Advancements in Gas Turbine Repair Technology Resulting from Gas Turbine Design Evolution

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Canadian Gas Association
Association canadienne du gaz

IAGT™

IAGT Fall 2010 Course – Hamilton, Ontario

Agenda

- Gas Turbine Design Evolution
- Repair Process
- Technological Advancements to Address Repair Challenges

Design Evolution

Westinghouse
W191 Blade

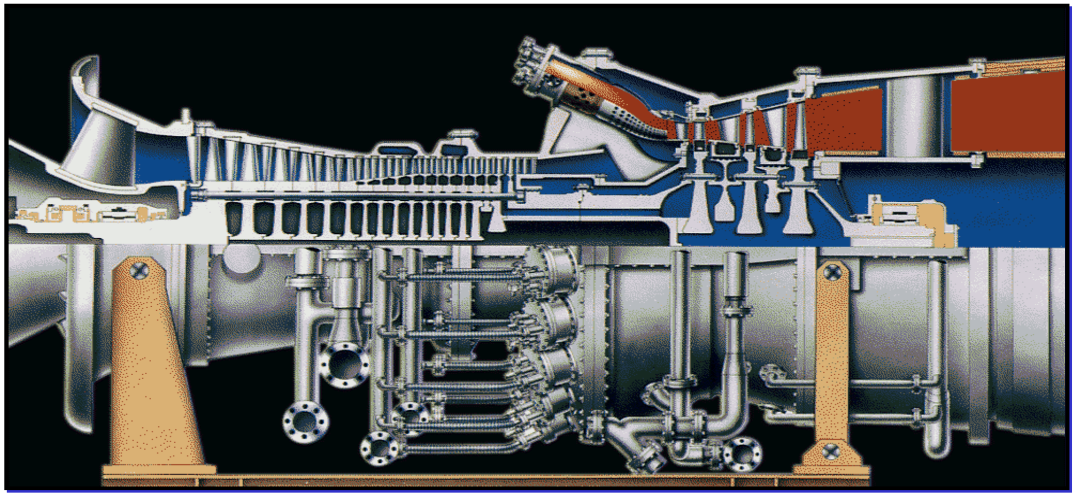
GE Frame 7FA
Row 1 Bucket

Gas Turbine Design

- Performance Improvements
- Increased Power Output
- Increased Efficiency
- Reduced Emissions
- Increased Firing Temperatures
- Increased Flexibility
- Extended Maintenance Intervals

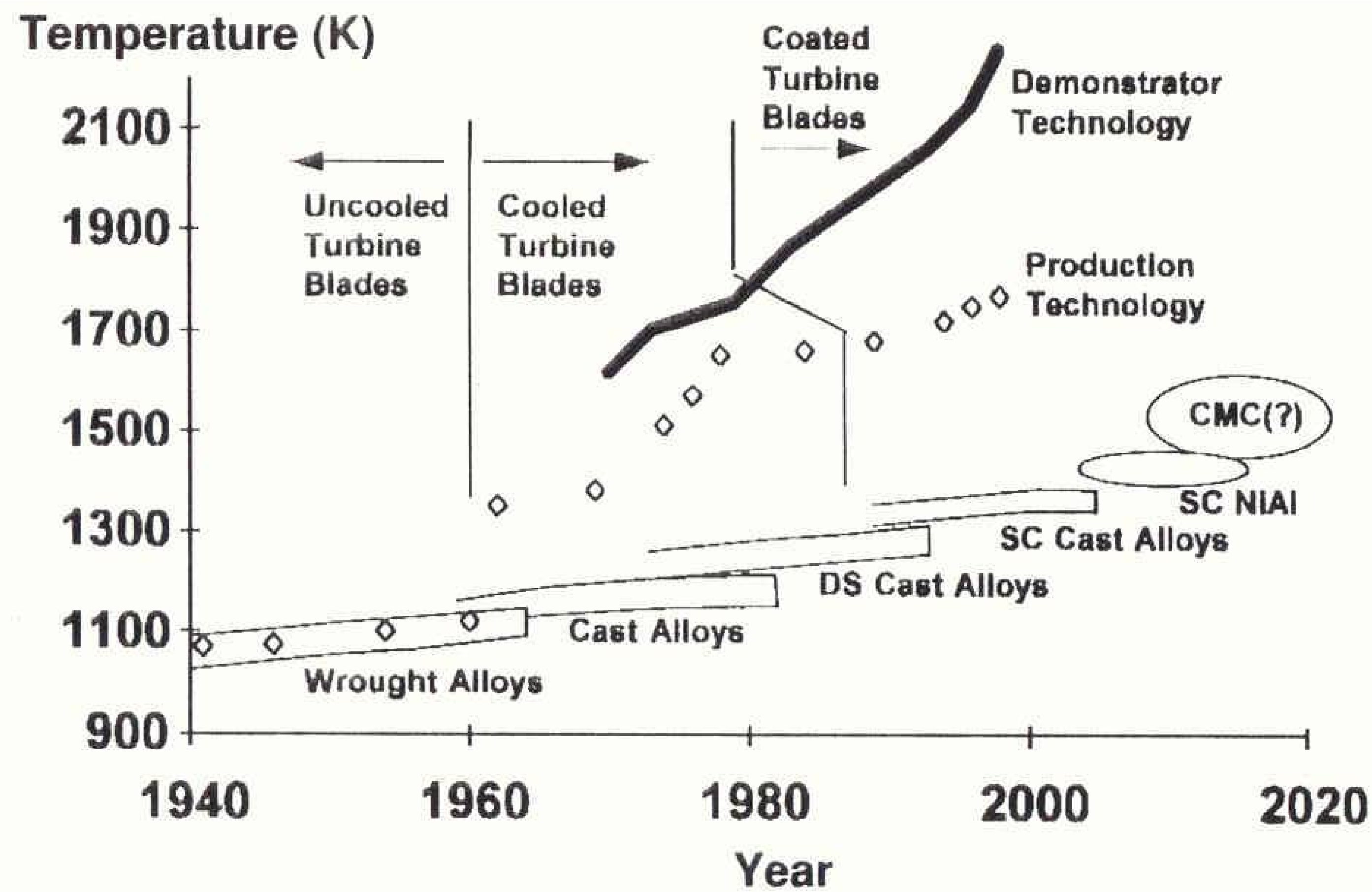
Gas Turbine Design

- Material Improvements
- Advanced Coatings
- Advanced Cooling Designs
- Advanced Geometry



Frame 7FA

Design Evolution



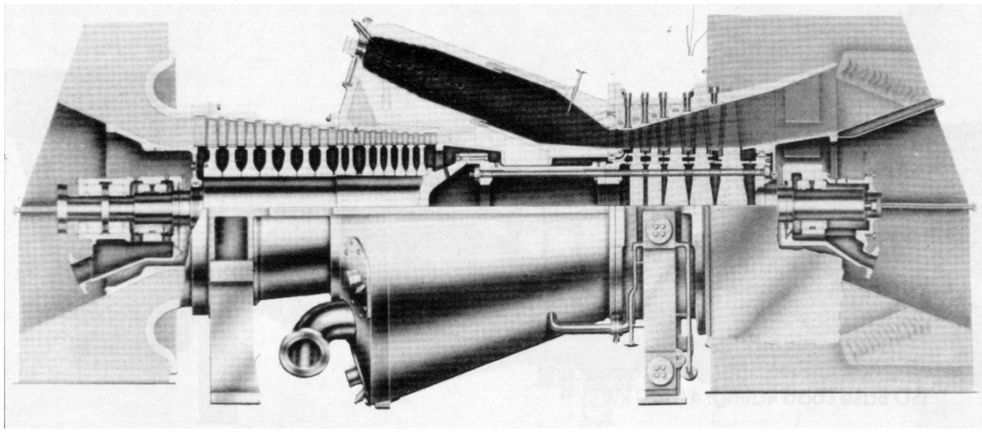
F – Class Design

- F – Class Design derived from Aero Blade
    - Internal cooling circuit design, alloy selection
    - Advanced technologies applied from GE, Rolls-Royce aero experience

F – Class Design

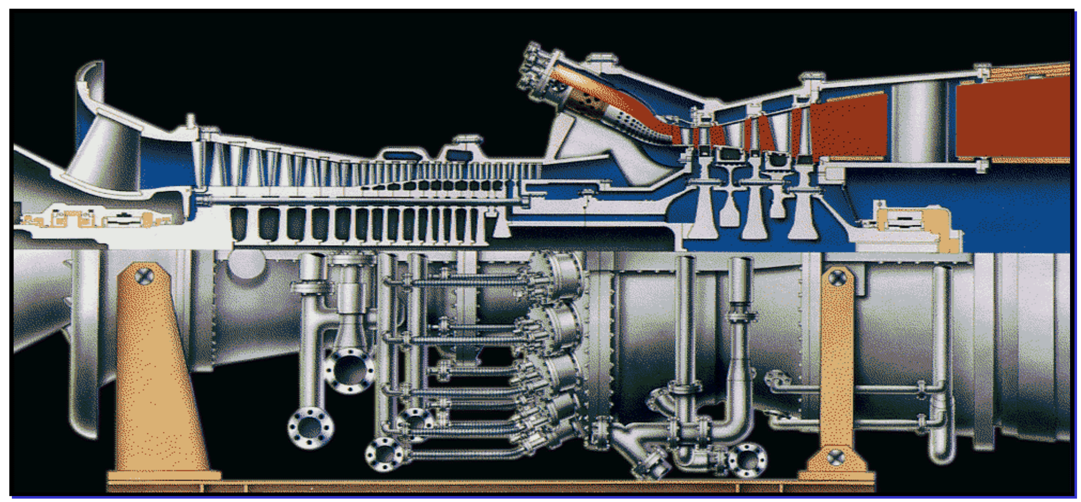
Manufacturer/Model	First Stage Turbine Blade / Bucket
Alstom-GT26	Single Crystal, Ni-Base Matrix Cooled VPS-NiCoCrAlY with APS-TBC
GE-Frame 7FA	Directionally Solidified, GTD111 Serpentine Cooling w/Turbulators LPPS-CoCrAlY/DVC-TBC, Plus Internal Coatings
Siemens V94.3A	Single Crystal PWA1480 VPS-CoNiCrAlYSi Plus Internal Coatings
Siemens-Westinghouse 701G	Directionally Solidified CM247 Serpentine, Film & Showerhead VPS-NiCoCrAlY/TBC
GE LM6000 / RR Trent	Single Crystal, Serpentine, Film, Showerhead Internal coating, EBPVD TBC

