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Testing and Nuclear Qualification Strategy for CFETR Breeding Blanket

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Breeding Blanket is in charge of breeding tritium for tritium self-sufficiency, shielding neutron for environment protection and extracting fusion energy for electricity generation. There are three candidate blankets for Chinese Fusion Engineering and Test Reactor (CFETR), including the Helium Cooled Ceramic Breeder (HCCB) Blanket, Water Cooled Ceramic Breeder (WCCB) blanket and supercritical CO2 cOoled Lithium-lead (COOL) blanket. The operating conditions and functional requirements for blanket are critically harsh, and this is resulted from the multiple effects of nuclear, electromagnetic, thermal hydraulic, thermal-mechanical as well as the tritium safety issues. Installation of a breeding blanket in CFETR without prior fusion testing is found to result in high risks of not attaining the required tritium self-sufficiency, blanket system reliability and an adequate device availability. Therefore, in the support of Comprehensive Research Facility for Fusion Technology (CRAFT), the testing and nuclear qualification strategy for CFETR blankets will be performed, as the followings: (1) The water / S-CO2 loop with high temperature and pressure will be used for thermal hydraulic test on the blanket structural components, i.e. High Heat Flux (HHF) test on the FW with one-side heating, Critical Heat Flux (CHF) occurrence, flow distribution into different components and channels, as well as the flow instability for parallel channels; (2) The PbLi loop can be used to study the MHD effects, including the phase diagram/turbulent transition mechanism under different Re/Ha, MHD flow in complex geometry channel and multi-channels under electromagnetic coupling effects. The more importantly, it is can be further used to test the ability of FCIs minimizing the pressure drop under magnetic field, and quantify the performance of material corrosion resistance; (3) Using the pebble beds experimental platform, we can test the flow / heat transfer performance between the purge gas and pebble beds, characterizing the thermal expansion stress using the thermal-mechanical facility, mixing and sieving the pebbles, and analyzing the packing structure using CT, as well as carry out the packing structure stability using the vibration facility; (4) Using the Oxide Dispersion-Strengthened (ODS) alloy ferritic steel, the full-sized blanket module will be manufactured and hydraulic tested through the 3D printing technology, and this aims to reduce the welding joints for high thermal-mechanical strength; (5) The nuclear test for tritium generation for the scaled mockup of WCCB has been finished, and the test for COOL blanket is under going, in which the Tritium Production Rate (TPR) will be measured using the DT neutron source, combined with the 6Li glass on-line measurement lithium glass detector and offline liquid scintillator. This aims to understand the uncertainty degrees deviation from the target of tritium self-sufficiency, i.e. the nuclear reaction cross-section, analysis codes and the spacial distribution of neutron source. Therefore, the above various testing and qualification will ensure the confidence of attaining the required tritium self-sufficiency and system reliability before the installation of blanket into the CFETR.

Speaker's title

Mr

Speaker's email address

jiangkecheng@ipp.ac.cn

Country/Int. organization

China

Affiliation/Organization

Institute of Plasma Physics, Hefei Institutes of Physical Scienc

Authors: JIANG, Kecheng (Institute of Plasma Physics, Hefei Institutes of Physical Science, Chinese Academy of Sciences); Mr CHEN, Lei (Institute of Plasma Physics, Hefei Institutes of Physical Science, Chinese Academy of Sciences); Mr ZHU, Qingjun (Institute of Plasma Physics, Hefei Institutes of Physical Science, Chinese Academy of Sciences); Mr LIANG, Qingzhu (Institute of Plasma Physics, Hefei Institutes of Physical Science, Chinese Academy of Sciences); Mr LIU, Songlin (Institute of Plasma Physics, Hefei Institutes of Physical Science, Chinese Academy of Sciences); Mr MA, Xuebin (Institute of Plasma Physics, Hefei Institutes of Physical Science, Chinese Academy of Sciences)

Presenter: JIANG, Kecheng (Institute of Plasma Physics, Hefei Institutes of Physical Science, Chinese Academy of Sciences)

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