PFC Meeting

Optimization of Hypervapotron Geometries for First Wall Applications

Dennis Youchison, Michael Ulrickson
Jim Bullock
Sandia National Laboratories
Albuquerque, NM

August 11, 2011

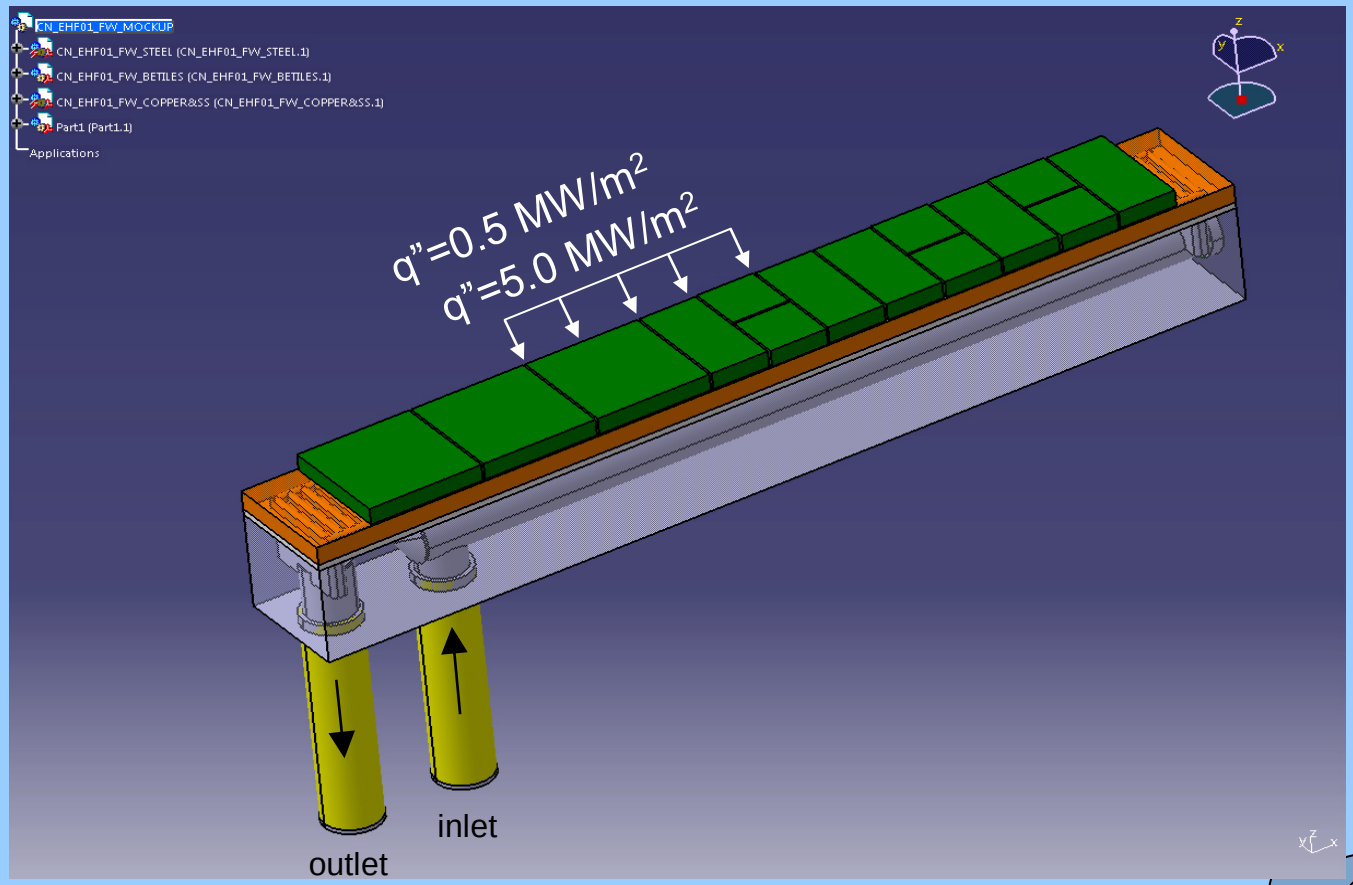
Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Outline

