

UV-VIS-NIR as an In-process Monitoring Tool

Jay Disser¹, Ben Cipiti², Larry Ticknore³, Mark Schanfein⁴, Sam Bryan⁴

¹Idaho National Laboratory, ²Sandia National Laboratory, ³Los Alamos National Laboratory, ⁴Pacific Northwest National Laboratory

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Continuous near real-time measurements provided by an in-process monitoring tool could improve the timeliness of IAEA safeguards by providing the Agency with an early warning of process changes or possible diversions of material at a nuclear facility. This paper summarizes preliminary work investigating a change detection approach to detect abrupt and protracted diversions based on in-process measurement data.

The basis behind change detection is to look for deviations in downstream conditions that do not reflect upstream conditions. Some variability while the plant is operating is expected, but a difference between the input stream and output stream could indicate a diversion or process change.

The UV-VIS-NIR spectrometer was chosen as the in-process measurement system. This instrument has been shown that it can provide continuous monitoring of solution concentrations and has been field tested at a reprocessing facility.^a Using the Separations and Safeguards Performance Model (SSPM), UV-VIS-NIR measurements were modeled at six process tanks within the main solution processing area of a notional reprocessing plant.

Six substitution diversion scenarios were examined to cover a range of abrupt and protracted material loss. The most abrupt case was a loss of 8 kg of plutonium over 50 hours by diverting 12% of a process stream. The most protracted case was a loss of 8 kg of plutonium over 600 hours by diverting 1% of a process stream.

The change detection approach was applied to the data generated by the UV-VIS-NIR instruments for one run of each diversion scenario and a non-diversion scenario. This enabled the calculation of the normalized residual values (the residual value is the difference between the downstream probe and PUREX Feed Tank concentration measurements; dividing by the estimated standard deviation then provides normalization). Page's CUSUM was then applied to generate the Page's test values. Page's CUSUM is a cumulative sum statistic that looks at diversion losses; summing up losses, but not gains. The statistic is set up to be positive when there are material losses. Therefore the resultant value is either positive or zero and

^a Smith, Nicholas A., J.F. Krebs, A.S. Hebden, 2014, "Development of spectrophotometric process monitors for aqueous reprocessing facilities," Symposium on International Safeguards: Linking Strategy, Implementation and People, Vienna, Austria, October 20-24, 2014.

does not take into account material gains, making the test more sensitive to diversions while maintaining a false alarm rate less than 5%.

Figure 1, shows the difference between the normalized residual values and Page's test values on the same sets of data. The two plots on the left show the normalized residual values for plutonium at the Pu Separation Tank for the 50-hour (top) and 600-hour (bottom) diversions of plutonium product. The abrupt diversion can easily be seen, but the protracted diversion is less obvious. However, plotting the Page's test values made the protracted diversion much more evident, which can be seen in the two plots on the right.

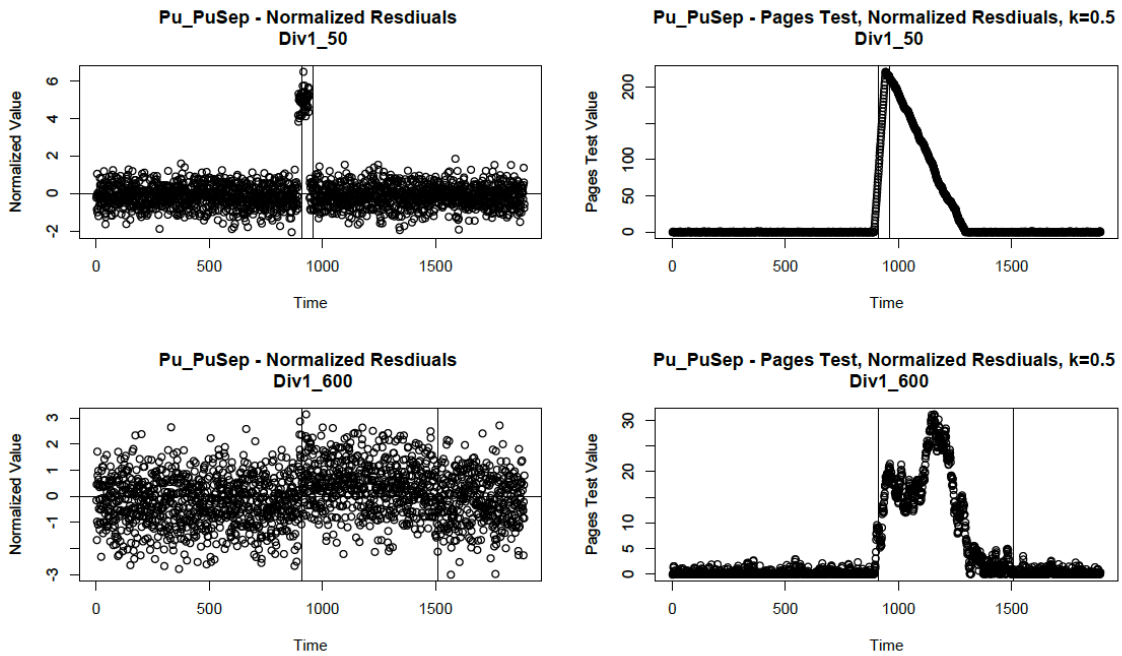


Figure 1: The Normalized Residual Values and Page's Test Values for Plutonium at the Pu Separation Tank for the 50-hour and 600-hour Diversion Scenarios

For all six-diversion scenarios, there were signs of the diversions in the plots for plutonium in the Pu Separation Tank. Possible signs of the abrupt diversions could also be seen in the plots for plutonium in the HALW Tank. Although the diversion in the plots above can be clearly seen at certain process points, the detection probabilities could not be calculated since only one data set for each diversion scenario was examined before completion of this project.

UV-VIS-NIR shows promise as a monitoring system using the change detection approach to observe process changes. This approach has the potential to provide the Agency with more timely information regarding process disturbances and material diversions. Furthermore, even though the change detection approach was applied to a PUREX model with UV-VIS-NIR instrumentation in this project, it has the potential to be applied to other in-process measurement systems as well.