RECONNECT

SYMPOSIUM 2022

KNOWLEDGE • OPTIMIZATION • INNOVATION

Stamicarbon 75 YEARS

Continuous improvement of high-pressure CO2 stripper design

From inspections to re-design

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Jaarbeurs, Utrecht

RECONNECT SYMPOSIUM 2022

Stamicarbon 75 YEARS

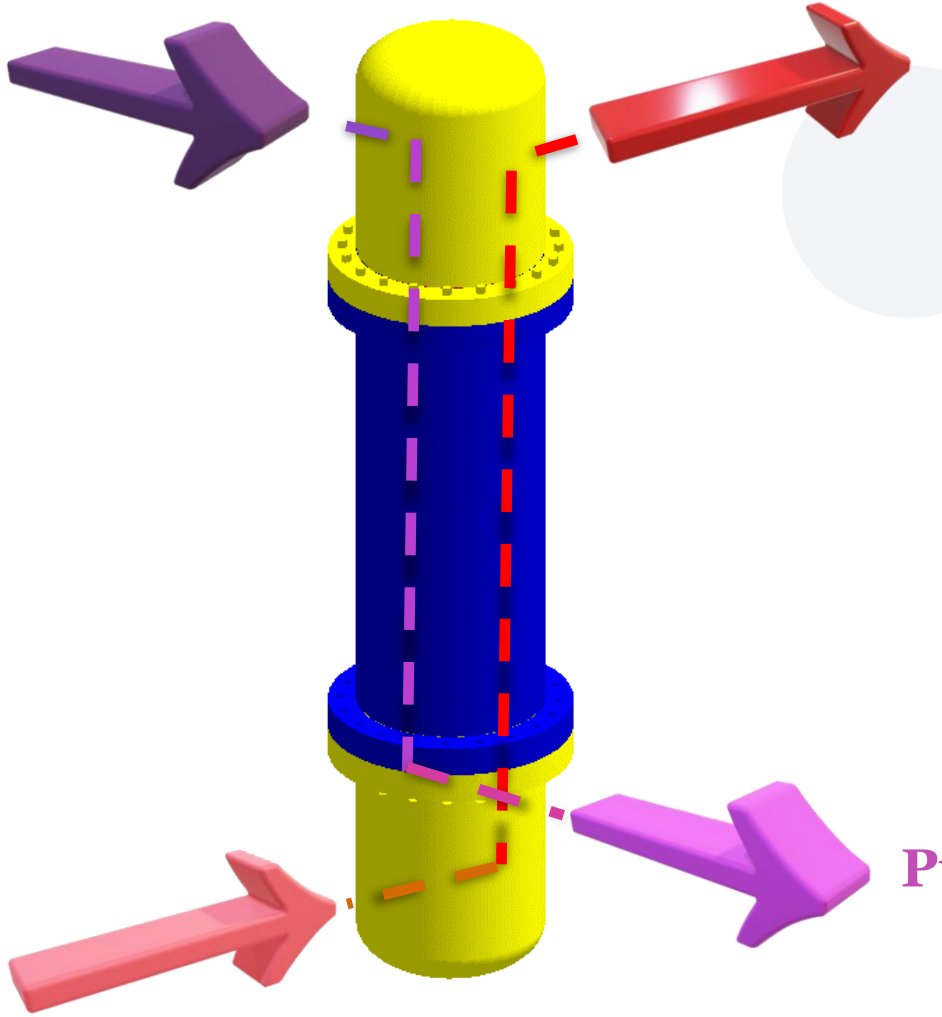
Agenda

- New corrosion phenomenon
- Root cause analysis
- Re-design
- Conclusions

HP Stripper

Urea solution (l)

(USO)



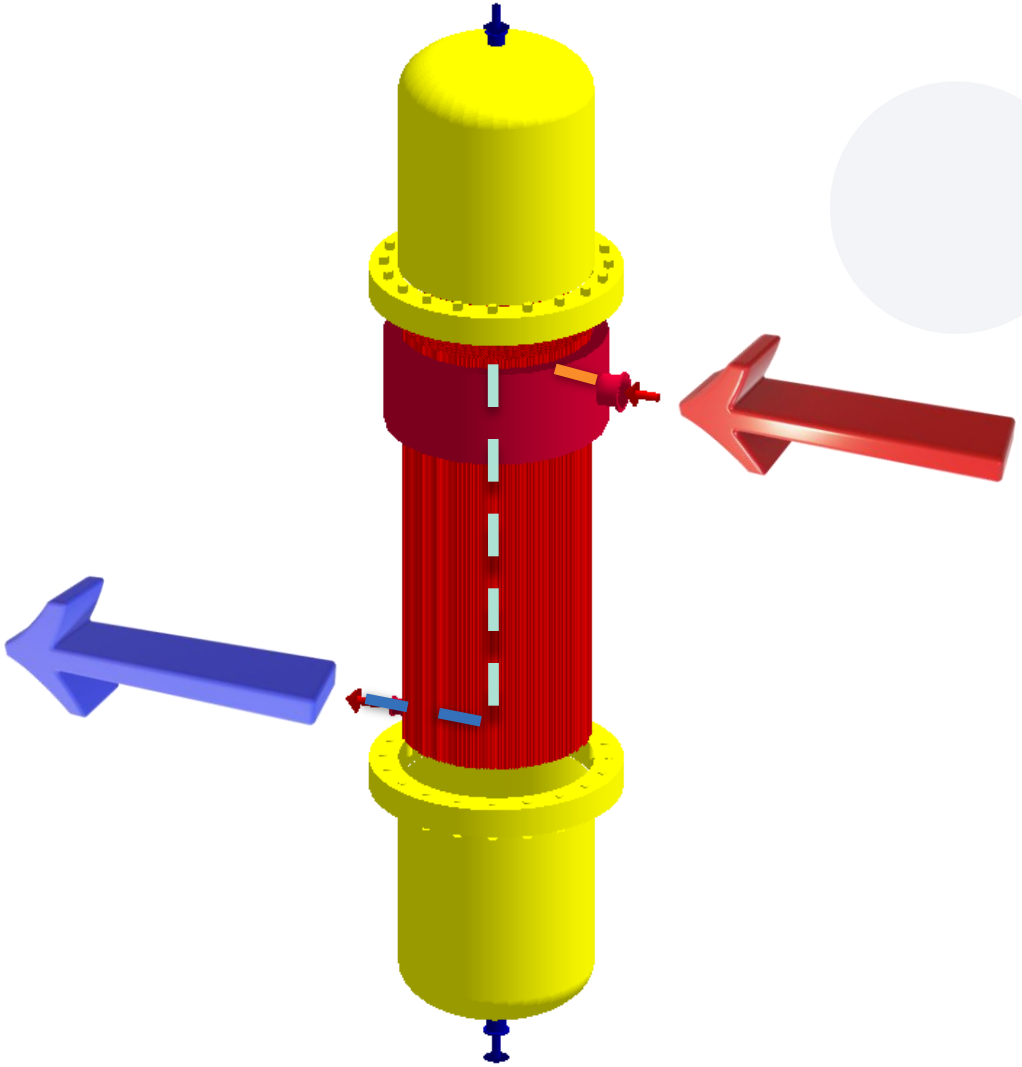
CO_2 (g) + stripped carbamate

(NH_3, CO_2)

CO_2 (g)

Purified urea solution (l)

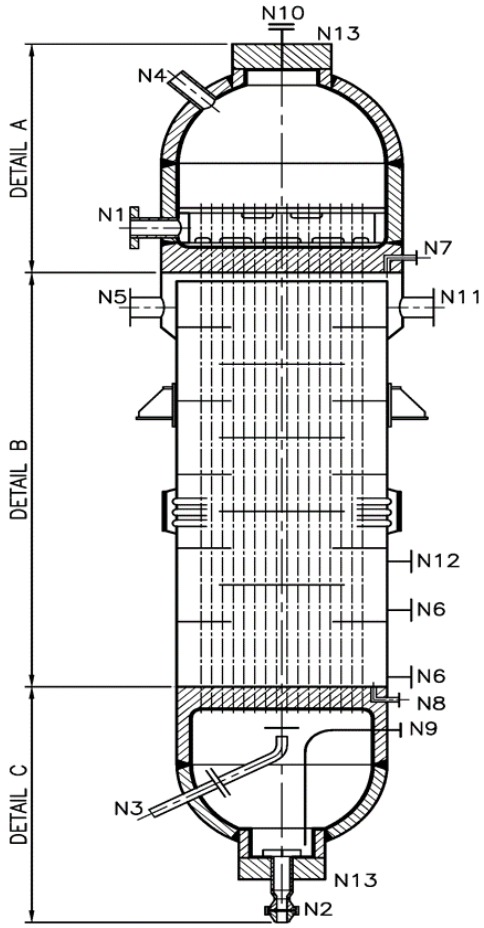
HP Stripper



HP Steam (g)

