MANCHESTER 1824

The University of Manchester

The Suitability of Fire-Field Modelling for Enclosure Fires involving Complex Solid Fuel Loads

STIFF Meeting Sept 2006

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Introduction

- Two types of solid fuel source: Cars and Wooden Cribs.
- Discussion of European Commission report on steel in closed car park fires.
- Comparison of FDS with other CFD simulations for car fires.
- Findings of simulations from compartment fire tests using cribs.
- Alternative modelling approaches for cars and wooden cribs.

European Commission Report

"Development of design rules for steel structures subjected to natural fires in closed car parks." EUR 18867 EN

- Closed car park tests.
- Suggested HRR curve (Figure 1).
- Fire-field simulations in 'representative' closed car parking floor.

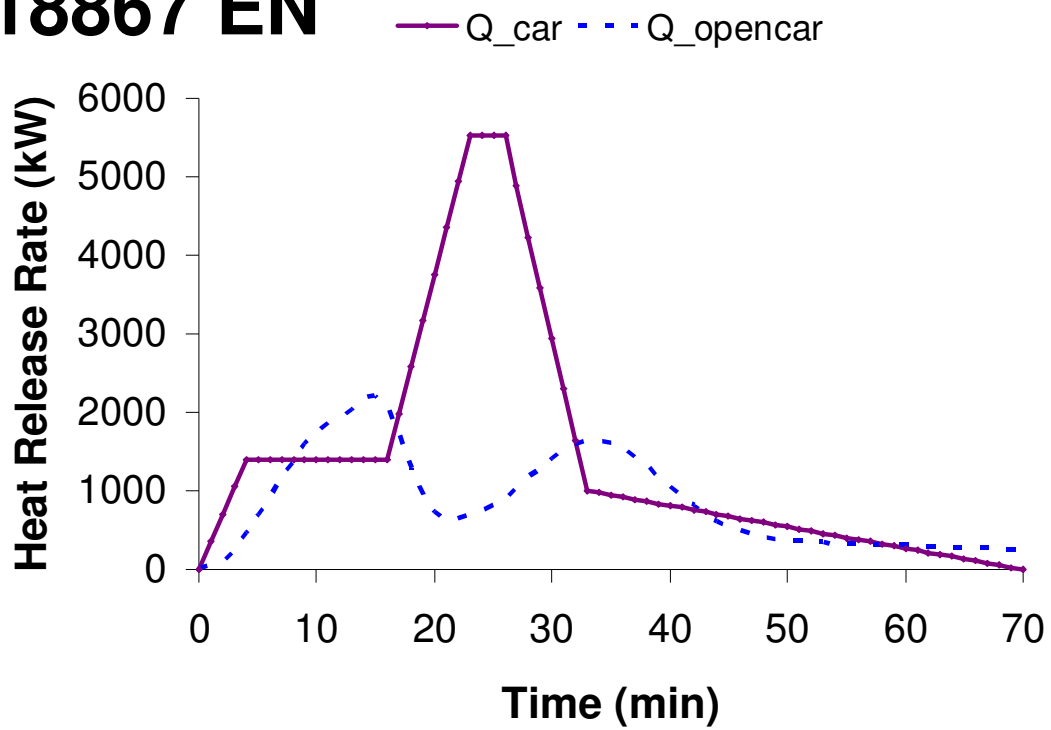


Figure 1: European Commission HRR curve comparison.

Car Fire Observations

- Open car fires: ~*2 MW* peak fire, over *1-2 hours*.
- Closed car fires: higher intensity (> *4 MW*) peak, shorter duration (< *1 hour*).
- Car type and age: More combustibles in modern cars $\longrightarrow$ greater fire intensity (over *8 MW*).
- Fire spread: *12 – 30 mins* to adjacent cars, via external plastics and tyres.

Fire Dynamics Simulator

- Computational Fluid Dynamics (*CFD*) model from NIST.
- Mass, momentum, energy and species conservation and turbulence model.
- Large Eddy Simulation: Small-scale turbulence is modelled (sub-grid), as larger eddies contain most turbulent energy.
- Combustion model: Infinitely fast reaction.
- Radiation Model: Based on local intensities.

European Commission Simulations

- "Representative" closed car park configuration.
- Car location under steel beam at point of max. bending moment.
- No combustion modelling used by European Commission.

