

ROTECH SYSTEMS
Why Accept Anything Less?

Thermo-Hydraulic CFD Investigation of a PF-Fired Drum-Type Steam Generator

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Presentation Overview

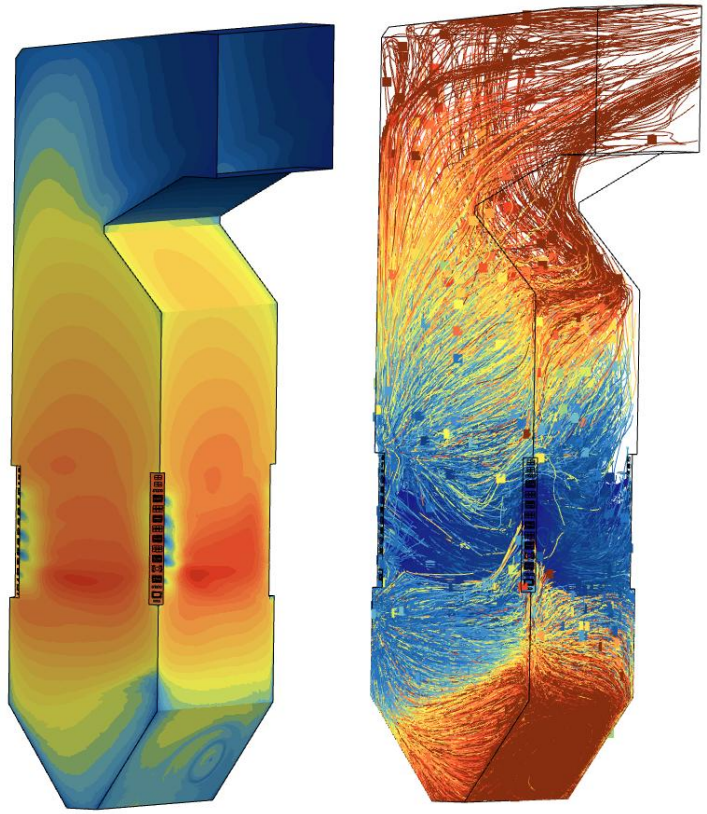
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1. **Engineering Analysis Workflow**
   From plant information to integrated CFD and 1D modelling

2. **PF-Fired Boiler Investigation**
   Combustion, furnace flow and heat loading

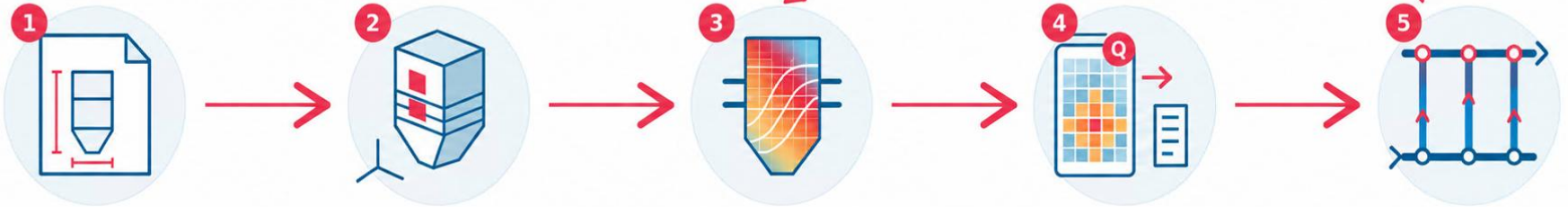
3. **Evaporator Investigation**
   Water-side flow and boiling behaviour

4. **Local Sub-Scale Tube Analysis**
   Detailed component-level CFD



Rotech Systems Engineering Analysis Workflow

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1 Drawing Review

PLANT INFORMATION

Drawings and dimensions
Operating information

2 3D CAD Modelling

SOLIDWORKS

Equipment geometry
Fluid domain definition

3 CFD Analysis

STAR-CCM+

Mesh, boundaries and physics
Simulation and checks

4 Data Extraction

HEAT-LOAD MAPPING

Wall heat-load extraction
Mapping to tube segments

5 1D Modelling

FLOWNEX

Water-side flow and boiling
Pressure and steam quality

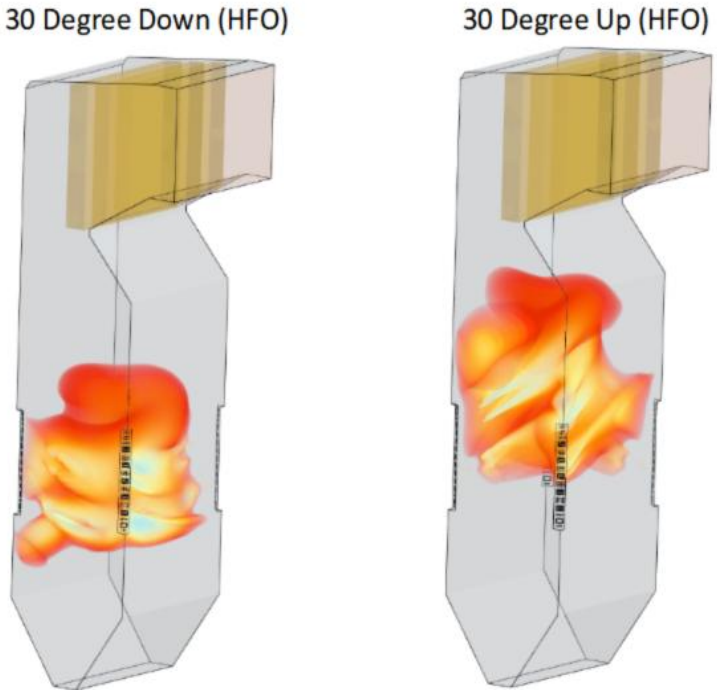
FLOWNEX BOUNDARY CONDITIONS

OPTIONAL FOLLOW-ON
Targeted Detailed CFD
Explicit tube or piping model

Where required, selected locations return to CFD for more detailed investigation

PF-Fired Boiler Investigation – The Engineering Challenge

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Reported plant concerns:

