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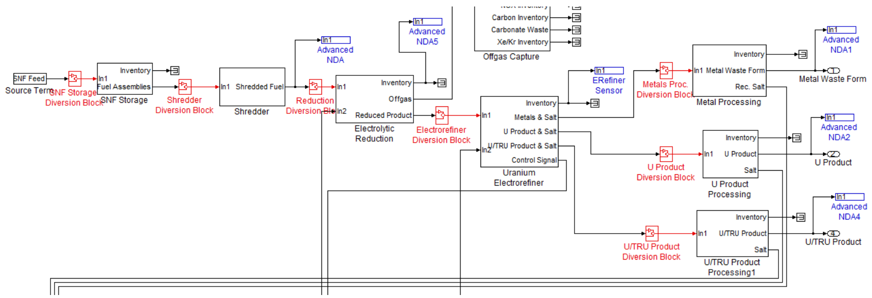

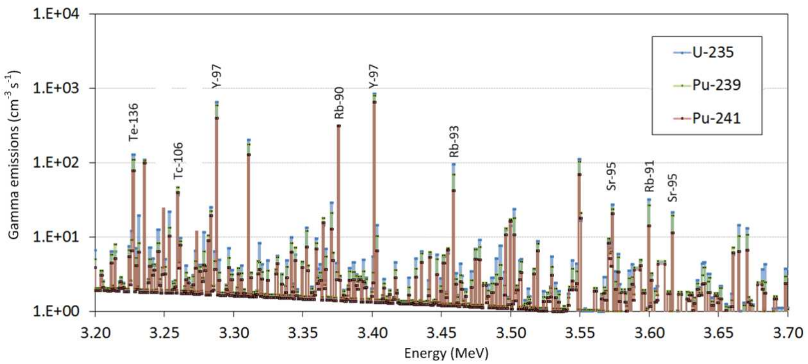

Electrochemical Processing Measurement Uncertainty Requirements for MPACT

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U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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Outline

- Discussion of measurement technology options (including both MPACT and JFCS work)
- Measurement uncertainty requirements
- Preliminary NRTA design
- Delayed gamma NDA measurement

Measurement Technologies

Input Measurement
- NDA/DA of Volox Powders
- LIBS of Volox Powders
- NDA of Shredded Fuel

