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First Wall Quality Mockup Testing

ITER FWQM 5 meeting

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Caderache, Fr

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Outline

- Testing conditions at SNL
  - Test article
  - Heat flux conditions
- What is the failure criteria?

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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

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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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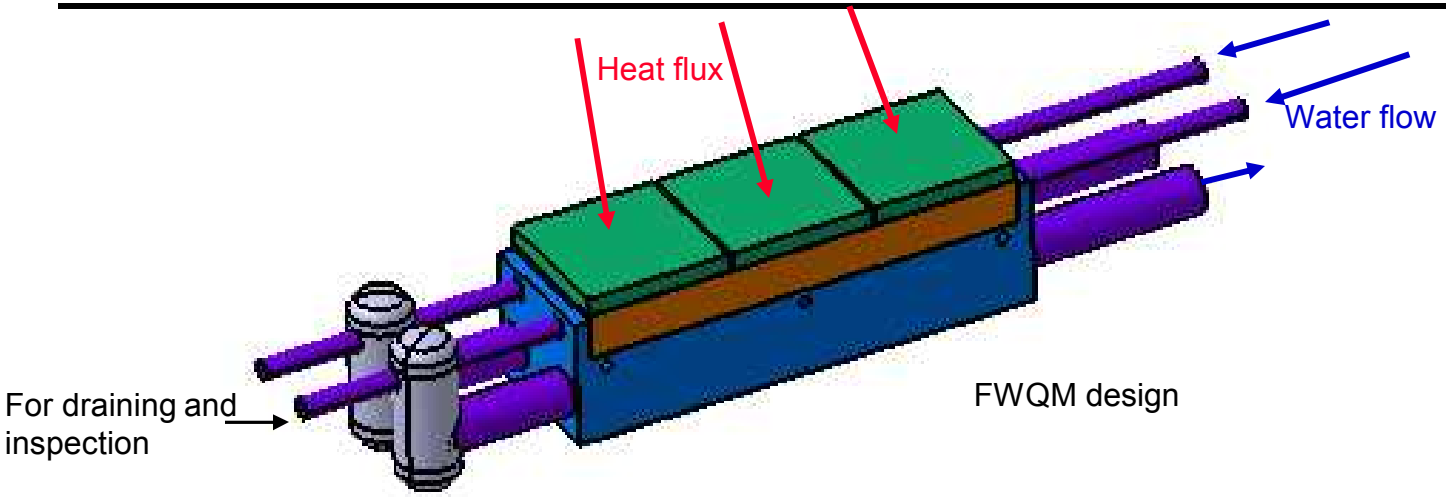
Test Article