Design Evolution



Not only applicable
To Blades

W191



Frame 7FA

Gas Turbine Materials

Compressor
Some 300SS
403, 410, 422,
450 Stainless
IN718
Ti64 titanium

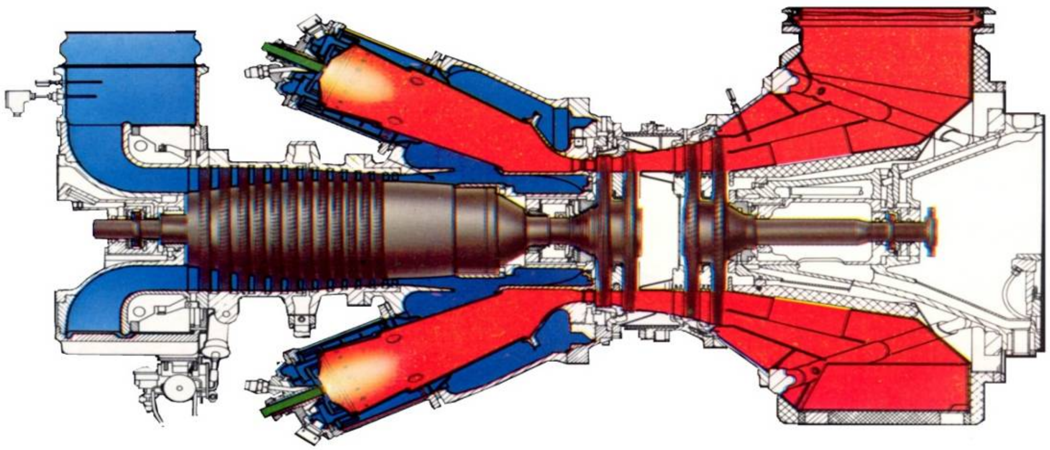
Combustor
300SS
Hastelloy-X, RA-33
IN-600, IN-617
Nimonic 75, Nimonic 263
Haynes 230

Compressor Casings
Grey Cast Iron
Carbon Steel
Aluminum

Turbine Shells
Ductile Cast Iron
Stainless Steel
Nickel Alloy

Compressor Wheels/Disks
Ni-Cr-MO-V
Forging

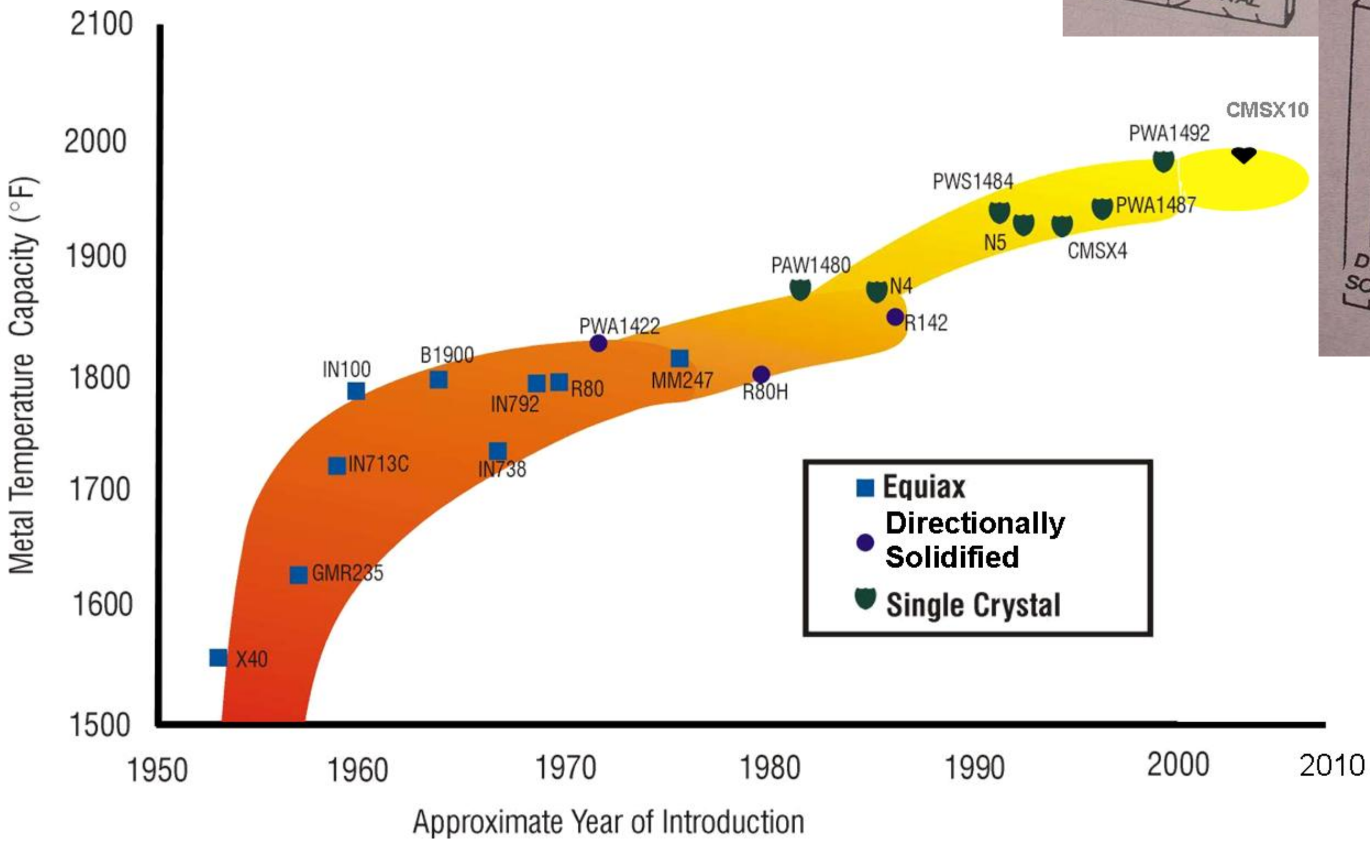
Turbine Wheels/Discs
Ni-Cr-MO-V Steel
Cr-Mo-V Forging
12Cr Stainless
Discalloy
A286
IN718

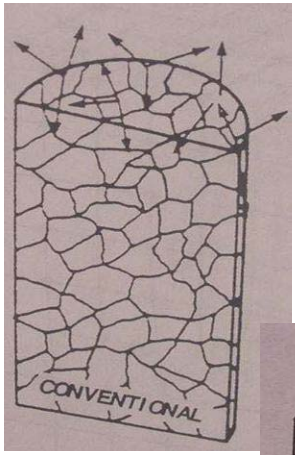


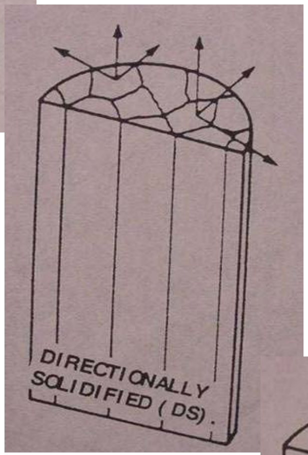
Turbine Rotating
N105, N108, N115, Waspalloy, U-500, U520, U700,U710, U720, INX750, IN738, Rene80, GTD111, Mar-M247, Mar-M002, PWA1483, CMSX4, ReneN5

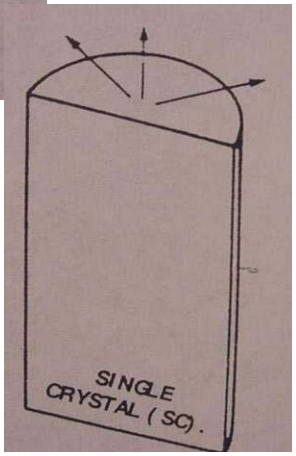
Turbine Stationary
300SS, 400SS, C242, C1023
N-155, M509, HS-188,L605
X-40, X-45, FSX-414, ECY-768
IN738, R80, GTD222, GTD444