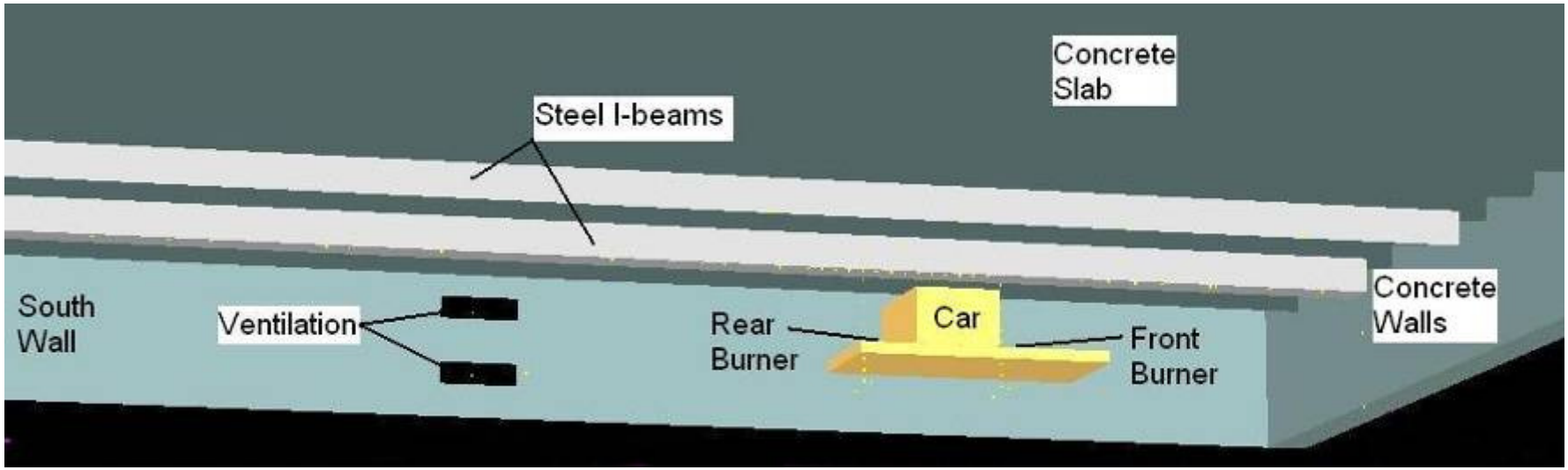
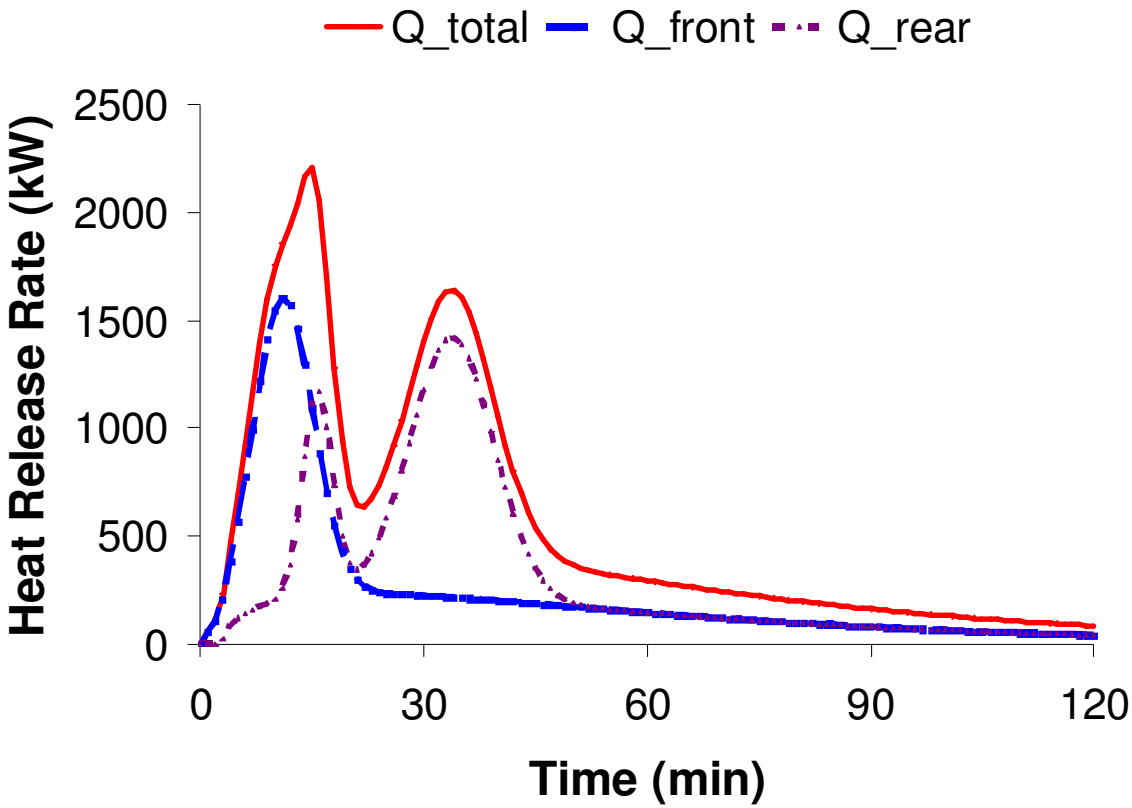


Figure 2: Detail of European Commission simulation domain.

Fire Source Modelling Approaches

- FDS extended to supply purely convective heat sources.



- HRR curve from older, open car fire (Figure 3).
- Radiative flux: Adiabatic condition.
- Fine grid needed for combustion modelled simulations.

Figure 3: HRR curve for European Commission Simulations.

