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First Wall Quality Mockup Testing

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Outline

- Background on ITER first wall
- Testing conditions at SNL
  - Test article
  - Heat flux conditions
- What is the failure criteria?

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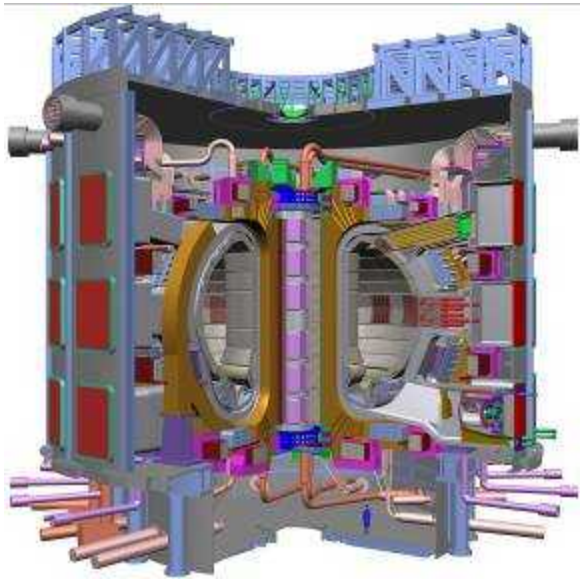
ITER is an International Project



ITER

- **ITER is being built by 7 parties**
- **Unlike for other components where one or two parties are collaborating…**
- **<u>SIX</u> different parties are building the first wall**

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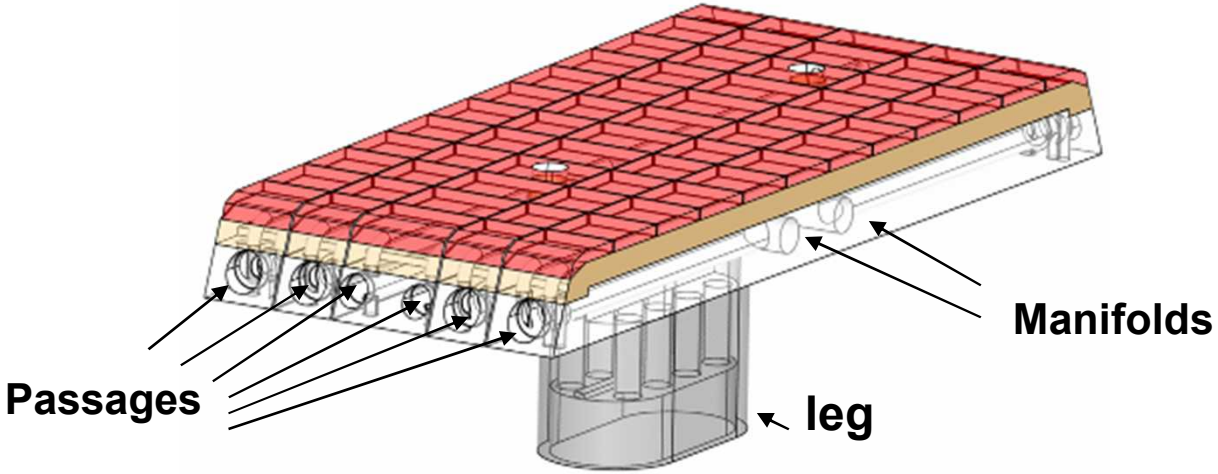
First wall-the initial heat and radiation barrier for the vacuum chamber