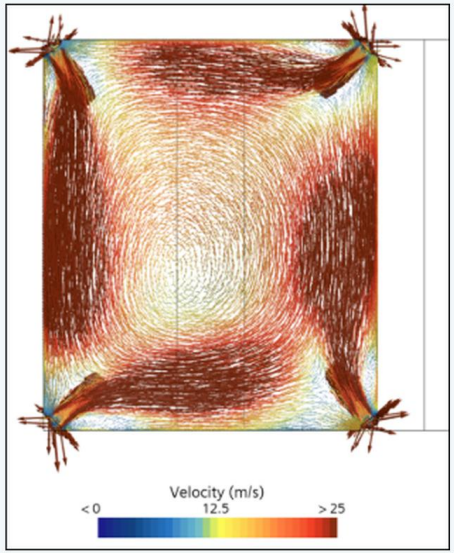
- Water-wall tube failures had been experienced.
- Concentrated thermal loading was suspected around the burner region.
- Changes to the firing arrangement required assessment.

Can changes to the burner configuration redistribute furnace heating while maintaining acceptable downstream temperatures?

PF – Fired Boiler
Global Scale Results Overview

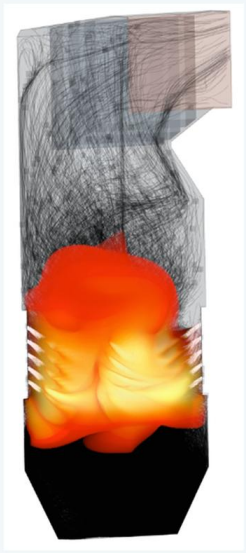
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1 Furnace Swirl



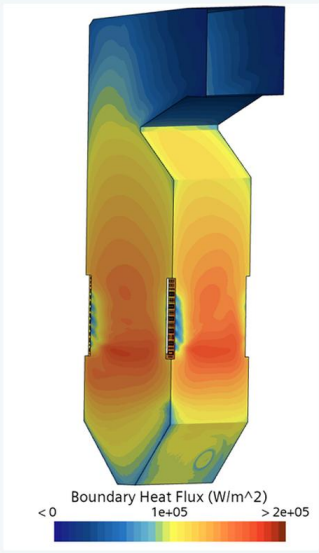
Tangential furnace circulation

2 High-Temperature Region



Temperature and particle-flow field

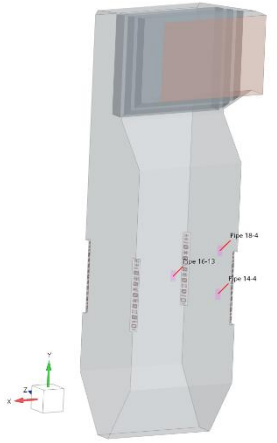
3 Wall Heat Loading



Boundary heat-flux distribution

PF – Fired Boiler
CFD to 1D network data transferring

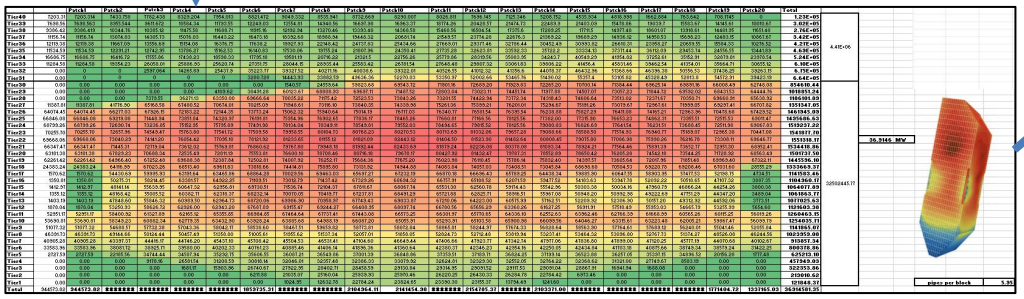
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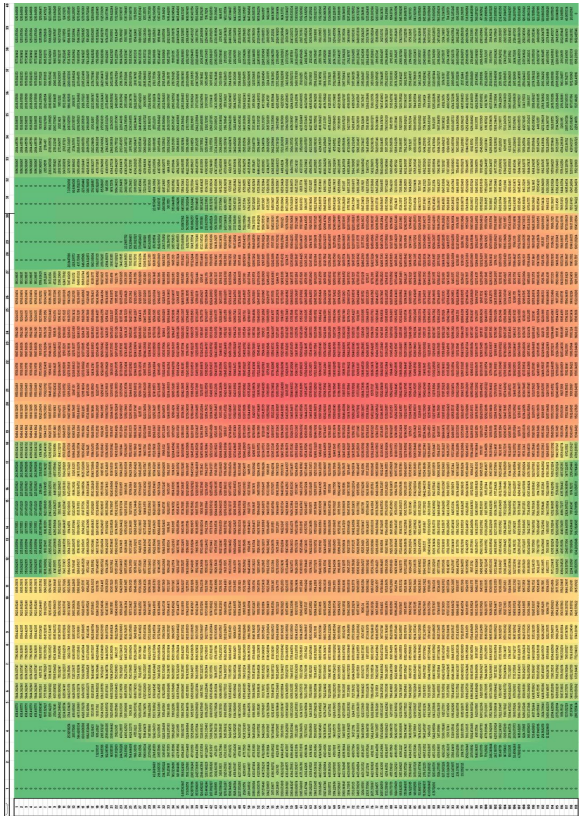


Incremental Heat transfer from CFD

Interpolation of mesh to increase the resolution

- **CFD heat-transfer data was interpolated to provide higher spatial resolution for the Flownex model.**
- **Original heat-flux matrix: 40 × 20.**
- **Interpolated heat-flux matrices:**
  - **40 × 119 for the left and right walls.**
  - **40 × 139 for the front and rear walls.**
- **Interpolation ensured total heat transfer was conserved for each boiler wall.**