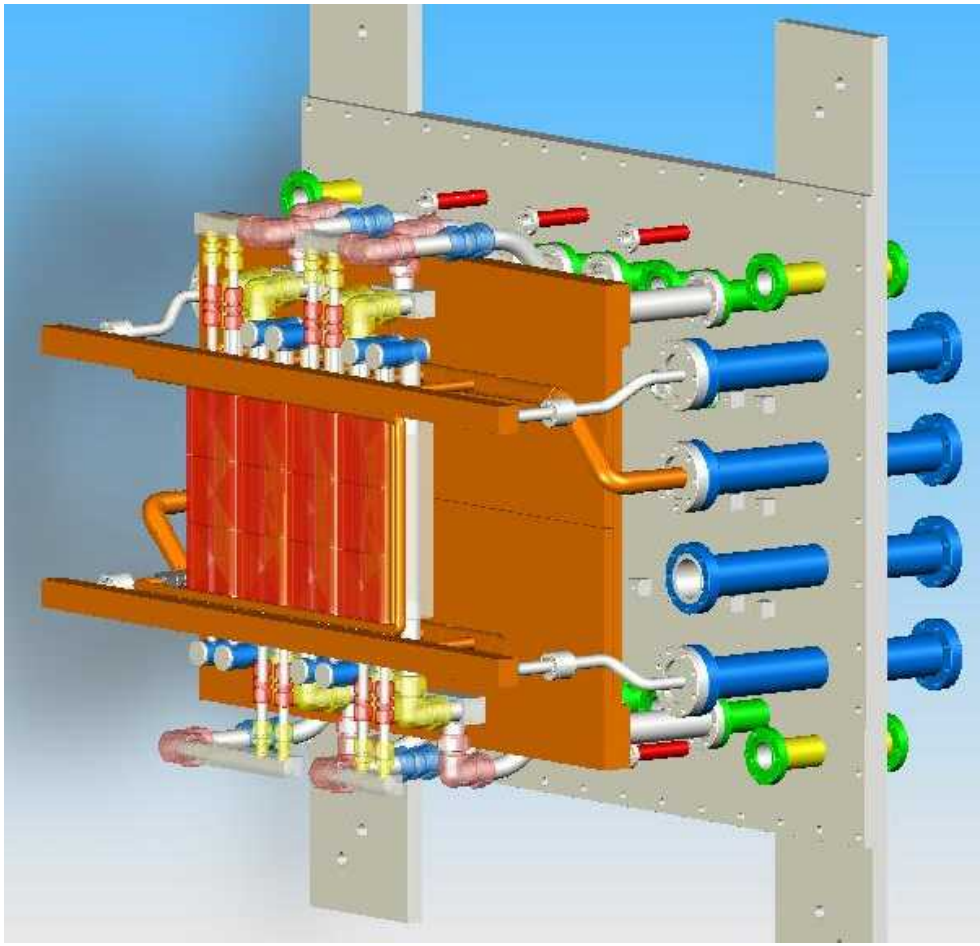


- **The ITER international organization (IO) has proposed a mockup to be used for qualification of the joining process**
- **Mockup uses typical (80 x 80 x 10 mm) tile sizes, copper alloy thicknesses from the inboard vacuum vessel**
- **But does not include the curved tubes that are in the real first 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 neutron heating**

Test conditions at SNL

- **We plan to test four FWQM at one time using 2 e-guns**
- **2 IR cameras will determine surface temperature**
- **Coolant velocity slowed to simulate neutron heating**

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
Absorbed power/cycle	13.4 kW
Temperature rise (coolant)	~20C
Cycle time (on and off)	96 s



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Testing Time Table

Facility ready	November 2007
Time to test 4 mockups	3.5 months
First set of mockups (Nov)	EU, JA, US, and ?
Second set of mockups (Apr)	CN, KO, ? and ?

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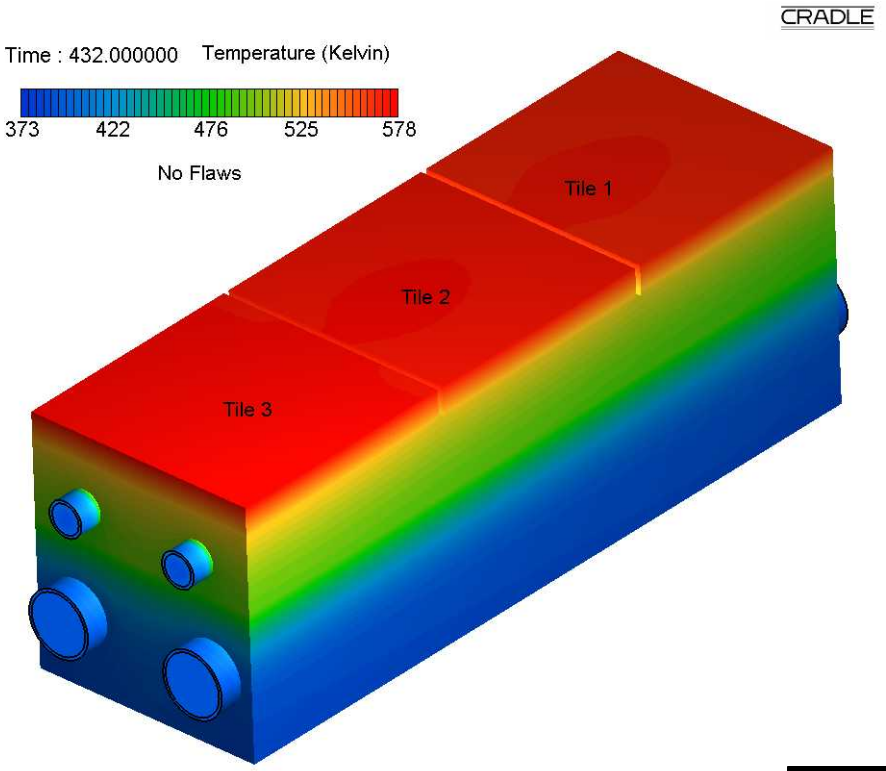
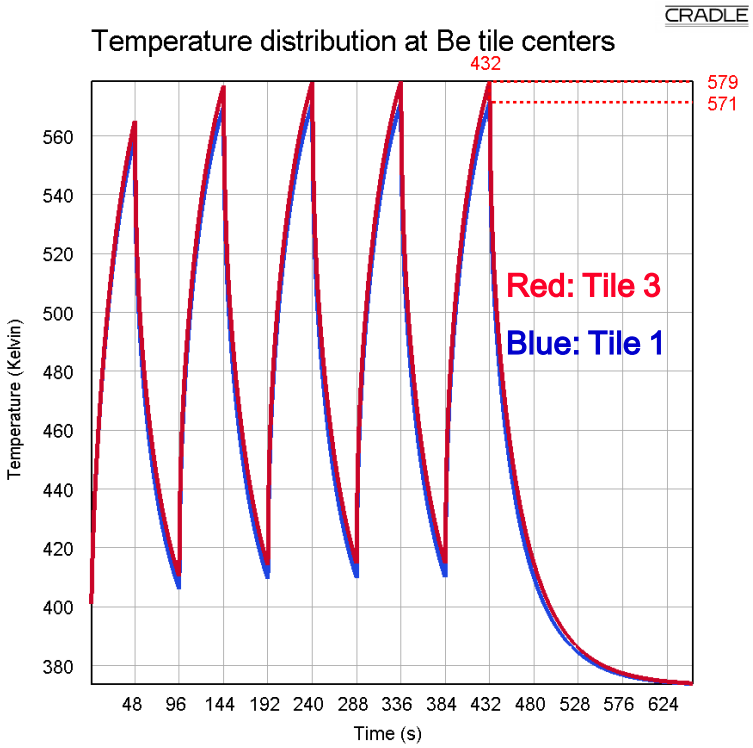
Diagnostics

