HEALTH & SAFETY LABORATORY

Examining the means to protect against fuselage burnthrough

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Outline

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- Introduction
- Methods for protection
- Assessment of protection methods
- Experimental
  - *ISO 2685 and UL94 tests*
  - *Example results*
- Modelling approach
  - *Modelling of burner*
  - *Modelling of material response*
- Summary

Methods for Protection – 1

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- Protective shields

  Stainless steel panels

  Dimpled steel (4/1000") or plain (0.6 mm)

- Surface coatings

  Ceramics

  Fastblock

- Rear face ventilation

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- Hardening of materials
  - *Addition of retardants*
    - Polyphosphate
    - Nano clays
    - Carbon nano tubes
- Higher performance composites
  - *HEXCEL (not yet tested)*

Assessment of performance

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- Carried out experimentally:
  - *Enhanced ISO 2685 test*
  - *UL94 test*
- Modelling approach:
  - *Ultimately would like to model response of panels*
  - *Use testing to provide data to develop models*

ISO 2685 Test

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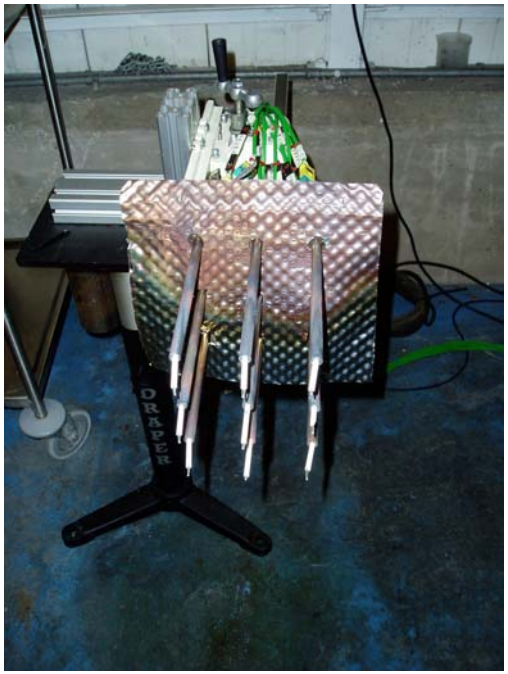
- Tests carried out according to ISO 2685 protocol
- Use propane burner as fire source
- Facility to apply +ve and –ve pressure to back face
- Facility to vibrate sample

