Thermal and Flow Simulation of a High Temperature Printed Circuit Heat Exchanger

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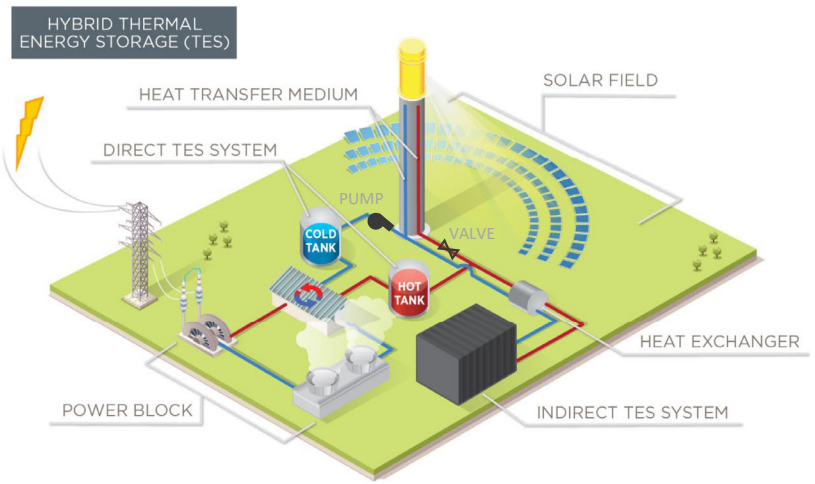
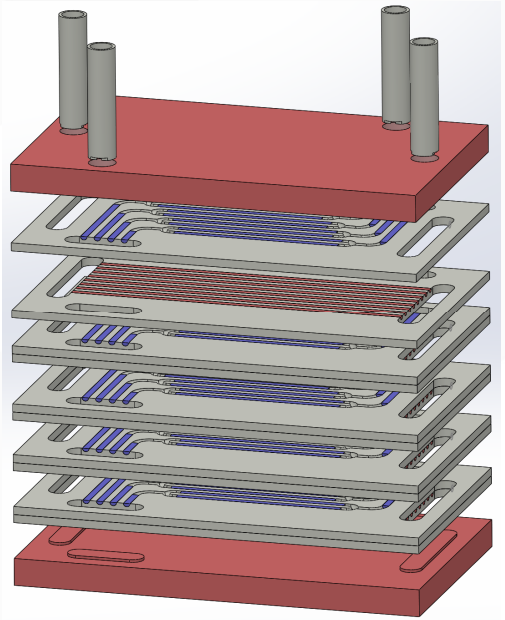
BACKGROUND

- Higher operation temperature, higher efficiency and lower LCOE for CSP plant
- DOE targets >750 °C for the next generation CSP
- Compact PCHEs capable working above 550°C are not commercially available
- Need to design and build a low cost high temperature high pressure PCHE



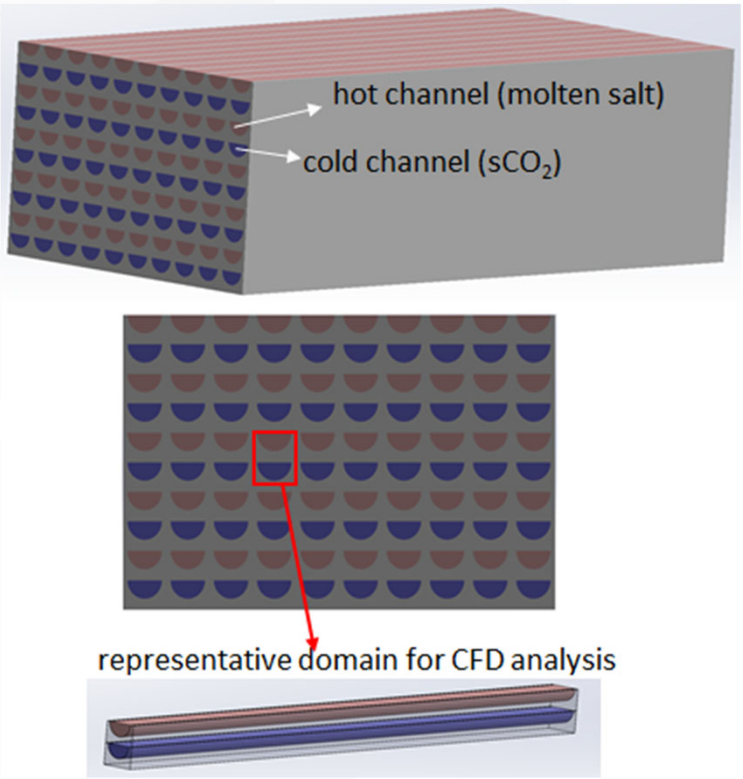
HIGH TEMPERATURE PRINTED CIRCUIT HEAT EXCHANGER

- Working fluid: molten salt and sCO2
- Working temperature: 750°C
- Working pressure:
  - sCO2: 20 MPa
  - Molten salt: 0.1 MPa
- HEX material: ZrC/W
  - High strength, high corrosion and creep resistant, low cost



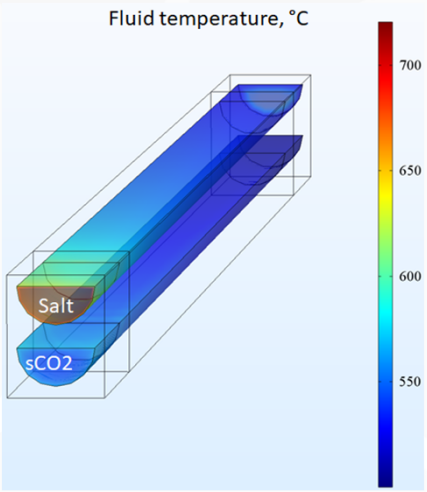
SINGLE CHANNEL SIMULATION

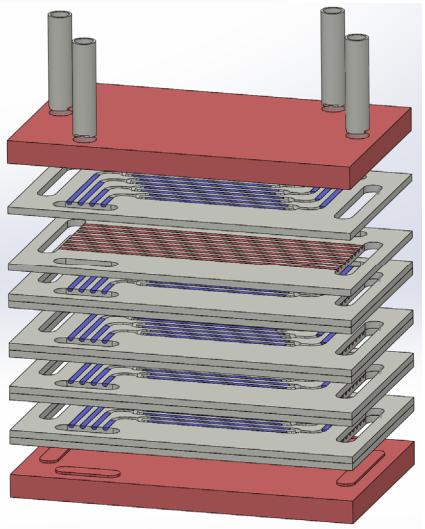
- Representative simulation unit:
  - one molten salt channel
  - one sCO2 channel
  - plate surrounding the two channels
- BC settings:
  - Periodic boundary conditions on top/bottom and side surfaces
  - Inlet velocity and out let pressure
  - Inlet temperature
- Mesh number: ~100K



