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#4-159 Direct Observation of Xenon-135 Poisoning in a Zero-Power Reactor via Gamma Spectroscopy

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Xenon-135 (Xe-135) is a high yield fission product with high neutron capture cross section, a commonly encountered reactor reactivity poison. Direct observation of Xe in reactors typically relies on off-gas measurement techniques, which can be challenging or costly to implement and often require high-flux reactors. Gamma spectroscopy of irradiated U or Pu samples provides an alternative method for obtaining fission yields and population estimates. When predicting the Xe populations of a given reactor, we rely on calculations and models to estimate the instantaneous reactivity worth and post-shutdown dynamics of Iodine-135 (I-135) and Xe-135 decay that leads to the so-called 'Xenon pit'. In our work, to achieve a direct estimate of the total Xe-135 population in an operating reactor, we measured the gamma-ray emissions of Xe-135 and I-135 emanating from the CROCUS zero-power reactor using a high-purity germanium detector in an irradiation channel. CROCUS is a uranium fueled, light water moderated, zero-power reactor operated by the Laboratory of Reactor Physics and Systems Behavior at EPFL, Switzerland. Specifically, we placed an Ortec GEM-15180-P detector in the irradiation beam port of CROCUS at roughly 4.3 meters from the core center. We measured the gamma ray spectra using a CAEN DS5730 500 MS/s digitizer to obtain gamma-ray time stamps and pulse integrals for the start-up, at-power operation for 1 hour at 20 W, and subsequent shutdown of the reactor for 100 hours. We show the obtained gamma ray spectra for the different reactor states. At power, the spectrum is dominated by the gamma ray emission from fission and neutron capture in water and aluminum. Following shutdown, the spectrum transforms, displaying a dense set of characteristic line emissions. To observe Xe135, we used its 250 keV emission, whilst for I-135 we observed the 1260 keV emission. We binned the spectra in time for 60-minute intervals to accumulate sufficient counts under the photopeak of interest. The time dependent behavior of the I-135 count rates was then fitted with an exponential decay, while the Xe-135 population used a combined exponential decay with production from I-135 model. The Xe-135 population indeed shows the famous 'Xenon pit'shape, peaking in intensity at roughly 14 hours after shutdown.
We also simulated the experiment using Serpent 2 to obtain the detector efficiency in counts per emission in the fuel - taking into account the fission rate distribution from a k-static calculation. This allowed us to finally estimate the whole-core Xe-135 and I-135 populations for 100 hours after reactor shutdown. Our results are among the only direct measurements of Xe-135 in a nuclear reactor. Given the published IRPhE geometry of CROCUS, this dataset holds significant potential as a validation benchmark for reactor poison prediction models.

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