Comparison of Results

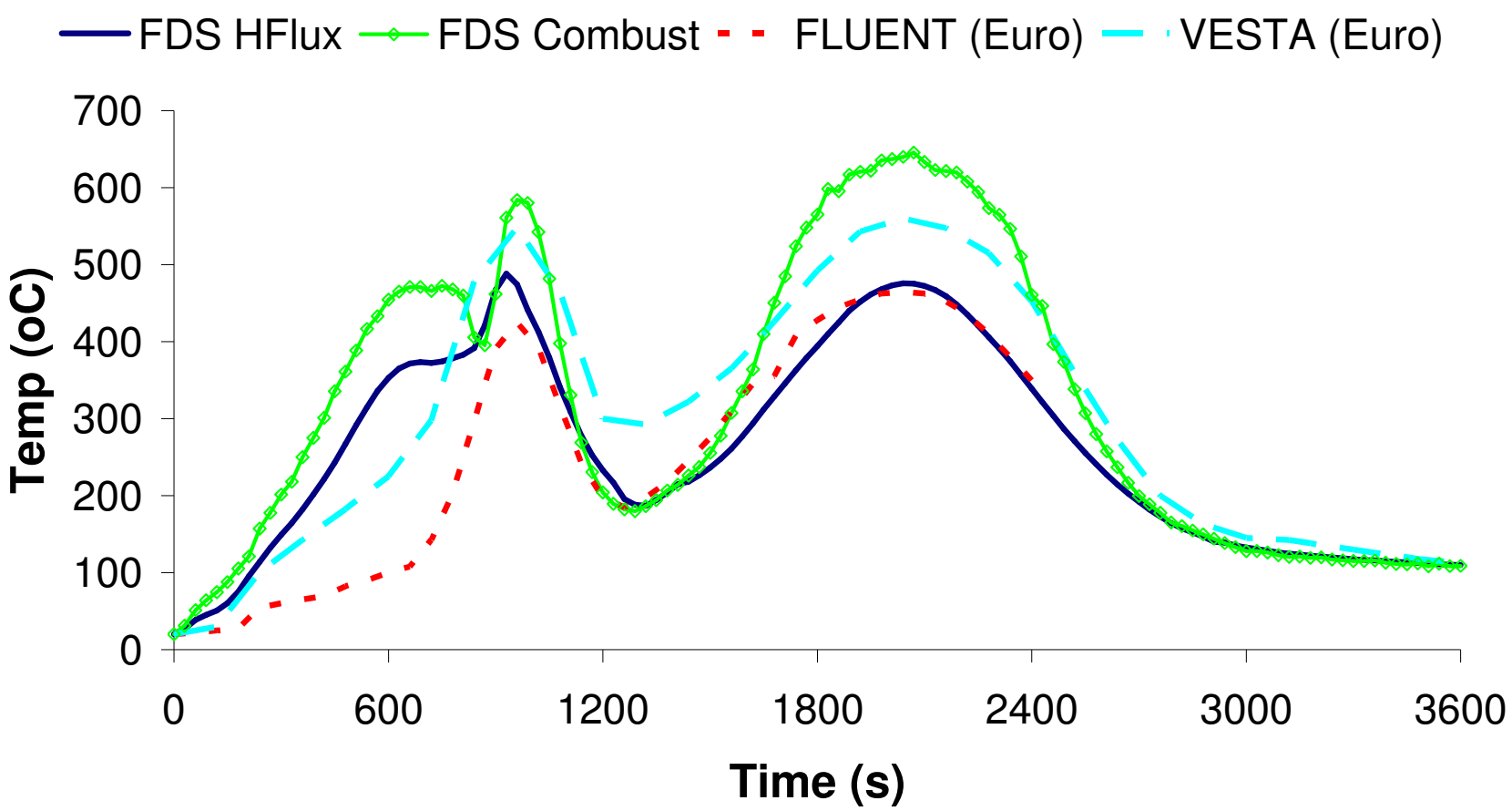


Figure 4: Above rear heat/fuel source temperatures, ceiling height.

Comparison of Results

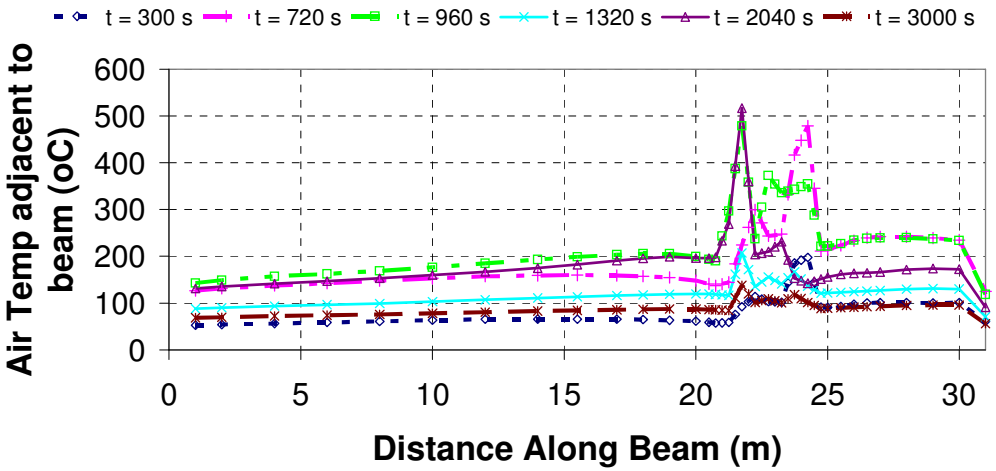


Figure 5: Temp. adjacent to lower flange of beam, heat flux sim.