SINGLE CHANNEL SIMULATION

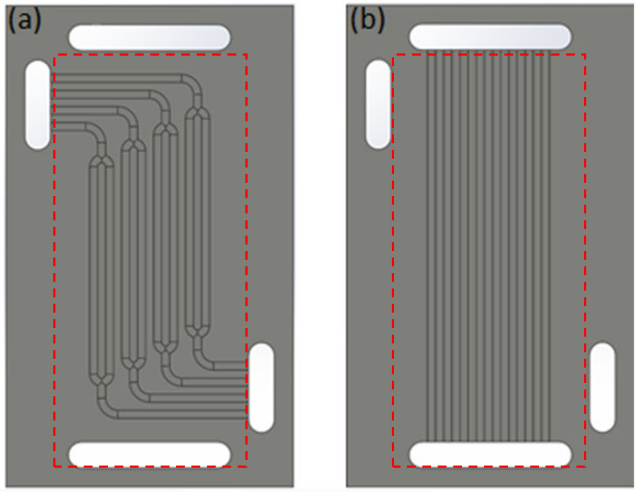
- Information obtained:
  - Temperature → power density
  - Velocity
  - Pressure → pressure drop
- Information missed:
  - Flow pattern effects
  - Less HT-effective region
  - Flow mal-distribution in inlet and outlet header

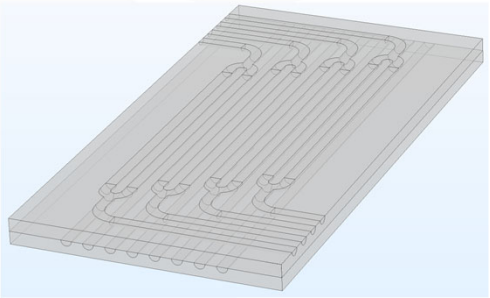




SINGLE PLATE SIMULATION

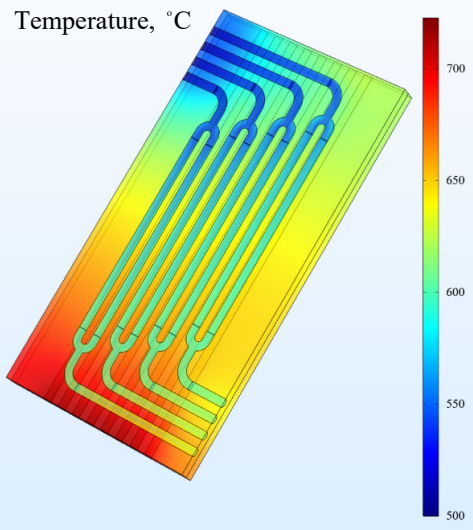
- A HEX plate simulation provides more realistic results.
- Serpentine channel for sCO2 and straight channel for molten salt.
- Flow pattern effects are accounted for.
- Periodic BC on top/bottom surfaces
- Mesh number: ~500K

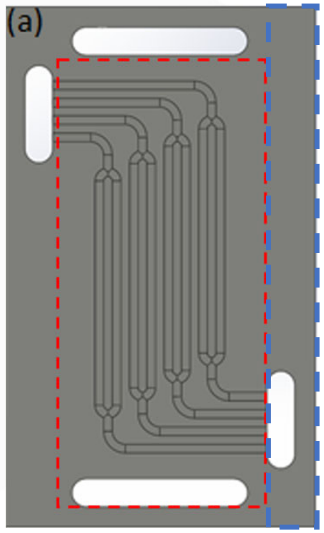




SINGLE PLATE SIMULATION

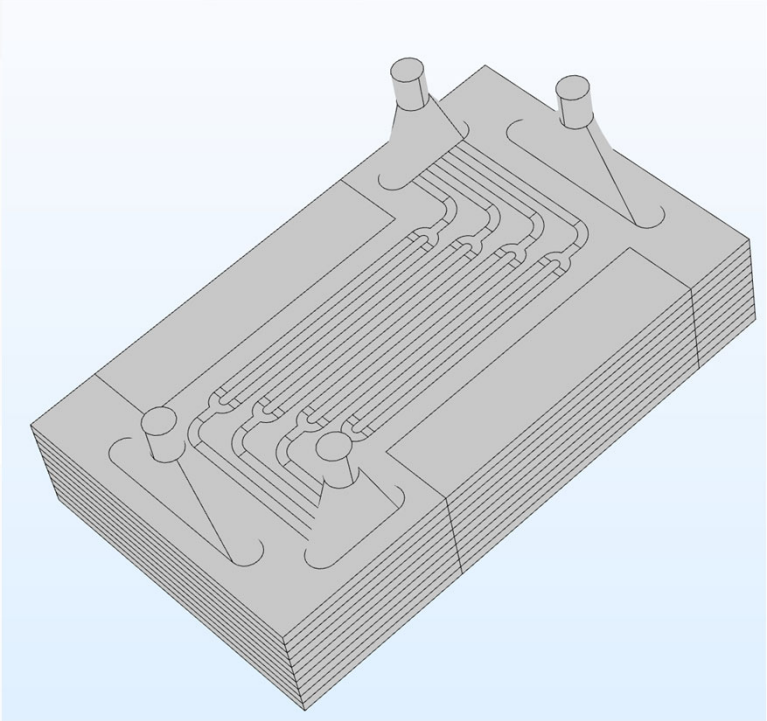
- New information obtained:
  - Channel pattern effects on the HEX performance
- Information missed:
  - Less HT-effective region
  - Flow mal-distribution in inlet and outlet header





