

NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594

September 14, 2021

**Attachment 10 –Pratt & Whitney PW4168A-1D LPT Case Materials Analysis
Report**

POWERPLANTS

DCA18LA163



GO BEYOND

PW4168 ESN 733603 UNDERCOWL FIRE LPT CASE EXAMINATION

5/3/19

Not subject to the EAR per 15 C.F.R. Chapter VII, Part 734.3(b)(3).

This document has been publicly released.

A UNITED TECHNOLOGIES COMPANY

P733603 LPT CASE

SUMMARY

- The low pressure turbine (LPT) case from PW4168A-1D engine 733603 was returned to Pratt & Whitney East Hartford for examination. No other hardware or debris from the subject engine was received.
- Teardown of the subject engine occurred at Pratt & Whitney Eagle Services Asia (ESA) in Singapore. Reports produced by Airbus and ESA during the engine teardown were reviewed to understand the post-event condition of the engine.
- Examination of the case identified two holes and cracking in the plane of the 4th stage rotor and cracking in the plane of the 3rd stage rotor.
 - Material associated with the holes noted during teardown (documented in teardown reports) was not received at Pratt and Whitney with the case and thus was not available for review.
- The case exhibited an appearance consistent with a significant thermal event, particularly between the 12 and 6 o'clock positions (ALF)*.
- Destructive examination including metallography confirmed a significant thermal event on the outer diameter side of the case between the 12 and 6 o'clock positions
 - Incipient melting observed in the microstructure indicated exposure to temperatures in excess of 2400F on the OD.
- Examination of the deposited material on the OD of the case found a composition with high amounts of aluminum, nickel, and chromium.
 - This composition did not match any known materials.
 - The deposit was thought to be a mixture of multiple materials.

*Aft looking forward

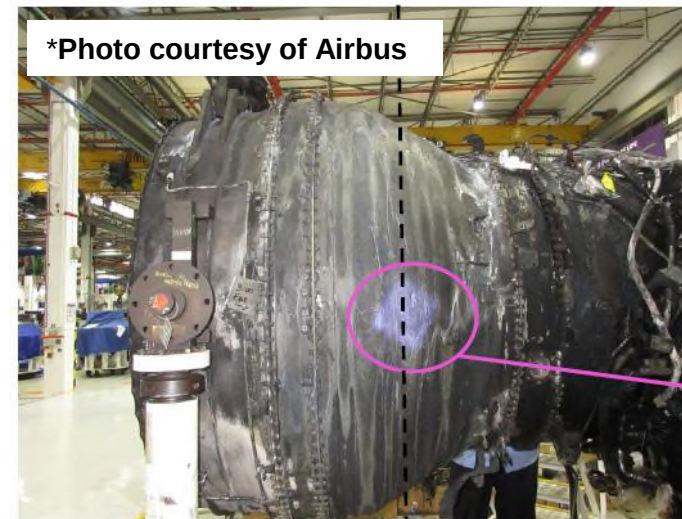
P733603 LPT CASE – OBSERVATIONS FROM TEARDOWN REPORTS

REFERENCE AIRBUS REPORT FROM ESA VISIT

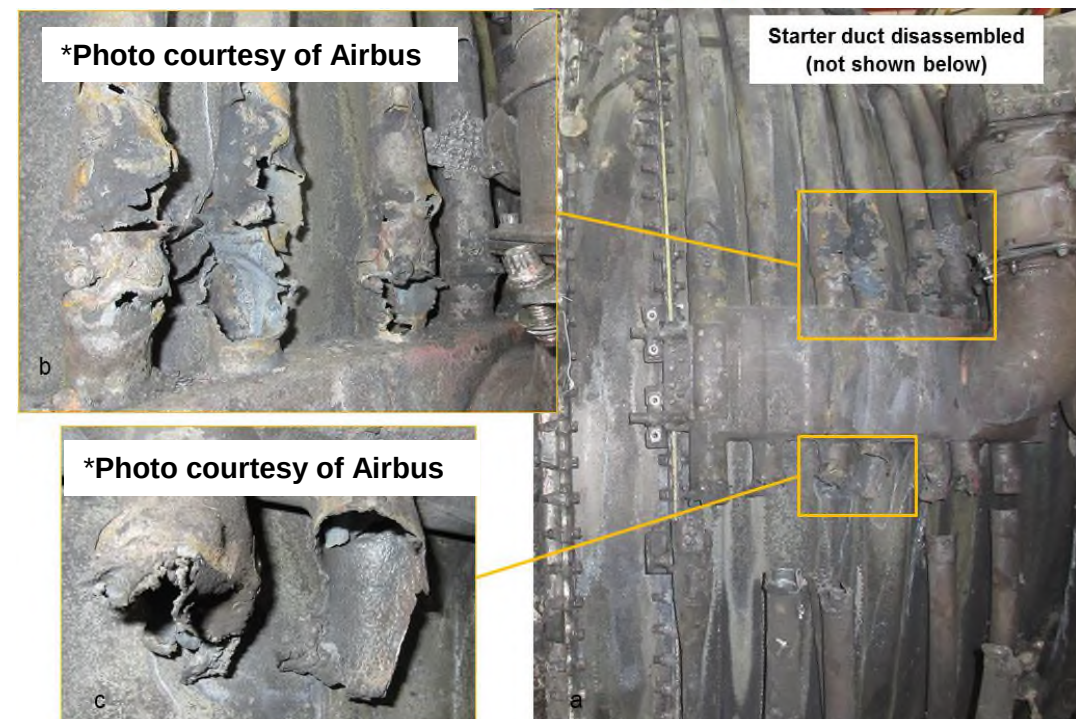
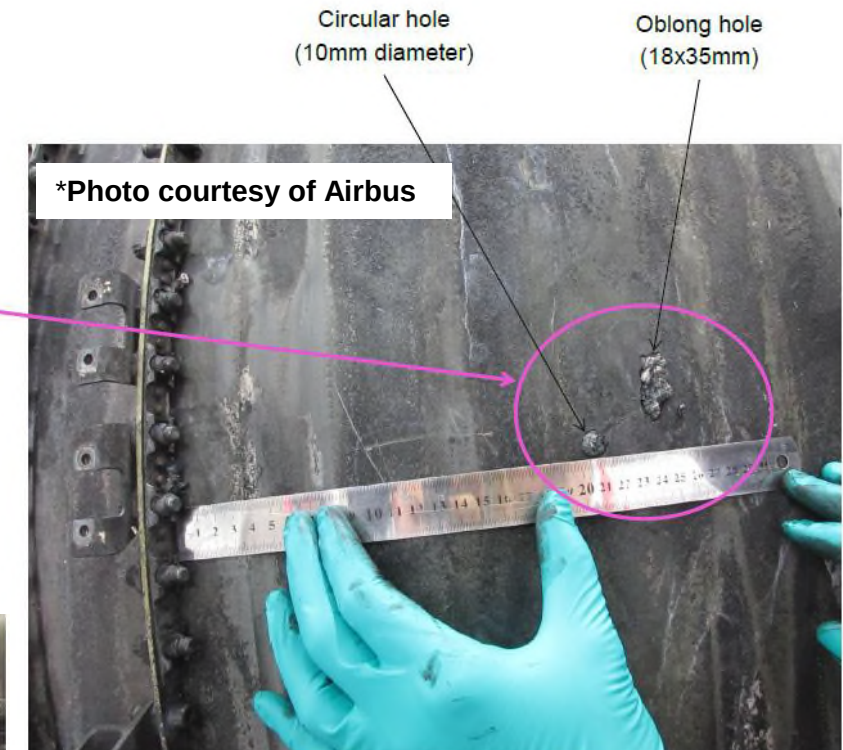
*Summary of teardown findings on LPT case:

- During teardown, two holes in the LPT case located in line with the TCC duct were noted
- The TCC manifolds and external surface of the case in the area of the holes exhibited significant thermal damage
- The holes were filled with molten material

*Reference Airbus report “*Observations made during engine undressing at ESA Singapore, May 2018*” dated 9/20/2018



LPT2 rotor axial position (TBC)