- 3 TC's per mockup installed 2 mm above Be/Cu interface-spring loaded and provided by USPT
- Flow meters on total flow into each mockup
- RTD on water inlet and outlet for each mockup at the door position for calorimetry
- 2 IR cameras to measure surface temperature, 1 camera for 2 mockups
- Pressure drop outside of door
- 2 IR pyrometers-backup for interlocks
- Video recording of visible image

Expected temperatures for test conditions (No flaws in Be-Cu joint)



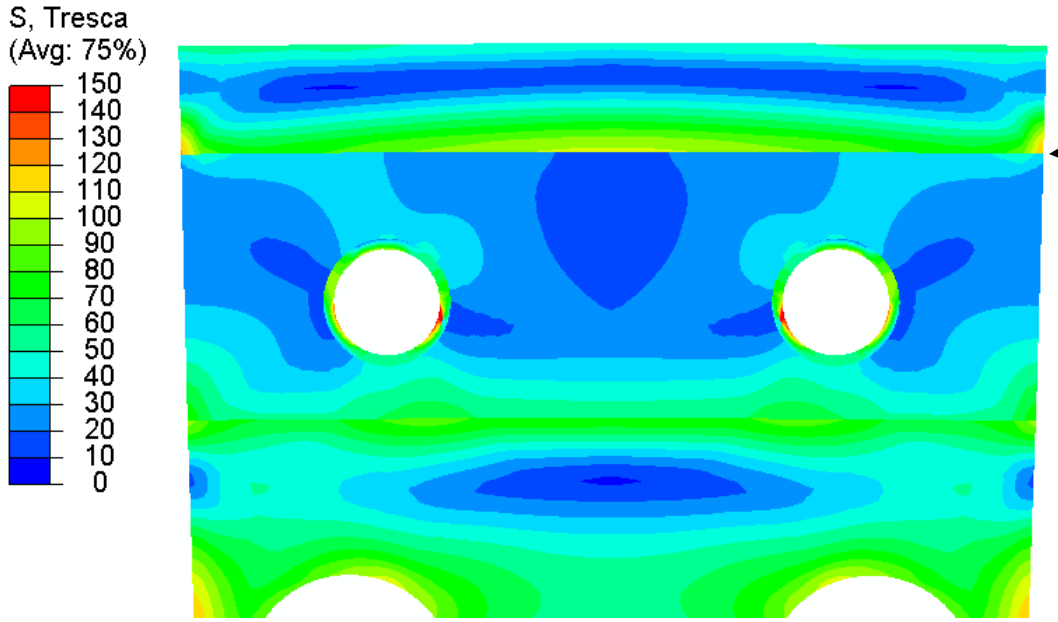
FWQM temperature distribution at 432 seconds into heating cycle



Tiles subject to 5 heating cycles of 48 seconds each. (48 sec on 48 sec off)

Max Temperature/ Be-Cu interface	~250 C
Min Temperature/ Be-Cu interface	~235 C
Max Temperature/ Be	~300 C

How will a mockup fail?



