CFD activities at EDF Energy R&D UK Centre.

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Modelling and Simulation Centre

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Outline

EDF Energy: United Kingdom

Generation

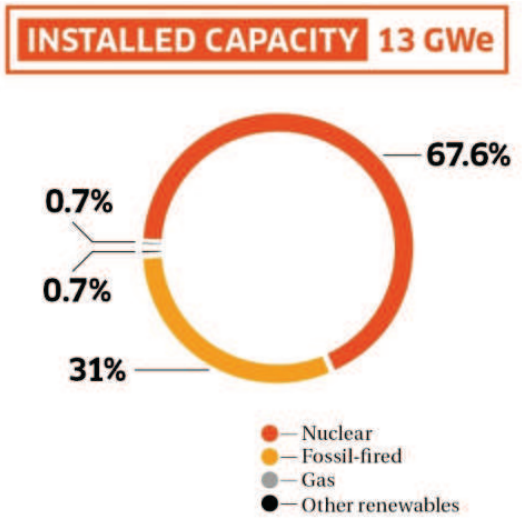
Nuclear: safety review and reinforcement.
New nuclear: authorization for preparatory works at Hinkley Point.

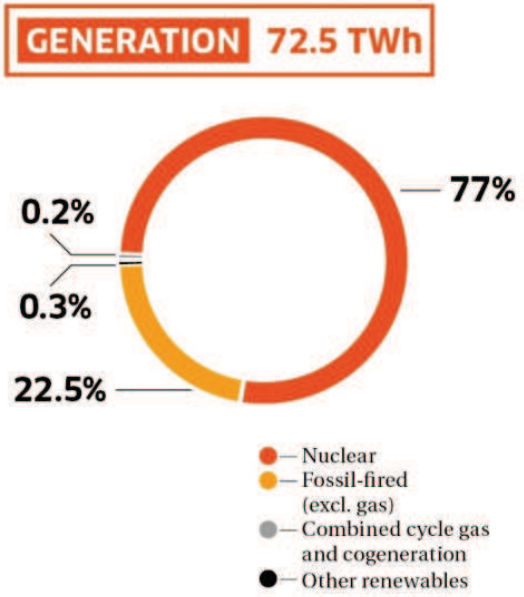
Sales and marketing

5.8 million customers
Electricity: **52.8 TWh** sold
Gas: **25.7 TWh** sold

Results

Sales contribution: **€8.6 billion**
Group EBITDA contribution: **€1.9 billion**
Employees: **15,536**





Role of the R&D UK Centre

Creating value today and preparing for tomorrow

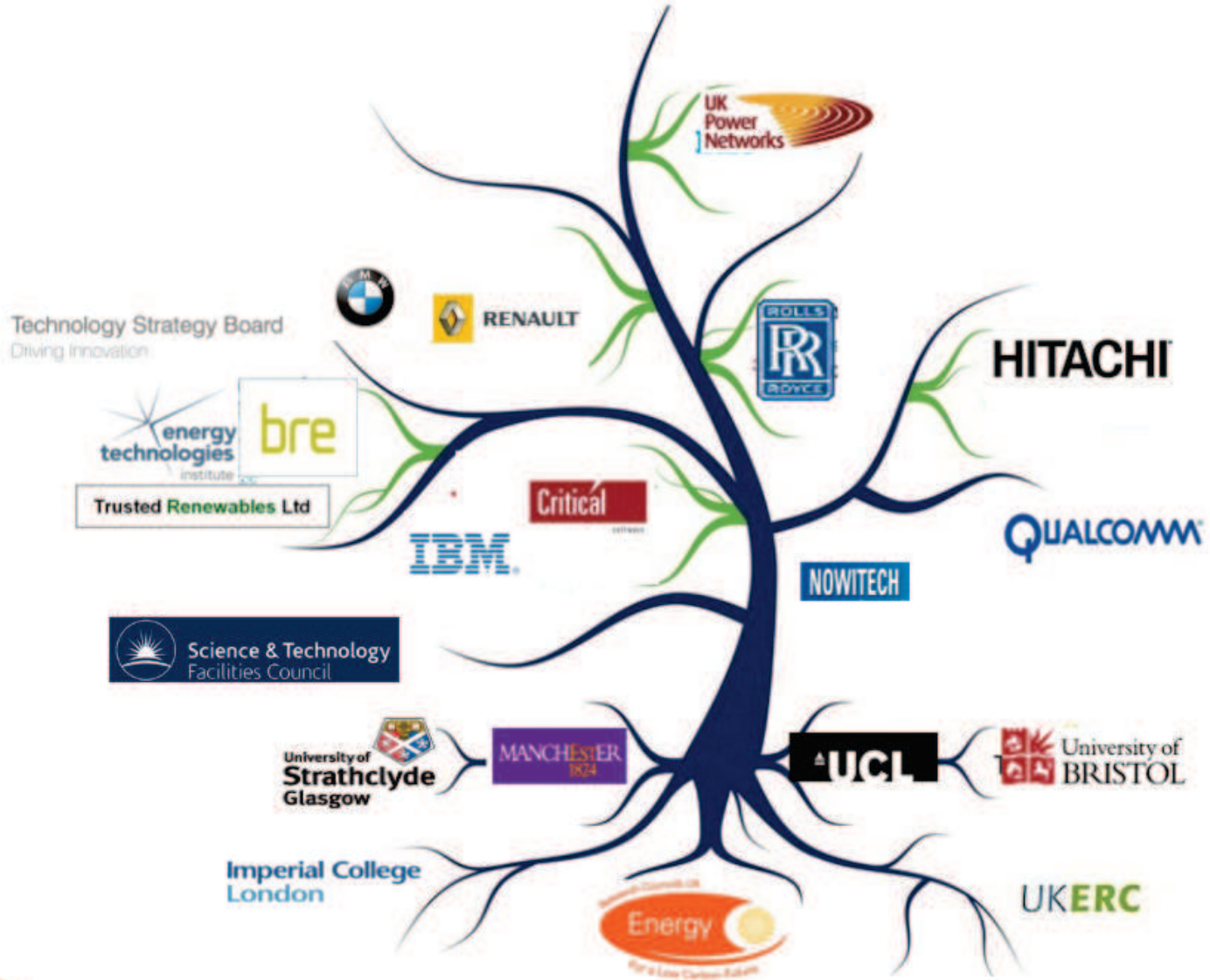
A growing presence in the UK's R&D and Innovation agenda

- Deliver R&D in the UK.
- Opportunities in the positive UK environment.
- Collaboration with EDF Group and R&D France.

The core Activities of R&D UK centre

- To support EDF Energy in its business and commercial activities.
- To lead R&D activities in UK for EDF group that will benefit from the UK's encouraging environment and its strong experience.
- To contribute to the International Nuclear Development, supporting the lifetime extension of existing nuclear in UK and to provide the R&D support for the nuclear new build agenda.
- To contribute to the revival of specific skills and competences for energy research in the UK and allow EDF Group to benefit from the scientific excellence of key UK research centres.

Partnerships



UK Context for nuclear energy

- Nuclear power will need to play an important role in support of a sustainable decarbonised electricity generation system in the UK.
- This outlines the need for both new nuclear build and life extension of the existing operating nuclear stations.
- Life extension will require R&D to address the technical, scientific and engineering challenges that it will present.
- R&D is key to attracting and maintaining the high level skills needed to support operations now and nuclear over the long term.

Nuclear Generation Challenges

R&D roadmap themes

- Improve Plant Performance.
- Understand Plant Condition.
- Improved Modelling.
- Skills.

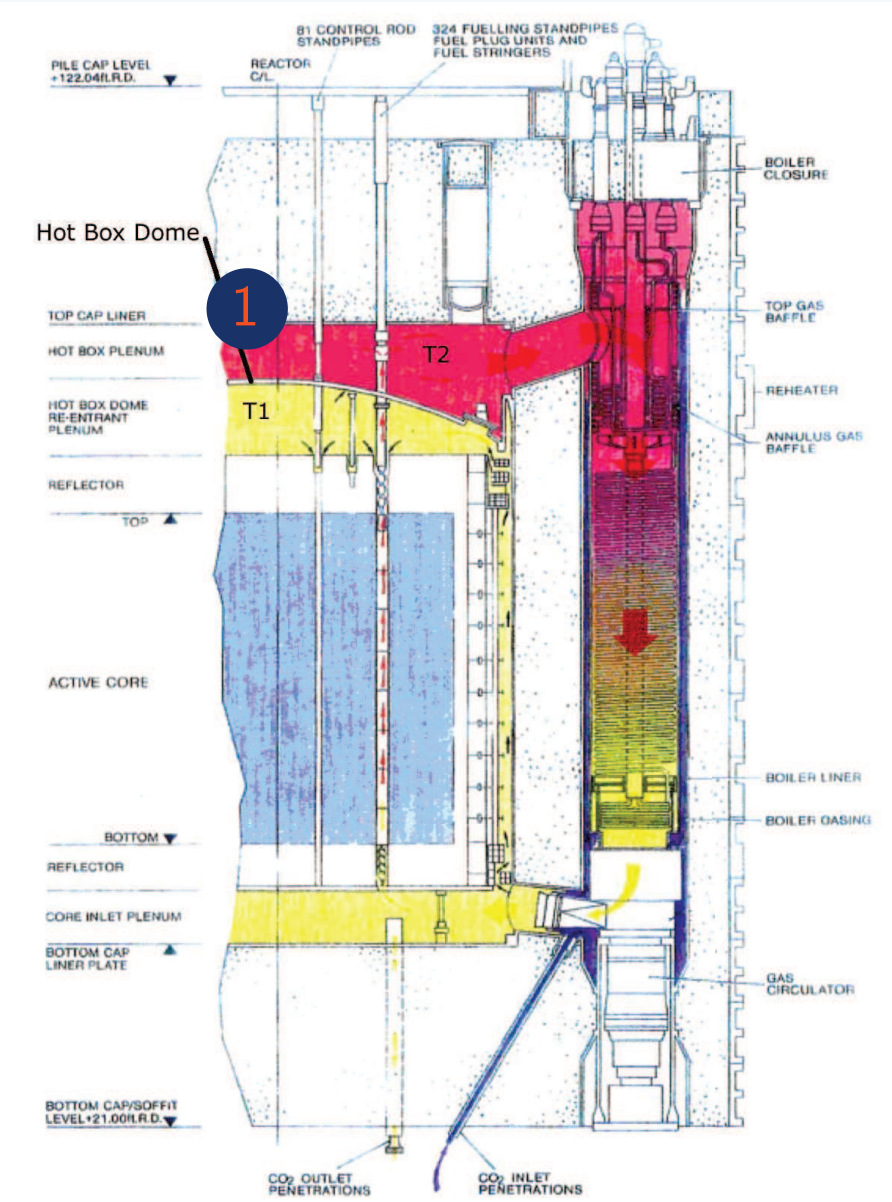
- For R&D the focus is around lifetime supporting the AGRs and SZB.
- Technical lifetime for both will be determined by the non-replaceable components that degrade through use.
- To achieve the right lifetime related decisions it is necessary to have the correct underlying technical understanding and knowledge.