Reduction Inventory
- Neutron

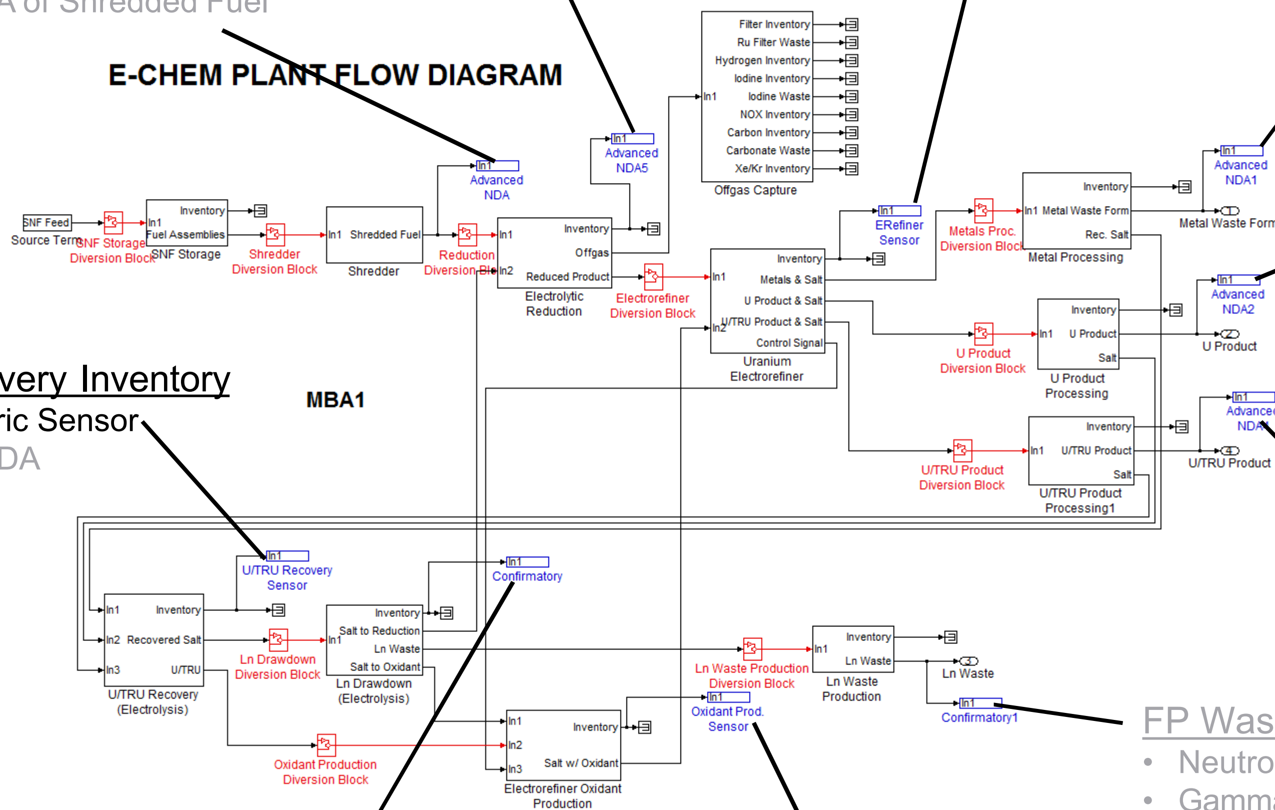
Electrorefiner Inventory
- Sampling, TIMS & Double Bubbler
- Potentiometric Sensor
- Voltammetry
- LIBS

