Target Wheel, ESS TAC 12

Consorcio ESS-BILBAO & European Spallation Source ERIC

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Introduction

ESS-BILBAO Consortium

Role and functions

- The Spanish Government has taken the decision to make ESS-BILBAO the only contractor from Spain to ESS project.
- ESS-BILBAO has been nominated as Spanish representing entity for ESS operational phase.
- On November 2014, ESS-Bilbao was chosen as ESS partner for Target Wheel, shaft and drive unit.
- On December 2014, ESS-Bilbao was chosen as ESS partner for Beam Dump, Proton Beam Entrance Window and Monolith Vessel.
- On September 2015, ESS-Bilbao was chossen as ESS partner for the Neutron Beam windows.

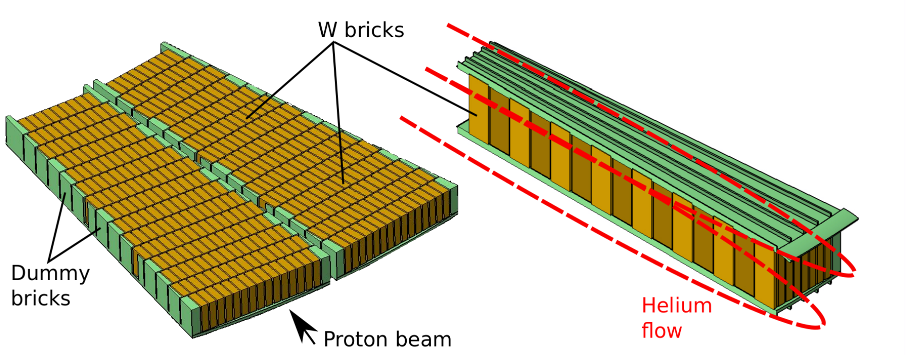
Target Wheel base line

Target Wheel base line

Tungsten blocks placed in bricks configuration

In order to reduce maximum stress in the slabs tungsten in the current model, we propose tungsten blocks (10 x 30 x 80 mm) in a “cross flow“ configuration where protons will not cross the target without interacting with spallation material.

Selection process

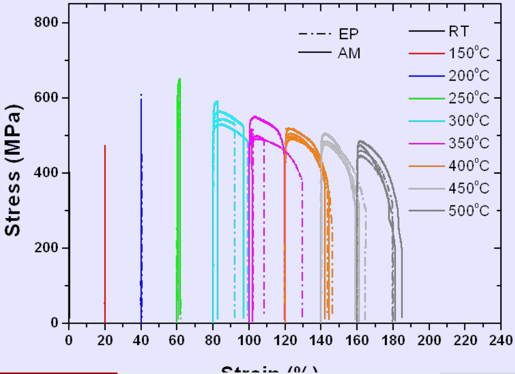


Tungsten production

Hot Rolled Tungsten

The geometry simplification allow to consider the production of the tungsten by "Hot Rolled Processes" (industry standard for 10 mm thickness). Hot rolled tungsten has better mechanical properties than forged.

Hot rolled W in the X direction
courtesy Dr. Dai



ESS physical tungsten requirements.

Physical Requirements

- Maximum velocity close to tungsten bricks: **100 m/s.**
- Maximum nominal temperature: **500^{o}C**.
- Maximum accidental temperature: **700^{o}C**.
- Maximum mean stress: **100 MPa**.
- Maximum peak stress amplitude: **50 MPa**.

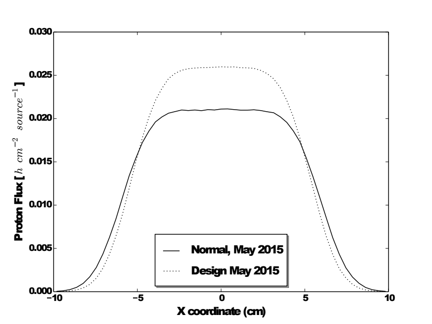
Reference: Requirements for maximum stress and maximum temperature in proton-irradiated tungsten. ESS-0009043

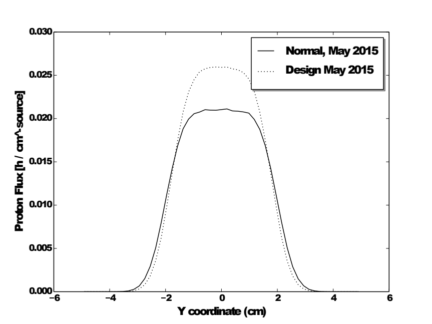
Beam conditions: June 2015

Beam profile compared with previous beams

The current design source is around 20-25% higher than the nominal one.