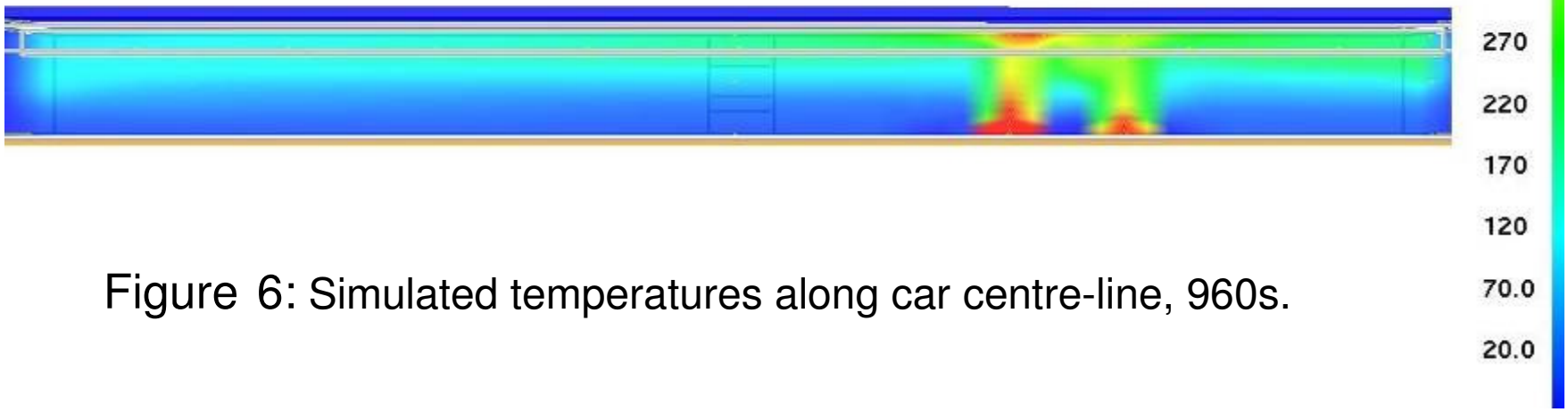


Figure 6: Simulated temperatures along car centre-line, 960s.

Mixture Fraction Combustion

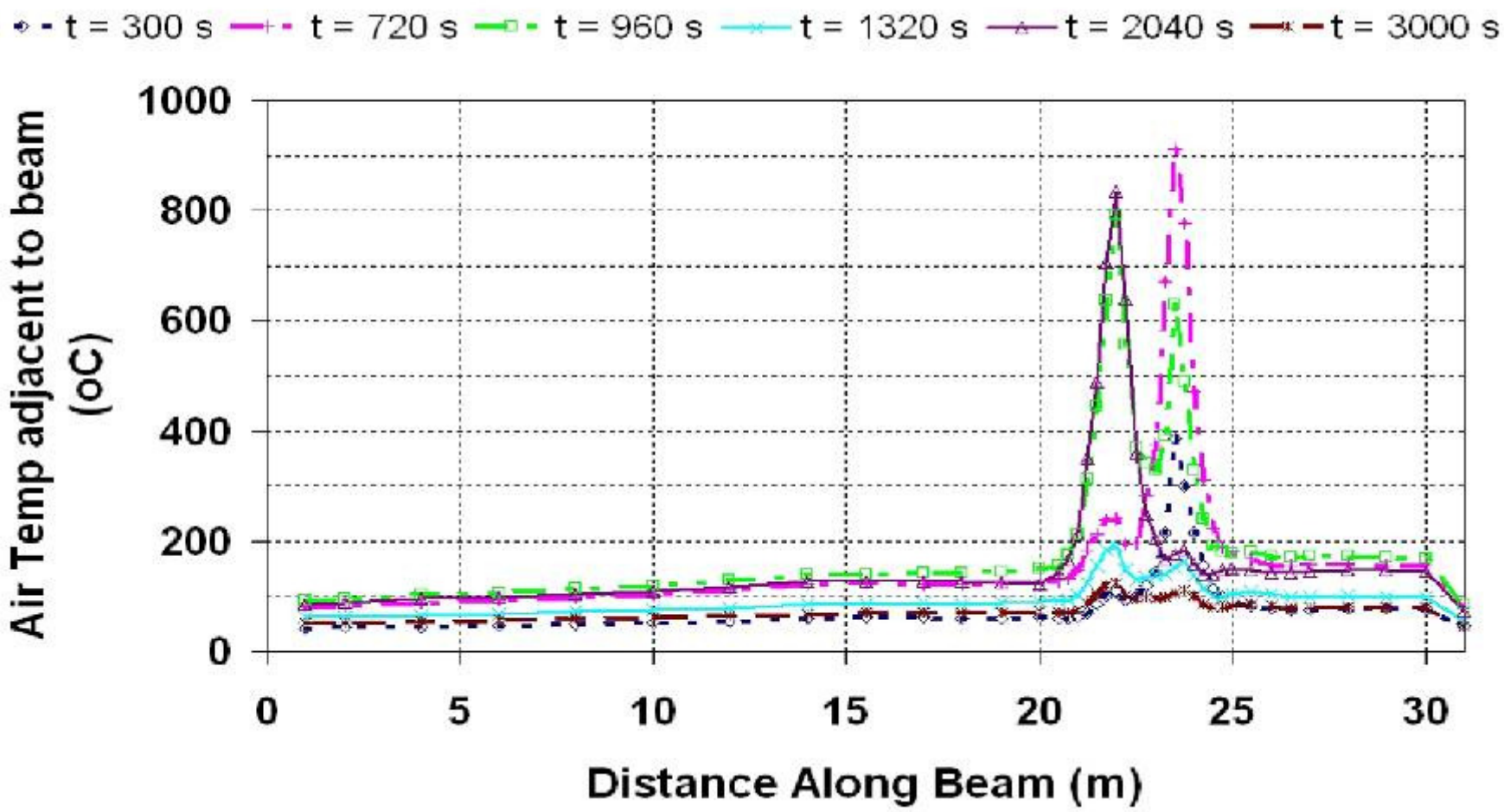


Figure 7: Temps adjacent to lower flange of beam, combustion simulation.