Materials









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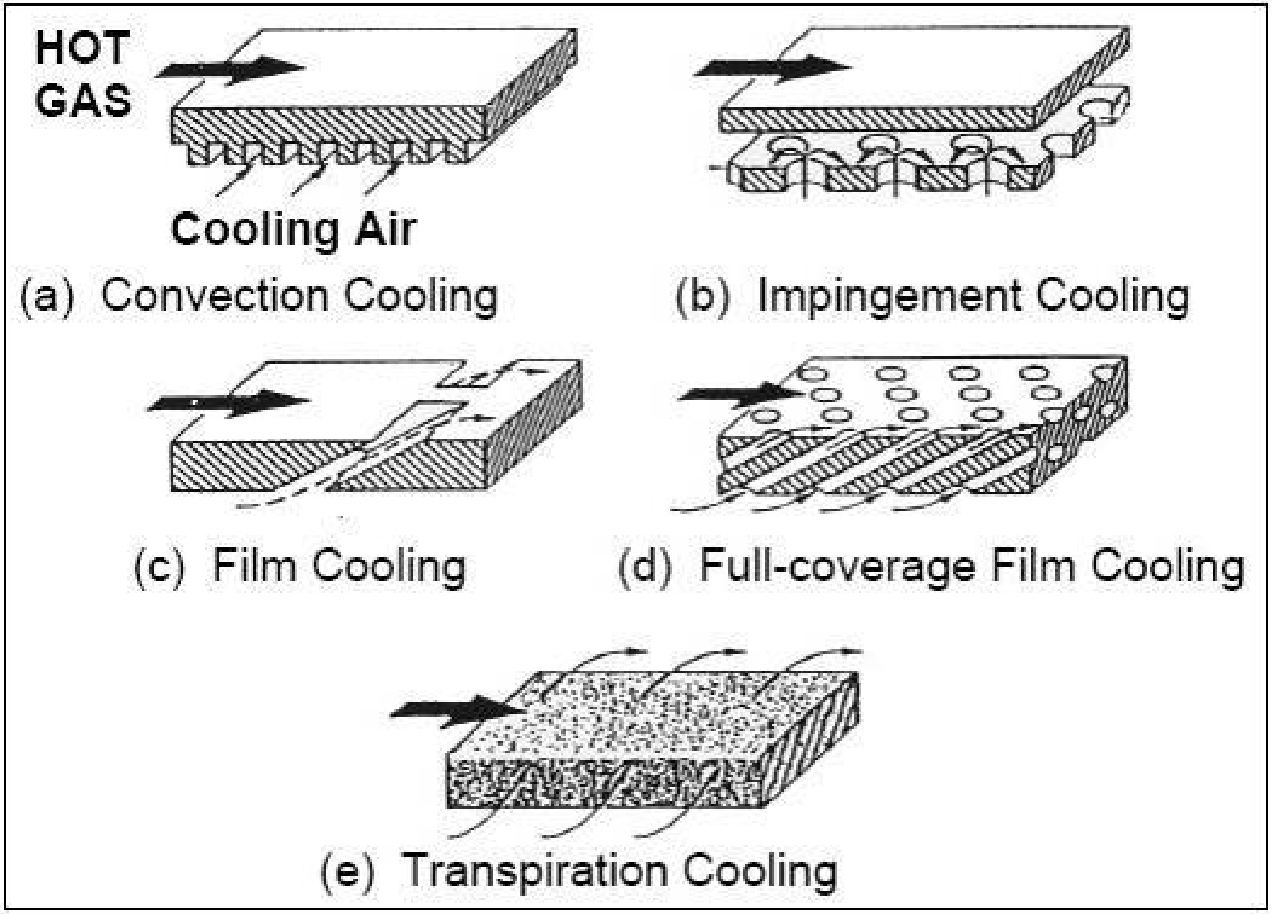
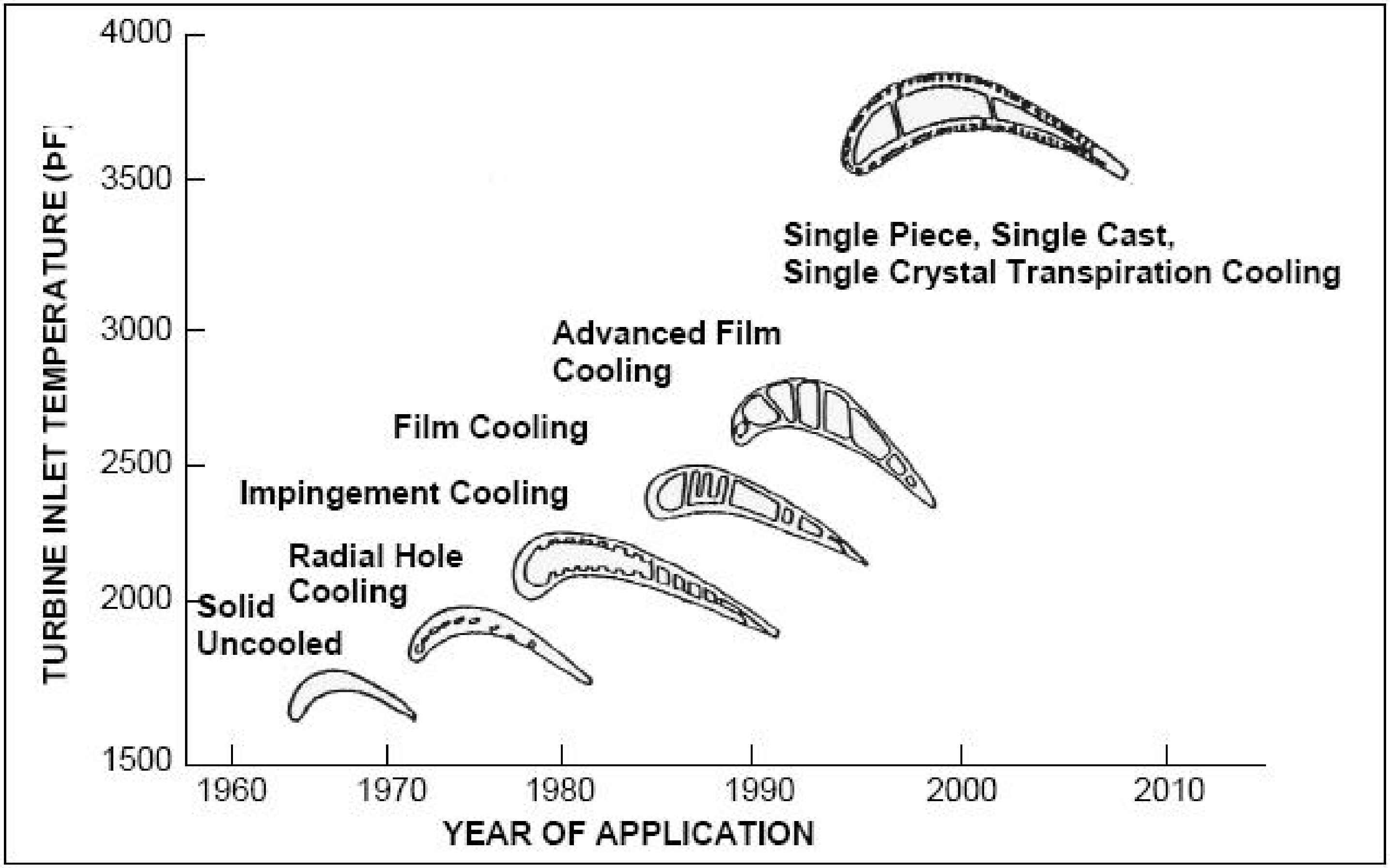
Design Evolution - Cooling



Design Evolution - Cooling



After Frasier US Patent 5295530

Blade Repair Process

- Incoming Inspection
- Strip Coatings
- Fluorescent Penetrant Inspection
- Dimensional Repair
- Machine/Finish Geometry
- Rejuvenation Heat Treatment
- Pre-Coating Inspection
- Coating
- Final Inspection

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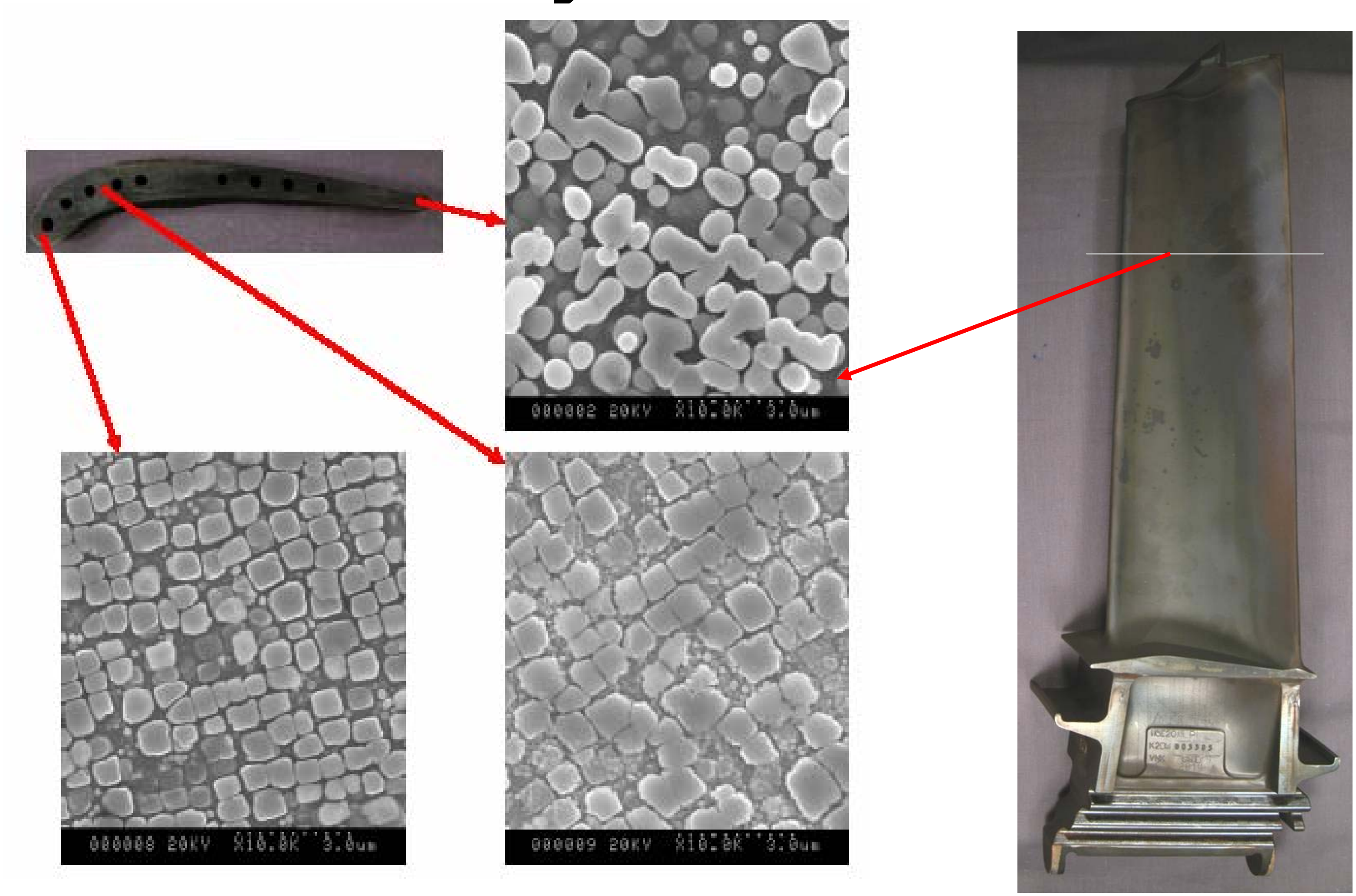
Incoming Inspection