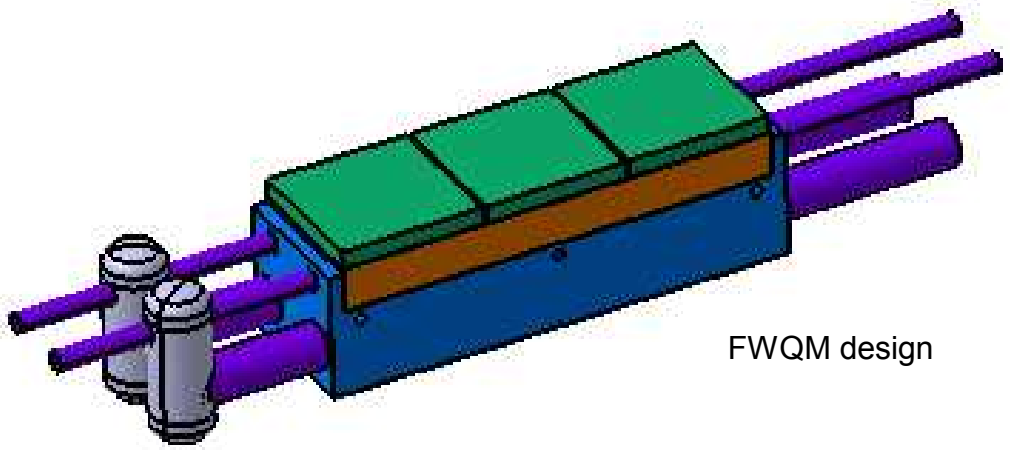
- Steady state heat load
  - 10,000 “shots” at 0.25-0.50 MW/m^2 of surface heat
  - 20,000 shots at below 0.25 MW/m^2 of surface heat
  - Approx 6 MW/m^3 of nuclear heating from the neutrons (exact estimates vary with nuclear analysis)
- MARFE
  - 1,000 shots between 0.5 and 1.4 MW/m^2 <10s long
- VDE
  - 10 shots with <60 MJ/m^2, <0.2 s long

First Wall Design



- Beryllium tiles that are between 57-90 mm wide and long, 10 mm thick
- Cu alloy substrate (C18150) with embedded stainless steel tubes and water coolant inside that is 22-25 mm thick
- Stainless Steel (316LN) with water coolant passages
- Water coolant flows about 3 m/s through 10 mm diameter tubes in copper alloy, temperature 100-120 C

Test Article



FWQM design

- The ITER international organization (IO) has proposed a mockup to be used for qualification of the joining process
- Mockup uses typical tile sizes, copper alloy thicknesses from the inboard vacuum vessel
- But does not include the curved tubes that are in the real first wall.
- Parties are required to make 3 mockups and have 2 that pass fatigue tests
- Test conditions were proposed by IO which includes slowing water velocity to make up for lack of neutronic heating

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Mockups will be tested in US or EU

- The US facility is the Plasma Materials Test Facility at Sandia National Laboratories
- We plan to use EB1200 which has an electron beam that can be focused and moved across the beryllium tiles

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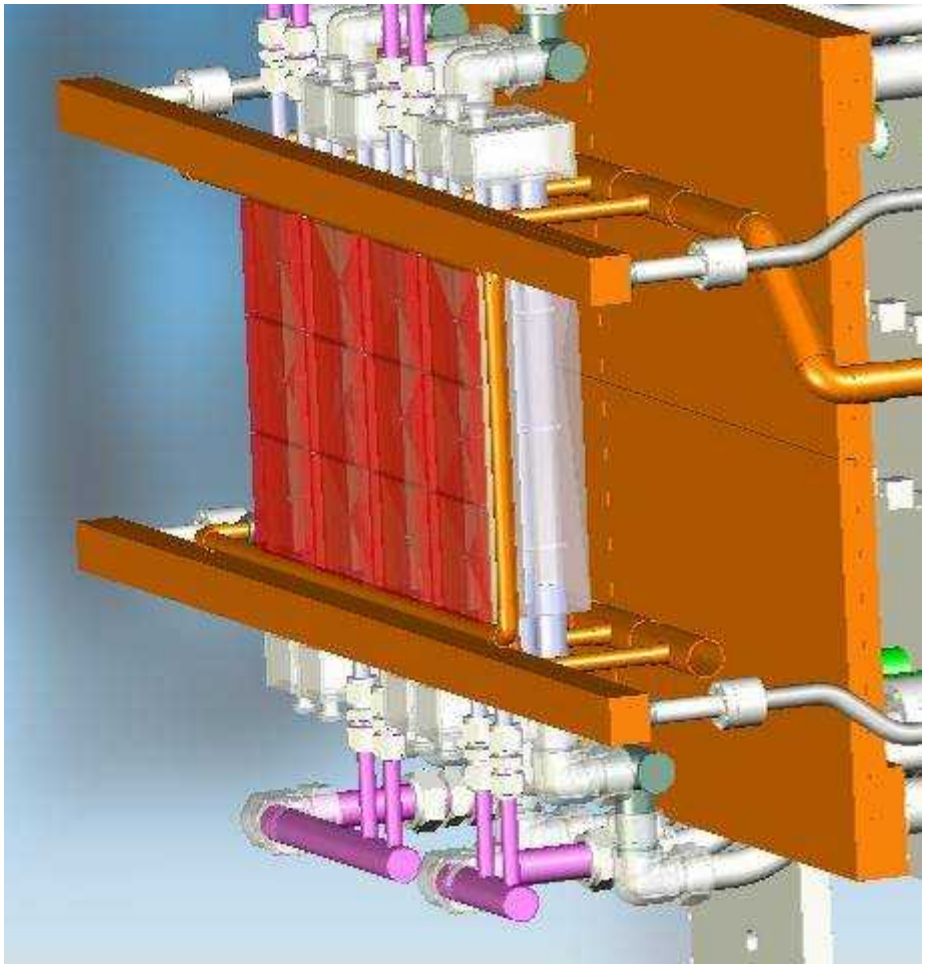
Test conditions at SNL