Metal Waste
- Neutron
- Gamma

U Product
- Melt Sampling
- NDA
- LIBS

U/TRU Recovery Inventory
- Potentiometric Sensor
- Sampling & DA

U/TRU Product
- Melt Sampling
- NDA
- LIBS



FP Waste
- Neutron
- Gamma

Ln Drawdown Inventory
- Neutron

Oxidant Production Inventory
- Neutron

Measurement Uncertainty Requirements

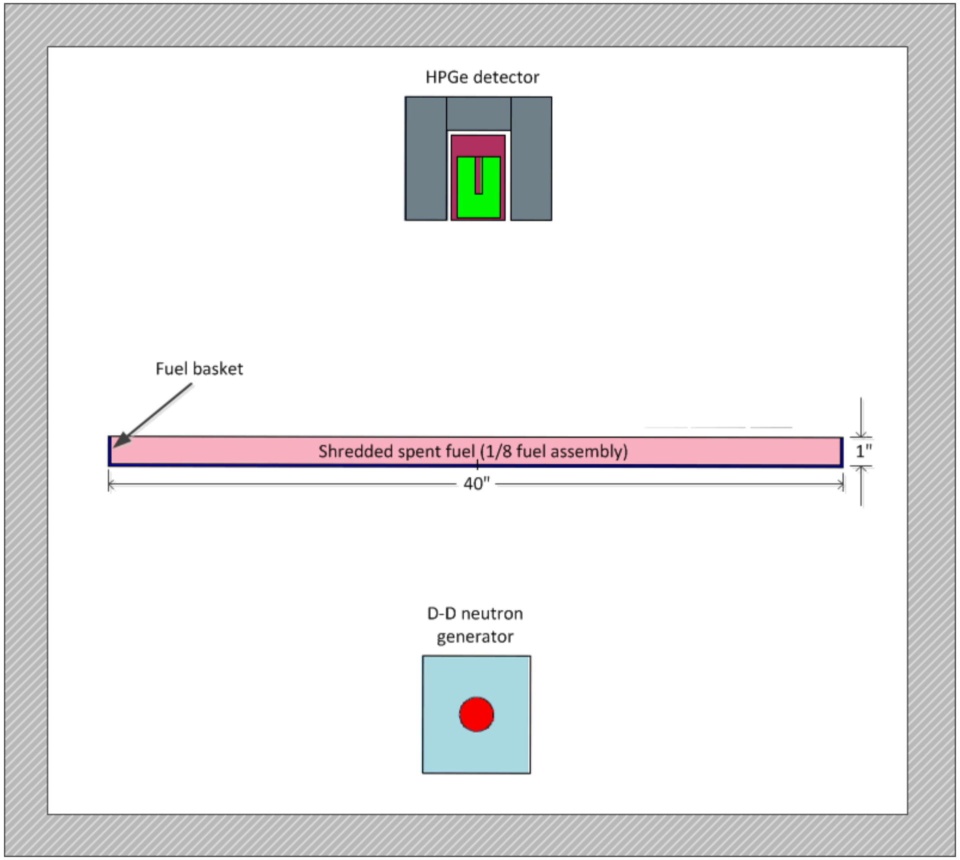
- The facility size plays a significant role in measurement uncertainty requirements due to the realism of protracted diversion scenarios:
  - For a 100 MT/yr facility, in order to accumulate 8 kg Pu, a 1% material diversion would take close to a year of operations, whereas for a 10 MT/yr facility a 10% diversion would take a year of operations.
- A 100 MT/yr facility would need to achieve the following in order to meet both NRC and IAEA goals:
  - 0.5% measurement uncertainty on the ER salt
  - 1% measurement uncertainty on the inputs and outputs
- A 10 MT/yr facility can meet IAEA goals with higher measurement uncertainty, but NRC goals would not be met:
  - 1% measurement uncertainty on the ER salt
  - 3% measurement uncertainty on the inputs and outputs

NRTA Design

- The Page's test (statistical test) calculation was updated to compare balance periods.
- A ten-day material balance period performed better than a daily plant balance.
- Since the ten-day balance is on par with the Rokkasho IIV/SIV, recommend designing the safeguards system (and plant) around this balance period.
- Materials accountancy would require measuring all input and output batches, and measurement of the plant inventory once every ten days.

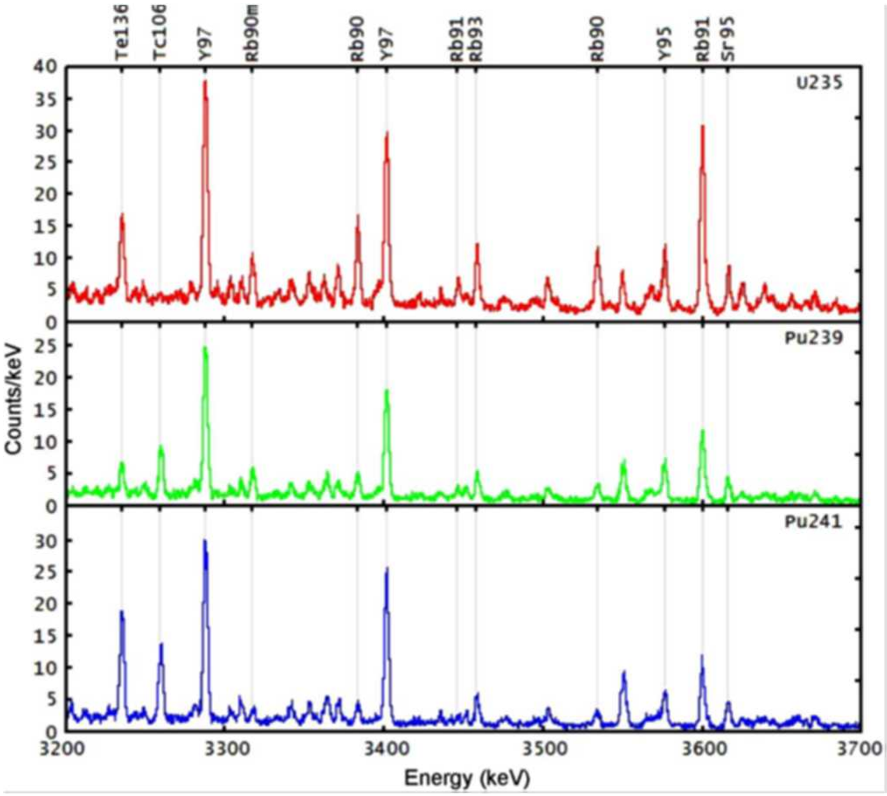
Delayed Gamma NDA for Input Accountability