2D generalized plane strain calculation using ABAQUS

- **We expect failures to start at the edge of the tile, where stresses are higher**
- **If the Be tile starts to peel up from Cu, we expect that the surface temperature will increase because the tile is no longer well connected to the heat sink**

Failure criteria

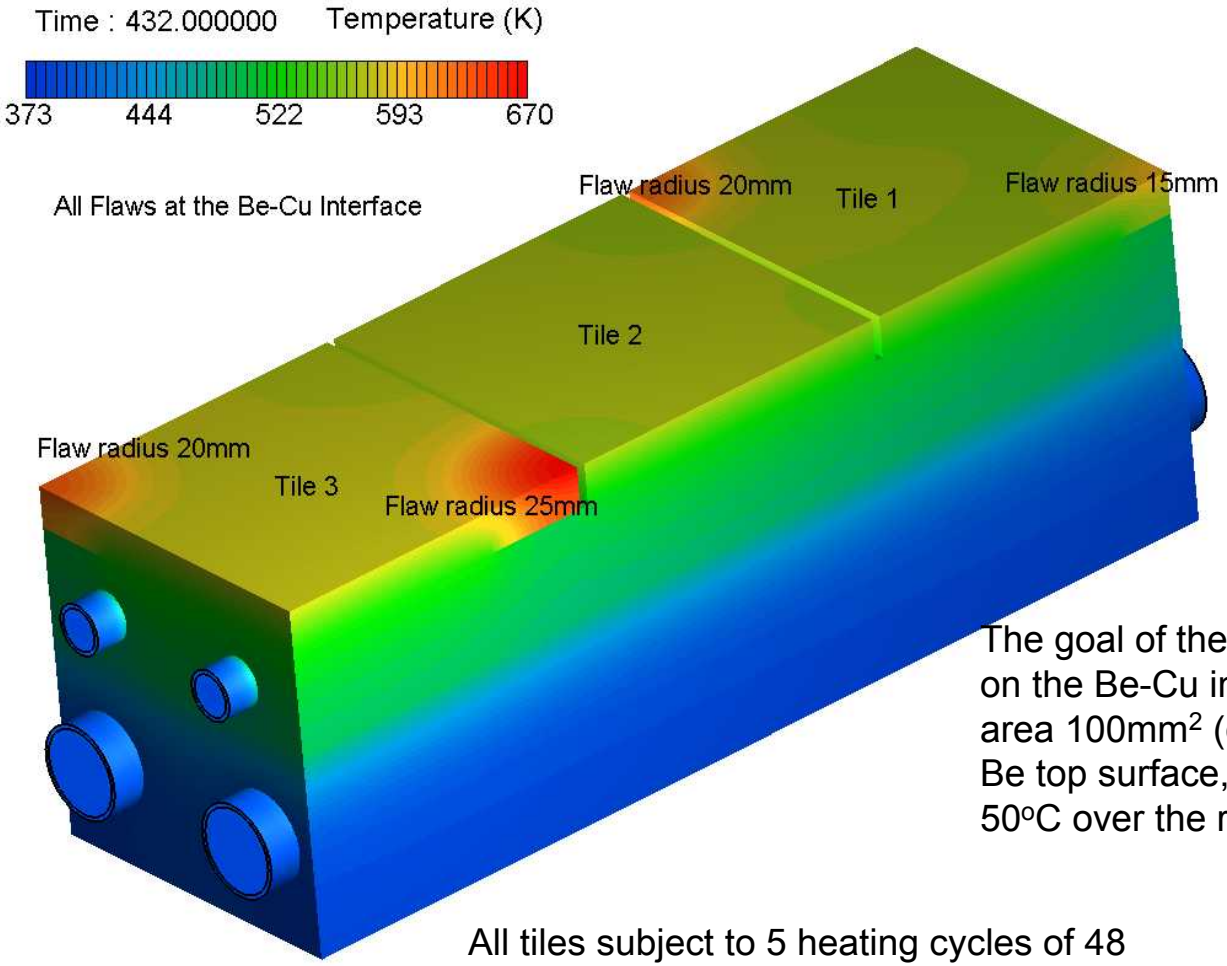
If at any time, the average temperature on any 100 mm^2 local area minus the average temperature on the whole Be top surface is greater than 50 ºC, the mock-up has failed

