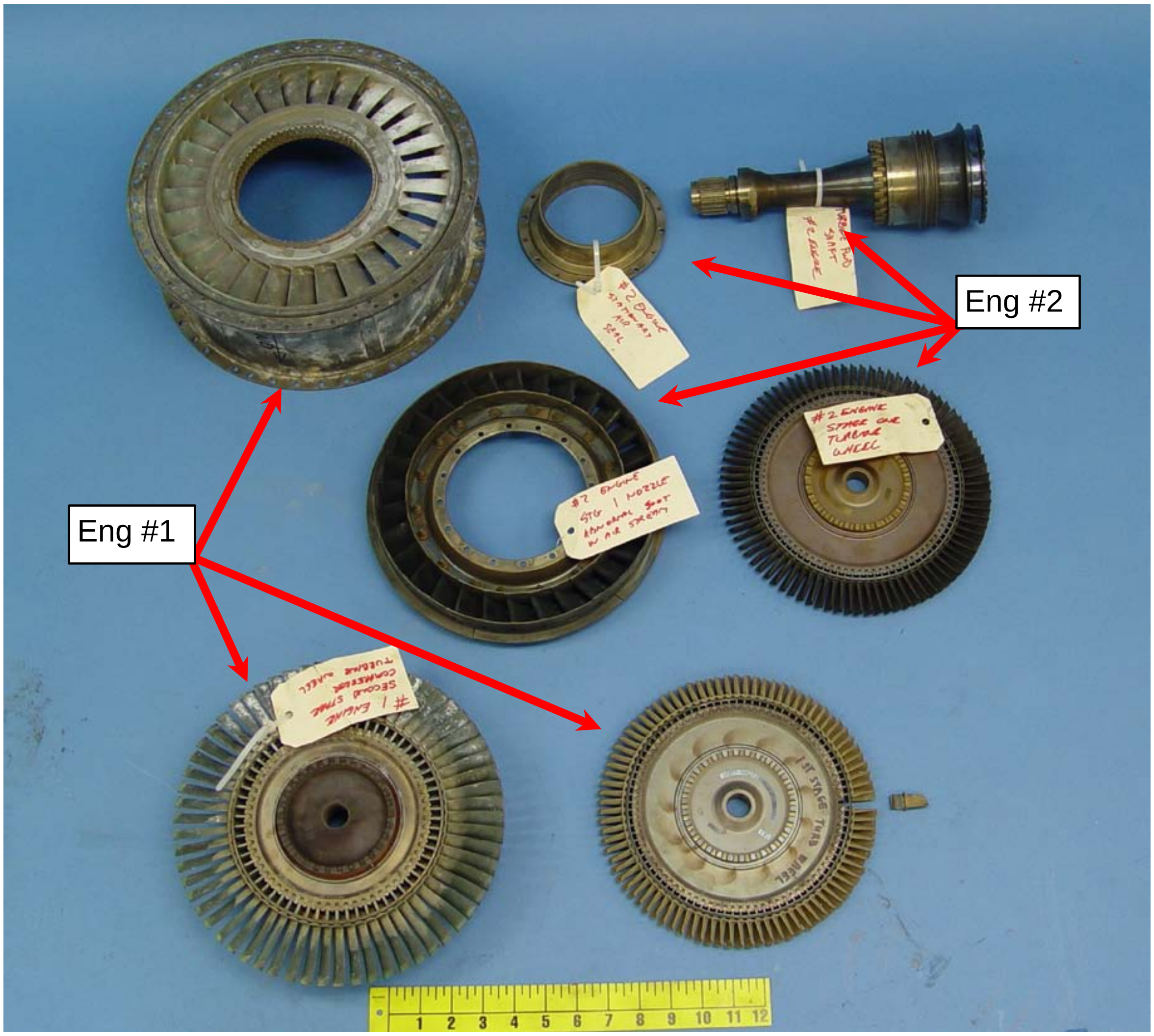

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Figure 1--An overall view of the as-received components from the #1 and #2 engines.

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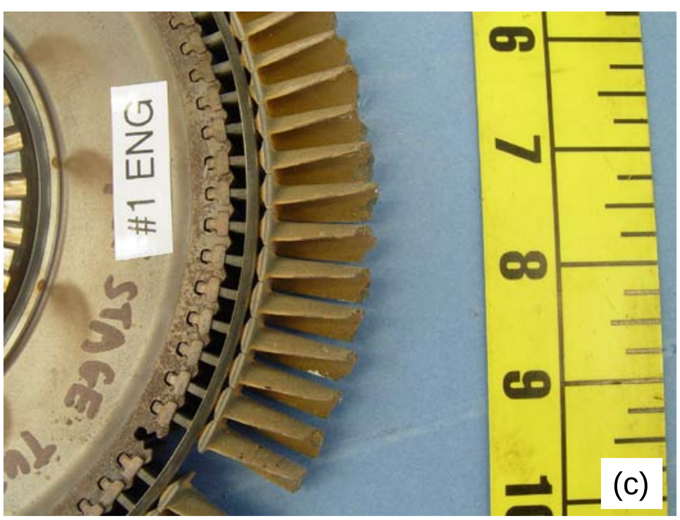
Figure 2--The 1st and 2nd stage turbines from the #1 engine (a) with closer views, (b) and (c), showing the blade damage to the 1st stage turbine.