Condensate (l)

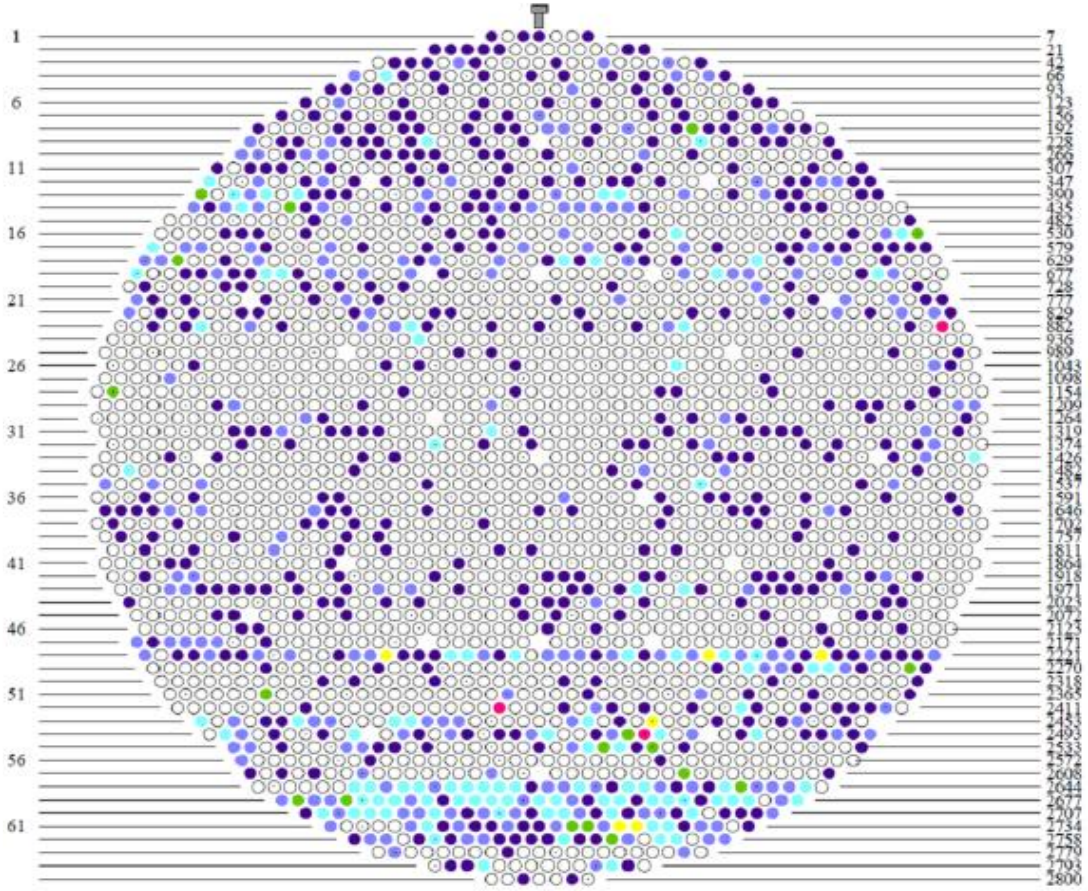
HP Stripper

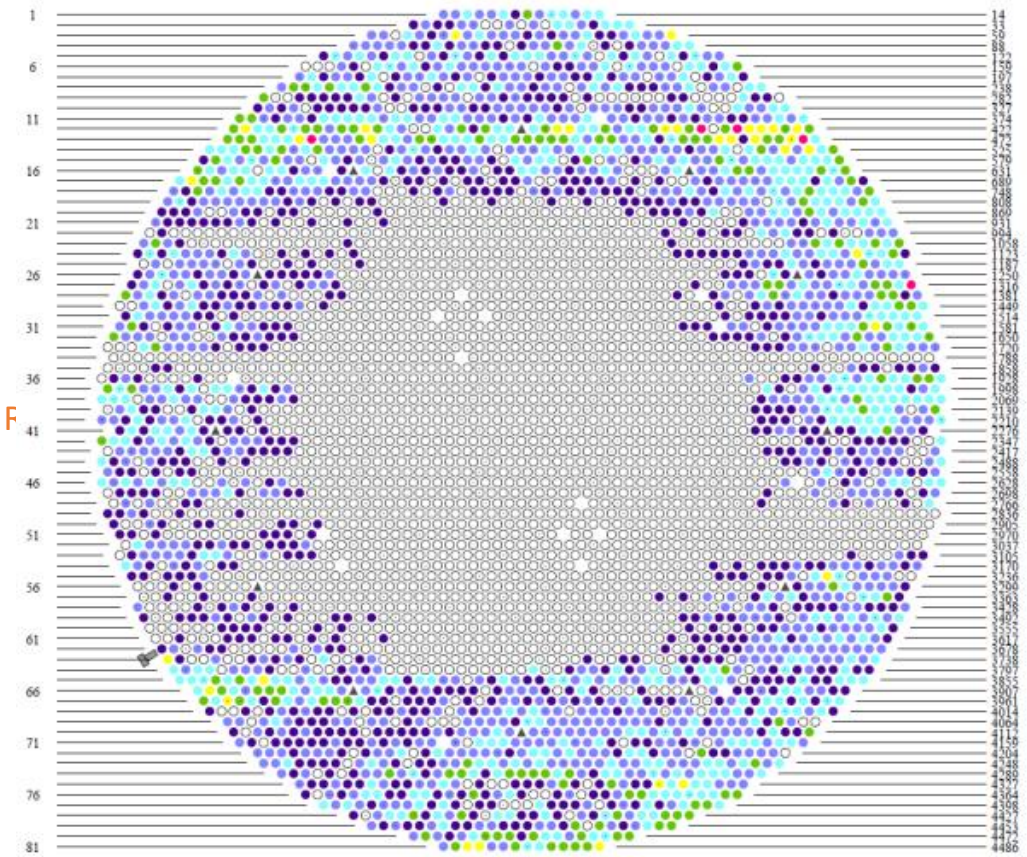


- In general, HP stripper tubes do face the highest temperatures in urea plants
- As a result, in general, stripper tubes do face the highest corrosion rates in urea plants