  Enhance with IR Imager for rear face temperature measurement

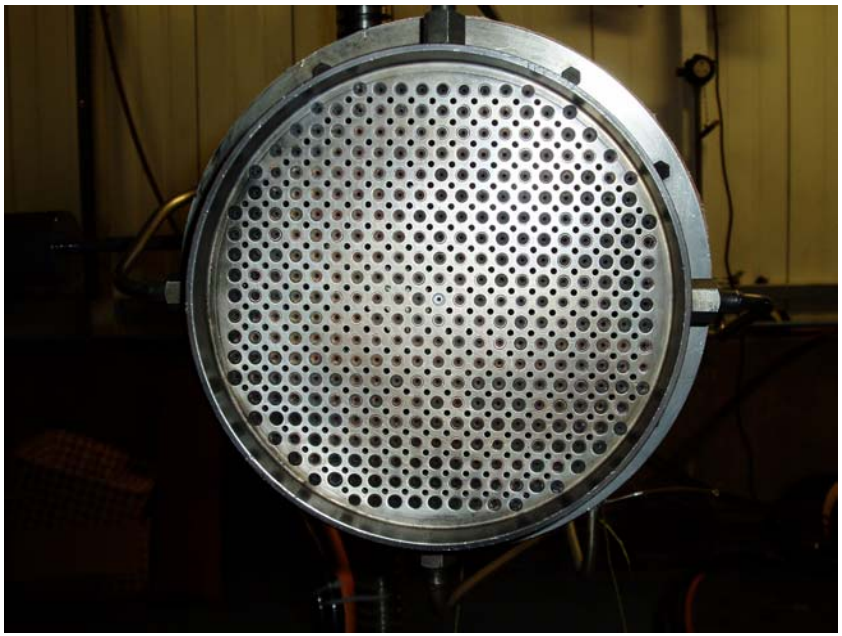
ISO 2685 Pre-Test Calibration



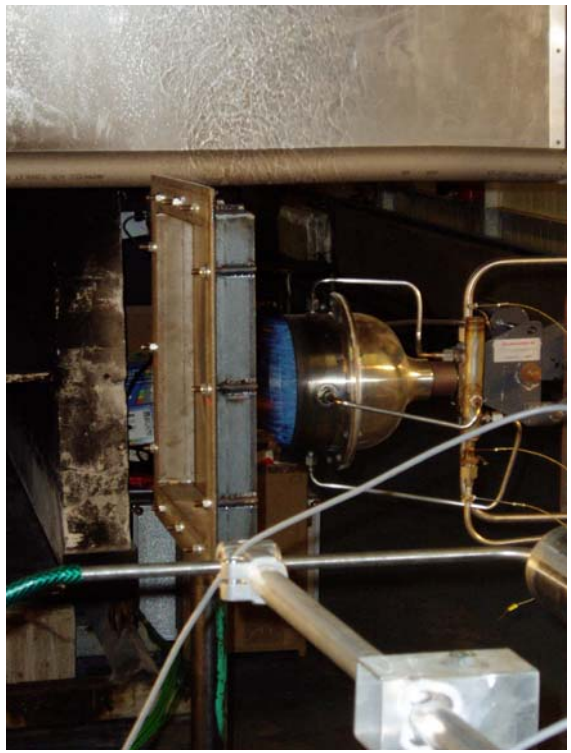
Measurements of temperature with an array of nine thermocouples

Measurements of heat flux using a continuous water flow calorimeter

ISO2685 Burner



Burner exit plane, 373 large holes – fuel and primary air, and 340 small holes – secondary air



Fuselage burnthrough test in progress

UL94 Test

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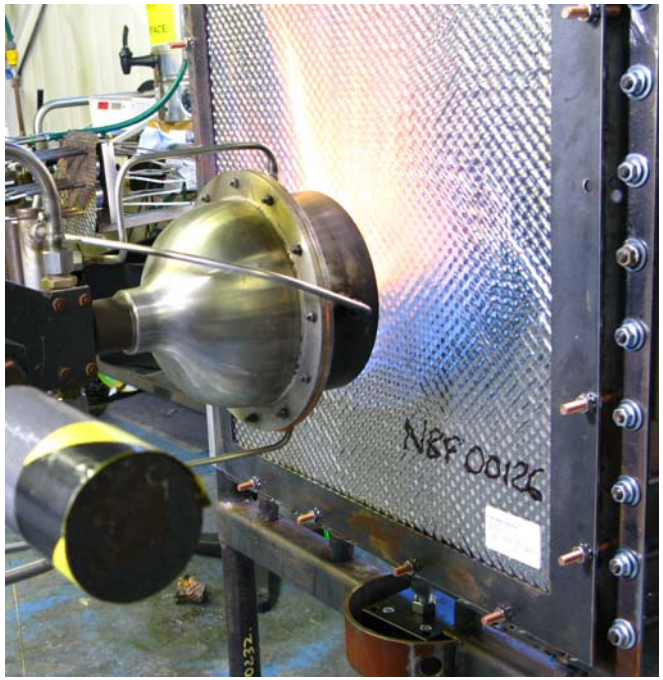
- Flammability testing
- Vertical testing with bunsen burner
  - Flame applied for 10 s and then removed
  - Flame is reapplied for another 10 s once the flaming has stopped
- Persistence & length of burn measured