Current projects using CFD

R&D UK Centre CFD projects:

Projects on the gas flows on Advanced Gas-cooled reactors (AGRs)

1. Hot Box Dome, upper plenum.



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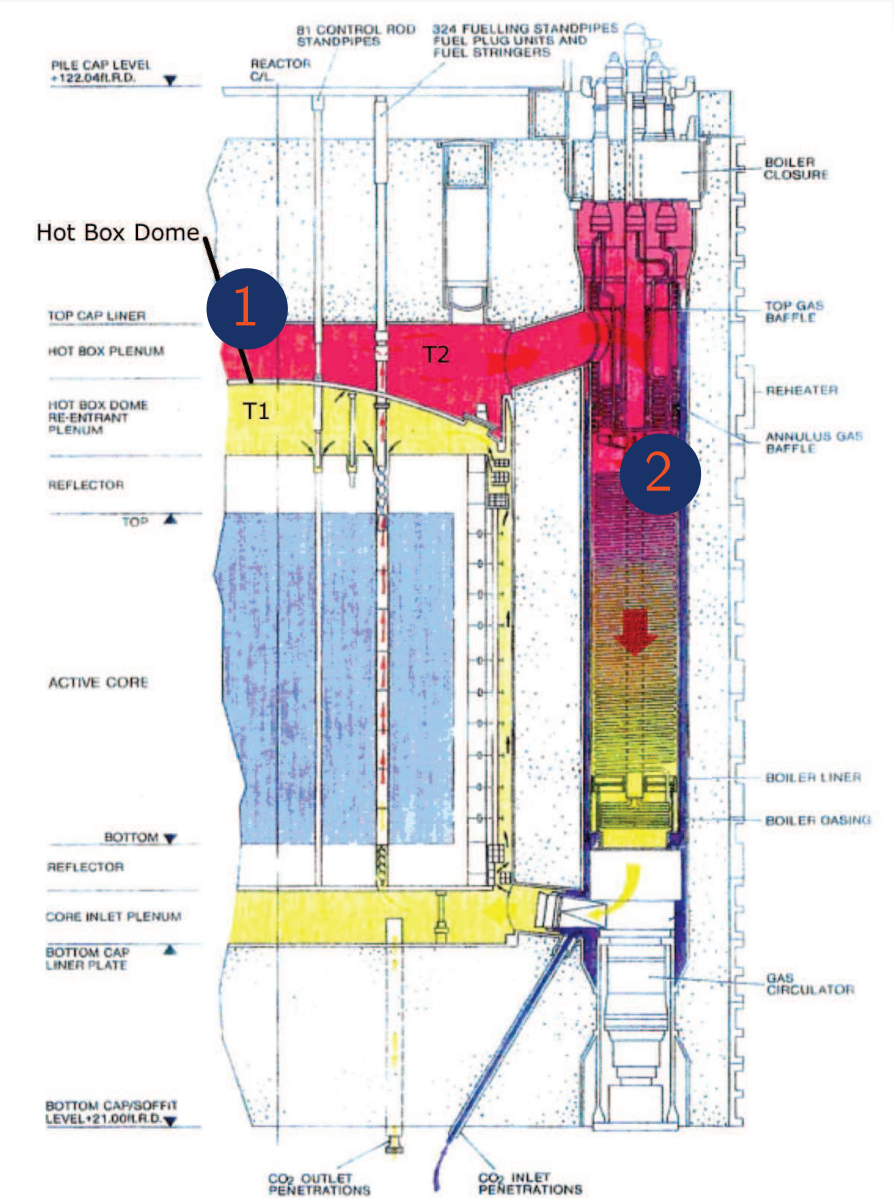

Current projects using CFD

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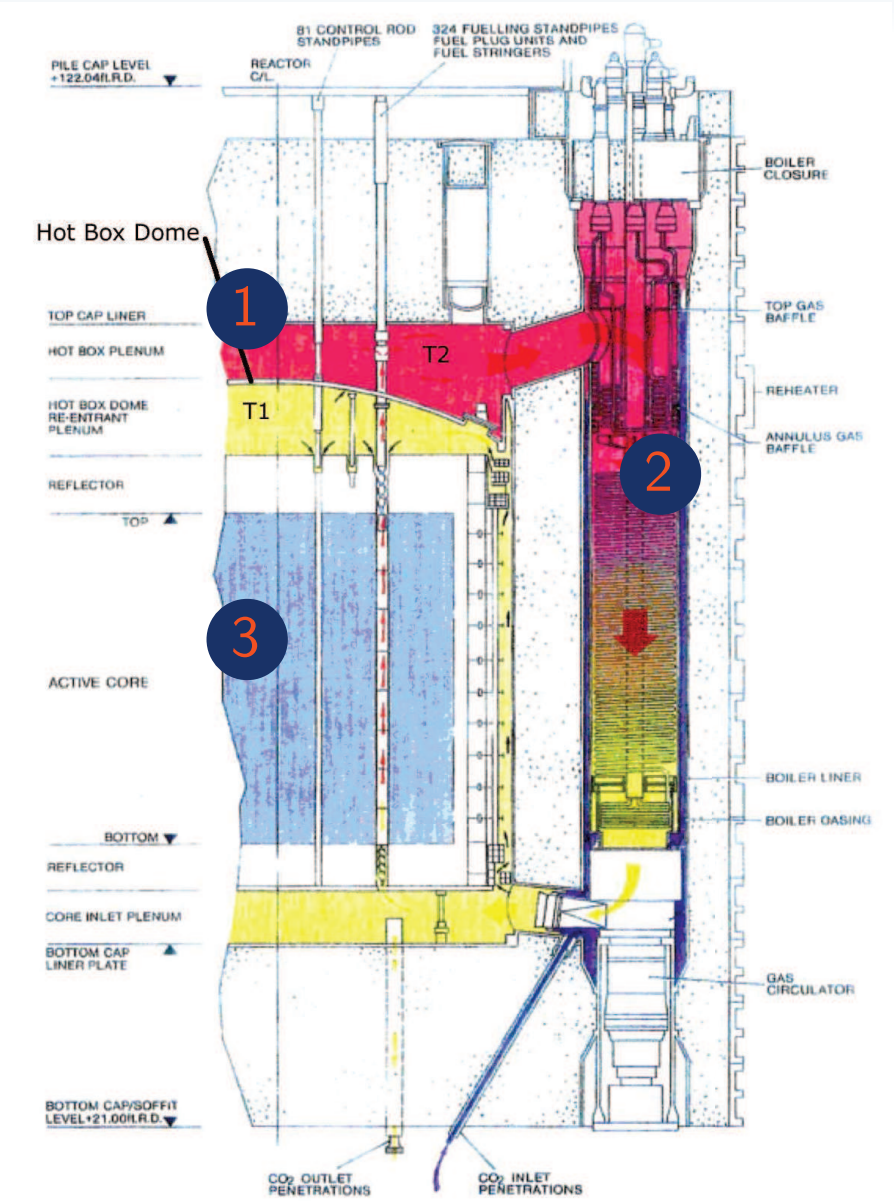

