Sensibility analysis

Consorcio ESS-BILBAO & Instituto de Fusión Nuclear & ESS-ERIC

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Uncertainty on the design

The ESS Target will be the first of a kind for 5 MW targets. We have to consider that our design is in some way in an unexplored range of operation conditions thus, some unexpected effects could appeared. As an example, the 1 MW mercury targets (J-PARC and SNS) produces a much more intense cavitacion compared with its expectations.

Sensibility analysis

Based on this uncertainty, it is critical to evaluate how sensible is our design to variations on the boundary conditions of the design. Several scenarios not included in the design are considered:

- Nominal beam
- Low conductivity of the spallation material
- Design power increase.

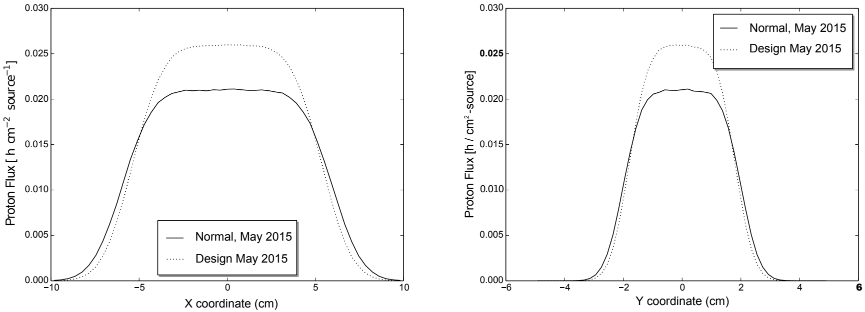
Nominal beam conditions

Nominal beam conditions

Safety margin produced by the Design vs Nominal Beam

As described on previous presentations, the design beam was postulated considering the worst case associated with the instrumentation uncertainty. This means that design conditions introduces some safety margin that can compensate the uncertainty associated to negative effects.

Design vs Nominal beam

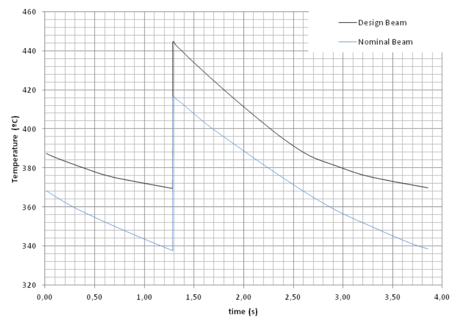


Nominal beam conditions

Thermal analysis for nominal beam

Figures shows the temperature evolution of the spallation material on nominal beam conditions. The maximum temperature at the end of the pulse achieved with the nominal beam is 26 $^{\mathrm{o}}\mathrm{C}$ below. It is not clearly proportional to the heat load density due to the tungsten hight conductivity.

Temperature evolution



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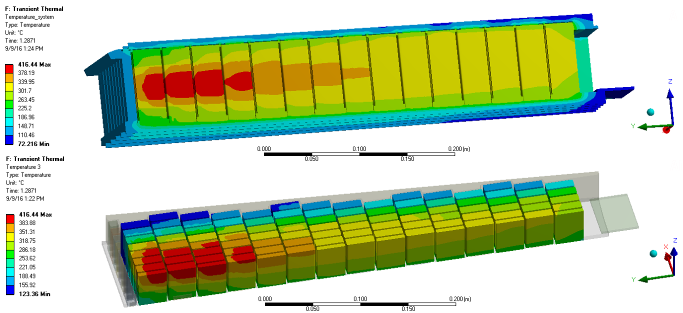