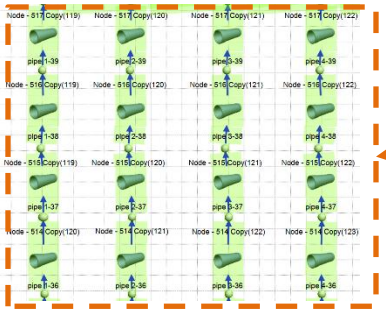


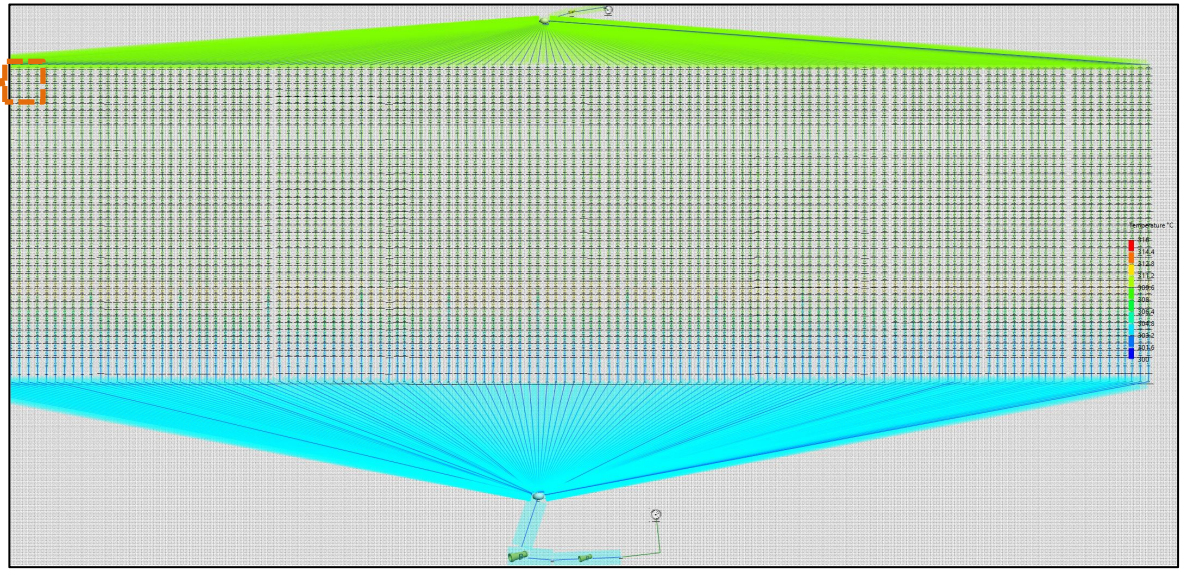


Single wall heat transfer incremental details

PF – Fired Boiler
1D modelling of a single furnace wall

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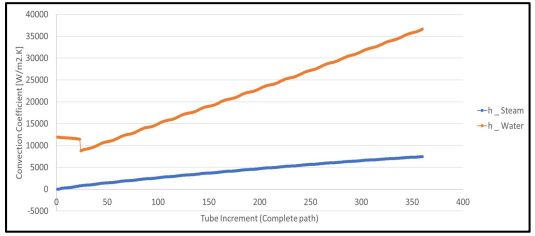
- **Model the radiant furnace walls as a 1D pipe network.**
- **Represent individual tubes and flow paths using discretised pipe sections with assigned heat inputs.**
- **Account for pressure losses, flow distribution, and variations in heat input between tubes and walls.**
- **Calculate the local fluid conditions along each tube increment, including two-phase flow properties.**
- **High level of detail modelled for each boiler wall.**

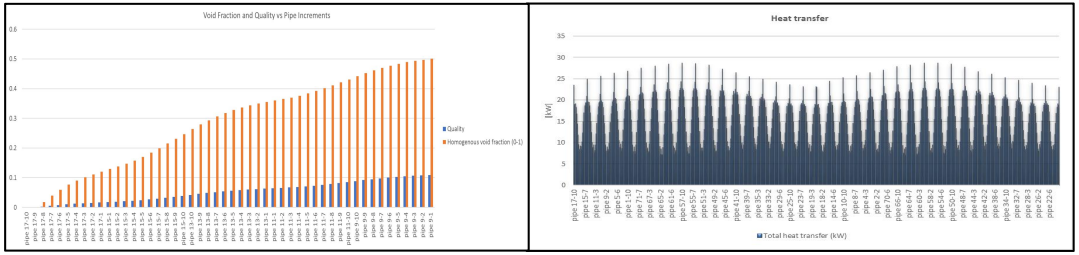
- **Front and Rear walls : 5560 pipe segments per wall.**
- **Left and Right walls : 4760 pipe segments per wall.**

PF – Fired Boiler
Key 1D Thermo-Hydraulic Findings

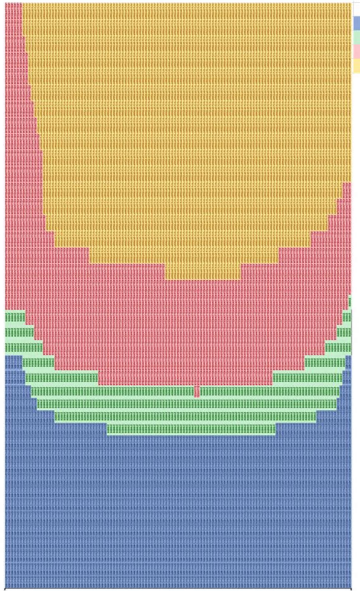
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- **Extract incremental fluid properties and hydraulic results from Flownex.**
- **Post-process the results to visualise variations in fluid conditions throughout the boiler.**
- **Identify potential regions of concern by combining calculated operating conditions with tube failure locations.**
- **Investigate the interaction between heat input, mass flow distribution, and two-phase flow behaviour.**
- **Use the results to guide further investigation into possible tube failure mechanisms.**