- **This will be determined by IR camera**
- **The IR camera has 220 x 400 pixels, and each mockup has a top surface of 244 x 80 mm, so 100 mm^2 is easily resolved**
- **Total temperature range of surface is expected to be 200 ºC without flaws, so a 50 ºC excursion is large**

Be-Cu Joint Flaw Size Study

A series of four quarter circular regions of varying sizes were assigned zero interface conductance at the Be-Cu interface to simulate a flaw in the joint

CRADLE



Flaw sizes introduced at Be-Cu:

Tile 1: radius 15mm and 20mm

Tile 2: no flaw

Tile 3: radius 20mm and 25mm

The goal of the study was to ascertain the flaw size on the Be-Cu interface that causes a hot spot of area 100mm^2 (quarter circle radius ~ 11mm) on the Be top surface, with a temperature in excess of 50^{o}C over the rest of the surface

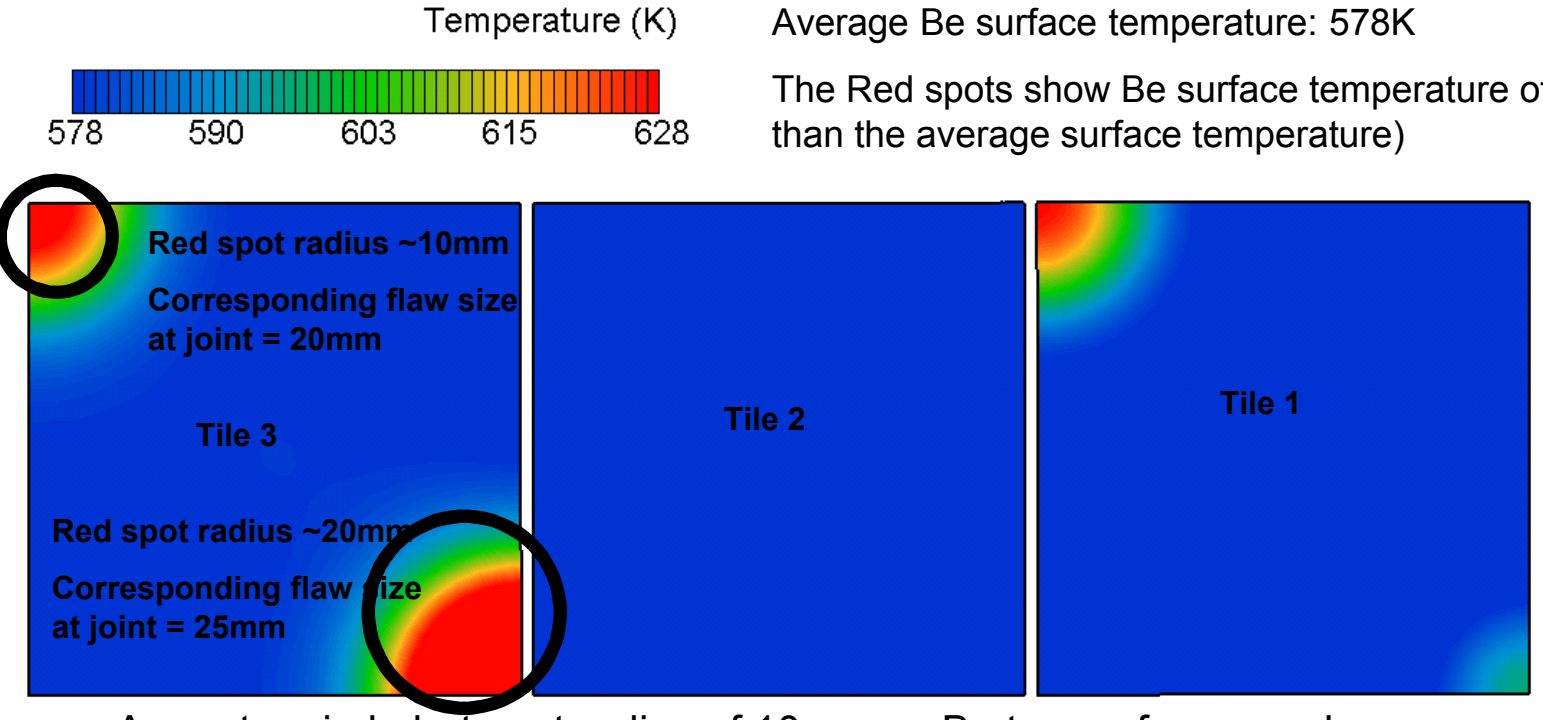
All tiles subject to 5 heating cycles of 48 seconds each. (48 sec on 48 sec off)