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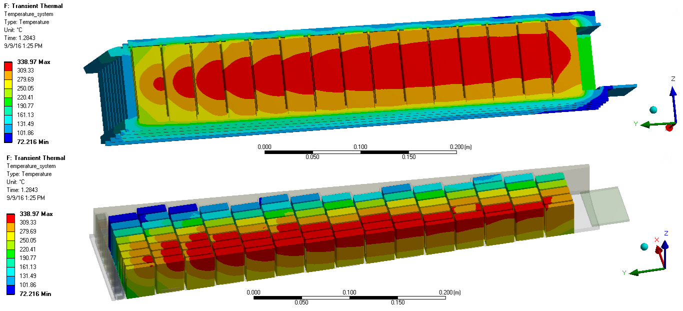
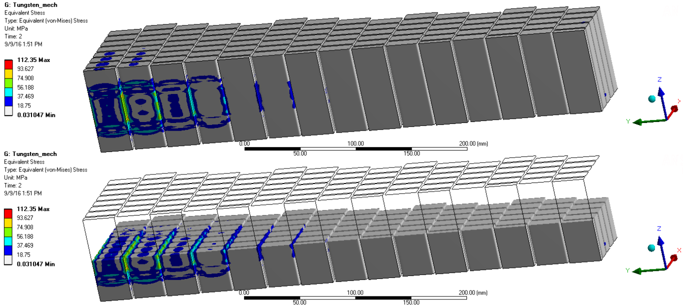


Nominal beam conditions

Mechanical analysis for nominal beam

The maximum stress at the end of the cooling is 40 MPa and after the pulse is 112 MPa. The stress profiles using the nominal beam and the design beam are very similar so, this conditions do not introduce a significant safety margin on stresses.

Von misses equivalent stress



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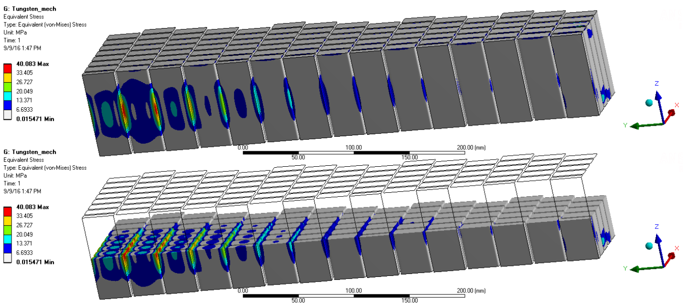


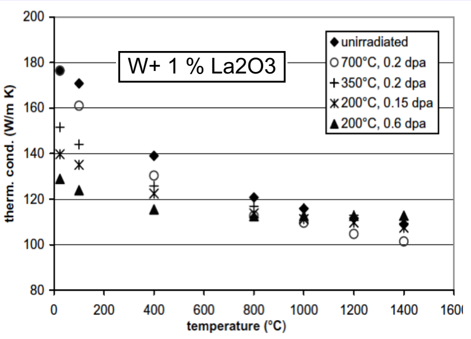
Low conductivity

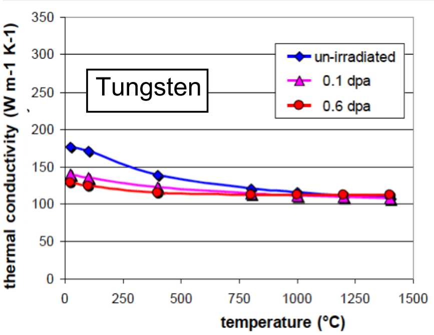
Low conductivity

Tungsten radiation damage

The available Data [ESS Materials Handbook] shows a clear reduction of the spallation material thermal conductivity with the radiation damage. Based on that a 20% reduction on conductivity is considered.

Degradation of thermal conductivity due to radiation damage



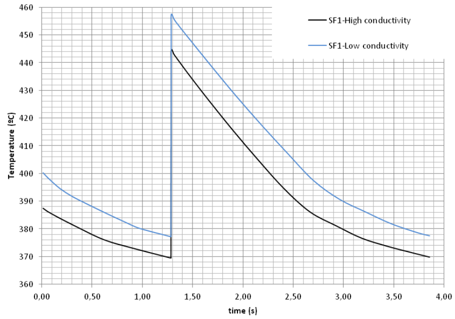


Low conductivity

Thermal analysis for SF1 conditions (Design Beam)

The maximum temperature at the end of the cooling is 377 ^{o}C and after the pulse is 457 ^{o}C. The 20% decrease of the tungsten conductivity leads to an increase of 12 ^{o}C in the system maximum temperature.