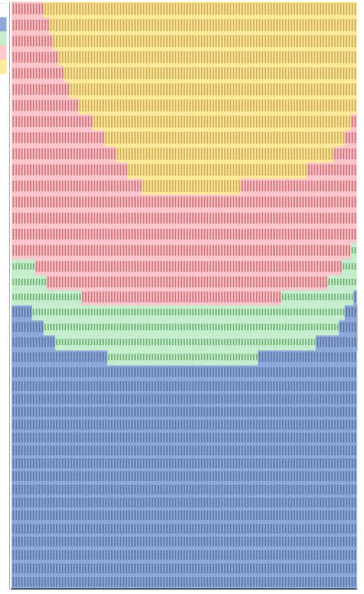




LHS 30 deg downwards



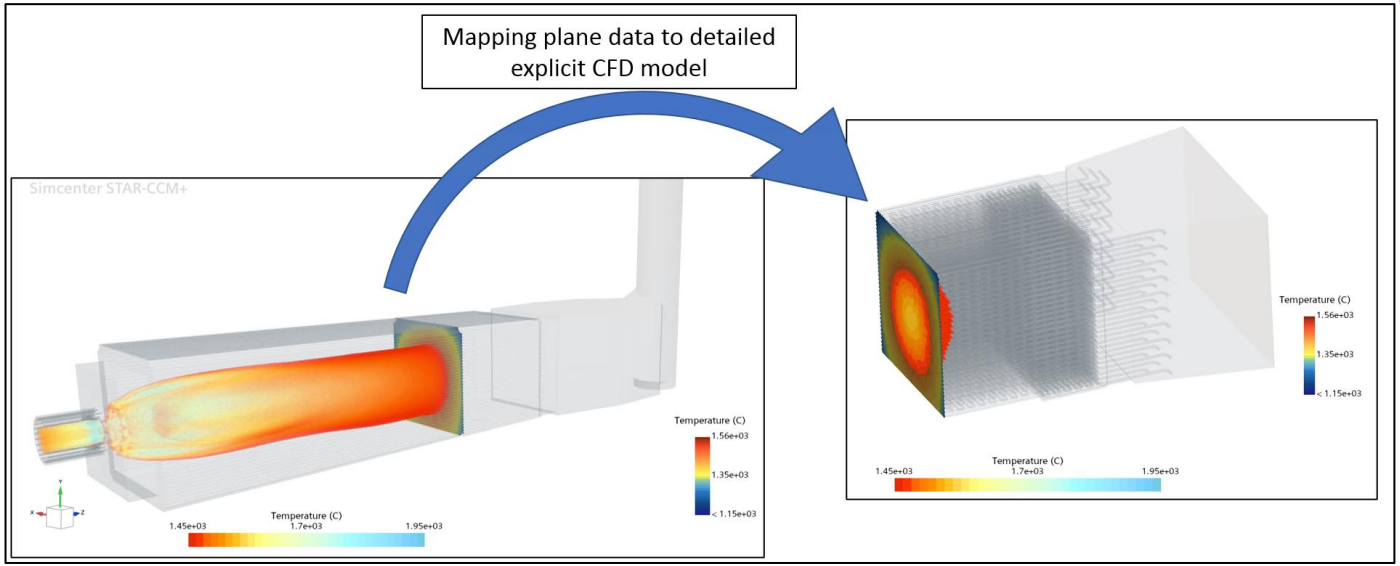
LHS 30 deg upwards

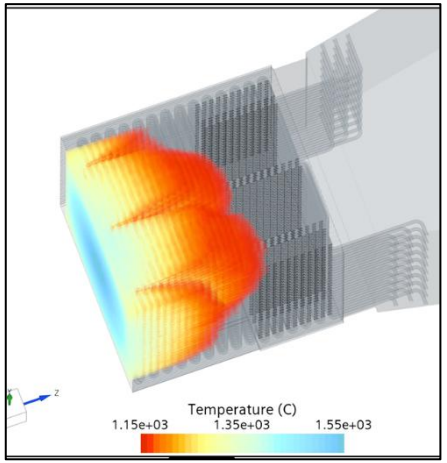


Examples of some of the data that can be obtained from post processing the 1D model

Evaporator Investigation

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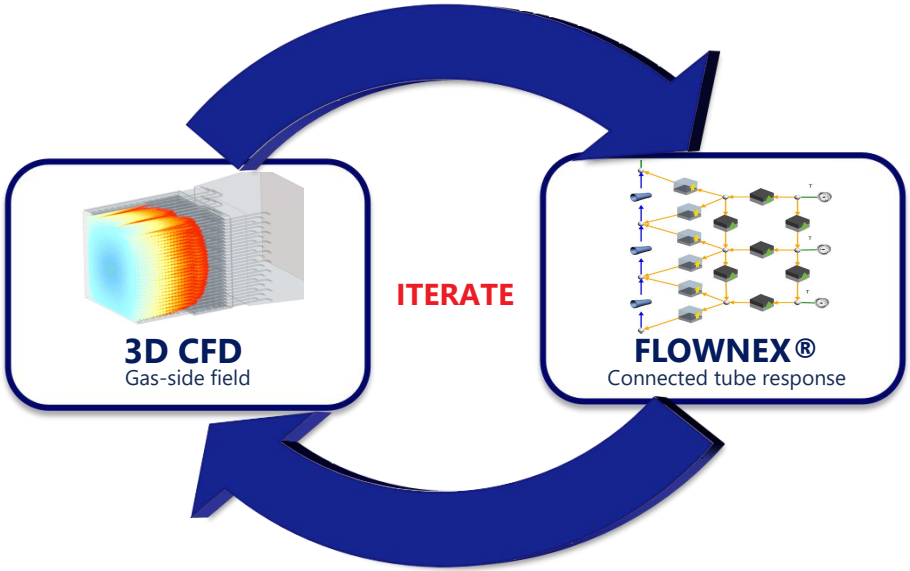