New beam conditions requires a review of the previous analysis



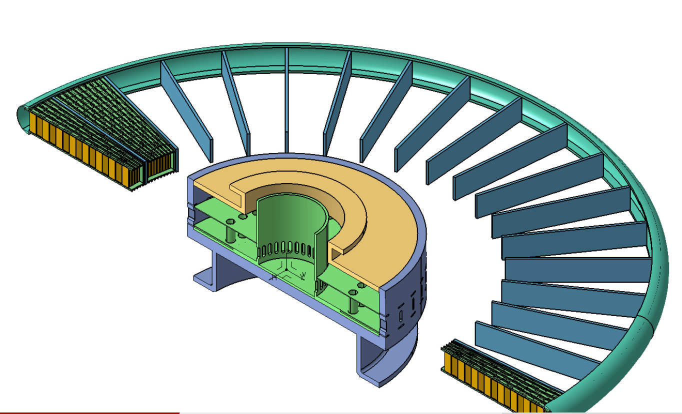


Target Wheel base line

Target Vessel

On the basis of the base line helium flow path, an alternative configuration for the vessel is proposed.

Selection process



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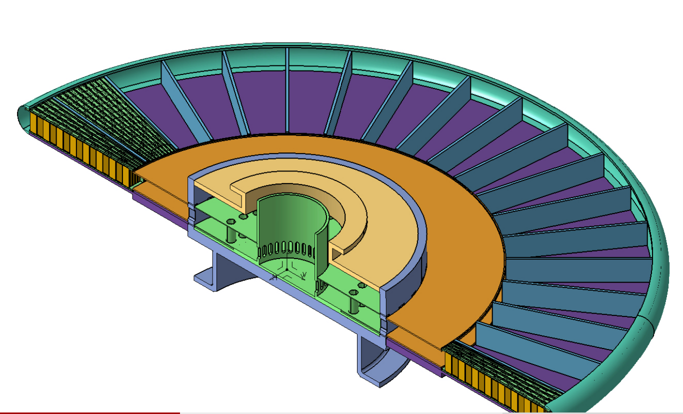

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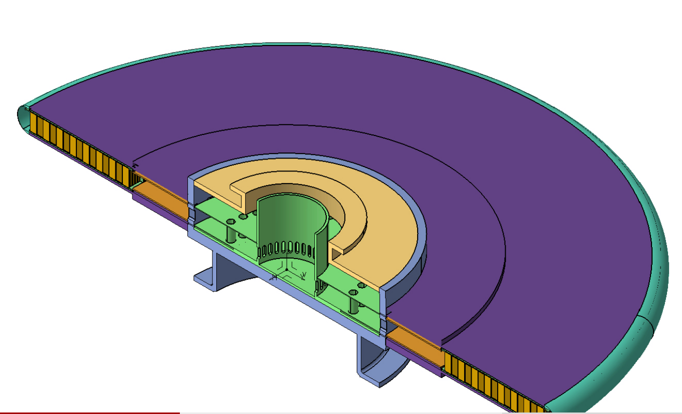
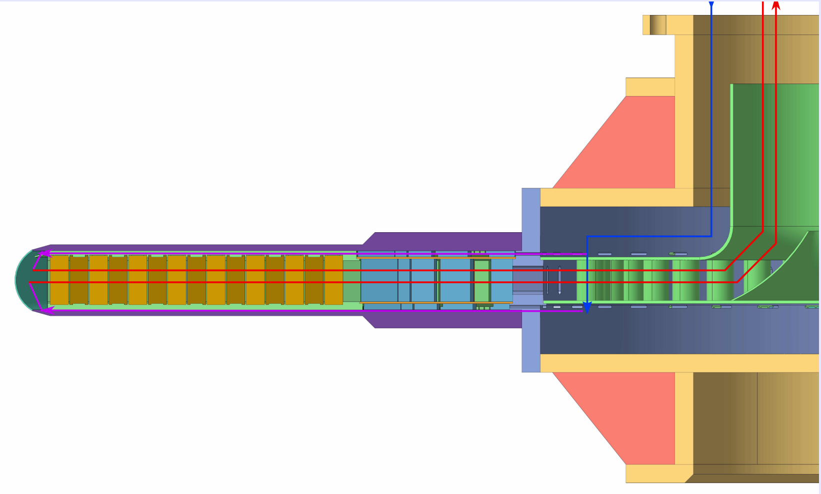


