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SAIGA : an in-pile test largely instrumented and devoted to study the degradation of a Sodium Fast Reactor core with mitigation device in Severe Accident Conditions

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As part of the CEA's development of the Sodium Fast Reactor technology, innovative options are investigated to improve the SFR's safety in severe accident conditions. These options include an additional in-core safety system, called a mitigation device (corium transfer tube), which is designed to transfer a large fraction of the molten fuel into a core catcher and thus avoid prompt criticality. This mitigation device is designed to help to bring the reactor back to a safe state after a severe accident. CEA, with NNC-RK, are jointly preparing an in-pile test under the SAIGA (Severe Accident In-pile experiments for Gen-IV reactors and the Astrid prototype) program aiming to study the degradation of a SFR fuel pins bundle with a molten fuel discharge device for mitigation. The scenario of the SAIGA test is close to the physical conditions of an Unprotected Loss Of FLOW-type (ULOF) severe accident hypothetically encountered in a SFR.

The test device under construction is expected to be housed in the Impulse Graphite Reactor operated by NNC-RK in Kazakhstan, which is scheduled for experimental testing in 2025. This test device consists of three azimuthal sectors: two sub-assemblies of 16 fuel pins with different enrichments allowing getting two different powers and a third sector filled with sodium simulating a corium transfer tube. A sodium loop, also under construction, will be connected to the in-pile device to drive the sodium flow inside the fuels bundles. The main objectives of this SAIGA experiment are to improve our understanding of mitigation and to enrich the experimental database necessary for the validation of scientific computational tools dedicated to severe accidents.

From an experimental standpoint, the SAIGA test can be considered as a two-phase test. A first phase which aims to reach a nominal steady state of a SFR, followed by a second one corresponding to the ULOF step. While the liquid sodium is circulating at 400°C in the test section, the IGR will become critical and will quickly reach its nominal power in order to bring the test sections into a thermal equilibrium representative of the industrial sodium fast reactor conditions. This first phase during which equilibrium is reached is estimated to last less than 15 seconds.

While maintaining the reactor at power (neutron heating), the sodium flow rate will be progressively reduced, which will lead rather quickly to the sodium boiling (estimated at less than 10 seconds after starting the progressive shutdown of the pumps). The degradation of the fuel before the rupture of the tube wall between the fuel sub-assemblies is estimated between 8 and 10 seconds later.

Various physico-chemical events will rapidly follow one after another during the SAIGA irradiation test, leading to phase changes, with as consequence, the temperature rises in intensity and frequency, and the pressure evolution. In order to record these events and to improve our experimental database, which is a crucial element to validate the results of the modeling, particular care is given to the instrumentation of the SAIGA test section. Although very strong constraints (in terms of pressure, temperature, tightness and available space) are imposed, the SAIGA test section will include a significant number of different types of instrumentations which will be detailed in this paper, some of them are very innovative and all exposed to high levels of radiations.

High temperatures (up to 1800°C – 2000°C) will be monitored with 36 C-type thermocouples (1 mm outer diameter) distributed in different places, some of them wound around the fuel pins (instead of spacer wire). More than 30 K-type thermocouples and a few E-type ones will be added in the test section to measure temperature up to respectively 1200°C and 900°C. Twelve fission chambers will be placed as close as possible to the fuel sub-assemblies to monitor as best as possible the relocation of the corium in the fuel sub-assemblies and then in the transfer tube. Compton emission neutron detectors will give additional information.

At least two Optical Fiber Bragg Grating sensors lines will be inserted in the fuel pins bundle (also in place of spacer wires) to be able to measure the axial temperature profile history up to, at least, the sodium boiling. Dynamic pressure sensors will complete the instrumentation in order to “catch” and record the expected pressure events. While void sensors should measure the sodium depression and movement resulting throughout the degradation of the fuel pins bundles.