European HRR Curve

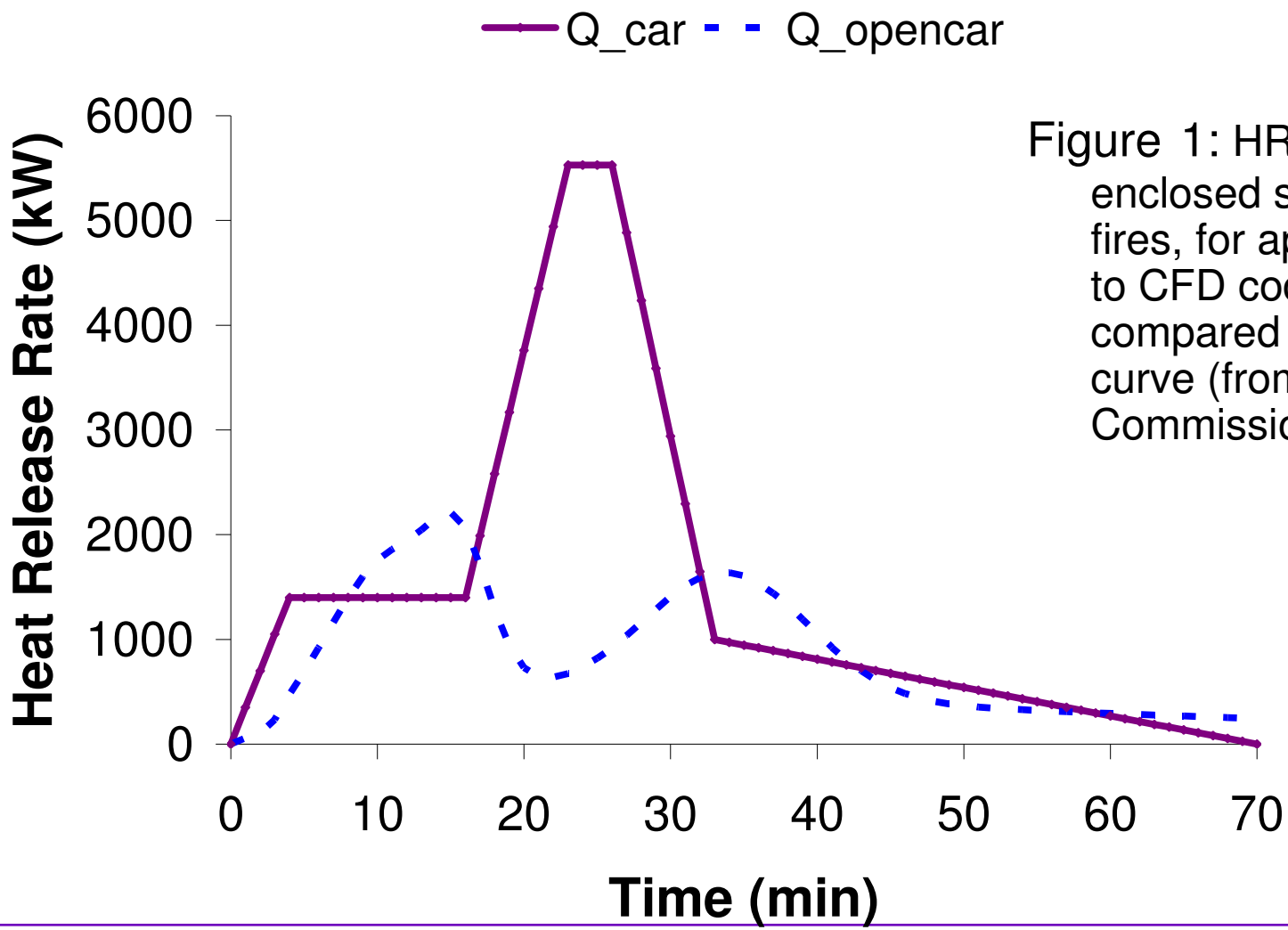


Figure 1: HRR curve for enclosed single car fires, for application to CFD codes, compared to previous curve (from European Commission, 1999).