- What is a hypervapotron?
- Width study
- Tooth/Groove study
- CHF performance

Beryllium armored hypervapotron

Model

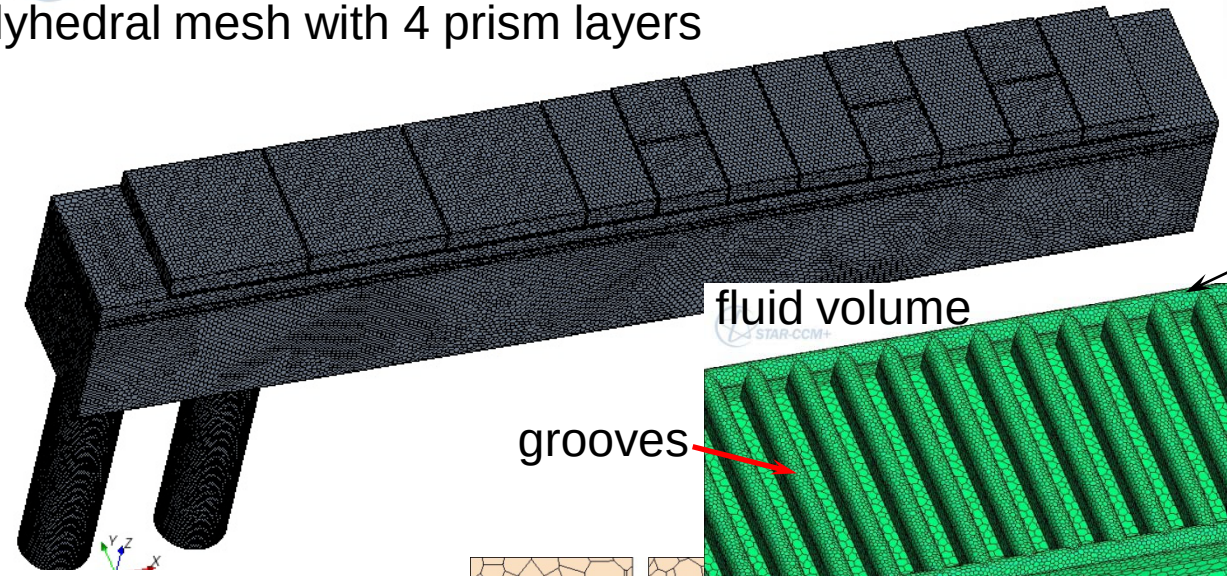


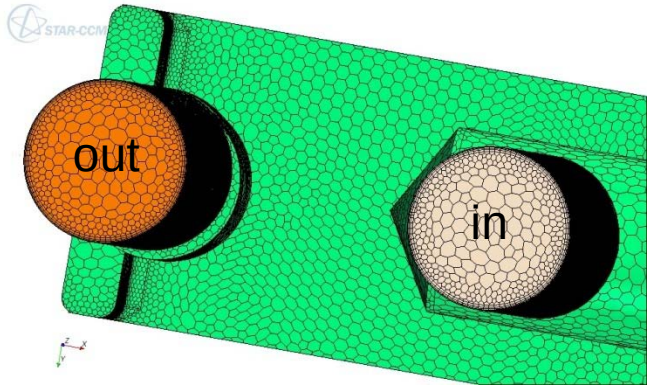
410 mm long x 52 mm wide

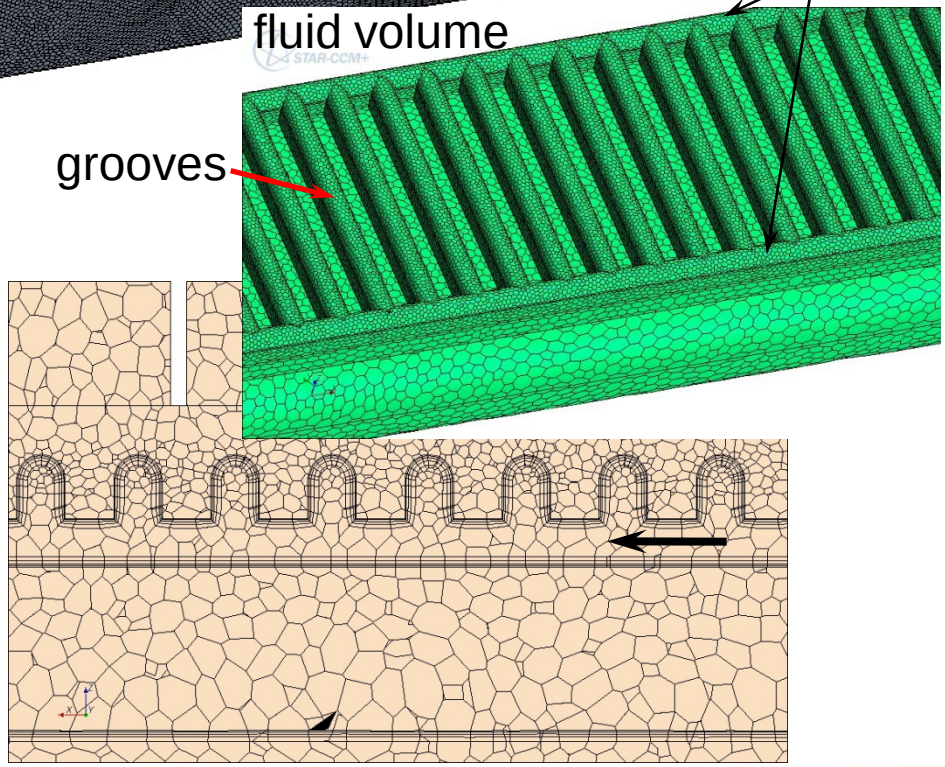
What is a hypervapotron?

1.4 M cell polyhedral mesh with 4 prism layers

Mesh

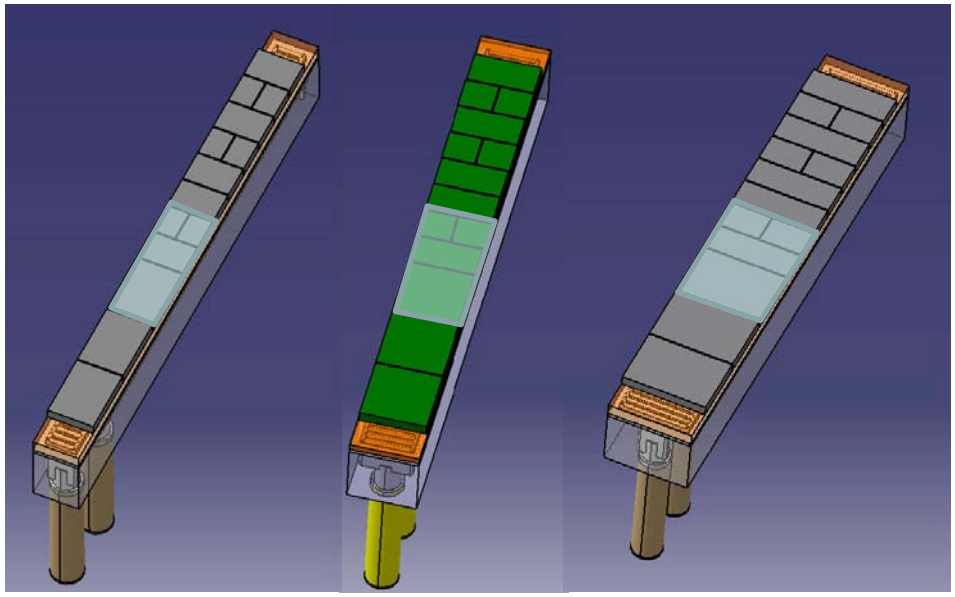






Channel Width

36 mm, 50 mm and 70 mm channel widths

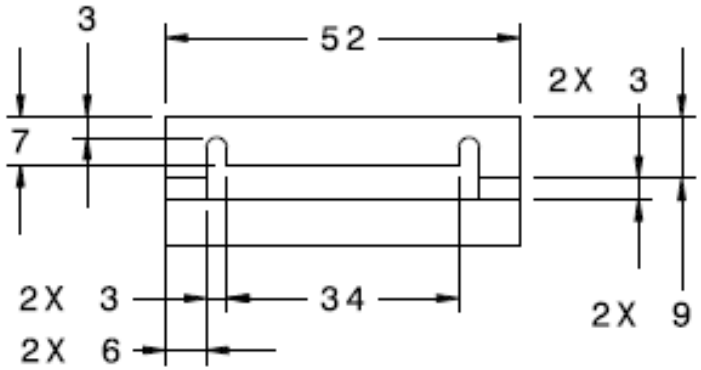


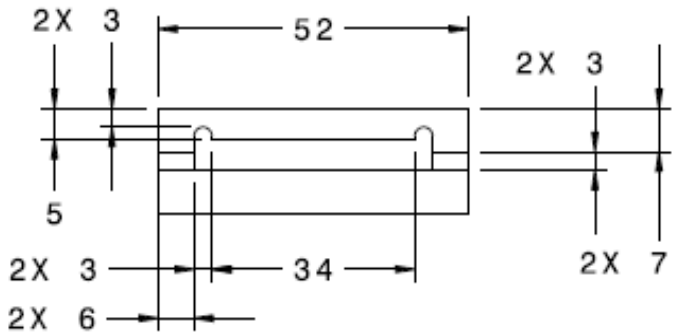
Nominal q”=0.5 MW/m^2
Off-normal q”=5.0 MW/m^2
CHF q”=?

