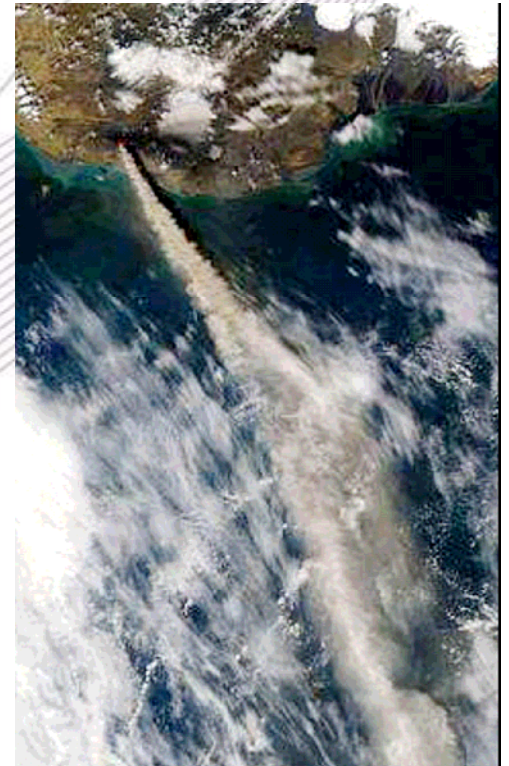


Atlantic Conference on Eyjafjallajokull and Aviation

CFM and Snecma Perspectives

Sept. 15-16, 2010

Jacques Renvier



Effects of volcanic contamination on engines

■ Exposure to high concentration / short term effect (operational impact)

➤ Glassy deposit on non-rotating hot section parts (High Pressure Turbine nozzle guide vanes)

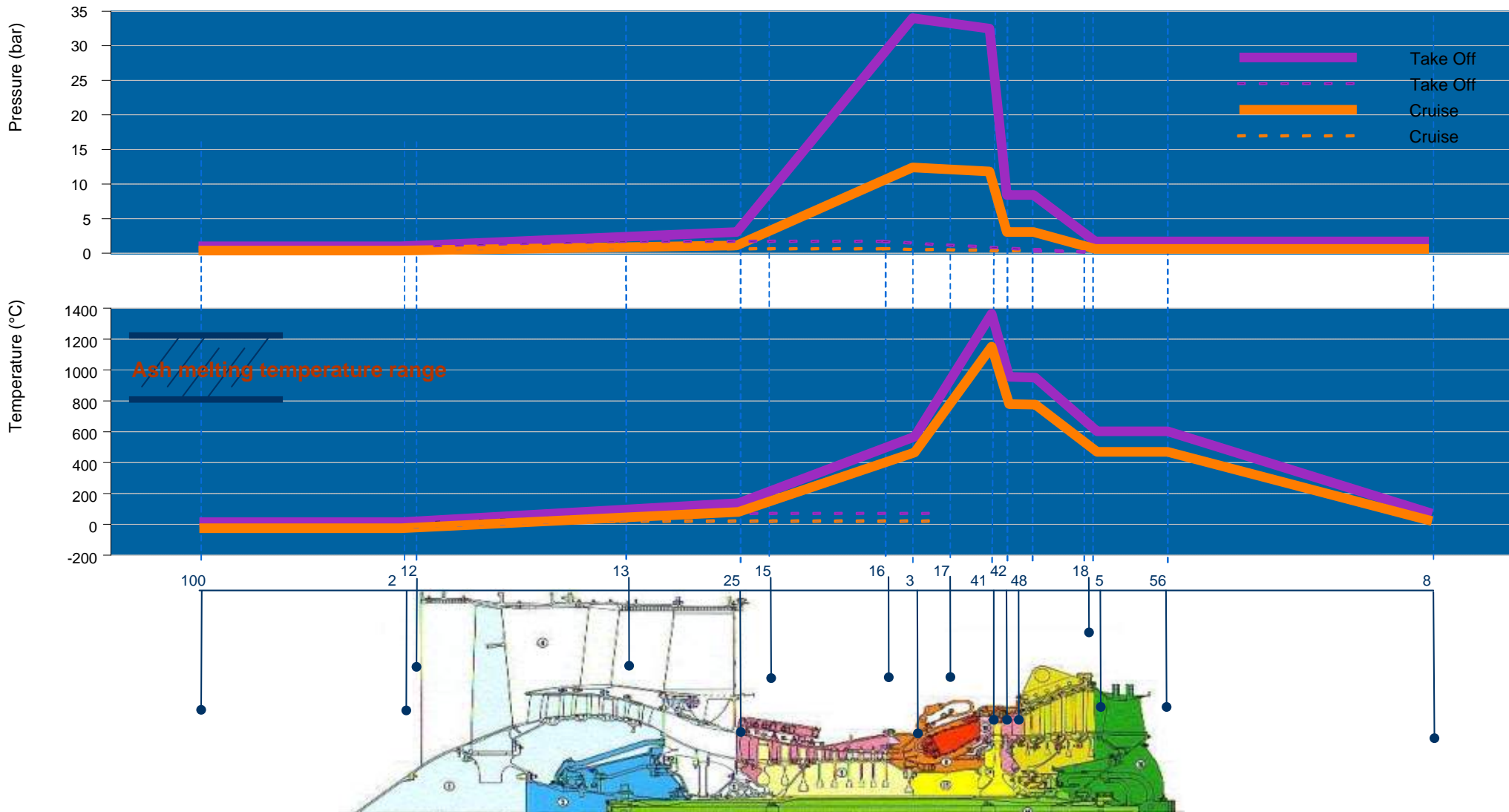
- ✓ Reduces the flow area available for hot gases to go downstream
- ✓ May result in Compressor aerodynamic instability (so called compressor surge or stall)
 - *Up to Engine flame out and inability to restart engines immediately*
- ✓ Other experience have shown:
 - *Almost simultaneous multiple engine flameouts : 3 cases on 4-engine aircrafts, 3 different engine models*
 - *Engines restart after up to 7 attempts (thermal cycling can break the glass deposit and restore flow area)*