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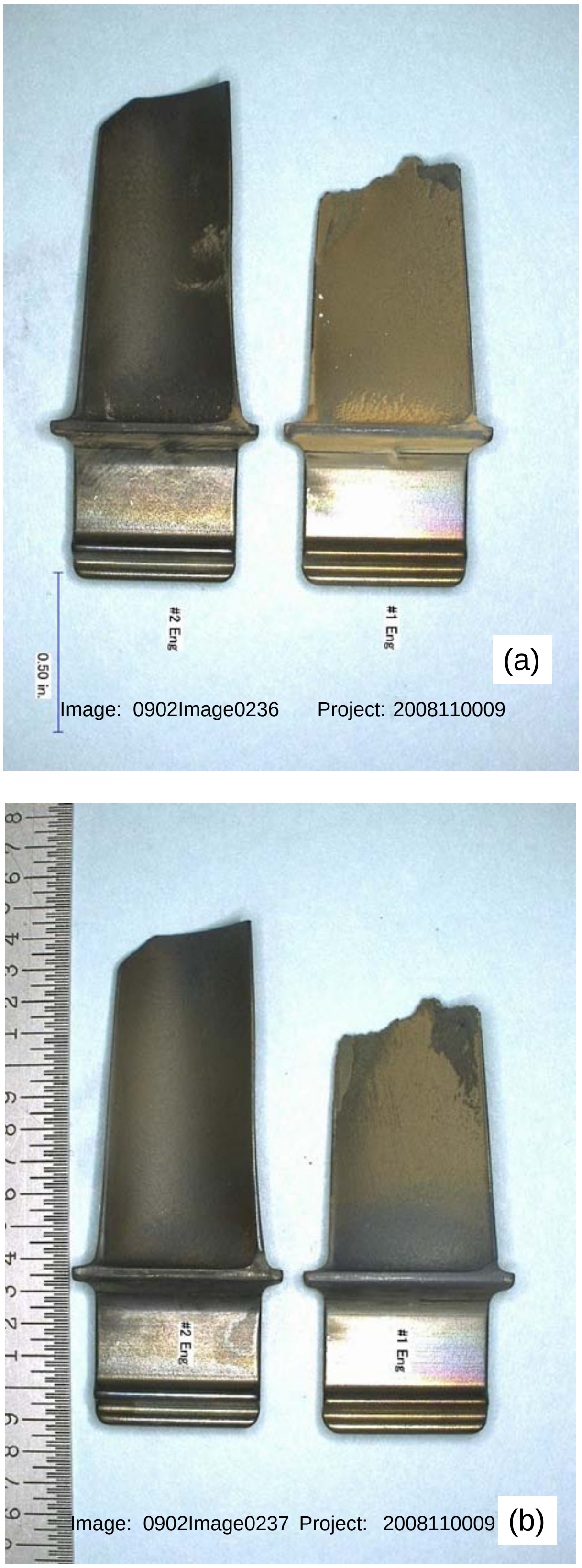
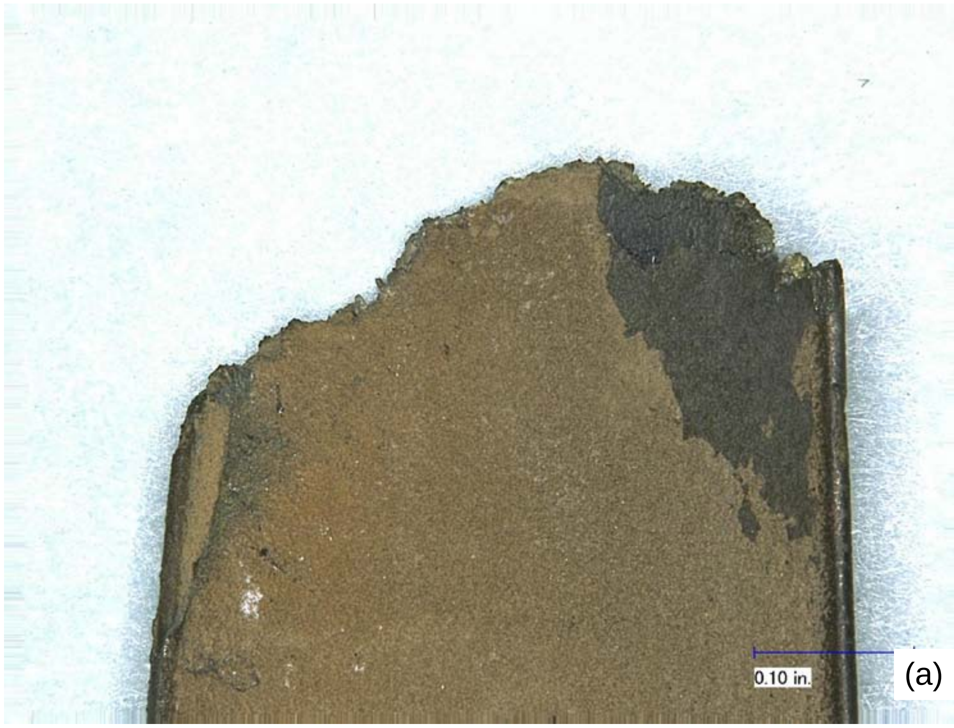


Figure 3--Comparisons of the 1st stage turbine blades from the #1 engine (right) to the #2 engine, before (top) and after (bottom) cleaning.