Current projects using CFD

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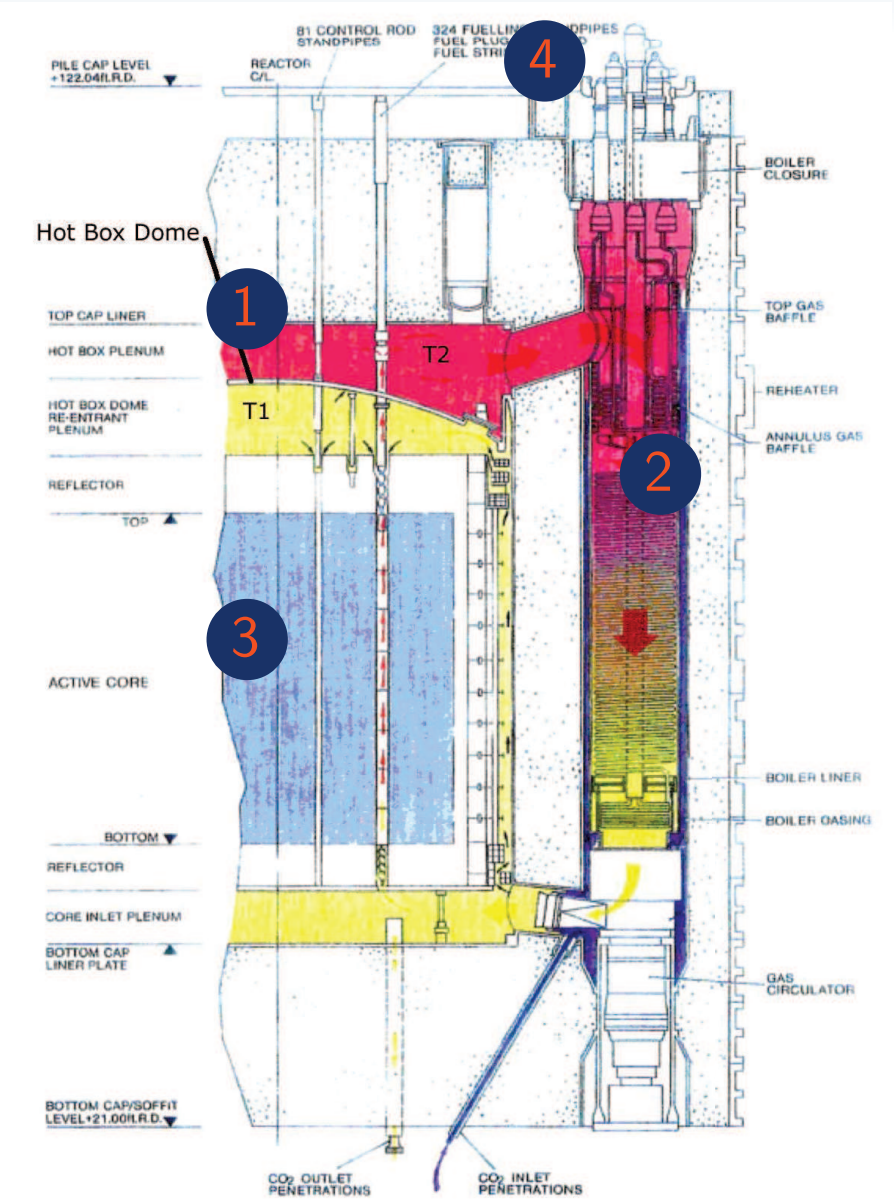
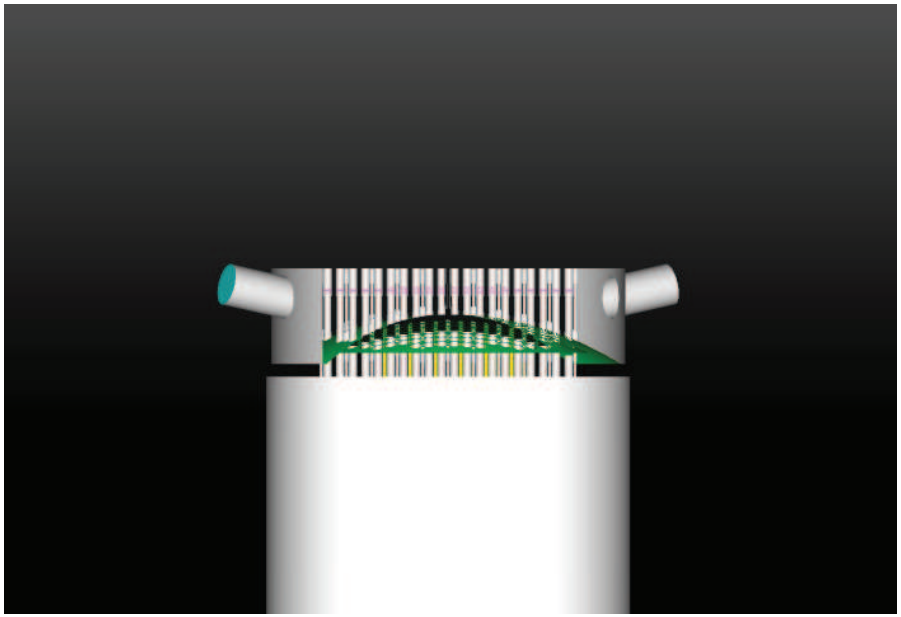
1. Hot Box Dome, upper plenum.
2. Pod Boilers.
3. Flow along nuclear fuel rods.
4. Steam penetration.



Hot Box Dome - upper plenum

The Hot Box Dome is a steel structure that separated the hot gas (T2) from the cold gas (T1) surrounding the core. It is a very important component and its temperature must be monitored to ensure compliance. To achieve lower temperatures, holes were drilled in the central control rod guide tube of the reactors.

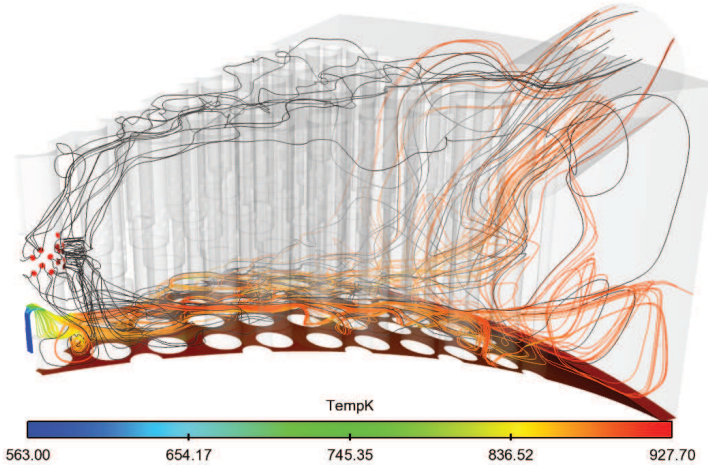
- The modification had another effect: increase insulation effect on the upper part of the dome.
- But this could not be controlled. It was produced by the equilibrium between two jets in which many factors are important (temperature, turbulence levels, etc).
- A new modification was proposed in order to enhanced the effect of the cold jet.

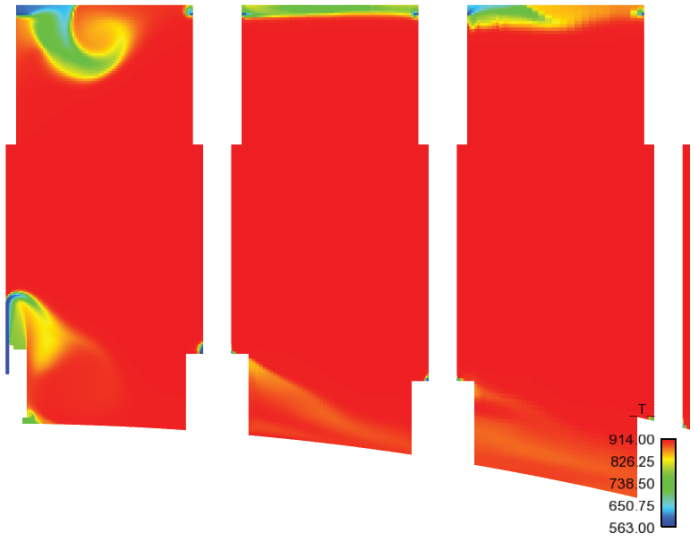


Hot Box Dome - upper plenum

Modified flow

- Deflection of the cold jet by the hot gas coming from the pepper pot holes, with a separation point around 2.65m
- Large recirculation zone.
- High level of unsteadiness.
- Cooling of the central dome region due to the impingement of the deflected jet.
- Strong mixing after the first row of fuelling guide tubes, away from the dome.

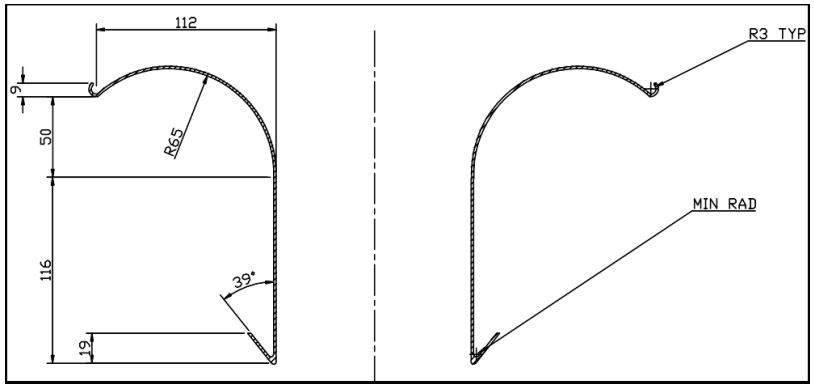




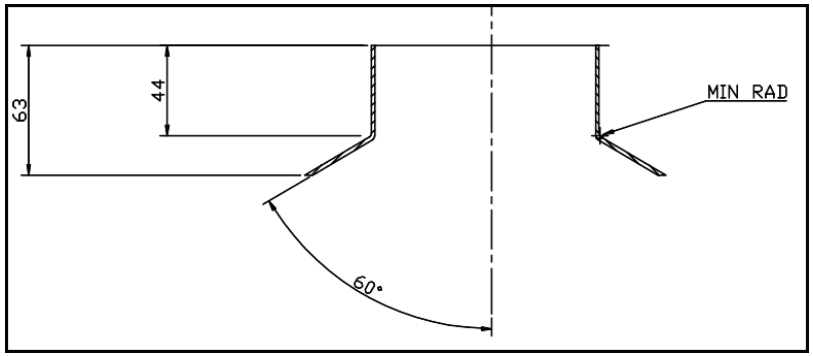
Hot Box Dome - upper plenum

It was proposed to install a flow redirection device (cowl) in order to keep the cold gas closer to the surface of the dome. CFD was used to analyse the effect of several possible shapes.
There are two types of shapes considered:

- Curved cowl (type A) Characterised by 3 points that make up the arc (11 in total).
- Flat cowl (type B) Characterised by attachment point, angle and length (8 in total).