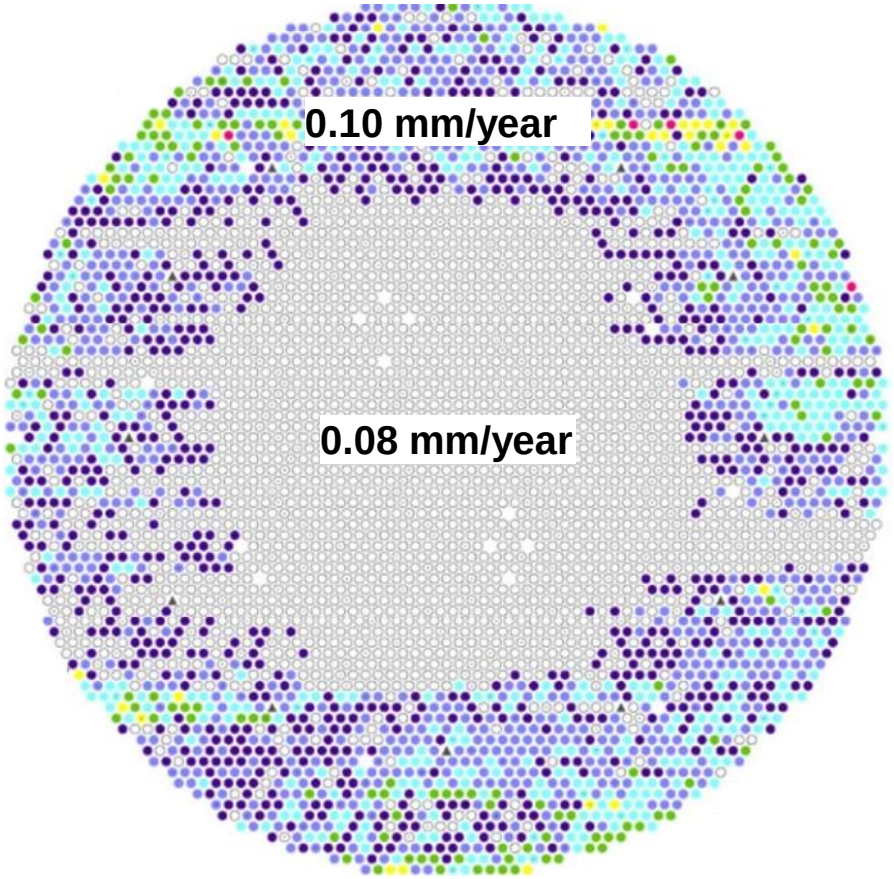
Inspection of HP Stripper Tubes

Eddy current visualization





First observations

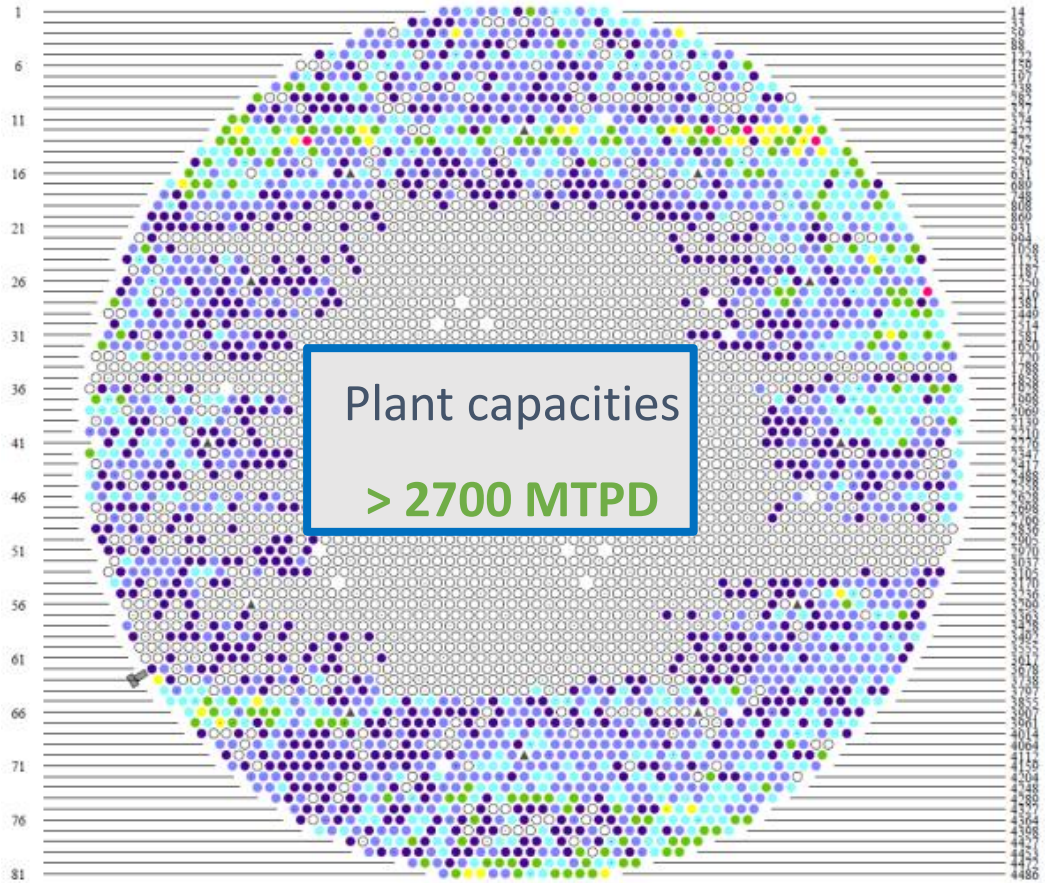


- 1.60 mm
- 1.65 mm
- 1.70 mm
- 1.75 mm
- 1.80 mm
- 1.85 mm
- > 1.85

Peripheral enhanced corrosion

Stripper was in operation
for 12 years

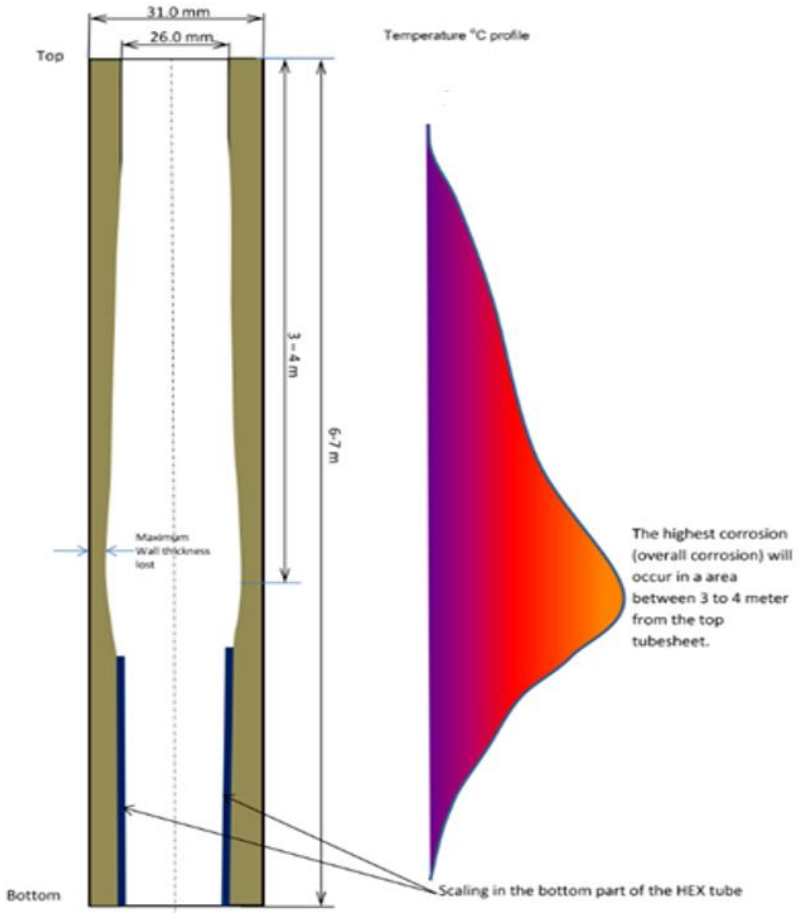
More observations and first conclusions



After more inspections at different clients, we could conclude the following:

- **Peripheral corrosion is not related to the material of construction**
- **Peripheral corrosion is only taken place at large capacity plants**

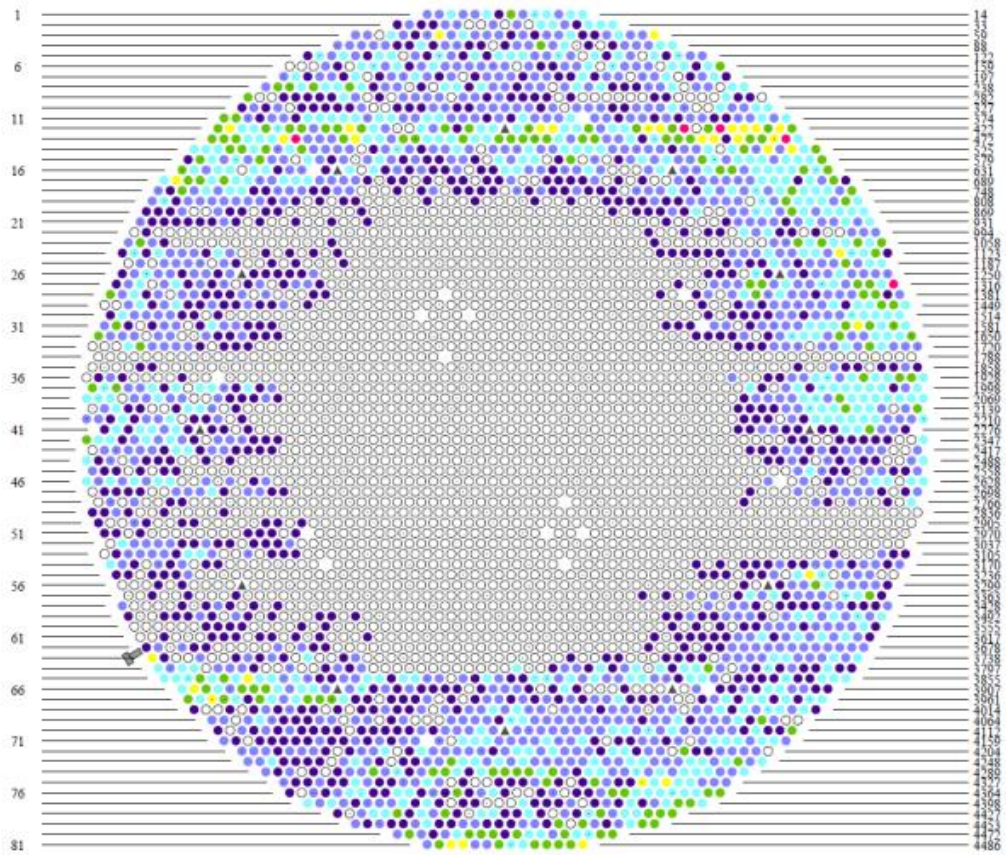
No scaling on center tubes



Looking to tubes more in detail:

- In the tubes in the centre there was no iron oxide scaling.
- In general, the more carbamate is decomposed the more iron oxide will precipitate to the tube wall

Additional observations



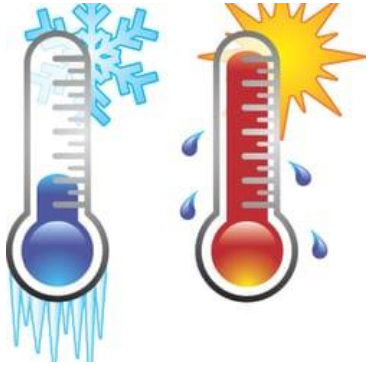
- The stripping efficiency between the tubes located at the inside periphery and the outside periphery is increased.
- At plants operated above name plate capacity and high onstream times the effects are more severe.

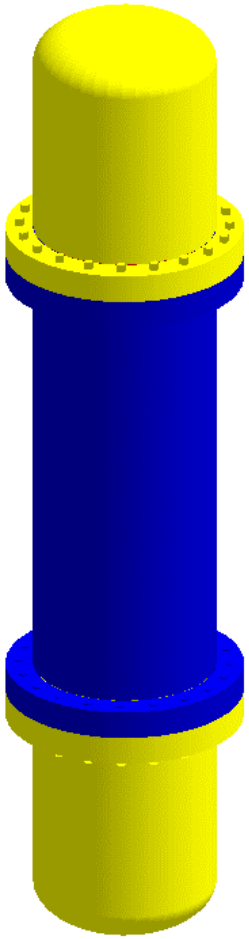
Peripheral corrosion

What could be the **reason** for this significant difference in stripping efficiency between the inside and the outside periphery as a result of **upscaling** HP strippers?

Corrosion is promoted by…

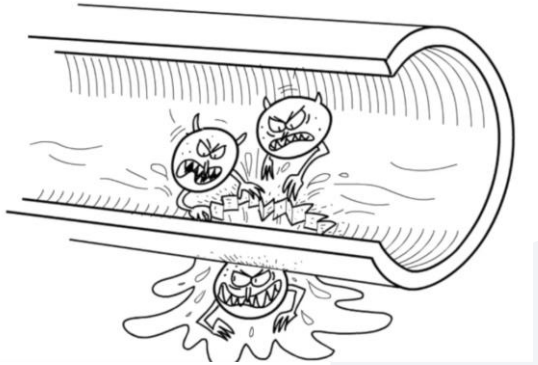
HIGH TEMPERATURE



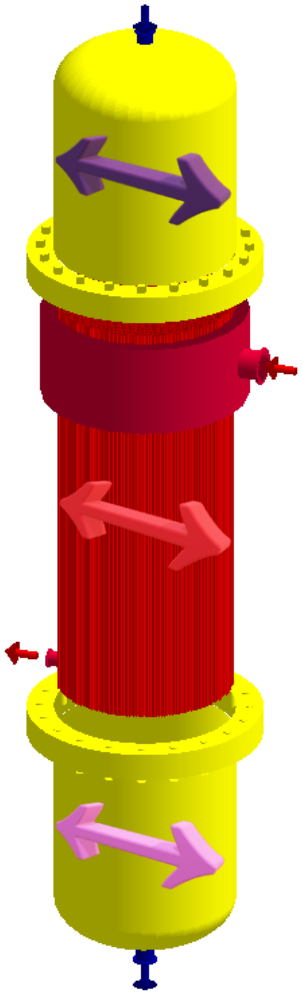


NOT ENOUGH OXIGEN

HIGH CARBAMATE CONCENTRATION



Looking for radial maldistribution of…



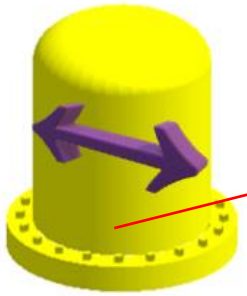
Urea solution (l) over tubes
(Carbamate concentration)

Heat transfer to the tubes
(Temperature)

CO2 (g) to the tubes
(O2)

Radial Maldistribution

Not RC

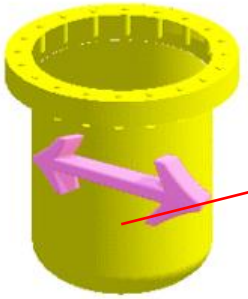


~~Urea solution (l) over tubes~~

~~(Carbamate concentration)~~

Top Liquid and **bottom gas maldistribution** are ruled out as Root Cause.
Please find the explanation in our paper.