Exposure to low concentration / mid or long term effects

- Erosion of Compressor blades
- Clogging of cooling air circuit calibrating holes
- Corrosion of metallic parts
- Oil circuit contamination
- Pneumatic control sensors contamination

Exposure to high ash concentration is a safety concern – No accident so far
Exposure to low concentration raises durability problems (accelerated aging)

Pressures and temperatures : Typical distribution



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CFM/ Snecma experience with Ash and Silica

Experience with solid particles ingestion is with Sand

- Sand physico chemical characteristics slightly different from ash (melting temperature $>1250^{\circ}\text{C}$ vs $800-1200^{\circ}\text{C}$, size and shape of particles –rounded sand grains)
- Military engines are submitted to Sand ingestion tests
 - ✓ Per military standard the test concentration is 53 mg/m^3
 - ✓ Such tests are known to result in engine degradation such as blades erosion, sand deposits in cooling air circuits, local glassy deposits on hot section parts
- Commercial engines have no certification requirements for Sand
 - ✓ However some aircrafts are operated in frequently exposed area (desert regions) and some engineering tests has been completed (concentration 10^{-3} g/m^3 – $375\mu\text{m}$ to $< 10\mu\text{m}$)
 - *Particles within $10\mu\text{m}$ follow the air flow (maintain concentration in core flow), bigger particles more ballistics and centrifuged by fan .*
 - *larger particles drives erosion*
 - ✓ Inspection programs are customized to accommodate accelerated aging
 - ✓ Engines are removed and overhauled when Maintenance Manual limits exceeded

CFM experience with Ash and Silica

■ NASA DC8 (CFM56-2 engines) ash encounter (2000) - NASA report : NASA/TM-2003-212030

Mt. Hekla "old ash" encounter, 28 Feb. 2000, night time

Engines operation not affected by the encounter

➤ Engine condition

All engines exhibited a fine white powder coating throughout.

There was leading edge erosion on HPT vanes and blades, blocked cooling air holes, blistered coatings, and a buildup of fine ash inside passages. Serial number 692632 (the number four engine on the DC-8) had the most severe damage; this may be partially due to the older hardware still resident in this engine.

