



Rolls-Royce

Eyjafjallajokull

The impact of volcanic ash on aircraft engines



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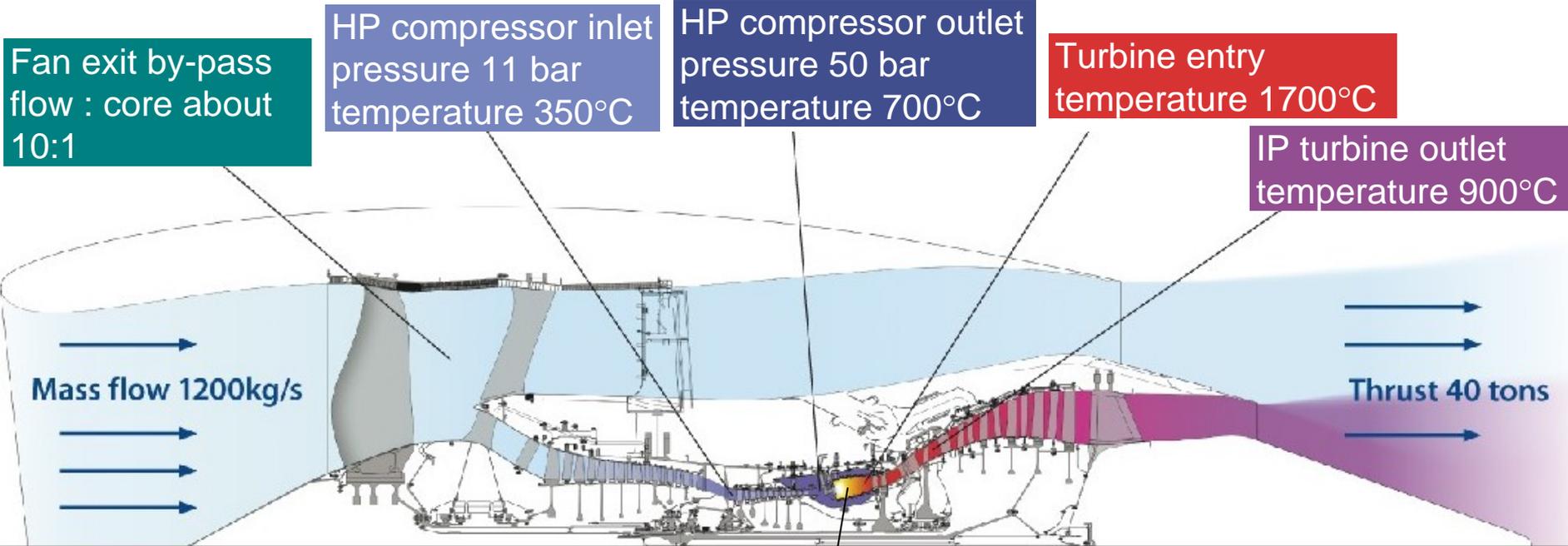
The impact of volcanic ash on aircraft engines

- Agenda
 - Why is operation in Volcanic Ash an issue ?
 - Engine OEM's understanding
 - Safe to fly
 - Ash & Engines
 - Service Sampling
 - Ash tolerant engine?
 - Conclusions

