AD collector: repairs in 2018 and mechanical considerations

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AD Electron Cooler Consolidation Review

26/03/2019

Outline

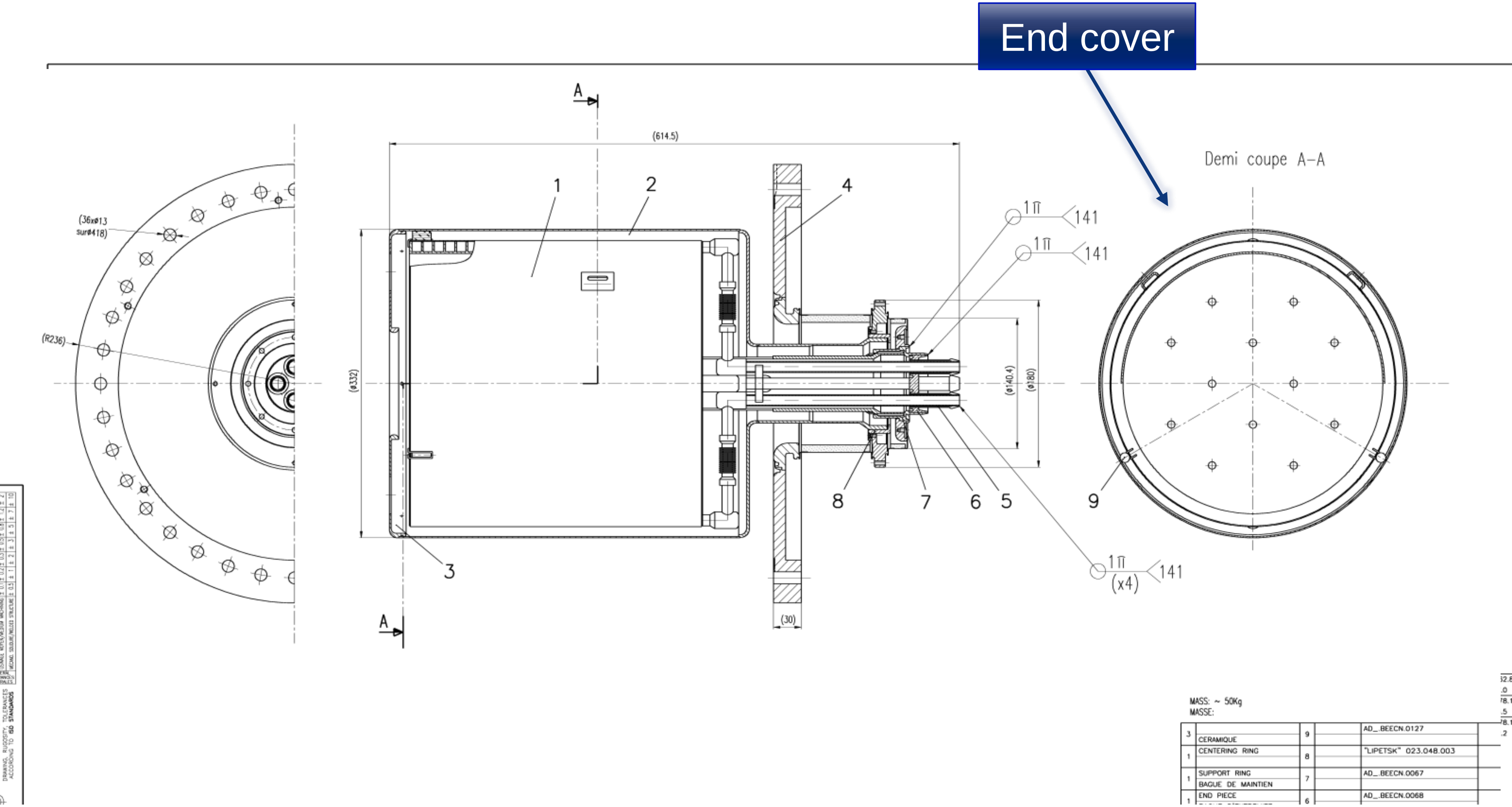
- Introduction
- Collector design
- Weld repair
- Mechanical considerations
- Conclusions

