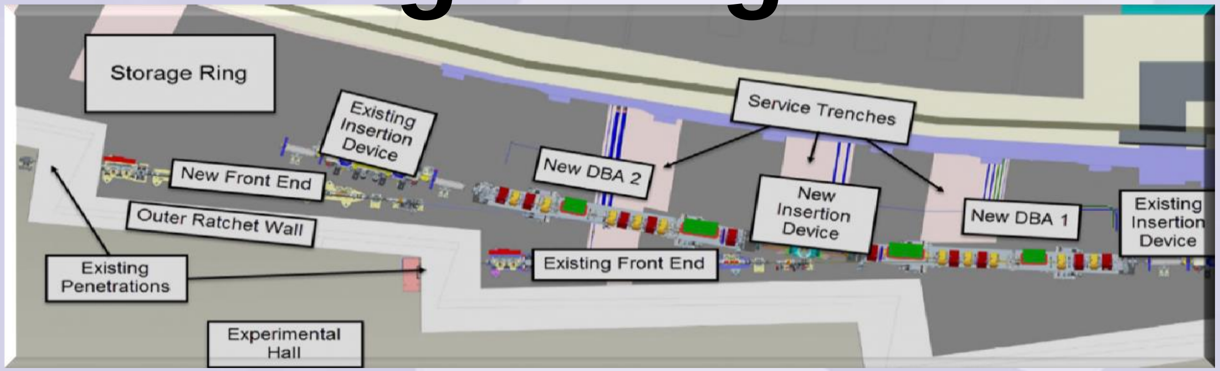
Thermal Stress Analysis and Assessment Criteria of Water Cooled Stainless Steel and Copper Vacuum Vessels in the new Storage Ring DDBA Cell

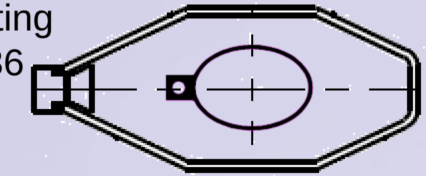


Nigel Hammond

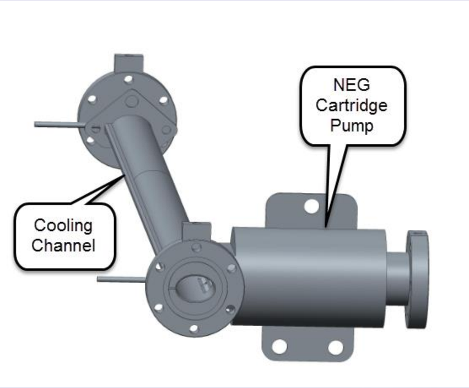
Diamond Light Source Ltd

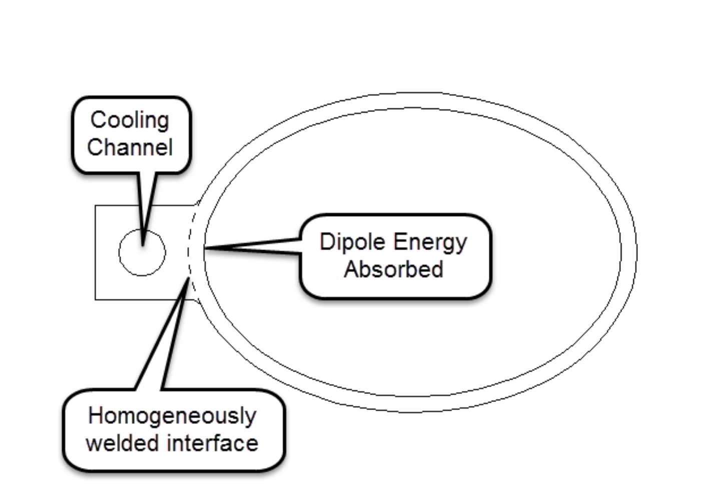
New Vessel profile

Existing
87x36



- To achieve the required Quadrupole gradient of 70 T/m the magnet pole tip radius is reduced from the existing 39mm to 15 mm
- To maximise the vessel aperture to allow the maximum amount of Undulator ID light to pass through unimpeded, a thin wall is required.
- To allow flexibility of location both horizontally canted, and straight ahead Insertion Device light trajectories had to be catered for, width must be maximised.