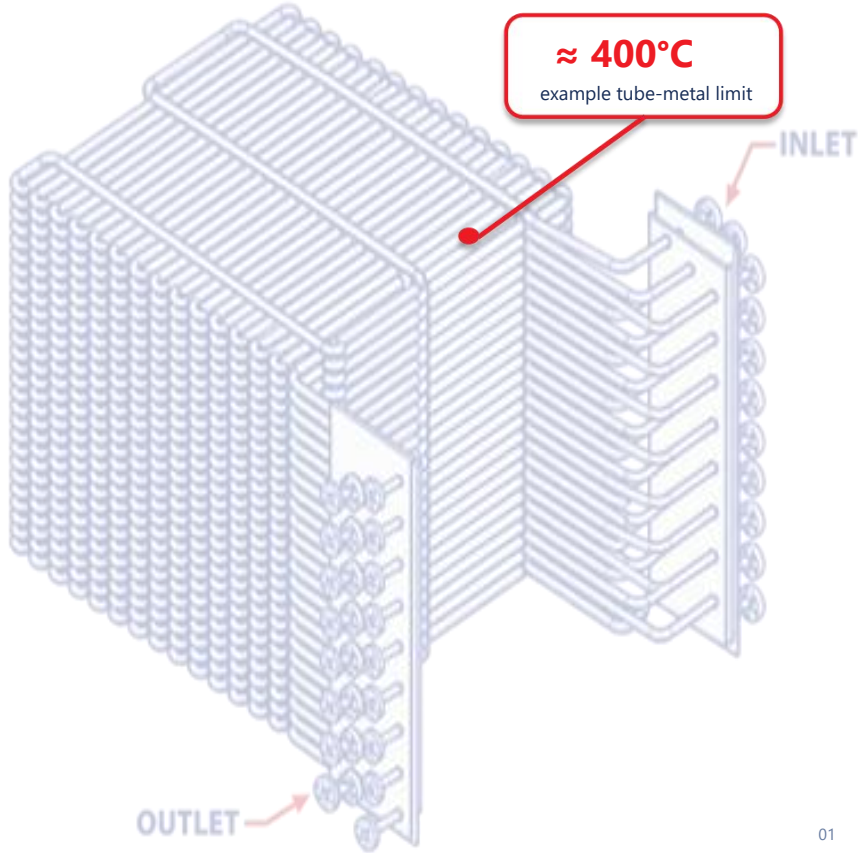
- **Apply the methodology to an evaporator section requiring detailed treatment of cross-flow heat transfer.**
- **Explicitly model the evaporator tubes in CFD to resolve local heat transfer from the flue gas to the tube surfaces.**
- **Discretise the heat-transfer results spatially and map them to the corresponding sections of the Flownex model.**
- **Represent the flue-gas flow and tube-side thermo-hydraulics at compatible levels of discretisation.**
- **Use an iterative approach to achieve consistency between the CFD heat-transfer predictions and the 1D model.**

Where on the tube network does the thermal limit get approached?

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If the tubes have a temperature limit, where do we look first?



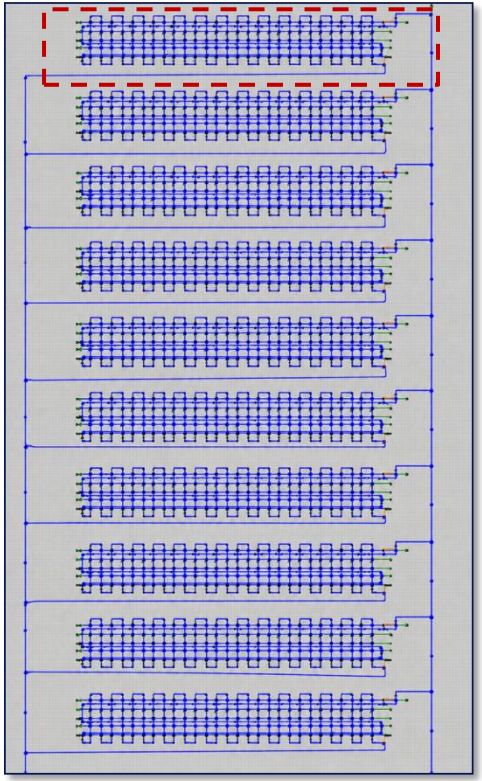


The tube network, resolved section by section.

Rather than treating the evaporator as a single equivalent heat exchanger, the connected tube network is resolved in much finer detail.

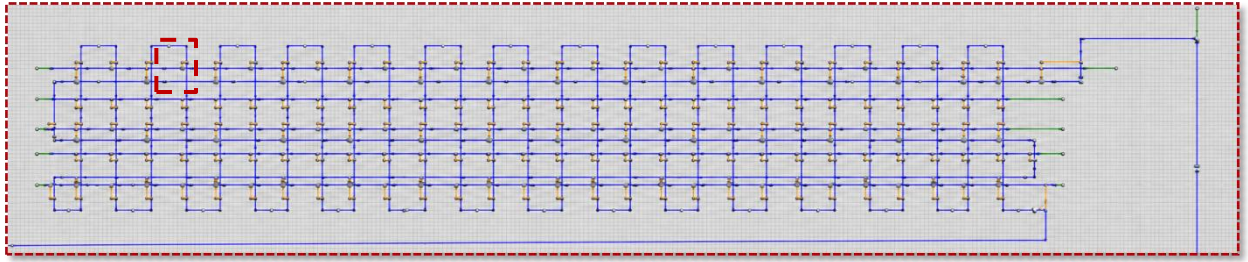
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01 SYSTEM