How engines work

Operating principle of a modern jet engine and some key figures

Overall Pressure ratio: ~50

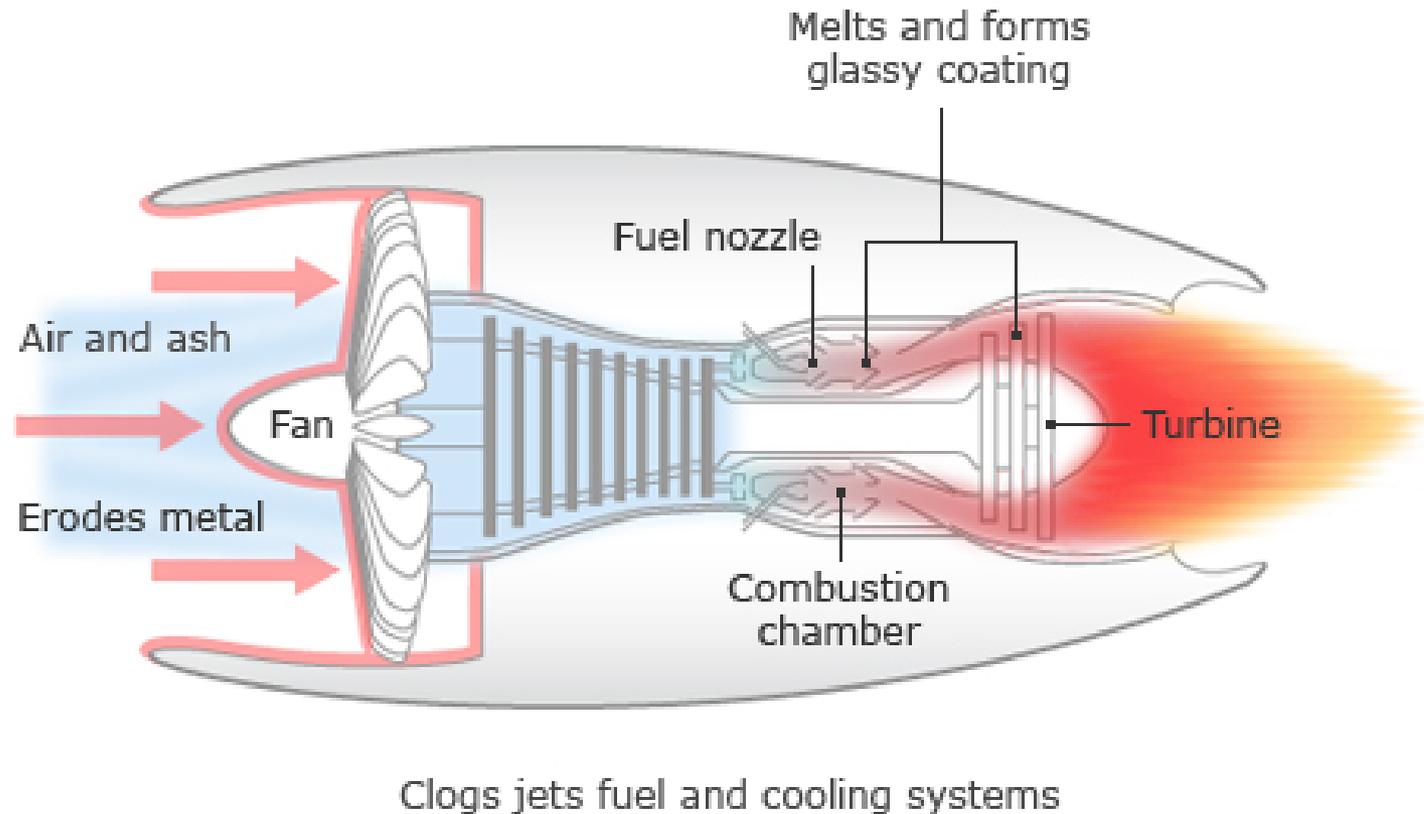


Combustion chamber
7 lb/sec of fuel

Steel starts to glow red at 700°C

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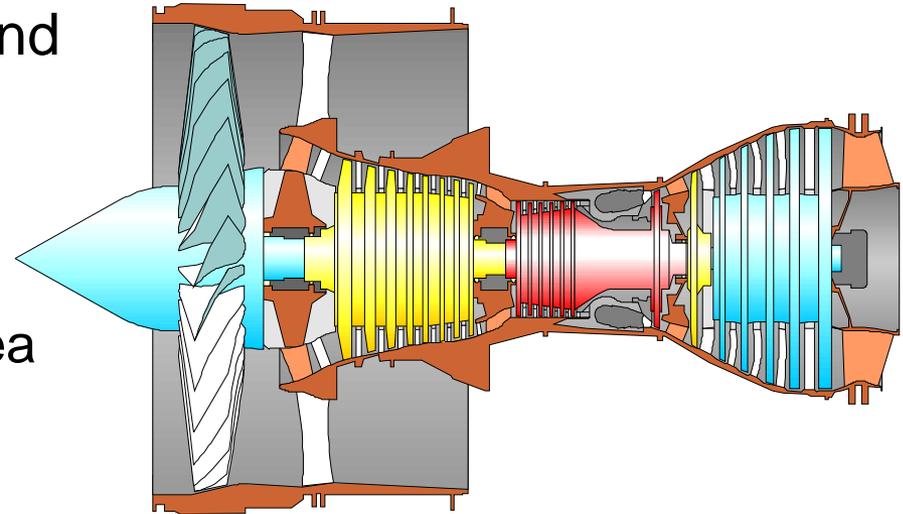
What does the ash do in the engine ?



