PCCE - A PREDICTIVE CODE FOR CALORIMETRIC ESTIMATES

IN ACTIVELY COOLED COMPONENTS INTERESTED BY PULSED POWER LOADS

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During operations of fusion experiments, some components can be interested by high heat fluxes, that can lead to local damages and component burnout if the heat load is not dissipated by a proper cooling system. Among these high heat flux components, there are for example some parts of the Neutral Beam Injectors (drivers, back plate, acceleration grids, neutralizer, residual ion dump, calorimeter), of the Radio Frequency antennas, of the Divertor and of the Blanket.

Measuring the temperature and thermal energy can be useful for the design and correct dimensioning of fusion experiments, and to have information on the energy fluxes inside the machines for monitoring them during operations. In particular, measuring the energy absorbed by these components during short pulses can be useful before operating the experiment with long pulses, which are much more critical because of the risk of damages.

The analytical interpretative models for calorimetric measurements found in literature can consider close systems (without heat exchange with the external environment) in steady-state and transient conditions, or open systems (with heat exchange with a cooling fluid flowing in the component) but only in steady-state conditions. The PCCE code (Predictive Code for Calorimetric Estimations), here presented, introduces some novelties in this regard. In fact, it can simulate with an analytical approach both the heated component (to be kept under observation) and the cooling circuit (where the temperature and flow measurements are usually made), evaluating the heat fluxes due to conductive and convective processes both in steady-state and transient conditions.

The main goal of this code is to model heating and cooling processes in actively cooled components interested by pulsed power loads, that are not easily analyzed with purely numerical approaches (like Finite Element Method or Computational Fluid Dynamics). A dedicated mathematical formulation, based on concentrated parameters, has been developed with this goal and is here described in detail. In order to better explain the models of the thermal analysis, an equivalent electric circuit is introduced and often referred to. Following this approach, a set of relationships can be found between the main involved parameters, i.e. the component's mass, its geometry and material, the coolant type and mass flow, the coolant inlet and outlet temperatures, the time needed for a complete heating and cooling of the component. A numerical routine is then iteratively implemented in the code to refine the solution by setting the parameters to proper values, following non-linear functions of the coolant and component temperatures.

After a comparison and benchmark with other commercial codes, the PCCE code is applied to predict the calorimetric parameters in simple scenarios of the SPIDER experiment.