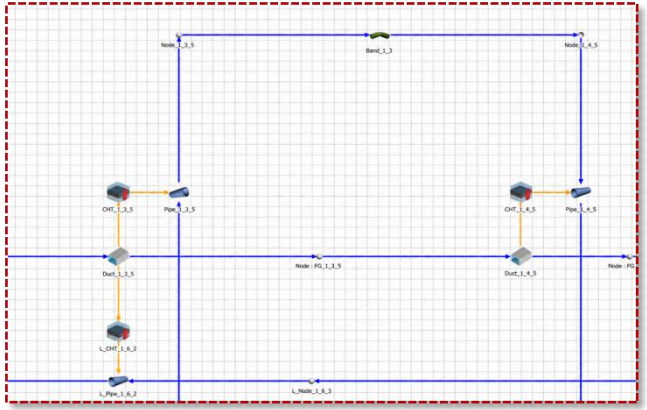
ZOOM

02 CIRCUIT



ZOOM

03 TUBE SECTION



10,000+
elements in the full model

ELEMENT KEY

	**PIPE**	water / steam flow
	**DUCT**	flue-gas conditions
	**CHT**	gas → metal → fluid heat transfer

From network data to a physical thermal picture

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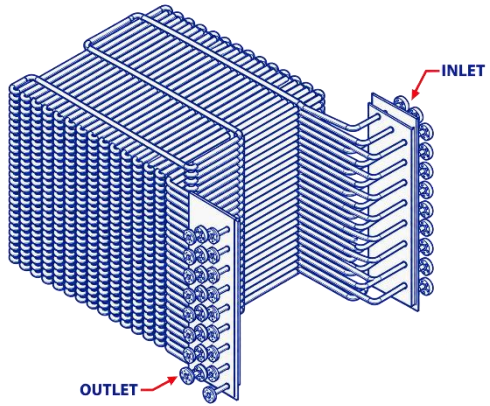
The calculated tube-side results are mapped back onto the corresponding physical tube locations using Python.

01
FLOWNEX RESULTS
tube-side results

02
PYTHON MAPPING
mapped back onto physical tube locations

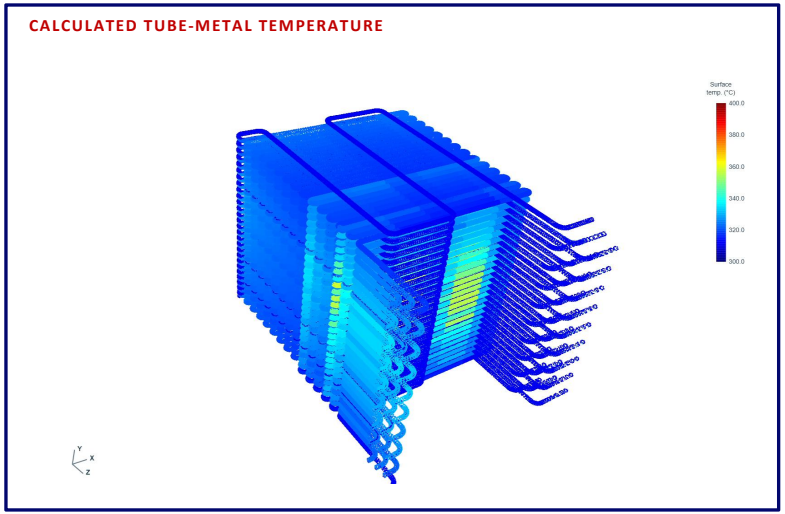
03
THERMAL PICTURE
highlight hotter sections / limits / regions of interest

DESIGN GEOMETRY



MAP BACK

CALCULATED TUBE-METAL TEMPERATURE



Adjust the displayed range to visually highlight hotter sections, specific design limits, or particular regions of interest

Local Scale (Horizontal) Single Tube Simulation

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Tube Skin Temperature Evaluation presented results (consistent across multiple furnaces) which indicate tube skin temperatures well above 400 to 470°C.

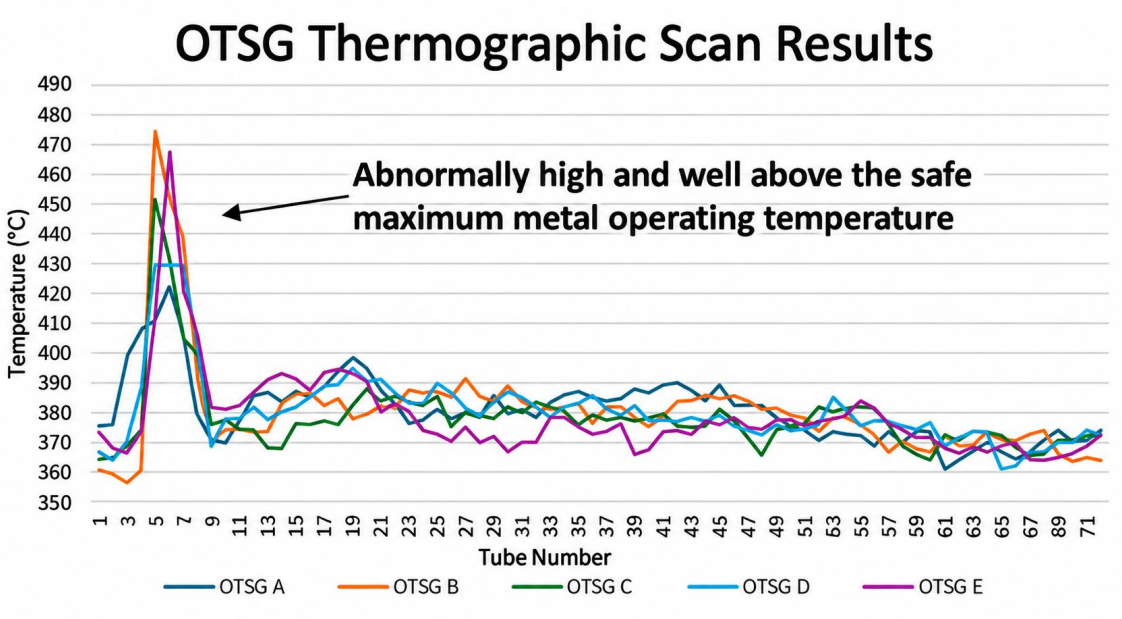
Temperature (T_Sat) of the liquid entering the furnace is in the order of 300 to 330°C. It is unusual for skin temperatures to deviate (depending on heat flux) by more than 10°C to 20°C above the internal fluid temperature.