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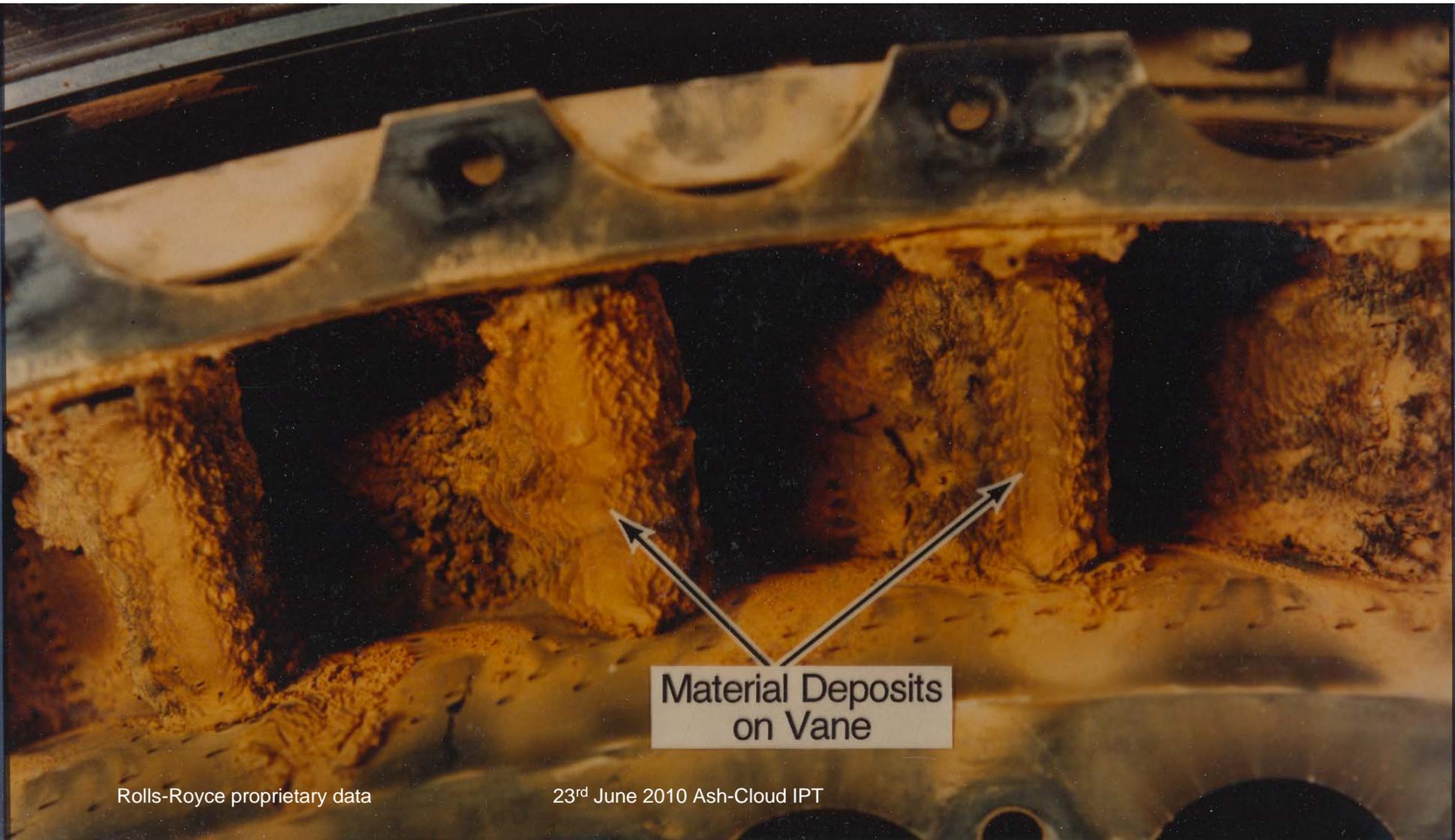
Why Is Operation In Volcanic Ash An Issue ?

- Erodes compressor blades and linings
- Ash melts in Combustor and deposits in HP Turbine
 - Reduced HPNGV throat area
 - Increased HPC pressure
 - Engine surge
 - Internal cooling airflow blockage
- Fine particles can get in to oil system and damage transmissions components
- Pneumatic controls blocked by small particles