Protective shields



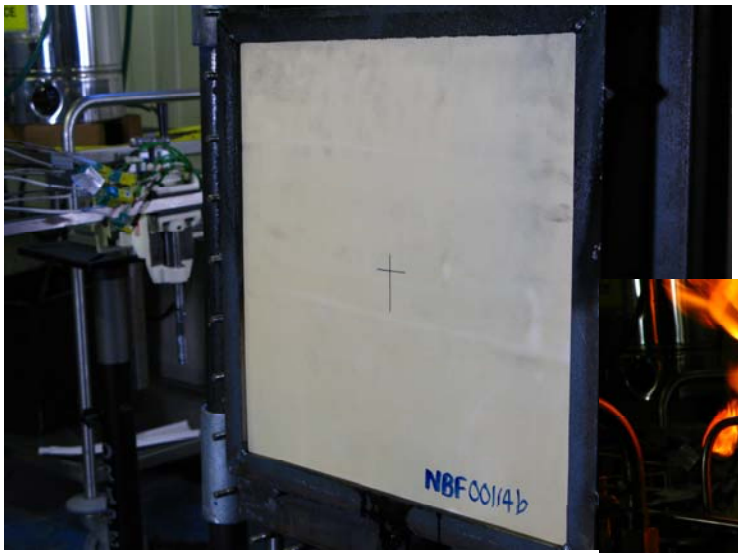
Shielded composite

Shield survives but deforms

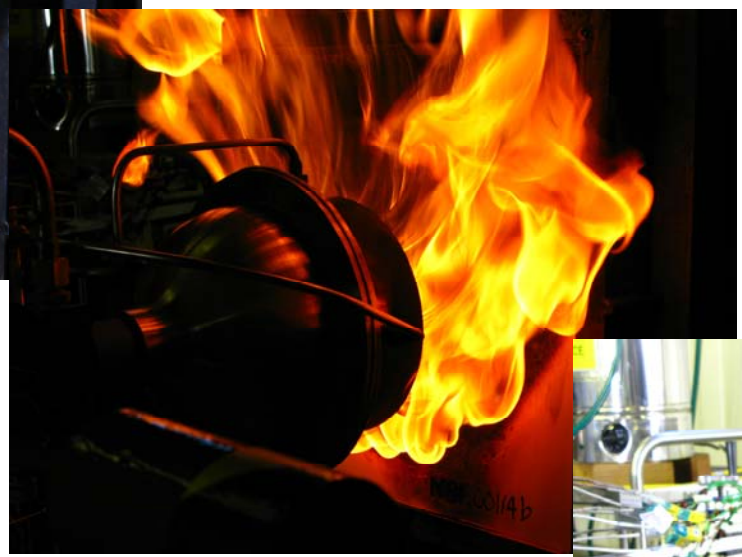
Panel off-gases & collapses

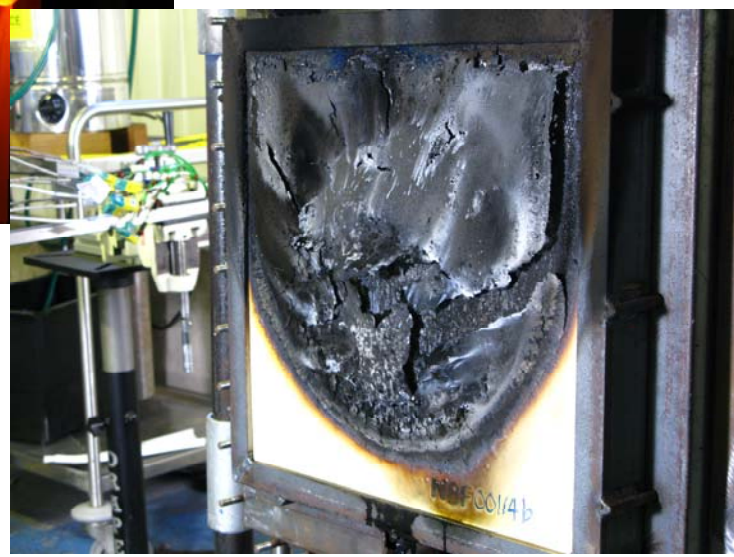
Volatiles burn-off at edge of panel

Surface coatings - 1



Thin ceramic coatings on composite