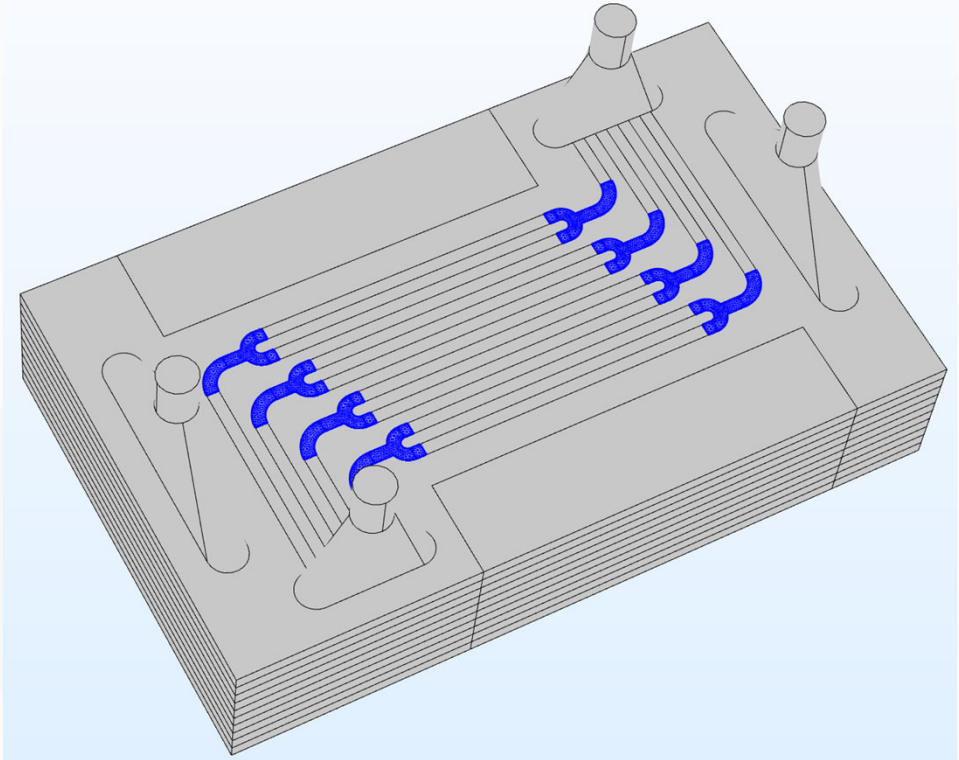
FULL HEX GEOMETRY SIMULATION

- Simulate the full HEX geometry
- Include all the dead zones and header region
- Mesh is challenging
- The mesh should be fine enough to capture the change of physics and course enough to keep the computational cost affordable.



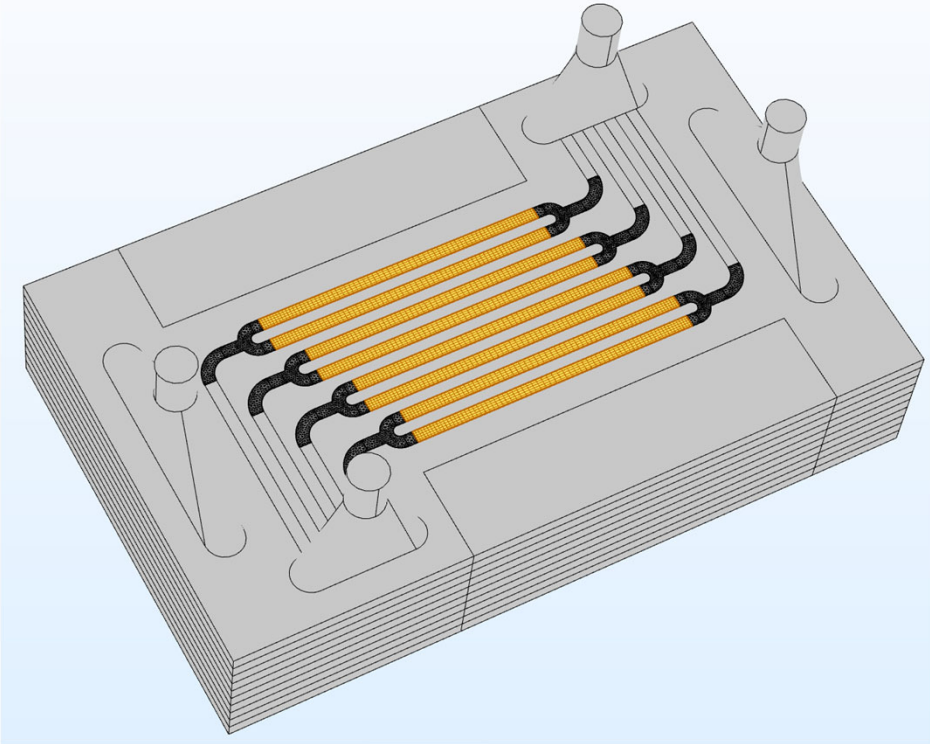
MESHING SEQUENCE FOR FULL HEX SIMULATION