- **We plan to test four FWQM at one time using 2 e-guns**
- **Detection of failure with IR cameras**



Heat flux on tiles	0.7 MW/m^2
Coolant velocity in tubes	**1 m/s**
Coolant Temperature	100 C
Number of cycles	12,000
Cycle time (on and off)	96 s

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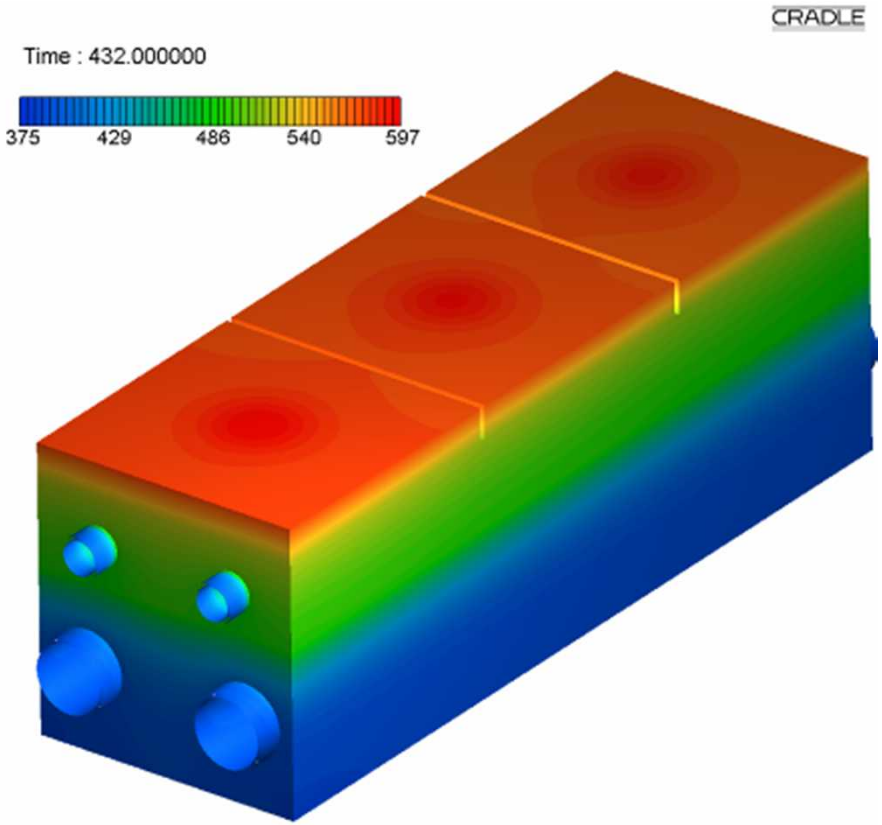
Expected temperatures for test conditions



Max Temperature/ BeCu interface	227 C
Min Temperature/ BeCu interface	127 C
Max Temperature/ Be	282 C