Internal dimensions:
27mm (H)
18.4mm (V)
1mm wall thickness

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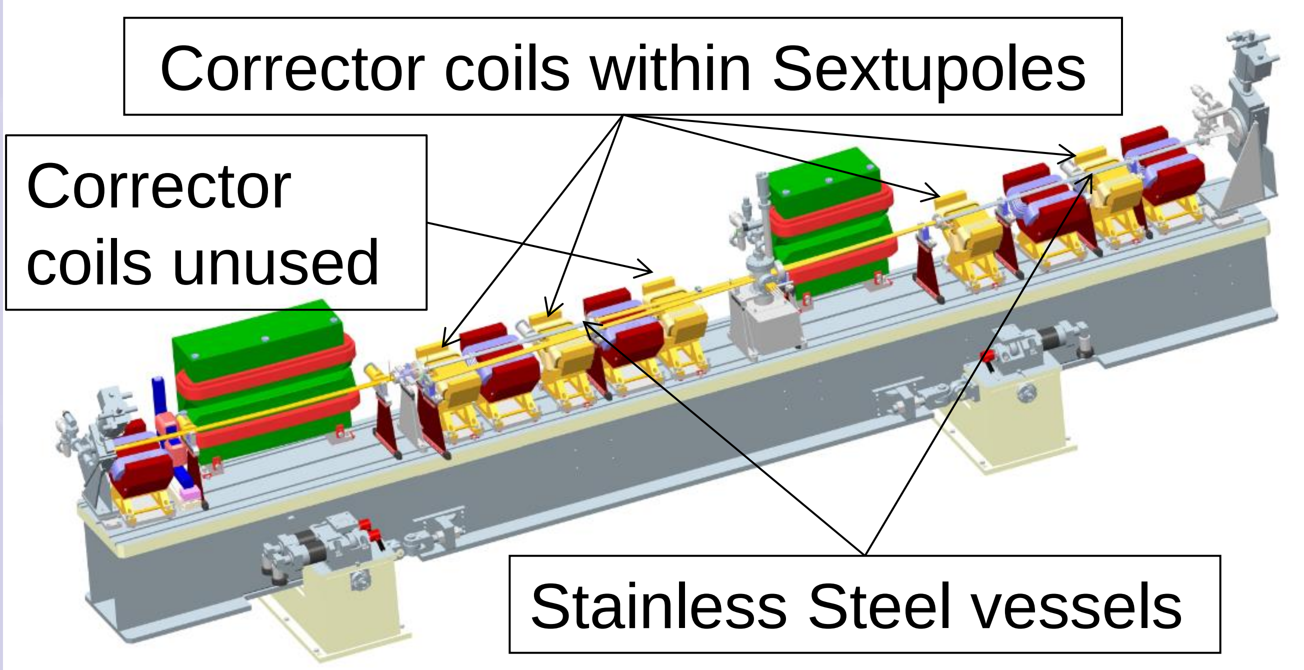
Previous Assessment Criteria

For Thermal Stresses:

- The present design of the storage ring only has OFE copper material (C101) intercepting significant amounts of energy.
- The criteria against which the vessels are assess is strain based, i.e. using non-linear finite element analysis techniques. Limits are set at 0.5% strain peak surface value and 0.2% global limit for copper and copper alloys.