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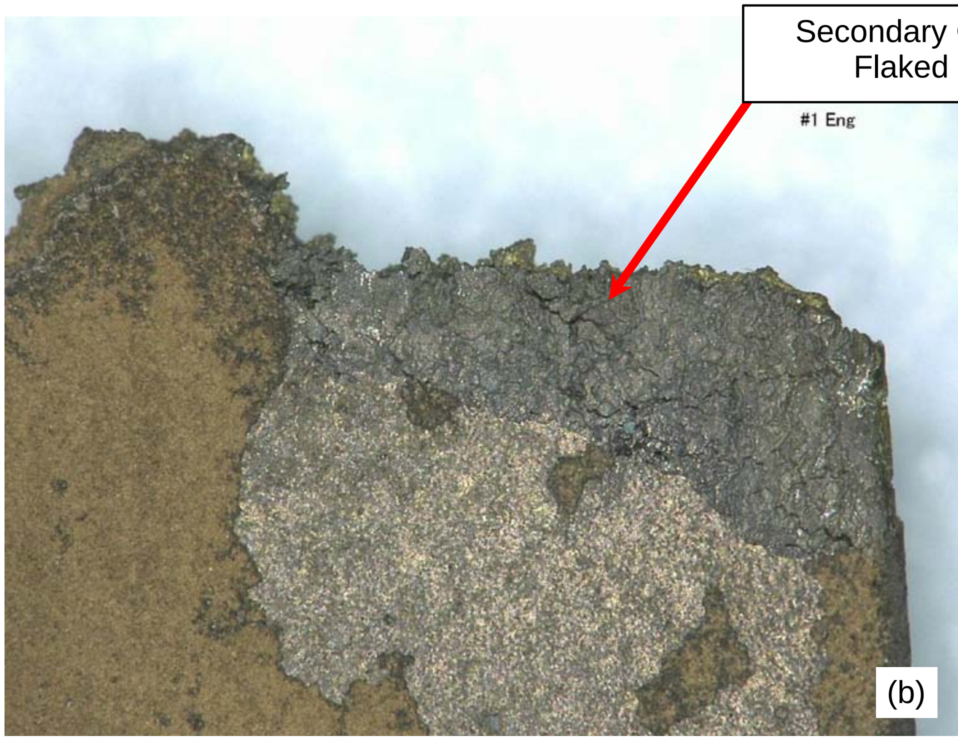

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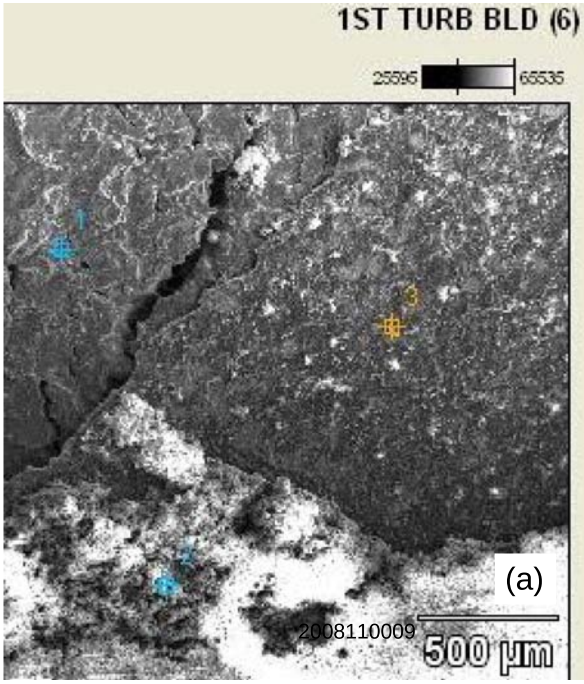
Figure 4--Magnified views of a typical blade from the #1 engine at the fracture showing secondary cracking, tan surface debris and flaking of the coating.



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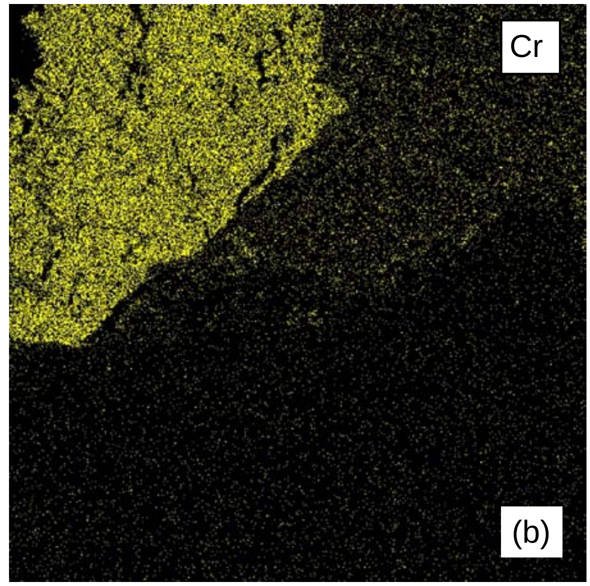

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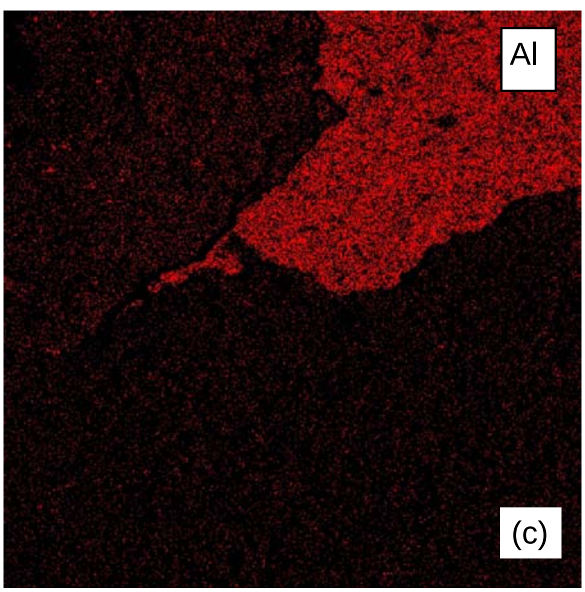

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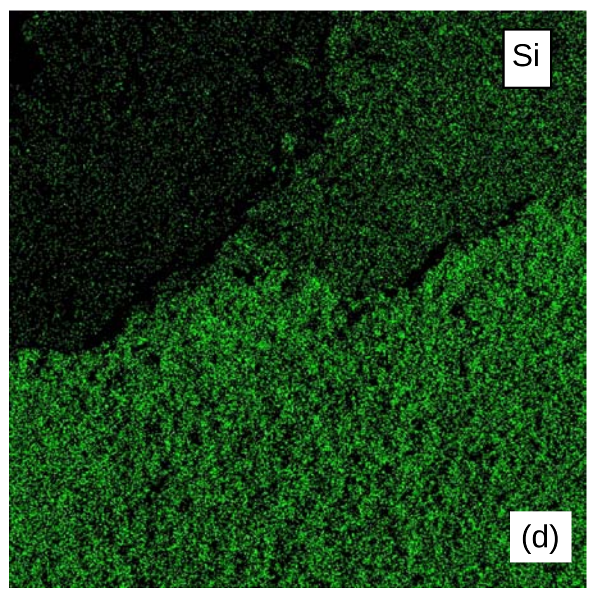