Introduction

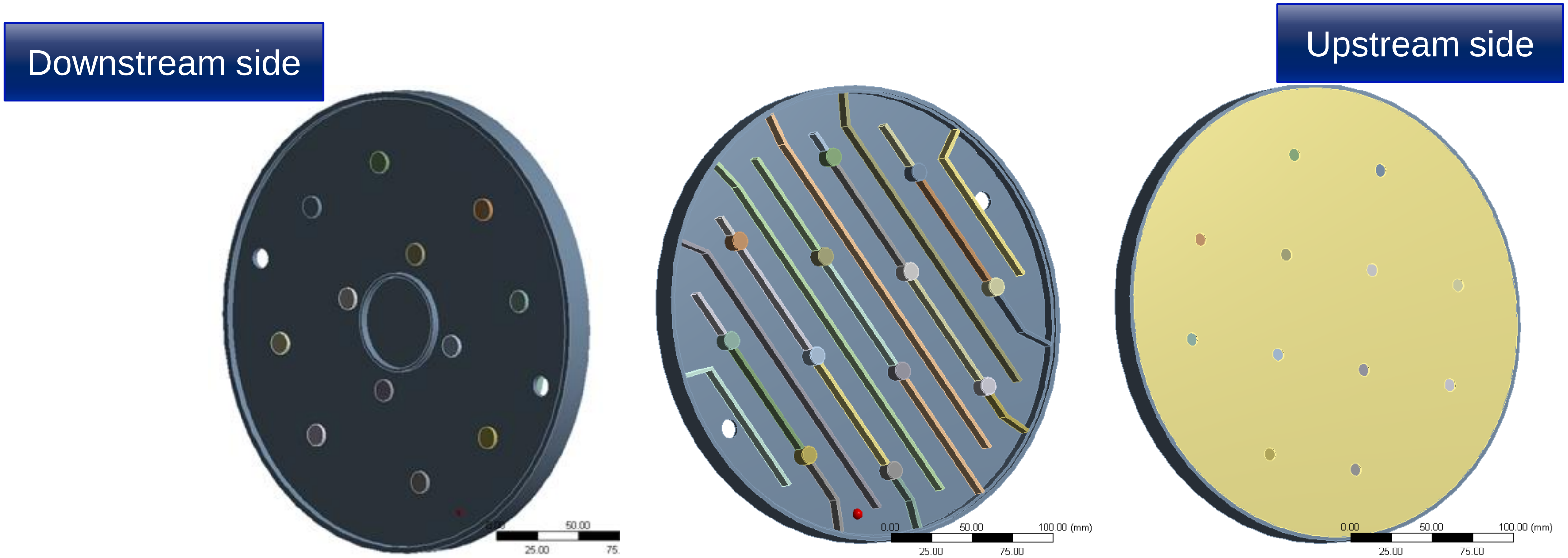
- 23rd July 2018: water leak to vacuum in the AD collector, replaced with a spare unit
- 6th September 2018: same issue to the spare collector.
- 21st September 2018: original unit repaired at the EN-MME workshop and made available to BE-BI
- 28th September: leaking spare unit replaced with repaired original collector

Courtesy of J. Cenede

Collector design



Collector design: end cover

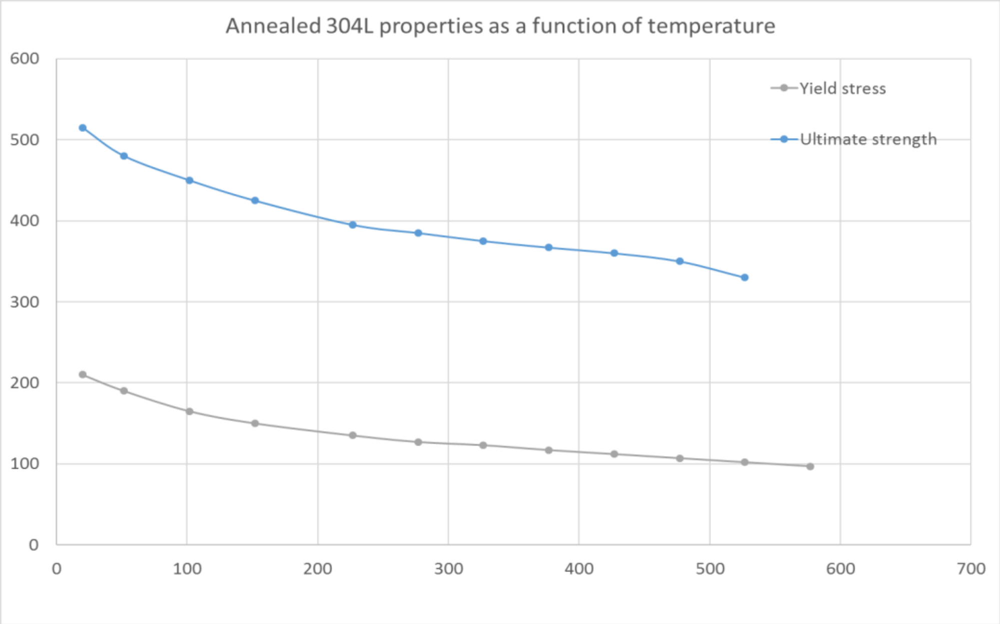


- Two-walled cover, walls made of 316LN, welded circumferentially (upstream side: impacted by the electrons; downstream side: not impacted by the electrons)
- Cover is water cooled, at a pressure of 3.2 bar
- Cylindrical stiffeners added to decrease stresses and deformations on the two walls
- Stiffeners are EB-welded to the two sides of the cover (12 welds per side)
- Material of the stiffeners could not be determined with certainty (austenitic stainless steel, but which one?)