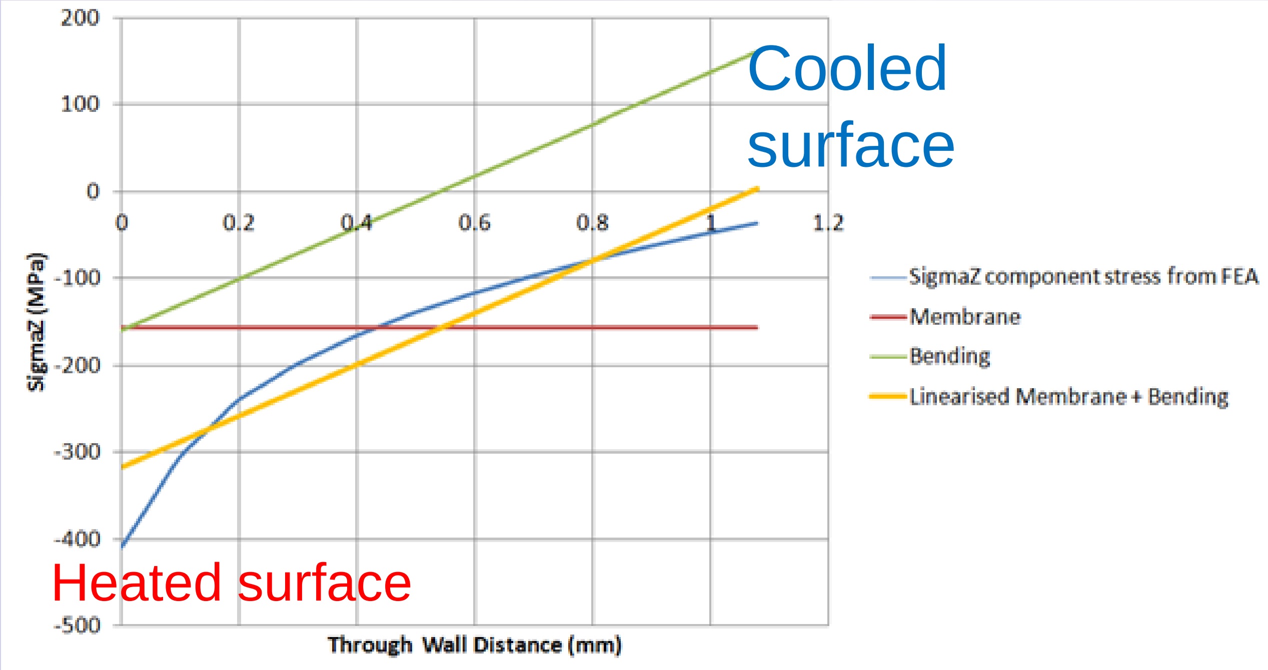
Why Stainless Steel Vessels?

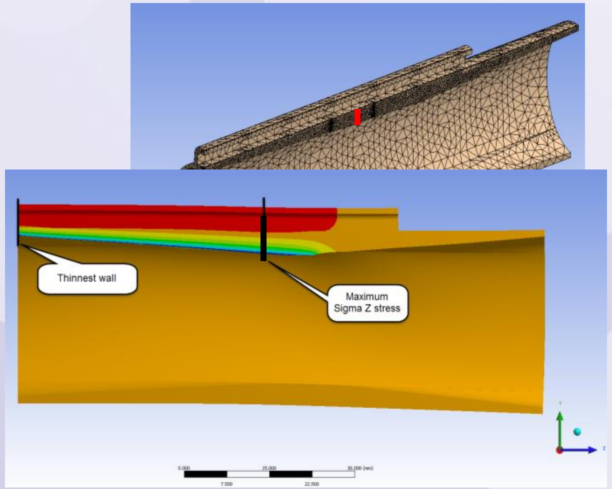
Corrector coils within the sextupole magnets have to transmit small variations in field at a sufficient frequency to stabilise the electron orbit to at least 100Hz.