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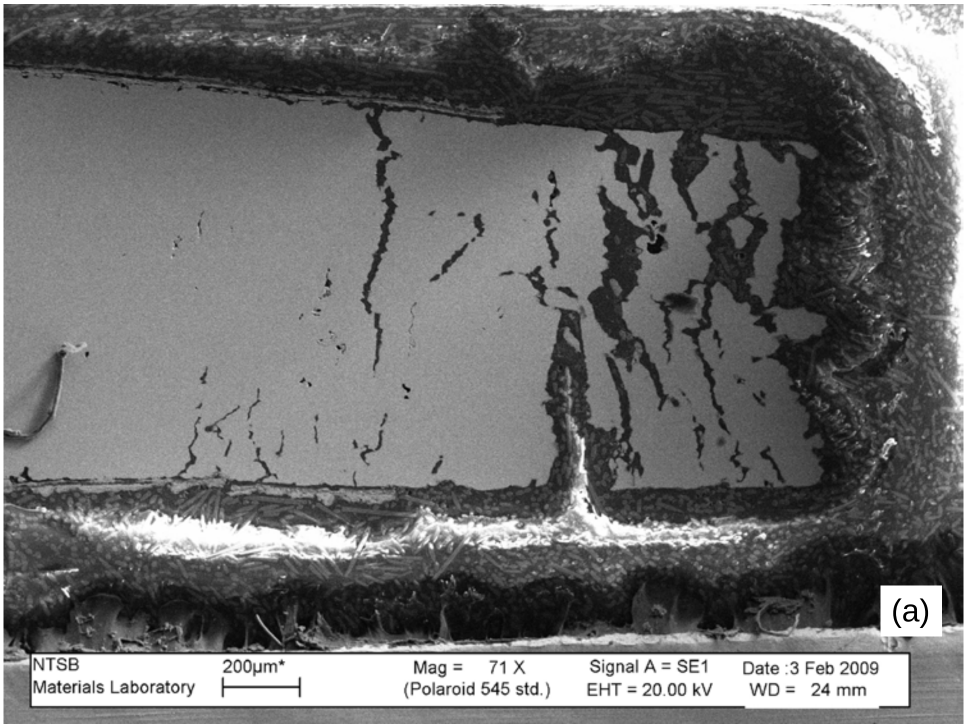
Figure 5--EDS maps showing the locations of base metal, represented by chromium (b), the intact coating represented by aluminum (c) and and the tan deposits represented by silicon (d).



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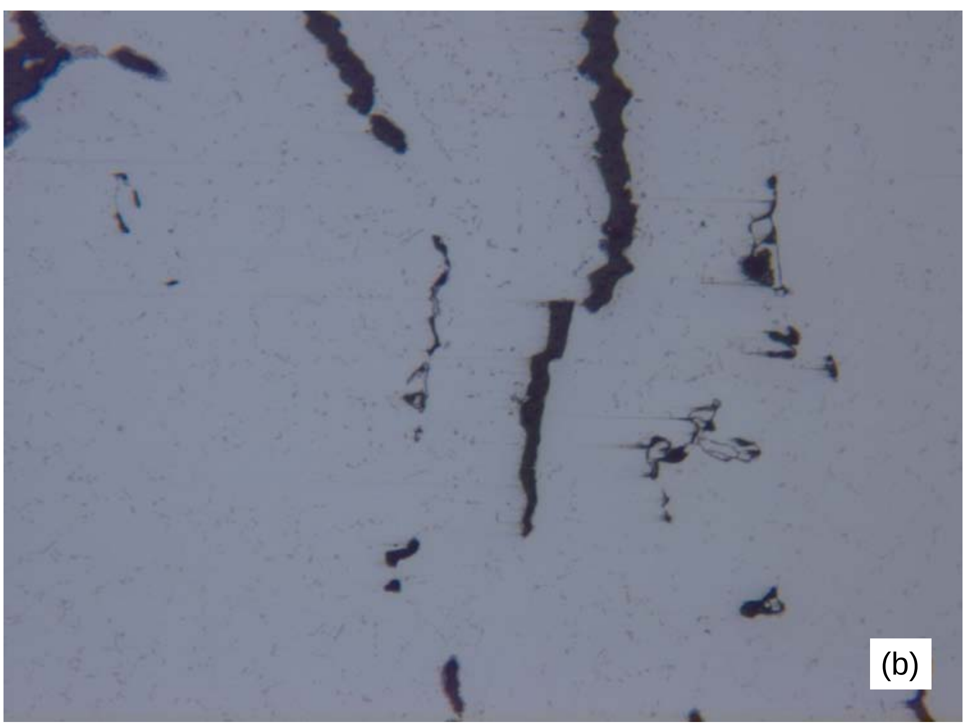

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Figure 6--SEM (a) and optical (b) views showing typical secondary cracking adjacet to the the fracture (at right in both views).