European HRR Curve

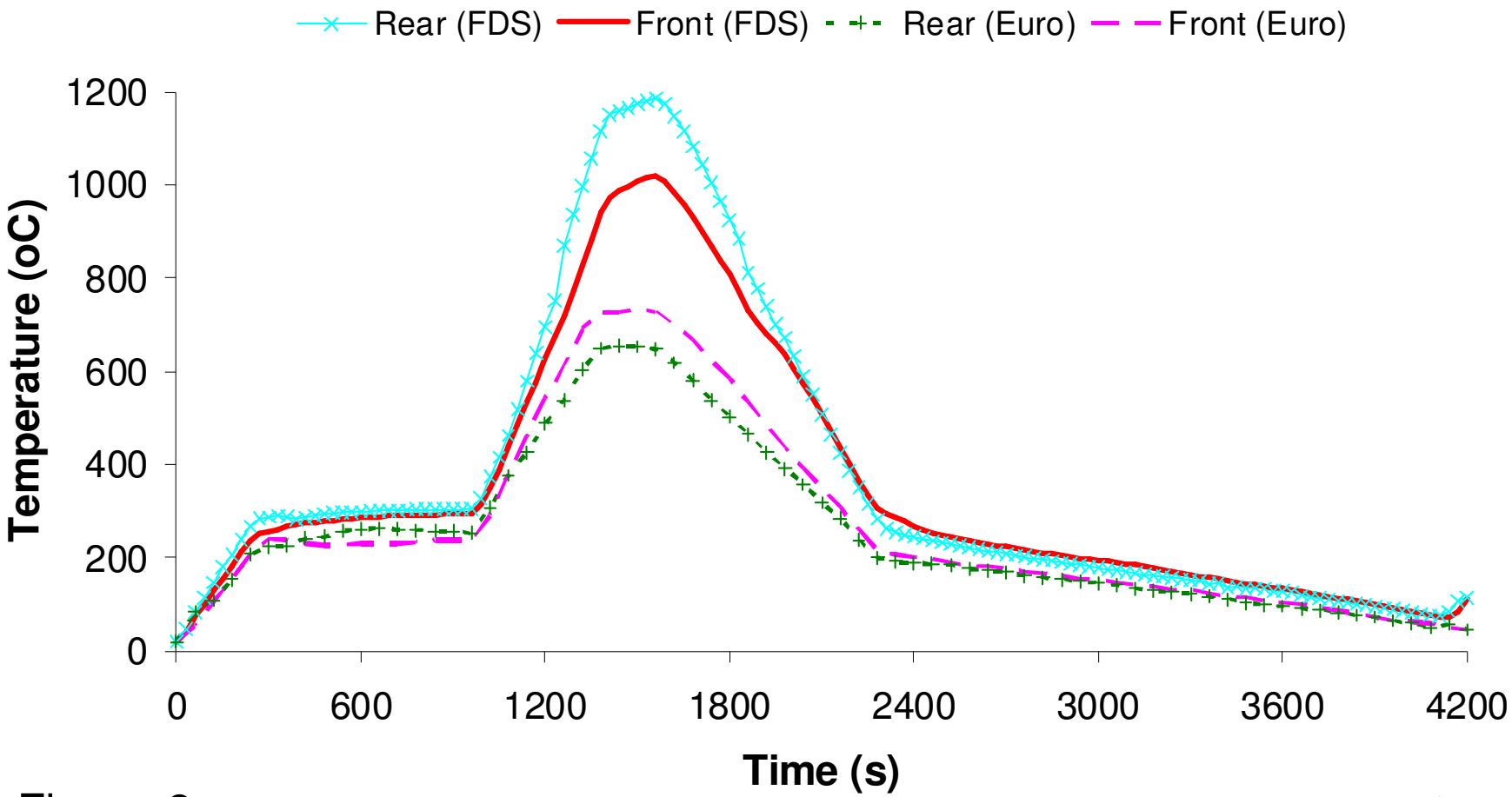


Figure 8: Estimated temperatures produced using the recommended curve for closed car-park fires, from FDS and European Commission report.

Issues Raised

- FDS successfully compared to FLUENT and TNO Vesta.
- European Commission report implies use of unprotected steel for closed car parks, based on simulations, despite tests (*1269°C* near ceiling).
- No validation of simulations with experiment.
- Higher peaks produced with combustion modelling than without.
- Questionable results for recommended design curve.