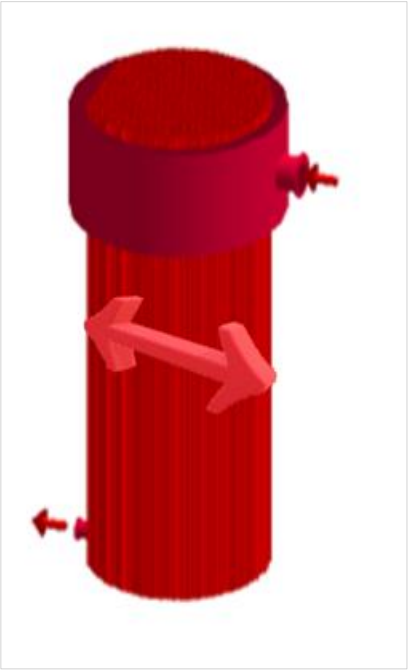
Not RC



~~CO2 (g) to the tubes~~

~~(O2)~~

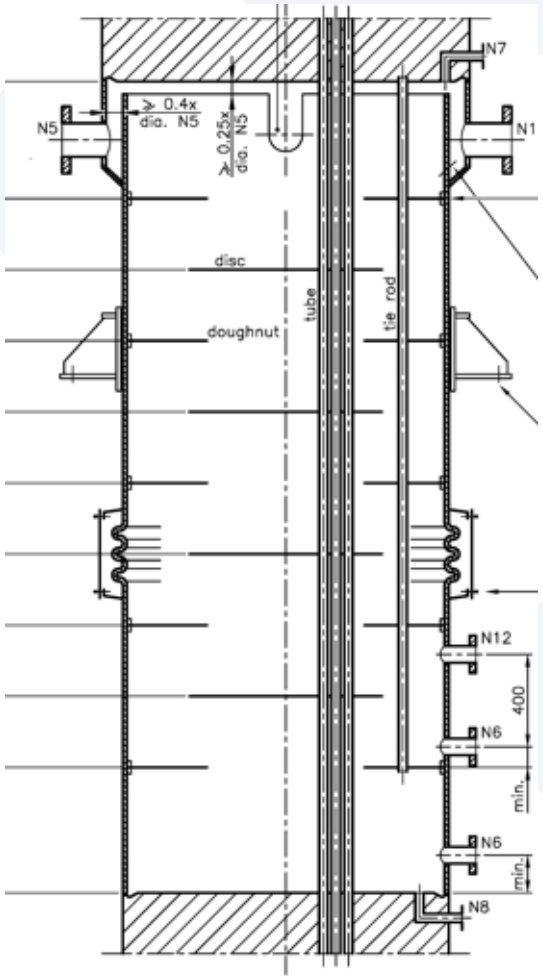
Radial maldistribution of *heat*



Heat transfer to the tubes

Radial maldistribution of *heat*: analysis shell

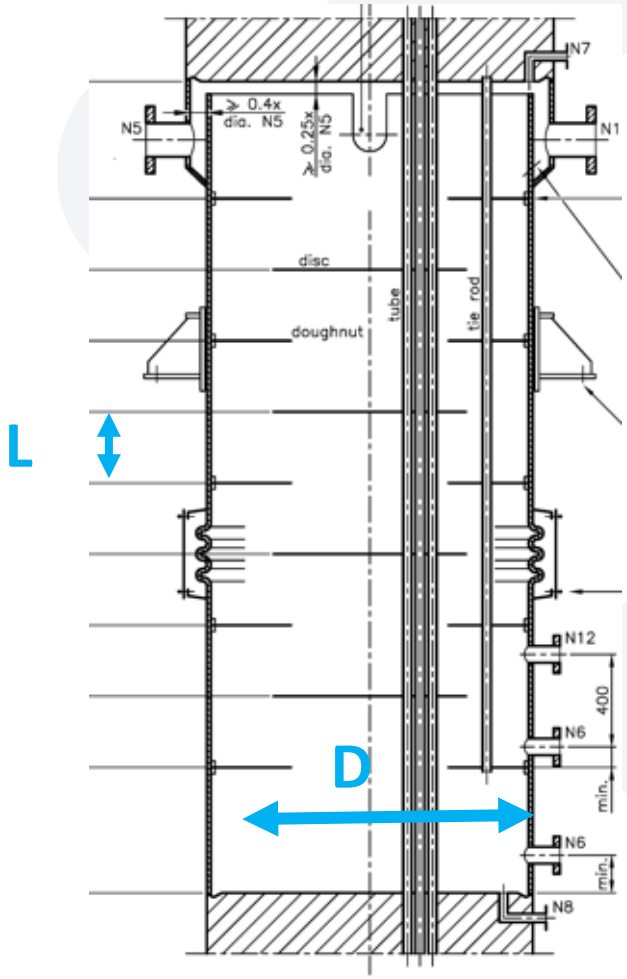
- Standard Disc & Doughnut design
- Only steam & condensate
- 100% condensation, no inerts



Radial maldistribution of *heat*: scaling up

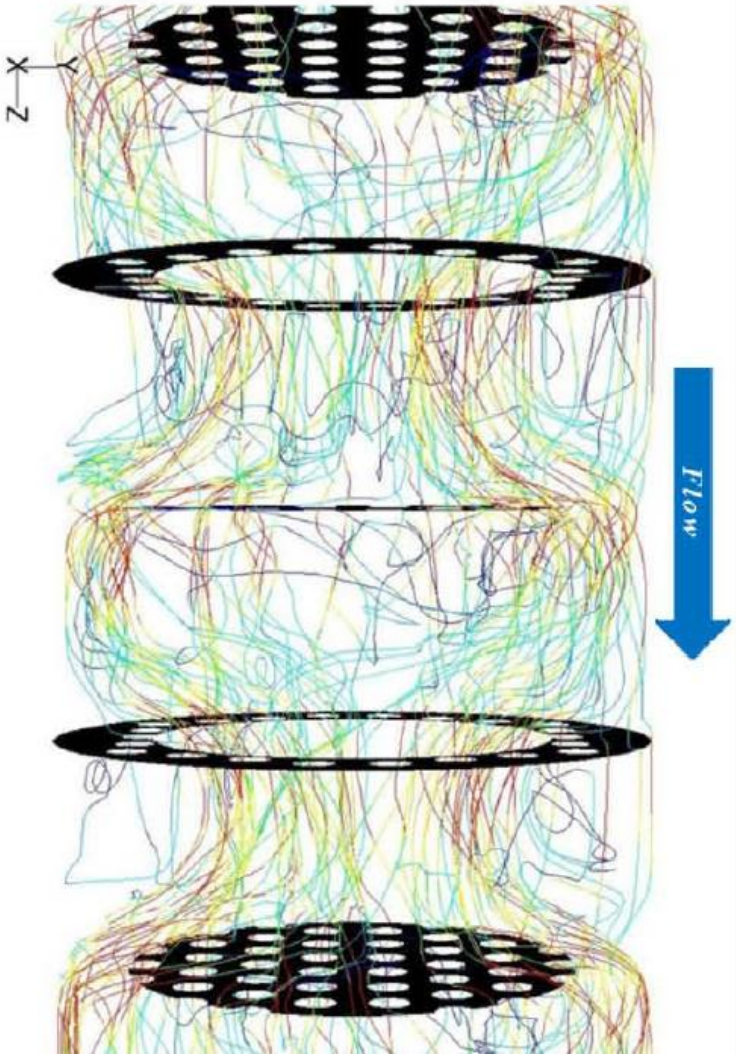
- Distance between baffles is fixed, baffle cut is % of the shell diameter

- Upscaling is leading to a lower L/D baffle ratio -> higher radial velocities



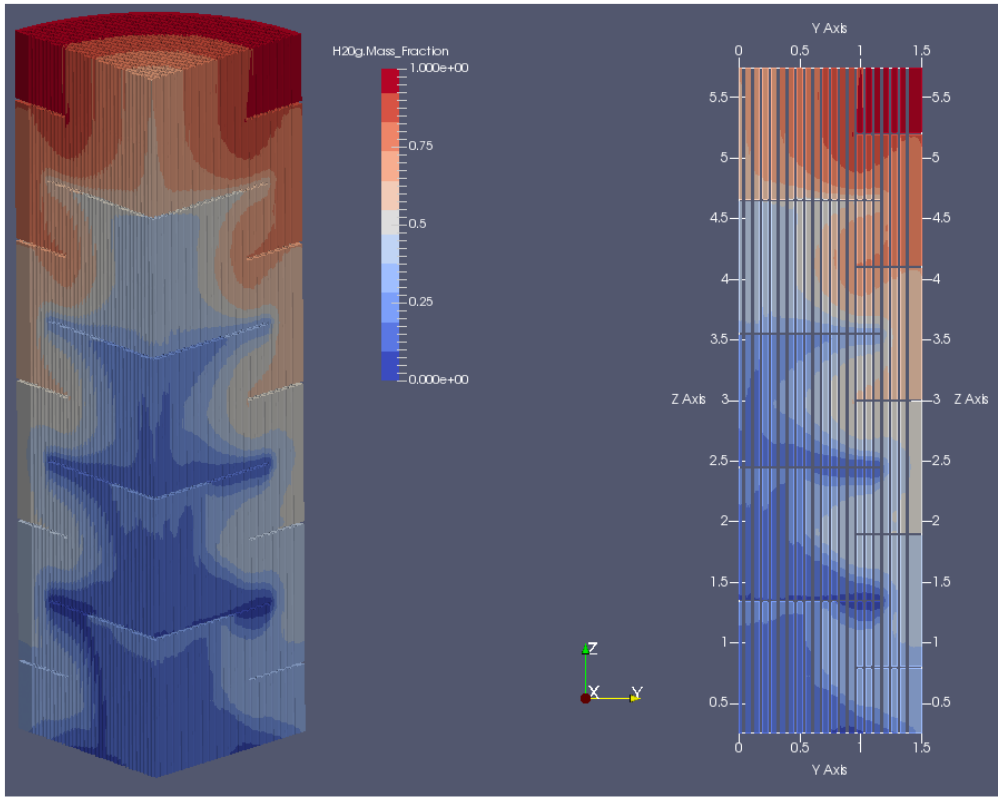
Radial maldistribution of *heat*: scaling up