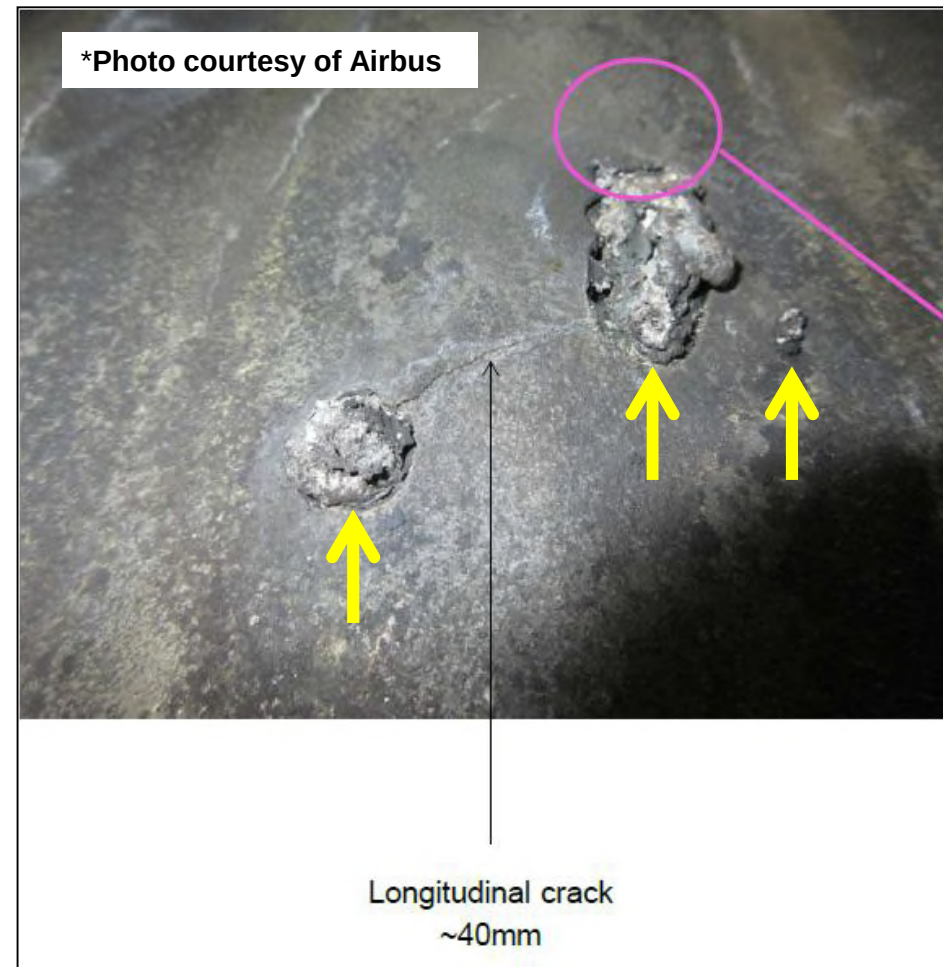
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P733603 LPT CASE – OBSERVATIONS FROM TEARDOWN REPORTS

REFERENCE AIRBUS REPORT FROM ESA VISIT

*Summary of teardown findings on LPT case :

- Airbus teardown report identified two large regions of molten material filling the holes in the thermally damaged area
- These two large regions of molten material were removed during the Airbus visit and were not returned to Pratt & Whitney East Hartford for examination
- Review of the photos contained in the report found that the two large regions were similar in appearance to a third, much smaller surface deposit (yellow arrows, right)
- Continued teardown found that the 4th stage rotor and BOAS appeared intact with no significant damage noted



*Reference Airbus report "*Observations made during engine undressing at ESA Singapore, May 2018*" dated 9/20/2018

P733603 LPT CASE – PRATT AND WHITNEY REVIEW

VISUAL EXAMINATION – OUTER DIAMETER SURFACE

- Visual review of the outer surface of the case as-received found that the area surrounding the 3 o'clock position (ALF) was dark and discolored
 - The surface in this area exhibited a dark, mottled appearance and texture from sooting and metal splatter
- Away from this area, the surface appeared smooth and lighter in color
- Deformation of the outer surface of the case was observed, particularly in the plane of the 4th stage rotor



Dark, mottled surface with sooting and metal splatter



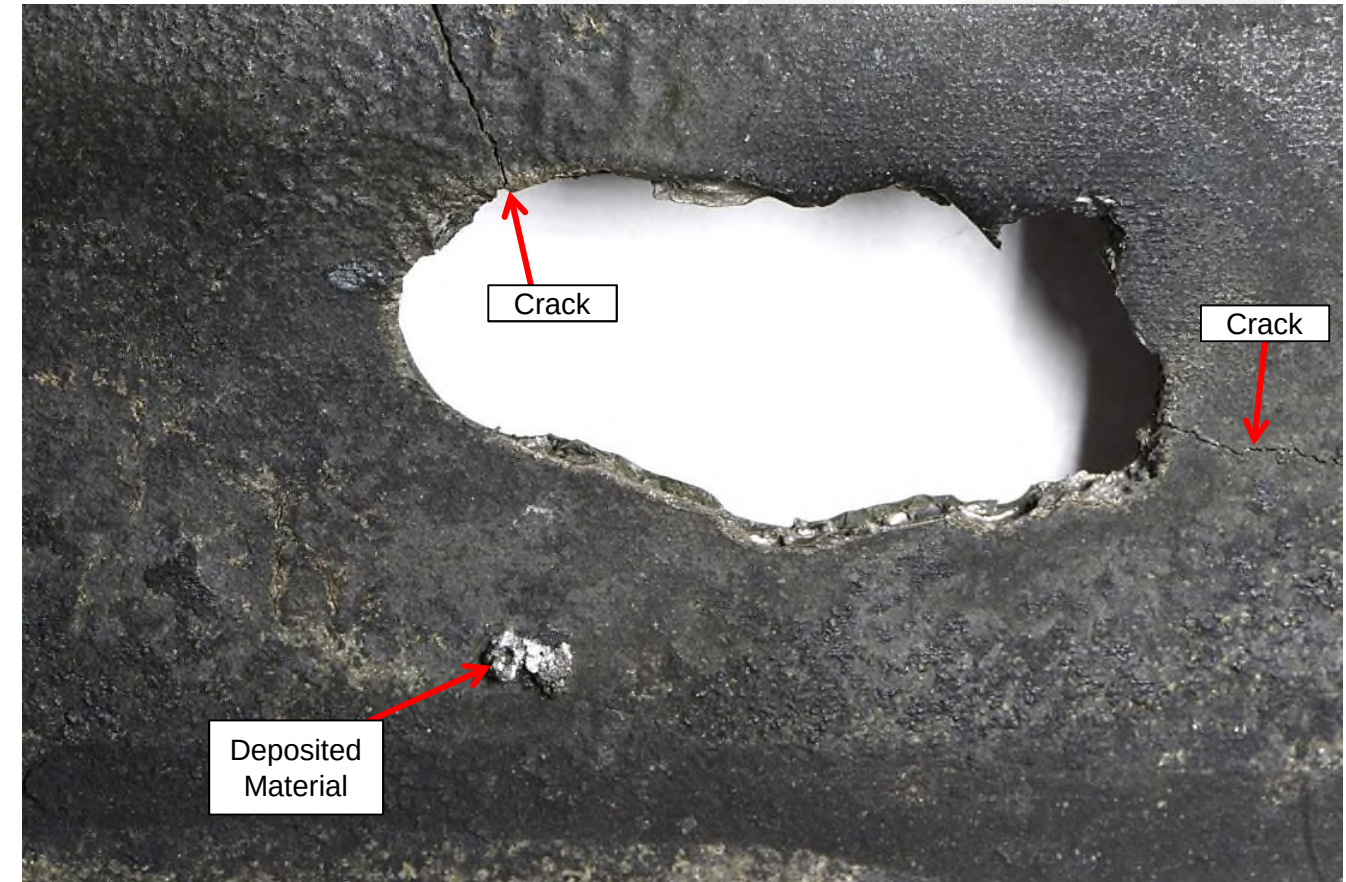
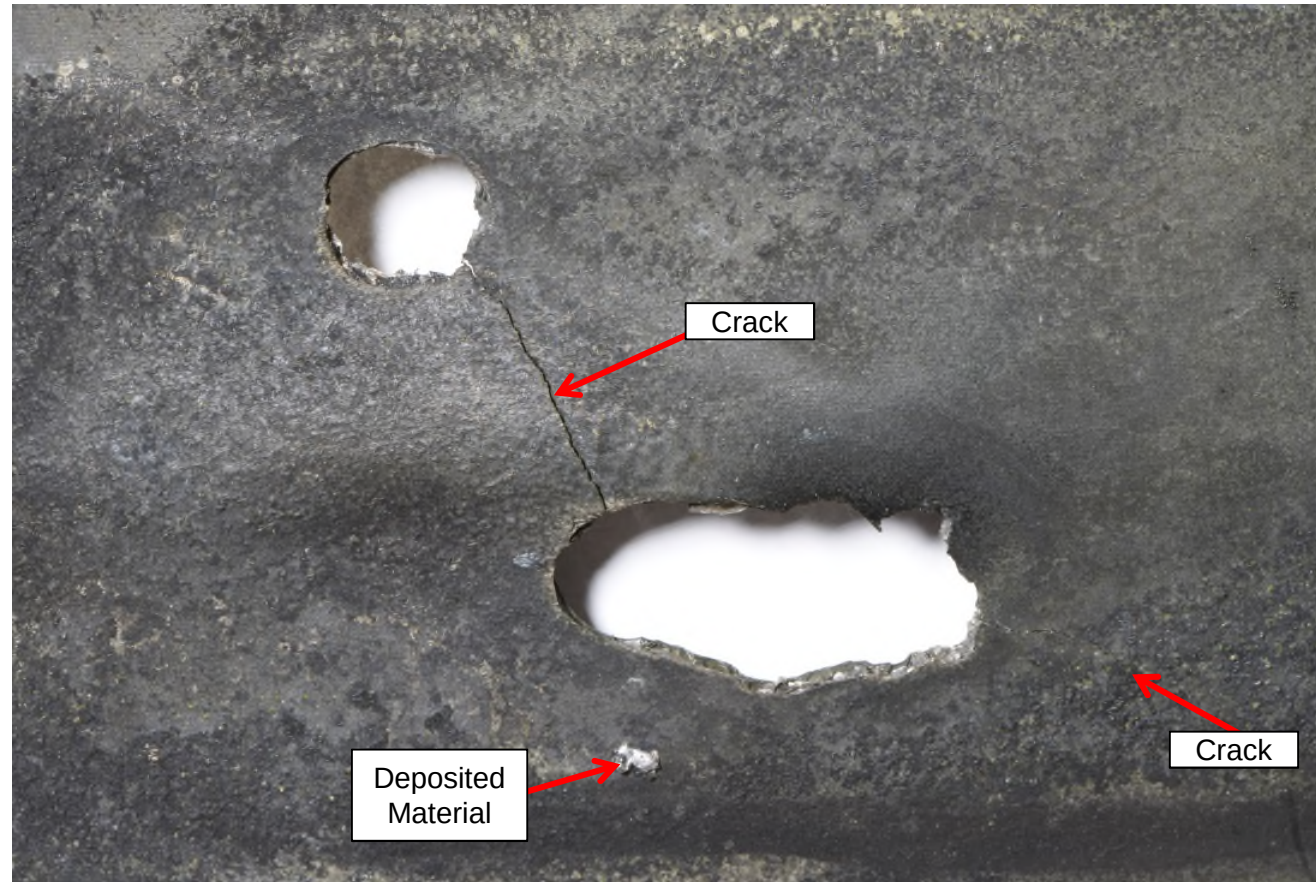
OD surface around the 9 o'clock location