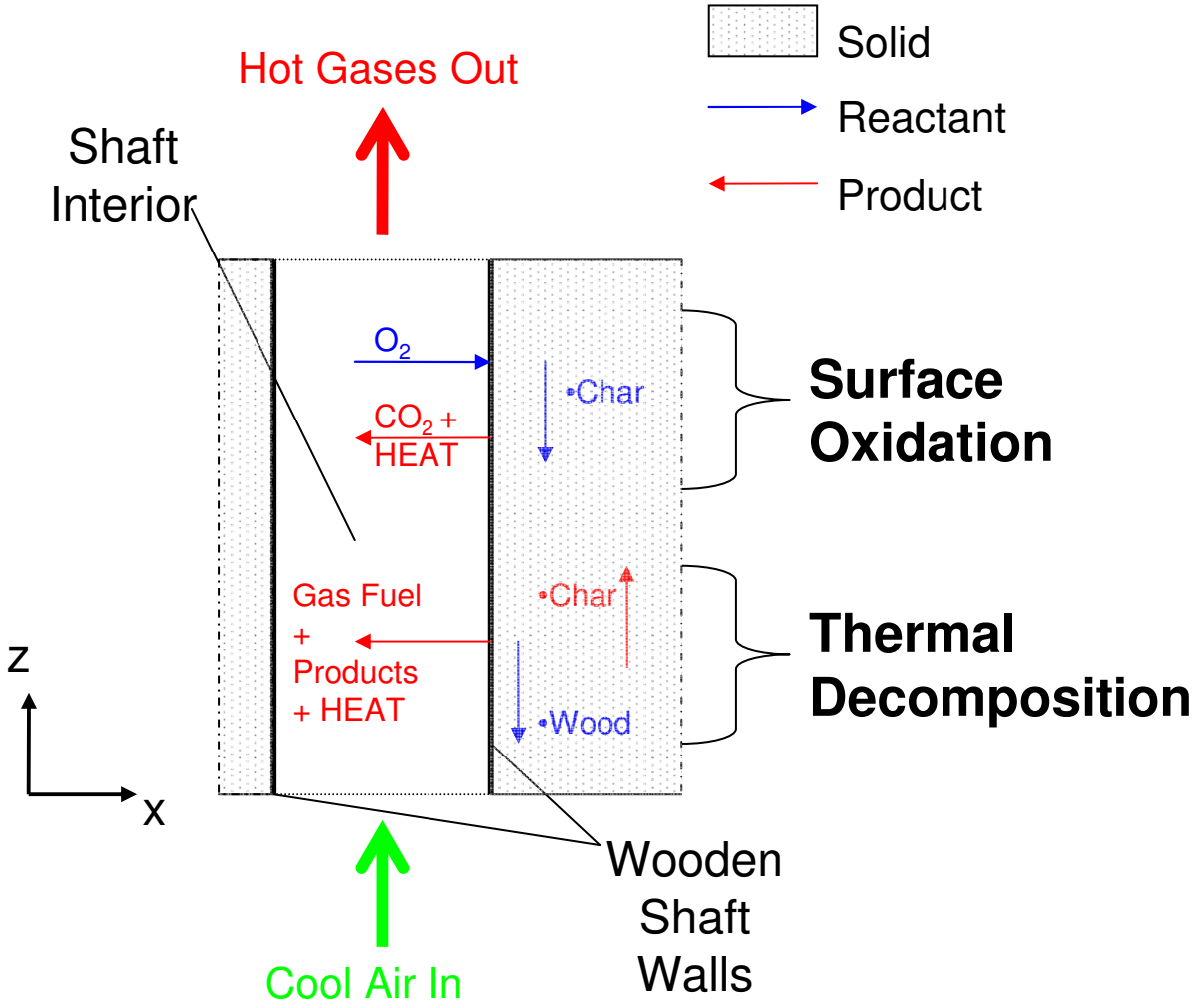
Suggested Car model

- Multi-zone model: one for each ‘compartment’.
- Balances for heat and mass transfer between zones and main simulation.
- Model fire spread through car.
- Supplies fuel and combustion product outputs.
- Dependence on heat feedback and oxygen availability.
- Direct modelling of major external plastics (thermoplastic model).

Compartment Fire Tests

- Wooden cribs often used, as self-sustaining and representative of office/residential fire loads.
- Can be mixed with plastics.
- Example Cardington 12m X 12m X 3.4m.
- Much data on wooden crib fires, since early 60's.
- Simulations are dependant on HRR curves and do not represent solid burning processes.

Principles of Wood Combustion



Crib Model Construction

- 1-D fluid-flow equations with time dependence.
- Mass and chemical species equations include source/sink terms for 3 processes.
- Energy equation includes heat sources from combustion.
- Compatible with Mixture Fraction combustion model: outputs fuel OR oxygen at top, not both.
- Crib is collection of parallel shafts.
- Re-evaluates crib combustion processes based on conditions outside the crib.

Aims of Models

- Model fires of given load and distribution in any compartment design.
- Allows calculation of fire-driving mechanisms.
- Maintain sufficiently course grids for large compartment simulations.
- Dynamically integrated – no HRR curve needed for fire.

Conclusions

1. FDS achieves comparable performance to other *CFD* packages.
2. Fire-field simulations highly dependant on HRR curves.
3. Combustion modelling produces higher air temperature peaks.
4. Need to develop complex solid fuel combustion models to improve adaptability and performance of fire-field models.

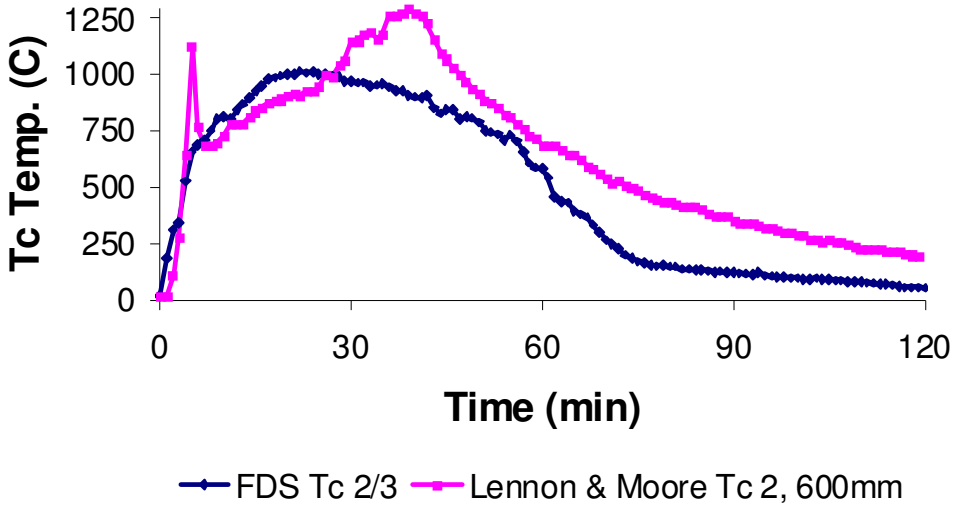
Acknowledgements

This work was produced as part of EPSRC-Corus case award No. 04300406. This financial contribution, together with the guidance provided by Dr Brian Kirby of Corus, is gratefully acknowledged. The knowledge, experience and time of Prof. Colin Bailey and Dr David Apsley of The University of Manchester is also greatly appreciated.

Appendix

Summary of previous progress

Cardington 12m X 12m Compartment Fire Tests:



- Dependence on Heat Release Rate curves.
- Need for time-dependent modelling solutions.
- Limited practical use.

Figure A1: Temperatures for Test 3: Rear, 600mm from ceiling.

Summary of previous progress

Car Fires:

- Combustion in car interior not considered.
- Underestimates heat transfer from car body.
- Limited consideration of fuel release about car.