Image out of a HTRI study, indicates flow patterns of a non condensable vapor

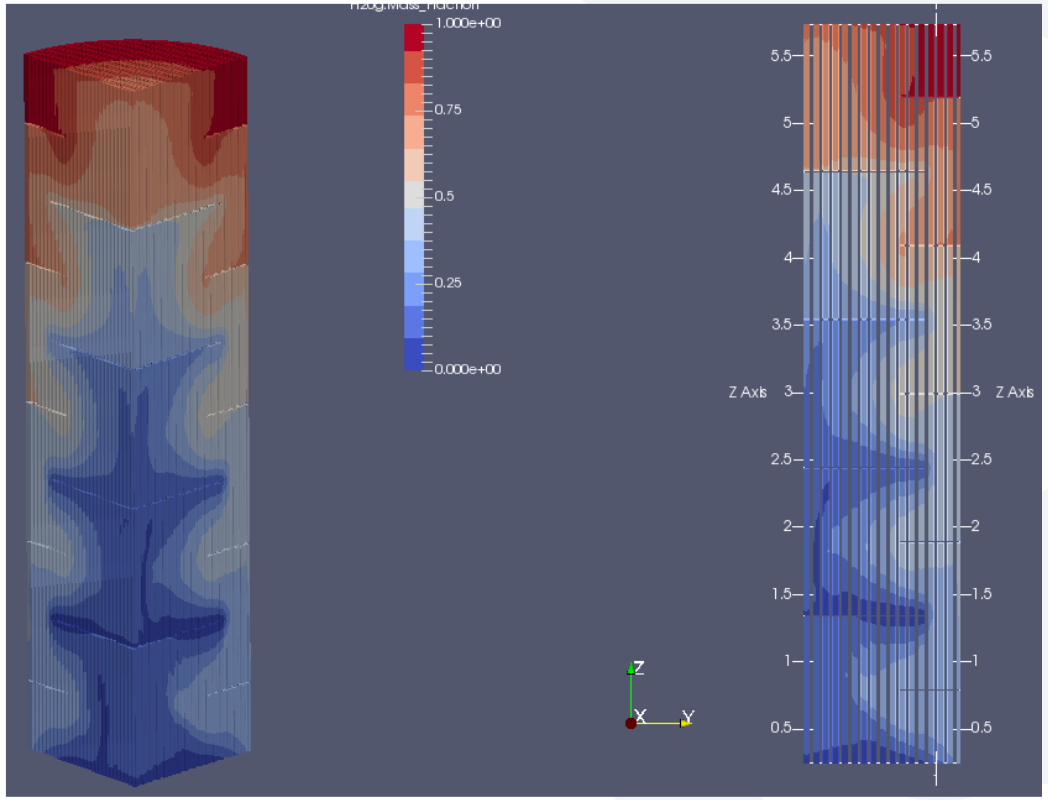


CFD Water Mass Fraction: accumulation

LARGE SCALE φ ~ 3 m



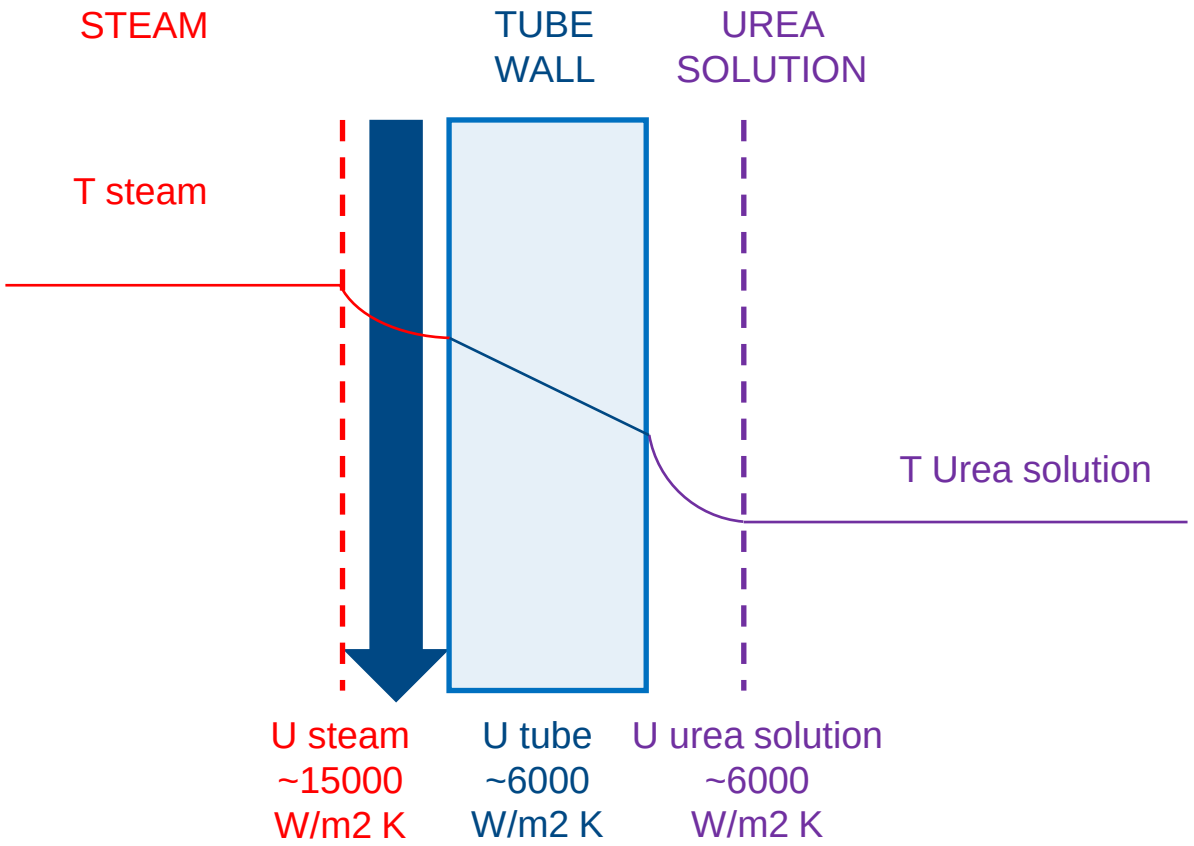
SMALL SCALE φ ~ 2 m



Condensate accumulated in last 3 disks.

Bigger strippers more trouble discharging condensate than smaller ones.

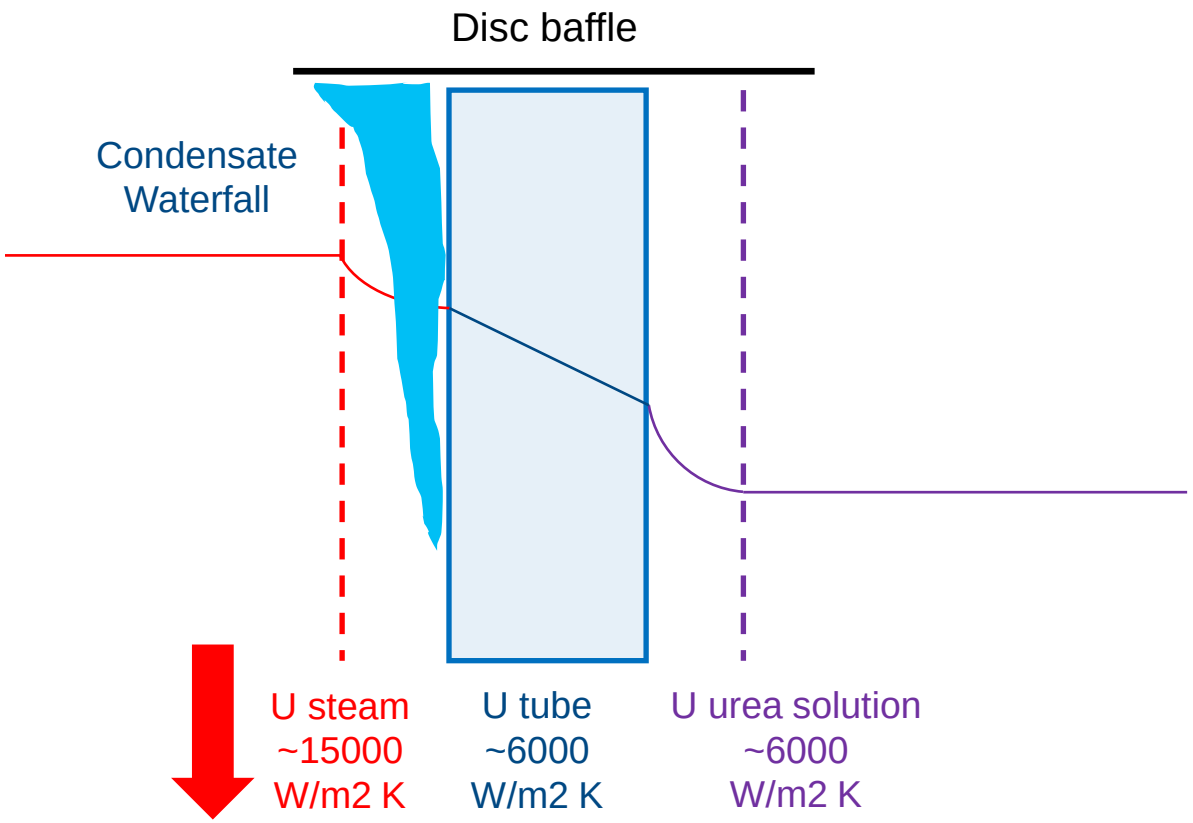
Temperature profile & overall heat transfer coefficient (U) in HTRI (order of magnitude)



U TOTAL
2500 W/m2 K

Gravitational
flow of condensate

Temperature profile & overall heat transfer coefficient (u) in HTRI (order of magnitude)