- Triage
  - Is the component repairable?
  - What is the expected level of repair?
- Solid Blades vs. F-Class Internal Geometry
- Increased reliance on life analysis of blade

Life Analysis



Life Analysis

DS Alloy Damage

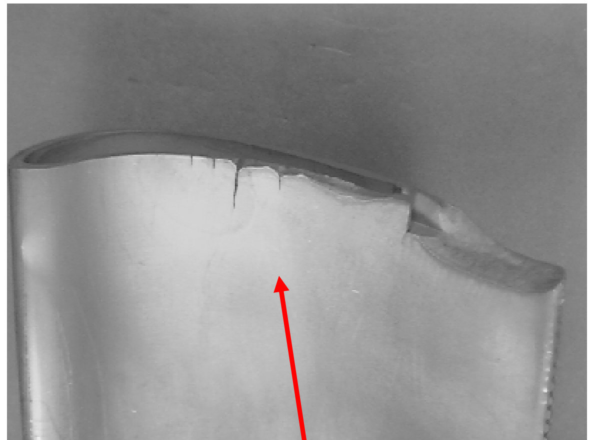
Cracking along DS grain boundaries at tip

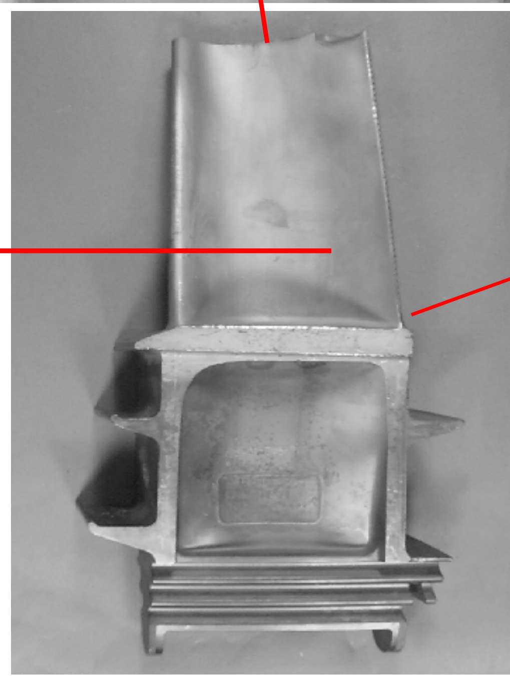
Oxidation burning at tip

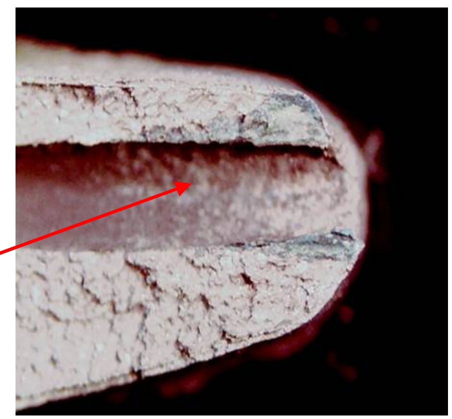
Coating cracks in airfoil

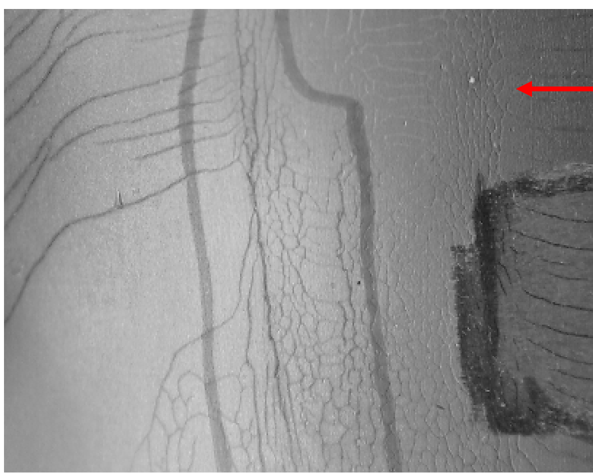
#1 Cooling hole crack

Incomplete internal coating



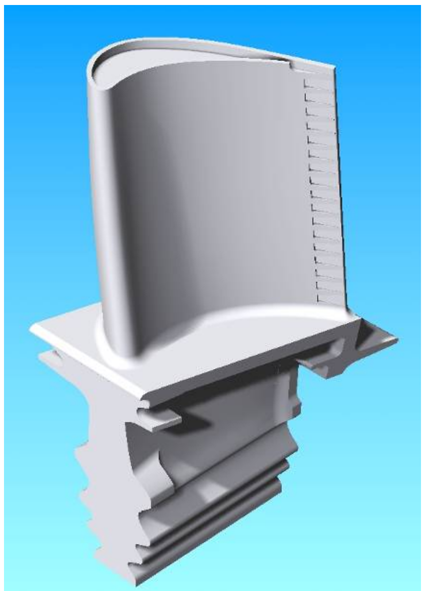
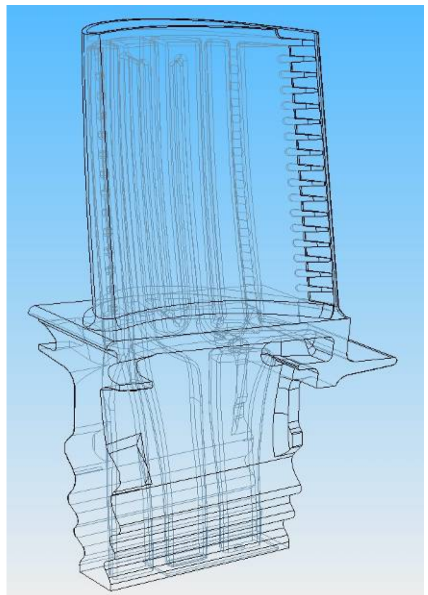