Such deviations are indicative of either:

- **Incorrect temperature measurements?**

or

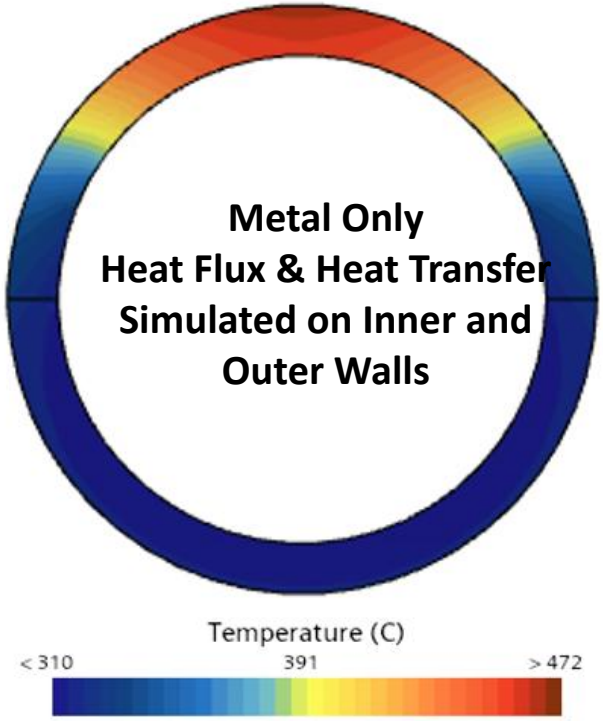
- **In case of horizontal tubes, internal fluid phase separation leading to the loss of cooling on the upper part of the tube wall.**



Local Scale Single Tube Simulation

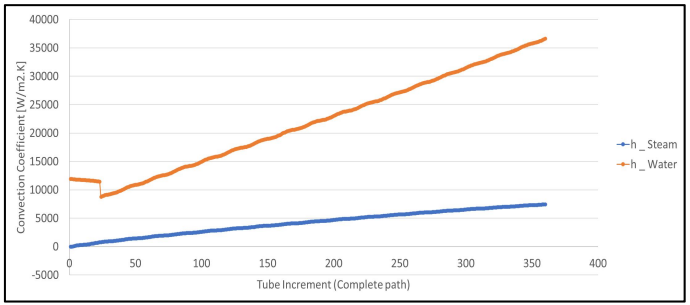
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Steady State Results



Tube Internal Convective Heat Transfer Coefficients defined by phase properties.

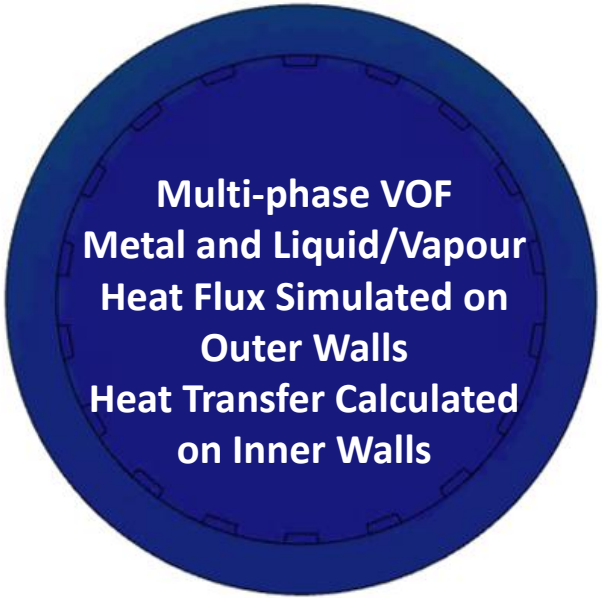
External Heat Flux from global scale CFD model.

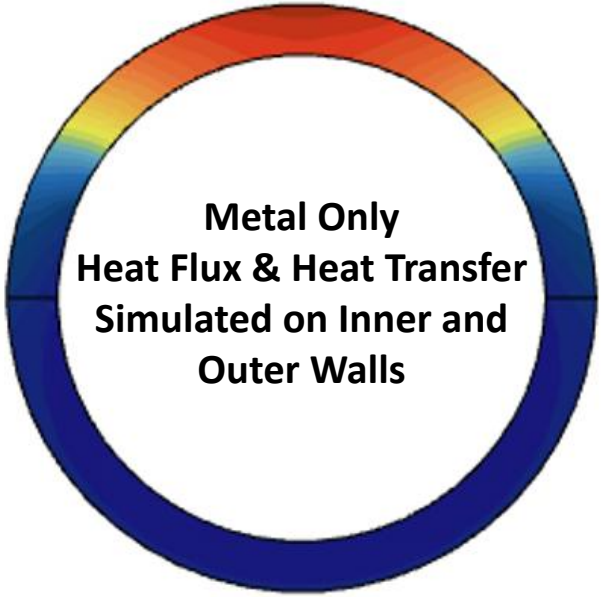


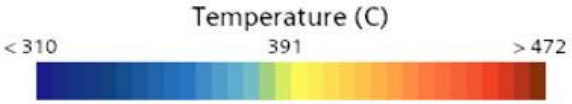
Local Scale Single Tube Simulation - Change Normal Tubes to Riffle Bore Tubes

