Measurements of the Effective Thermal Conductivity of the ITER TF Coil Case Cooling System

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**ITER Toroidal Field Coil Cases**
- Each ITER TF winding pack is enclosed in a thick stainless steel case:
  - Provides mechanical support
  - Also acts as a thermal screen
  - During operation, the coil case is subjected to:
    - Eddy current heating
    - Nuclear heating
    - Static heat loads: conduction and radiation
  - The TFCCs are cooled by He at 4.5 K circulating thru an array of pipes
  - The cooling pipes are resin-bonded to a set of grooves in the TFCC

**Finite Element Model**
- Output from THEA 1D model
- Convection boundary in 2D FEM

**Experimental measurements**
- Care to avoid thermal shock to the samples
- No signs of cracks or delamination affecting the contact conductivity
- Steady state temperature
- Time constants by fitting an exponential function to the transients
- The FEM assuming the prop of wollastonite-charged resin accurately predicts T
- The conductivity in mock-up C is dominated by the poor contact between the metallic shims and the cooling pipe
- TC1* and TC4* are ~3× higher than TA14*
- The time evolution is 15 to 50 times slower compared to mock-ups A and B

**Conclusions**
- A four point bending process introduces a small contact resistance, but it does not compromise the overall heat conductivity
- An alternative design relying exclusively in the contact between metallic shims and the cooling pipe is not as effective as the baseline design

**Experimental set-up**
- The samples were tested in SULTAN (hanging from the 100 kA trafo)
- A constant flow of He at 10 bar and 4.5 K circulates through the pipes (1.1 to 2.7 g/s)
- A steady state heat load is applied in the sample heater (5 to 30 W)
- The effective thermal conductivity is evaluated by comparing the measured temperature distribution with the predictions from a finite element model

**TFCC Mock-up samples**
- Mock-ups A and B explore the effective thermal conductivity in the baseline design: thermal contact given by wollastonite-charged putty
- In mock-up C the thermal path is provided by 6 pairs of stainless steel and copper shims
- A heater is installed in each mock-up
- Cernox sensors (range 4 to 325 K) are used to measure the temperature
- Mock-up B was also tested after a four point bending at room temperature

**Eddy current heating**
- Nuclear heating
- Static heat loads: conduction and radiation

**Convection boundary in 2D FEM**
- Heat load applied at the bottom
- Boundary condition in the pipe imported from a 1D thermal-hydraulic model in THEA
- All other boundaries are assumed adiabatic
- Thermal properties of the putty: 3 assumptions
  1. “Epoxy-like” putty
  2. “Stainless-steel” putty
  3. Measurements of wollastonite-charged resin from KIT

**Output from THEA 1D model**
- Dittus-Boelter correlation for computing HTC
- All other boundaries are assumed adiabatic

**Mock-up C**
- The samples were tested in SULTAN (hanging from the 100 kA trafo)
- A constant flow of He at 10 bar and 4.5 K circulates through the pipes (1.1 to 2.7 g/s)
- A steady state heat load is applied in the sample heater (5 to 30 W)
- The effective thermal conductivity is evaluated by comparing the measured temperature distribution with the predictions from a finite element model