Spallation material analysis

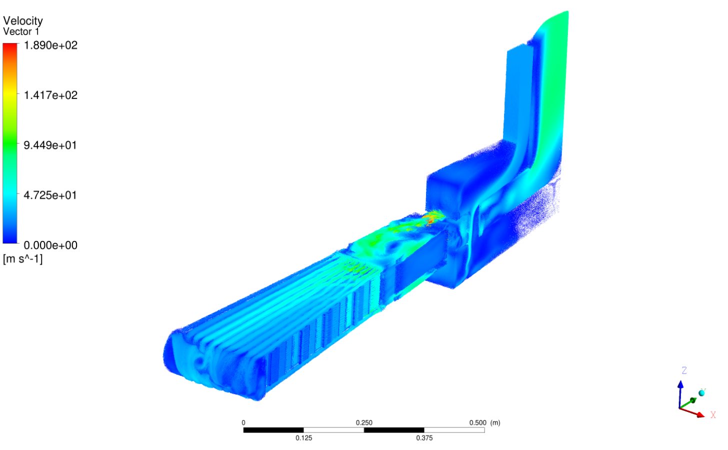
Whole Target

Helium Path



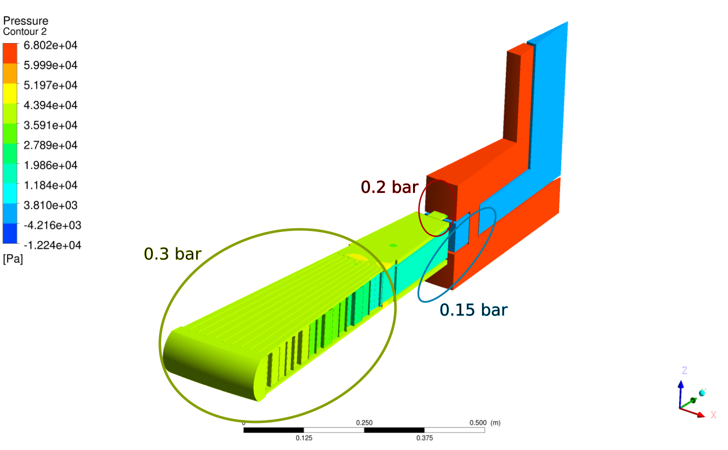
Velocity Profile

Velocity profile in a whole sector



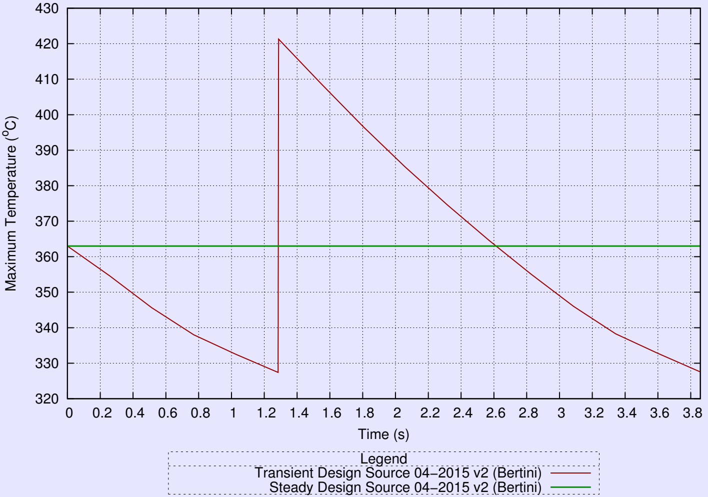
Pressure Drop

Pressure drop in the wheel. $\Delta P = 0.65 bar$



Transient Temperature

Transient state temperature before and after a pulse. $\Delta T = 93^oC$ (Design beam, bertini model)



