Ensuring that CFD for Industrial Application is “Fit for Purpose”

November 19th, 2009

Agenda

Ensuring that CFD for Industrial Applications is "Fit for Purpose"

November 19th,, 2009

7am PST (Seattle) / 10am EST (New York) / 3pm GMT (London)

- Welcome & Introduction (Overview of NAFEMS Activities)
  - Mr. Matthew Ladzinski, NAFEMS North America
- Ensuring that CFD for Industrial Applications is "Fit for Purpose"
  - Chris Lea, Ph.D., Lea CFD Associates Ltd
- Q&A Session
  - Panel
- Closing

Ladzinski

Lea

THE INTERNATIONAL ASSOCIATION FOR THE ENGINEERING ANALYSIS COMMUNITY

An Overview of NAFEMS Activities

Matthew Ladzinski
NAFEMS
NAFEMS North America

Planned Activities

- Webinars
  - New topic each month!
    - What is V&V? – December 3rd, 2009
  - Recent webinars:
    - How to Ensure that CFD for Industrial Applications is Fit for Purpose
    - Practical CFD
    - Composite FE Analysis
    - 10 Ways to Increase Your Professional Value in the Engineering Industry
    - Dynamic FE Analysis
    - Modal Analysis in Virtual Prototyping and Product Validation
    - Pathways to Future CAE Technologies and their Role in Ambient Intelligent Environments
    - Computational Structural Acoustics: Technology, Trends and Challenges
    - FAM: Advances in Research and Industrial Application of Experimental Mechanics
    - CCOPPS: Power Generation: Engineering Challenges of a Low Carbon Future
    - Practical CFD Analysis
    - Complexity Management
    - CCOPPS: Creep Loading of Pressurized Components – Phenomena and Evaluation
    - Multiphysics Simulation using Implicit Sequential Coupling
    - CCOPPS: Fatigue of Welded Pressure Vessels
    - Applied Element Method as a Practical Tool for Progressive Collapse Analysis of Structures
    - A Common Sense Approach to Stress Analysis and Finite Element Modeling
    - The Interfacing of FEA with Pressure Vessel Design Codes (CCOPPS Project)
    - Multiphysics Simulation using Directly Coupled-Field Element Technology
    - Methods and Technology for the Analysis of Composite Materials
    - Simulation Process Management
    - Simulation-supported Decision Making (Stochastics)
    - Simulation Driven Design (SDD) Findings

To register for upcoming webinars, or to view a past webinar, please visit: www.nafems.org/events/webinars

- Established in 2009
- Next courses:
  - Dynamic FE Analysis – January 12th, 2010 (*six-week course*)
  - Non-Linear Analysis – March 2nd, 2010 (*four-week course*)
  - Composite FE Analysis – April 13th, 2010 (*four-week course*)
- Proposed course offerings:
  - Optimization – Summer 2010 (*four-week course*)
- For more information, visit: www.nafems.org/e-learning

NAFEMS Events

- Multiple opportunities to attend conferences, seminars/workshops and training courses

Ensuring that CFD for Industrial Applications is 'Fit for Purpose'
19th Nov 2009
Webinar
Online,UK

FEM Basic 2 - Praxisorientierte Grundlagen für FEM-Analysen
23rd Nov 2009
Course
Wiesbaden,Germany

Introduction au Calcul de Structures, aux Éléments Finis et à la Simulation Numérique
24th Nov 2009
Course
Paris,France

Composites FE Analysis
24th Nov 2009
Course
e-Learning,Online

Practical Stress Analysis & Finite Element Methods
1st Dec 2009
Course
Stratford Upon Avon,UK

Analisi sismica: metodi & applicazioni
2nd Dec 2009
Seminar
Bologna,Italy

Simulating Composite Materials and Structures
2nd Dec 2009
Seminar
Esbjerg,Denmark

What is V&V?
3rd Dec 2009
Webinar
Online,USA

Finite Element Analysis - A Universal Tool for Engineering Analysis
4th Dec 2009
Workshop
Bangalore,India

Modélisation Systèmes et Réduction de Modèles
9th Dec 2009
Seminar
Paris,France

Finite Element Analysis - A Universal Tool for Engineering Analysis
17th Dec 2009
Workshop
Pune,India

Finite Element Analysis - A Universal Tool for Engineering Analysis
17th Dec 2009
Workshop
Pune,India

Dynamic FE Analysis
12th Jan 2010
Course
e-Learning,Online

Simulating Composite Materials and Structures
2nd Feb 2010
Seminar
Esbjerg,Denmark

Practical Analysis of Laminated Composite Structures
3rd Feb 2010
Seminar
Bristol,UK

Delivering CAE for the Nuclear Energy Industry
23rd Feb 2010
Seminar
Knutsford,UK

Non-Linear Analysis
2nd Mar 2010
Course
e-Learning,Online

Practical Stress Analysis & Finite Element Methods
9th Mar 2010
Course
Stratford Upon-Avon,UK

Coupling 1D and 3D CFD: The Challenges and Rewards of Co-Simulation
17th Mar 2010
Seminar
Gaydon,UK

Composites FE Analysis
13th Apr 2010
Course
e-Learning,Online

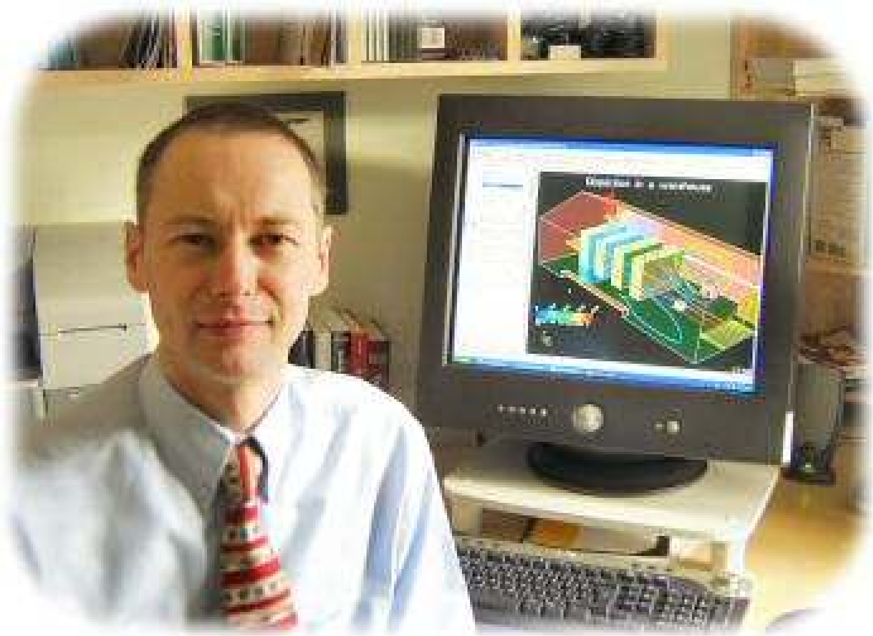
UK Conference 2010 - Engineering Simulation: Contributing to Business Success
8th Jun 2010
Conference
Oxford,UK

- Let us know if you would like to schedule an on-site training course

Ensuring that CFD for industrial applications is ‘Fit for Purpose’

Dr Chris Lea

- Dr Chris Lea, FIMechE
- 25 years experience in CFD
- BSc Mechanical Engineering
- MSc by research – experimental fluid flow
- PhD in CFD – turbulence modelling for in-cylinder flows
- 12 years leading CFD team in UK HSE – industry regulator
- Independent CFD consultant since 2004



