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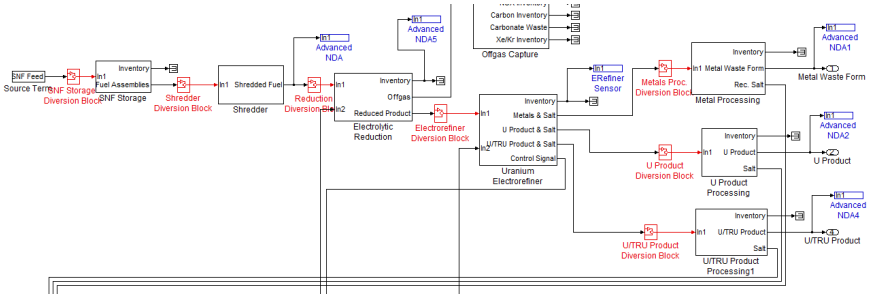

Integration of Process Monitoring for Electrochemical Safeguards

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U.S. DEPARTMENT OF ENERGY
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Overview

- This work is evaluating the integration of process monitoring (PM) data into safeguards for electrochemical plants.
- Progress:
  - The Echem SSPM model has been updated to provide more realism, and a Matlab parallel cluster is being used to speed up the diversion scenarios analyses (10X improvement).
  - Each unit operation has been evaluated for potential PM measurements that could be used.
  - PM data is being evaluated for potential to replace high uncertainty safeguards measurements or to provide more assurance.
  - Diversion scenario analysis is being updated.

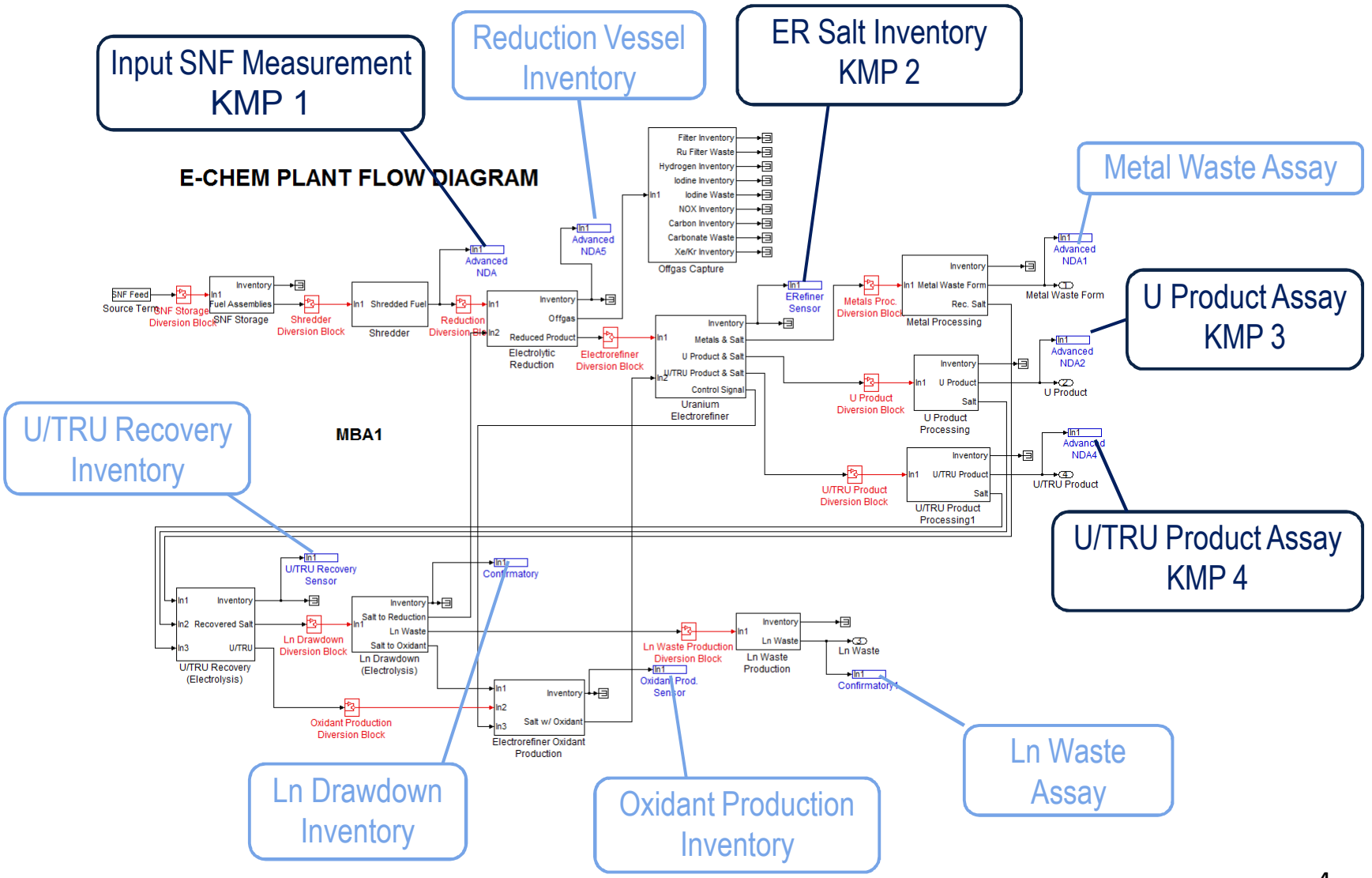
What is Process Monitoring?