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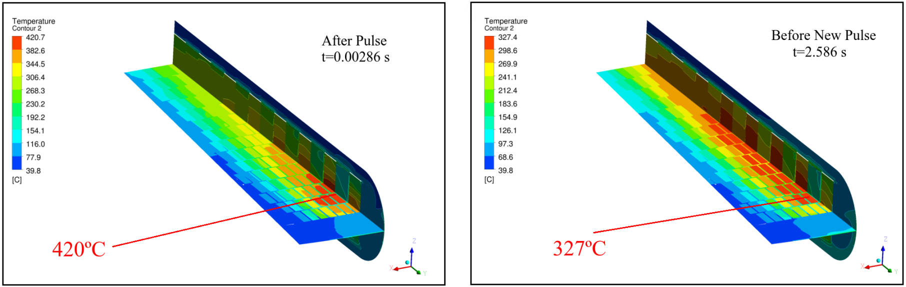
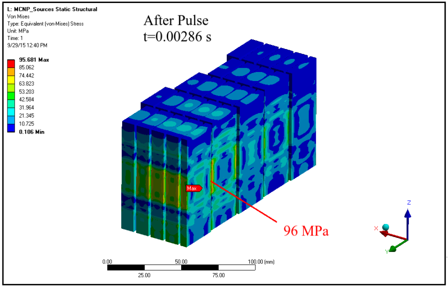
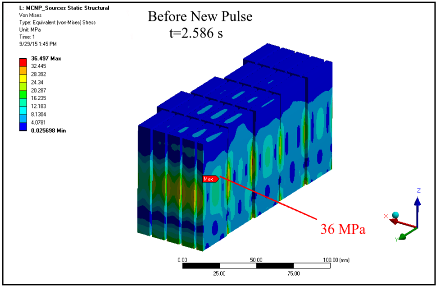


Transient Stress

Transient State Equivalent Von Mises stress.

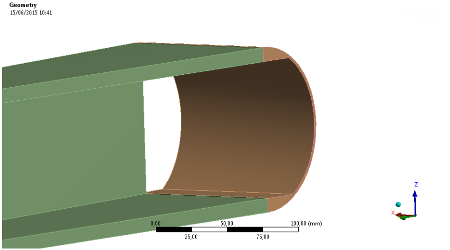
$\Delta\sigma = 60$ MPa. It is a little bit higher than the peak amplitude established by ESS in 50 MPa.

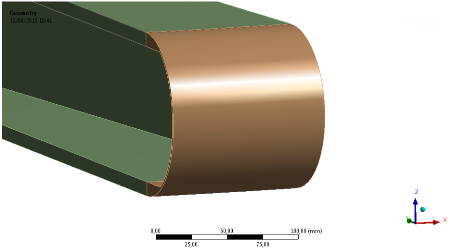




Target Vessel

Target Vessel

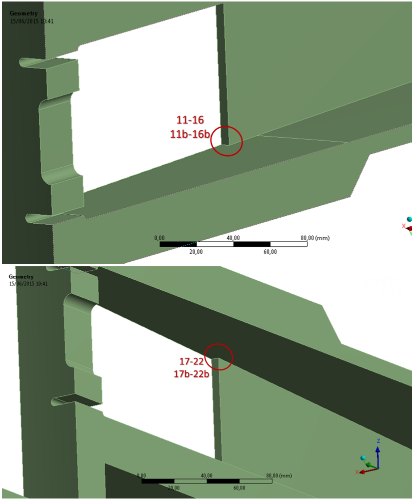




BEW zone results. Elastic analysis

- 38.2 MPa (P_m) $\leq$ 123 MPa ($S_m(200^o C)$)
- 55.8 MPa ($P_m + P_b$) $\leq$ 184.5 MPa ($1.5 * S_m(200^o C)$)
- 229.1 MPa ($P_m + Q$) $\leq$ 3257 MPa ($S^A_{em}(200^o C, 2.75 dpa)$)
- 277 MPa ($P_m + P_b + Q + F$) $\leq$ 5600 MPa ($S^A_{et}(200^o C, 2.75 dpa)$)

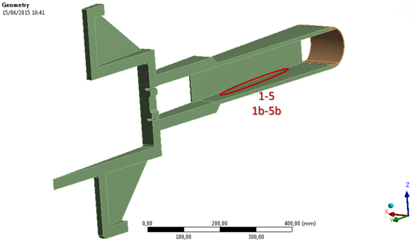
Target Vessel

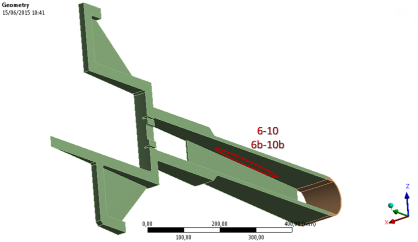


Rib-plate joint zone results. Elastic analysis

- 132.9 MPa $(P_L) \leq$ 190.5 MPa $1.5 * S_m(100^o C)$
- 145 MPa $(P_L + P_b) \leq$ 190.5 MPa $(1.5 * S_m(100^o C))$
- 141.3 MPa $(P_m + Q) \leq$ 3711 MPa $(S^A_{em}(100^o C, 2.75dpa))$
- 148.3 MPa $(P_L + P_b + Q + F) \leq$ 6371 MPa $(S^A_{et}(100^o C, 2.75dpa))$