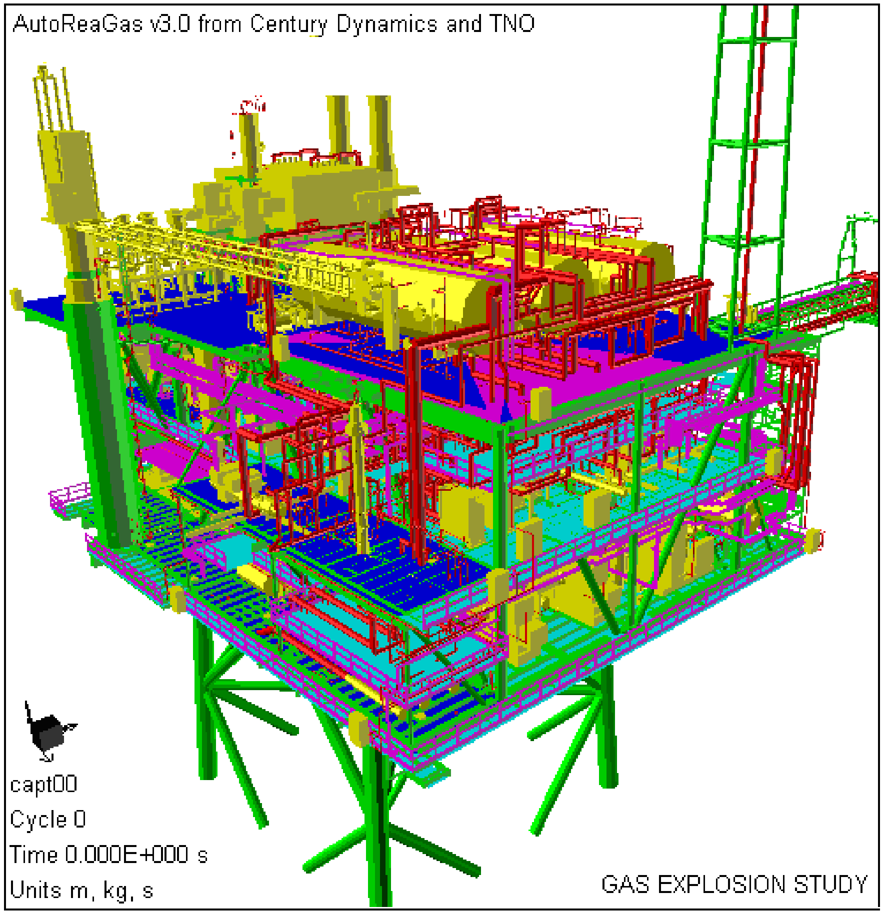
www.leacfd.com

Overview

- Need for, and meaning of, ‘Fit for purpose’ CFD
- Examples of simulations which are fit for purpose
- General procedure for fit for purpose CFD
- Idealisation – an introduction
- Building confidence
- Further examples of idealisation, and potential pitfalls
- Concluding remarks
- Questions and answers

Industrial CFD project
- common characteristics

- Complex geometry
- Complex physics
- Uncertain boundary conditions
- ………...
- Time-constraints
- Accuracy demands
- Finite compute resources
- ………..etc



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‘Fit for Purpose’

- To met project aims, resources must be allocated to best effect and so that an appropriate compromise is obtained between accuracy, timeliness, staff effort and computing costs.

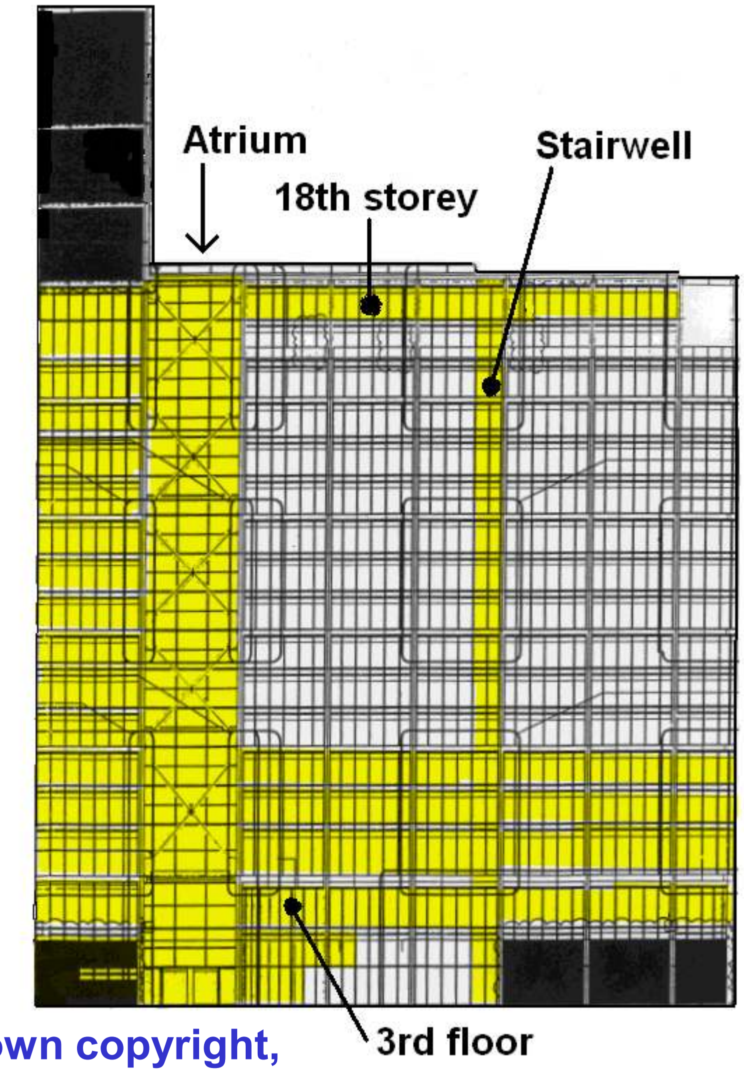
“CFD which is fit for purpose meets project aims with an optimal use of available resources”

"Ensuring that CFD for industrial applications is Fit for Purpose"

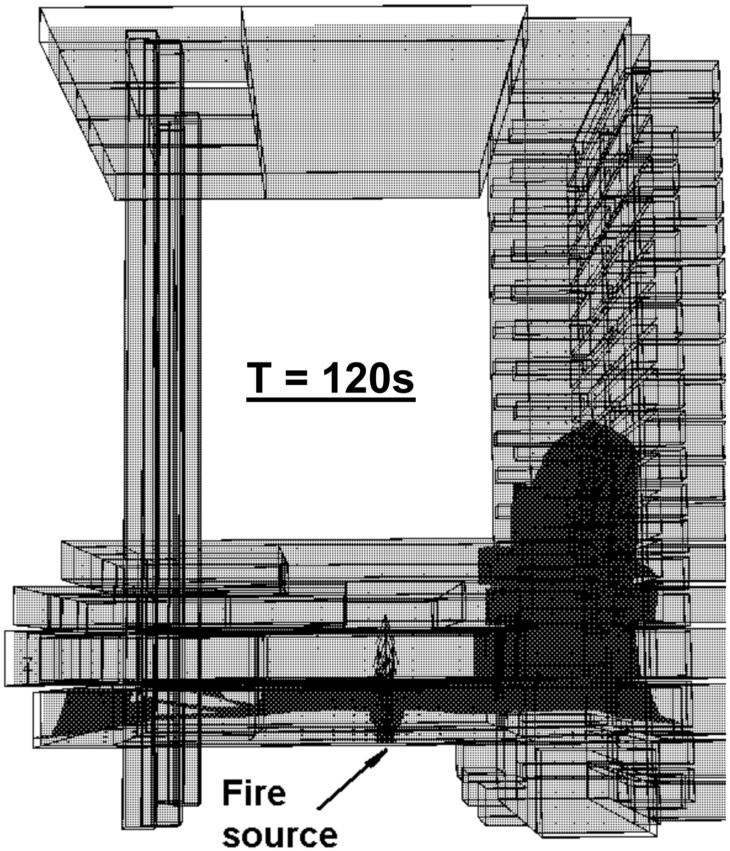
- New NAFEMS book
- Targeted at new and improving CFD analysts
- Main focus is industrial applications with significant complexity
- Examples contributed by industry, software vendors, consultants, academia and other research institutions
- ~80 pages, >40 references
- Due for printing and distribution in early 2010