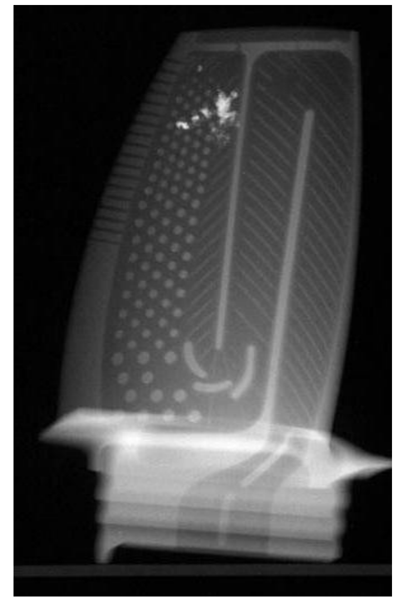




Incoming Inspection

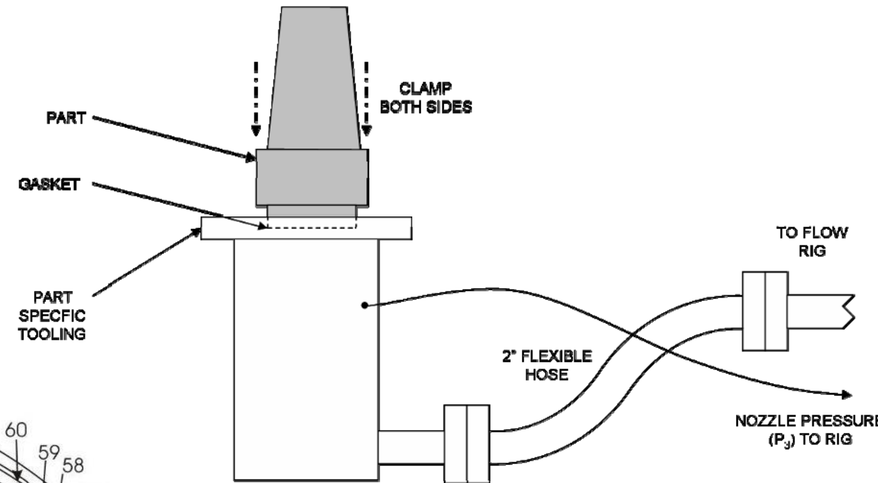
- Internal Geometry

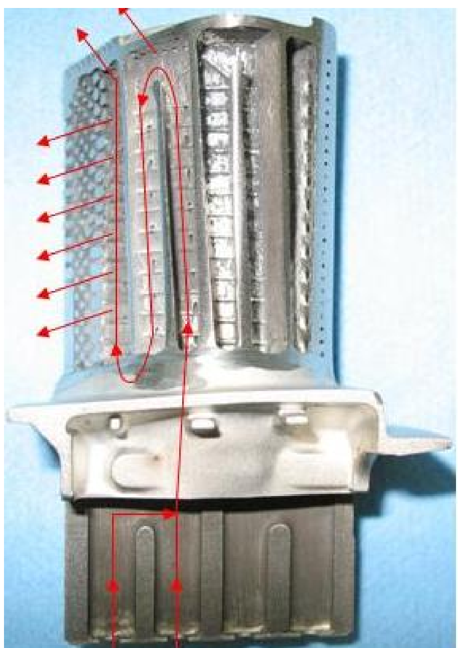





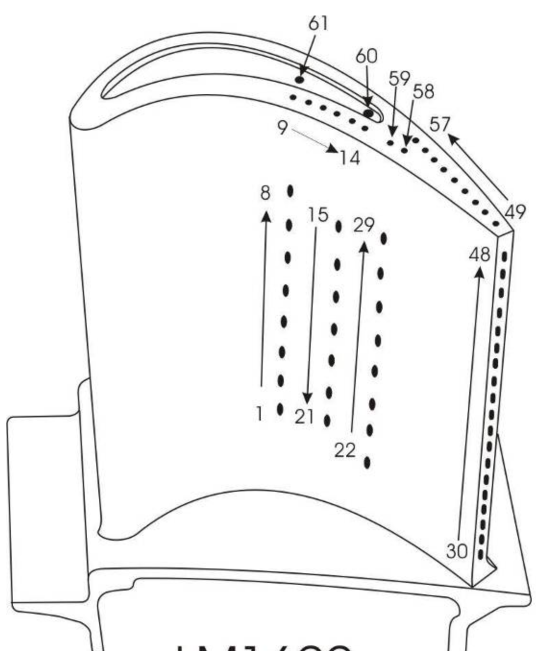
Incoming Inspection

- Cooling Hole Inspection
- Air Flow
- Cooling Flow Analysis





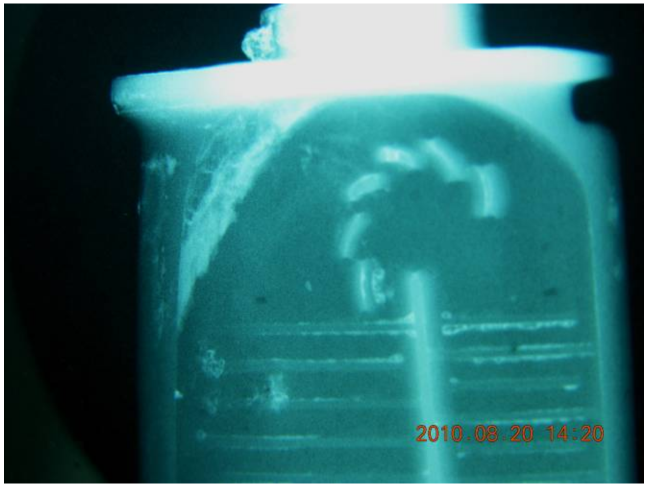
Trailing-Edge Circuit

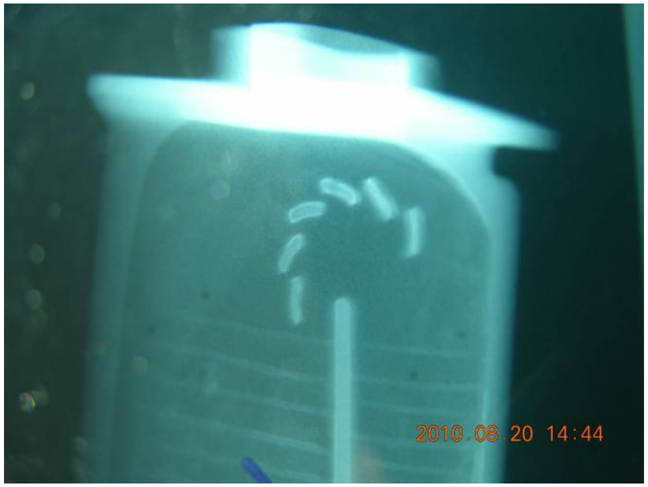


LM1600

Internal Cleaning

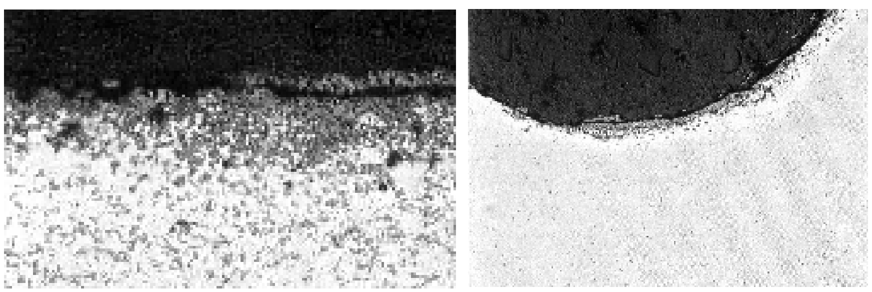
- Internal Cleaning using thermal and chemical process are necessary before stripping
  - Internal deposits and oxides limit effectiveness of stripping process



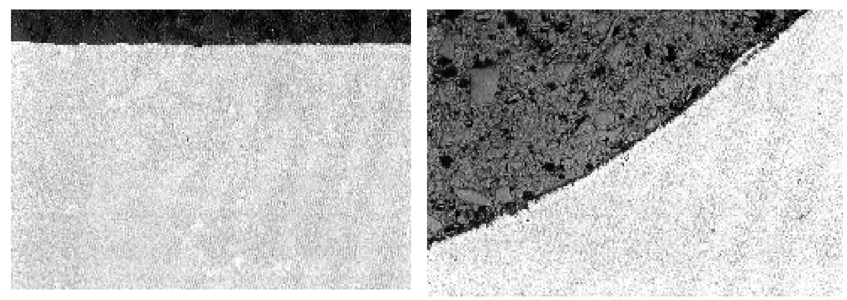


Internal Cleaning

- Oxide removal allows complete stripping



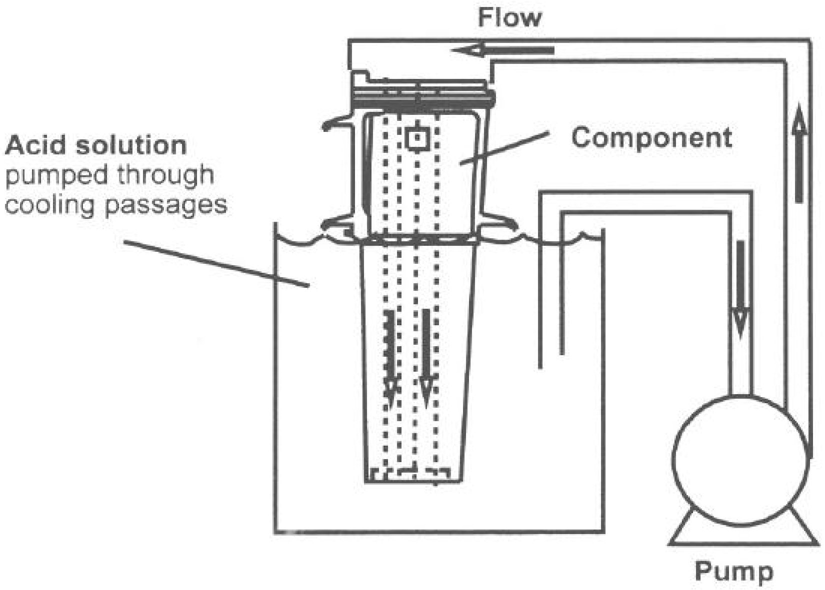
Before cleaning



After cleaning

Coating Stripping

- Masking Required for Internal Only Strip
- Internal Stripping



Dimensional Repair

- Tip weld of un-shrouded blades
- Z-notch restoration of shrouded blades
- Seal fin restoration

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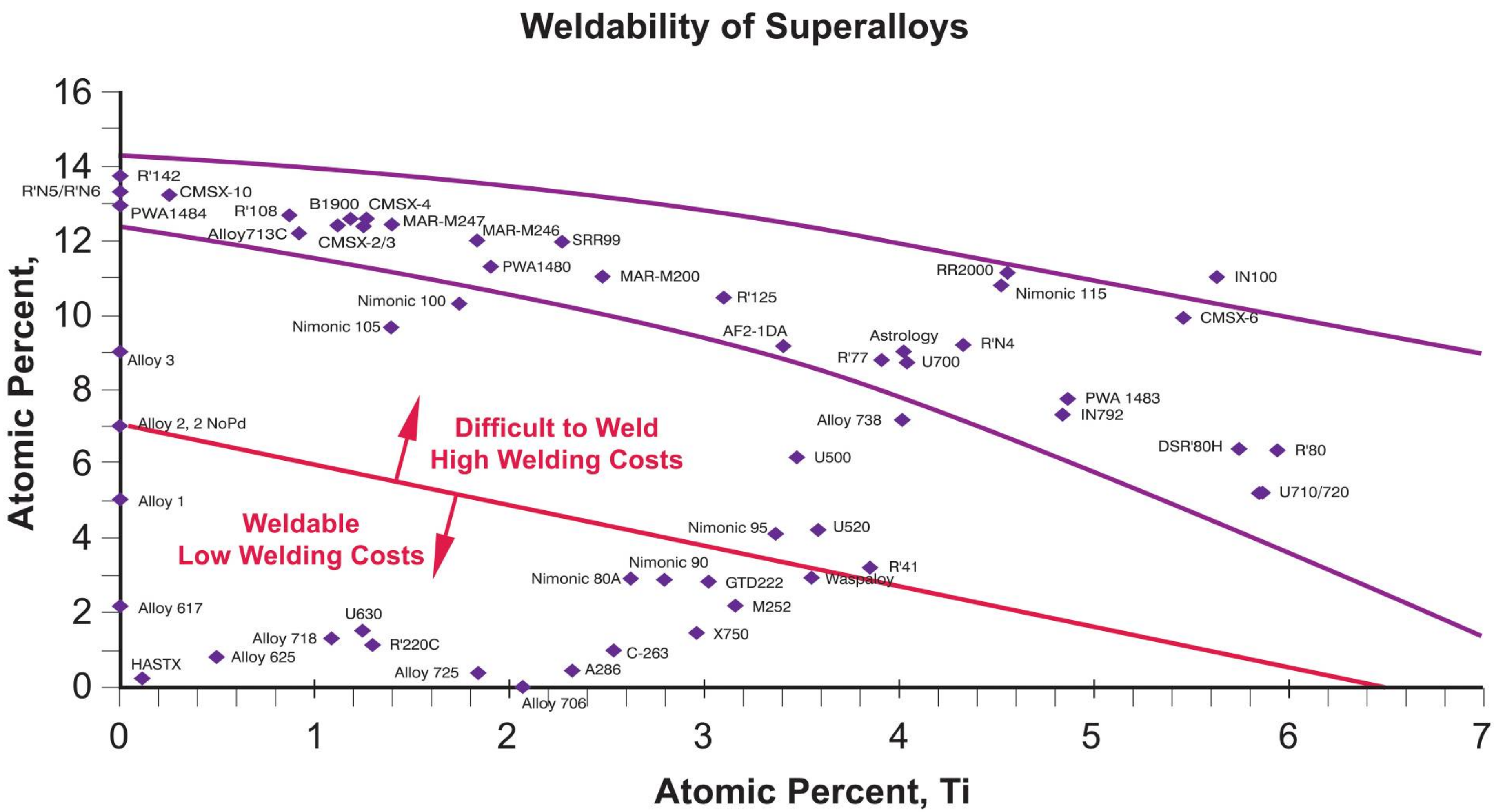
Weldability