Linearized analysis results





Rib zone results. Elastic analysis

- 20.5 MPa $(P_L) \leq 190.5$ MPa $1.5 * S_m(100^o C)$
- 179 MPa $(P_L + P_b) \leq 190.5$ MPa $(1.5 * S_m(100^o C))$
- 236.3 MPa $(P_L + Q) \leq 3711$ MPa $(S^A_{em}(100^o C, 2.75dpa))$
- 228.2 MPa $(P_L + P_b + Q + F) \leq 6371$ MPa $(S^A_{et}(100^o C, 2.75dpa))$

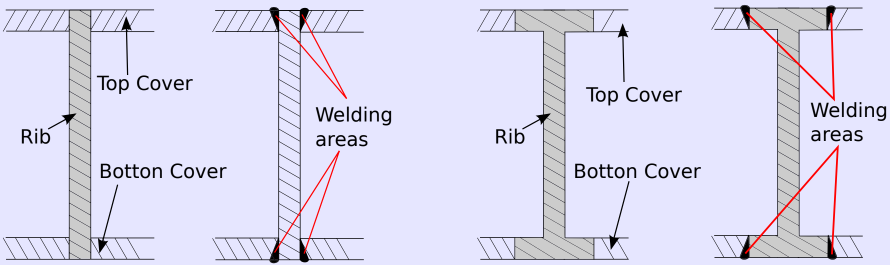
Welding analysis

Welding analysis

The welding regions has been agreed with manufactures and reviewed based on the RCC-Mrx criteria. Full penetration, volumetric inspections and one face surface inspections are need for the ribs. The stress values in the beam entrance window are much lower and only surface inspection will be needed.

Full penetration weldings in the ribs

Alternative 1 ($P_L = 179$ MPa in welding area) Alternative 2 ($P_L = 125$ MPa at 2 cm)

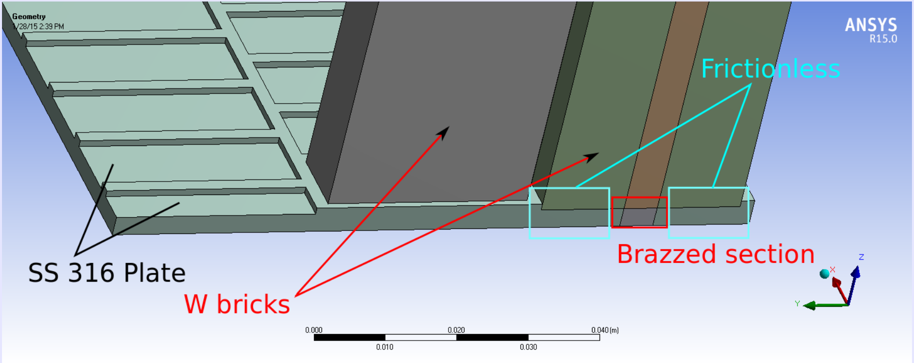


EDD activities

Brazing of W to the steel plates

Partial brazing surface

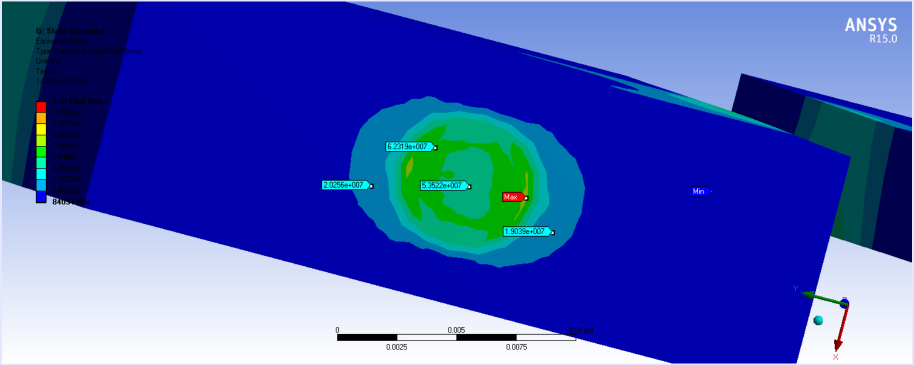
The technical solution to reduce the mechanical stress at contact is to reduce the brazing area as close as possible to a single point. To evaluate this option a FEM model has been prepared dividing the contact surface between tungsten and plate is divided in two areas. In the first area (a circle with 5 mm of diameter) in with we consider a bounded contact and frictionless in the second.