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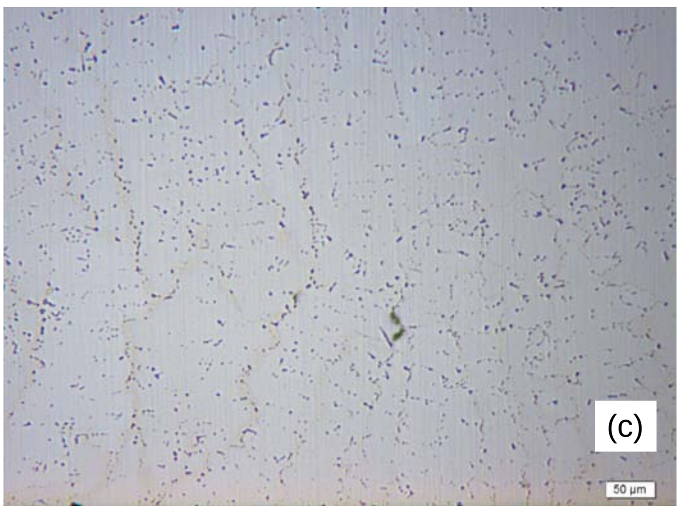

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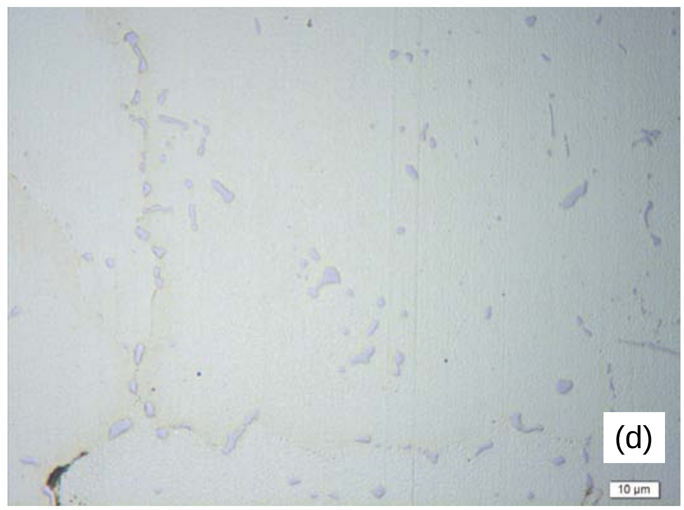

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Figure 7--The microstructure of the 1st stage turbine blade from the #1 engine in the base (a) and (b) and near the fracture (c) and (d) showing resolution of the gamma prime phase. Kalling's Reagent etch.

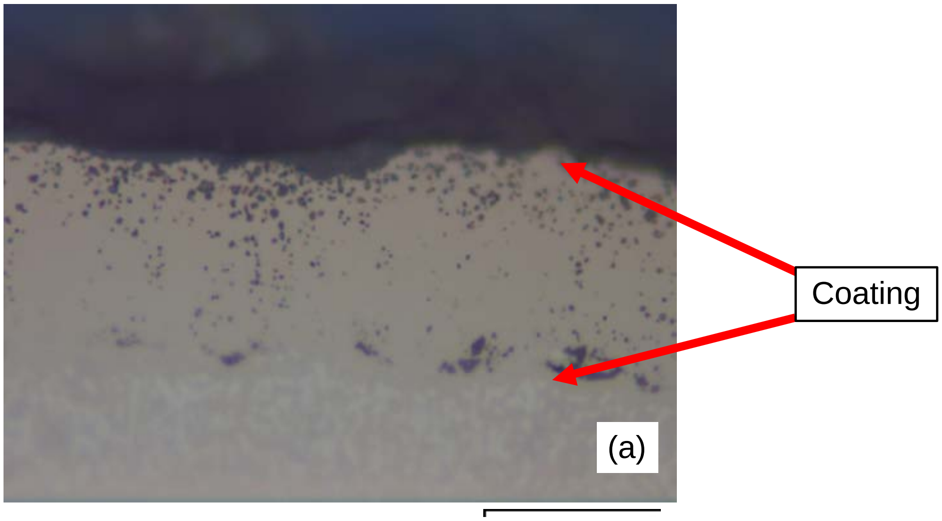

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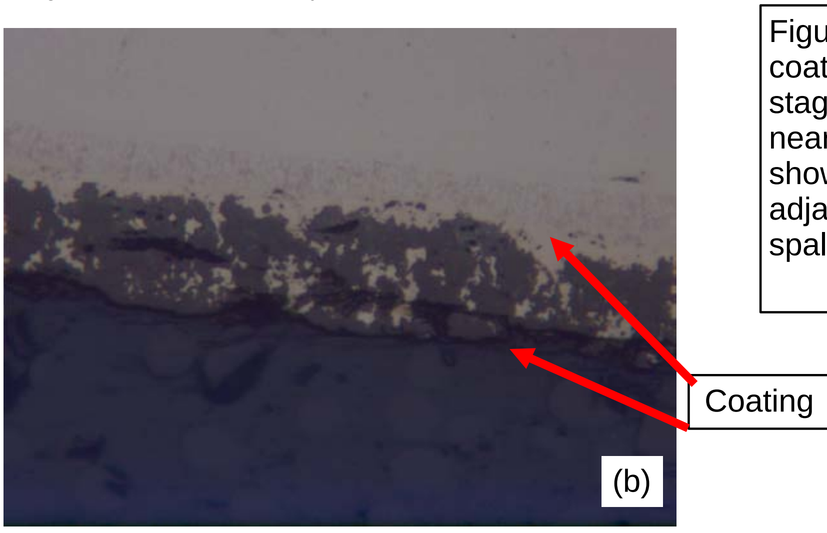
Figure 8--Microstructures of the coating material on the airfoil of the 1st stage turbine from the #1 engine, (a) near the base, (b) near midspan showing oxidation and cracking and (c) adjacent to the fracture showing spalling.