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Steady State Results



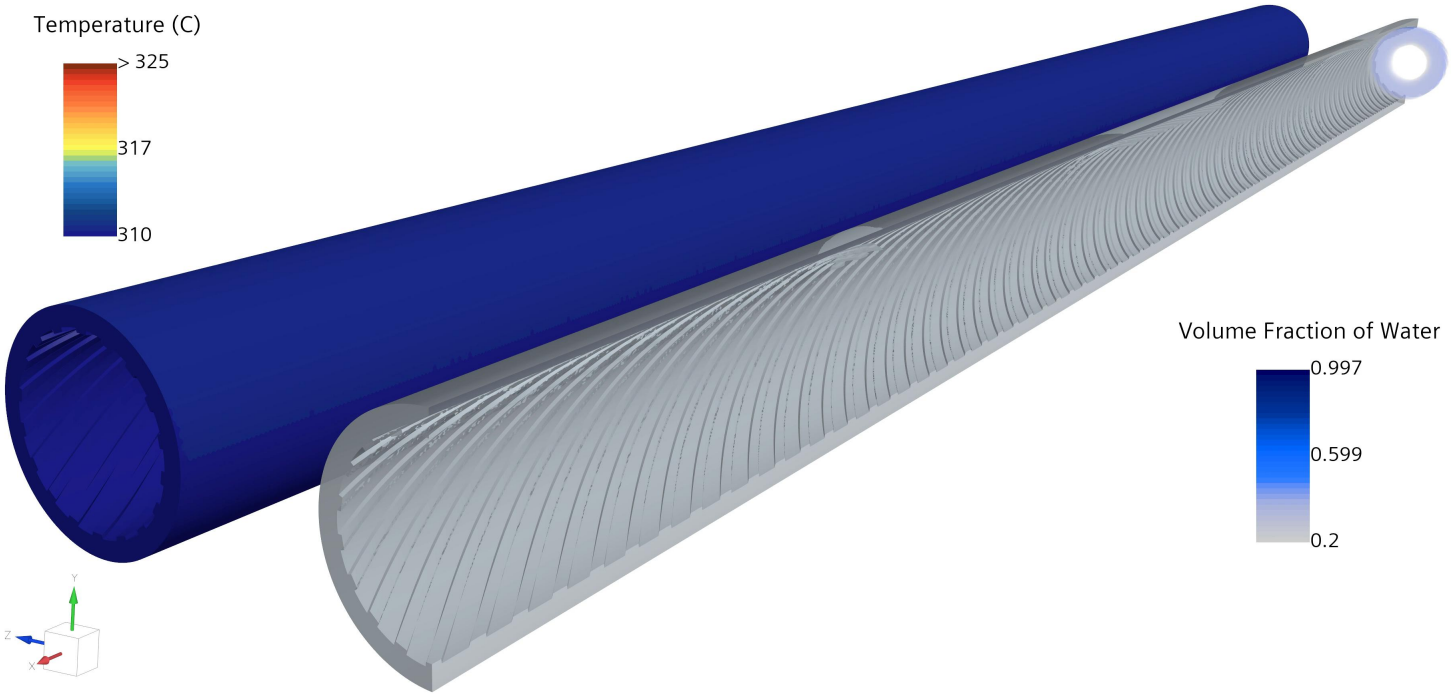




Local Scale Single Tube Simulation - Change Normal Tubes to Riffle Bore Tubes

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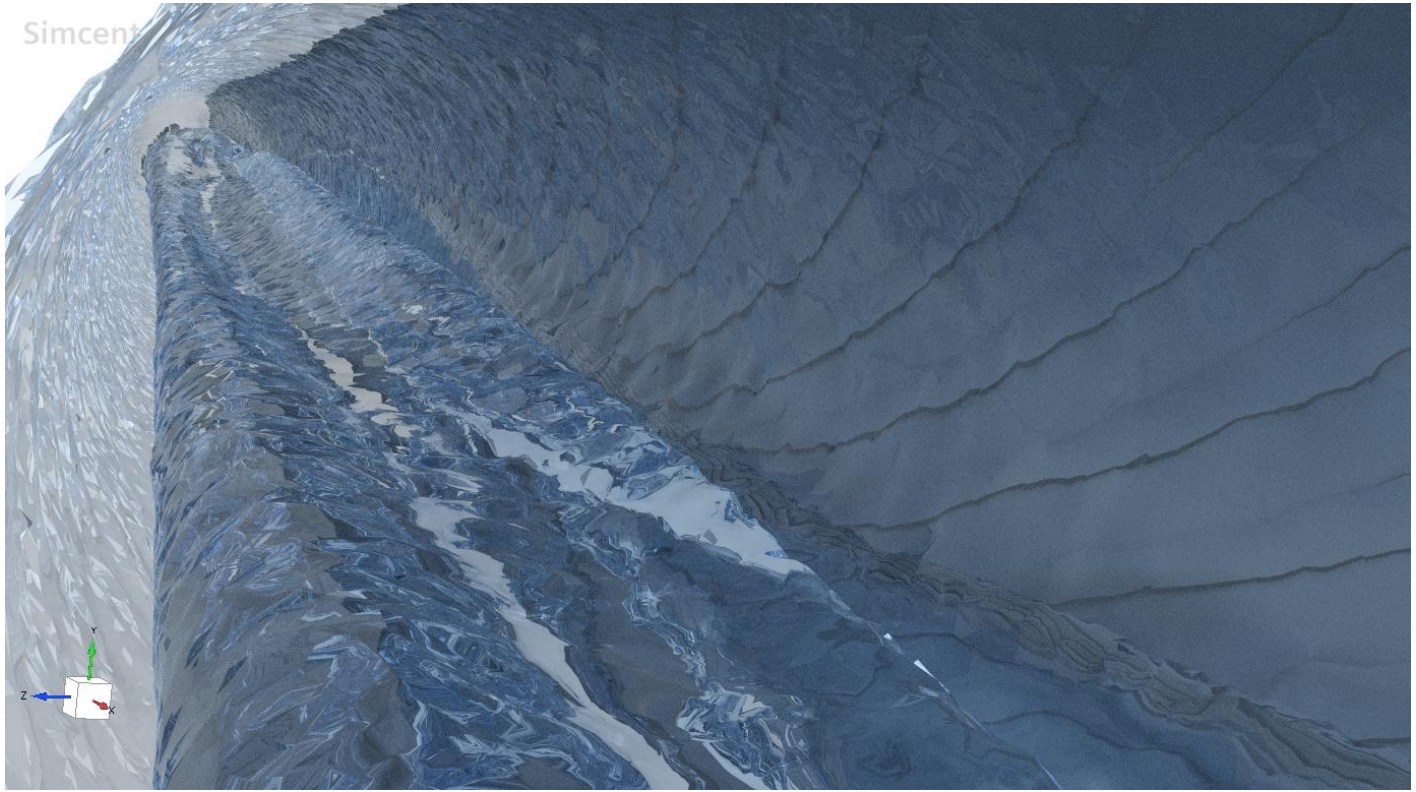
Simcenter STAR-CCM+



Solution Time 0.01 (s)

Local Scale Single Tube Simulation - Change Normal Tubes to Riffle Bore Tubes

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Liquid Fraction
Iso-Surface (0.8)



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Thank You

Please feel free to post any questions in the **Q&A** section on **Teams.**