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#4-231 Nuclear heating rate measurement in the MIT research reactor using a new compact CALORRE differential calorimeter

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To design and propose innovative nuclear instrumentation, Aix-Marseille University and the CEA as part of the LIMMEX joint laboratory (Laboratory for Instrumentation and Measurement in Extreme Environments) created in 2009 are conducting several research programs addressing key values for research reactors and tokamaks, such as fast and thermal neutron fluxes, prompt and delayed photon fluxes and intense absorbed dose rates (nuclear heating rate). A comprehensive approach has been developed particularly regarding heat-flow calorimetric sensors by coupling experimental work with 1D calculations and 3D simulations (heat transfer, ray-matter interactions) from out-of-flux laboratory conditions to irradiation campaigns in nuclear environments. Two types of calorimeter integrating at least one heater have been patented by AMU and the CEA (one differential calorimeter in 2015 (CALORRE) and one single-cell calorimeter in 2020 (Mono-CALO)). After successful tests of a first prototype of the CALORRE differential calorimeter in the MARIA reactor in November 2015, different challenges associated to this sensor type were and are targeted such as the extension of the measurement range from very low values for TRIGA reactors to high values for MTRs such as the JHR reactor, the sensor miniaturization to design a micro-sensor in the future, and the characterization of different materials for fission and/or fusion purposes.
In this context, a research program, called CALOR-I (compact-CALORimeter Irradiations inside the MIT Research Reactor), funded by Aix-Marseille University foundation (A*Midex) and involving the Nuclear Reactor Laboratory of the MIT and the CEA, began in 2020 with four main objectives: (1) the design of a new CALORRE prototype, (2) the study of this prototype from laboratory to irradiation conditions, (3) the axial mapping of an in-core channel of the MIT Research Reactor (MITR) in terms of nuclear heating rate (never realized before by a calorimeter), and (4) the comparison of measurement methods and sensors. By taking the feedback from the MARIA campaign into account and carrying out thermal and neutron modeling, a new CALORRE calorimeter prototype of reduced size and similar height to that of the usual single-cell calorimeters was defined and manufactured.
This paper will deal with the experimental study realized on this reduced-size CALORRE prototype under laboratory conditions and inside the in-core water loop of MITR in October 2024.
The first part of the paper will present the design of this CALORRE calorimeter and its main features (mass, geometry, size, materials, etc.) will be given. The second part will be dedicated to the experimental characterization of CALORRE under laboratory conditions by simulating the nuclear heating rate by Joule effect. The main metrological performances of the CALORRE prototype (sensitivity, linearity, range, reproducibility, response time and maximum temperature) will be detailed. The last part will present the results obtained during the MITR irradiation campaign. Firstly, the calorimeter vehicle placed into the water loop autoclave and its components will be shown. Then the experimental operating protocol by moving the calorimeter with the reactor in operation will be described. The influence of several experimental conditions on the calorimeter response will be presented (reactor power, axial position, temperature and velocity of the coolant fluid). The axial profile of the nuclear heating rate in the B3 channel for the fuel zone and beyond the fuel top will be shown for a reactor power of 5 MWth with different space resolutions depending on the axial position. The measured nuclear heating rate as a function of the reactor power at a specific position will be presented. A comparison of the nuclear heating rate obtained by moving or not the sensor will be realized to see the impact of the reduction of the sensor size. The nuclear heating rate measurement will be confirmed thanks to

different measurement method applied (with or without the use of the 4-wire heaters of the calorimeter) at a specific axial position. The measurement of the delayed nuclear heating rate from the reactor shutdown will presented. Finally, the reliability and the robustness of the calorimeter will be demonstrated by comparing the calibration curves obtained in the shutdown reactor before and after the irradiation campaign for different coolant fluid temperatures.

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