OD surface around the 3 o'clock location

P733603 LPT CASE -PRATT AND WHITNEY REVIEW

VISUAL EXAMINATION – OUTER DIAMETER SURFACE

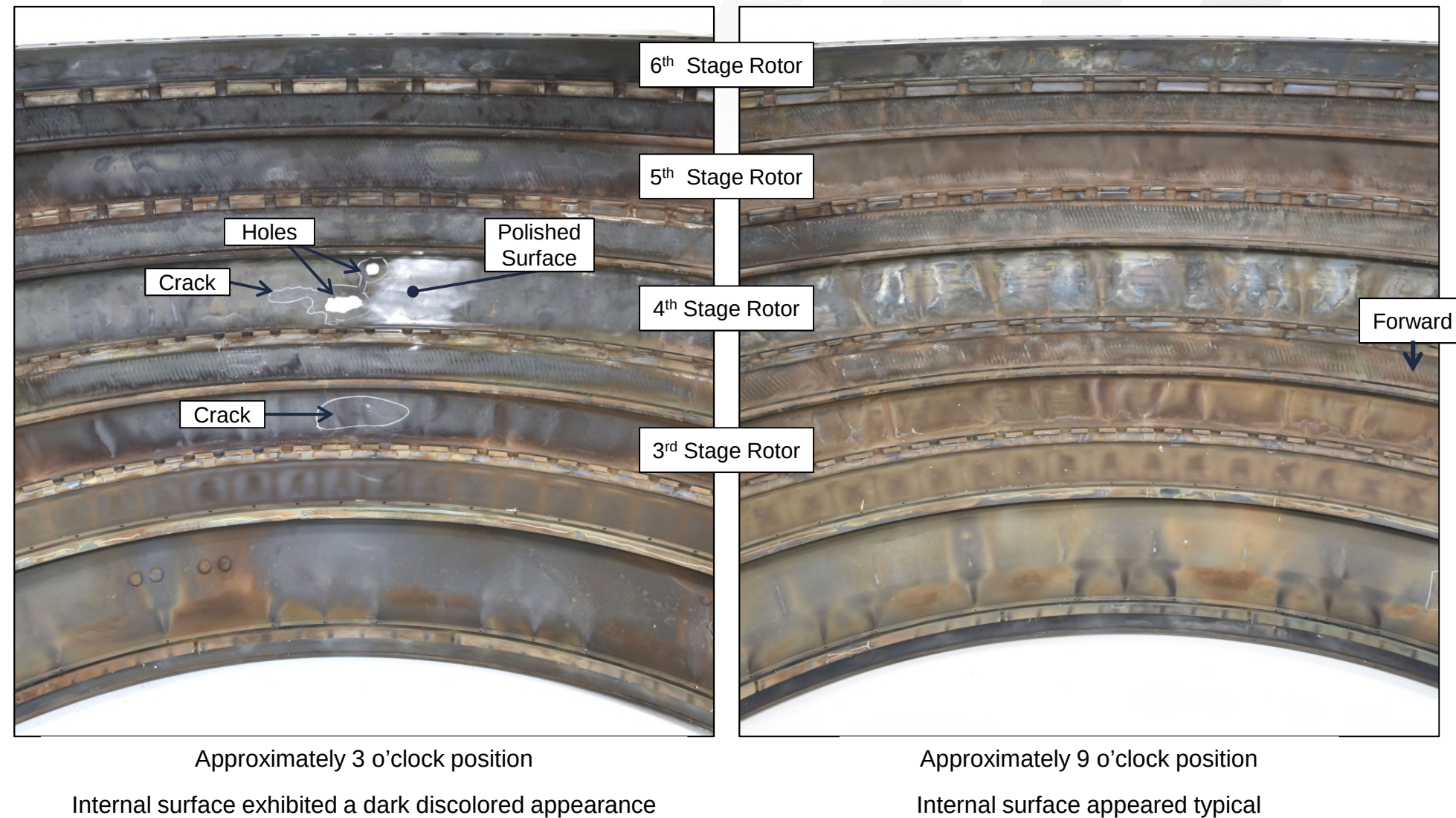


- The OD surface of the case surrounding the holes exhibited a dark, mottled appearance consistent with exposure to a significant thermal event.
- Cracks were observed between the two holes and extending from the larger hole.
- Deposited material noted during the teardown was still in place adjacent to the larger hole.
- No other deposits of significant height were observed on the external surface of the case.