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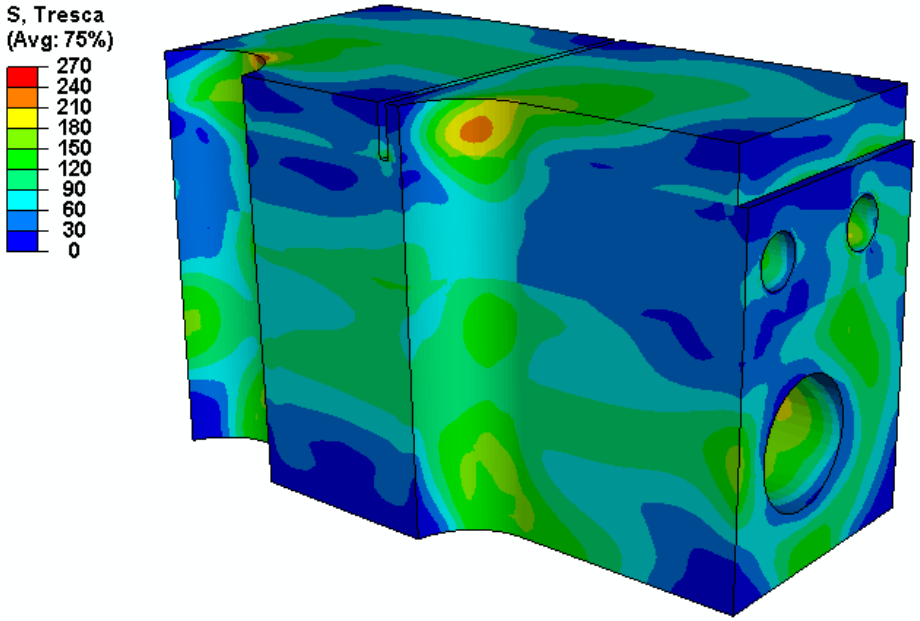
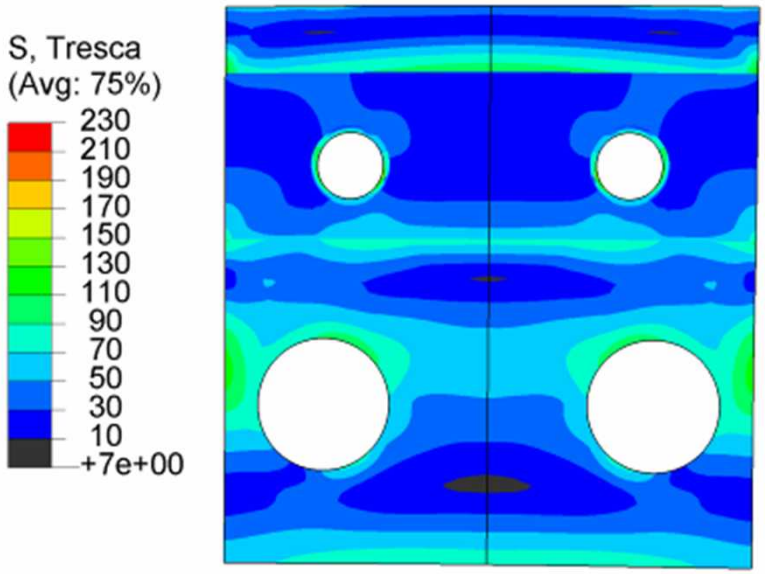
Stress calculation comparisons





First wall stresses calculated with plasma and neutron heating

Max stress near BeCu interface* 90 MPa
Min stress near Be Cu interface* 37 MPa

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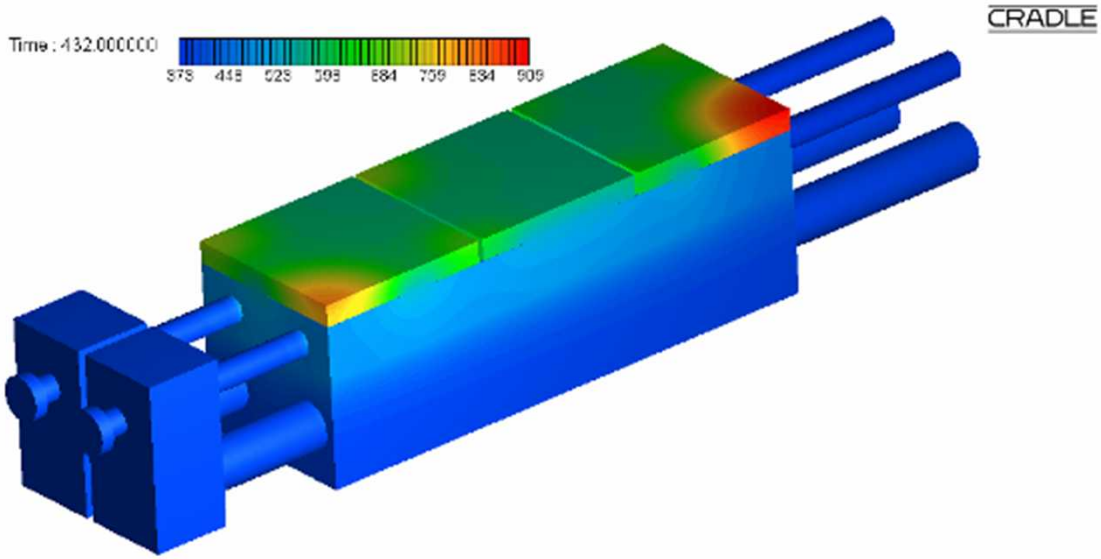
Failure criteria