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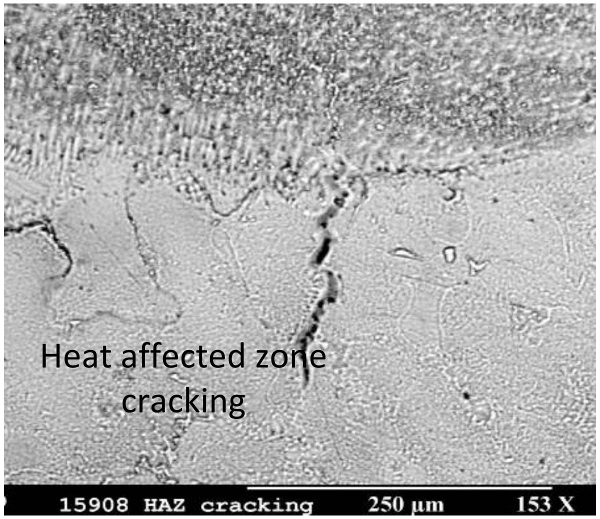
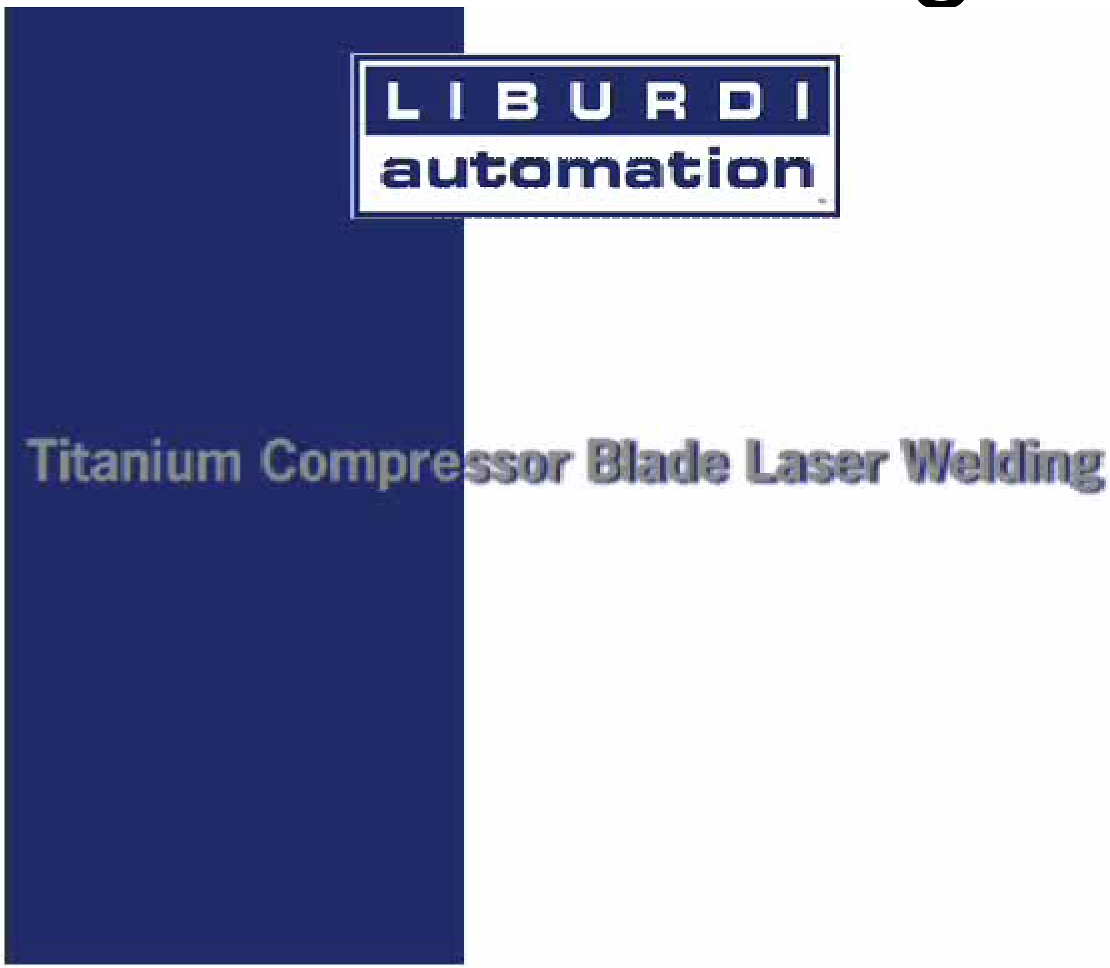
Dimensional Repair

- Welding of gamma prime (γ') strengthened superalloys is not as easy when compared to welding of cobalt base alloys or stainless steel alloys.
- Fusion Zone cracking
- HAZ cracking (microfissuring)
- Post weld heat treat cracking (strain age cracking



Automated Welding



Materials – Single Crystal

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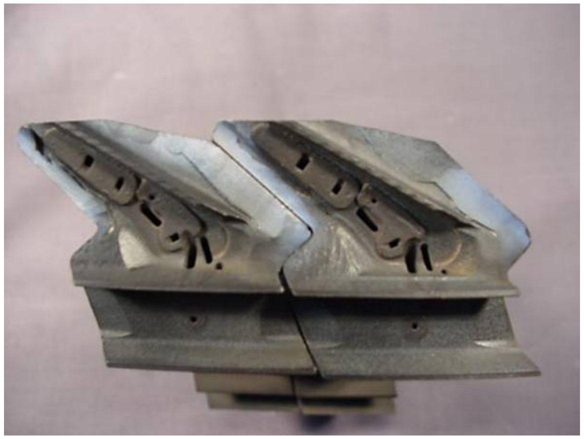
Material Selection

New Blade

Repaired Blades



Geometry Repair - Vanes

Liburdi Powder Metallurgy (LPM™) is a modified wide gap brazing process.

Can be used to fill very large gaps of more than 0.5” size

Build-up damaged surfaces

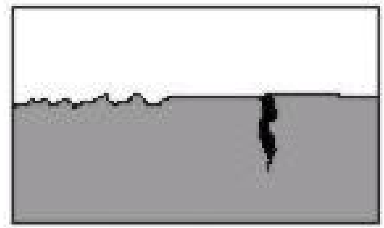
Up to 0.15” thick per application, multiple layers per repair

Heat treatments tailored to match the substrate alloy.

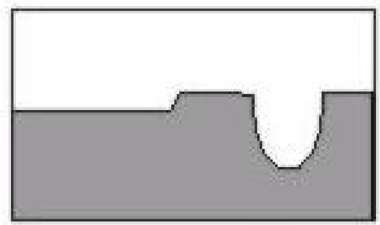
Component distortion greatly reduced using LPM™ compared to conventional weld methodology.

Much stronger than braze repairs.

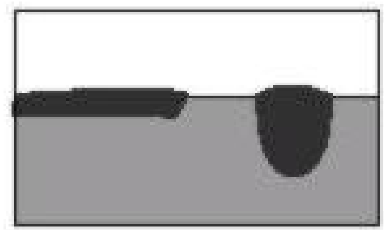
Nickel based LPM™ materials can be applied to nickel, cobalt and stainless steel alloys.