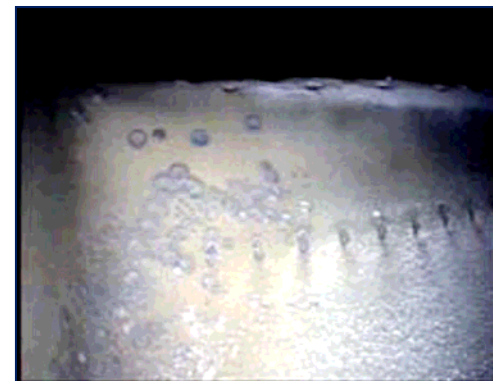
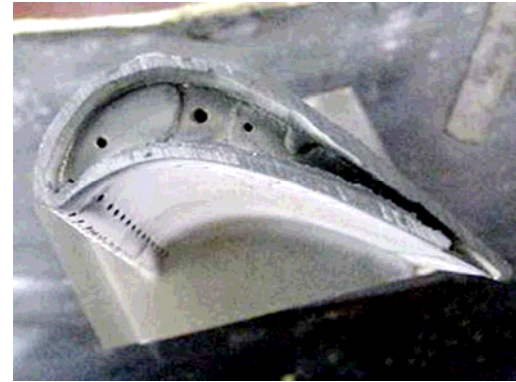
➤ Estimated ash properties

TIT estimate 1050°C

Diffuse plume, 35 hours old 800NM from Volcano

Ash sample Basalt particles 1 to 10 microns diameter collected from filters

Accompanied with Sulfur Dioxide (SO₂)



(a) Blistered thermal coating, and plugged cooling holes.

Volcanic Ash



(b) Erosion of leading edge.

■ KLM B747 (CF6-80C2 engines) encounter with Mt redoubt volcanic ash cloud (1989)

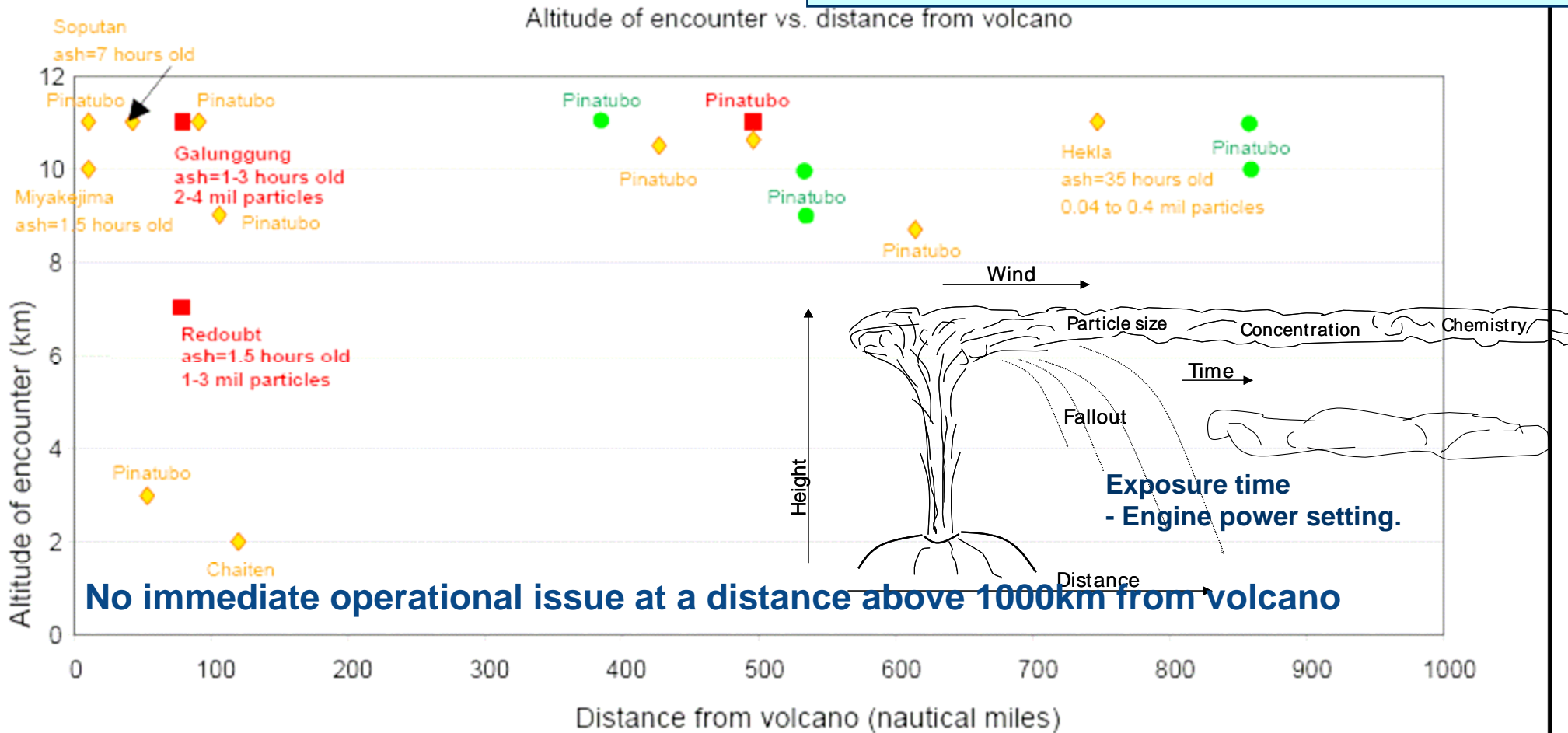
- 1 minute encounter
- All Engines operation significantly affected by the encounter
 - ✓ Heavy molten ash deposits on stage 1 NGVs – area blockage, **stall, rollback sub idle (4 engines)**
 - ✓ Minor erosion on aft HPC blades
 - ✓ Stage 1 HPT blade tip erosion
 - ✓ Air seals/oil system contaminated
 - ✓ **4 engines restarted after 5 to 7 attempts**
- Estimated ash properties
 - ✓ Concentration estimated : 2 g/m³
 - ✓ Ash simple from fan discharge mostly (Ca Na) (Si Al)₄O₈
 - ✓ Melting over entire range : 1050-1200 °C
 - ✓ Particle size : 25-75 μm