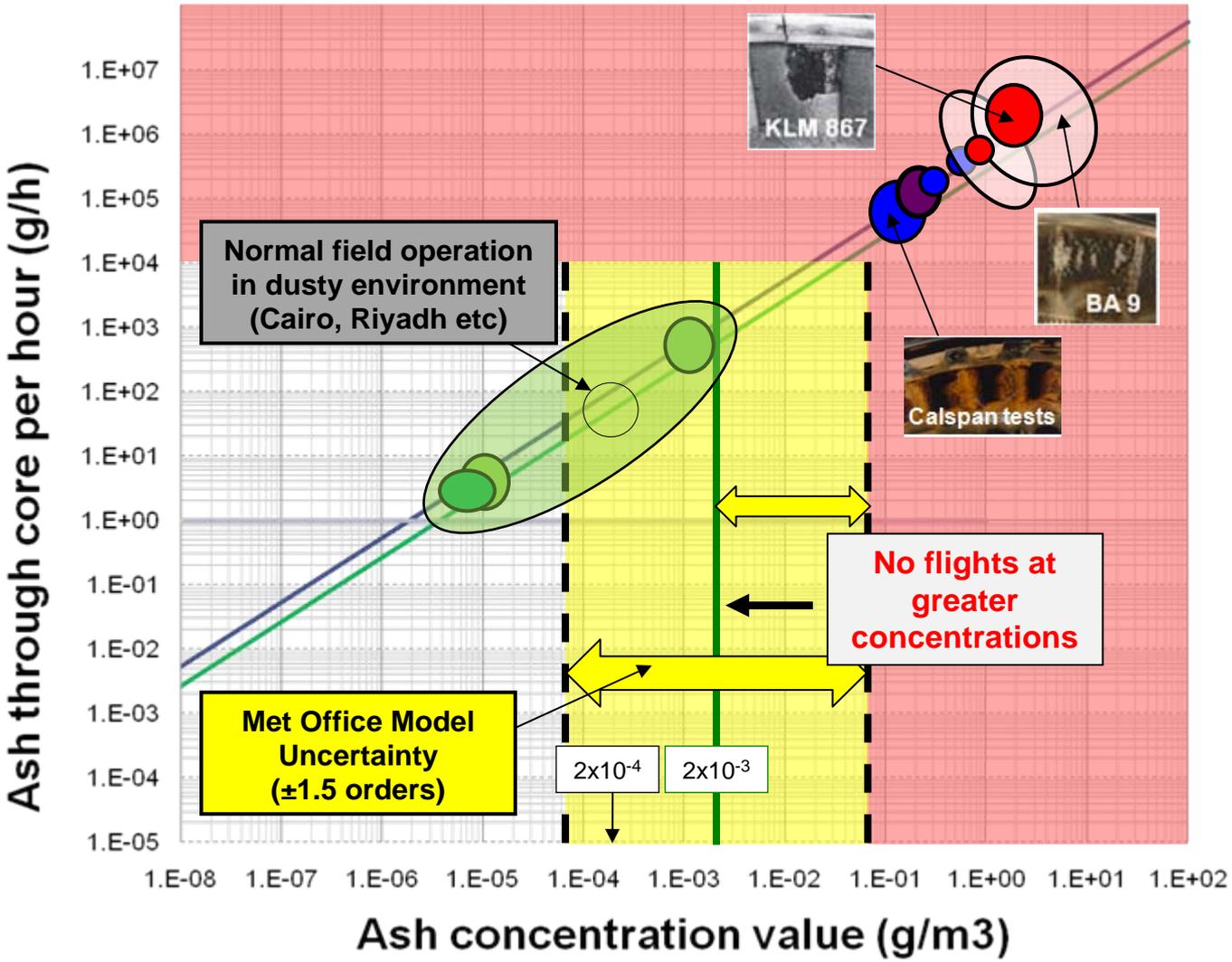
Heavy HP NGV contamination
(BA747, Jarkarta 1982)

HPT Vane; After Dust Exposure (concentration about $>2 \times 10^{-1}$ g/m³) (exposure around 1 hour)



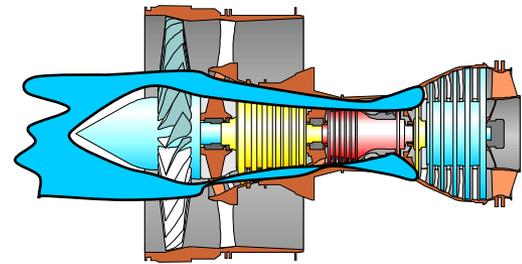
Material Deposits
on Vane

The Safe to Fly – Chart: 17th May 2010



Key

- KLM 867
- BA9
- BA / Dornier
- DLR Germany
- GE Earth Mix
- Calspan Tests



- 100% core flow
- 50% core flow

Service Sampling

- RR have inspected over 350 individual engines
 - On-wing borescope / visual inspections
 - Off-wing component analysis
- Targeted sampling based on potential exposure to ash
 - Utilising novel EHM & Operational modelling techniques
- Nil findings
 - Off-wing sampling & analysis will continue throughout 2010

Ash tolerant engine?

- R-R large engine fuel burn has improved ~20% in the last 20 yrs
- Emissions significantly reduced in the last 20yrs
- Improvement from:
 - Reduced core engine size
 - Higher pressure ratios
 - Increased Turbine Entry Temperatures
- Modifications to reduce susceptibility to volcanic ash would have a negative environmental impact.
 - Increased fuel burn
 - Increased emissions

Conclusions

- Analysis based on 'actual' ash density
- Actual ash concentration for safe operation $2 \times 10^{-3} \text{g/m}^3$
 - Engine OEM's do not support flight in visible ash
- Probabilistic risk assessment supports this value
- Extensive service sampling has provided evidence that RR products were not exposed to predicted ash concentrations
- Removing the uncertainty from the Met Office model will provide a significant benefit for operations during future eruptions
- Designing an engine to be more tolerant to volcanic ash would increase fuel consumption and emissions