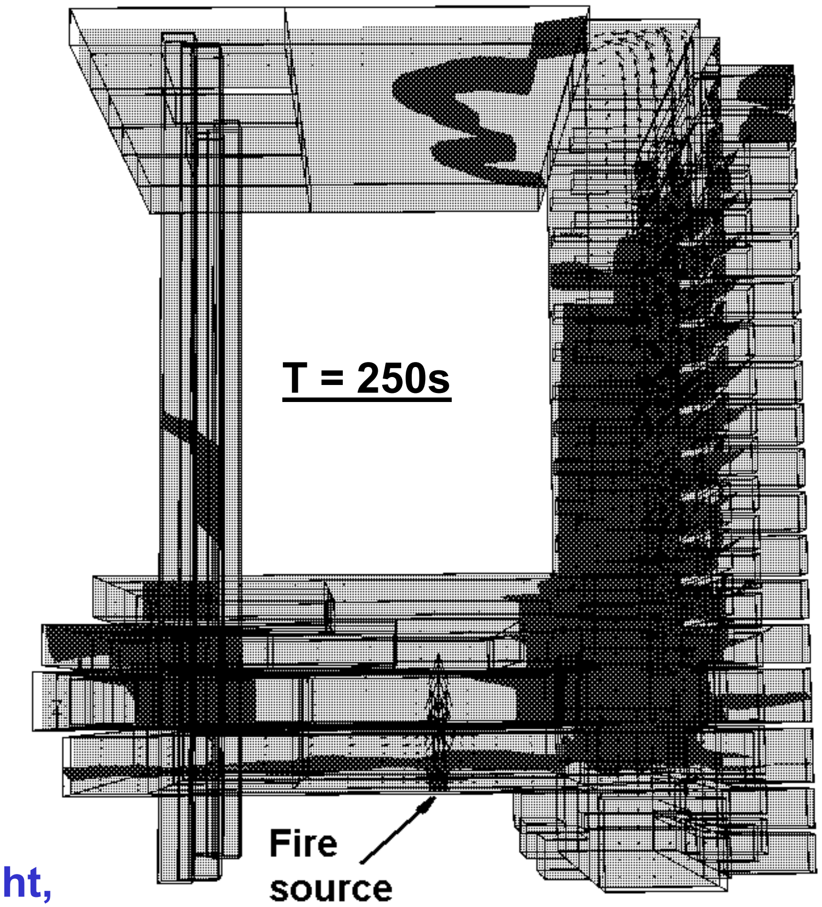
'Fit for purpose' simulation Example 1

- Smoke movement in a high-rise building
- Aim: How long for smoke to travel from a fire on the 3rd floor to the 18th floor?
- Computational domain highlighted in yellow
- Omitting intervening floors results in a more efficient simulation, which nevertheless still meets project aims



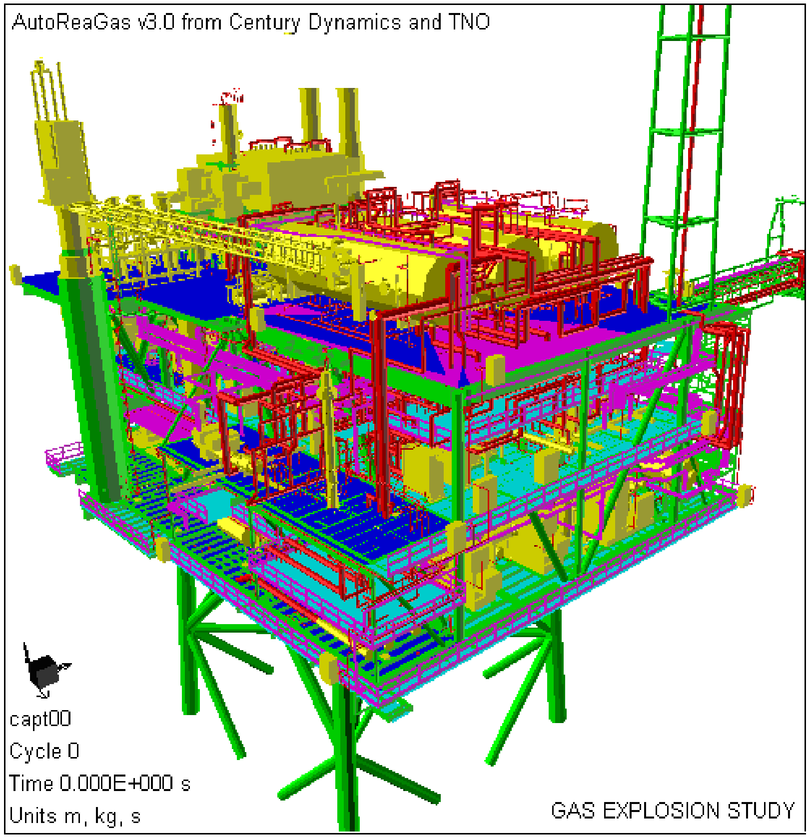
'Fit for purpose' simulation - Example 1

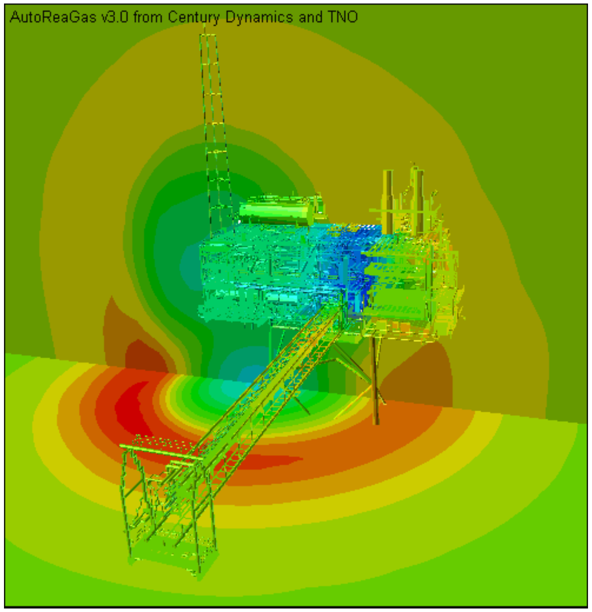




‘Fit for purpose’ simulation Example 2

- Gas explosion hazards on offshore platforms
- Aim: predict explosion pressure
- Effects of small-scale geometry on flame front are not resolved explicitly
- Instead, a ‘sub-grid model’ is used





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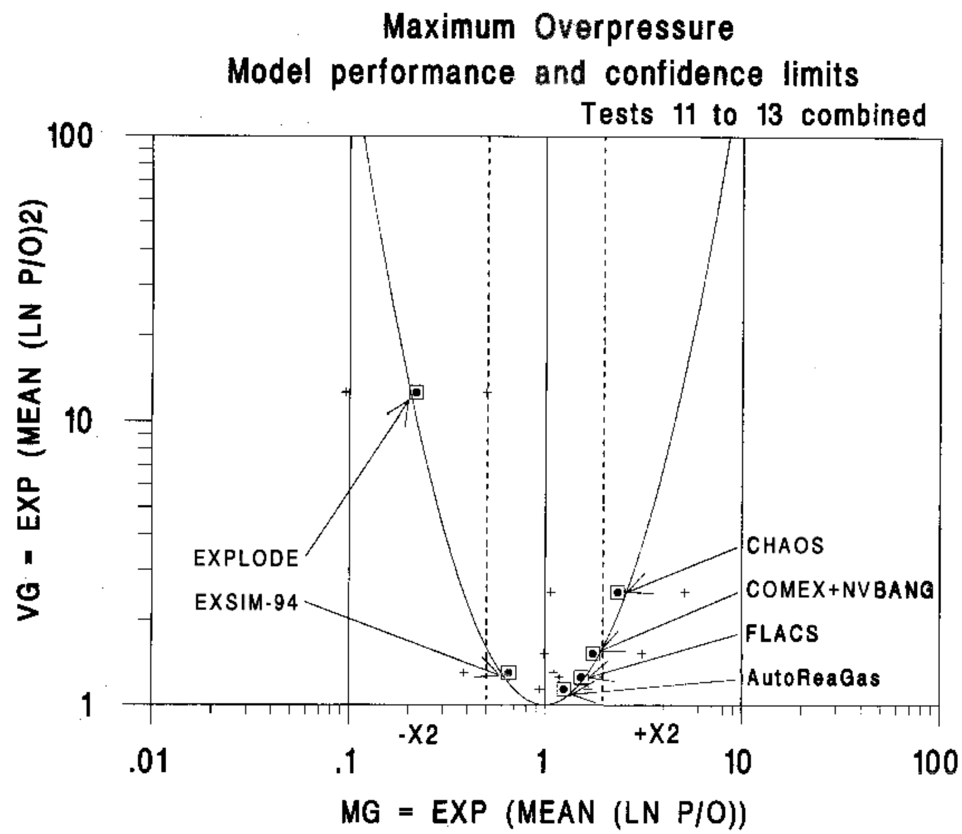