Mechanical considerations: finite elements model

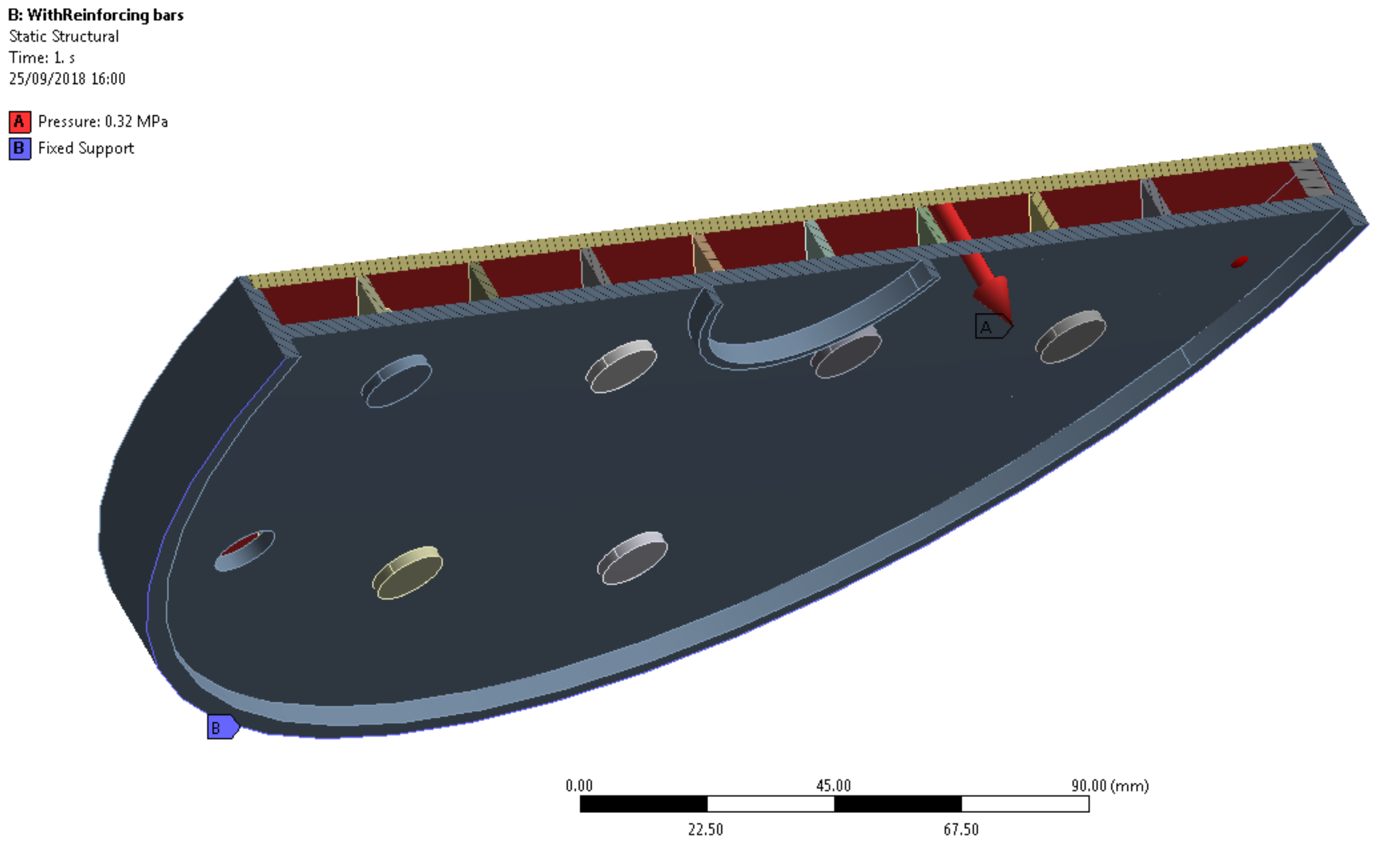
- Analysis were performed in the EN-MME unit to estimate the stress levels in the welds
- Given the uncertainties in the materials, calculations were performed both for 304L and 316LN
- Only the stresses arising from the water pressure were evaluated (no residual stresses from welding, no electron-induced stresses)
- Operating temperature not known: material properties assumed at room temperature (no significant effect expected on elastic constants, but may be relevant for yield stress)

Material	Young's Modulus E [GPa]	Poisson's ratio ν [-]	Yield Strength σ_y [MPa]	Ultimate Strength σ_R [MPa]
316LN v.p.	200	0.3	300	600
304L v.p.	200	0.3	220	520

