State of the art of the CEA R&D for Instrumentation and measurements in Experimental Nuclear Reactor

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Reliable and accurate measurements (neutron, gamma flux, dimensions, temperatures, chemical properties) are key stakes in the field of the nuclear reactor science. In addition to the primary need of instrumentation for a safe nuclear reactor operating (command-control), specific instrumentation is developed for experimental studies of the properties of the reactor structure materials and of the nuclear fuel elements.

In-pile experimental sensors and measurement systems have to satisfy several severe criteria due to the harsh environment encountered: high gamma and neutron radiation flux levels (up to 1E14n/cm²s) and doses (up to 1E21 n/cm², several GGy), high temperature (up to 700°C) and temperature gradients, but also strong operational criteria, such as miniaturization, high reliability (as no repairing is possible on irradiated sensors), long distance between sensors and electronics, etc. Finally, scientific requirements are also very high in terms of the measurement accuracy; as an illustration, neutron flux measurement accuracy has to be better than 10% (even 5%) to allow validation or improvement of calculation schemes.

After a summary of their goals and requirements (locations, ranges, uncertainties …) a description of the main sensor developments performed by the CEA is given: Neutron Self-powered Detectors, Sub-Miniature Ionization/Fission chambers, Calorimeters, extensometers, Optical fiber based sensors (Bragg gratings, Pyrometry techniques, optical extensometer,…), solid state dosimeters, sensors for dimensional measurements (LVDT), …

The calibration issues (prior, during and after irradiation) of these measurement systems are then discussed introducing associated modelling issues. Computational nuclear, thermos-hydraulic and mechanical codes as well as quality of the basic data (mainly nuclear data) are analyzed in order to highlight needs for improvements.

Finally, a conclusion on the state of the art of the measurement techniques in experimental reactor is drawn and the main future improvement axes are presented.