Flow conditions: 2.7 MPa, 2 m/s ave, 70 ^{o}C

36: m-dot=278 g/s
50: m-dot=435 g/s
70: m-dot=611 g/s

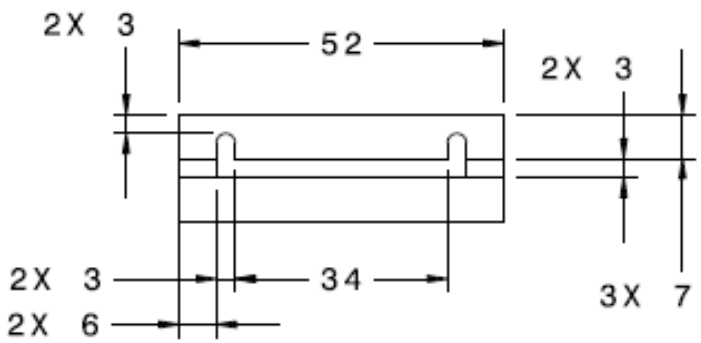
Channel Geometry

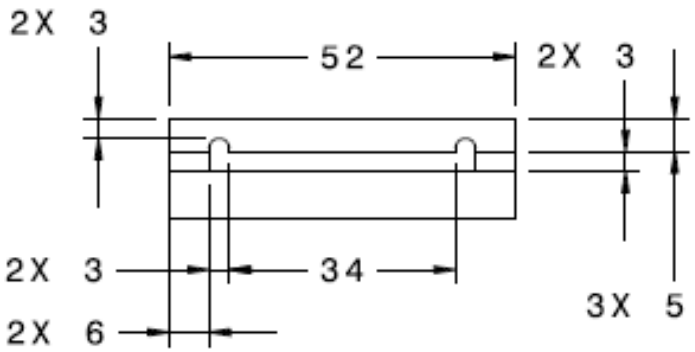




4 mm / 5 mm m-dot=435 g/s

2 mm / 5 mm





4 mm / 3 mm m-dot=263 g/s

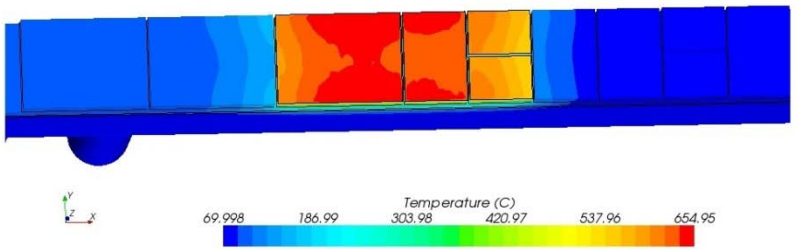
2 mm / 3 mm

tooth/backchannel depth

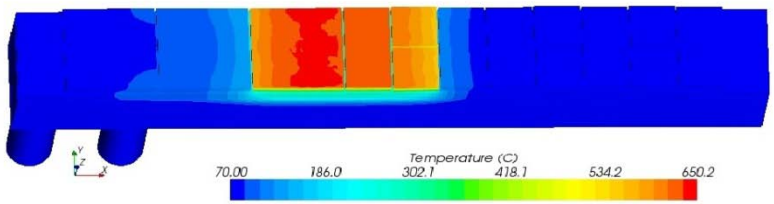
5 MW/m^2 exhibits little difference

surface temperature

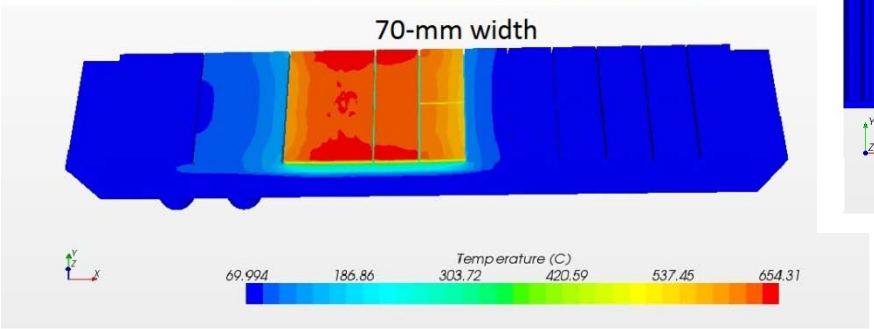
36-mm width



50-mm width