A



B

Hot Box Dome - upper plenum

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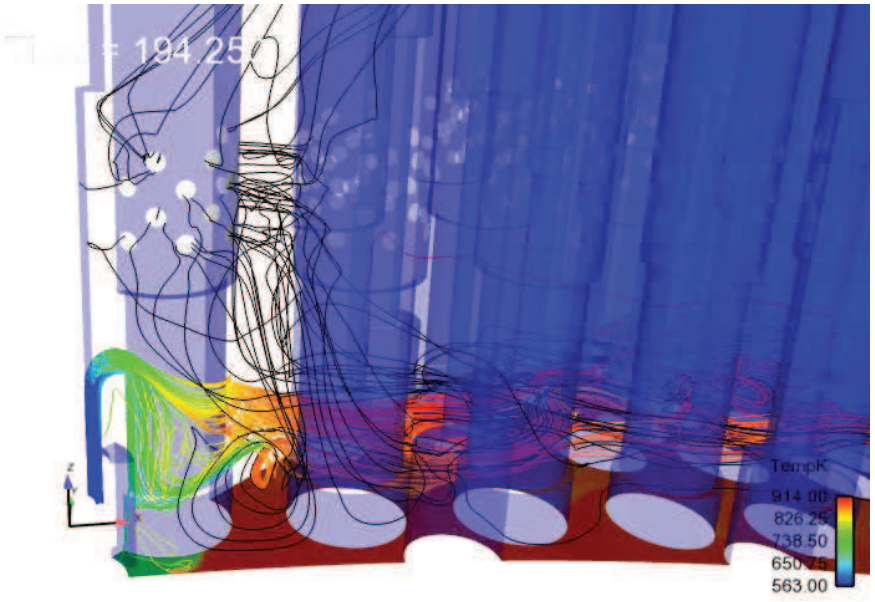
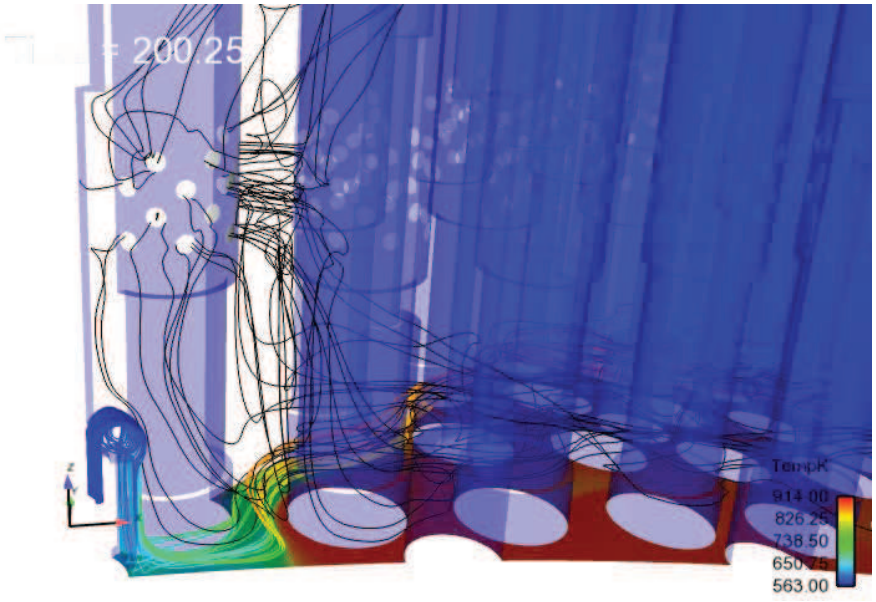
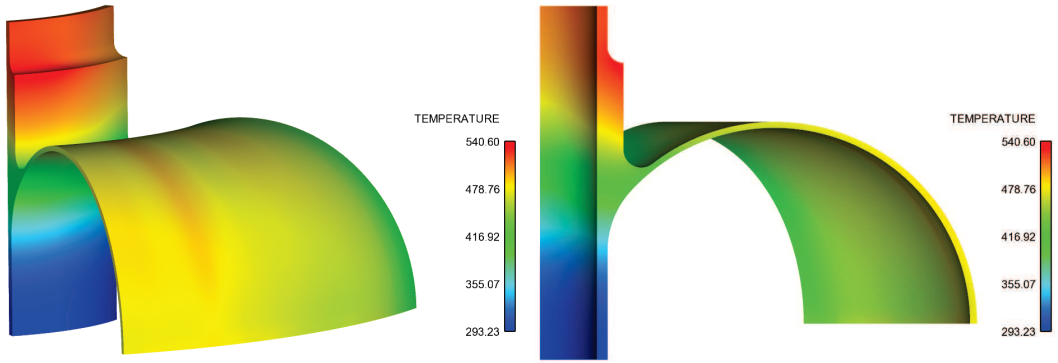


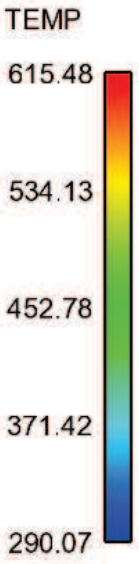


Hot Box Dome - Upper plenum

Coupling with SYRTHES

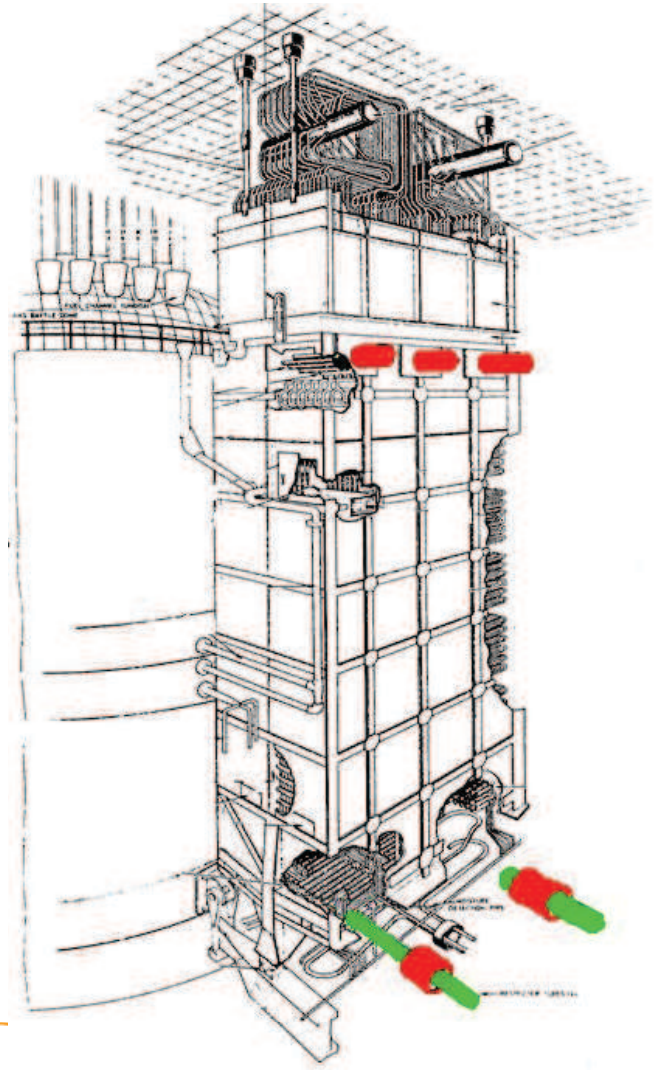
- Once the designed was agreed, the thermal stresses needed to be computed.
- Model of the central control rod guide tube and cowl in SYRTHES.
- Evaluation of the temperature inside the tube wall.
- Stress analysis yielded high stresses at the junction so new profile designed.

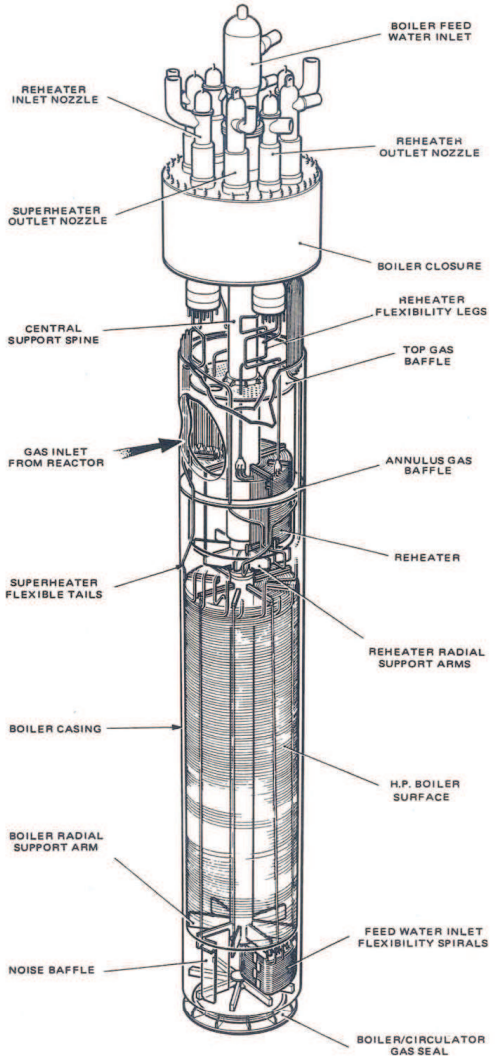




Pod Boilers

The boilers at Heysham and Hartlepool are a different design (helical) from the other reactors (serpentine).