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General procedure for fit for purpose CFD (1)

1. Determine the purpose of the simulation
2. Identify accuracy requirements and resources available
3. Break the simulation down into its component tasks:

   - domain
   - geometry creation/import/clean-up
   - meshing
   - physical models
   - physical properties
   - boundary conditions
   - numerical treatments & convergence
   - analysis of results

General procedure for fit for purpose CFD (2)

4. Identify idealisations leading to beneficial simplifications within each task, whilst still meeting project requirements
5. Make an initial allocation of resources to component tasks, taking into account the object and required accuracy of the simulation so as to balance resources appropriately
6. Consider any further idealisations and simplifications
7. Refine the allocation of staff and computing resources across simulation tasks.
8. Review simulation time-scales, required staff effort and computing resources – comparing these against project constraints, and if necessary repeat steps 6 to 8

Idealisation

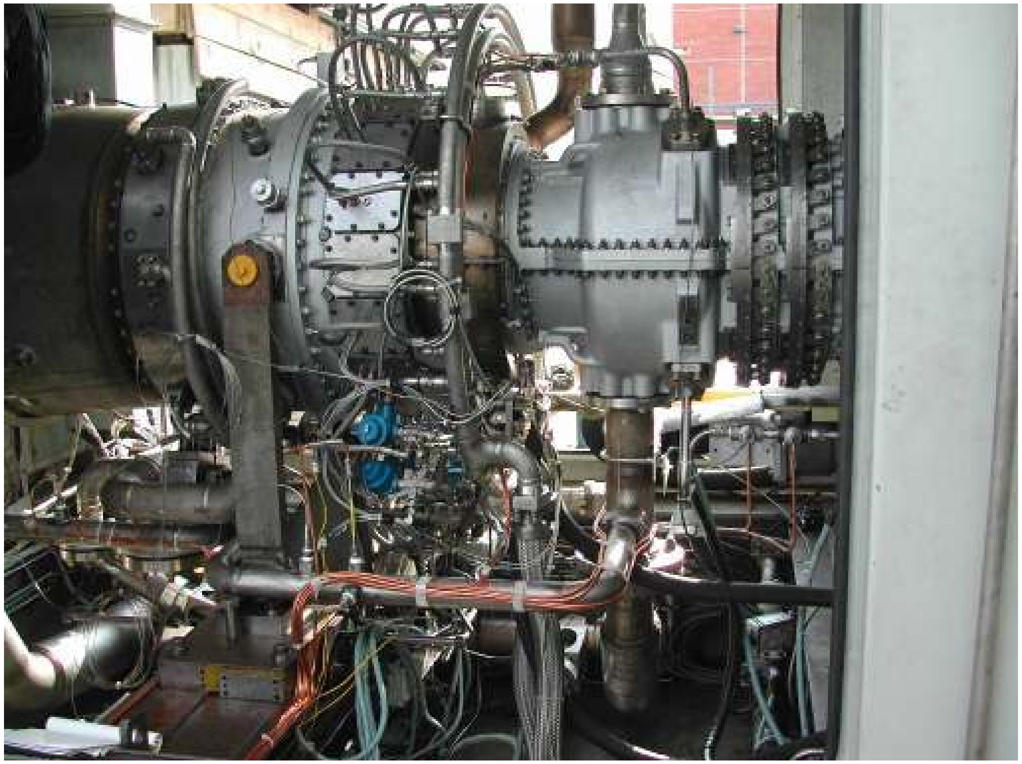
Idealisation is a key step in this general procedure

Seeking to apply knowledge and understanding of appropriate idealisations which will lead to beneficial simplifications

Idealisation – stripping away of unnecessary complexity

An example…….

Example of idealisation: Simulation of leak hazards in gas turbine enclosures



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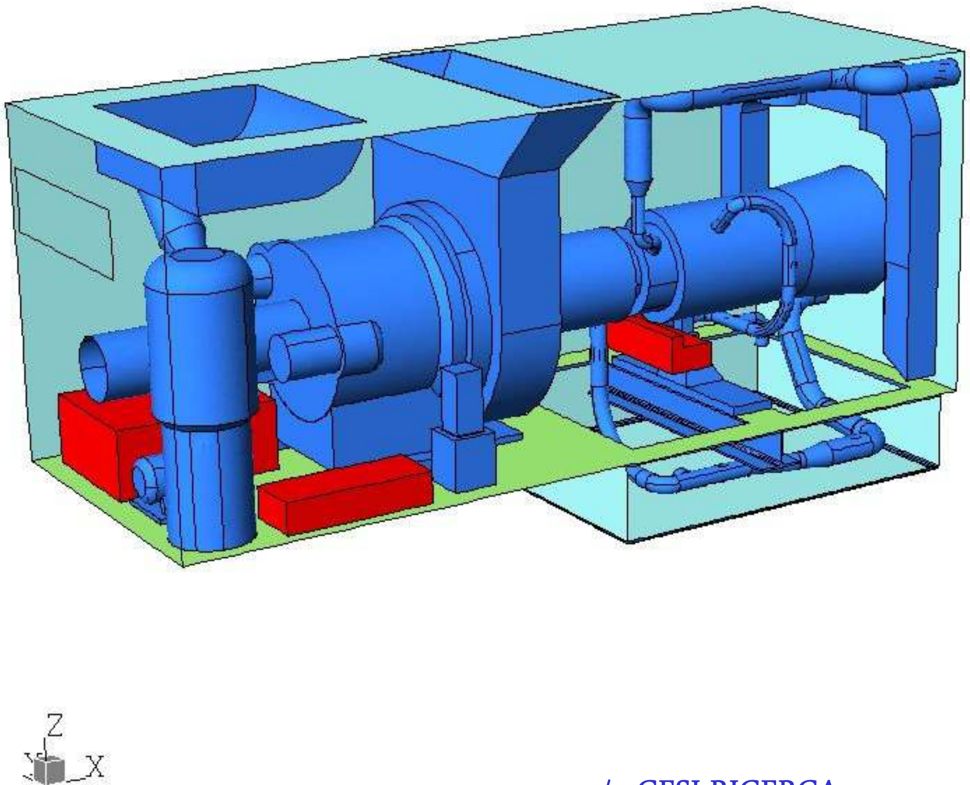
Example of idealisation: Geometry