Temperature evolution



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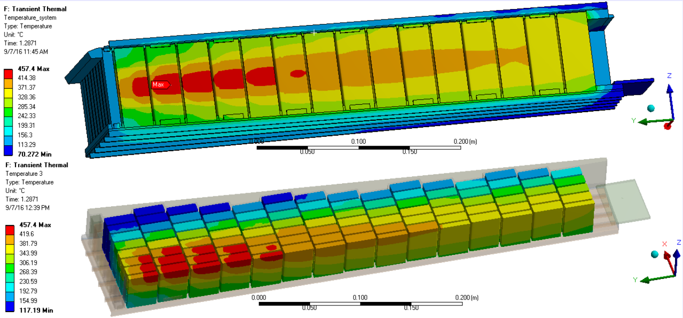
Temperature evolution. End of pulse



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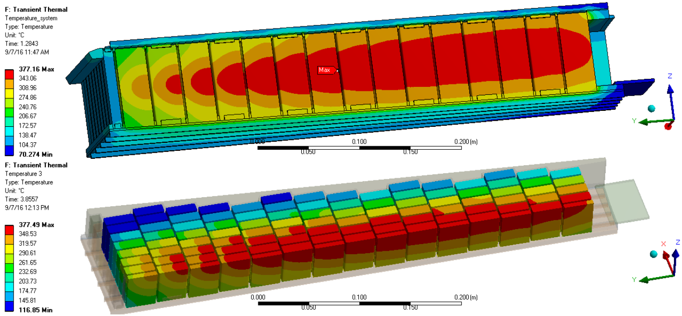
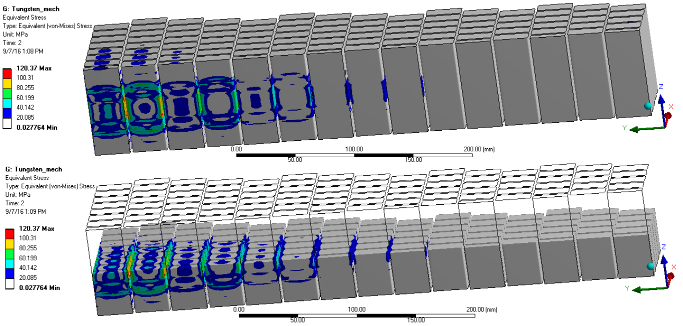


Low conductivity

Mechanical analysis SF1 conditions (Design Beam)

The maximum equivalent stress is 56 MPa at the end of the cooling and 120 MPa after the pulse. The 20% decrease of the conductivity increase by 10 MPa in the spallation material maximum equivalent stress.

Von misses equivalent stress. End of pulse



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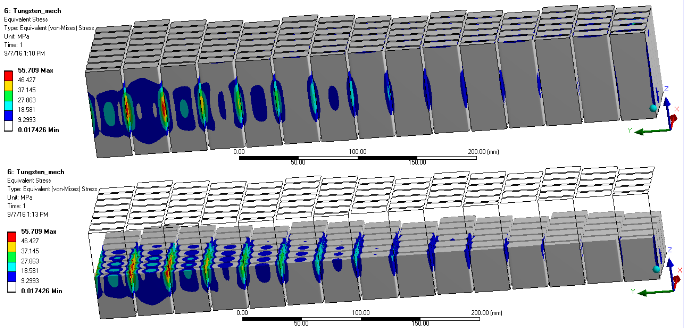


Design power increase

Design power increase

Uncertainty on beam instrumentation

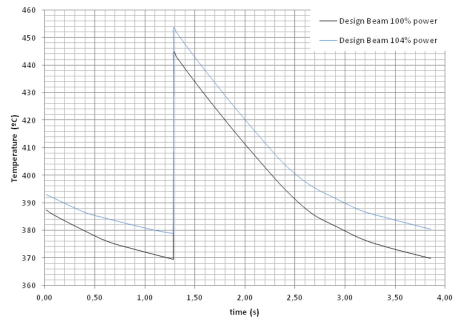
Beam instrumentation will have some uncertainty in the evaluation of proton energy and beam intensity. Based on that the maximum beam power on target could be increased by a 4% (up to 5.2 MW). Taking into account this effect, the spallation material behavior is evaluated.