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Engine damage correlates with cloud age, particle size

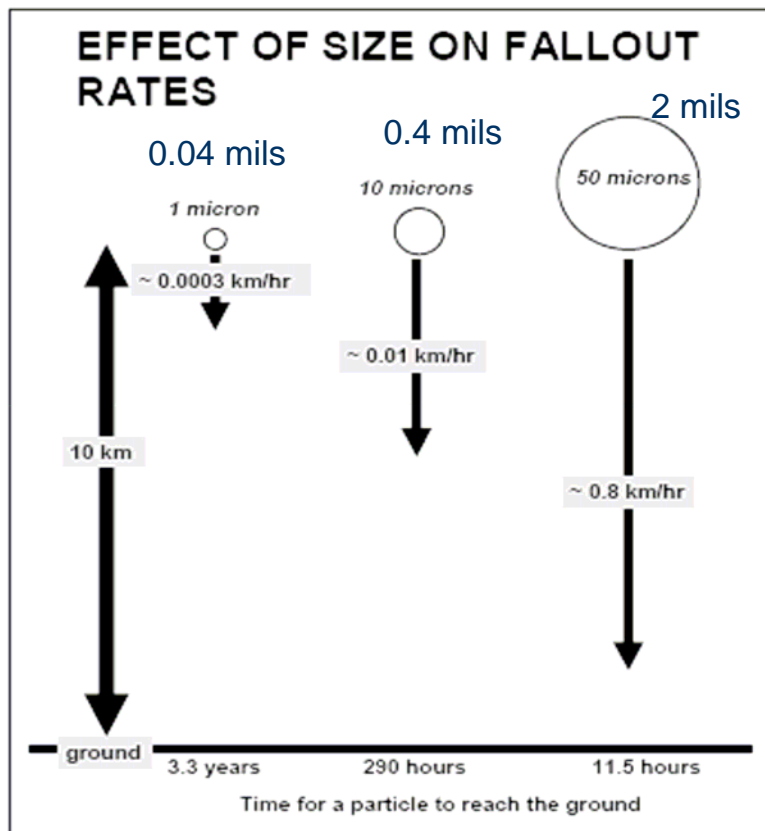
- No damage
- ◆ Damage w/o immediate operational effects
- IFSD



issue is time from eruption to allow ash to fall to earth or disperse in atmosphere.