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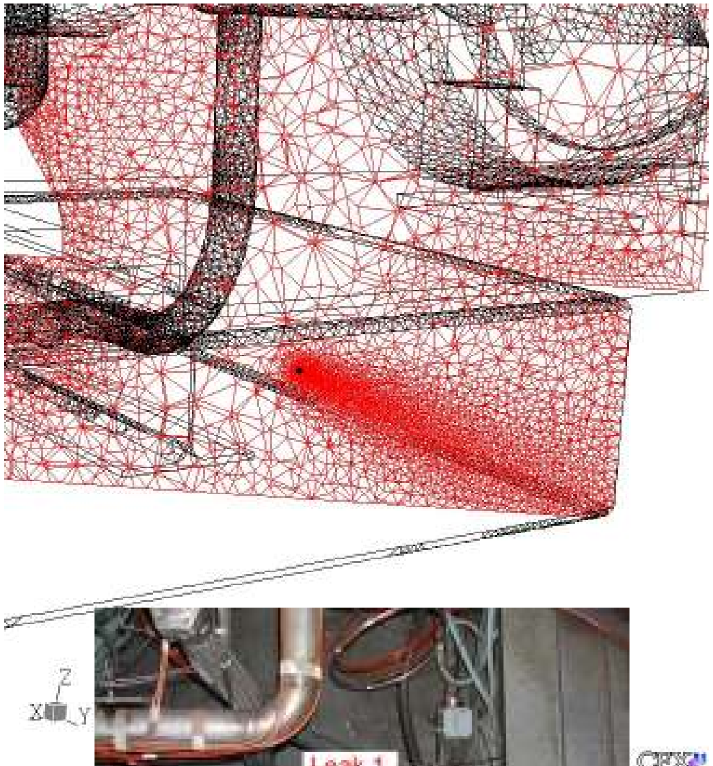
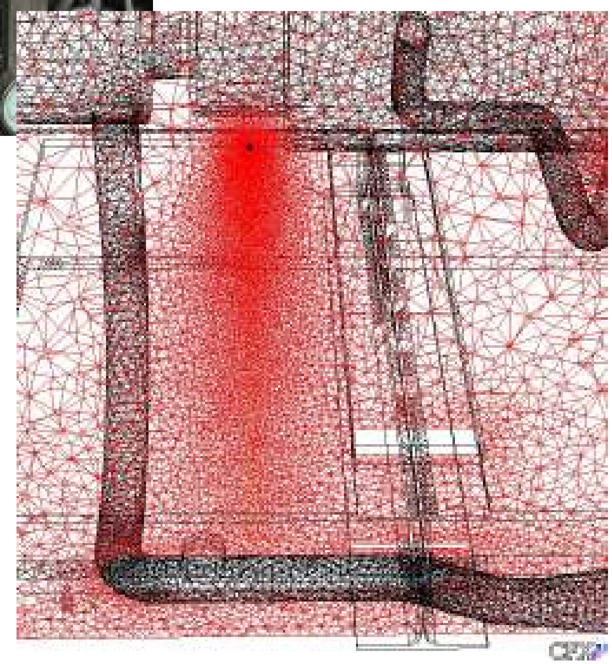
Example of idealisation: Mesh





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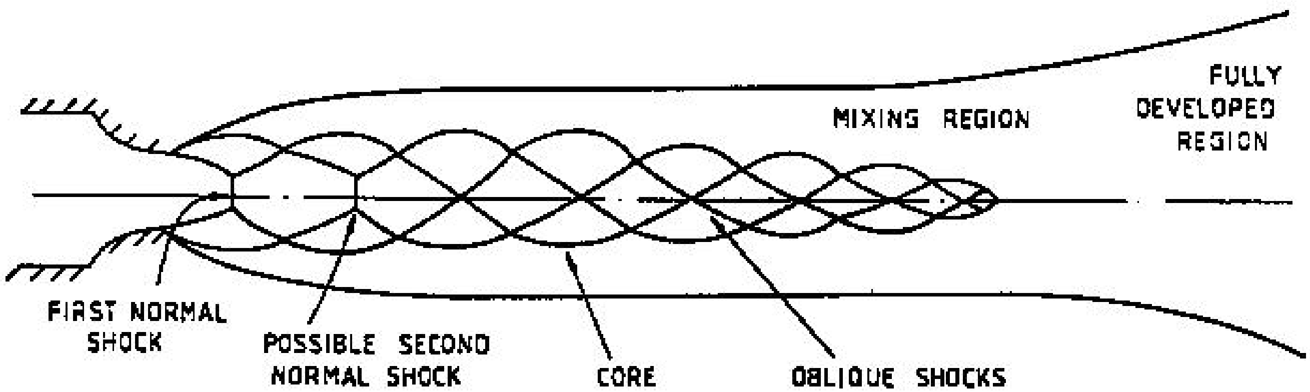
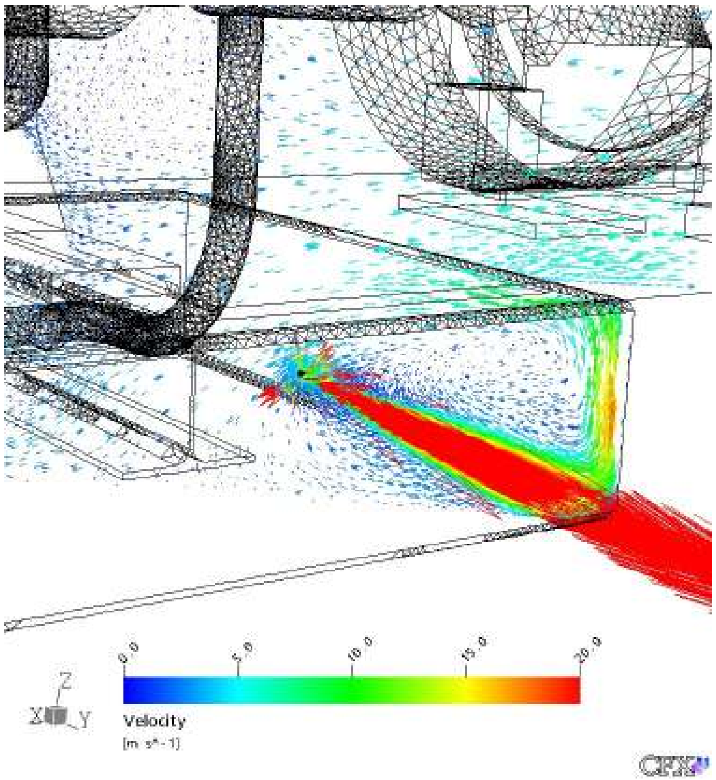
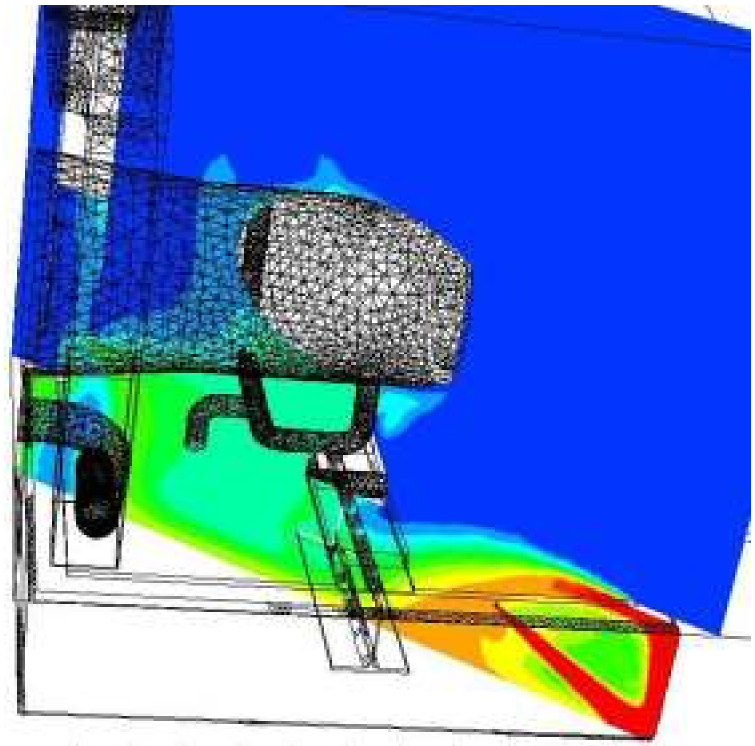
Example of idealisation

- Physical properties – methane CH_4 ,not natural gas
- Physical sub-models - sub-grid model for unresolved congested regions
- Boundary conditions – source model for gas release