- If at any time, the average temperature on any 100 mm^2 local area minus the average temperature on the whole Be top surface is greater than 50 C, the mockup has failed.
- This will be determined by IR camera for PMTF



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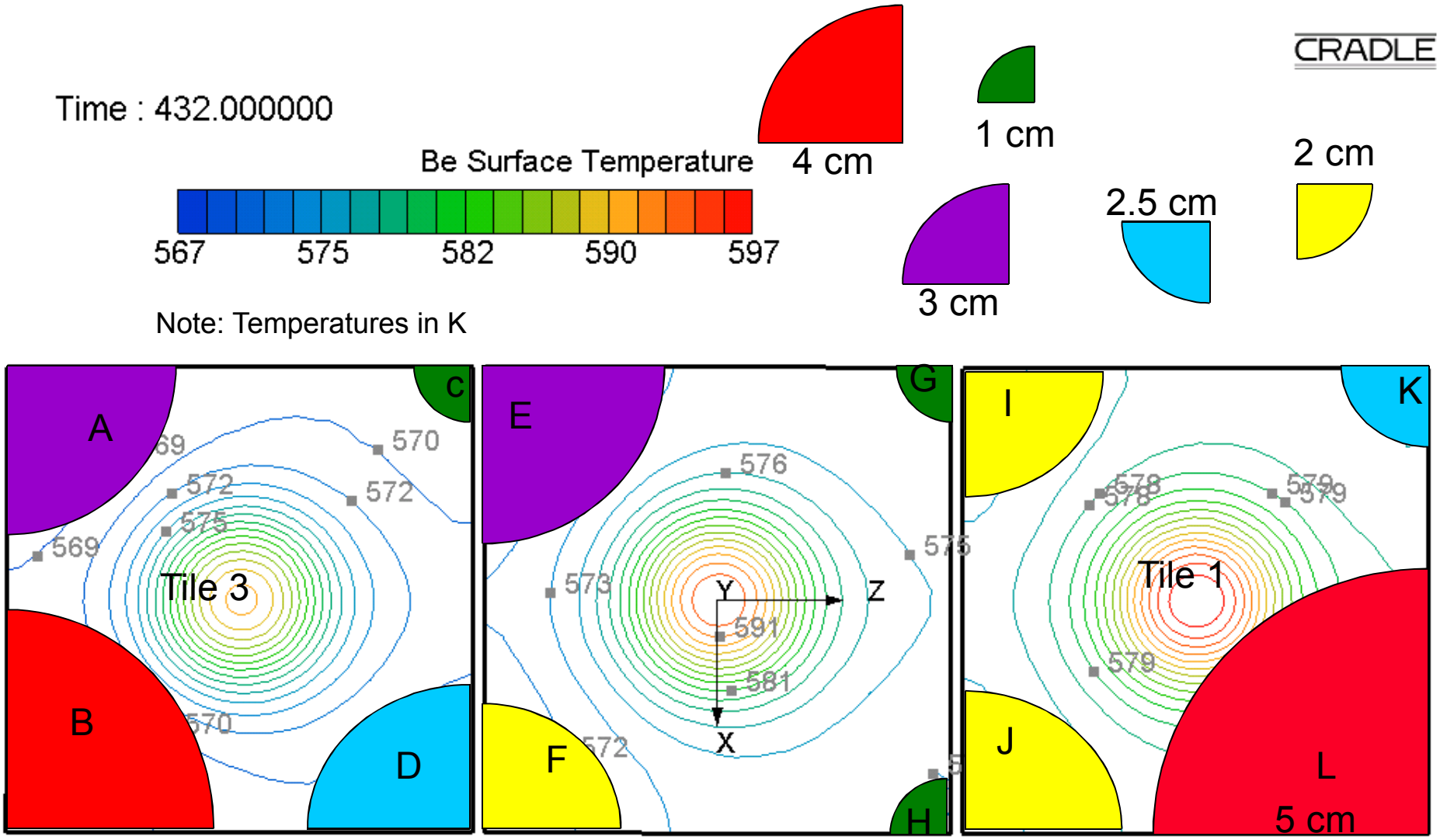