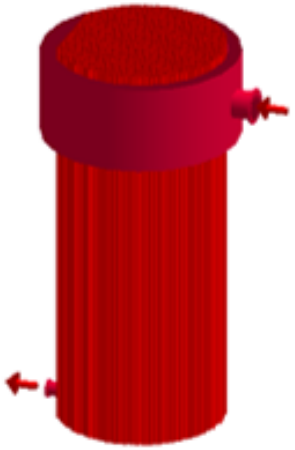


U TOTAL
2500 W/m2 K

Decreased heat transfer

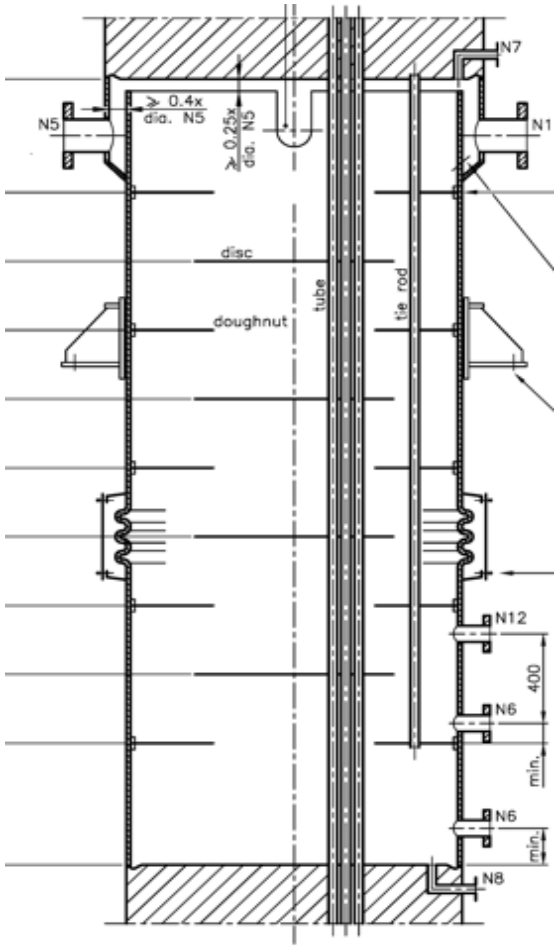
Inspection of large HP stripper tubes

Root Cause



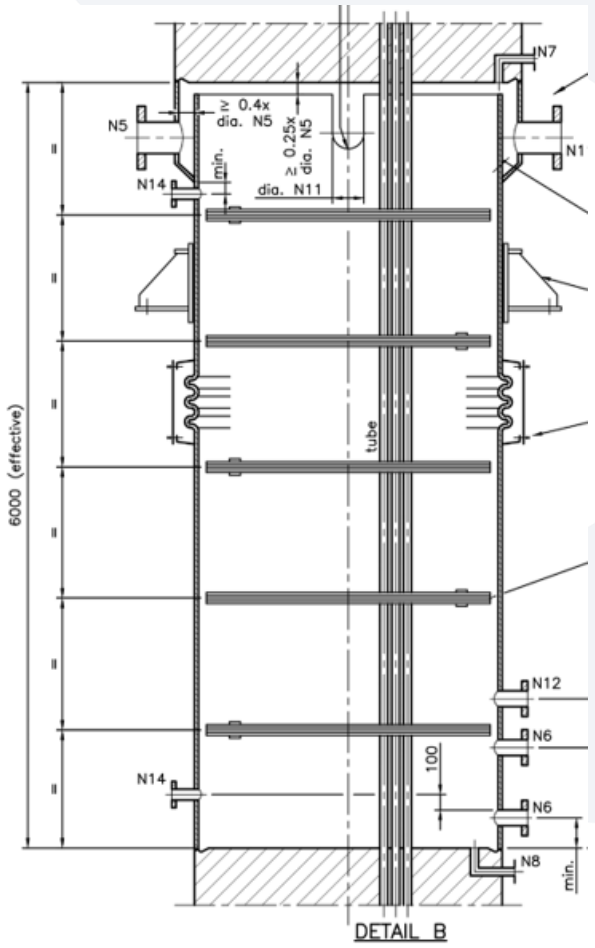
Lower overall heat transfer to the tubes in the center area of the shell side due to **water accumulation**

New HP Stripper Design



GRIDS

Open area evenly distributed over section so water homogenously discharged

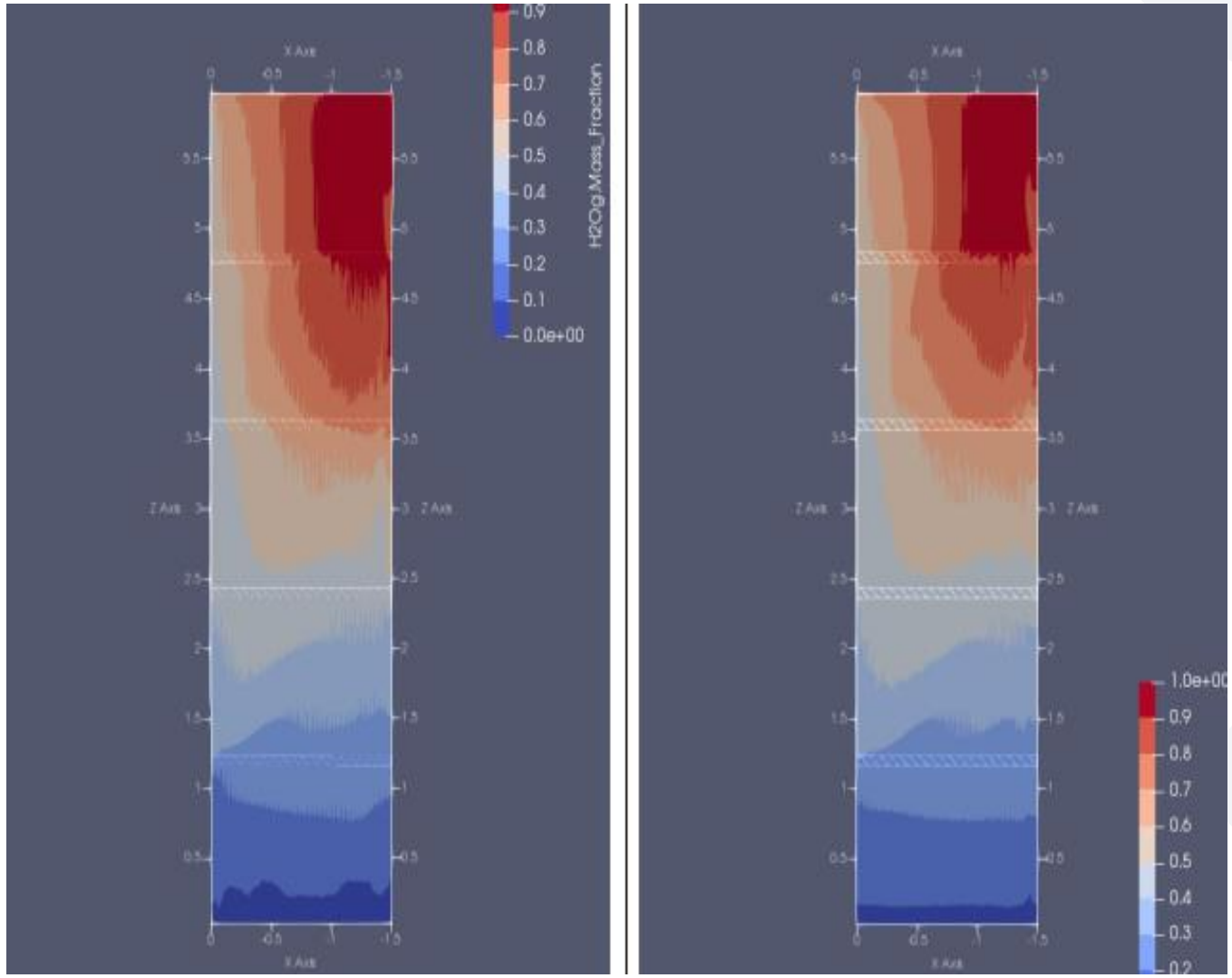


New HP Stripper design: Grids

Advantages

- Condensate discharge uniform, eliminating waterfall effects
- Heat transfer distribution more homogeneous

CFD Grid Design Mass FR. & velocity for 2 pitches: replacement & grassroot



No condensate accumulation

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Conclusions

RCA

- Peripheral corrosion overlaps D&D position
- Central tubes: Absence of iron oxide precipitate indicates higher carbamate concentration
- Outer tubes: Presence of iron oxide precipitate indicates lower carbamate concentration coming from a large decomposition and therefore corrosion.

Radial maldistribution of

- Heat load on shell: Root Cause (RC)

CFD shell

- Accumulation of condensate on disks (main RC)

Conclusions

Redesign from D&D to grids

- Grids support tubes and discharge condensate accumulation
- HTRI predicted improved overall heat transfer coefficient

Operational experience

- Operation of first commissioned grid design HP stripper has confirmed that overall heat exchange coefficient is indeed slightly higher than that of the replaced stripper, confirming the chosen design
- Inspections will reveal final corrosion performance after few years in operation

Thank you!