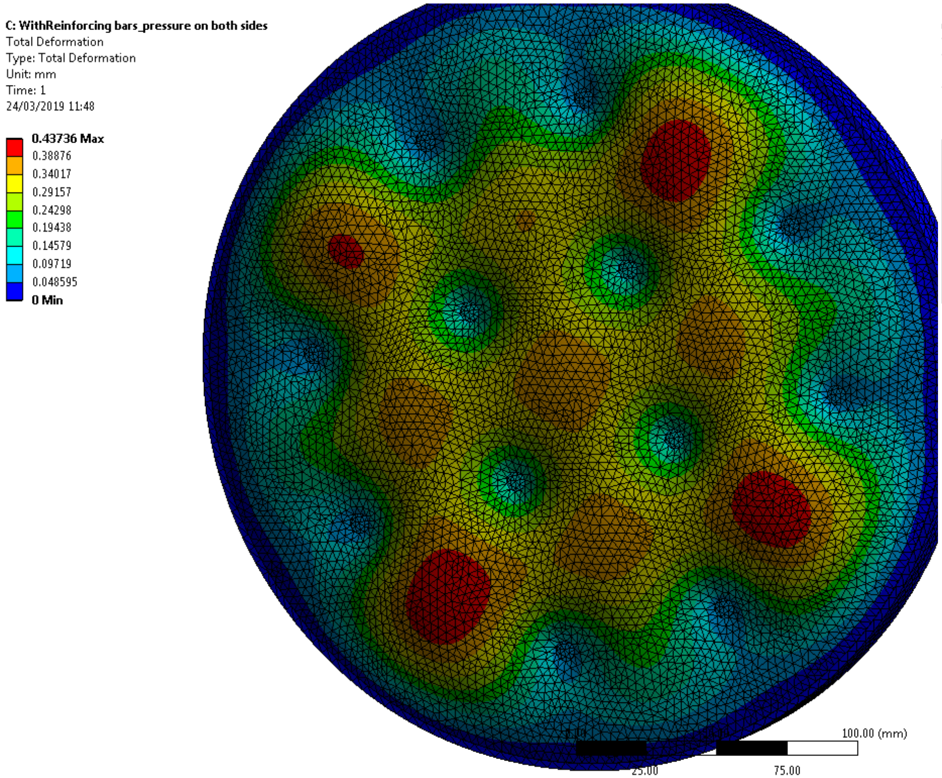


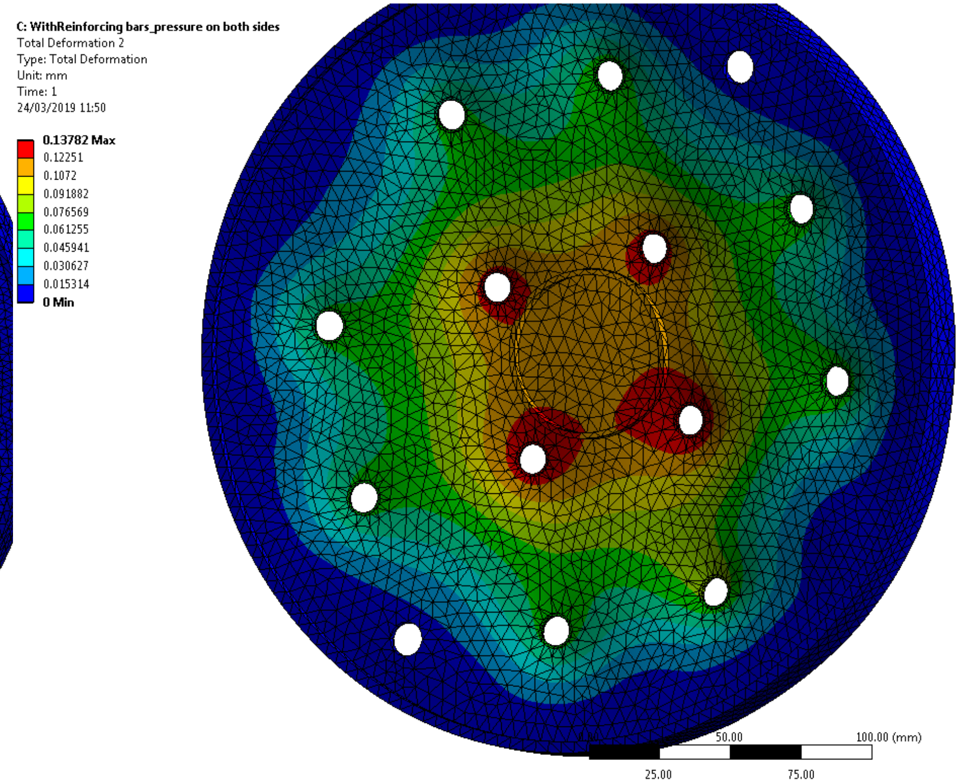
Mechanical considerations: finite elements model