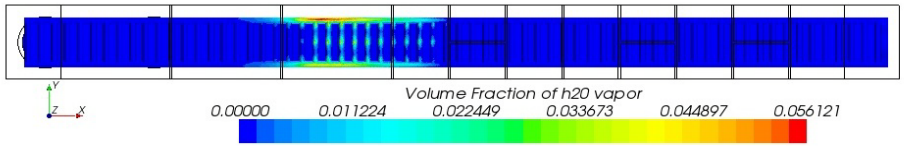


70-mm width

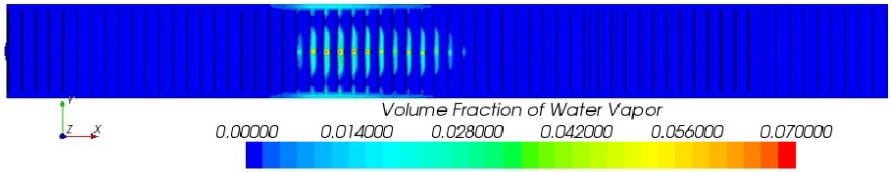


vapor fraction

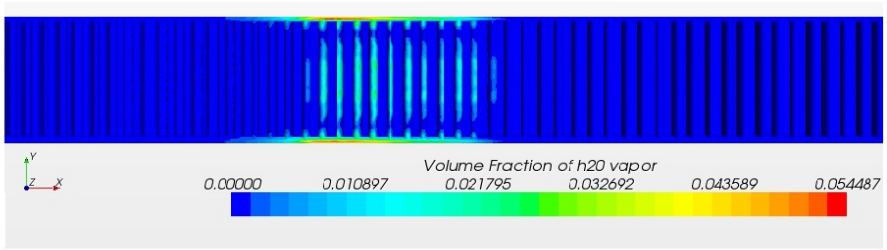
36-mm width



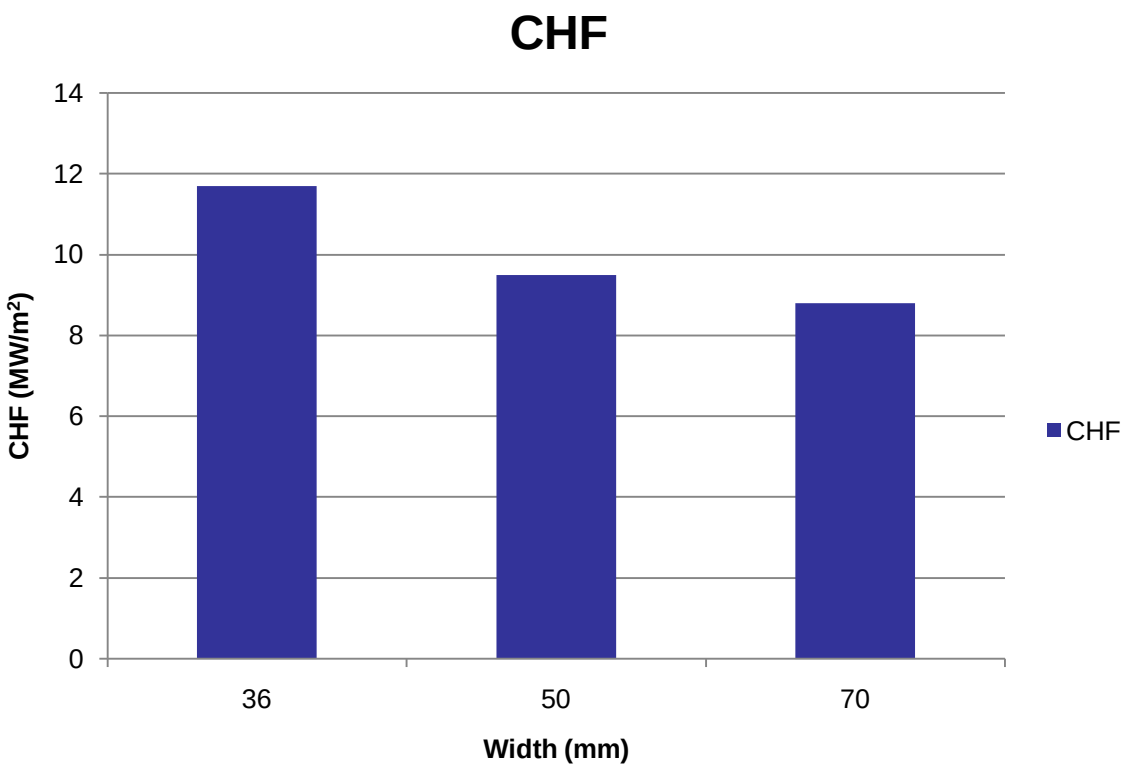
50-mm width



70-mm width



CHF decreases with increasing width

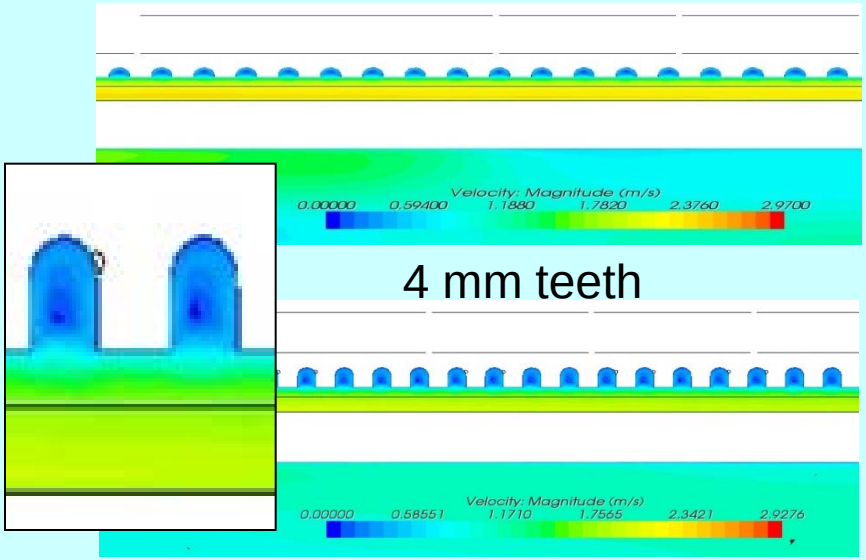


Velocity distributions

Results

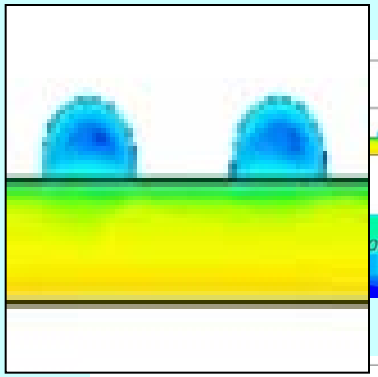
5 mm backchannel

2 mm teeth

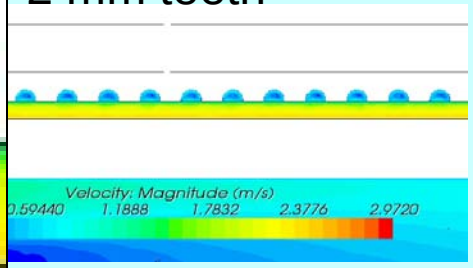


4 mm teeth

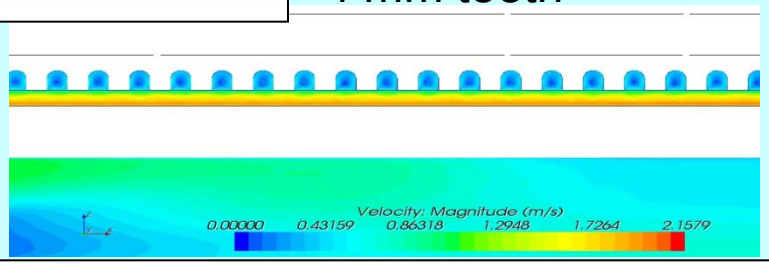
3 mm backchannel