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Larger ash particles fall to earth quickly



- Ash encounters can happen long after the eruption. Most engine damage events occur within a few hours of the eruption.
- Ash clouds 1-3 hours old are dense, with large particles (1-3 mils), and have caused IFSDs
- Older ash clouds are less dense, made of smaller particles.

Published data:

Removal Processes of Volcanic Ash Particles from the Atmosphere

Gregg Bluth, Michigan Technological University, Houghton, MI, USA; and Bill

Rose, Matt Watson, 2nd ICVAAS

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Experience with Eyjafjallajokull volcano (2010)

Volcano Eruption Impacts



- April 15th eruption closed a large part of European airspace

- Airspace re-opened 21st
- Impacted Travelers, & Cargo

- CFM worked to support the UK CAA, FAA, & customers

- Four (4) All Operators Wires / Eight (8) Service Bulletins issued 29/04/2010, Article in the April 2010 CFM56 Fleet Highlights
- Enhanced communications with Customers

Limited data on long term impact from low levels of volcanic ash on engines

- Used all available ingestion data

- Focus on maintaining safe operations:

- CFM recommends avoiding flight through visible ash clouds
- Positive industry experience when operators avoid visible volcanic ash, defined as 2 mg/m³.
- Flight into predicted ash concentrations of higher than 2 mg/m³ may be undertaken at operators' discretion, provided flight into visible ash clouds is avoided
- Follow current AMM maintenance requirements when operating in areas of potential volcanic ash encounters .Report findings to be provided to CFM

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Experience with Eyjafjallajokull volcano

Feed-back from the fleet

- **Several operators did perform thorough recordings and feed-back to CFM**
- **Main findings (photos on next slides)**
 - No operational issue reported
 - White deposit observed in the flow path (from engine inlet to exhaust)
 - More significant deposits found in 2 engines following a non-ash related emergency descent in “ash cloud” (unknown zone and concentration)
- ✓ Repetitive inspections recommended and performed at +40 and +80 flight cycles **with no sign of thermal distress**
- **However : actual exposure not known in terms of ash concentration and duration**
 - Current dispersion model known to have uncertainties (predict peak rather than average values?)
 - Instrumented test flights described ash clouds as several thin layers at different altitudes, not a bulk ash contamination

**No in service flight interruption ash related .
However actual exposure is unknown, assume low concentration**

White deposits on engines- No distress

White Deposit reported on exhaust



LPT Nozzles stg 1, white deposit with superficial pitting



HPT Nozzles, cooling holes with dust deposit
No signs of thermal distress



HPC Blades with small amount of contaminant
no indication of HPC damage or erosion



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CFM56 5B Volcanic ash encountered over Spain

Aircraft reporting encountering in Ash

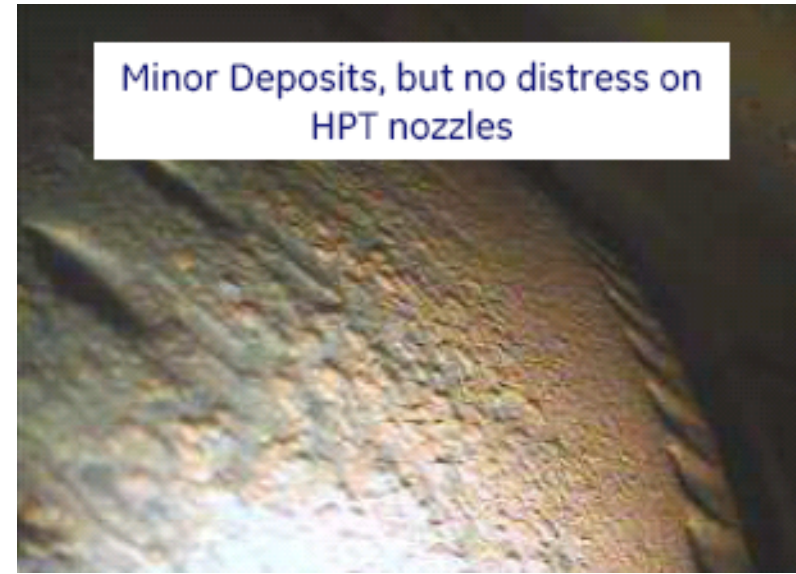
Ash deposit evident, no distress observed