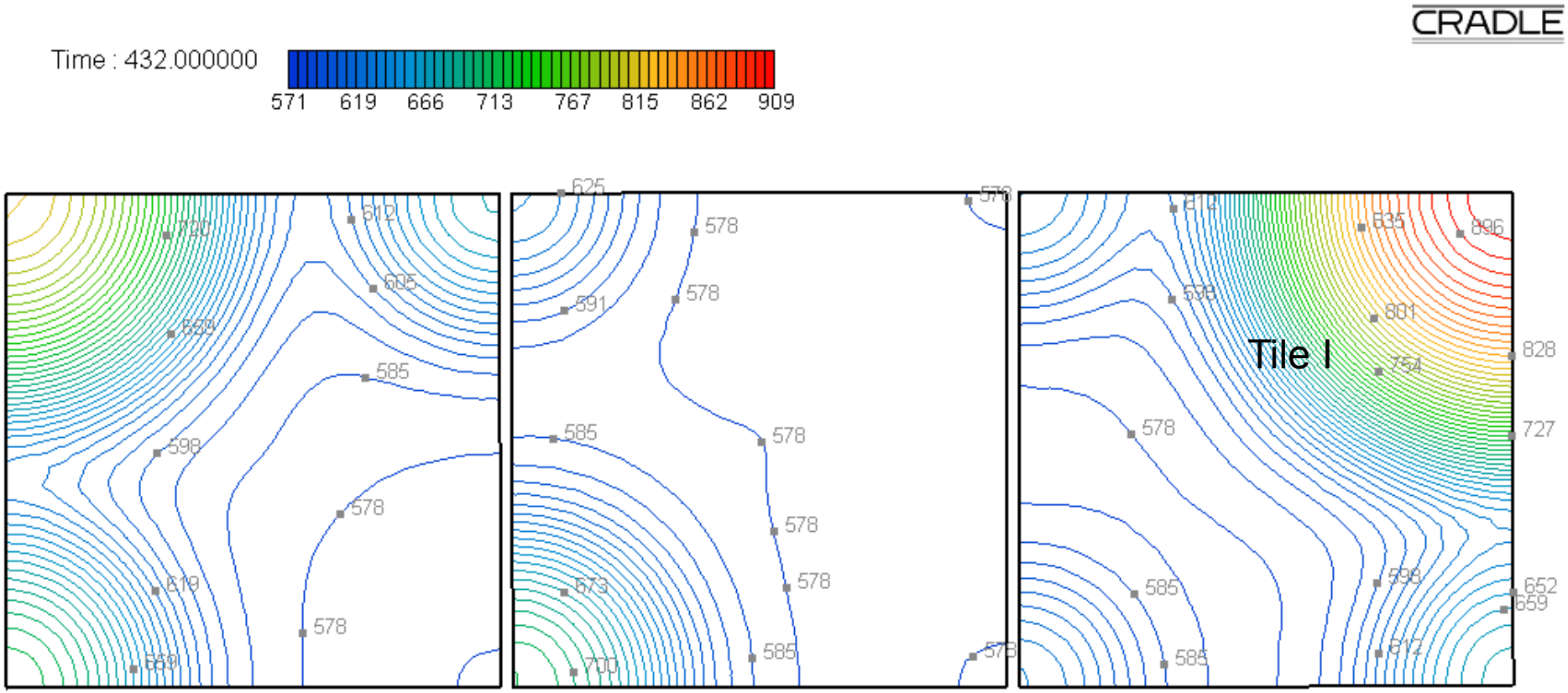
Various flaw sizes under study

In this set of calculation, a flaw means 0.1 mm deep gap of void in Be near Be/copper interface