Design power increase

Thermal analysis for SF1 conditions (Design Beam)

The maximum temperature at the end of the cooling is 379 °C and after the pulse is 453 °C. The increase of temperature compared with the 100% power is less that $5^o C$.

Temperature evolution



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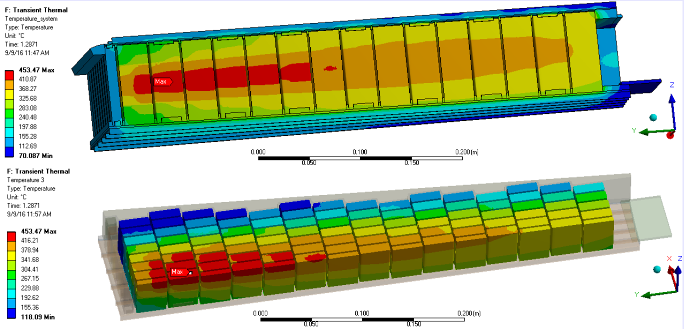

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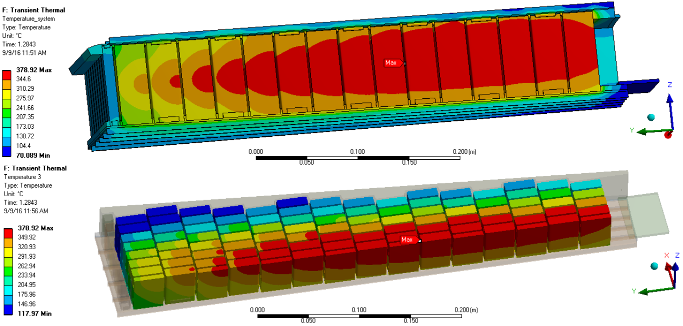

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The maximum equivalent stress is 56 MPa at the end of the cooling and 120 MPa after the pulse. The 20% decrease of the conductivity increase by 10 MPa in the spallation material maximum equivalent stress. There is no significant increase of stress.

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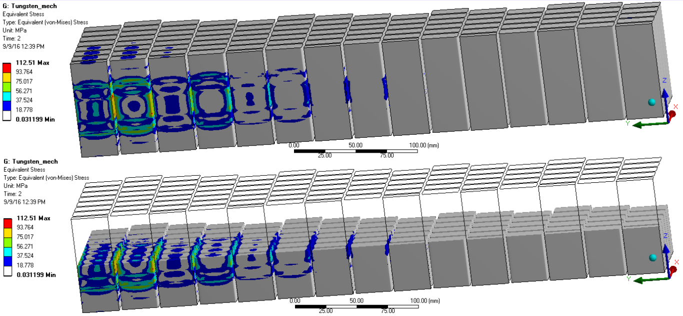

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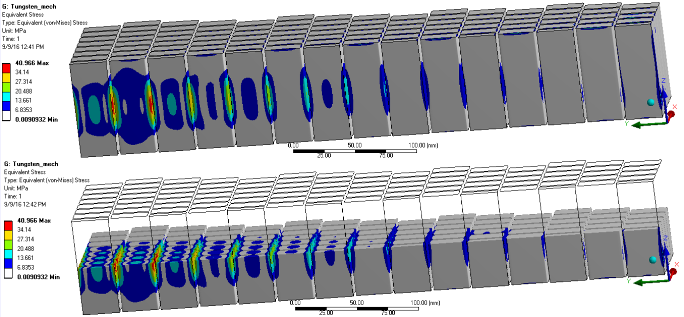

Conclusions

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Summary of sensitivity cases

	Temp. (^oC)	Max. Temp. Criteria (^oC)	Stress (σ)	Max. Stress Criteria (σ)
Nominal Beam	420	500	76	100
Low conduct.	457	500	88	100
104 %	453	500	77	100

Conclusion

Taking into account the conclusions from "SF3: Loss of coolant flow and pressure", the concept is robust under changes on boundary conditions.