2 mm teeth



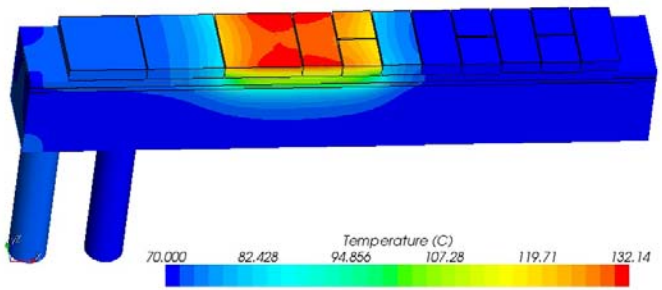
4 mm teeth



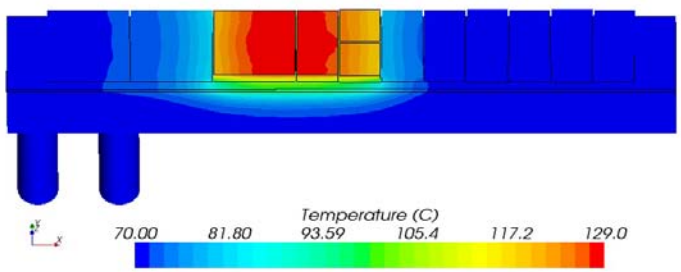
2mm teeth depth and 3-mm spacing optimized to produce a simple reverse eddy in the groove.

Temperature distributions – 0.5 MW/m^2

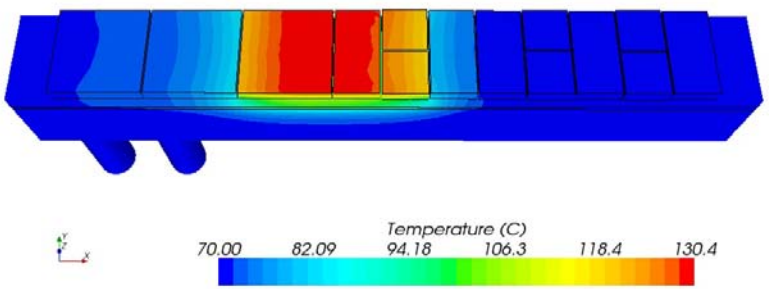
2 mm / 3 mm



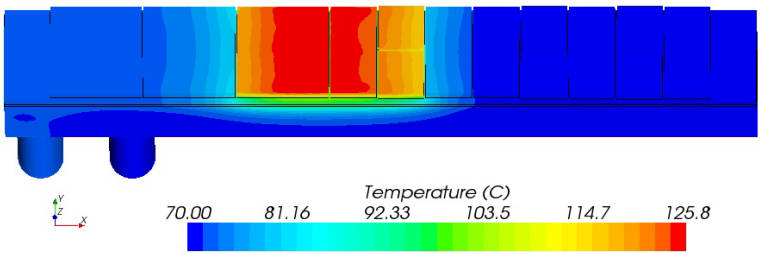
2 mm / 5 mm



4 mm / 5 mm



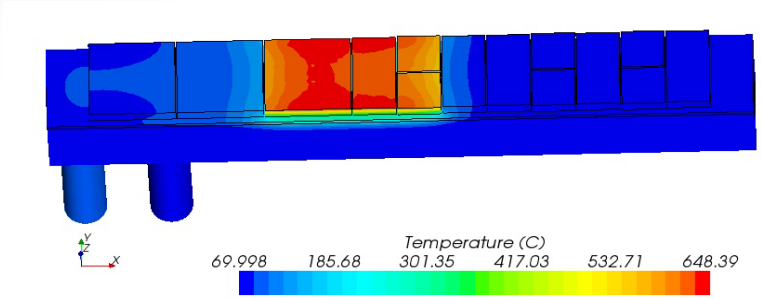
4 mm / 3 mm



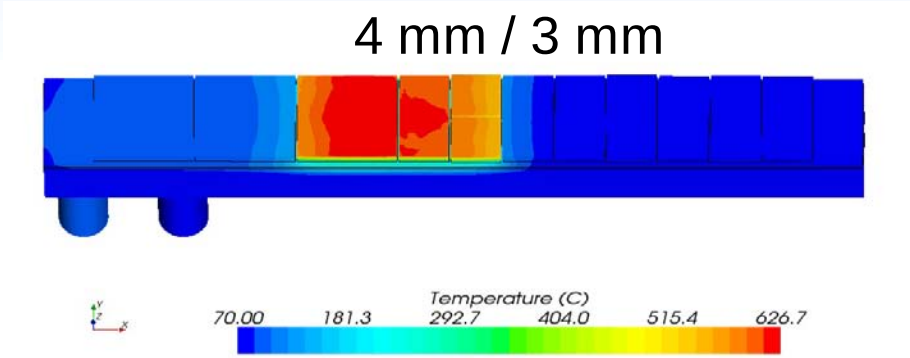
Surface temperatures are about the same for nominal conditions.