- Tetrahedral mesh in the CO_2 elbows



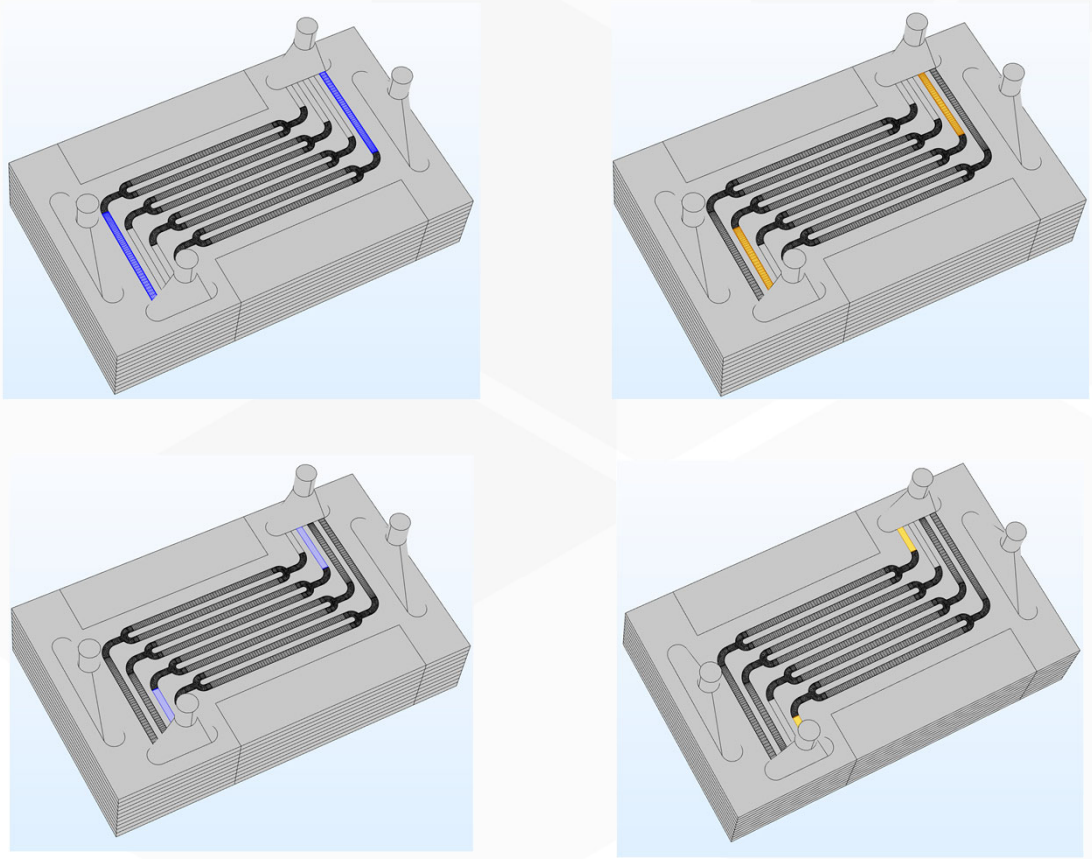
MESHING SEQUENCE FOR FULL HEX SIMULATION

- Swept mesh in the straight section of CO_2 channels



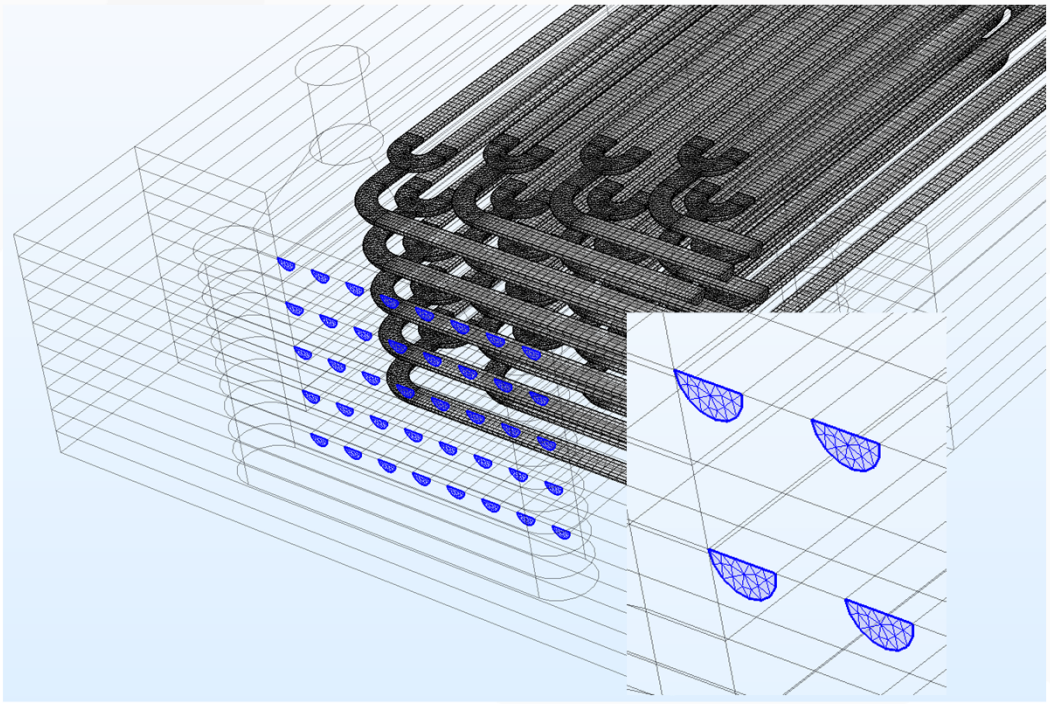
MESHING SEQUENCE FOR FULL HEX SIMULATION

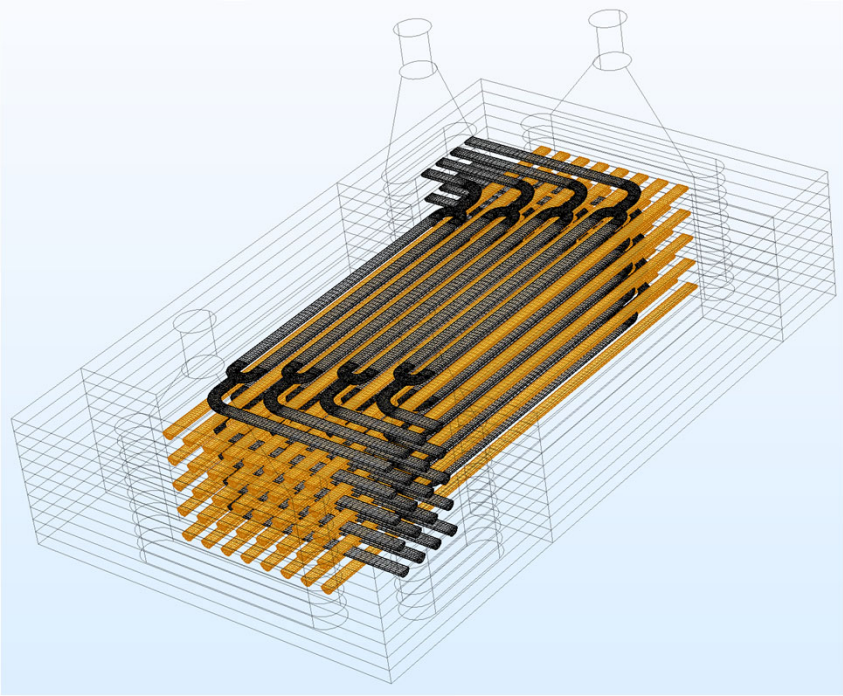
- Swept mesh in the straight section of CO_2 inlets and outlets