Brazing of W to the steel plates

Partial brazing surface

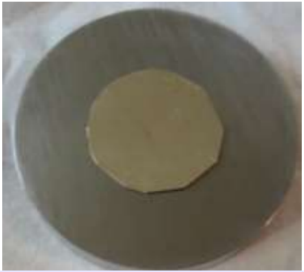
Considering the temperature profiles evaluated with optimistic assumptions (BER + ESS 2014), the brazing area increases the stress field by 50-60 MPa in both tungsten and steel. In the case of tungsten, this increase of the stress is produced in an area with low thermal stress values so it do not increase the peak value.

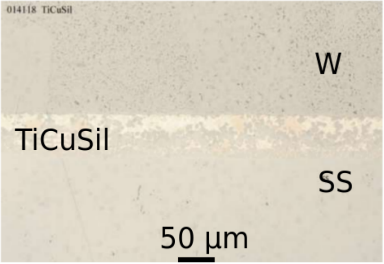


Brazing of W to the steel plates

Experimental validation:

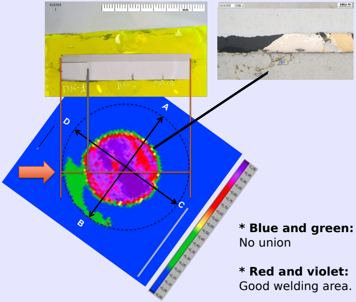
The FEM analysis of the W-SS 316L brazing shows that a 5 mm surface in the center of the brick produces stress below 50 MPa. In order to evaluate this option, a brazing test campaign was started on February 2015. The first step of the experiments has been completed with promising results.





Brazing of W to the steel plates

Experimental validation of the brazzing concept on going work



The ultrasonic measurements carried out by Technalia shows that TiCuSi allow produces a welding area very close to the required conditions.

Additional experiments will be done along 2015 in order to establish the parameters of the welding in order to produce a single point brazing.

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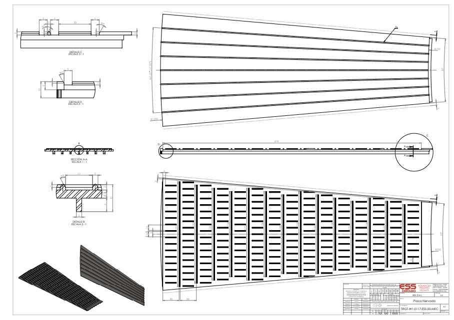
EDD: Cassette Manufacturing test

Target Vessel: Cassette Manufacturing Test

Cassette Manufacturing Test

The Cassettes are critical elements for the configuration of the He channels in between W bricks. Despite of the fact that cassettes are not part of the nuclear credited elements of the target, the geometry and the tolerances produces a complex manufacturing problem. Even more, the deformation produced in the brazing process in the cassette is unknown.

Contract award to Leading Enterprises



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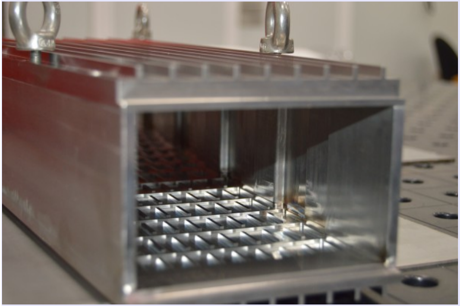
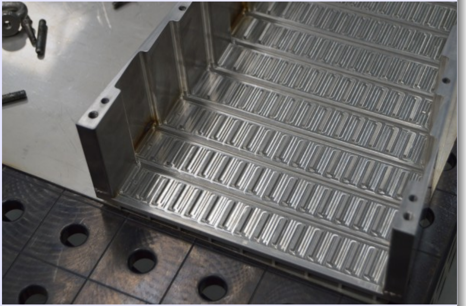
Target Vessel: Cassette Manufacturing Test

Cassette Manufacturing Test: Lessons learned

- Tolerances for positioning can be achieved. However, assembling process will be complex.
- Bolted union is recommended to avoid welding deformation
- Lid have to be redesigned to avoid the welding.