No improvement to performance

Resin burns off with loss of structural strength

Surface coatings - 2

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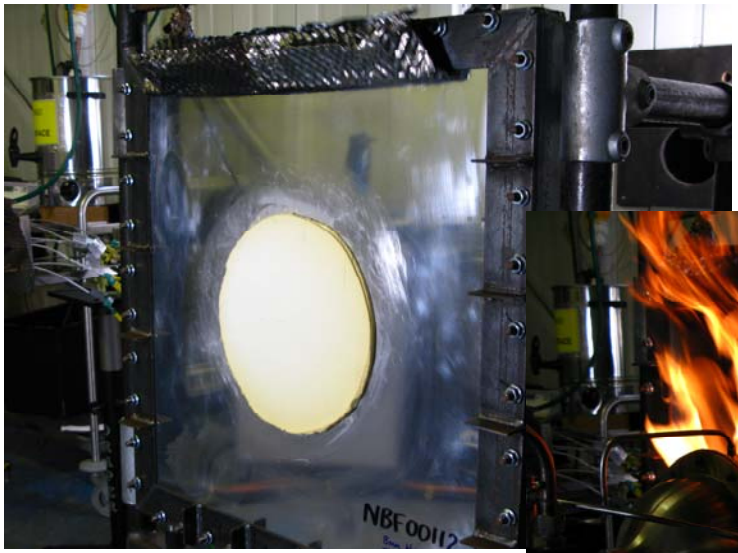
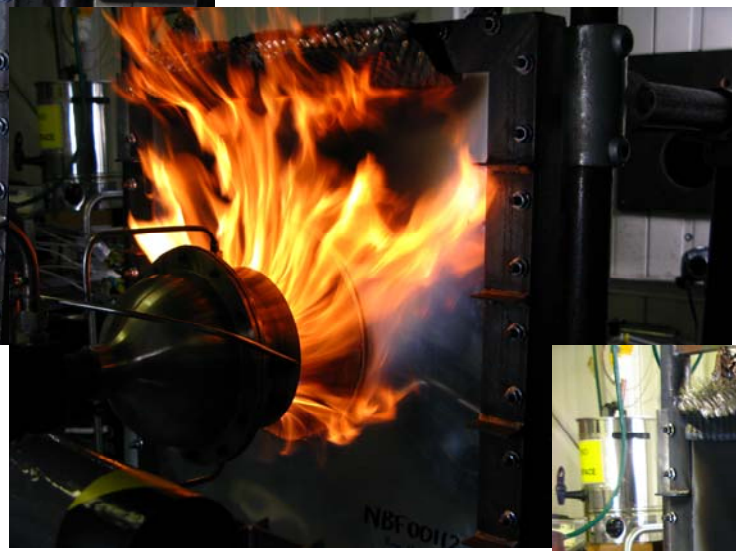
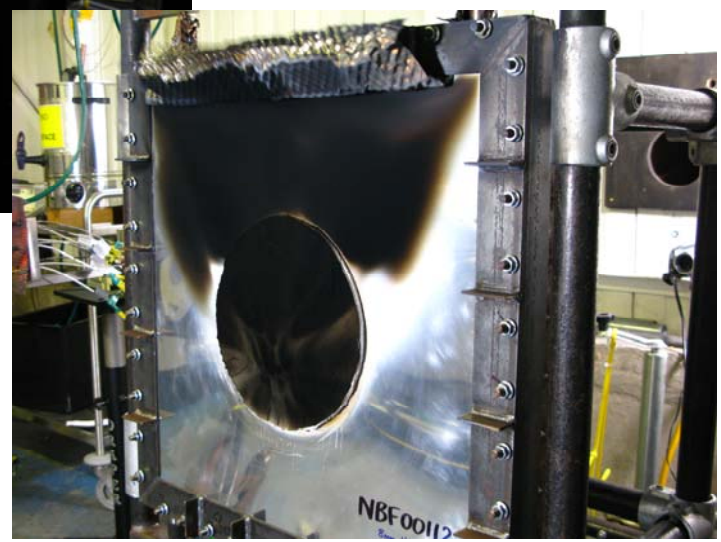