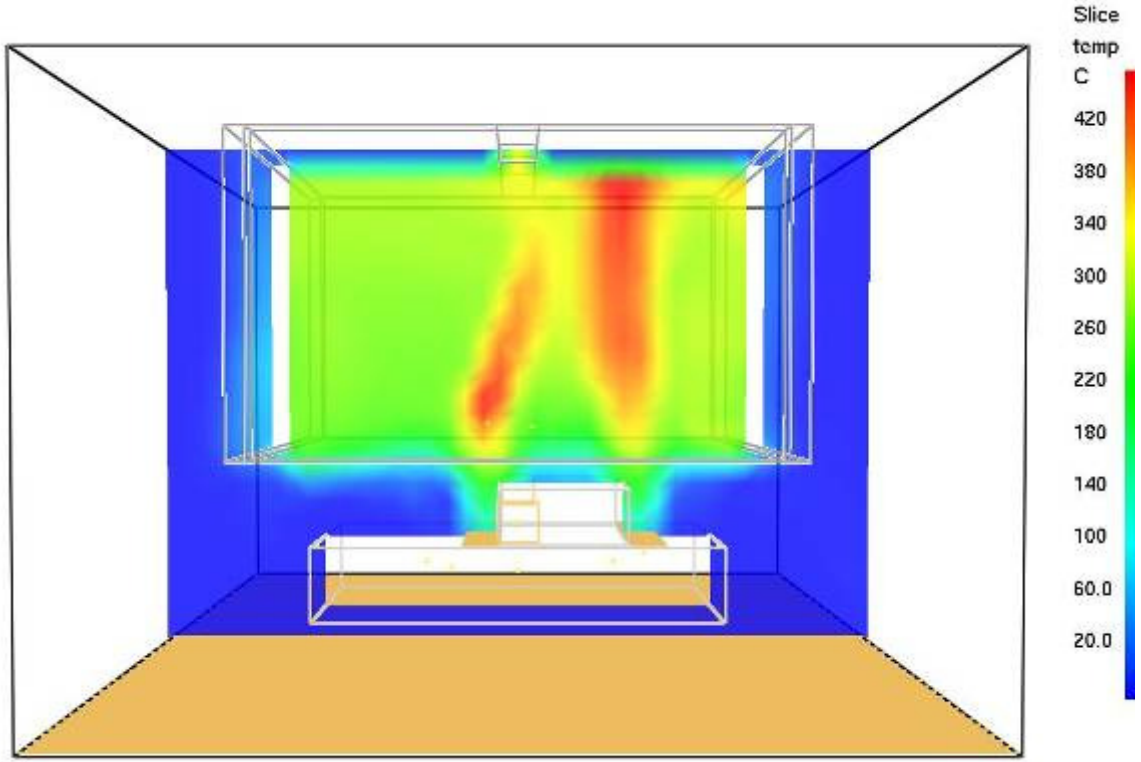


Figure A2: Open car fire temperatures at first peak burning period: Centre plane.

Heat Flux Vs. Combustion

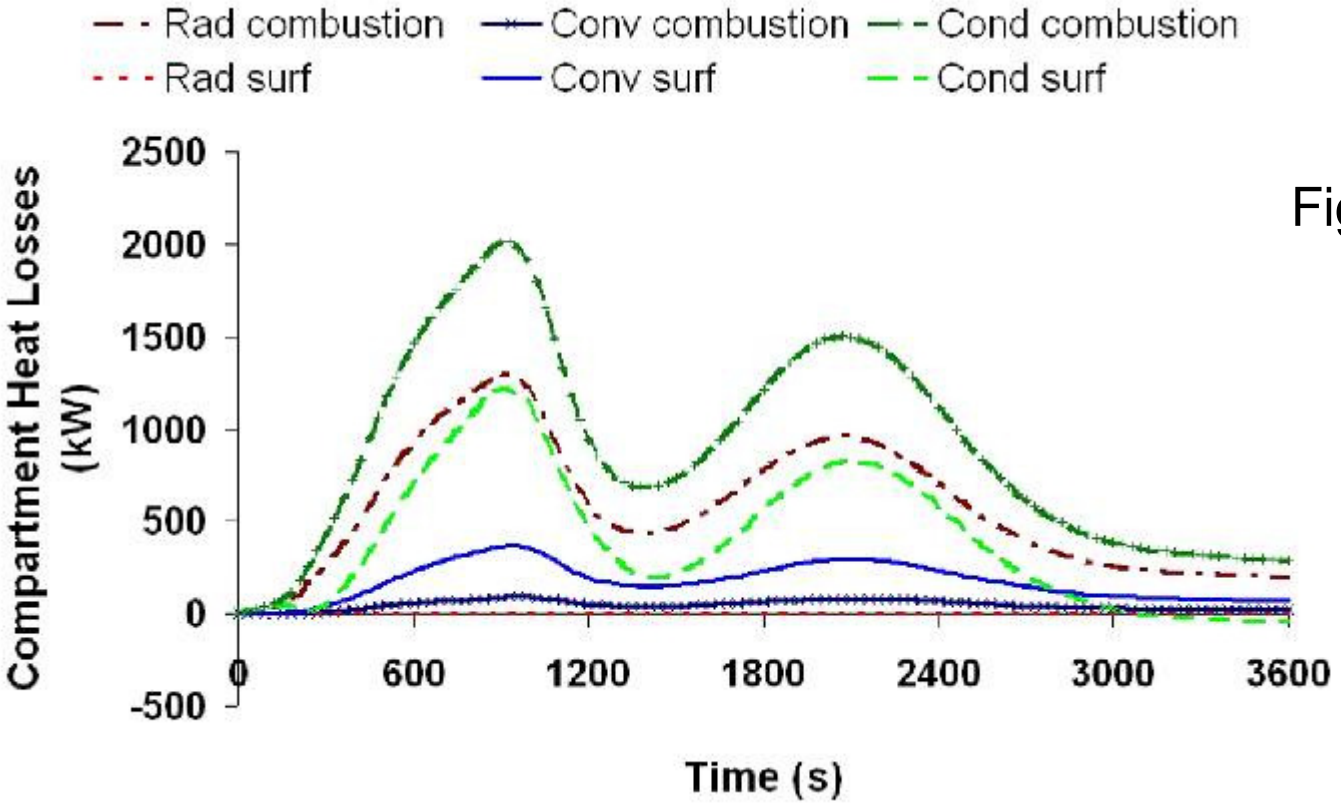


Figure A3: Total heat losses from FDS domain, for pure convective and combustion simulations.

- No net radiative losses in heat flux case.
- Double conductive losses in combustion case.

Suitability of CFD Modelling for Enclosure Fires

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