MESHING SEQUENCE FOR FULL HEX SIMULATION

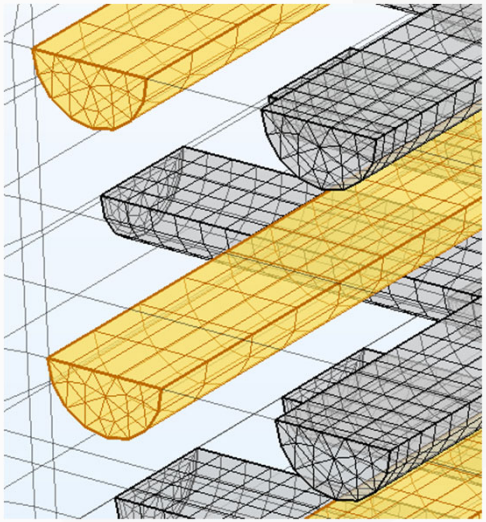
- Face triangular mesh for the salt inlet surfaces.
- Swept hexahedral mesh for salt domain.

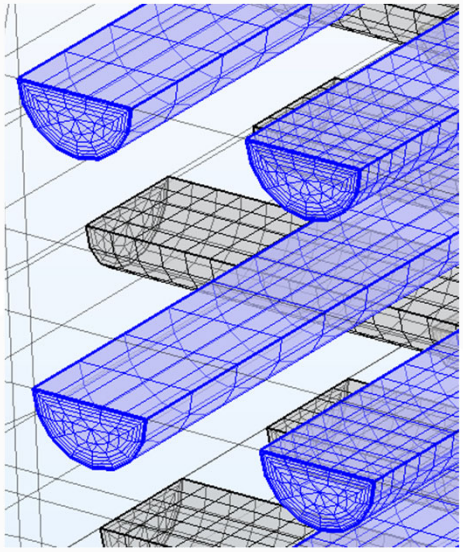




MESHING SEQUENCE FOR FULL HEX SIMULATION

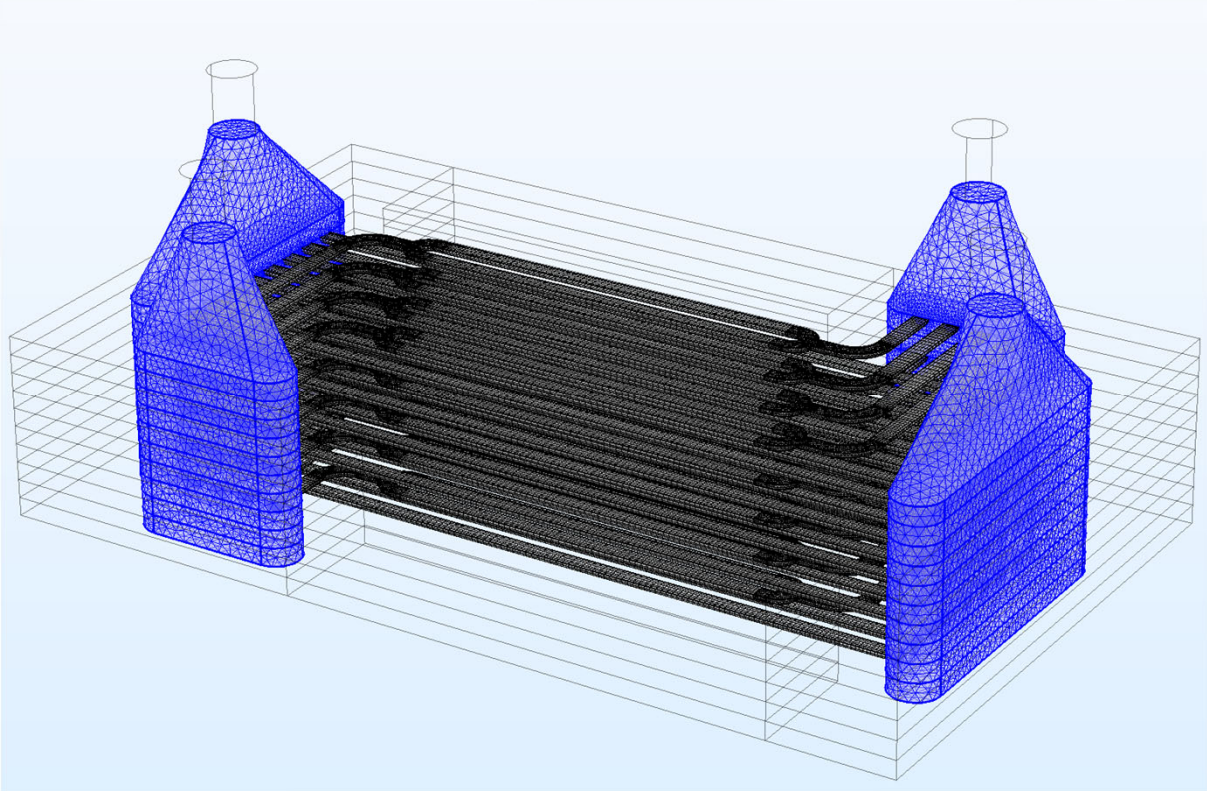
- Boundary layer mesh for the fluid domain