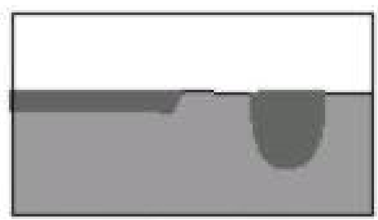
Crack, crazed & oxidized surface



Blend to remove crack, crazing & oxidation



LPM™ applied to surfaces



Heat treated and blended deposits

Geometry Repair - Vanes

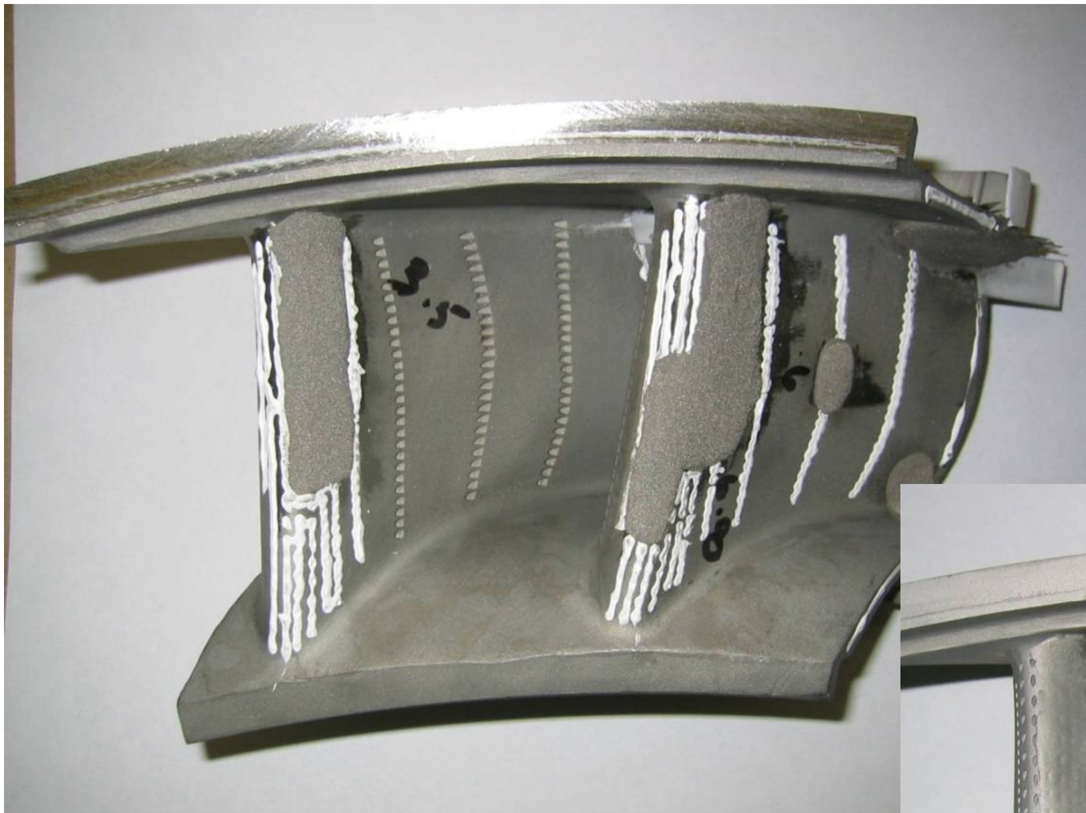
Original braze joint requires repair/restoration

•Incoming damage – burned leading and trailing edges , thin airfoils, burned outer shroud surfaces, shroud braze joints deteriorated

•**Previously NGVs were considered not repairable and were replaced with new.**

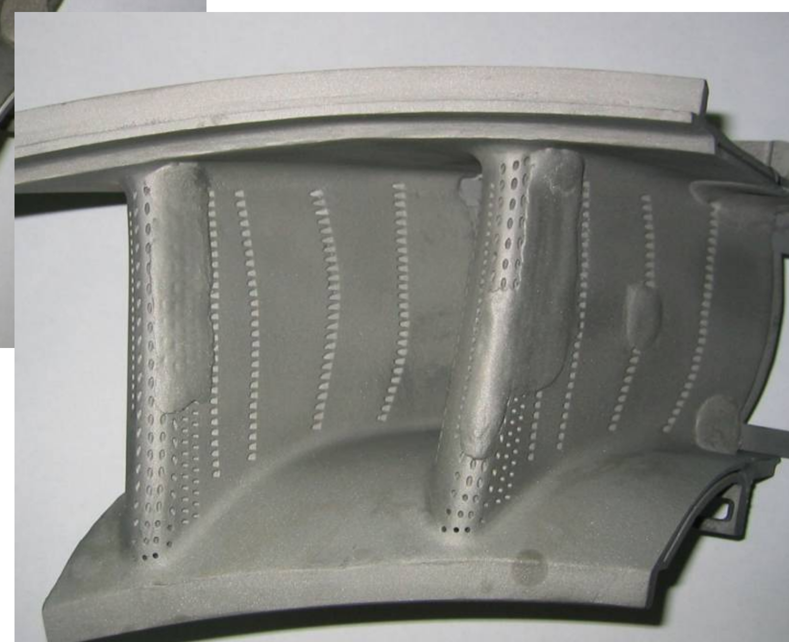
Severely burned trailing edges

Geometry Repair - Vanes



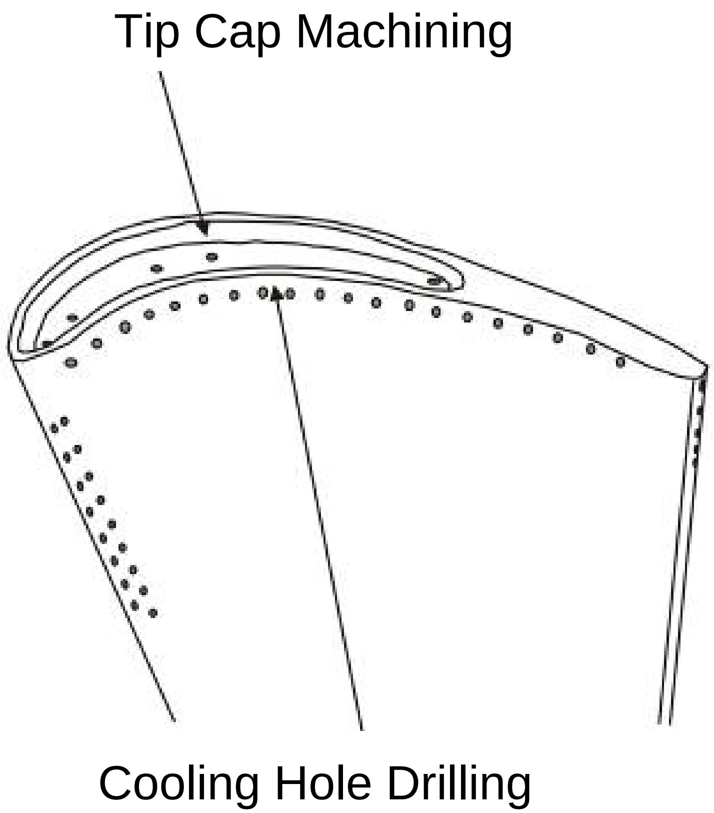
• LPM high strength alloy as-applied to leading edge, mid airfoil, and trailing edges

• LPM material after high temperature vacuum heat treatment to "cast" material to the airfoils