P733603 LPT CASE -PRATT AND WHITNEY REVIEW

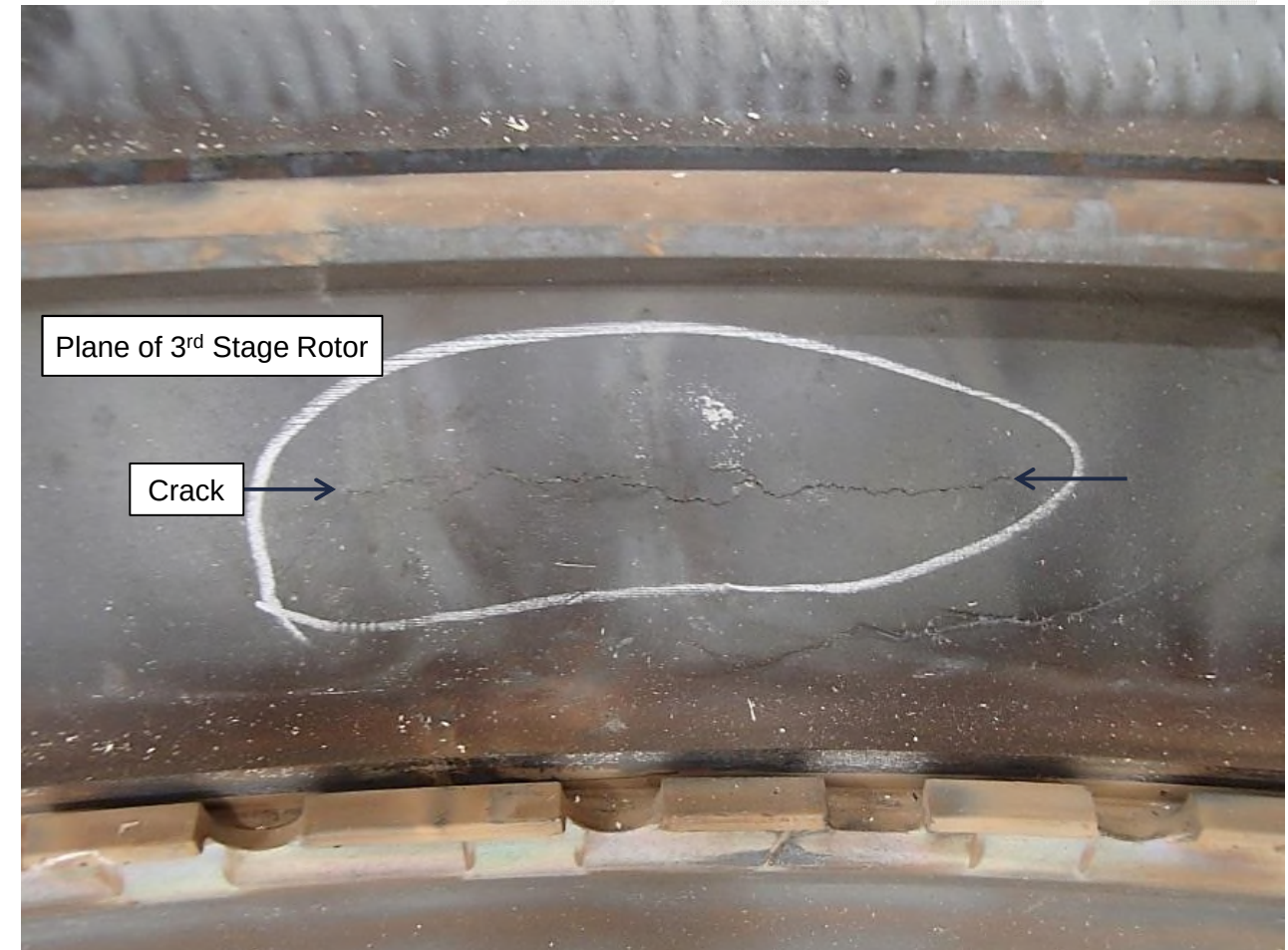
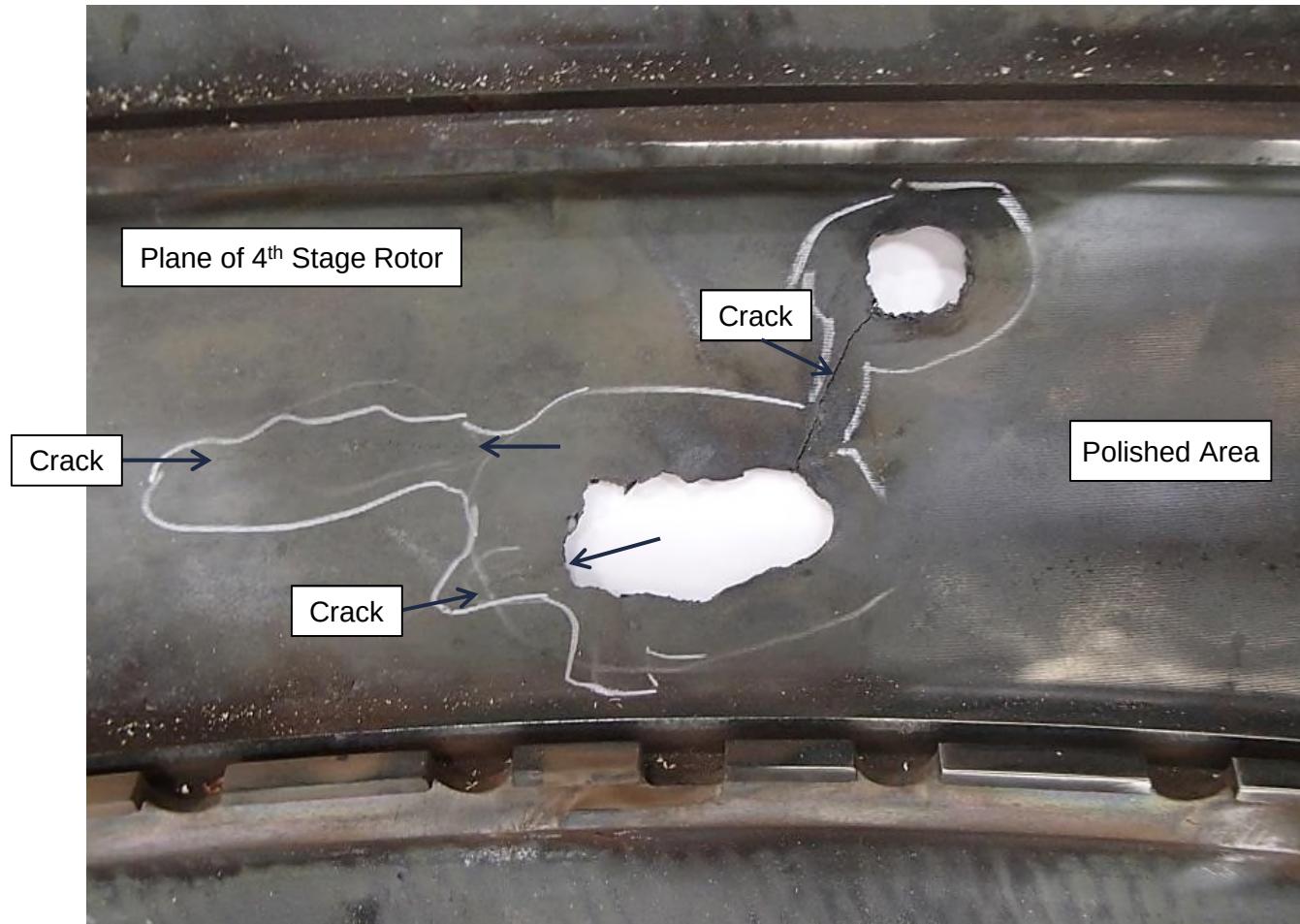
VISUAL EXAMINATION – INNER DIAMETER SURFACE

- Review of the internal surface of the case found that the region surrounding the holes (3 o'clock position, ALF) exhibited a dark, discolored appearance
- Two holes were observed in the plane of the 4th stage rotor. Cracking was observed in the planes of both the 3rd and the 4th stage rotors
- The internal surface adjacent to the holes appeared to have been lightly cleaned/polished