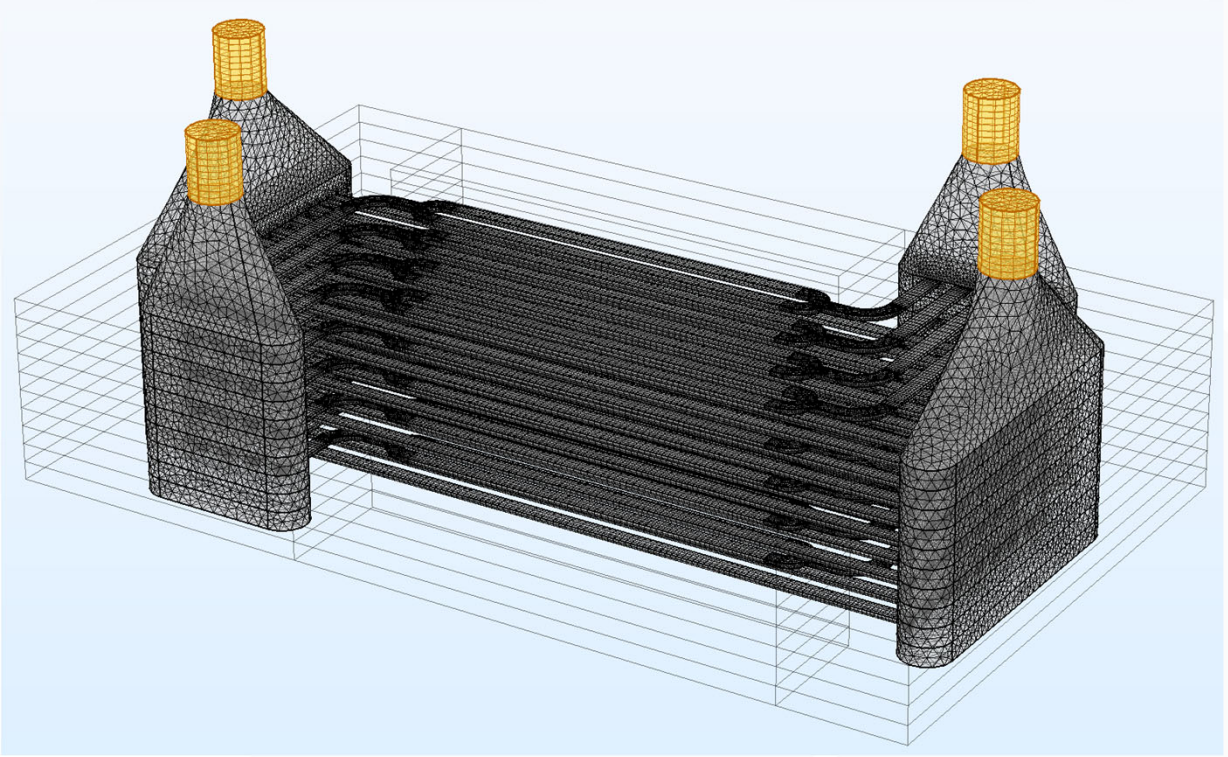
MESHING SEQUENCE FOR FULL HEX SIMULATION

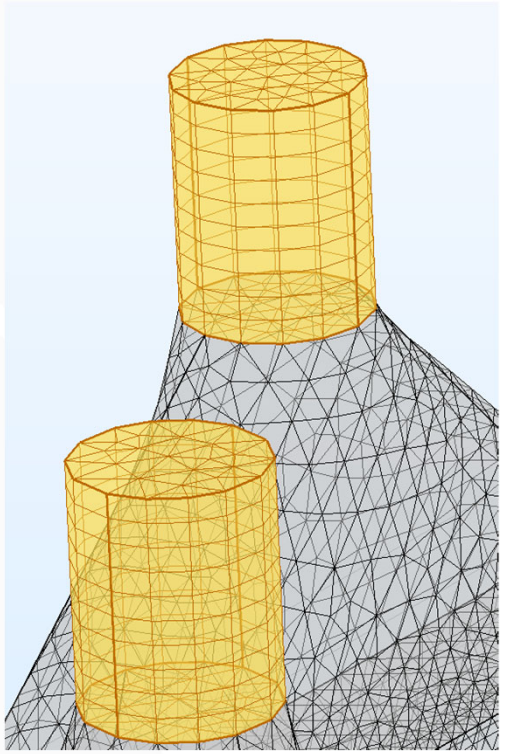
- Tetrahedral mesh in the headers



MESHING SEQUENCE FOR FULL HEX SIMULATION

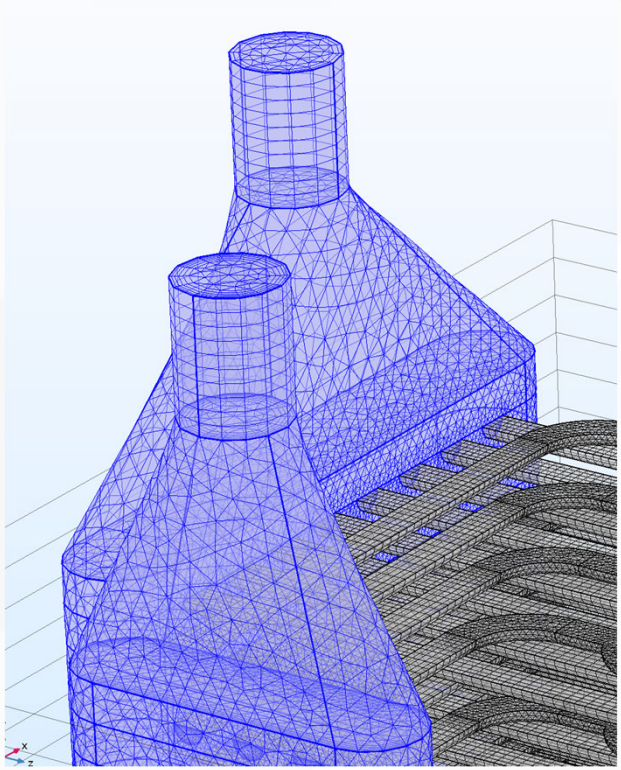
- Swept mesh in header tubes





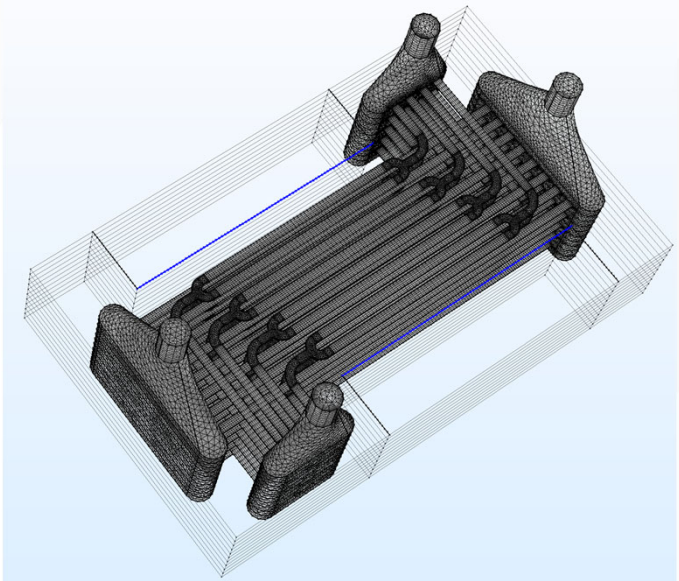
MESHING SEQUENCE FOR FULL HEX SIMULATION