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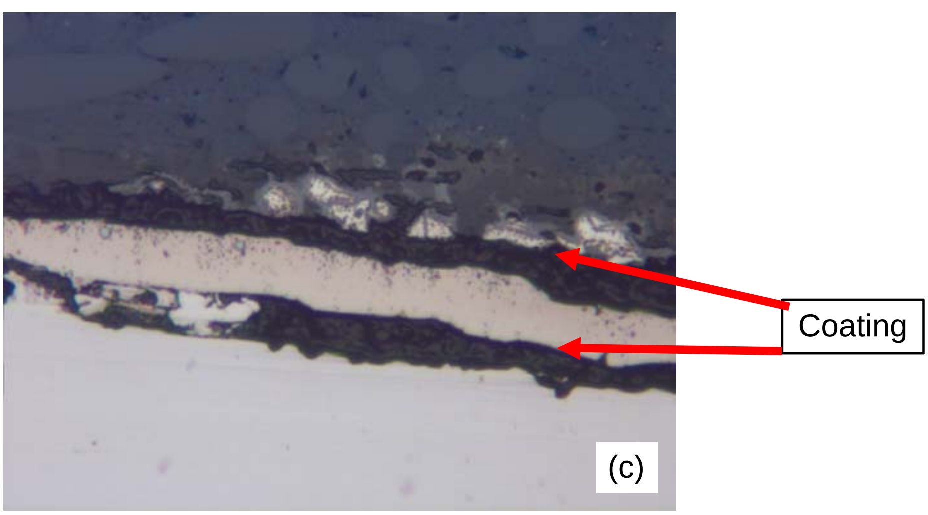

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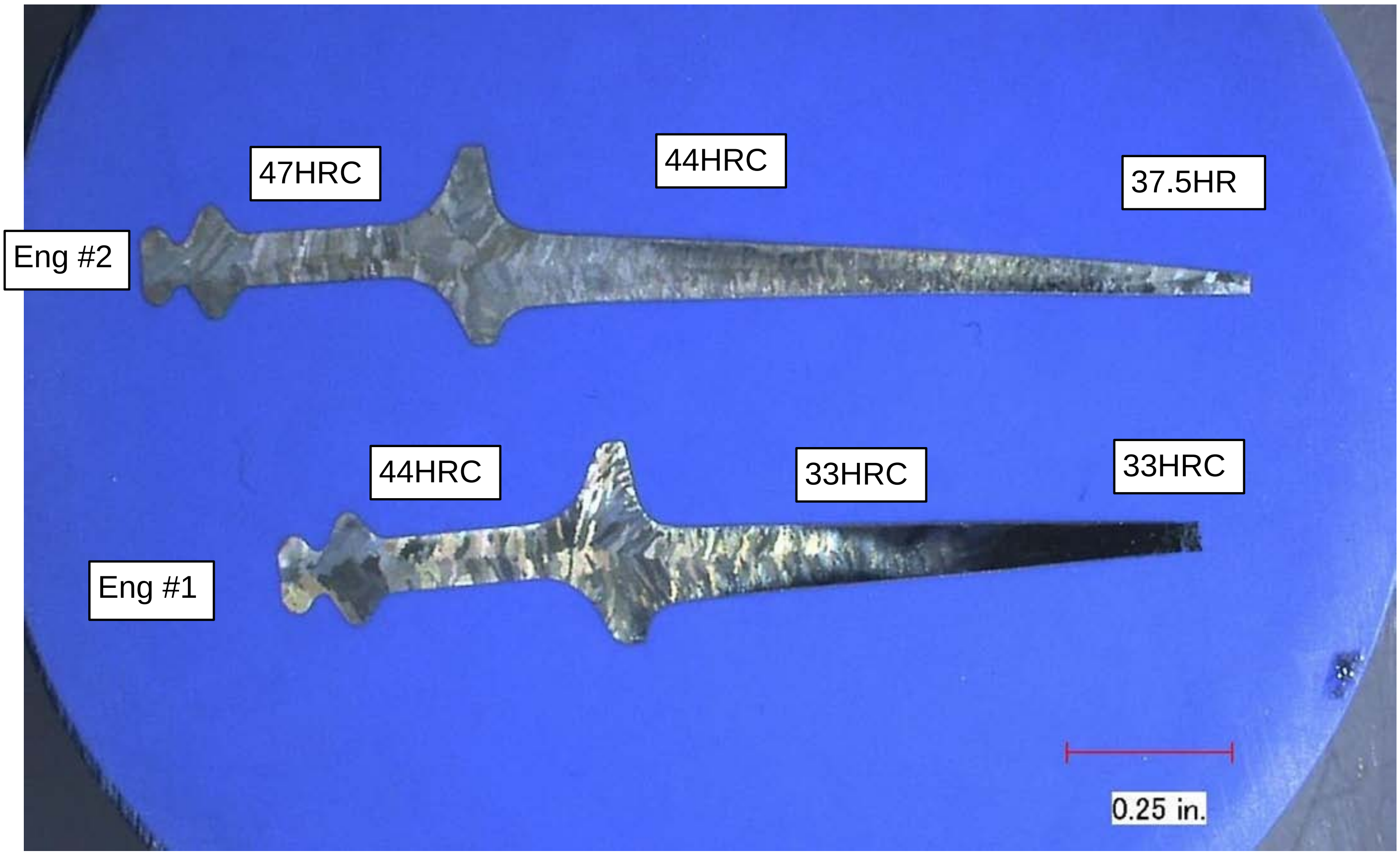

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Figure 9--A macrograph of the polished and etched blade sections from the two engines showing the overall macrostructure. Average hardness at different locations is also noted.