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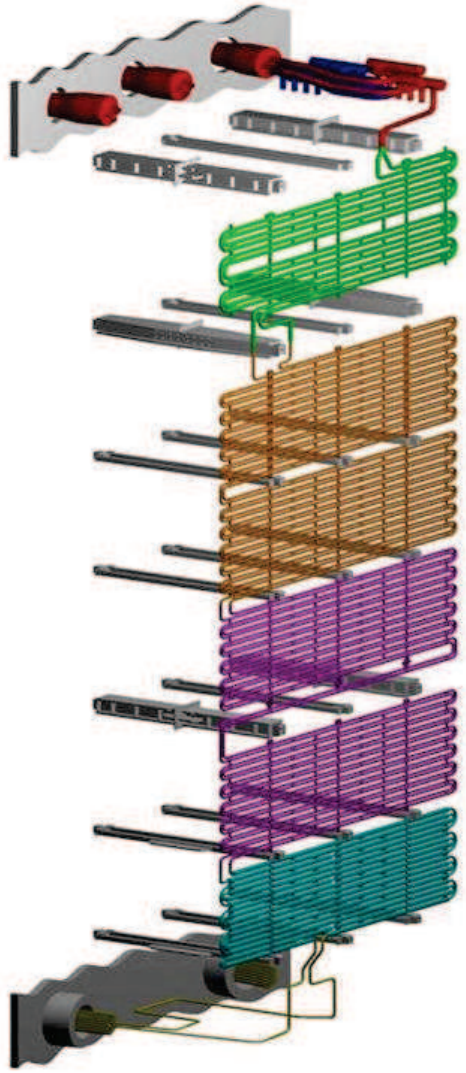
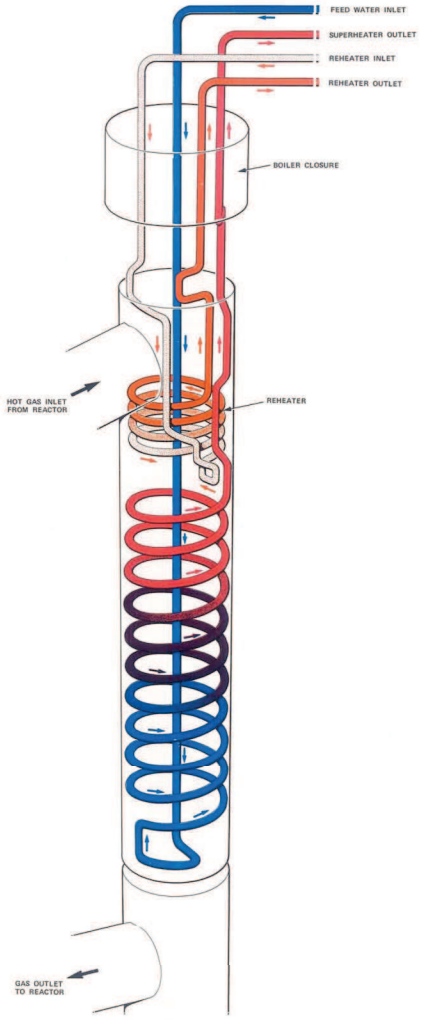
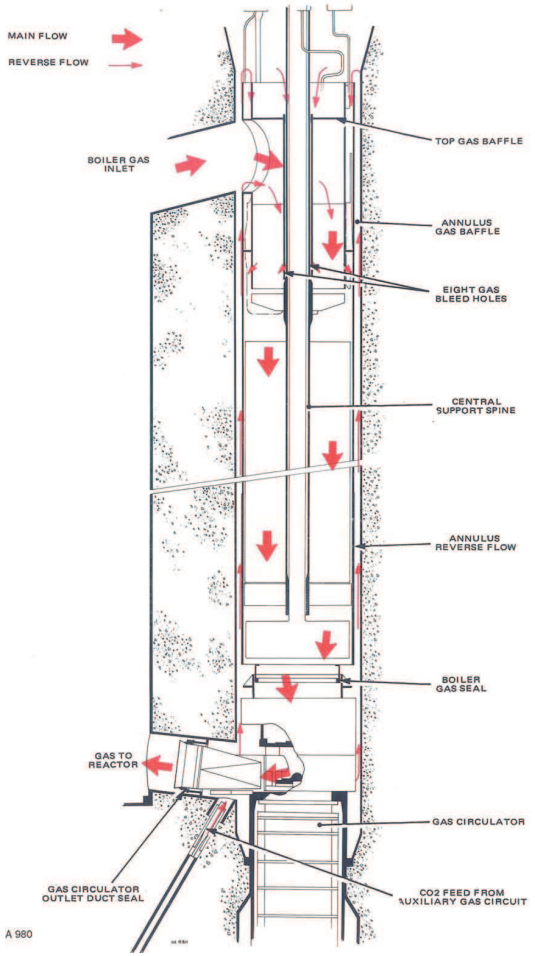
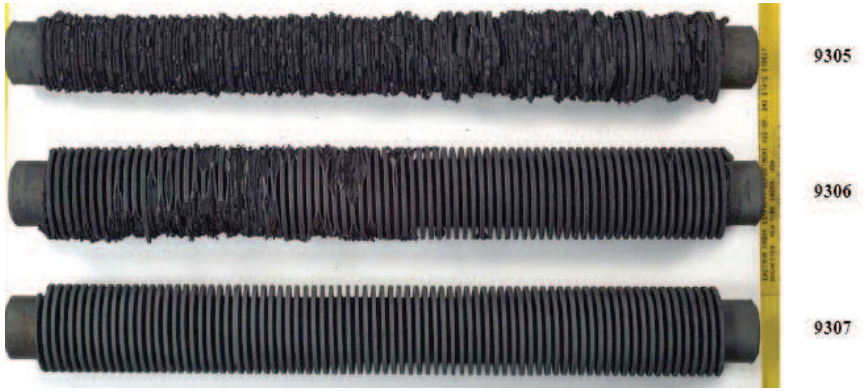




Pod Boilers

- Pod design is more compact. Gas flow path very complex.
- Originally was supposed to be replaceable, but due to problems during construction, it is now sealed under concrete.
- Water tubes are made of 3 different types of steel, according to the state of water inside.
- Temperature at the joints of different metals is a limiting factor.
- Major issues: oxidation (water and CO_2) and creep.





Pod Boilers

Current approach

- 2D modelling of boiler regions based on conservation of energy and momentum ($q = \dot{m}\Delta h$, $\rho U A \sim \Delta p$).
- Based on experimental correlations from rig in the 70's.
- Uses plant t/c readings to adjust geometrical parameters and then predict joint temperatures.

CFD model

- Full 3D.
- Components correlations determined by fine sub-models.
- Coupled with NUMEL (NG code for water side).
- Turbulence and cross flow explicitly computed.

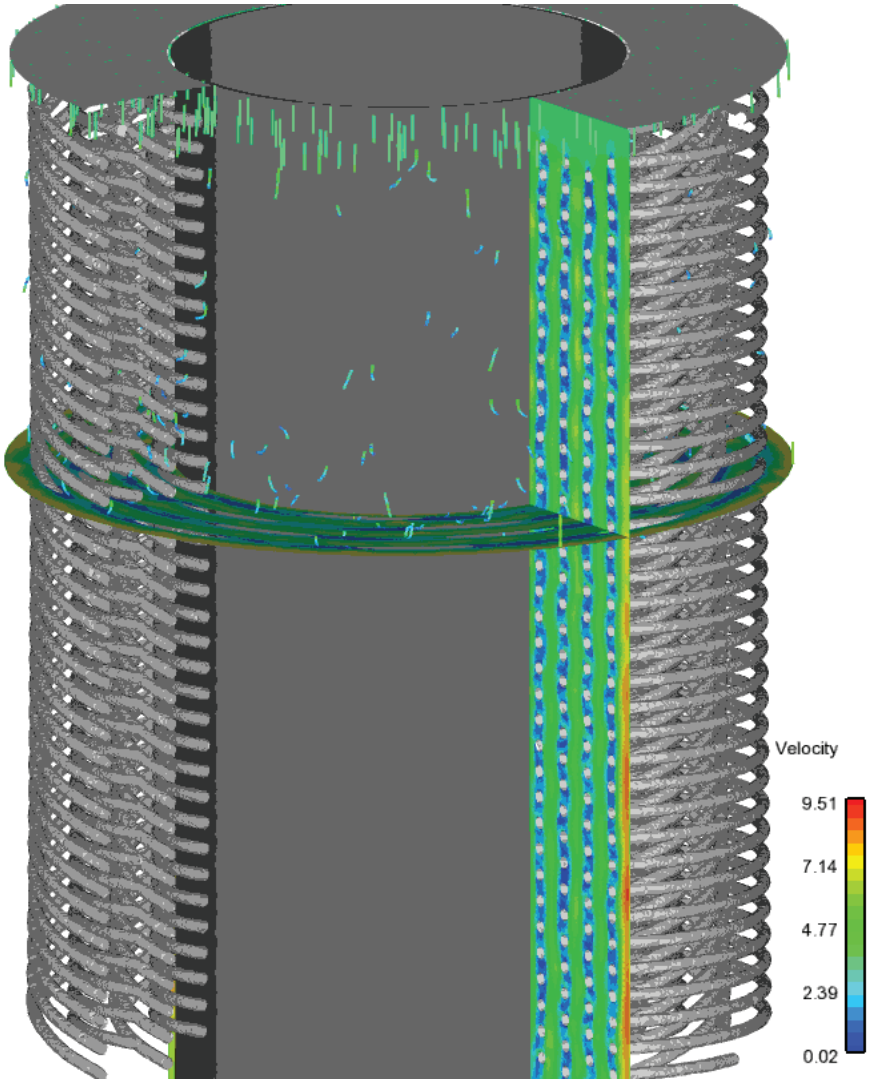
Pod boilers

Boiler Components

Pod boilers

Boiler Components

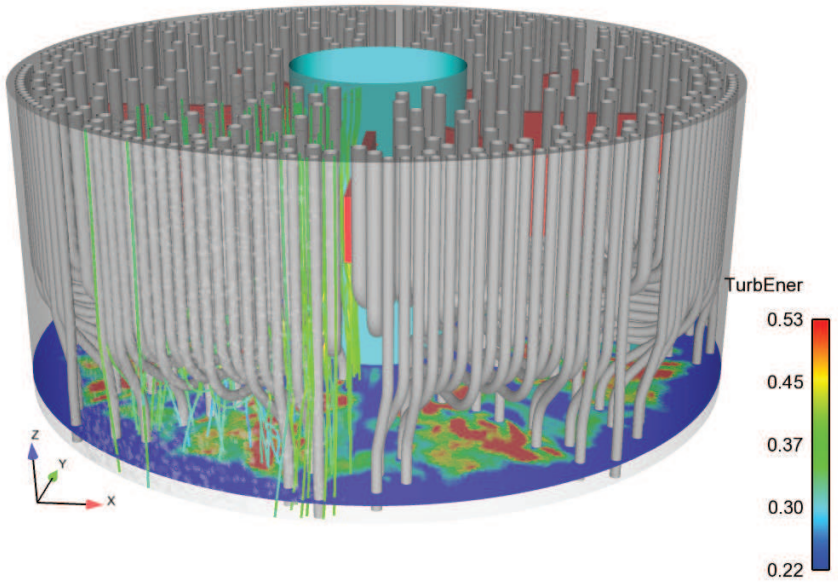
1. HP boiler.