Example of idealisation





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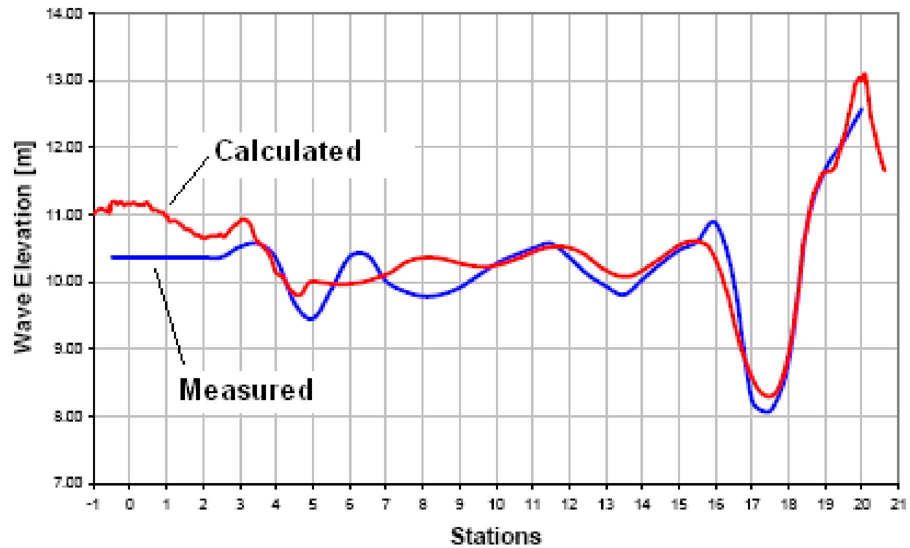
See Ivings et al (2004)

www.hse.gov.uk/research/fire.htm

Building confidence (1)

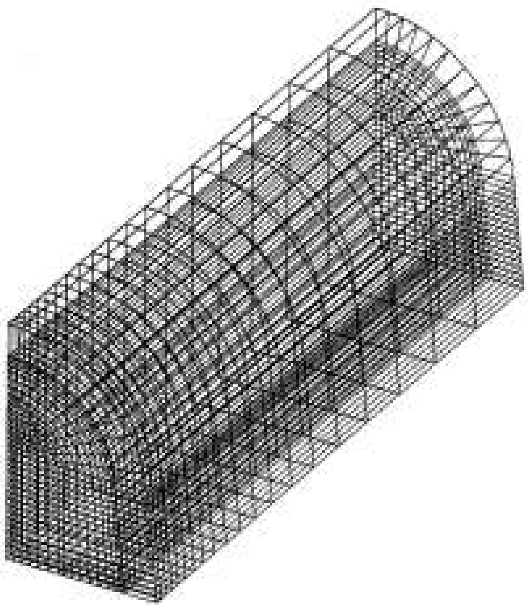
1. Validation – by comparison of simulations against well-documented measurements

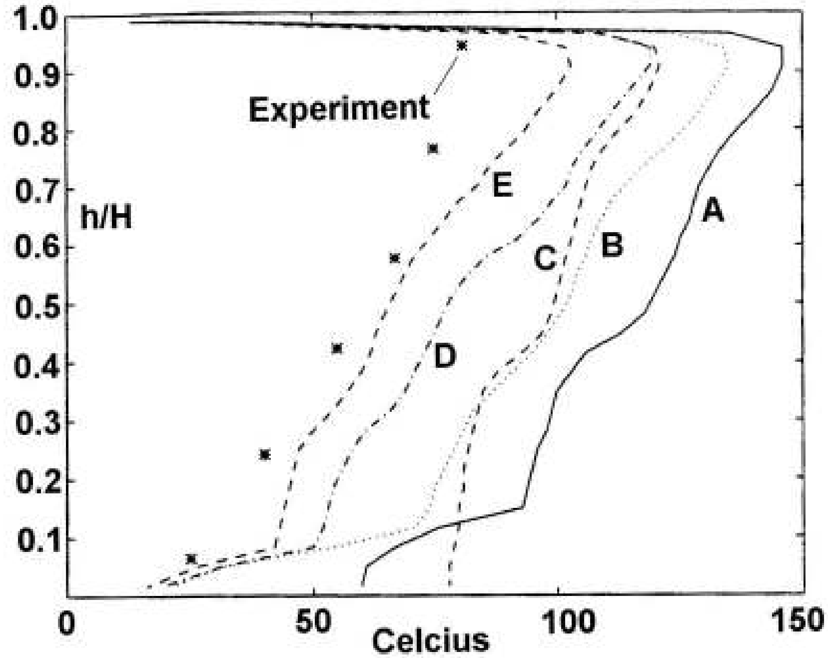


c/o Lloyds Register EMEA, Maritrans Operating Company & CD-adapco

Building confidence (2)

2. Sensitivity tests





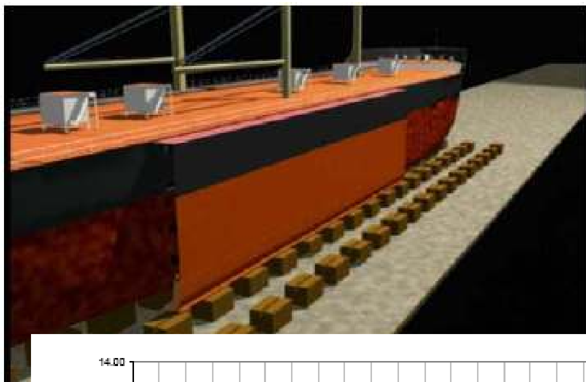
c/o Dr Peter Woodburn

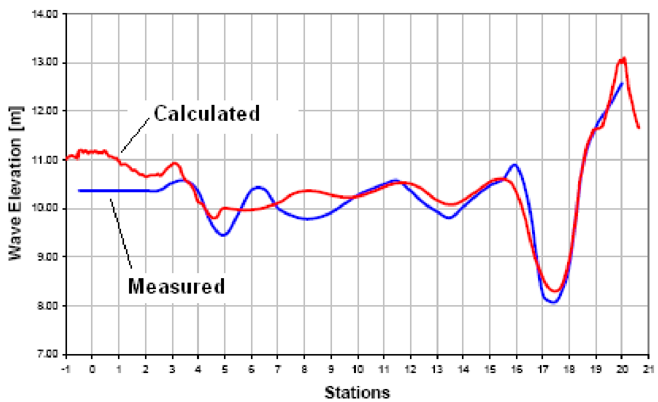
Building confidence (3)

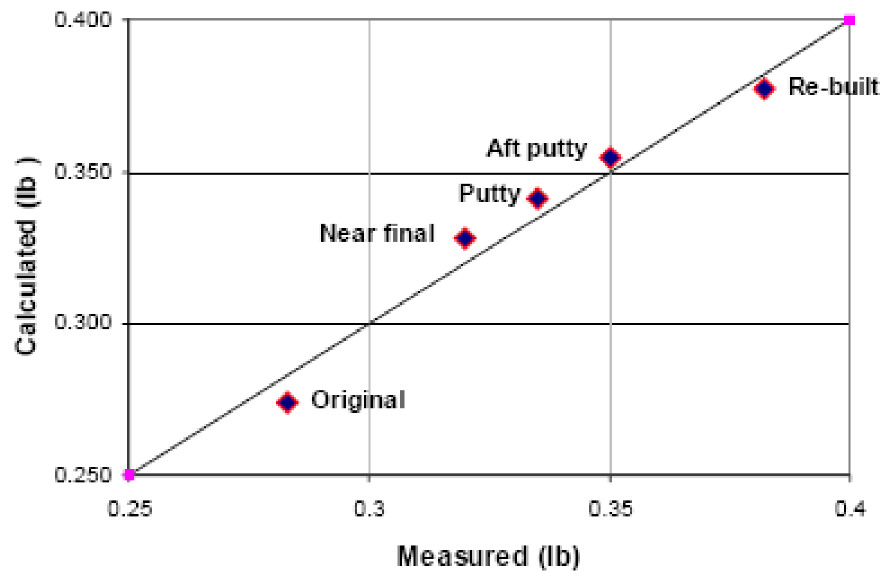
3. Draw on existing knowledge:
   - software vendor
   - wider CFD community (www.cfd-online.com, etc)
   - colleagues
   - published literature (books, journals, etc)
4. NAFEMS books – published & in-preparation (turbulence modelling, validation for industrial CFD)
5. Best practice guidelines, e.g. 'ERCOFTAC' - European Research Community On Flow, Turbulence And Combustion, 'Quality & Trust in Industrial CFD Analysis', 2000; also see QNET-CFD Wiki.
6. Hand calculations – for a reality check!