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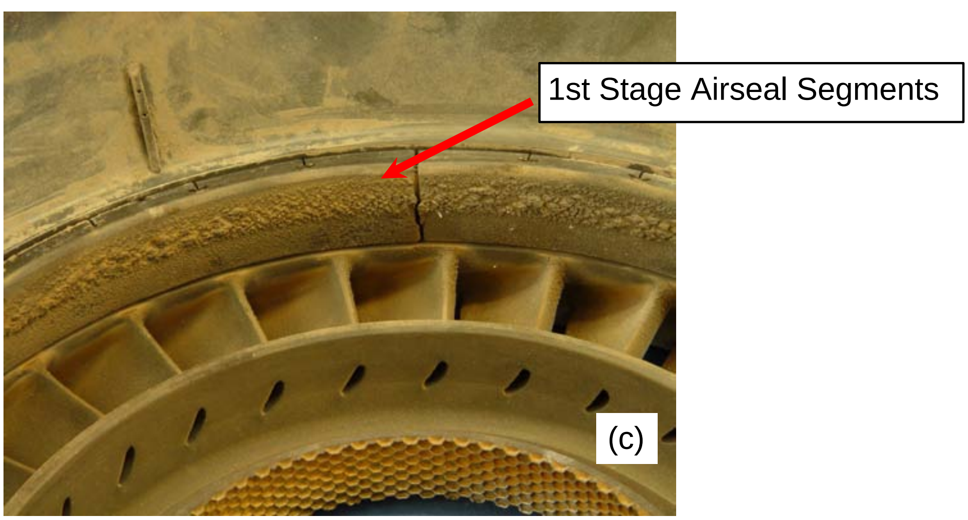
Figure 10--The 2nd stage turbine nozzle from the #1 engine showing the widespread tan deposits (a) with closer views (b) and (c) showing the deposits on the 1st stage airseal area.



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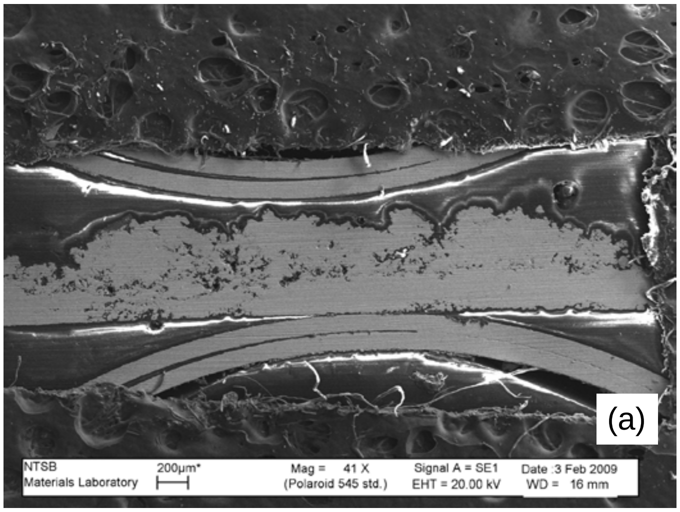

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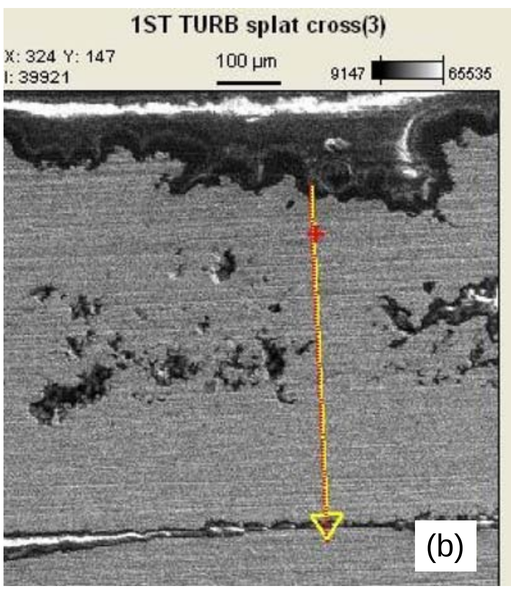

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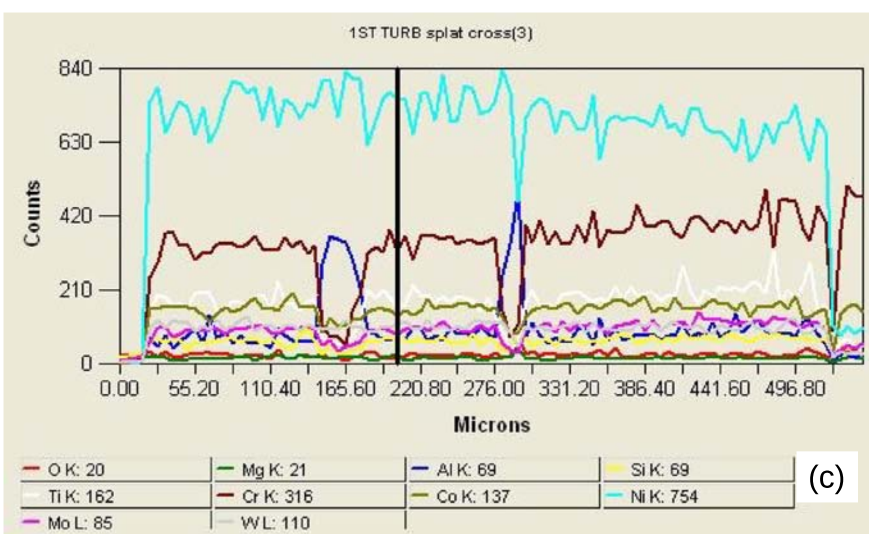
Figure 11--Cross section of deposited material on 1st stage airseal segments (a) with a closer view (b) showing the location of the EDS line scan presented in (c).



