Analysis of the thermal-hydraulic effects of a plasma disruption on the DTT TF magnets

**Introduction**
The fully superconductive Divertor Tokamak Test (DTT) facility, currently under construction in Italy, will test several DEMO-relevant divertor solutions.

**4C code model**
- 18 TF coils
- \( I_{\text{op}} = 42.5 \) kA

**Winding Pack (WP)**
- \( \text{Nb} \) base OCC
- \( \text{Double} \) pancake wound
- 10 hydraulic channels/cell (2D model)
- \( \text{She} \) \( T_m \approx 4.5 \) K, \( p_m \approx 6 \) bar, \( \Delta T \approx 2 \) bar

**Casing**
- Stainless-steel
- 4 parallel casing cooling channels (CCC)
- \( \text{She} \) \( T_m \approx 4.5 \) K, \( p_m \approx 6 \) bar
- 16 radial/toroidal cross-sections (2D heat diffusion model)

**Cut#1**
- Nuclear heat load (without neutron shield) [W/m²]
- Turn insulation
- Inter-peninsula
- Conductive heat load from gravity support (3D WP)
- Lifeline bath at 6.5 K
- Nuclear heat load from thermal shield (TS) @ 10K
- Friction factor: modified Darcy-Fortet-Hougeron
- \( \text{She} \) CT:
- Common size for each DP at coil tore

**Cut#11**
- High heat load
- Low heat load
- Testo e figure (font Century Gothic)

**Critical current calculation**
- Magnetic field due to PF/CS/plasma accounted for [S. Turtù, 2019]
- Heat transfer with LHe bath at prescribed \( T \)
- Piping and valves in order to provide self-consistent boundary conditions to the magnet (circuit suitably scaled down to account for a single TF)

**SHe circuit**
- Preliminary model of
  - Cold circulator with realistic characteristic
  - Heat transfer with LHe bath at prescribed \( T \)
  - Piping and valves in order to provide self-consistent boundary conditions to the magnet (circuit suitably scaled down to account for a single TF)

**Driver**
- Magnetic field variation during the disruption induces AC losses in the conductor (\( t_r = 250 \) ms)
- Eddy currents in the casing computed by EM model

**Plasma disruption conservatively induced at EoF**
- The mass flow rate reacts with a strong backflow at WP inlet on the 10 ms timescale
- \( \Delta T_{\text{marg}} \) is eroded by more than 5 K during the disruption on 10 ms timescale, due to direct AC loss deposition in the WP

**Conclusions and perspective**
- Thermal-hydraulic effects of a plasma disruption at EoF in DTT TF coils analyzed with the 4C code:
  - almost the entire temperature margin is eroded by the power deposited during the disruption at EoF
  - the coil is close to current sharing
- In perspective:
  - assess the impact of input uncertainties (\( m, \text{eddy currents}, ... \)) and of a fast current discharge following the plasma disruption

**Temperatures**
- \( T_n = 4.5 \) K (and the magnetic field) is assumed constant (as that at EoB) during the disruption
- \( \Delta T_{\text{marg}} \) in DTT TF coils analyzed with the 4C code:
- \( \Delta T_{\text{marg}} \) is eroded by more than 5 K during the disruption on 10 ms timescale, due to direct AC loss deposition in the WP

**Plasma disruption conservatively induced at EoF**
- \( \Delta T_{\text{marg}} \) is close to the target value (1.4 K) within \( \pm 1 \) K
- \( \Delta T_{\text{marg}} \) is reached at End of plasma Flat-top (EoF)

**Thermal effects**
- EoB
- \( m_f \) (without neutron contact) when the coil is charged
- \( m_f \) (with neutron contact): \( m_f = 250 \) ms

**AC losses in the conductor**
- \( AC_{\text{losses}} = \frac{1}{2} I^2 R_{\text{losses}} \)
- \( R_{\text{losses}} \) depends on the current and the magnetic field

**Power deposition heats-up**
- directly the WP on \( 10 \) ms timescale
- the casing \( \Rightarrow \text{heat is transferred to WP on} \) \( 10 \) s timescale (no effect on the \( \Delta T_{\text{marg}} \) because involves outermost turns, where \( B \) is lower (and \( T_m \) is higher))