- Weld penetration assumed: 1.5 mm (original welds)
- 3.2 bar water pressure



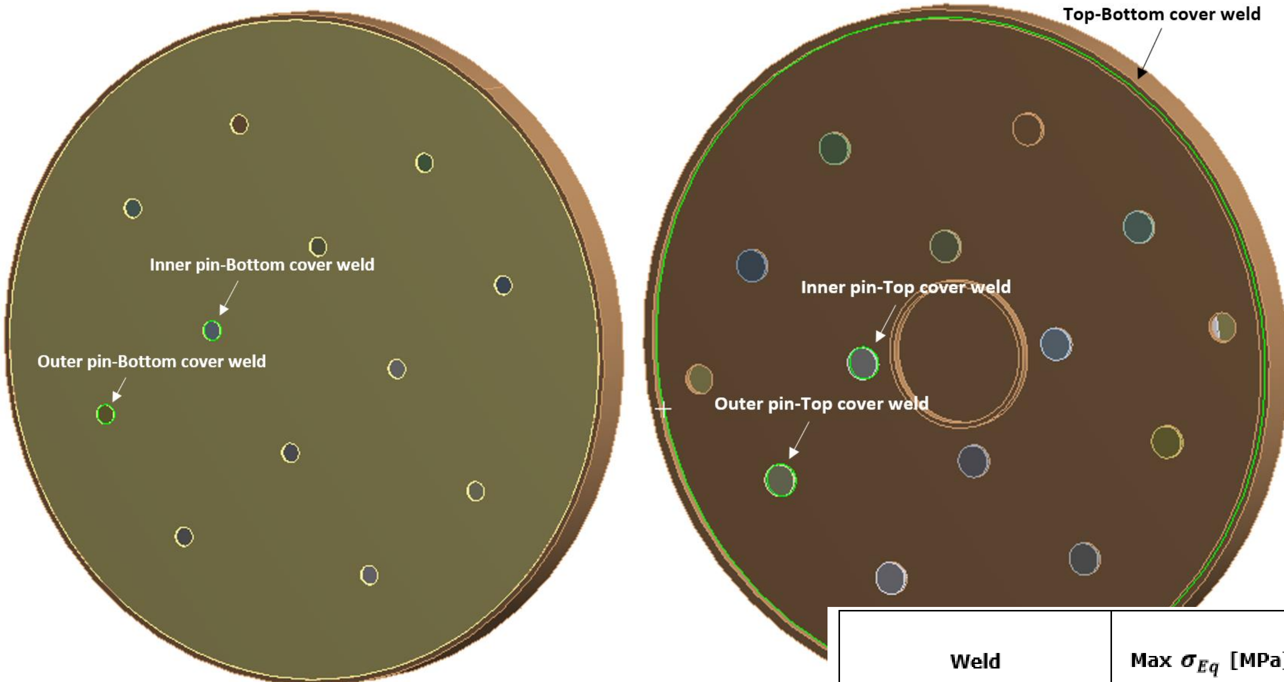
Mechanical considerations: finite elements results





- Cover deformation in the order of 0.5 mm

Mechanical considerations: finite elements results



- Safety factors on stiffener welds not very reassuring, considering that only water pressure is taken into account and room temperature properties considered…

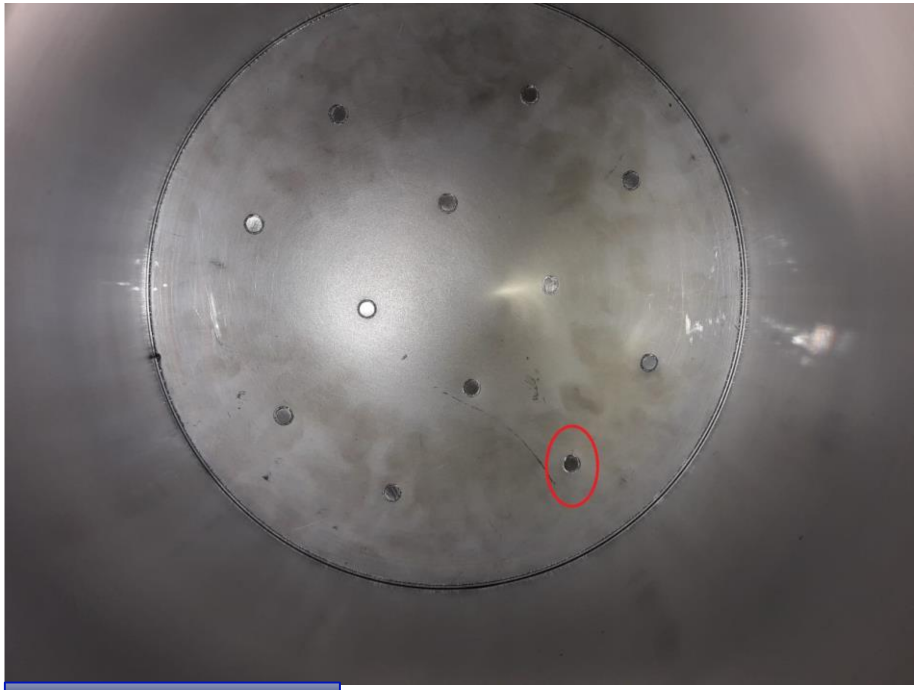
- Comparable stresses on both cover sides and on all stiffeners
- Lowest safety factor is found at the position where the leak developed

Weld	Max σ_{Eq} [MPa]	Max $\sigma_{\perp}$ [MPa]	316LN Safety factor	304L Safety factor
Top Cover/Bottom Cover	10	5	42.1	37.1
Top Cover/Outer Pin	67	37	6.0	5.2
Top Cover/Inner Pin	83	47	4.8	4.2
Bottom Cover/Outer Pin	95	38	4.2	3.6
Bottom Cover/Inner Pin	76	33	5.3	4.5