P733603 LPT CASE-PRATT AND WHITNEY REVIEW

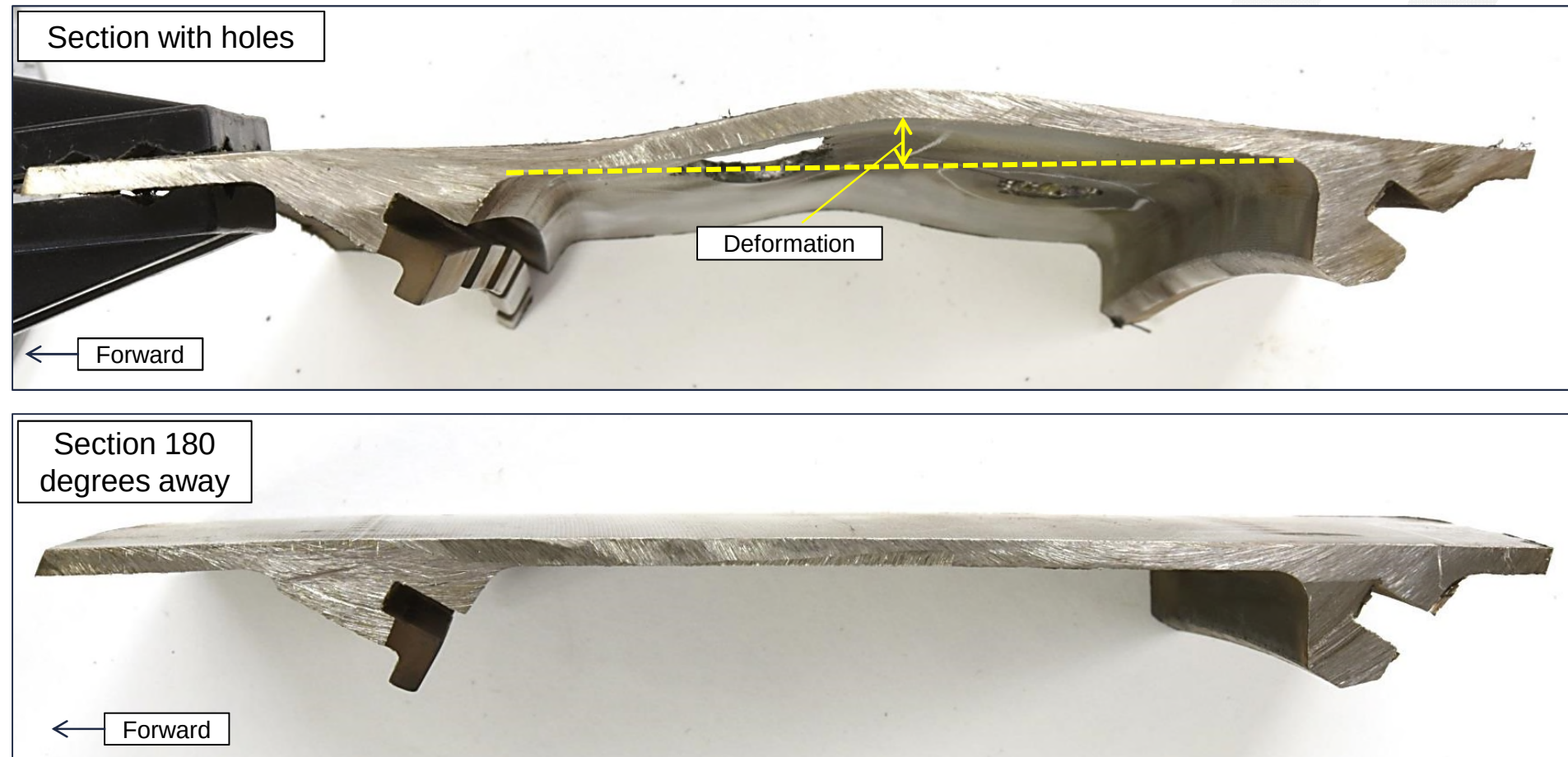
VISUAL EXAMINATION – INNER DIAMETER SURFACE AT THE 3 O'CLOCK POSITION, ALF



- Cracking in the plane of the 3rd stage rotor and a portion of the cracks in the plane of the 4th stage rotor did not appear to have extended through wall
- The internal surface adjacent to the holes in the plane of the 4th stage rotor appeared to have been lightly cleaned/polished

P733603 LPT CASE-PRATT AND WHITNEY REVIEW

DESTRUCTIVE EXAMINATION

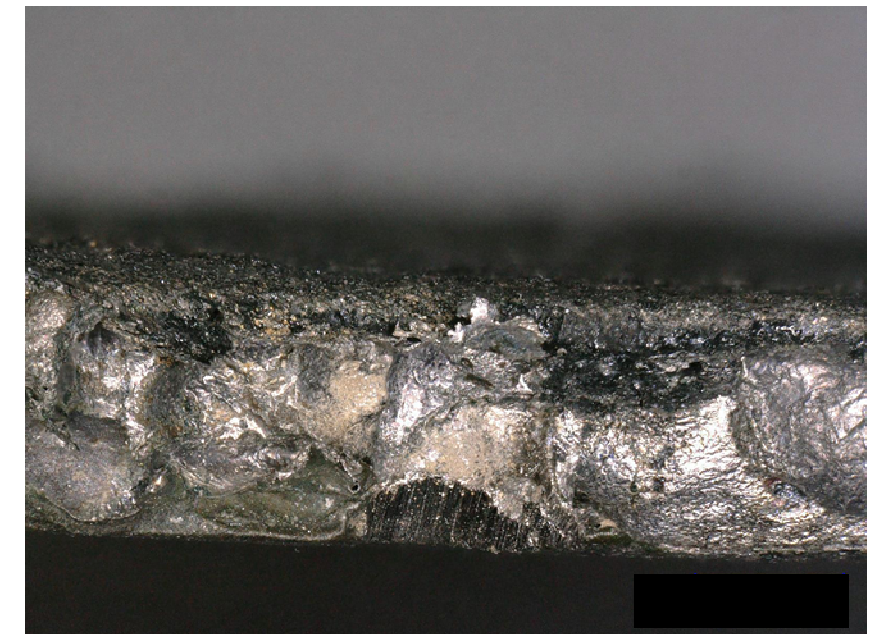
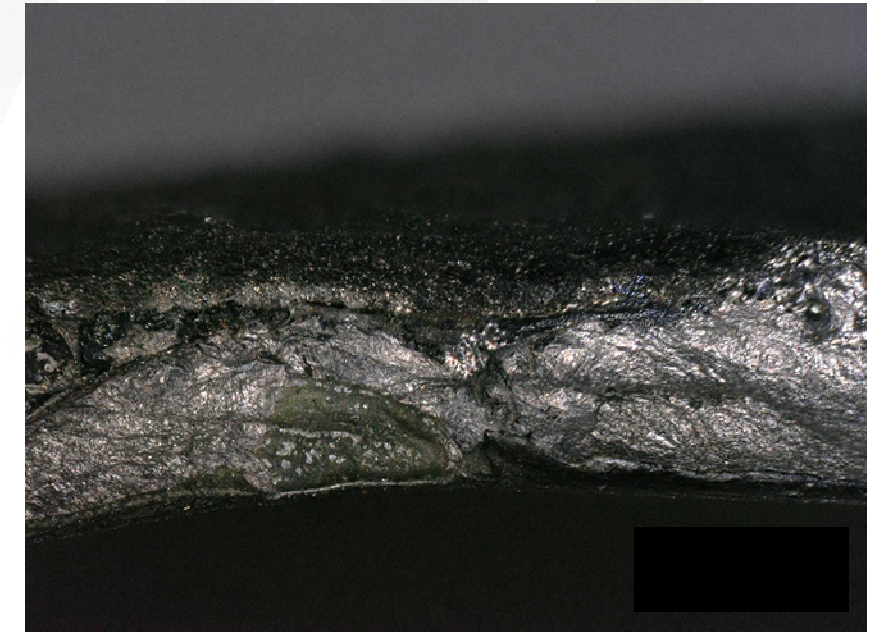


- Two sections were removed from the case
 - One section included both the holes and deposited material in the plane of the 4th stage rotor
 - The second section was from the plane of the 4th stage rotor, approximately 180 degrees away from the holes
- The section with the holes appeared deformed/buckled when compared to the section 180 degrees away