- Measurement is assumed in the front-end process cell (air environment and significant shielding required).
- LWR spent fuel disassembled and shredded
- Spent fuel basket is approximately 40"x40"x1" with porous stainless steel sides. Each basket contains about 75 kg of spent fuel (1/8 of a PWR assembly).
- Neutron source: D-D neutron generator (2.5 MeV) with polyethylene moderator.
  - Isotopic point source (10^{10} n/s, 2.5 MeV)
  - 10 second irradiation period
  - 1 second cool down
  - 30 second acquisition time
- HPGe detector system, 3.2 cm radius, 40% efficiency



Delayed Gamma Background

- Passive measurements of signature isotopes lead to high measurement uncertainties
  - Cs-137, Cs-134, Cm-244, Eu-134
  - Dependent on reactor history and initial fuel composition (supplied by operator) and subject to high uncertainties
- Delayed gamma assay
  - Delayed gammas from fission products serve as signature
  - Gamma line intensity ratios can differentiate between fission of U-235, Pu-239, Pu-241.
  - Intense radiation from spent fuel complicates ability to distinguish fissile isotopes
  - Mitigated by identifying high energy emitting isotopes as signatures (Campbell et al.)
    - 3 – 4 MeV range



Simulation Results (Decrease of U-235 content from 40% of fissile makeup to 38%)

Percent change in emission intensity for selected isotopes

Isotope	Tc136	Tc106	Y97	Rb90	Rb91
Energy (MeV)	3.235	3.260	3.288	3.383	3.600
Percent change (%)	-2.418	2.872	-3.112	-3.148	-3.562

- Pu content increased by 0.62/0.6 = 1.033
- U-235 content decreased by 0.38/0.4 = 0.95
- Fission product yields for Tc-106:
    - U-235: 0.402, Pu-239: 4.4

$$\frac{(1.033)(4.4) + (0.95)(0.402)}{4.4 + 0.402} = 1.026 = 2.6\%$$

Delayed Gamma NDA Discussion

- Count rates appear to be in the range needed for 1% counting statistics
- More work will be required to determine expected measurement uncertainties
- This geometry seems to be more desirable as compared to a fuel assembly (no axial variation, less self-shielding, less volume)
- Calibration could be a challenge, but probably easier than developing a spent fuel assembly calibration standard.
- Future work will focus on measurement uncertainty and can also examine the determination of fuel burnup and initial enrichment.

Conclusions

- A ten-day balance period appears to be adequate for safeguards and stays consistent with the existing IIV/SIV at Rokkasho. However, due to the inability to flushout the plant, the ten-day balance should be the main safeguards balance.
- For a smaller facility (10 MT/yr), goals:
  - 3% measurement on inputs and outputs
  - 1% measurement on the electrorefiner inventory
- For a larger facility (100 MT/yr), goals:
  - 1% measurement on inputs and outputs
  - 0.5% measurement on the electrorefiner inventory
- Active neutron interrogation and delayed gamma measurements of spent fuel continue to be evaluated as an alternative approach for input accountability.

Future Work

- Future work will focus on the integration of process monitoring data with NMA
- Process monitoring continues to be proposed as an alternative to fill in the gaps of traditional accounting or where traditional accounting cannot meet low measurement uncertainties.
  - May include monitoring voltage, current, off-gas releases, mass, etc.
  - This integration may require more detailed unit operation models.