Weld repair

- Leak test performed at the main workshop to identify the leaking weld
- Welding parameters from the original piece were not available
- New procedure developed at the workshop, with tests on samples to optimize the welding parameters

Courtesy of M. Redondas



Leaking weld

Welding tests on samples

Weld repair

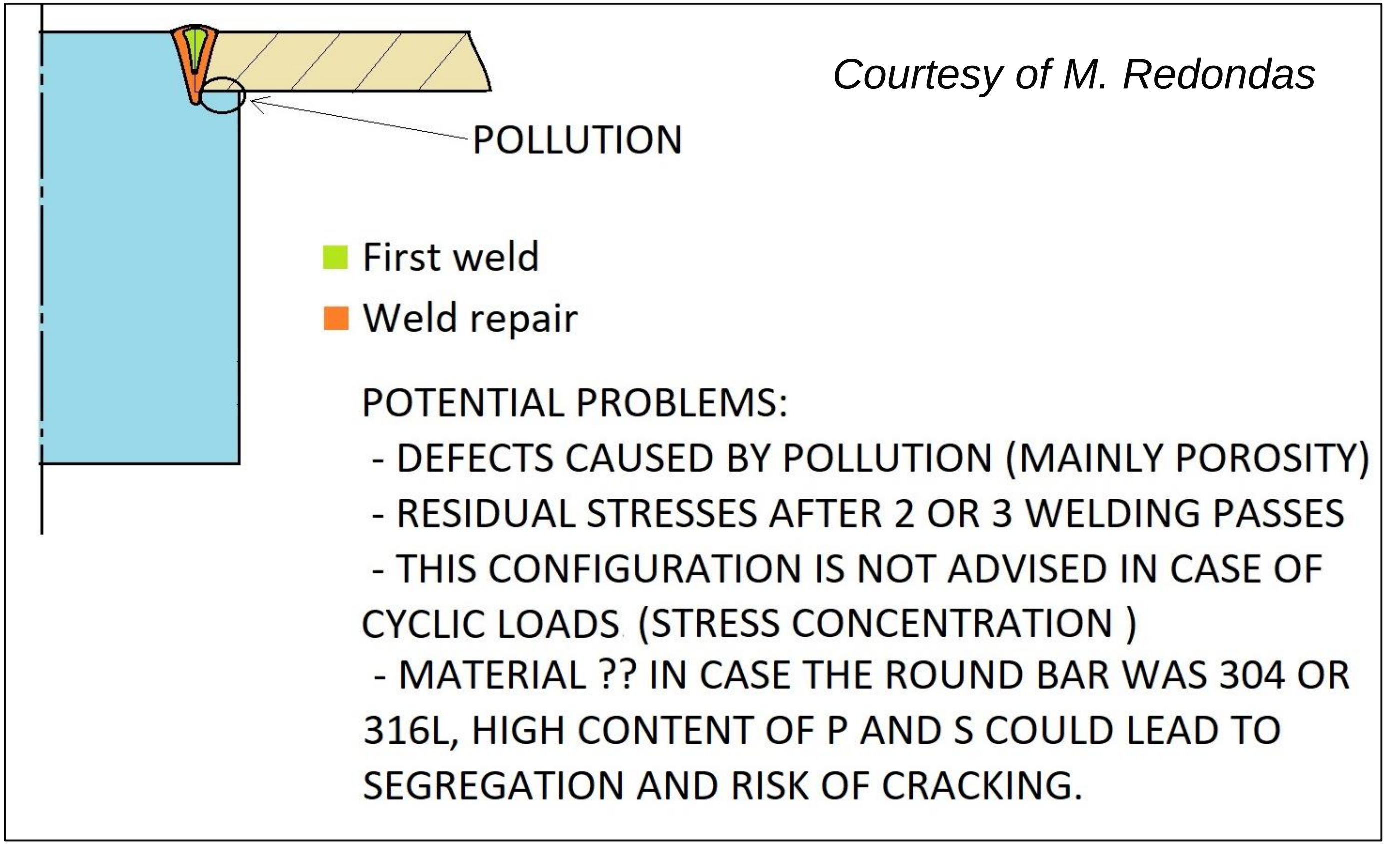
- Decision to repair all the stiffeners/cover welds on the accessible side
- Weld repair duration: 1 day (in total ~1 working week for disassembling, leak detection, welding, reassembling).
- Weld penetration depth: 2.5 mm (the old one was 1.5 mm)
- Electron beam welding parameters:

Courtesy of M. Redondas

WELDING PARAMETERS:

- FIRST WELD ??
- REPAIR: Focus current 1000/362 mA
  60 kV ; 12 mm/s ; 12 mA
  slope in 20° ; overlap 40° ; slope out 50°
- REPAIR 2 (only 2 pins): Focus current 1000/360 mA
  60 kV ; 12 mm/s ; 13 mA
  Overlap opposite to first pass

Weld repair: caveat



- Additionally: not a standard butt weld, presenting potential risks of corrosion from cooling water in the interstice
- Only the accessible side of the cover was repaired! But: non negligible stresses also on the other side…
- Several welds!