Be surface temperature for different flaw sizes

Coupled effect appear not significant

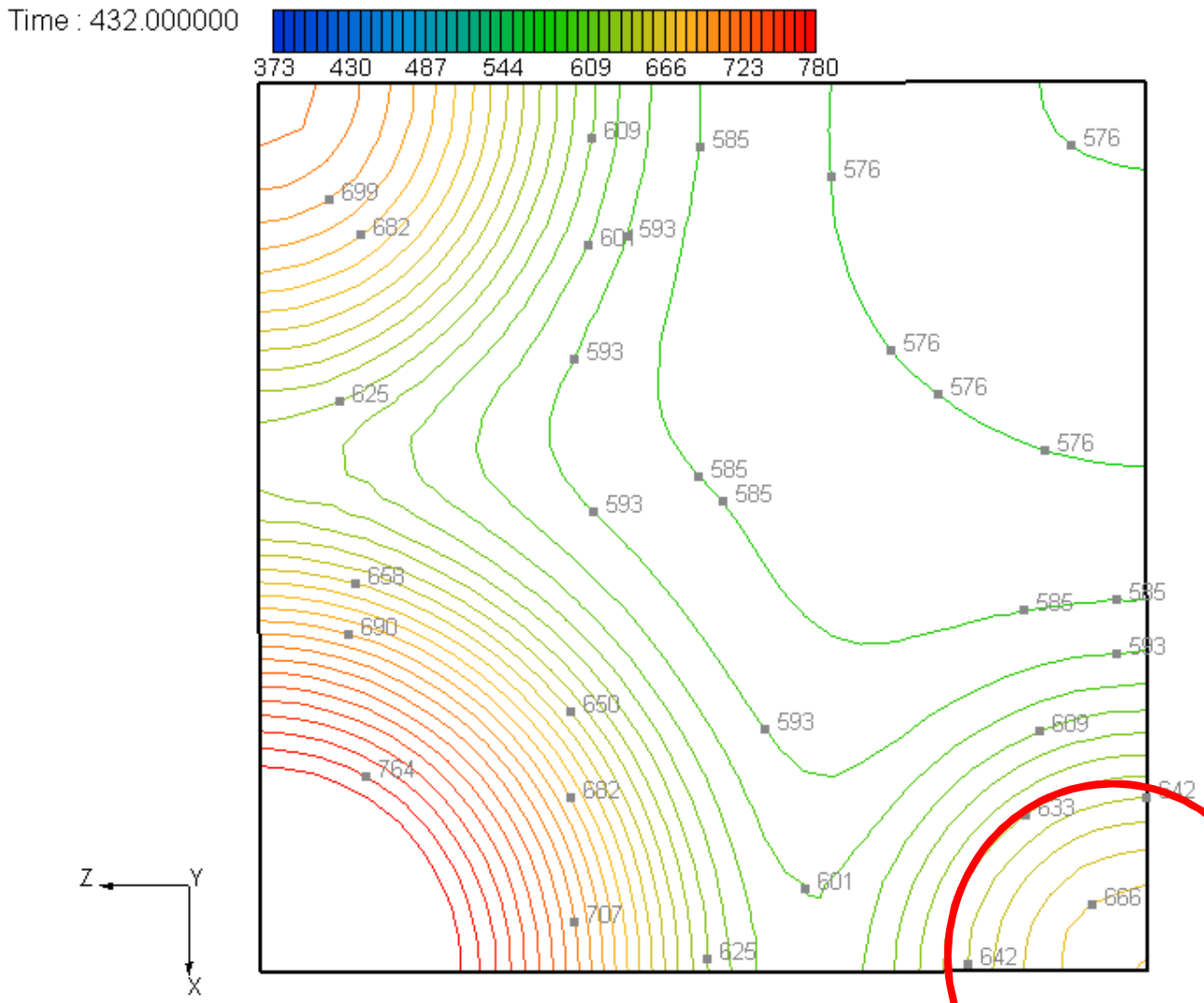
A flaw size of ~ 2 cm radius quarter circle creates a spot area of 100 mm^2 or larger with ΔT 50^oC higher than temperature under normal operating condition



Temperature (Kelvin)

T_{max} under normal operating condition for Tile III= 578K

Tile III Be surface temperature details



Temperature contour results from a 2.5 cm radius quarter circle flaw

A100 mm² Spot with T 50 degree higher than T_{normal}

Summary

- First Wall Quality Mockup testing will determine if a party team is qualified to manufacture first wall panels
- Testing will be performed at PMTF (Sandia National Laboratories) on an electron beam facility or in EU
- The failure criteria for the US facility is dependent on the surface temperature; a 100 mm^2 area that is 50 C above rest of tiles
- Predicted flaw size calculated to generate the failure criteria is a 25 mm radius quarter circle

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Acknowledgements

- ITER International Organization in Caderache, Kimihiro Ioki and Xiaoyu Wang for technical specifications and determination of the mockup test conditions
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