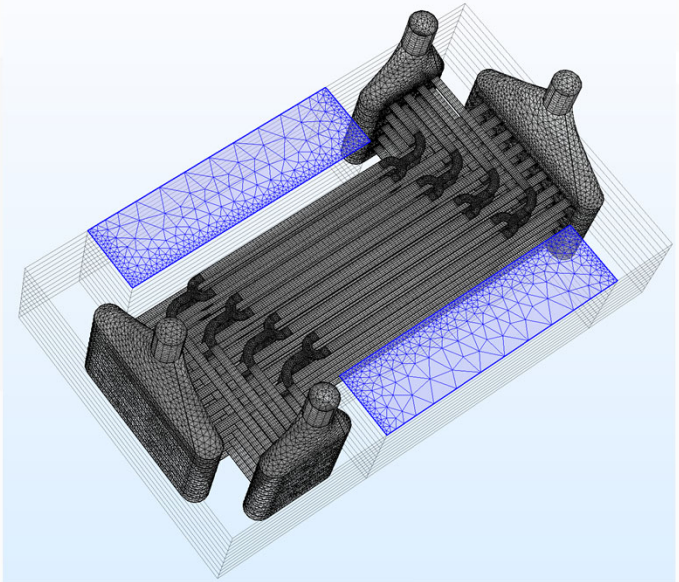
- Boundary layer mesh in headers

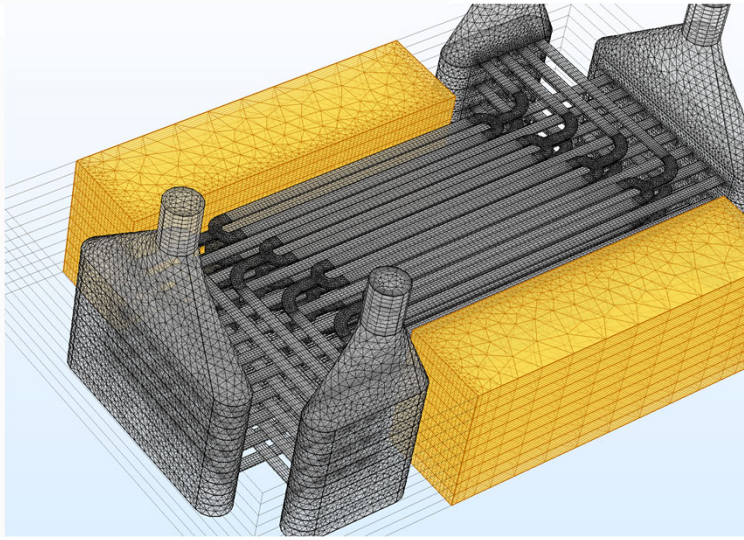


MESHING SEQUENCE FOR FULL HEX SIMULATION

- Edge mesh in the dead zone edges
- Surface triangular in the dead zone surfaces
- Swept mesh in the dead zones