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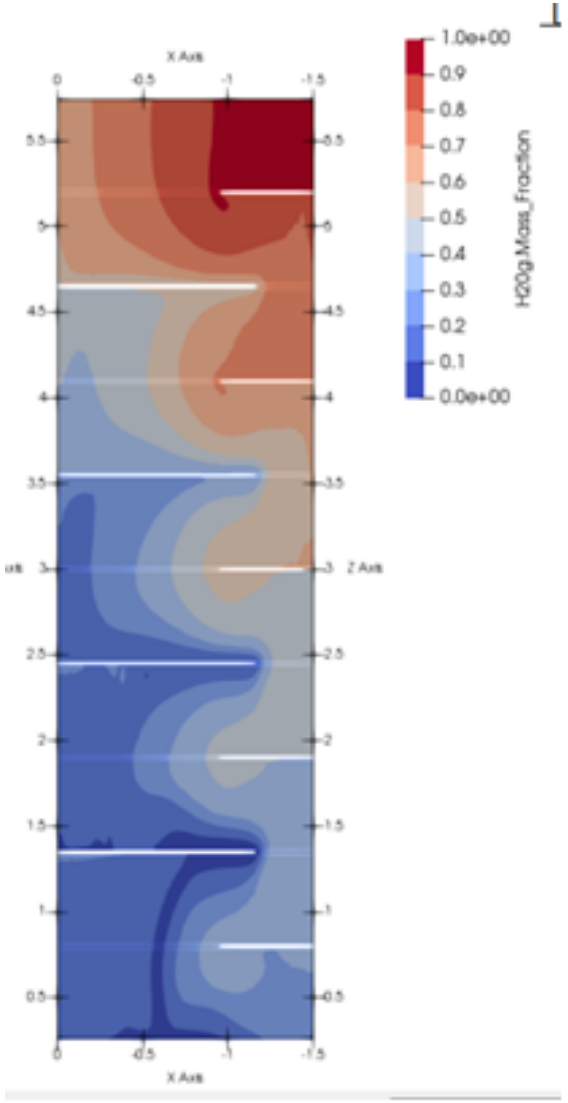
CFD VAPOUR fraction



mass fraction	vapor fraction
1	1
0.9	0.999
0.8	0.997
0.7	0.995
0.6	0.992
0.5	0.988
0.4	0.983
0.3	0.973
0.2	0.955
0.1	0.905
0	0

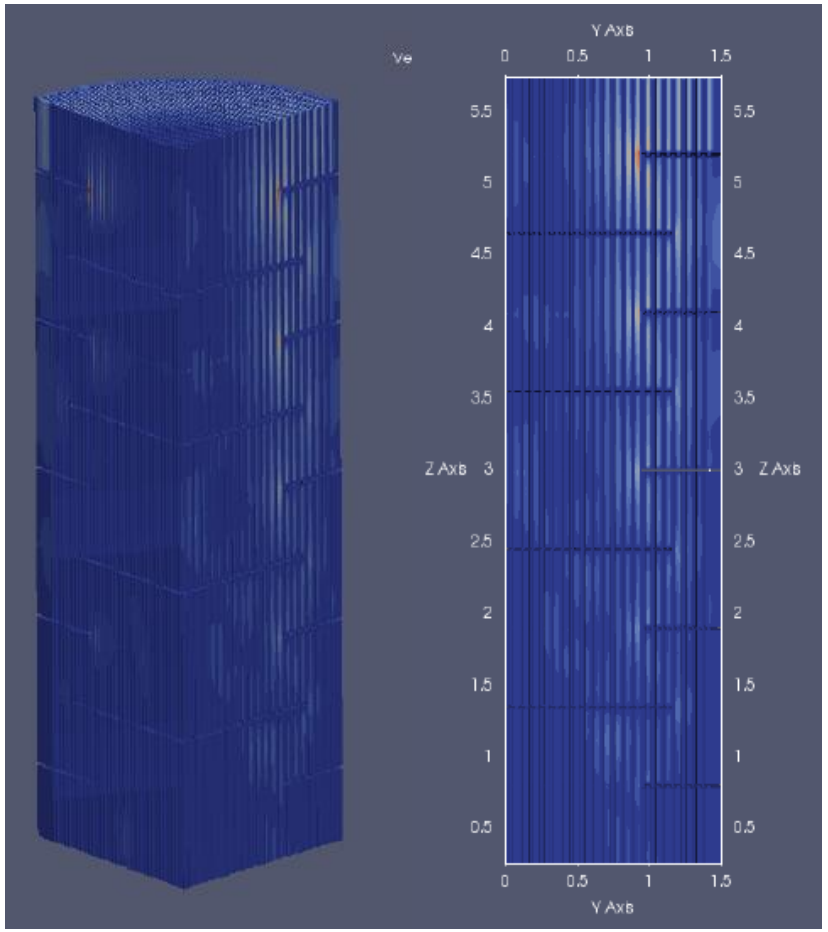
Vapor fraction much larger than mass fraction

due to density differences.

CFD VELOCITY profiles

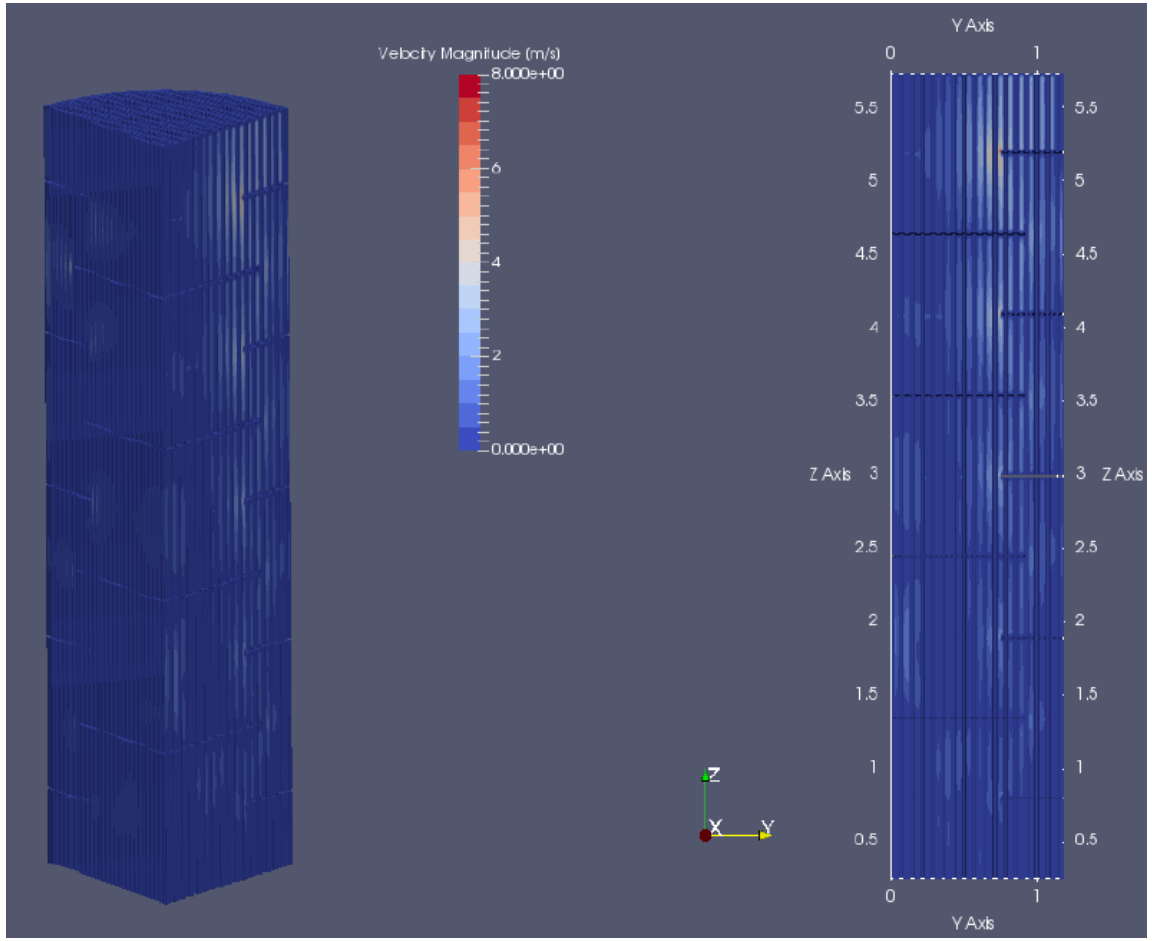
LARGE SCALE

~ 2 m/s



SMALL SCALE

~ 2 m/s



Small velocity differences radially