Temperature distributions 5 MW/m^2

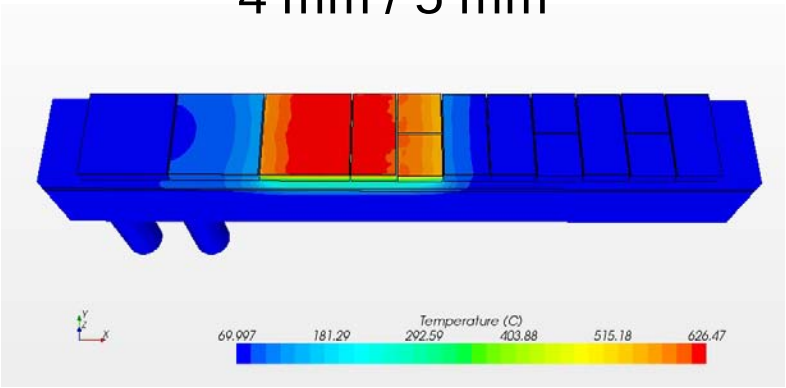
2 mm / 3 mm



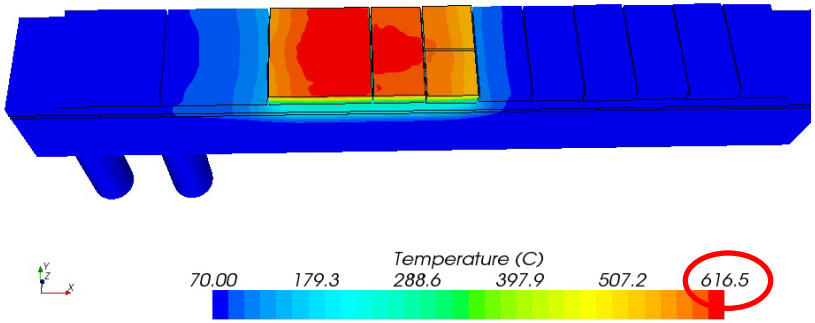
4 mm / 3 mm



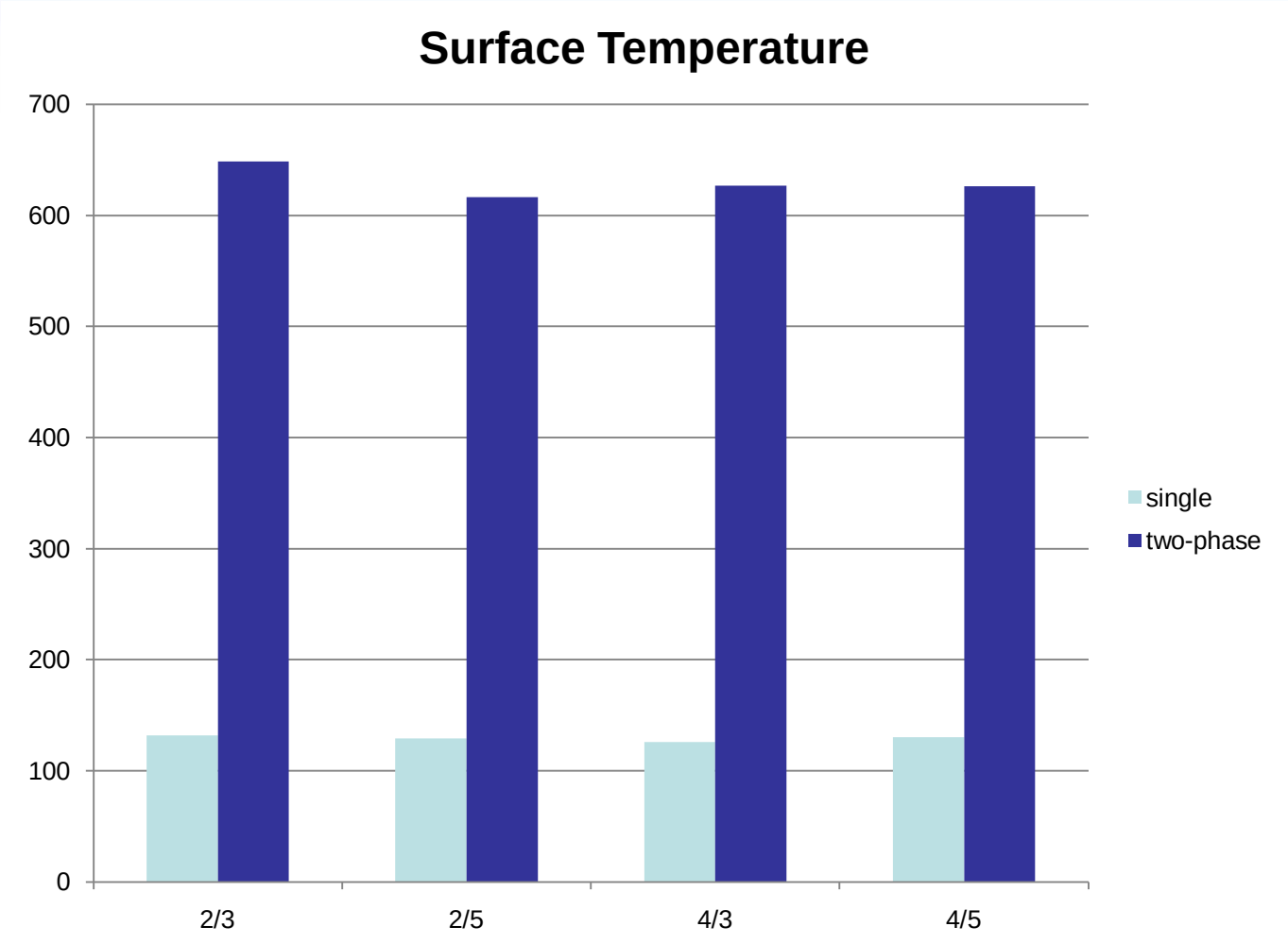
4 mm / 5 mm



2 mm / 5 mm

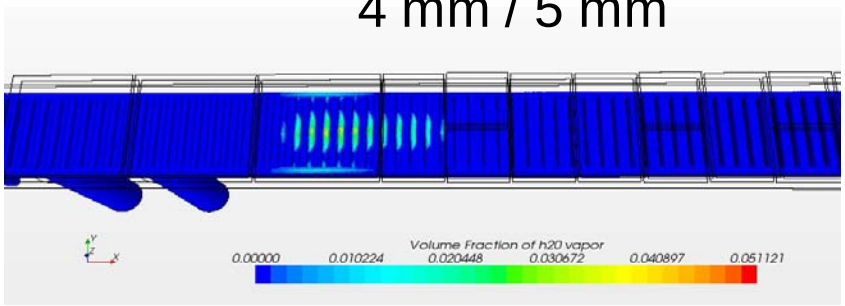


Deeper backchannel is more effective in mixing and condensation of vapor.
Shorter teeth / deep backchannel is best for off-normal conditions.