FASTBLOCK 300

Ceramic loaded silicon-based proprietary fire protection coating

2 mm AL panel survives test with 4 mm coating

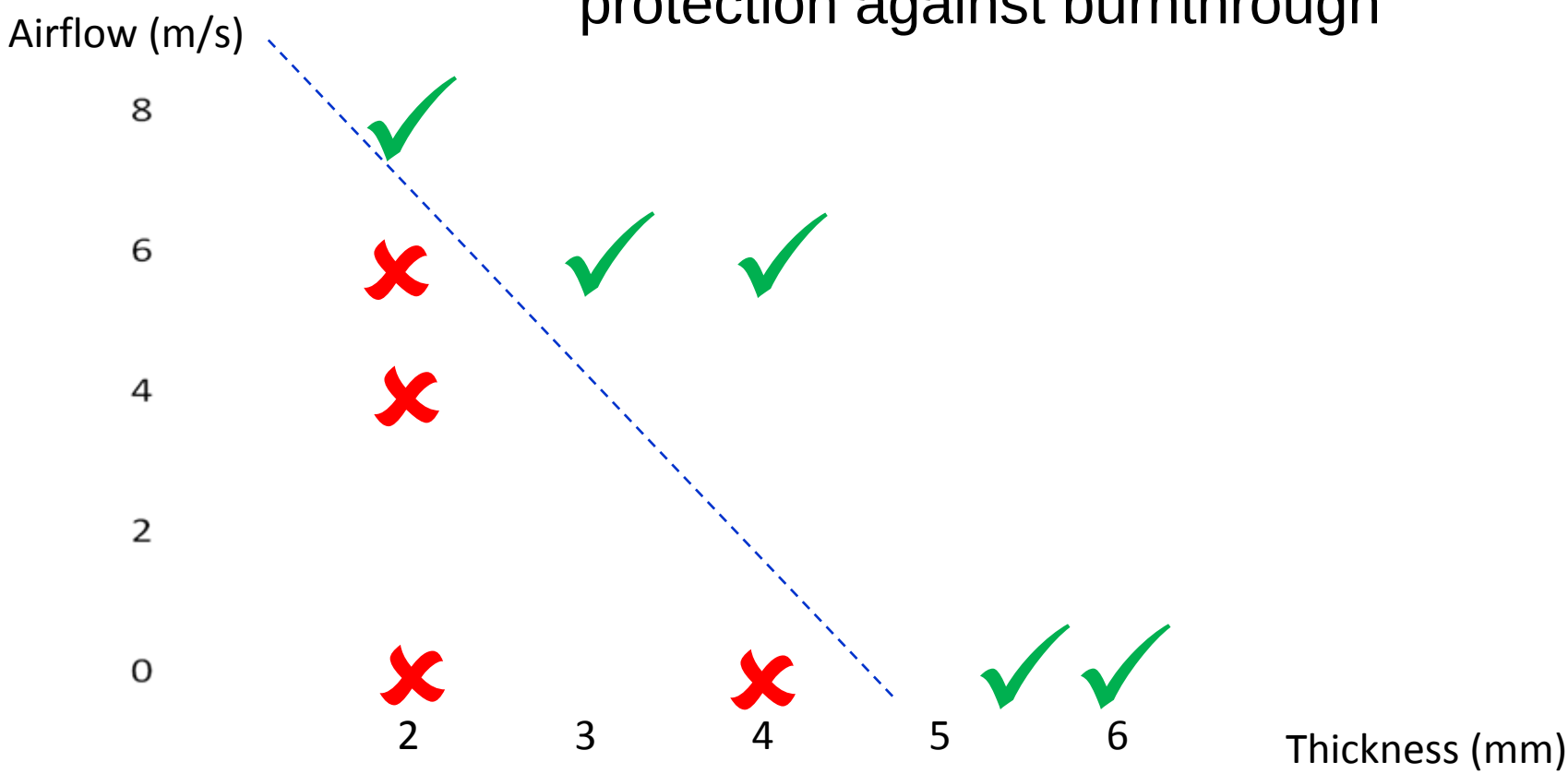
Rear temperatures little above ambient

Problems with adhesion to composite

Useful for repairs

Results: AL plate thickness & ventilation

Ventilation provides effective protection against burnthrough



Composite hardening

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- Composite hardened panels show good performance in lab-based UL 94 tests
- No improvement over unhardened materials in large-scale fire tests
- Toxicity problems with carbon nano-tube hardeners
- Hexcel composite shows promise but not yet tested