Pod boilers

Boiler Components

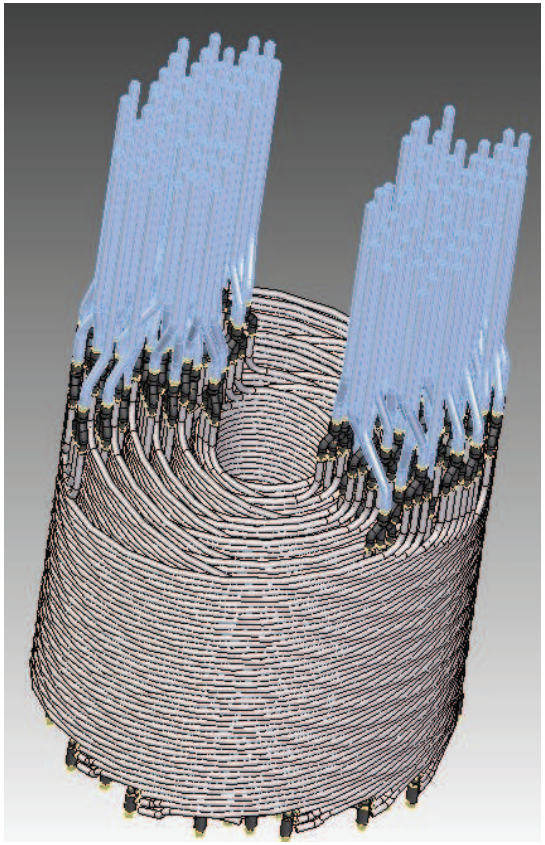
1. HP boiler.
2. Interbank.

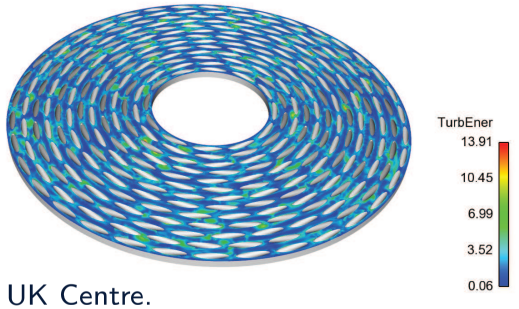


Pod boilers

Boiler Components

1. HP boiler.
2. Interbank.
3. Reheater.

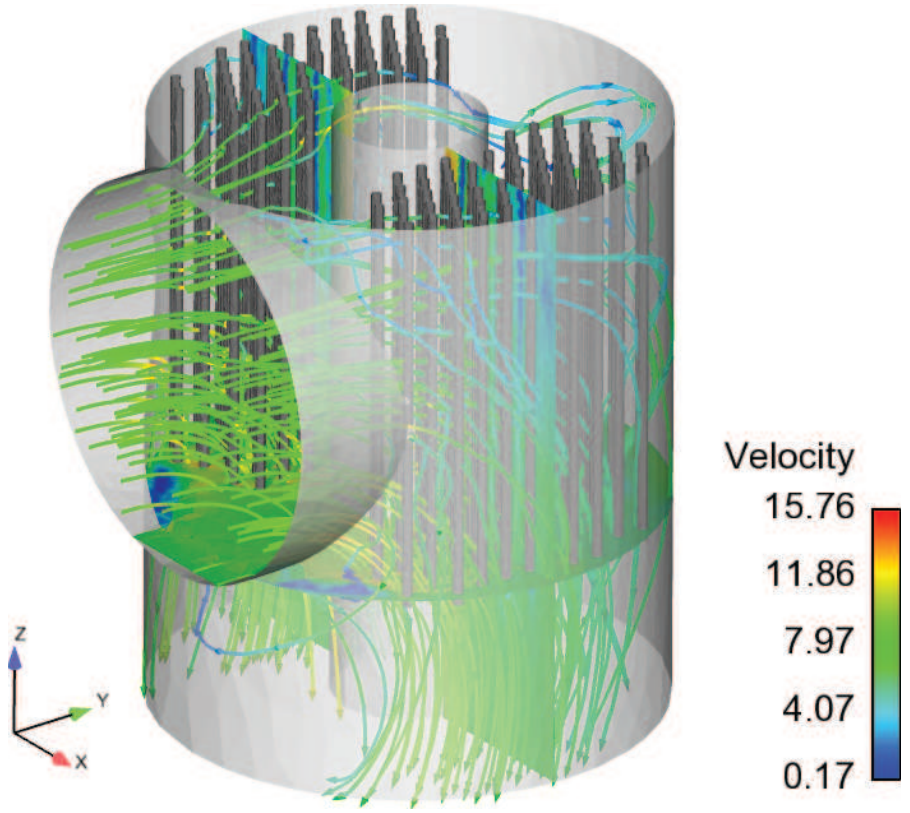




Pod boilers

Boiler Components

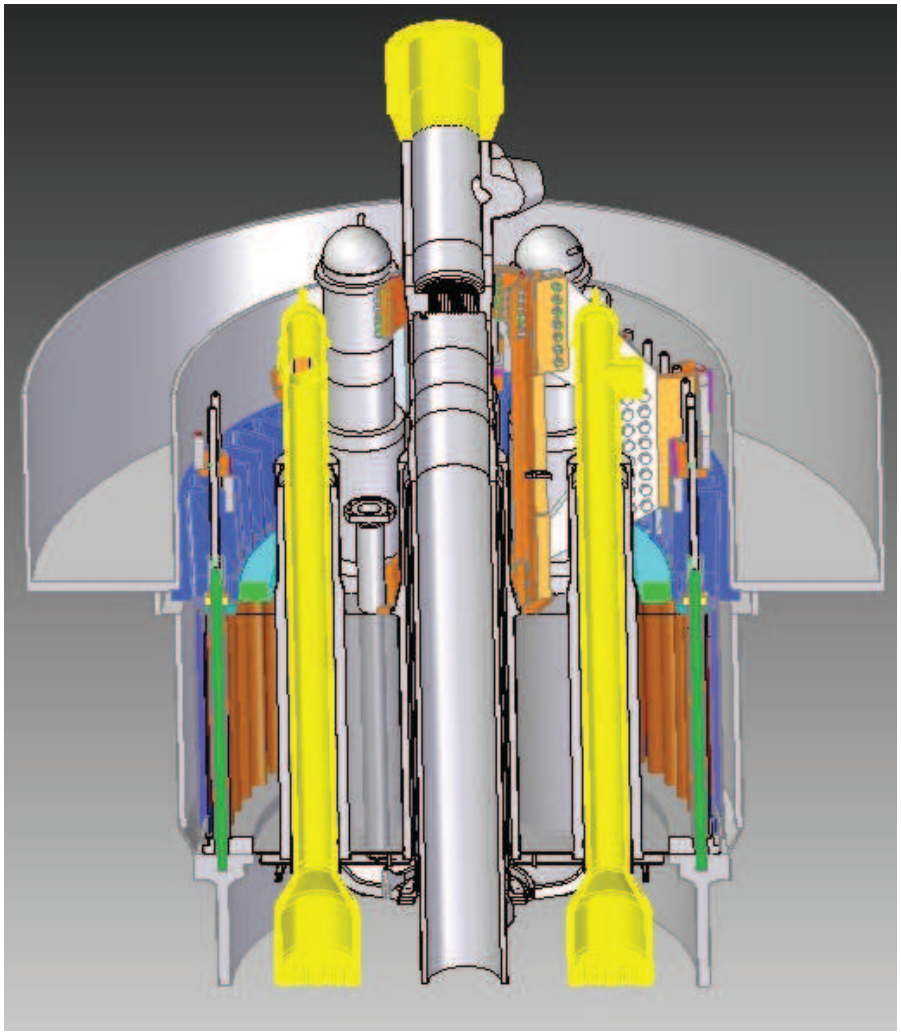
1. HP boiler.
2. Interbank.
3. Reheater.
4. Inlet.