Engine released back to services

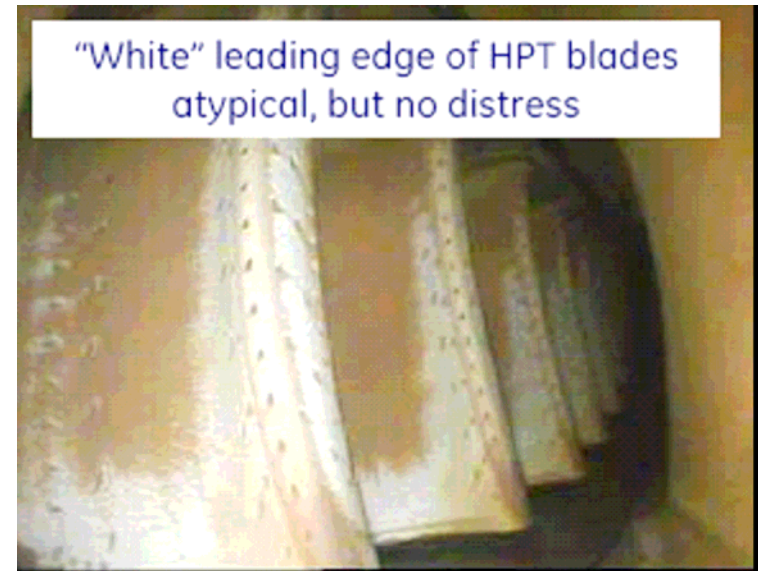


Minor Deposits on HPC blades/vanes

Minor Deposits, but no distress on HPT nozzles



"White" leading edge of HPT blades atypical, but no distress



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Way forward

Way forward (1/2)

- **CFM , GE ,Snecma are supporting International Volcanic Ash Task Force (IVATF)**
 - the ICAO launched on July 27-30, 2010
 - Task force completion targeted within 1 year

- **What needs to be addressed ?**
 - Review current flight crew guidance
 - Review current maintenance & inspection guidance
 - OEM's support of operators in next crisis
 - ✓ Minimize inspection as required
 - Define characteristics of ash that may impact aircraft
 - Assess airworthiness considerations of threat
 - Develop guidance for States to allow flight into ash contaminated areas
 - Establish a risk management approach to operations in volcanic ash contaminated areas
 - Study certification implications

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■ The current knowledge (test data and experience) on the threat is limited:

- A single concentration not sufficient to define a “safety limit”: the problem is a multi dimensional issue
- Need to understand engines susceptibility to volcanic ash
 - ✓ engine type dependant (internal temperatures, turbine blades technology, cooling system design , flight hours cumulated)
 - ✓ Ash composition dependant (density, particle size, melting temperature)
- Evaluate if we are able to generate a model to set the max ash concentration for safe operation
- Operations (Air Traffic Management, Airlines needs): use experience of Airlines exposed to volcanic ash

■ Need to calculate or measure accurately the ash concentration

■ Certification “ash rule” not the right answer : no safety case to drive it / does not address current fleet / multi dimensional

Positive industry experience when operators avoid visible volcanic ash

We continue to support operators in the area of volcanic ash, to maintain safe operation

CFMI/GE/Snecma are supporting the IVATF

Operational definitions of volcanic ash and expected operations in this environment are required to establish thresholds

- **define or measure accurately the ash concentration in flight**
- **provide additional knowledge and understanding of engine behaviour in volcano ash environment**
- **Evaluate if we are able to generate a model to set concentration for safe operation**

CFM/ GE / Snecma will continue to work with operators and the aviation industry to support safe flight and ongoing understanding of the world-wide volcanic ash threat

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