CFD Modelling – 1

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- ANSYS CFX-12
  - General purpose commercial CFD code
  - Compressible flow solver
  - Physics
    - Turbulence
    - Combustion
    - Chemical reactions
    - Radiation
    - Multi-phase flows
    - Multi-physics

CFD Modelling – 2

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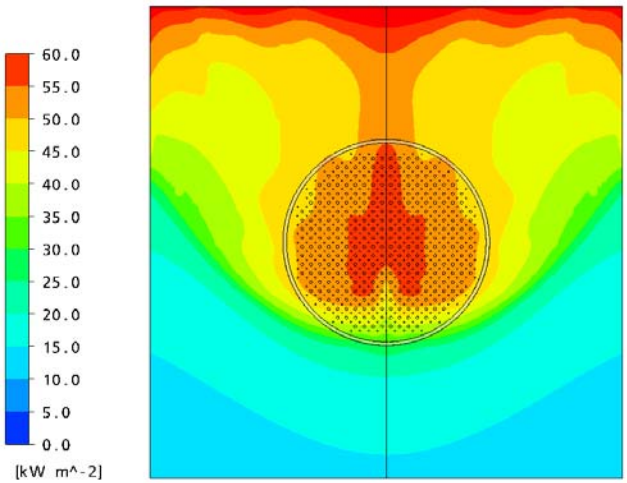
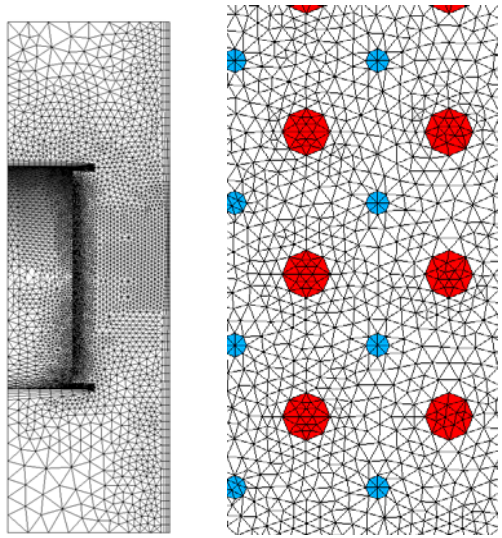
- Hybrid mesh
  - Prismatic cells in near-wall region
  - Tetrahedral cells elsewhere
- Menter's SST turbulence model
  - *K*-ω model in the near-wall region
  - *K*-ε model elsewhere
- Combustion
  - Eddy BreakUp model
- Radiation
  - P1 model
  - Discrete Transfer model
  - Monte Carlo model
- Sensitivity analysis – effects on the solution to
  - Mesh resolution
  - Choice of
    - Turbulence model
    - Radiation model (not shown here)
- All simulations were performed as steady state calculations