Further examples of idealisations, and some potential pitfalls (1)

- Use of symmetry planes







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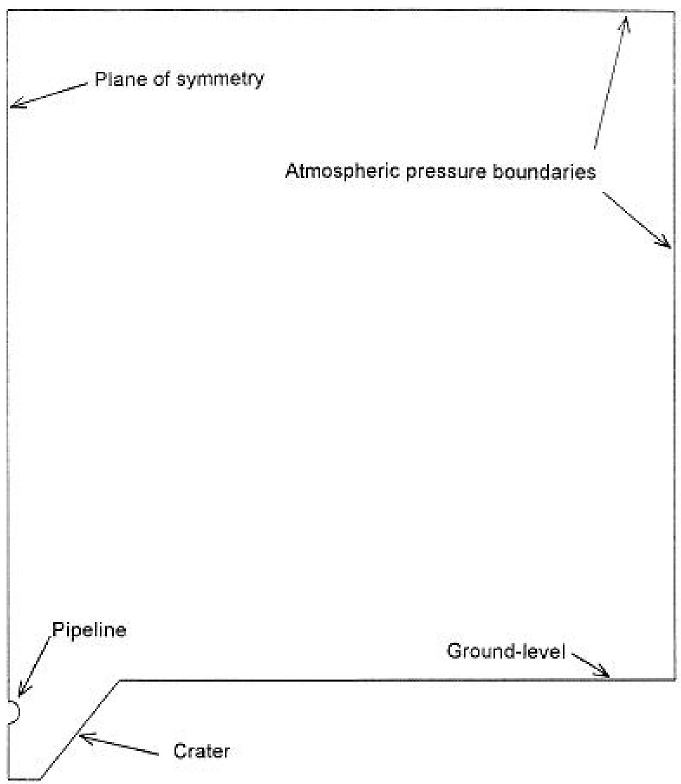
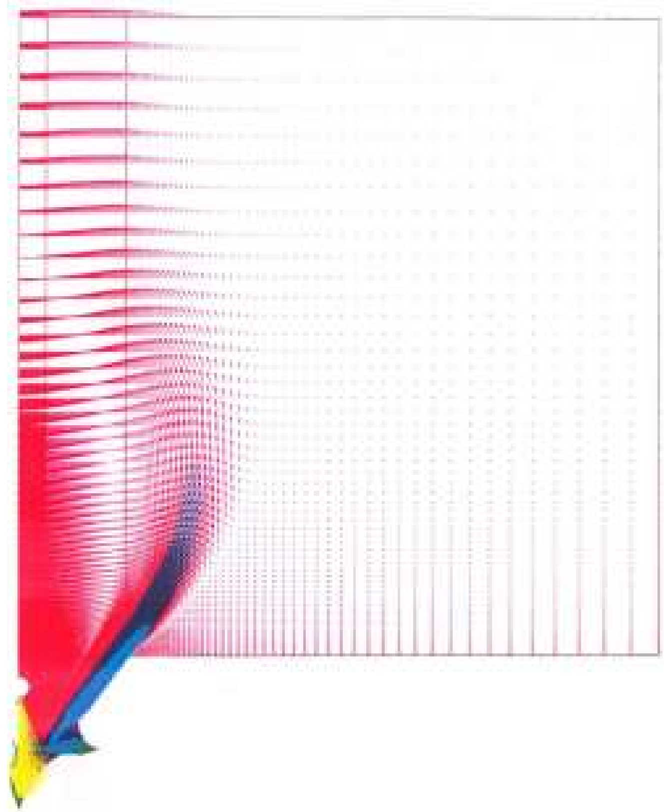
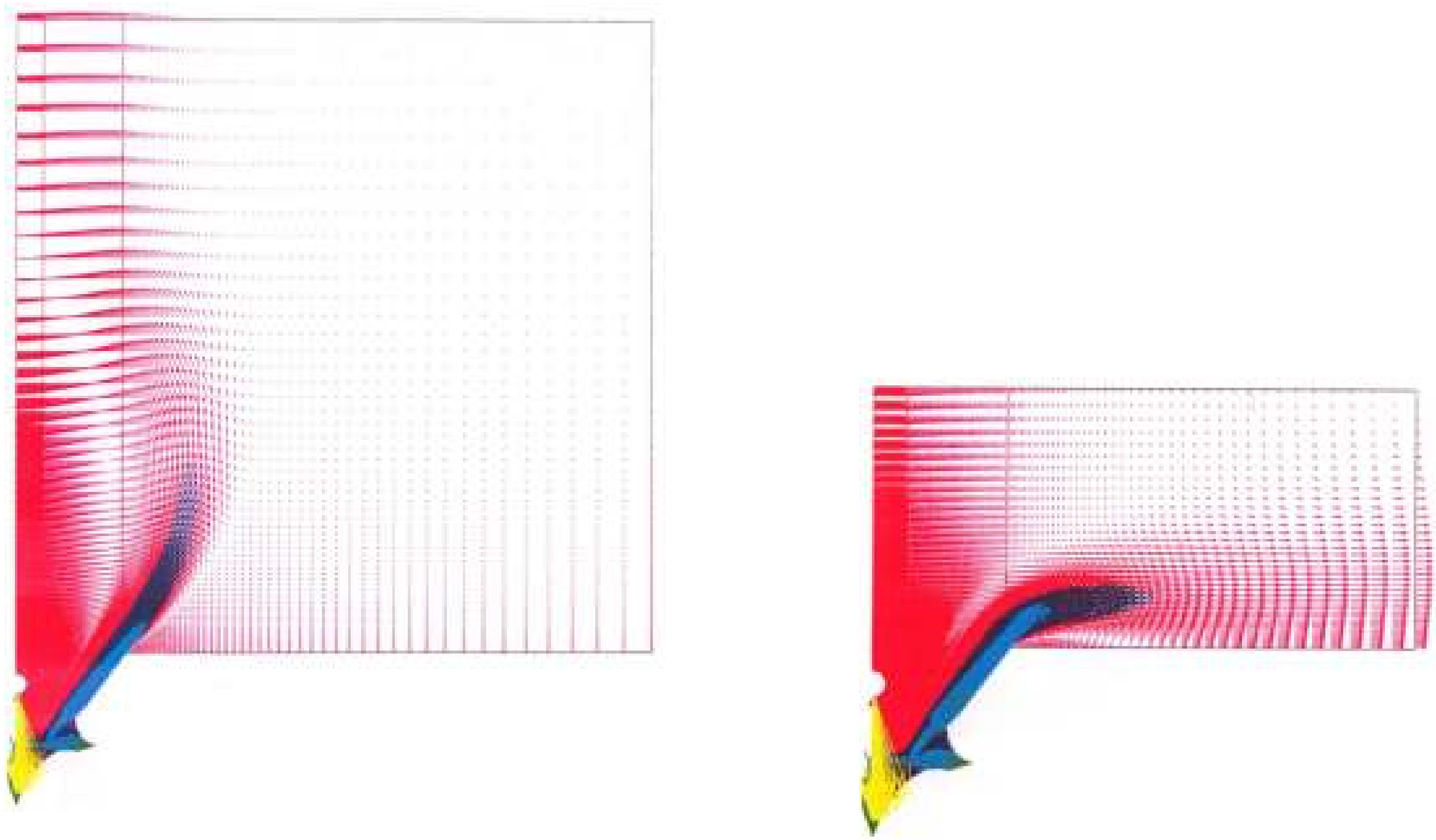
Idealisations and potential pitfalls 2-D simulations (1)