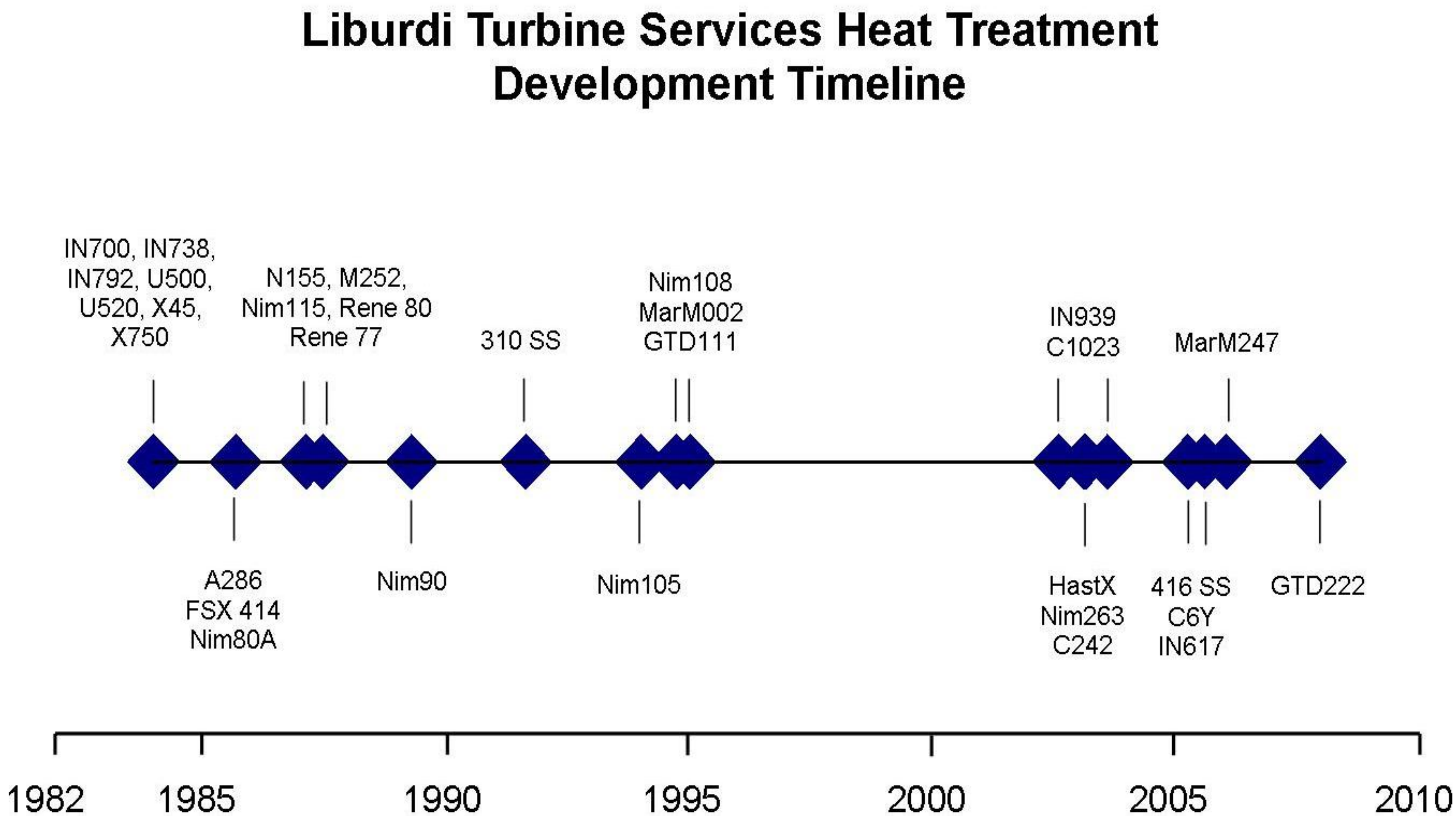


Machining / Finishing

- Tip Cap Machining
- EDM Hole Drilling

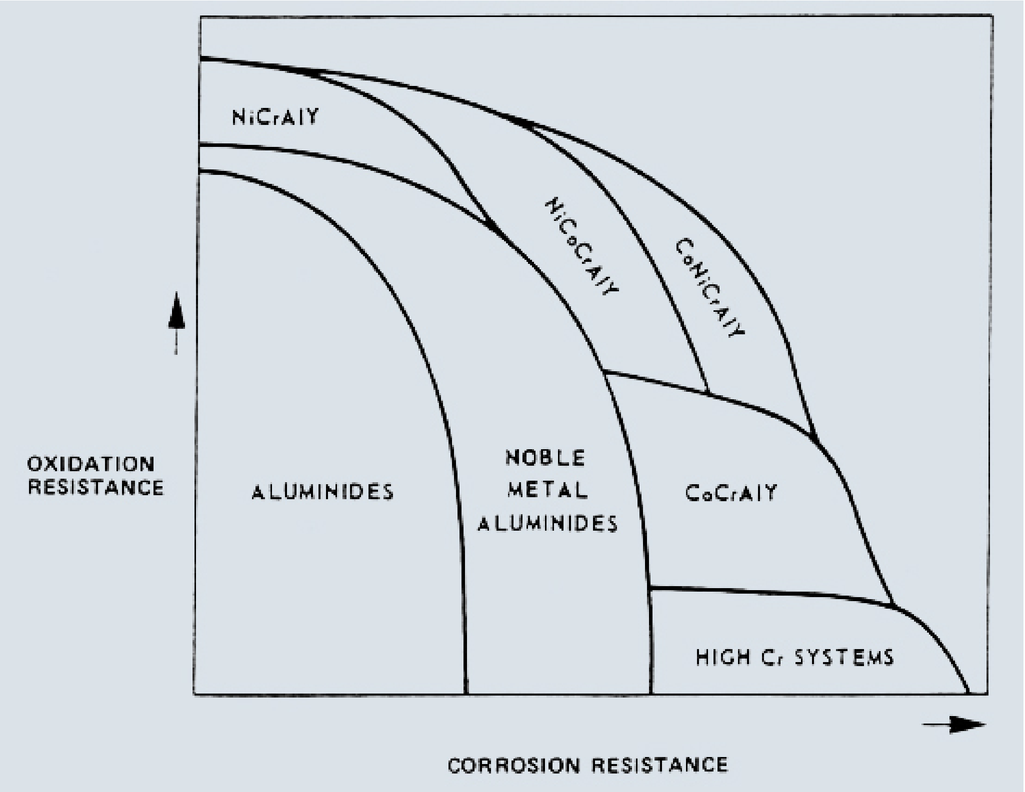


Heat Treatment



Coating

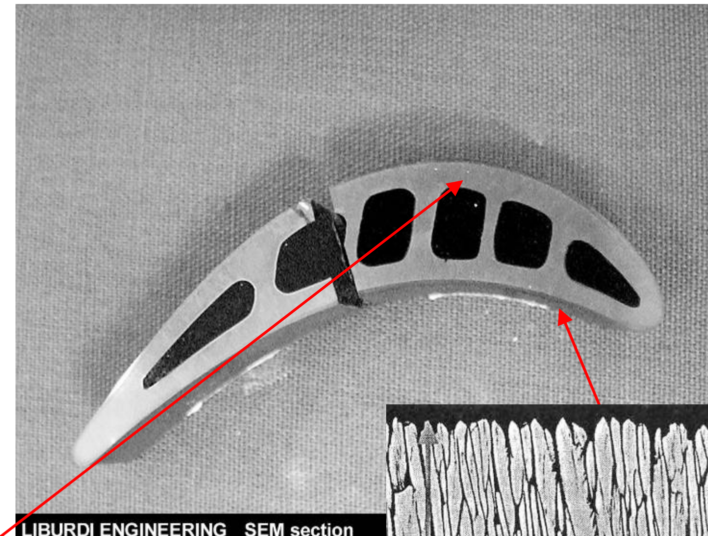
- Selection of Coating System

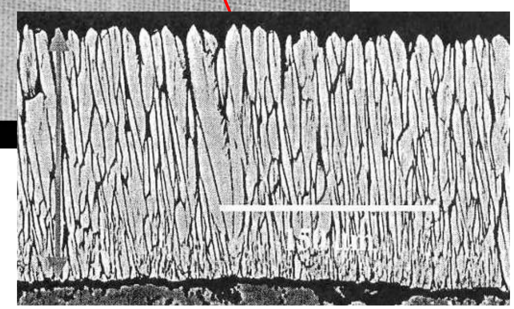


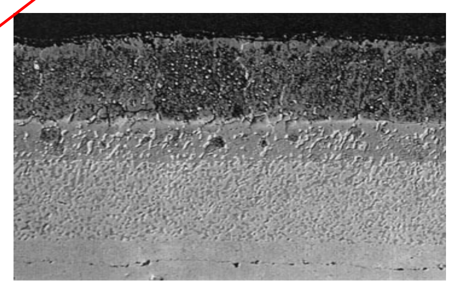
Coating

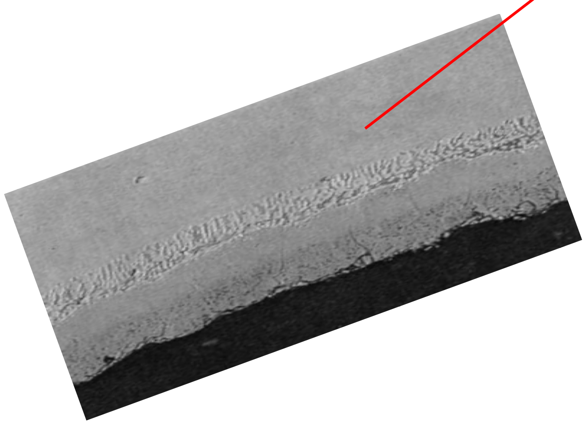
External airfoil surfaces – MCrAlY with over aluminize or MCrAlY bond coat with DVC or EB-PVD TBC.

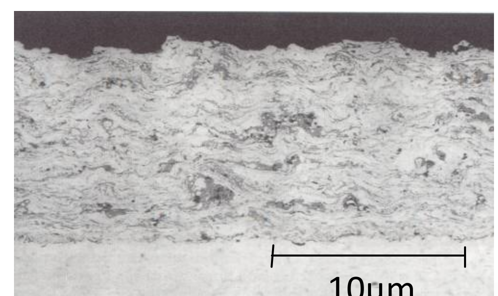
Recoating internal airfoil surfaces – diffusion aluminide or silicon aluminide











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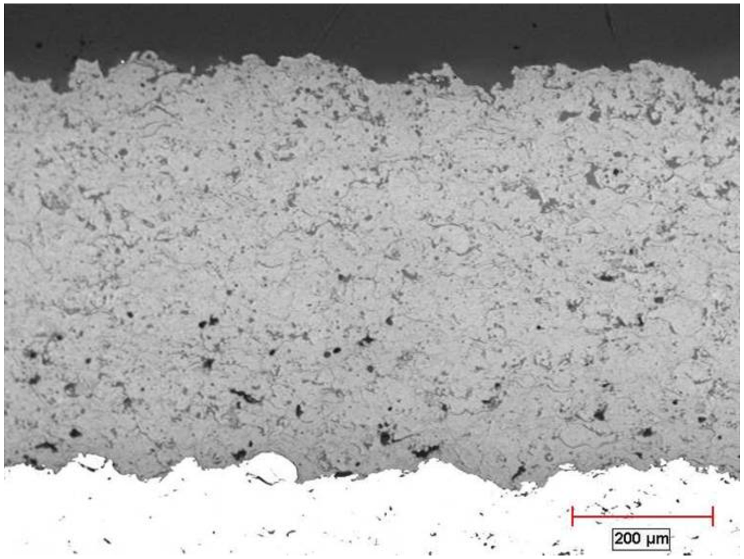

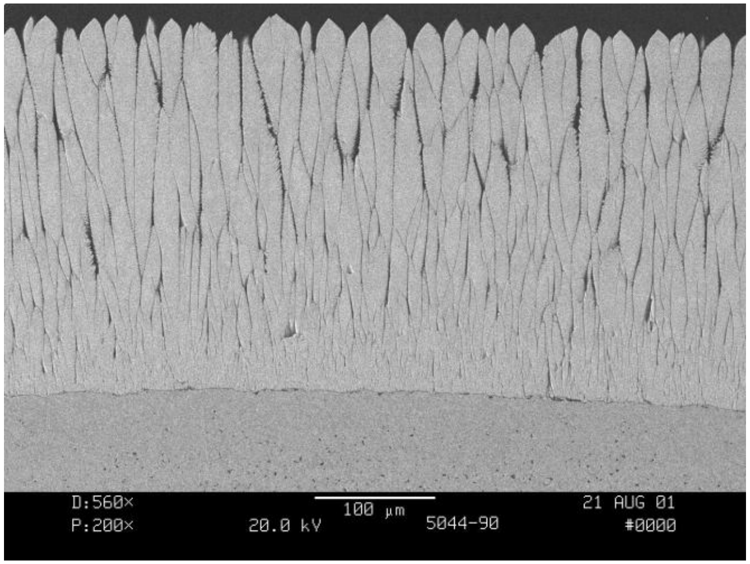

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Repair Evolution

Westinghouse
W191 Blade

GE Frame 7FA
Row 1 Bucket

Thanks for Listening.

Any Questions?