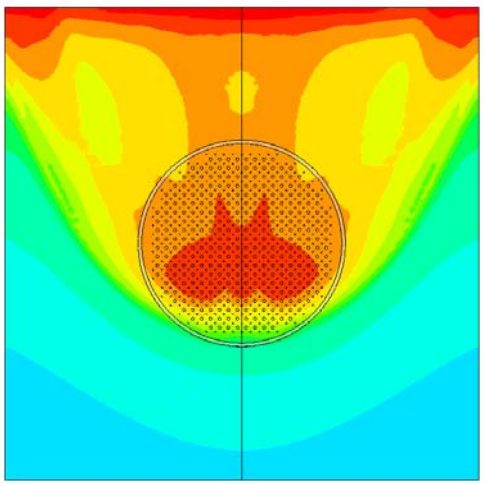
Mesh Sensitivity



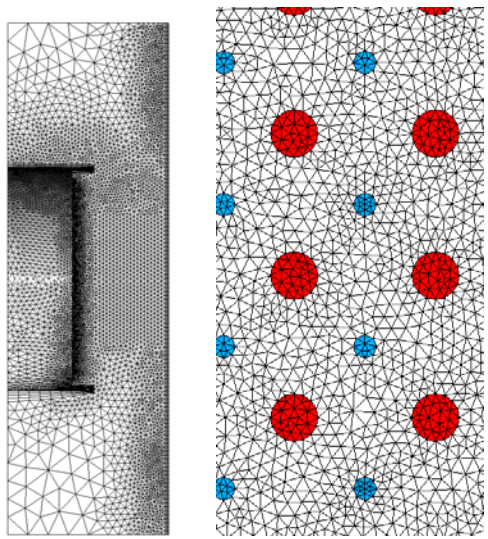
Coarse mesh



- Coarse mesh
  - ● 400,000 nodes
  - ● 1,600,000 elements

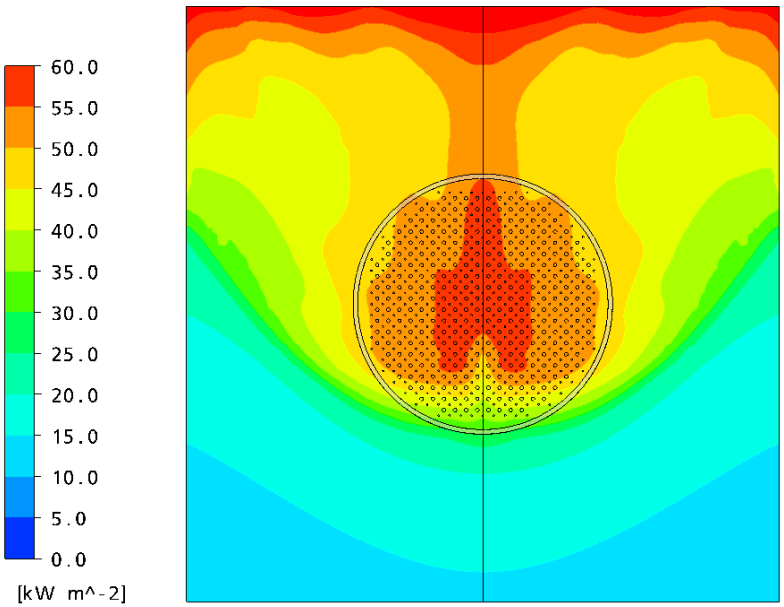


Fine mesh

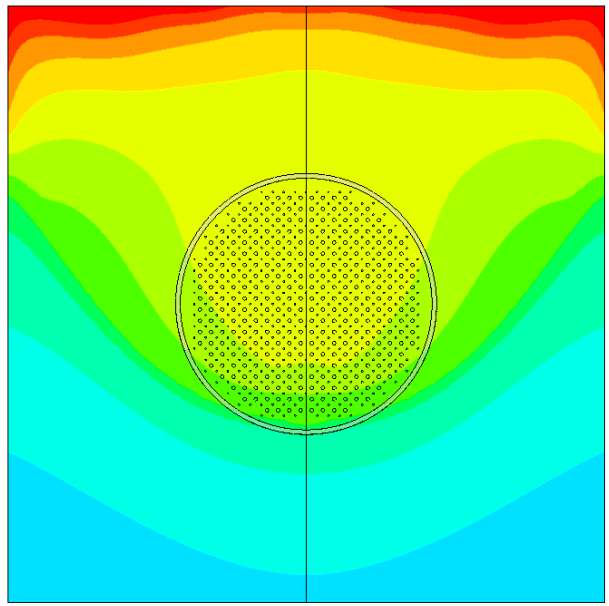


- Finer mesh
  - ● 800,000 nodes
  - ● 3,200,000 elements

Turbulence model

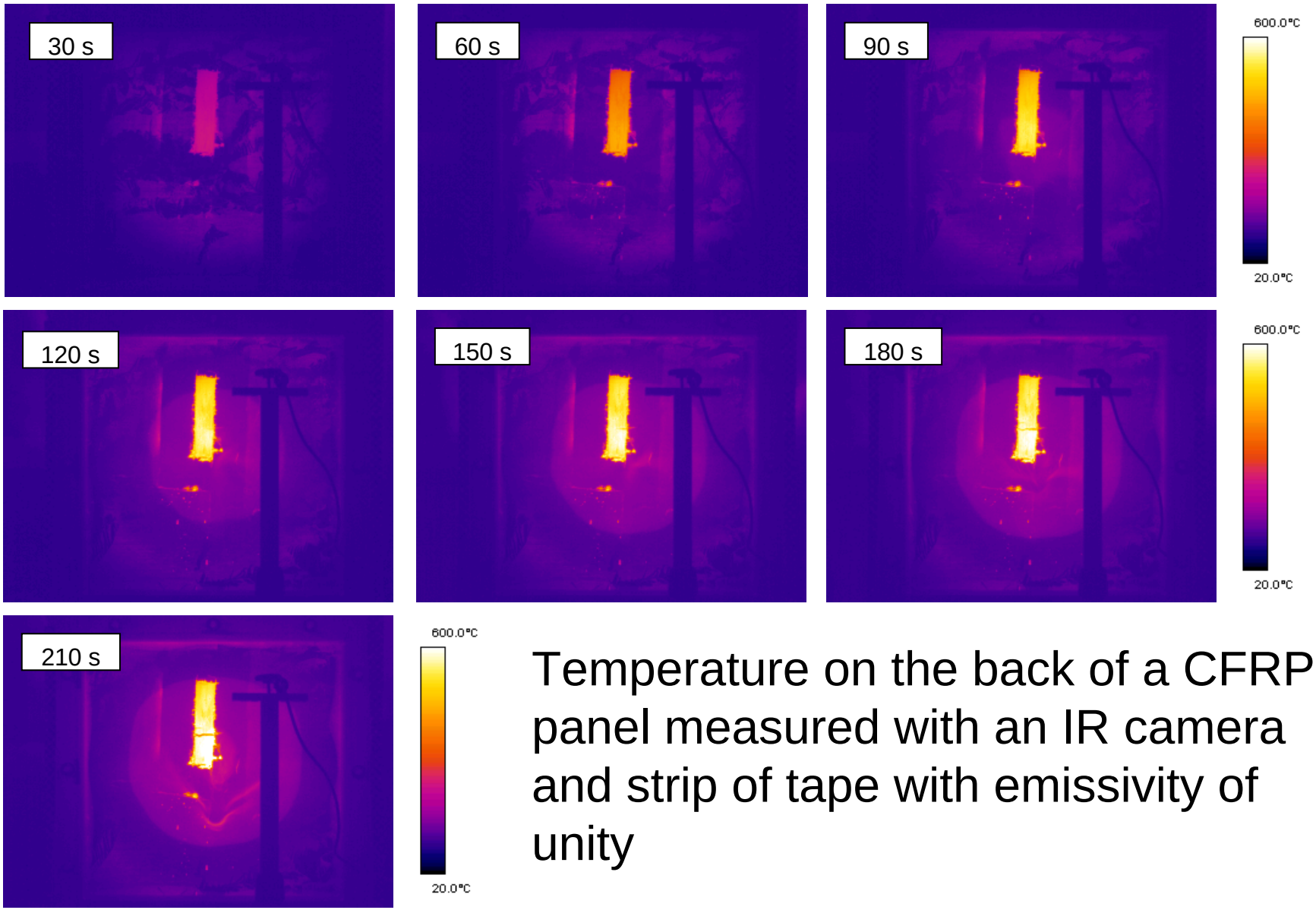


Menter's SST model



k-ε model

Temperature (IR)



Temperature on the back of a CFRP panel measured with an IR camera and strip of tape with emissivity of unity

Summary – Experimental

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- Material protection
  - Hardened composites provide little advantage
  - Thin ceramic coatings provide no benefit
  - Thick Fastblock coatings provide good protection and insulation
  - Thin stainless steel sheets prevent flame penetration but transfer heat sufficient to volatilise composite resins
- Testing
  - Testing must be carried out under pressure to fully examine composite performance
  - Lab scale fire testing does not give true idea of composite performance

Summary – Modelling

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- CFD modelling is feasible, but further work is required
- Outstanding tasks
  - Validation - no comparison between experiments and modelling yet
  - No conjugate heat transfer in the test panel
  - Material degradation is modelled with 1D model – not reported here

Acknowledgements

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  - EU FP6 Programme
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  - Rolls-Royce
  - Other UK Government Departments