Conclusions

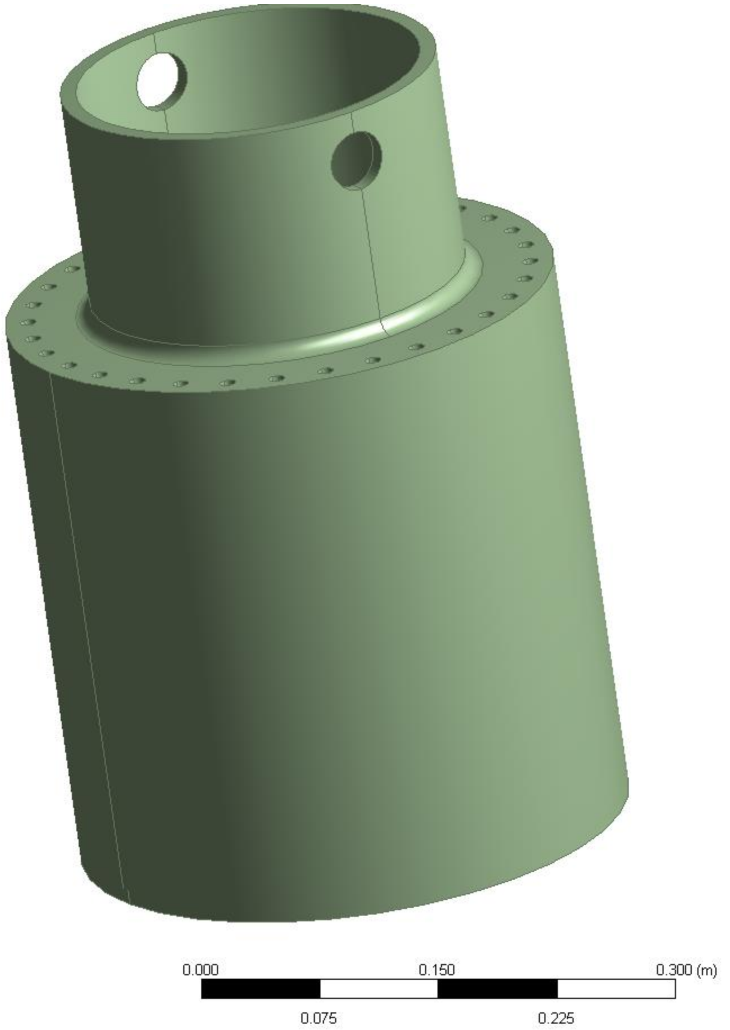
- In September 2018, the leaking collector was repaired in the main workshop at EN-MME
- The leak was detected at the weld between one of the 12 stiffeners and the side of the cover impacted by the electrons
- To prepare for the repairing, two actions in parallel at EN-MME:
  - Weld tests on samples at the workshop to determine the best welding parameters
  - Mechanical calculations to determine the stress levels on the pin welds
- The distribution of stresses is similar on several pins → it was decided to repair all the welds on the accessible side of the cover
- Non negligible stress state on the welds and high number of welds between water and vacuum (25 in total for the cover) → design weak point, to be addressed in future design of the collector (*e.g.* take inspiration from the e-lens collector)
- This weak point is not easily removable in the 2nd existing spare collector (which also developed a leak in September 2018)