Pod boilers

Boiler Components

1. HP boiler.
2. Interbank.
3. Reheater.
4. Inlet.
5. Top gas baffle.



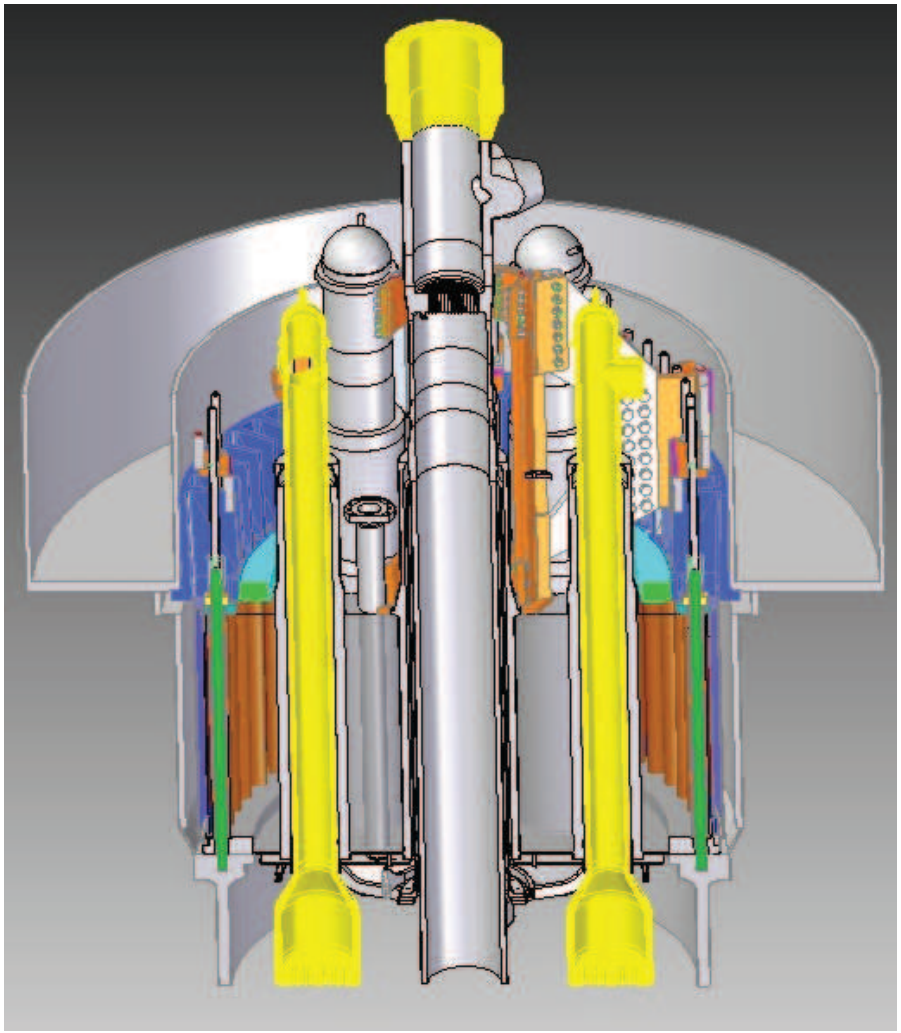
Pod boilers

Boiler Components

1. HP boiler.
2. Interbank.
3. Reheater.
4. Inlet.
5. Top gas baffle.

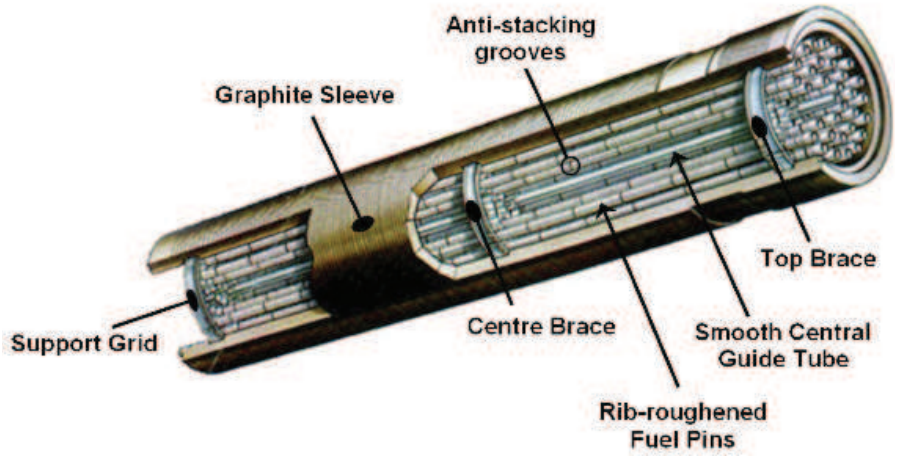
Project objectives

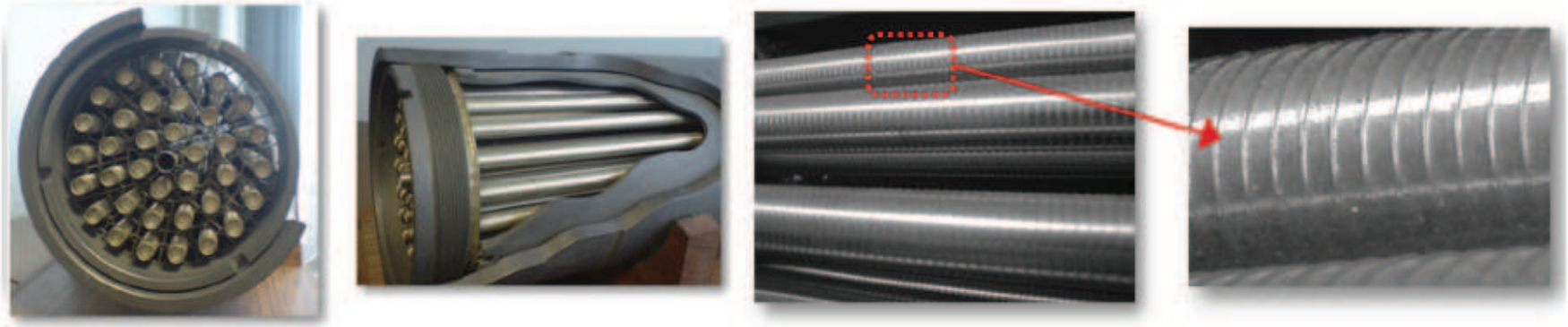
- Create a 3D porous model coupled with NG's system code.
- Ability to "blank" tubes and obtain 3D effects (non-equilibrium).
- Predict spine temperatures.



Fuel pins

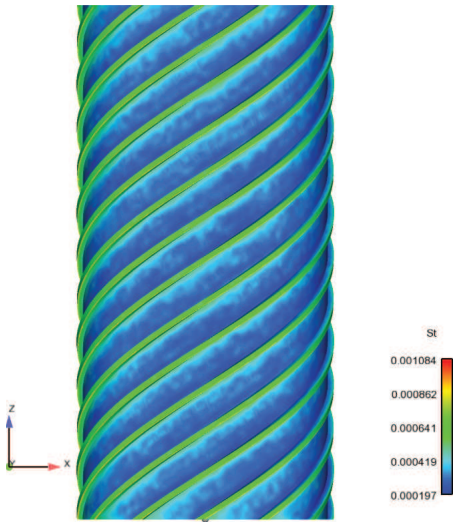
- Gas flows along the fuel assembly.
- The pins are finned in order to increase heat transfer.
- CO_2 reacts with the steel and produces carbon deposition.
- Deposits fill ribs gaps and lower heat transfer.
- Fuel rods heat and break needing replacement.

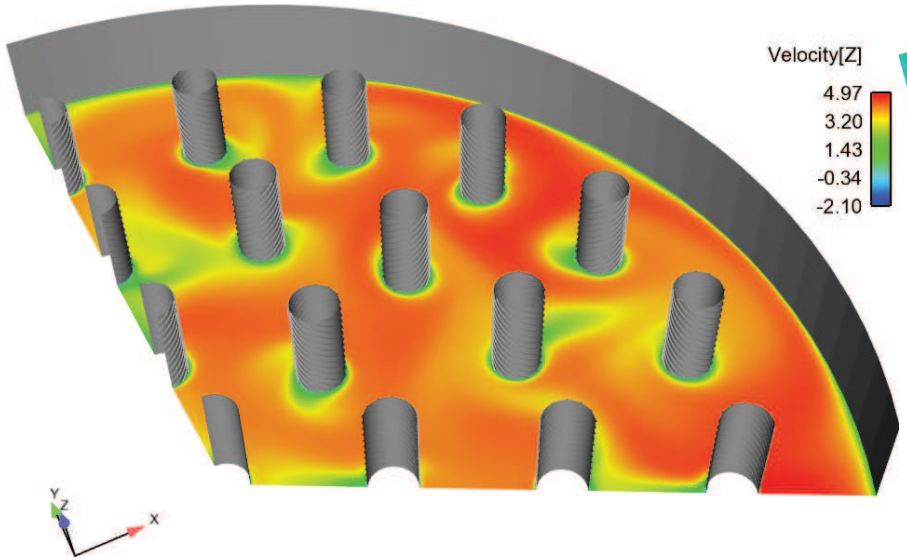


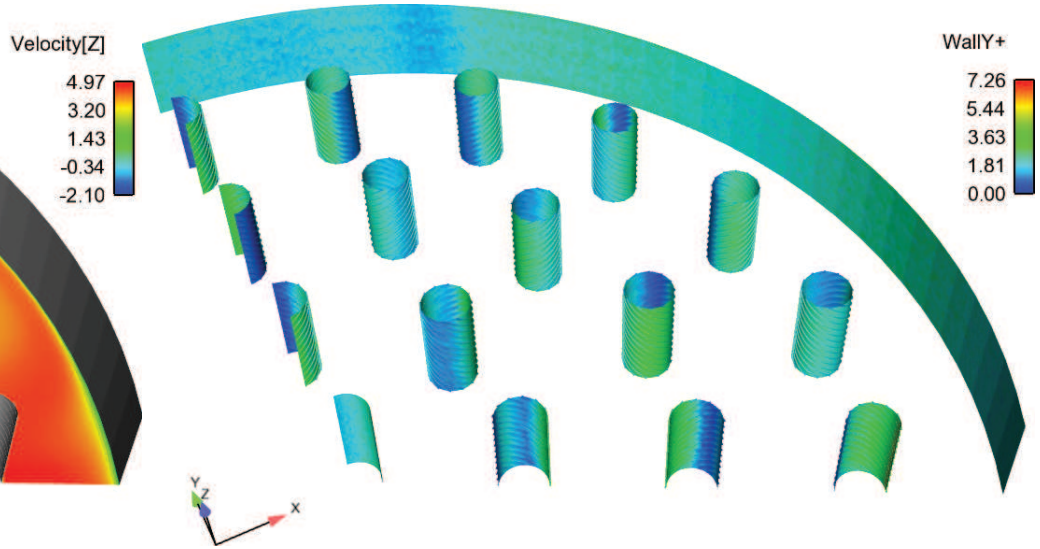


Fuel pins

- Validation against experiments for a single pin.
- Model of the 120^o section.
- Compute heat transfer for a range of values for the carbon deposition conductivity.