P733603 LPT CASE-PRATT AND WHITNEY REVIEW

VISUAL EXAMINATION – HOLE SURFACE

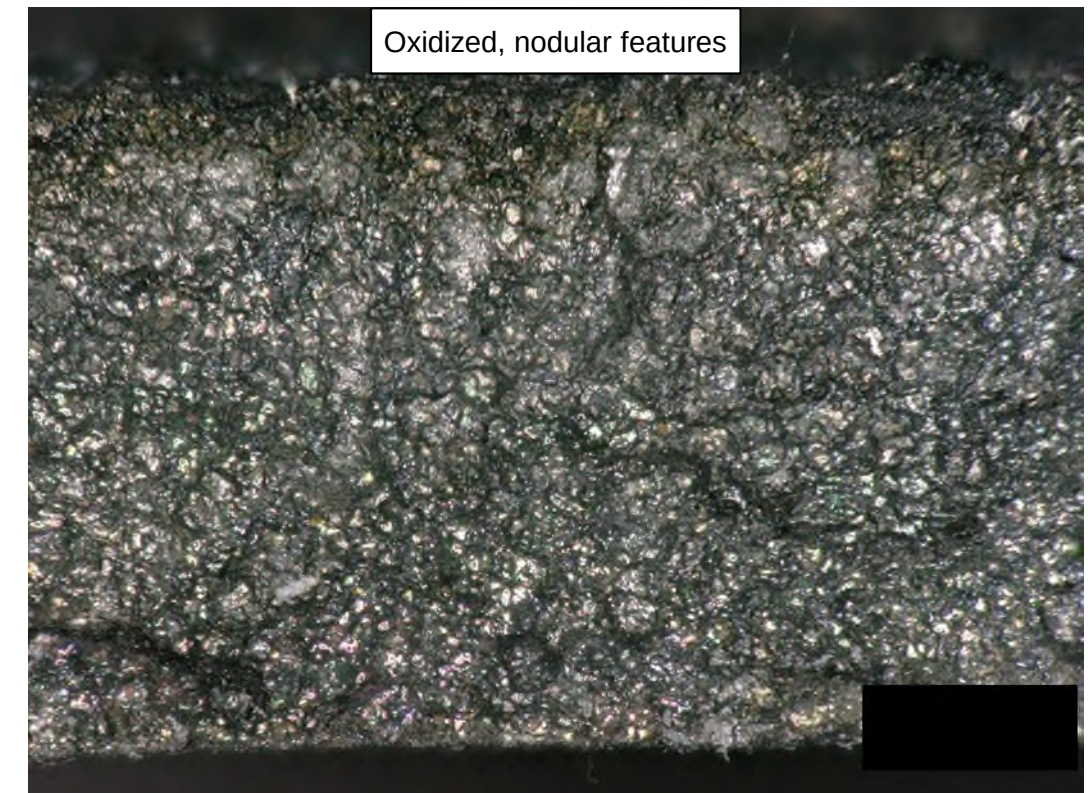
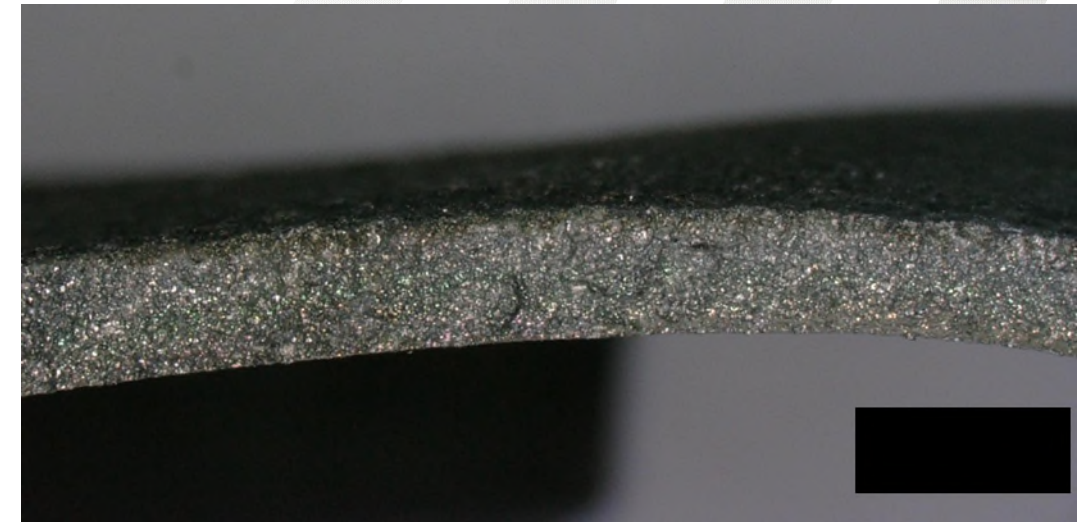
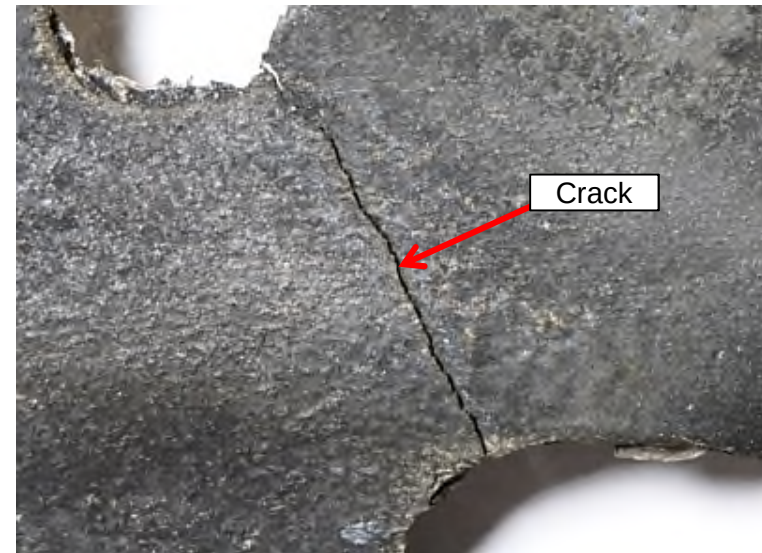
- Visual and binocular review of the hole surfaces was completed
- The surfaces exhibited an intergranular appearance with evidence of melting (grain boundary decohesion and/or liquation)
- The surface appearance was suggestive of significant grain growth
- No evidence of fatigue was observed



P733603 LPT CASE-PRATT AND WHITNEY REVIEW

VISUAL EXAMINATION – CRACK SURFACE

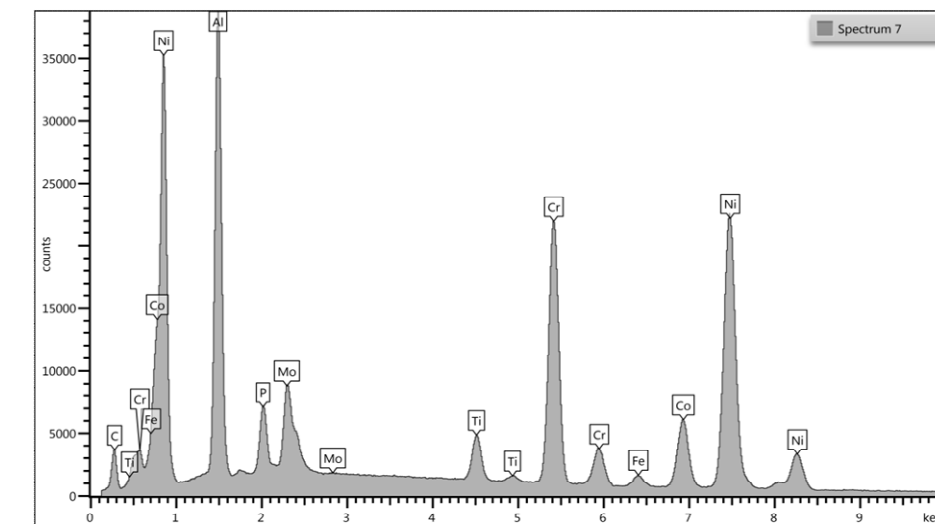
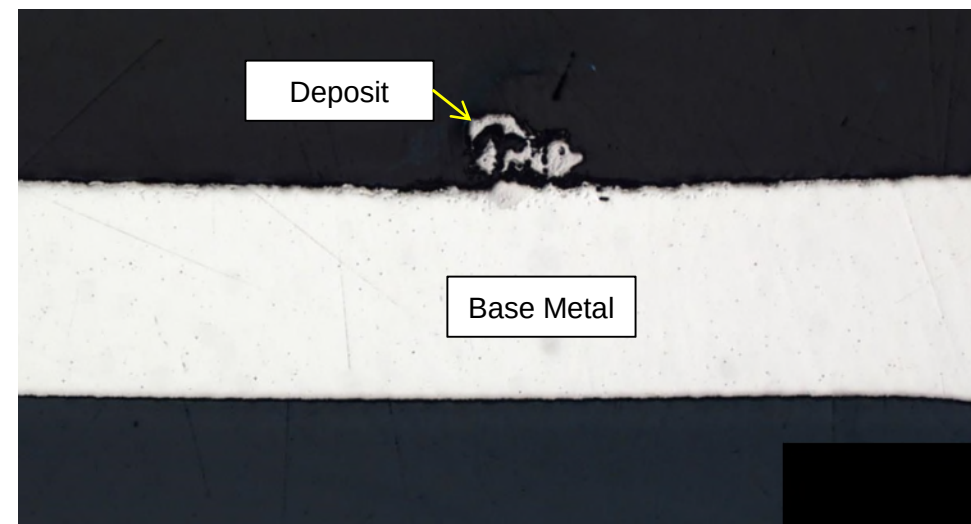
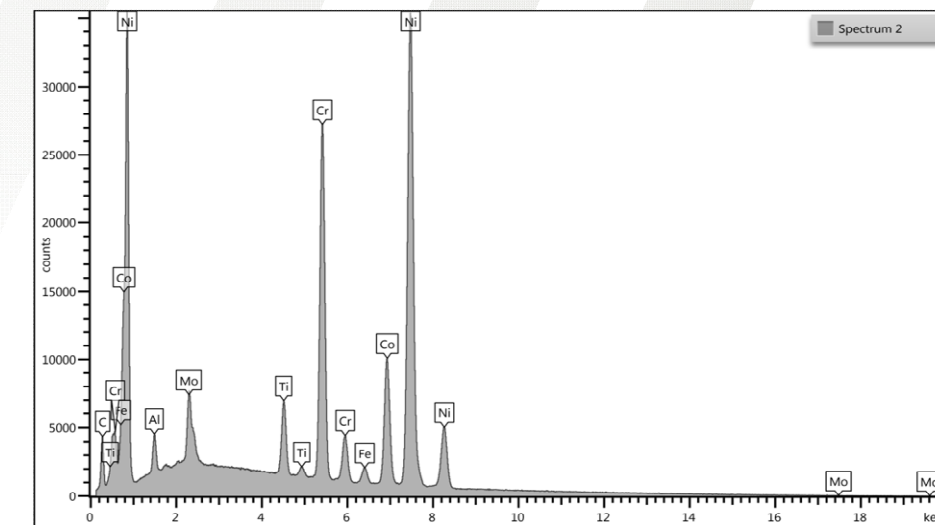
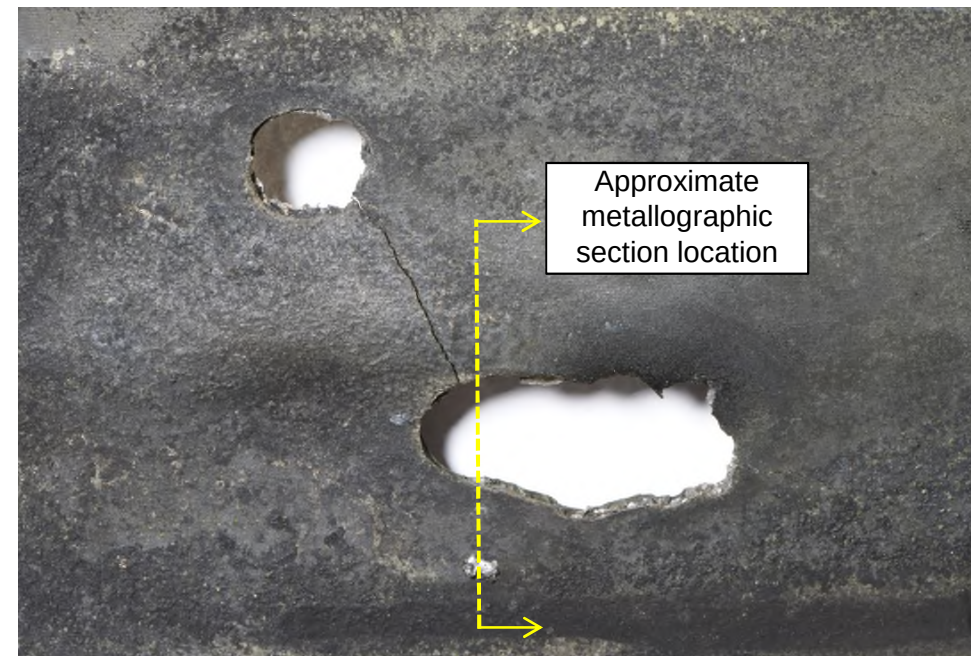
- The crack between the two holes was fractured open for review
- The crack surface exhibited an oxidized, nodular appearance consistent with intergranular cracking
- Crack features suggested a smaller grain size than that observed at the hole