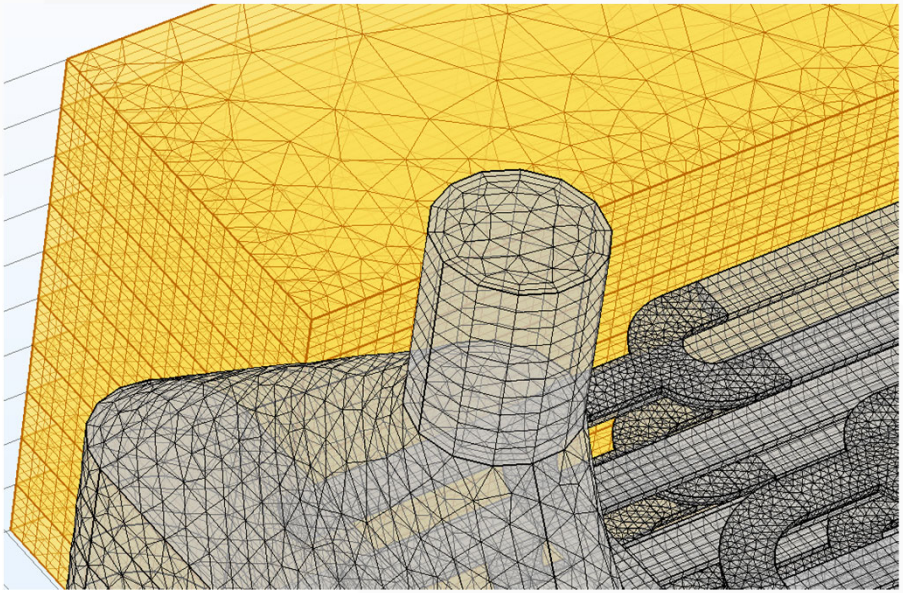


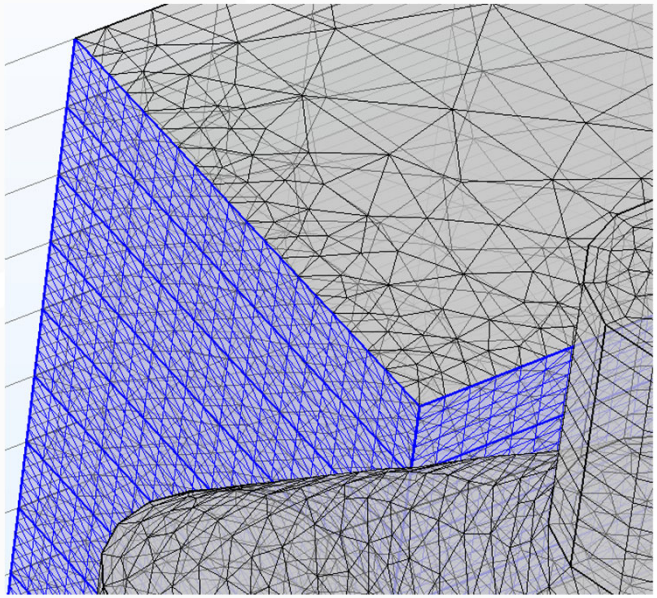




MESHING SEQUENCE FOR FULL HEX SIMULATION

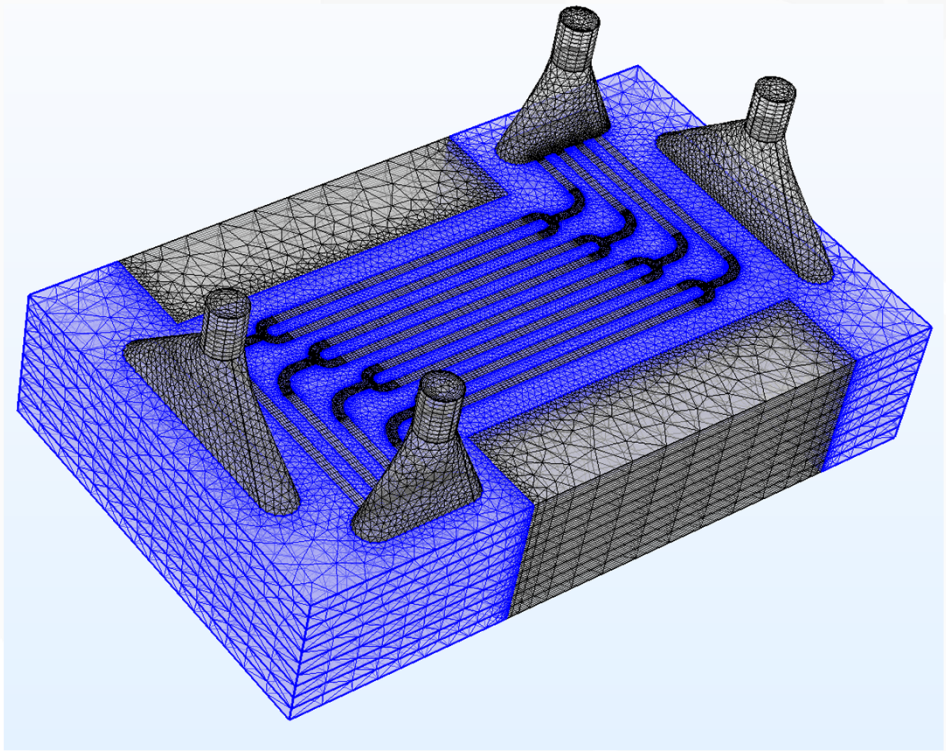
- Convert rectangular mesh to triangular mesh



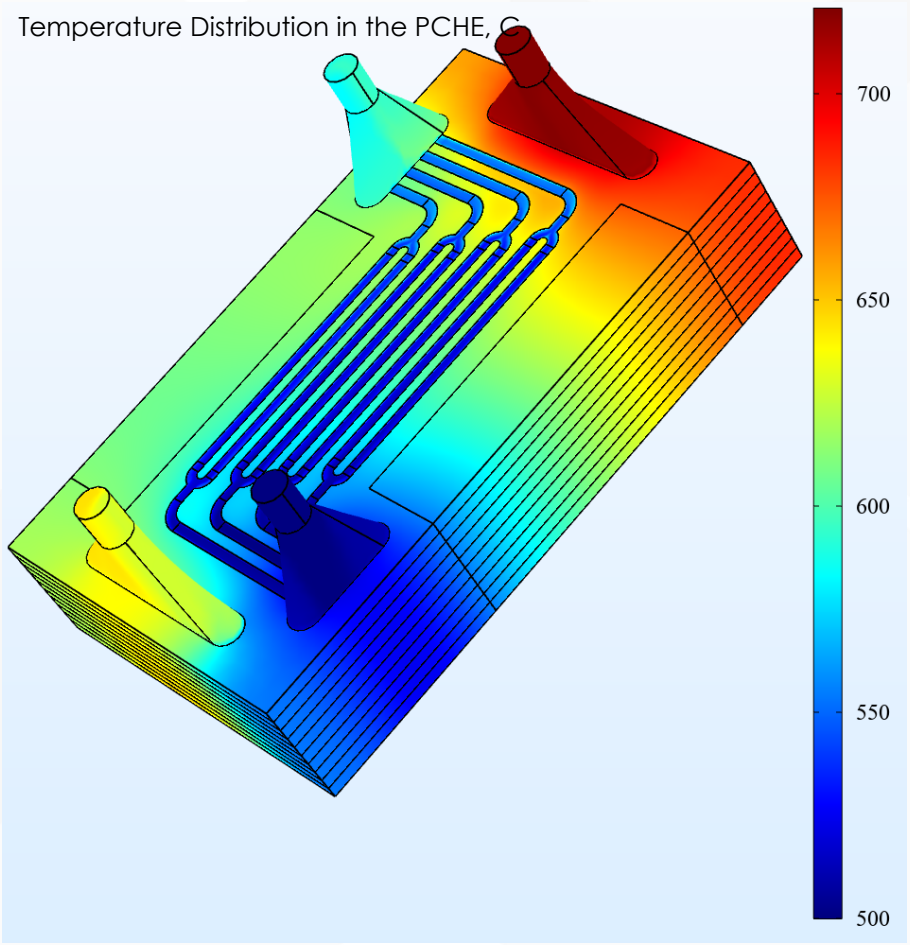


MESHING SEQUENCE FOR FULL HEX SIMULATION

- Tetrahedral mesh for the rest domain



FULL HEX DOMAIN SIMULATION RESULTS



THANK YOU

Questions