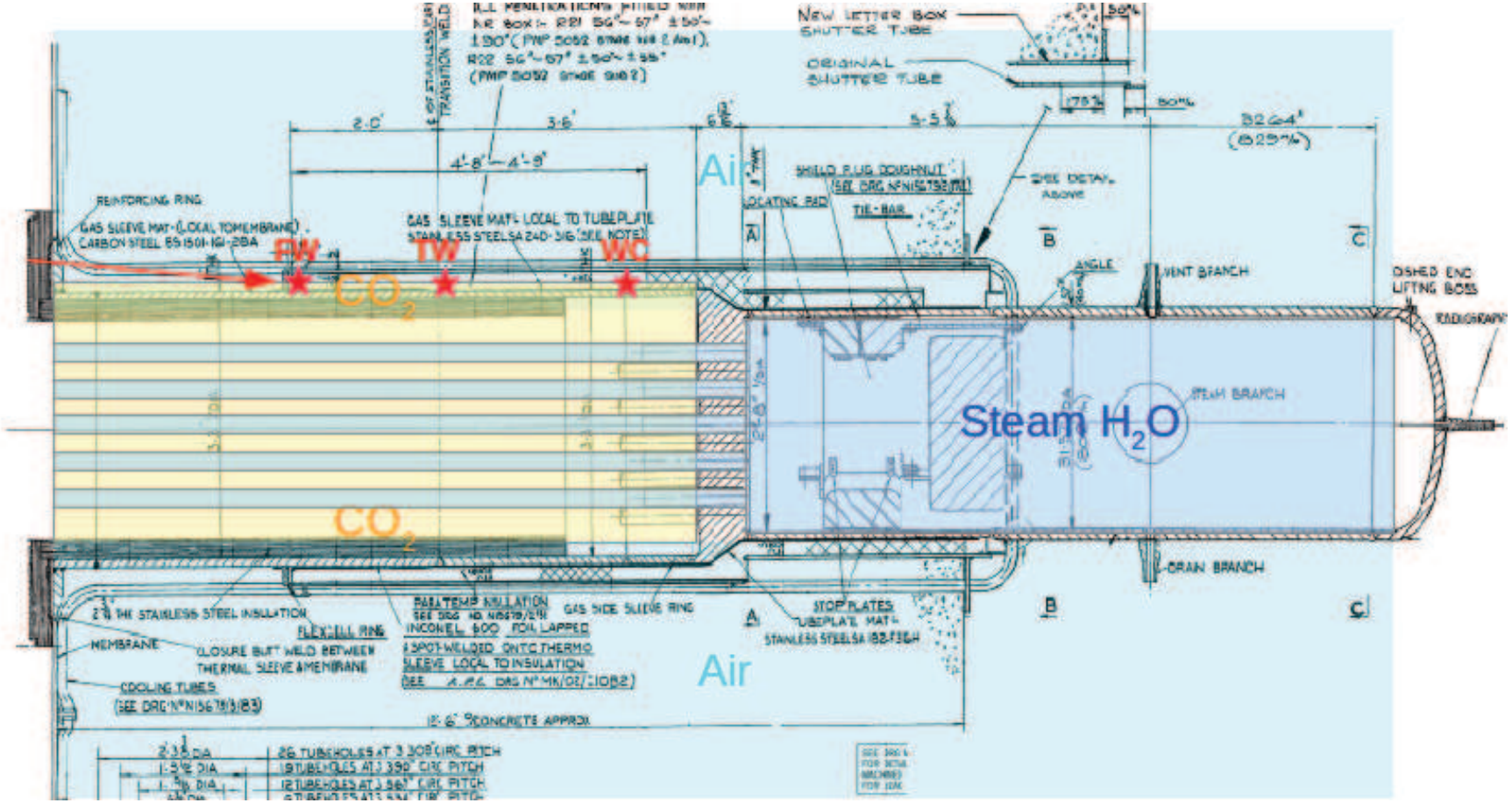




Steam penetration

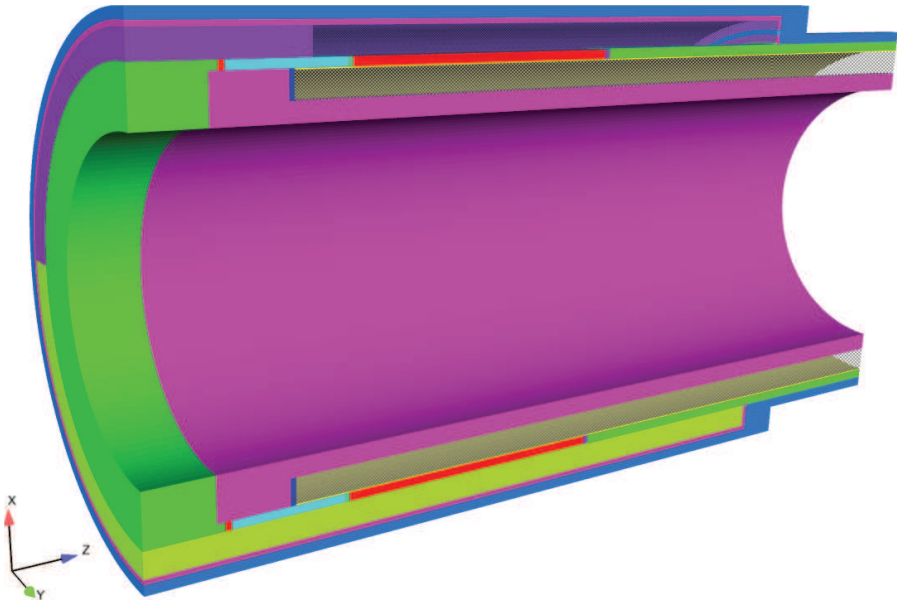
Welds in the reheater outlet penetration R21 D2 of Dungeness B power station have been subject to reheat cracking:

$\Rightarrow$ need of a better understanding of the temperature field.



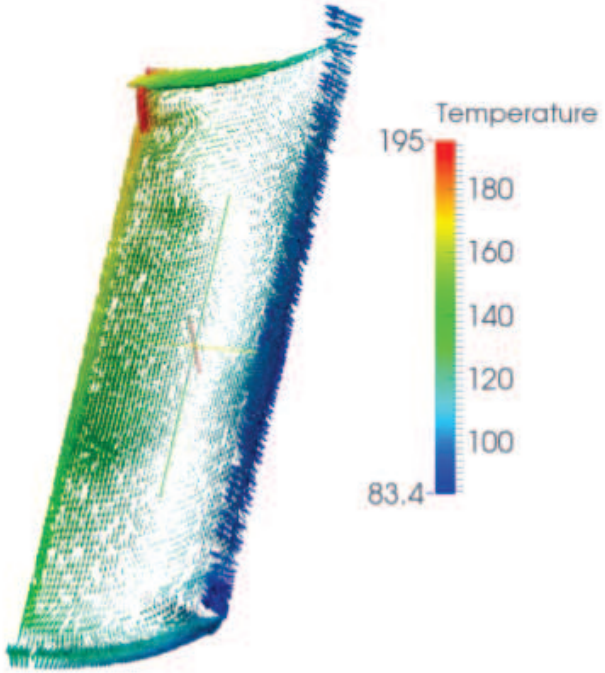
Steam penetration

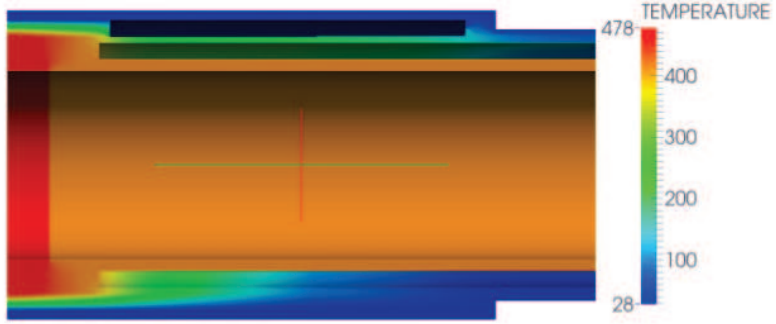
- 15 solids: liner, insulation...
- 1 fluid, the airbox.
- 1 porous medium, the bobbin.
- 2 coupled codes:
  - Code_Saturne.
  - SYRTHES.
- Convective, conductive and radiative heat transfer.

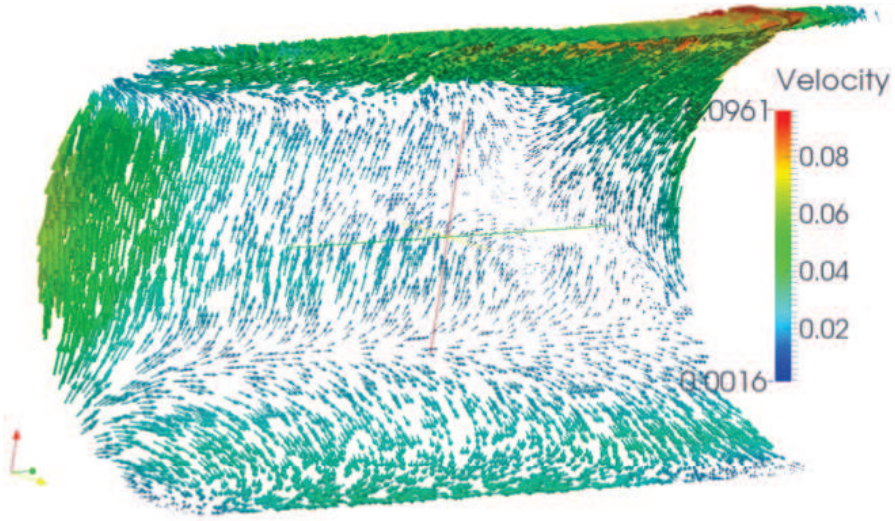


Steam penetration

- Complex interaction between the fluid and the solid.
- Bobbin modelling crucial but not much is known about it.
- Several parameters need to be studied.








thank you