P733603 LPT CASE-PRATT AND WHITNEY REVIEW

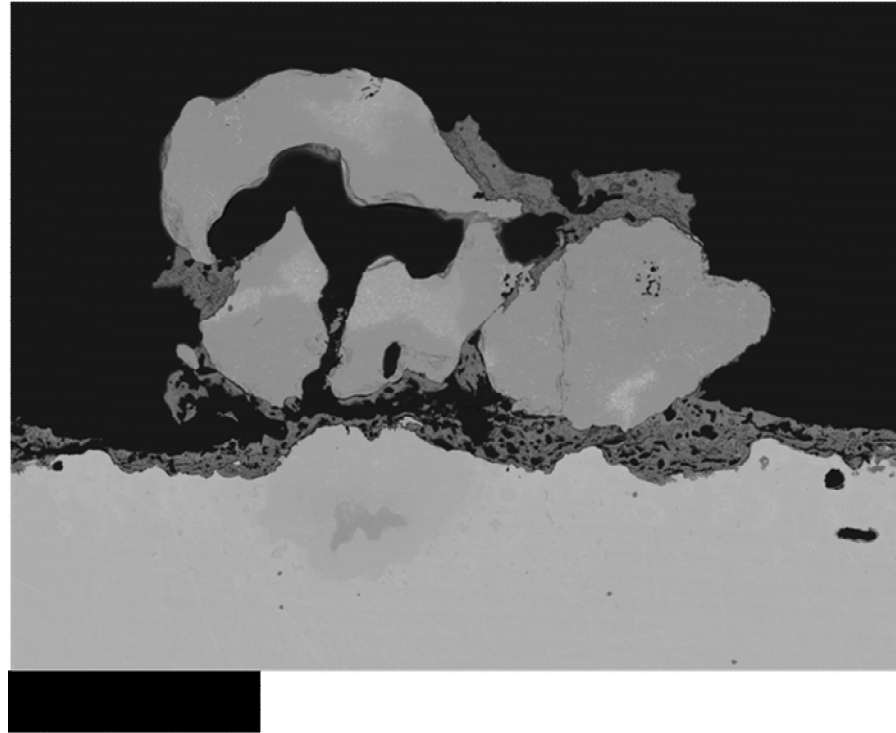
DESTRUCTIVE EXAMINATION

- A metallographic section was prepared through the deposit on the OD of the case
 - An oxide layer was observed on the case OD surface and the deposit surface
 - Some mixing/diffusion was observed into the base metal
- SEM/EDS analysis confirmed the base metal composition to be consistent with Waspaloy
- SEM/EDS analysis of the deposit typically found a composition with high amounts of aluminum, nickel, and chromium
 - The relative percentages of the elements varied depending on the location
 - This composition did not match any known materials