Thanks for your attention

Backup slides

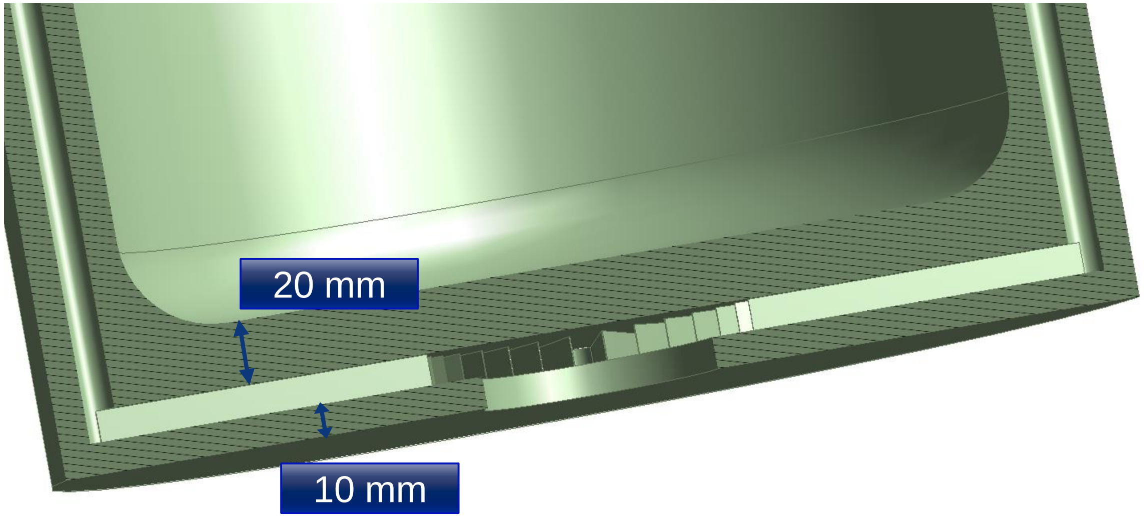
Snapshots HEL collector

Snapshots HEL collector



Courtesy of G. Gobbi

Snapshots HEL collector



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Snapshots HEL collector

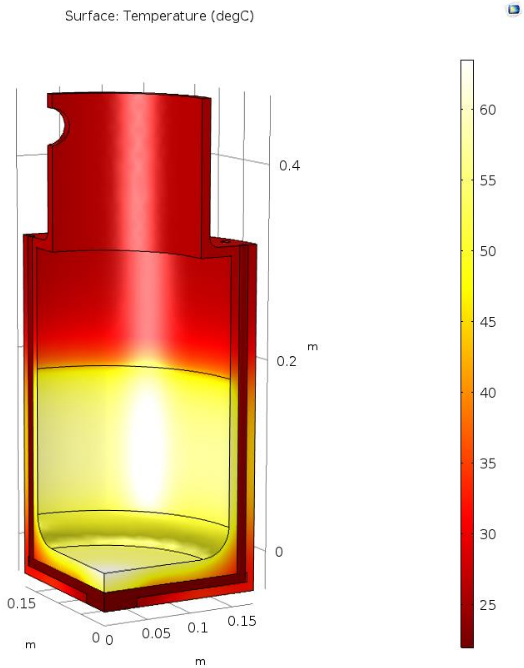
Case 6 – CuCr1Zr load = 50kW

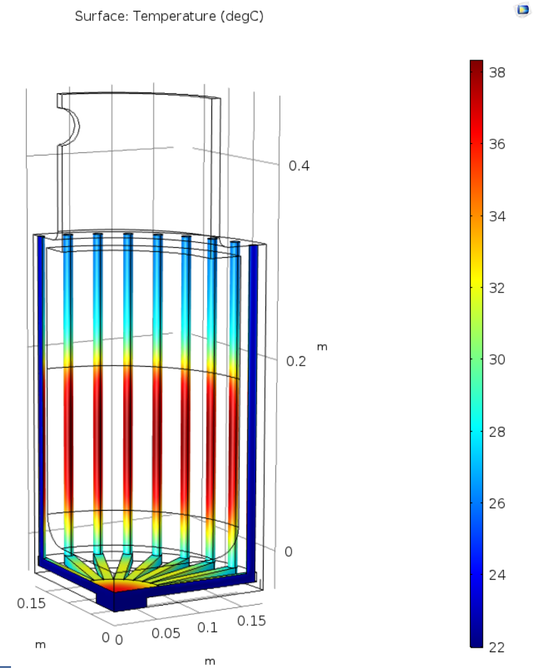
Advantage : $T_{lim\ max}$ = 500 ºC

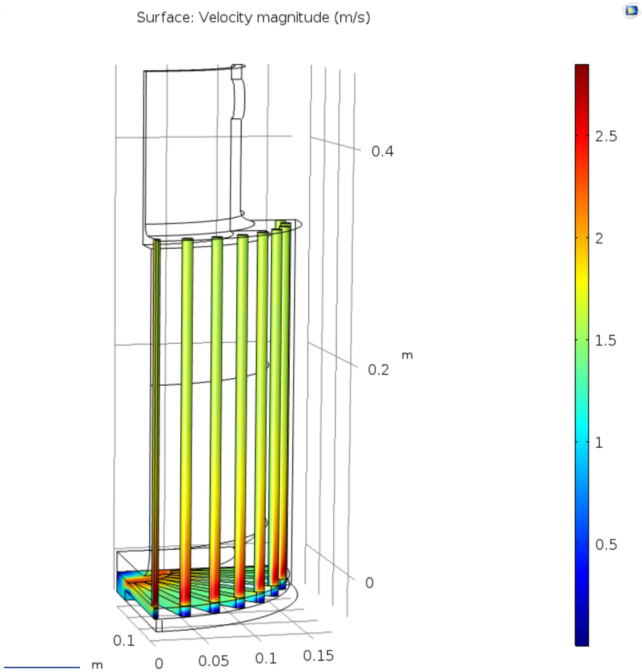
Output:

- T_{max} Cu= 63 ºC (bottom part of the collector)
- ΔT water = 16 ºC
- v_{max} water bottom= 2.7 m/s is the max reached on the back part of the tube

	T max Cu	ΔT water
Cu $v_{i\ water}$ = 1 m/s	57 ºC	16 ºC
CuCr1Zr $v_{i\ water}$= 1 m/s	63 ºC	16 ºC







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