EDD completed





Target Vessel: Cassette Manufacturing Test

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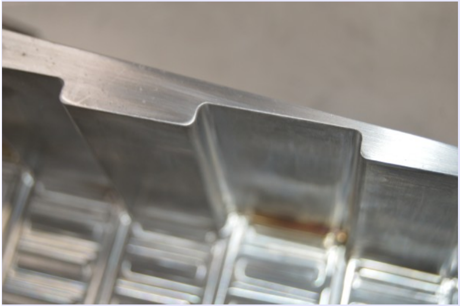

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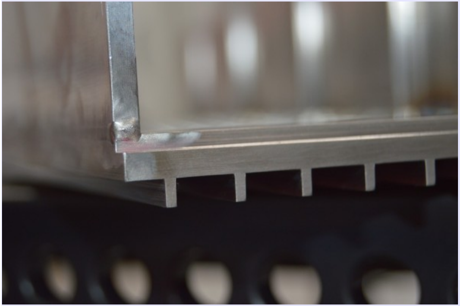


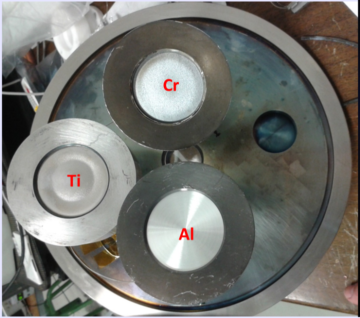
Wolfram Coating

W bricks Coating

Development a coating material to improved the W properties (Led by Yong Joong Lee, Head of ESS materials group)

In order to minimize the powder production and increase the fatigue properties of W, a coating layer is under develop based on standard sputtering technology. The Al-Ti-N layer will increase the resistance of the bricks to abrasion, corrosion. (Not yet approved)

Coating magnets at Nano4Energy facilities (Magnetron sputtering in the presence of Ar + N_2)

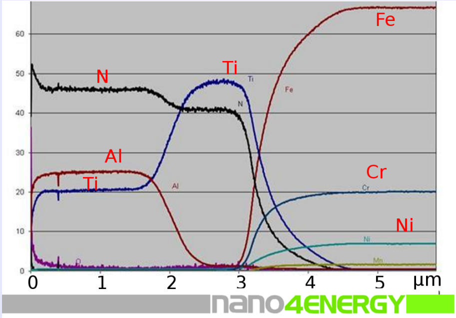


W bricks Coating

Development a coating material to improved the W properties

The production of the coating is been carried out by Nano4Energy and the final oxidation test is ongoing. After the evaluation of the optimum composition of the layer, material test (hardening, fatigue, oxidation and proton irradiation) will be perform in collaboration with ESS, PSI, Lund University, ESS-BILBAO and Nano4Energy.

GD-OES: Composition thick film on SS



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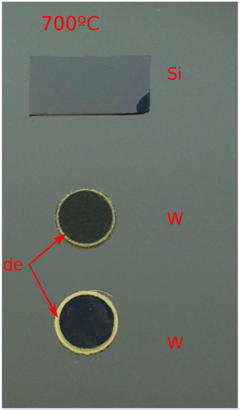


- The coating has been produced on W and Si samples..
- Oxidation test on air are ongoing.
- The tests shows that the coating avoid the oxidation at $500^o C$ and $700^o C$.
- However, experiments at $800^o C$ fails.

WP 12.2.3.2 Shaft

Shaft shielding

Shielding requirements

The internal shielding of the shaft is a critical requirement to reduce the dose rate values on top of the target monolith. Along the last months the average shielding requirement has been estimated ($\sim$ 60 % of steel density) but the shape of the shielding was not taken in to account so the neutron streaming was not properly evaluated.

Pressure drop & manufacturing

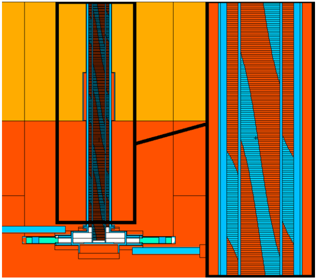
The configuration of the helium channels inside the shielding drives the pressure drop of the shaft. Several options are under evaluation in order to minimize the pressure drop and manufacturing requirements.