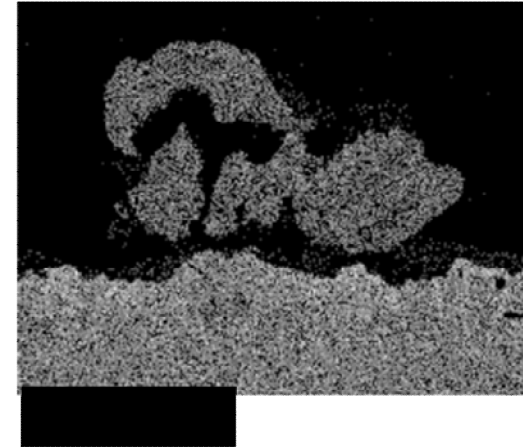


P733603 LPT CASE-PRATT AND WHITNEY REVIEW

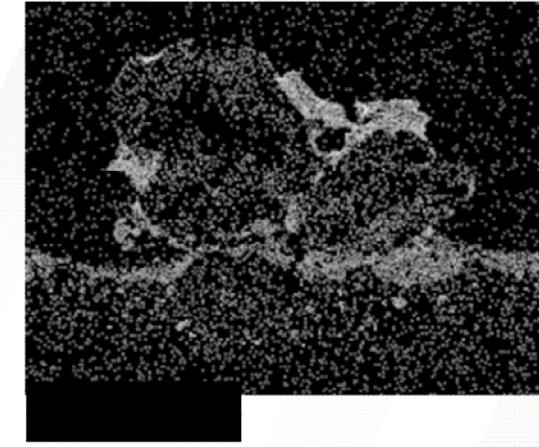
DESTRUCTIVE EXAMINATION



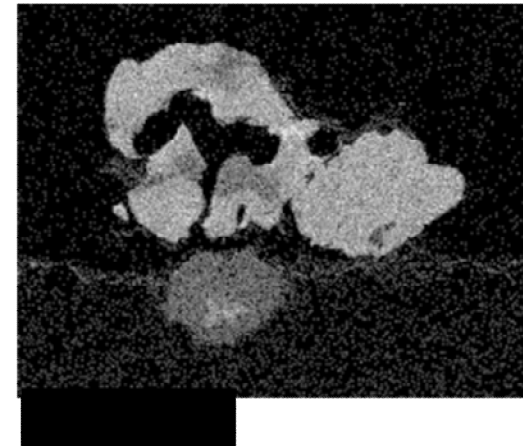
Ni K series



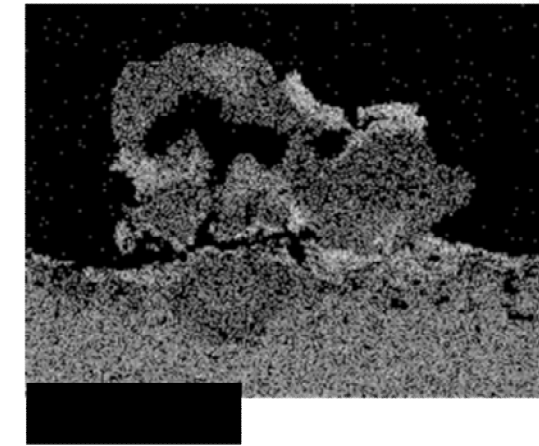
P K series



Al K series



Cr K series

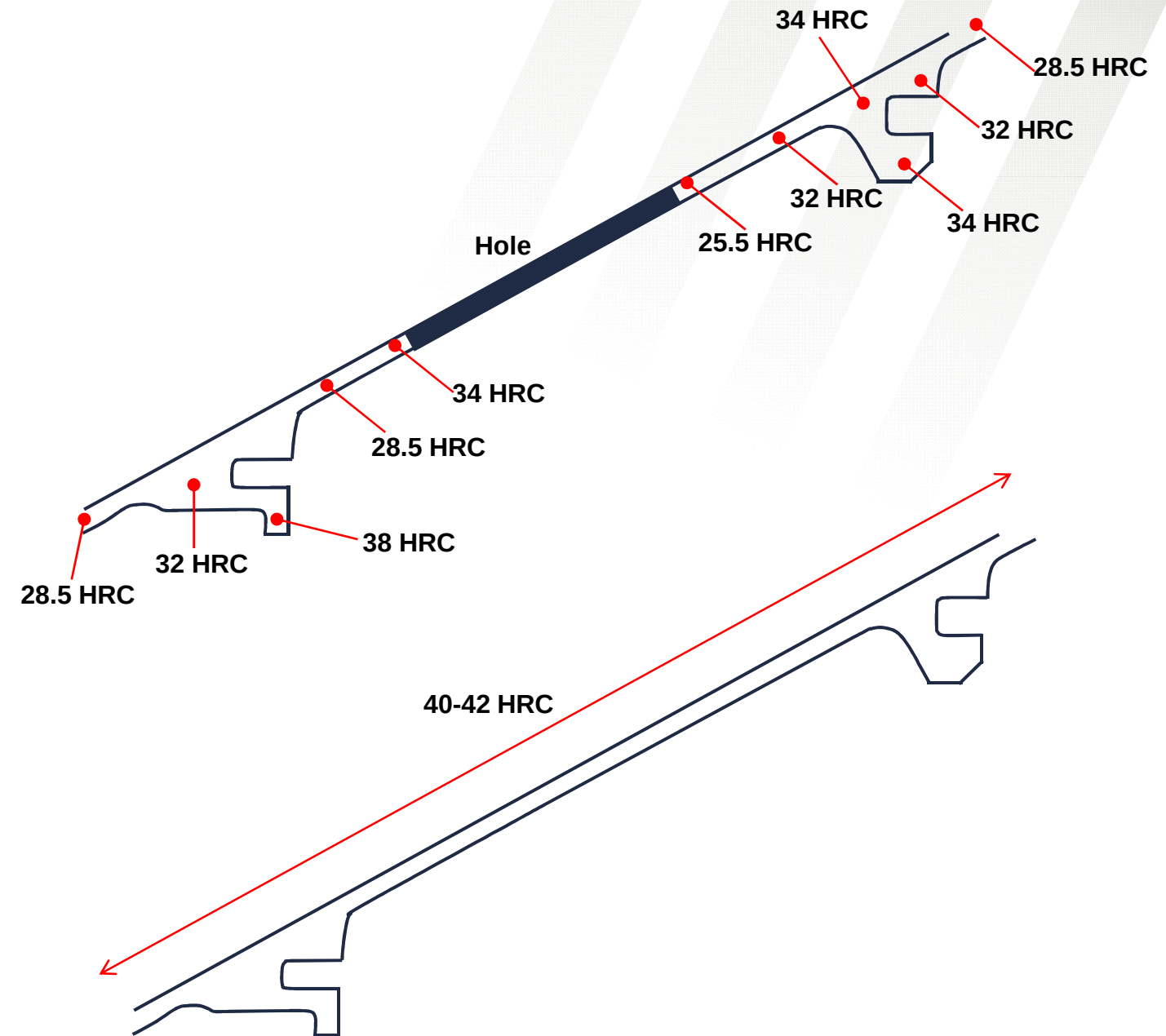


- SEM energy dispersive spectroscopy (EDS) and maps showed that the deposit included a high concentration of aluminum
- The composition of the deposit was not uniform; this indicated a mixture of different materials
- A layer of phosphorous was observed on the deposit and along the surface of the case; phosphorous is commonly found in hydraulic fluid and oil

P733603 LPT CASE-PRATT AND WHITNEY REVIEW

HARDNESS MEASUREMENTS

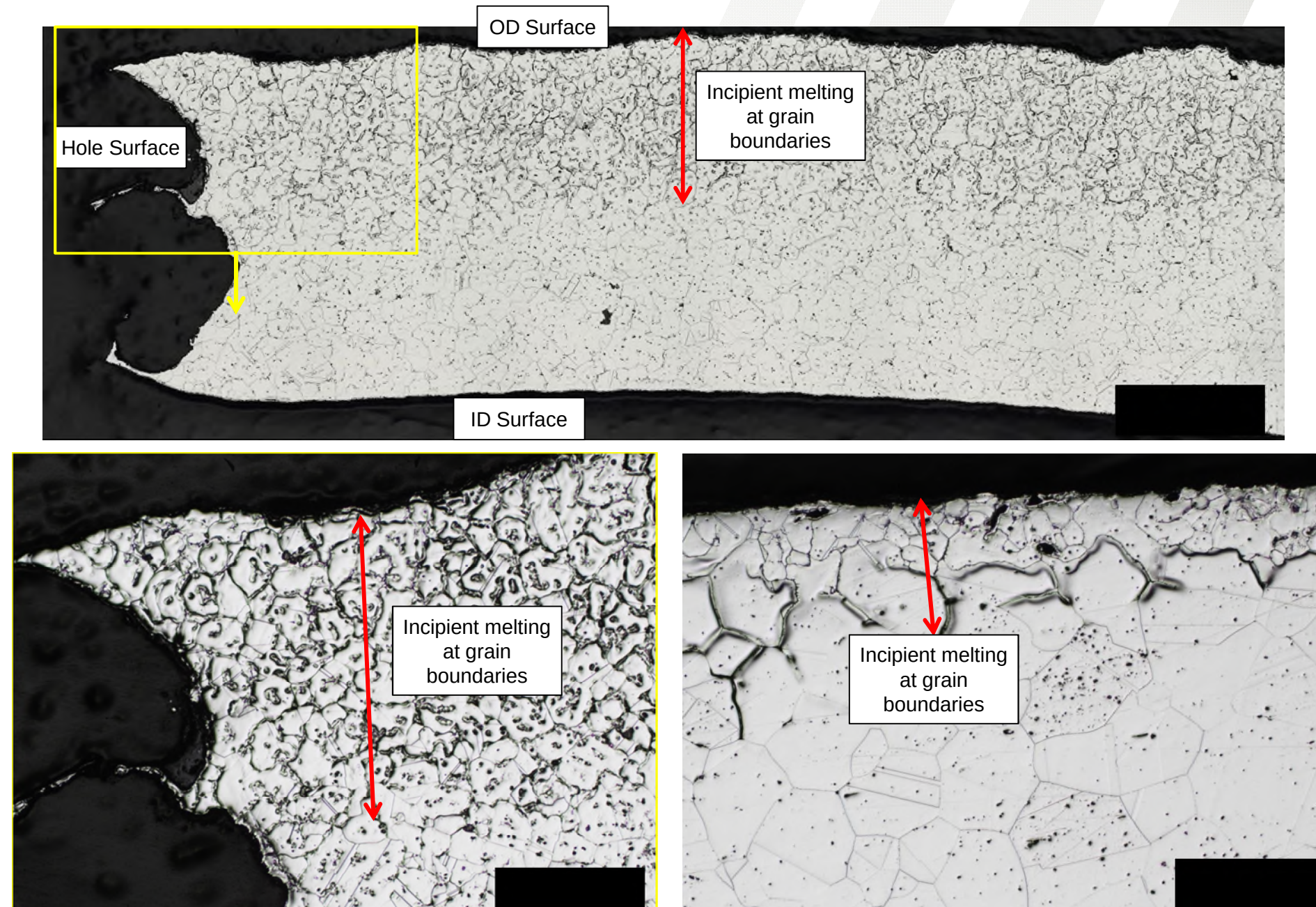
- Hardness measurements were taken across the section prepared through the deposit and hole
- Measurements ranged from a minimum of 25.5 HRC to a maximum hardness of 38 HRC
- Locally higher values near the hole may have been a result of rehardening of the material
- These hardness measurements indicate exposure to elevated temperatures of at least 1700F, based on a study of 10 hour exposures
- Hardness measurements on the section 180 degrees away ranged 40-42 HRC with no significant variation observed; these values conformed to the hardness requirement for the material



P733603 LPT CASE-PRATT AND WHITNEY REVIEW

METALLOGRAPHIC EXAMINATION

- Metallographic examination of the section prepared through the hole and deposit found evidence of significant thermal exposure
- Evidence of incipient melting at the grain boundaries was observed at the OD surface near the hole and extending up to halfway through the wall thickness
- Incipient melting in this material occurs at temperatures greater than 2400F



P733603 LPT CASE-PRATT AND WHITNEY REVIEW

METALLOGRAPHIC EXAMINATION

- Metallographic examination of the section prepared through the hole and deposit found evidence of significant thermal exposure
- Grain size in the heat affected area measured approximately ASTM 0 in the coarsest areas
- Immediately adjacent to the hole and towards the OD surface, grain size appeared finer – Grains in this area had likely recrystallized
- Grain size through the section from the location 180 degrees away from the holes measured ASTM 5 typical
- The material specification requires a grain size of ASTM 3 or finer