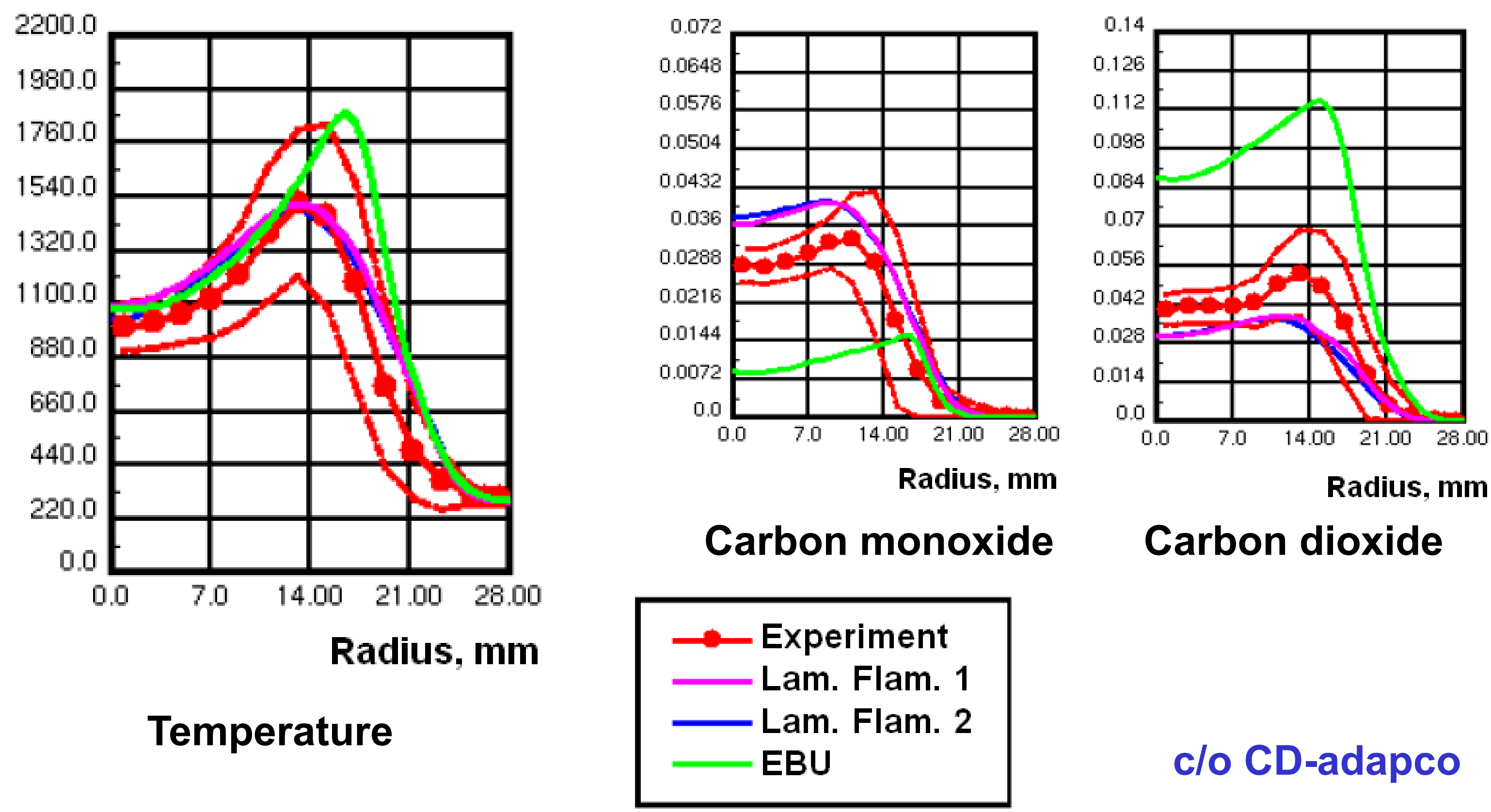


Idealisations and potential pitfalls
2-D simulations (2)



Idealisations and potential pitfalls, Flow physics

- Combustion modelling – gas burner



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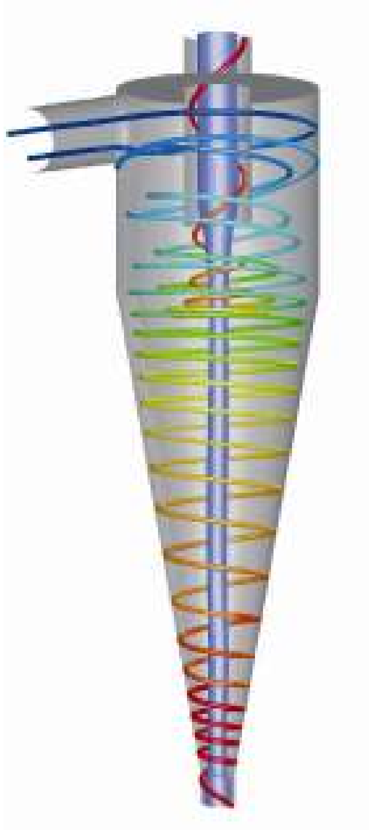
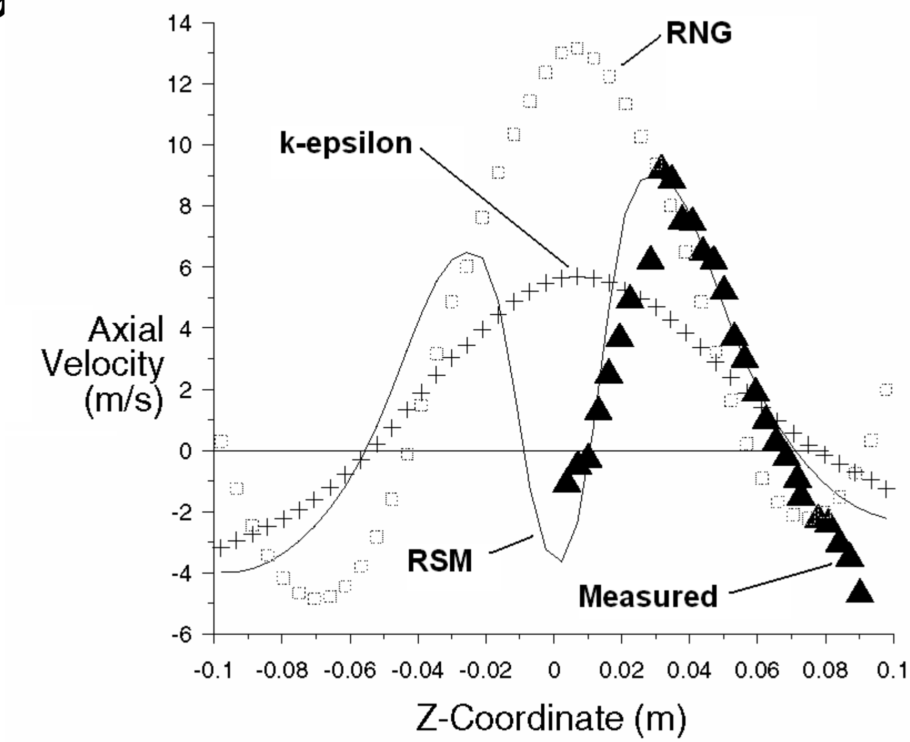
Idealisations and potential pitfalls, Flow physics

- Turbulence modelling





Cyclone separator

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Pitfalls - distractions

Meshing the geometry……or the flow?

- Are you meshing the geometry?
- But you should be meshing for the flow!
- So, mesh to resolve the key flow features – e.g. regions of steep flow gradients

Concluding remarks

- CFD is not an end in itself; it is a means to meet project requirements
- The object and required accuracy of a simulation should be kept in mind at all stages of a CFD project
- It is important that unnecessarily complex CFD simulations are not undertaken for their own sake or challenges
- Thorough planning is the foundation for CFD which is fit for purpose

Questions

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THE INTERNATIONAL ASSOCIATION
FOR THE ENGINEERING ANALYSIS COMMUNITY

Thank you!

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