CFD-MCNPX optimization loop

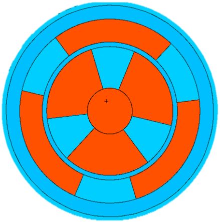
Based on previous requirements, a neutronic-fluid dynamic optimization loop is on going to evaluate several shielding solutions.

Shaft shielding

Shaft CFD-MCNPX analysis



Cross section



- Comparison between two shaft shielding options has been completed considering CFD and shielding analysis.
- After discussion with manufacturer Helical shileding has been choosen (three helical channels for inner and outer shielding)

Shaft shielding

Shaft CFD-MCNPX analysis

Geometry	Roughness (mm)	ΔP_int (bar)	ΔP_ext (bar)	ΔP_total (bar)
No shielding	0,015	0,002	0,005	0,007
	0,8	0,004	0,012	0,016
Bricks 40º	0,015	0,090	0,072	0,162
	0,8	0,266	0,213	0,479
Bricks 80º	0,015	0,142	0,230	0,372
	0,8	0,384	0,491	0,875
Helix	0,015	0,099	0,081	0,180
	0,8	0,276	0,222	0,498
Helix TDR	0,015	0,137	0,005	0,142
	0,8	0,311	0,012	0,323

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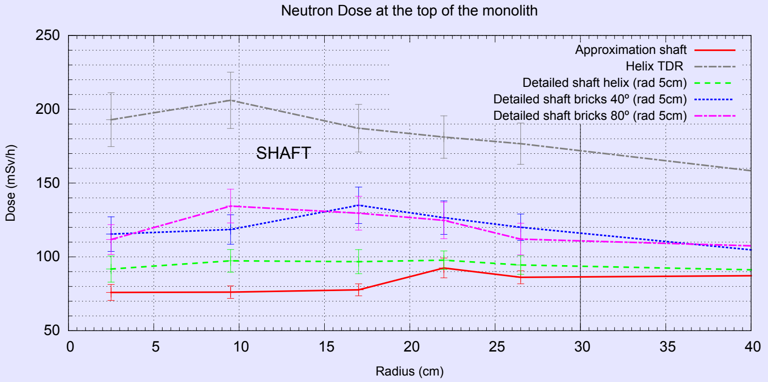
Shaft shielding

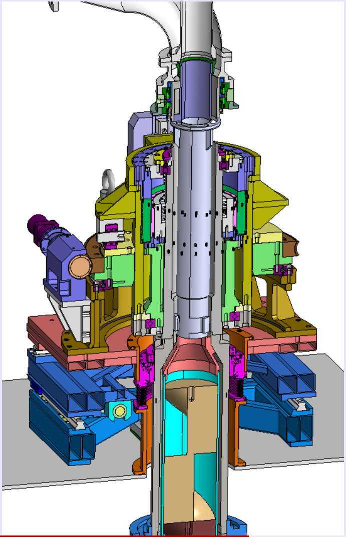
Dose rate on top of the vessel



WP 12.2.3.2 Drive Unit

Drive Unit & Positioning system

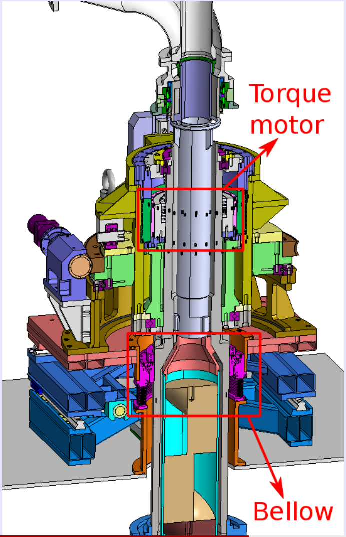
AVS ongoing activities



- ESS-Bilbao awarded a contract to A.V.S. for the design of the drive unit.
- Since April, several modifications has been included in the design to fulfill the requirements for the new vessel.
- Torque motor have been selected for the drive unit due to the low radiation environment.
- Discussions between pre-stressed axial contact ball bearing and axial-cylindrical roller bearing.

Drive Unit & Positioning system

AVS ongoing activities



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Conclusions

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Design modification proposals

- Spallation material is now brick-shaped and modification of the helium flow path. Modification appoved by ESS.
- Even number of sectors (36). Modification appoved by ESS.
- Shaft shielding modification. Under discussion

On going works

- Accidental analysis
- Welding test
- W procurement and QA process