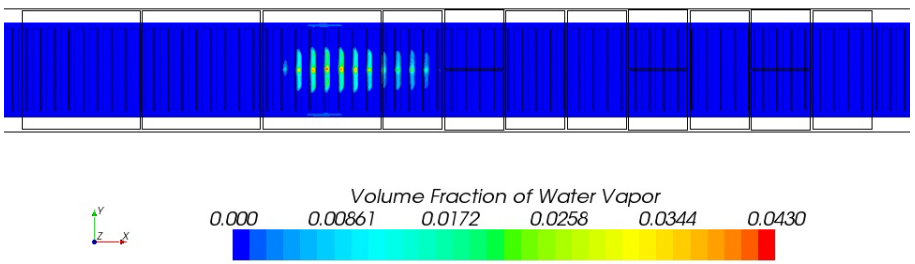

Surface Temperature
700
600
500
400
300
200
100
0
2/3
2/5
4/3
4/5
single
two-phase

Vapor fraction (5 MW/m^2)

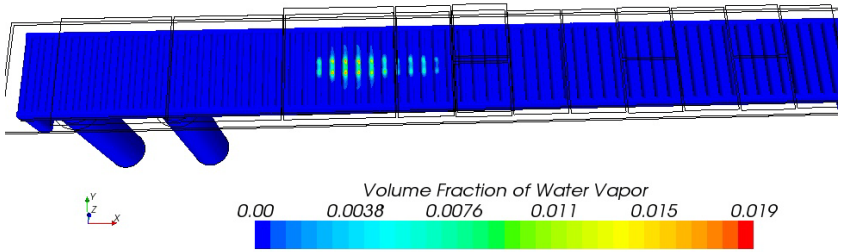
4 mm / 5 mm



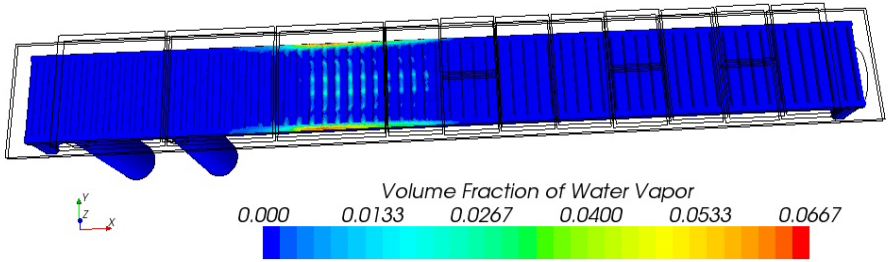
4mm / 3 mm



2 mm / 5 mm



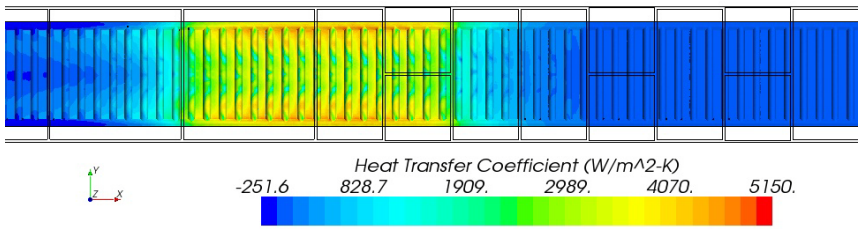
2 mm / 3 mm



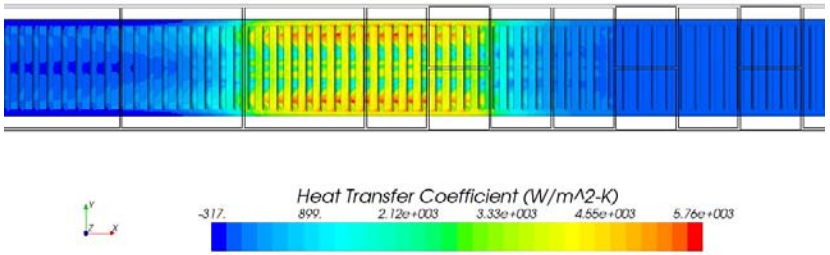
Hypervapotrons exploit the heat transfer regimes.

q”=0.5 MW/m^2 – single phase

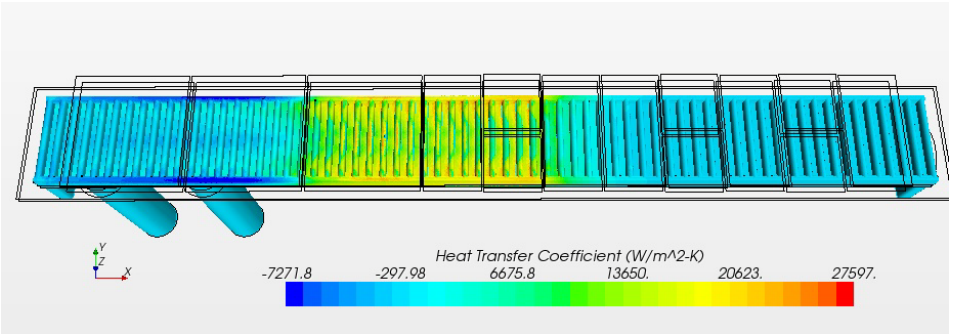
4 mm / 5 mm

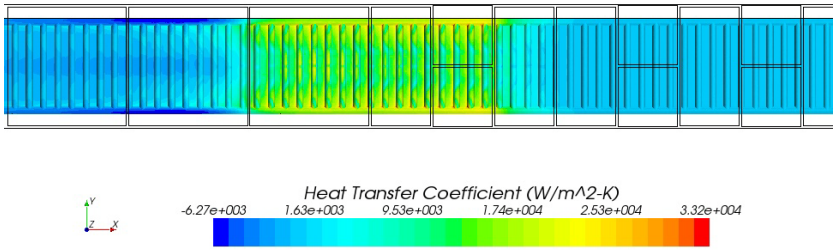


4mm / 3 mm



q”=5.0 MW/m^2 – two phase

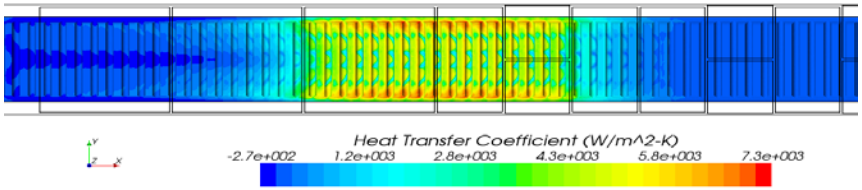




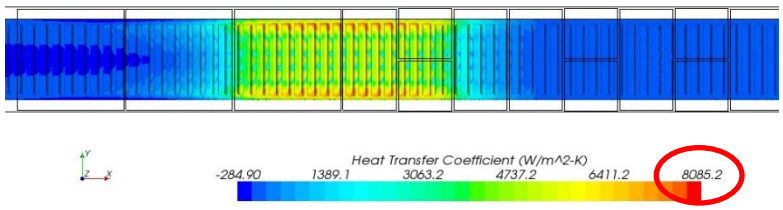
2 mm teeth, 5 mm backchannel performs best.