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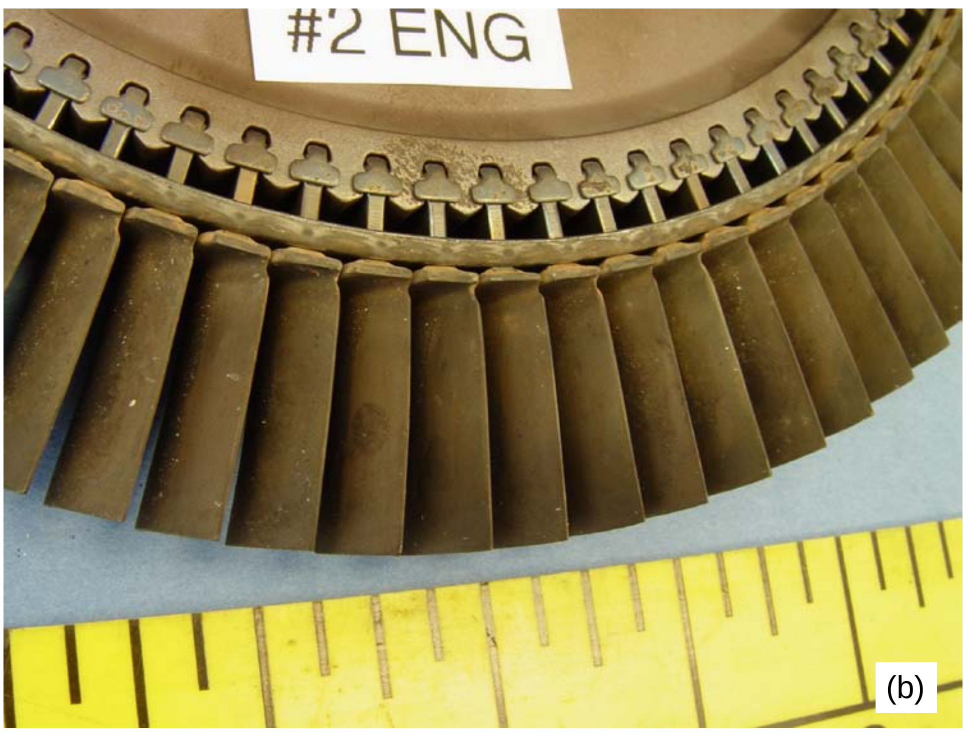

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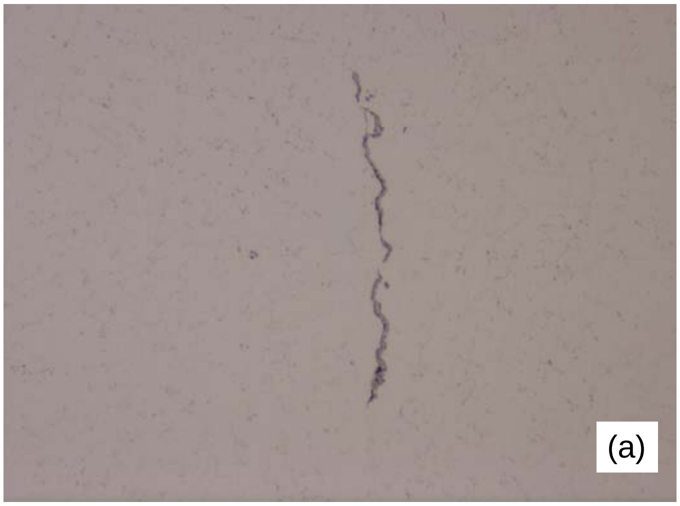
Figure 12--The 1st stage turbine from the #2 engine showing no apparent blade or coating damage.



200µm

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500µm

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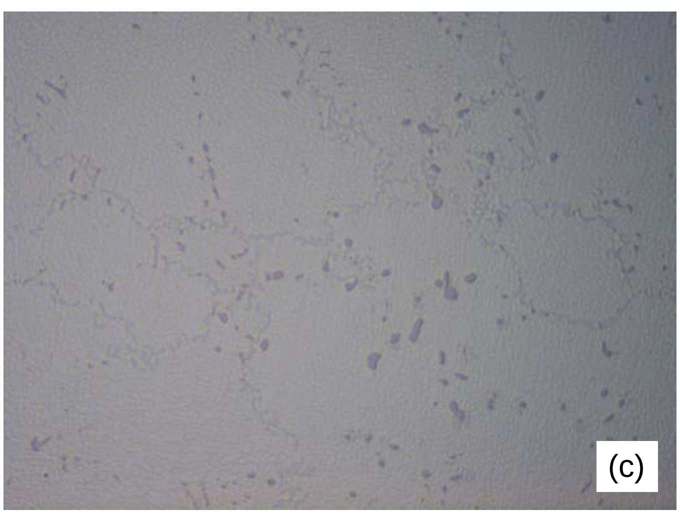
Figure 13--Micrographs of a 1st stage turbine blade from the #2 engine showing an oxide formation (a) near the tip (unetched) and the microstructures near the base (b) and at the tip (c).



20µm

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Figure 14--The 2nd stage nozzle assembly from the #2 engine (a) with aluminum splatter on the trailing edges of the vanes (b).

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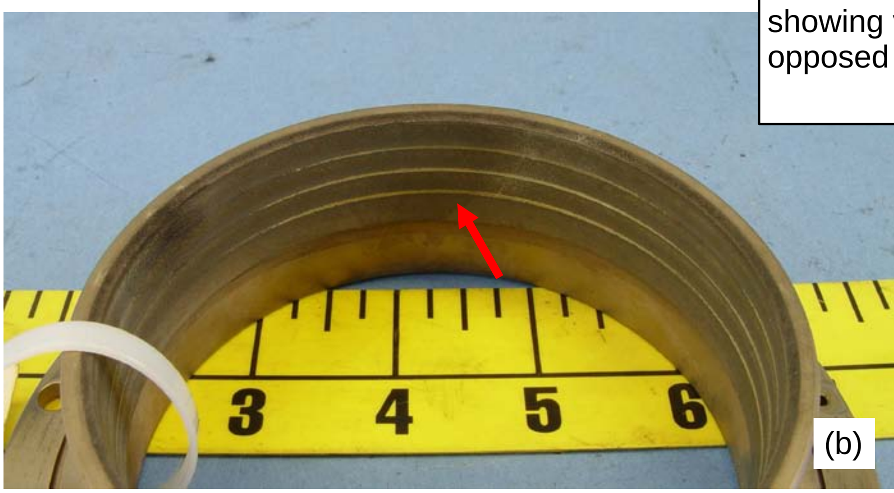
Figure 15--The foward turbine shaft and stationary seal (a) with the seal showing various depth groves on opposed sides (b) and (c).



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