Method used for Stainless Steel Vessel Thermal Stress Assessment

- 'Design by analysis' method using stress classification divides the stresses into different categories: membrane, bending and peak.
- (ASME and BS EN 13445 BPVC approach)



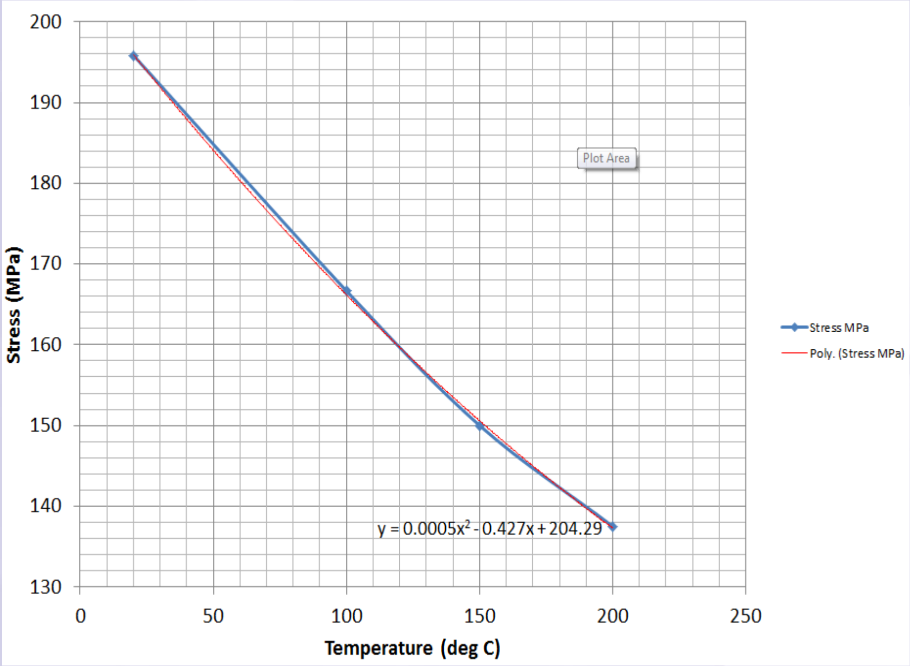


Assessment Criterion

As defined in BS EN 13445 BPVC Annex C

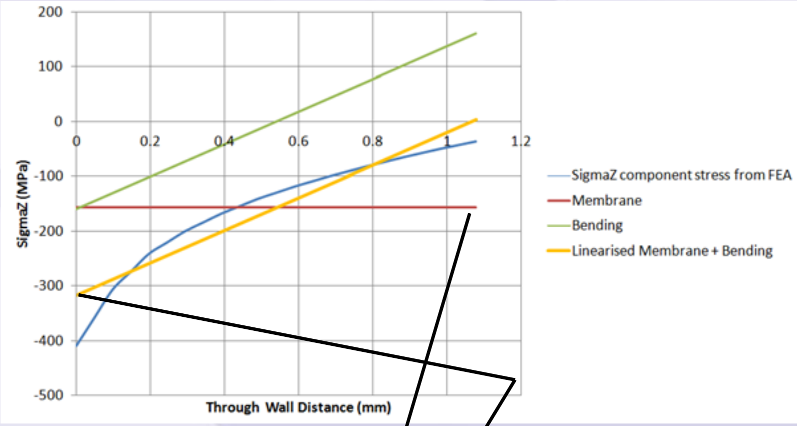
Design by analysis option.

(Similar to ASME III and VIII)



Design Stress ‘f’

At $T=(0.75T_{max}+0.25T_{min})$



Stress Classification BS EN 13445 Annex C	Allowable Stress in terms of Design Stress ‘f’
General Primary Membrane P_m	f
Local Primary Membrane P_L (near discontinuities)	1.5f
Secondary Membrane + Bending (thermal)	3f