q”=0.5 MW/m^2 – single phase

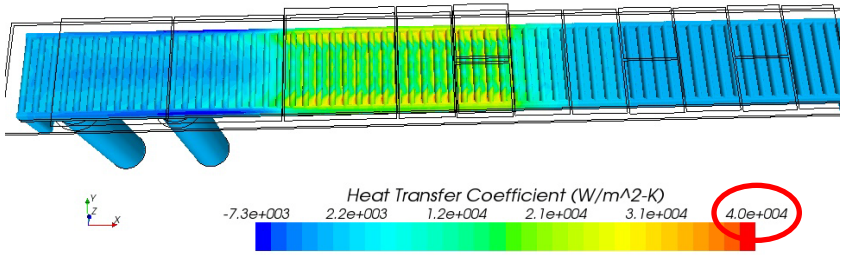
2mm / 5 mm

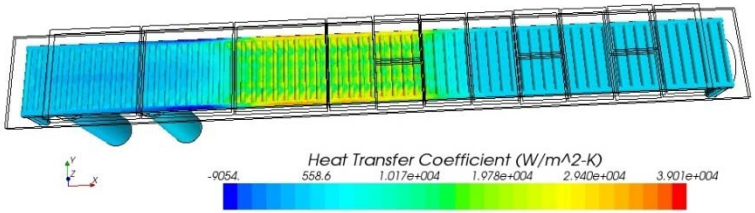


2 mm / 3 mm

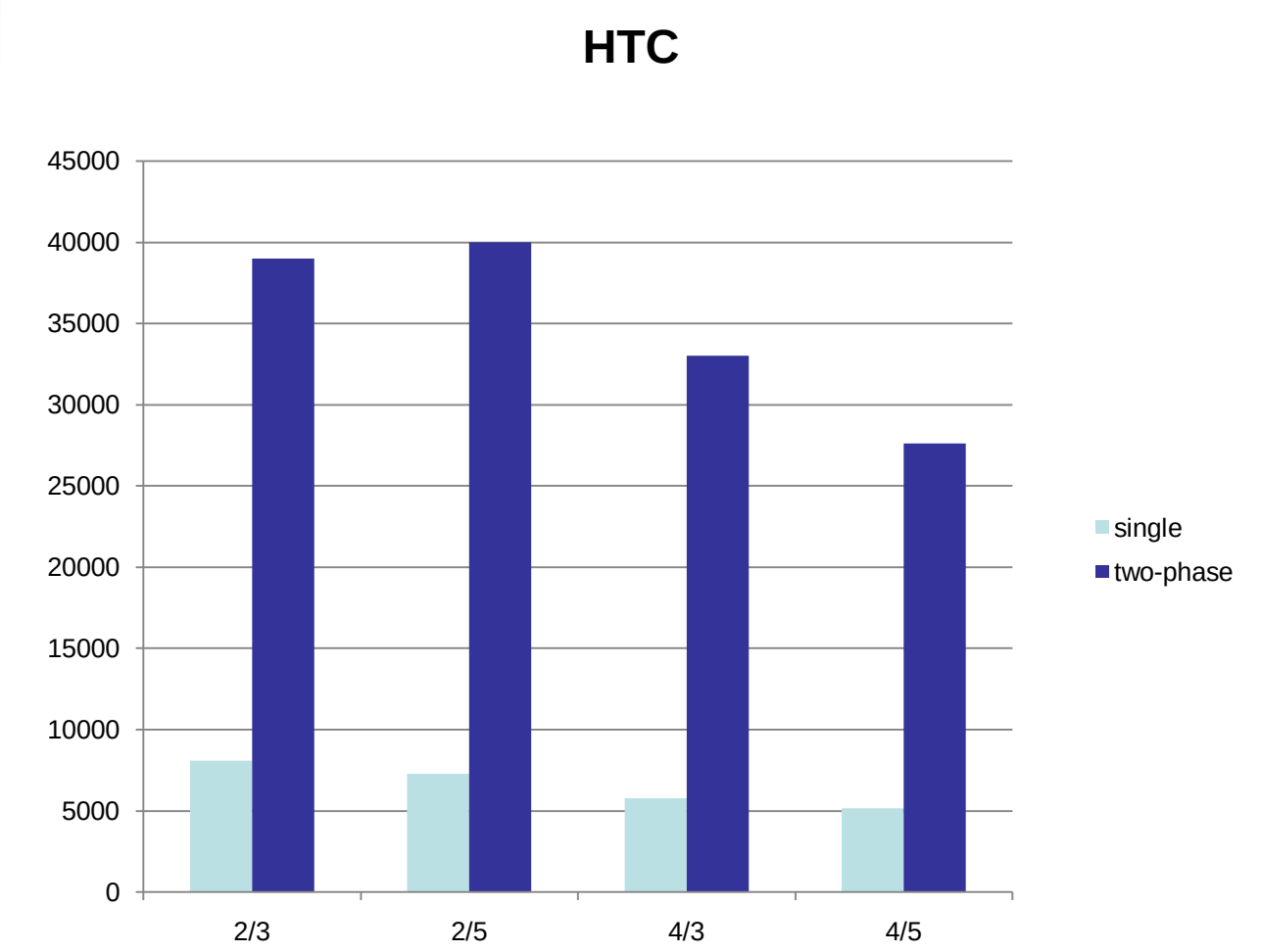


q”=5.0 MW/m^2 – two phase





Comparison of Heat Transfer Coefficients



Concluding remarks

- Engineering study on hypervapotron geometries completed.
- ITER reference design (4 mm/5 mm) is not optimal.
- Short teeth/deep backchannel gives best off-normal performance.
- Boiling heat transfer is 5x higher than subcooled forced convection.
- Nominal performance is not affected by width.
- CHF decreases with increasing width.
- Narrow channels or fingers are preferred.
- Side slots remove vapor – increase CHF level.
- Deeper backchannels are critical for condensation and mixing.