Be-Cu Joint Flaw Size Study

Be-Top surface temperature distribution under Be-Cu joint flaws at the end of 5th heating cycle CRADLE

Average Be surface temperature: 578K

The Red spots show Be surface temperature of 628K (50° more than the average surface temperature)



A quarter circle hot spot radius of 10mm on Be top surface equals an area of ~80mm^2

Hence a flaw size (for quarter circle flaws) of over 20mm and under 25mm will cause a hot spot on the Be top surface with a temperature in excess of 50°C from the rest of the surface.

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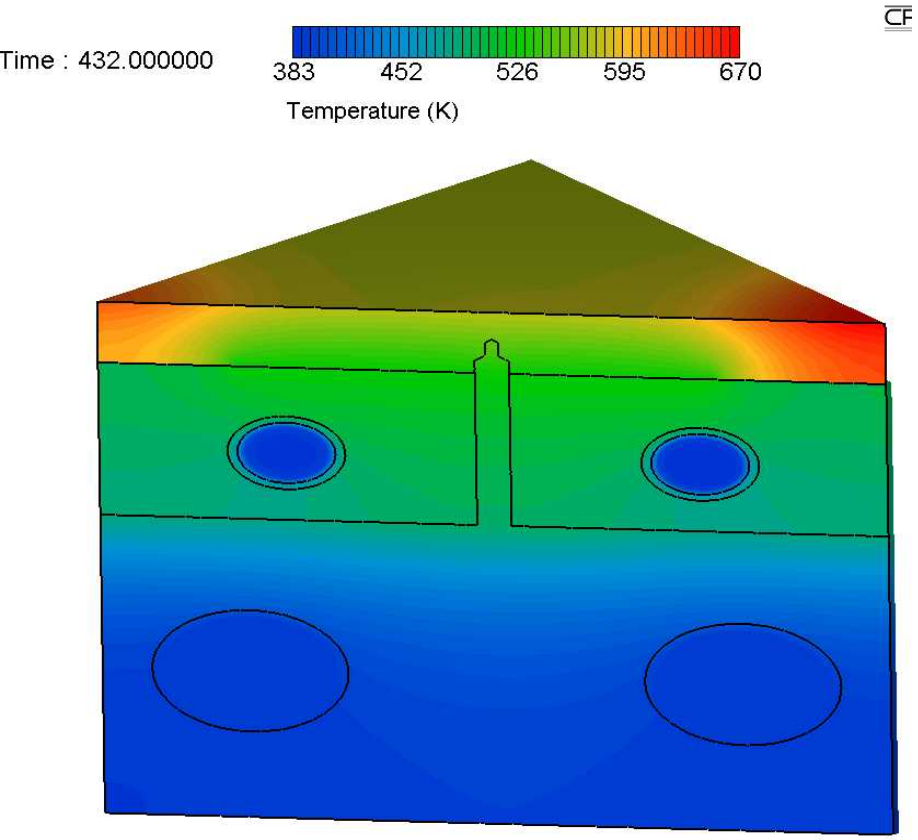
Effects of flaws on TC temperatures



Tile 3 cut diagonally

- Heating due to flaws is localized
- We cannot detect a flaw in the Be-Cu joint based on TC temperatures

TC temperatures

Tile 1 (No flaws)	**257.0 °C**
Tile 1 (With flaws)	**257.5 °C**

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Summary

- Testing will be performed at PMTF (Sandia National Laboratories) on an electron beam facility
- The failure criteria for the US facility is dependent on the surface temperature; a 100 mm^2 area that is 50 ºC above rest of tiles
- Predicted flaw size calculated to generate the failure criteria is a 20-25 mm radius quarter circle
- We cannot detect a flaw in the Be-Cu joint based on TC temperatures

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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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