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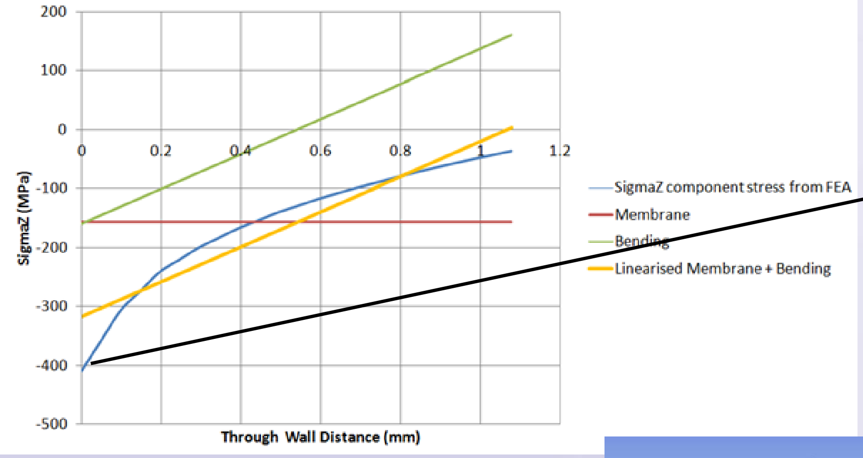
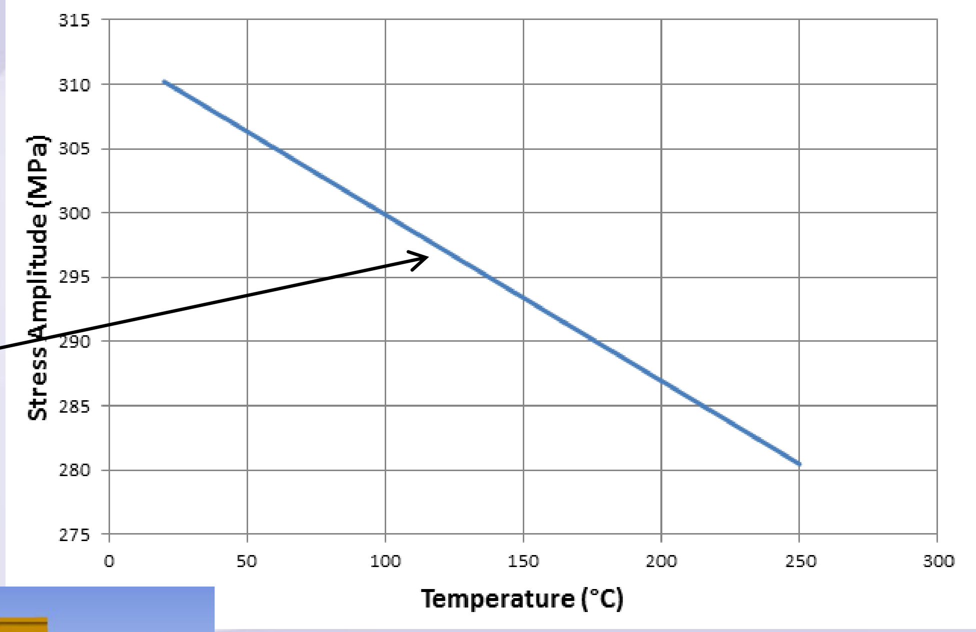
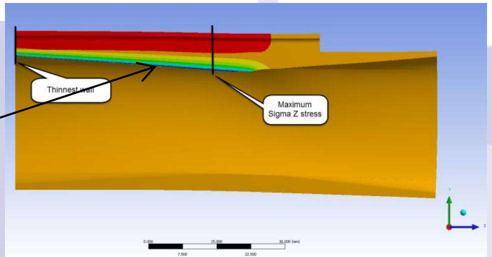
Peak Surface Stress vs. Fatigue Lifetime (OFE Cu and 316L)

- Both materials can become annealed through joining processes.
- Both significantly work harden through the first few hundred cycles.
- The high surface thermal stresses are compressive.
- The type of loading experienced during operation sustains the high stress for long periods of time, which can be important if sustained temperatures are in the creep range.
- The heated surface is in vacuum.







Increase length of taper

The End

Thanks to colleagues:

- Houcheng Huang for carrying out FEA.
- Chris Bailey and Riccardo Bartolini for input and suggestions.