- **"Process Monitoring is a methodology to ensure that special nuclear material is in its authorized location and when effectively implemented, it is a useful tool to detect anomalous process conditions and indicate losses of special nuclear material well before the scheduled physical inventory."**

  - U.S. DOE Standard, DOE-STD-1194-2011 Change 3, "Nuclear Materials Control and Accountability," paragraph 6.2.4.5 (2013).

- **Includes bulk measurements:**
  - Load cell, electronic balance, electromanometer, triple bubbler, flowmeter, temperature, current, voltage, power, capacitance, heating/cooling required, pH monitors
- **Or on-line process measurements:**
  - Off-gas monitor, voltammetry, UV-Vis-NIR spectroscopy, gross gamma or neutron measurement, MIP monitor.

Accountancy Structure



PM Analysis: Oxide Reduction

- In normal operation, shredded oxide fuel is contained in baskets and lowered into a molten salt. Electrolysis is used to convert oxides to metals, and oxygen is released in the process. Actinides stay in the basket, but some fission products will go into the salt (active metals and some lanthanides).
- **Safeguards Goal:** ensure that actinides are not in the salt and ensure that shredded fuel has not been removed. The realism of a diversion from this location is being considered.
- **PM Options:**
  - As opposed to salt sampling and DA or NDA, voltammetry should be considered to identify if actinides are present or if agents have been added to extract actinides into the salt.
  - Bulk mass balances can be considered, but a load cell on the reduction vessel may not be feasible. The mass of baskets before and after along with an off-gas monitor could provide enough information for a mass balance (but will have a slight positive difference due to the fission products that go into the salt).

PM Analysis: Electrorefiner

- In normal operation, a specified voltage applied across the cathode and fuel baskets will extract U onto the cathode. A separate cathode is operated at higher voltage to extract a U/TRU product. Noble metals remain in the basket.
- **Safeguards Goal:** Account for U/TRU content in the salt, ensure that actinides go where intended.
- **Key Measurement Point:** Due to the high TRU content in the salt, salt sampling will be needed to get a precision inventory measurement.
- **PM Options:**
  - The Triple Bubbler will be important to determine total volume/mass. An in-situ measurement like the potentiometric sensor or voltammetry should be considered as well, but note that the uncertainty goals will probably be low here (<0.5%).
  - Current and voltage monitoring can help ensure that full extractions occur (no material left in baskets) and that actinides go to the correct cathode.
  - Bulk mass balances probably not feasible since it would be difficult to install a load cell on the electrorefiner.
  - A hot cell off-gas monitor will likely be needed for monitoring anyway, but it can also be used to ensure that hidden extractions are not occurring.

PM Analysis: Metal Waste, U Product, and U/TRU Product Processing

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- For all three products coming from the ER, residual salt is distilled off, and remaining metals will be melted down to form a metal waste form, U product ingot, and U/TRU product ingot.
- **Safeguards Goal:** Confirm low levels of actinides in the metal waste, account for actinide content in the U and U/TRU product, and ensure salt is recycled.
- **Key Measurement Points:** Because these are all outputs, NDA will probably be required for the metal waste, and sampling may be considered for U and U/TRU product during melting. For the U product, it may be difficult to keep up with daily batches, so NDA is also being evaluated.
- **PM Options:**
  - Bulk mass balances can be considered to ensure all salt is recycled and to determine total mass of the products.
  - Since output accountancy measurements will be required, other PM measurements probably aren't needed.
  - Note that current and voltage monitoring at the ER helps to ensure that actinides do not stay in the basket and that U and TRU go where intended.

PM Analysis: Actinide Drawdown

- The distilled salt from the product processing steps is recovered for U/TRU drawdown.
- **Safeguards Goal:** Account for actinides in the salt.
- **PM Options:**
  - Accountancy will be required on the salt, but the actinide content is much lower than in the electrorefiner, so higher uncertainty measurements are okay. Can consider potentiometric sensor, voltammetry, or UV-Vis-NIR spectroscopy.
  - Bulk measurements can also be considered for total mass.

PM Analysis: Fission Product Drawdown

- One or two additional process steps will be required periodically to remove fission products from the salt. (Or salt could be removed periodically, depending on the design.)
- **Safeguards Goal:** Confirm no or trace actinide content in the salt and waste form.
- **PM Options:**
  - NDA measurements will probably be required for the waste form, but voltammetry or other in-situ measurements could be considered to confirm no or trace actinide content.
  - Bulk measurements can also be considered.

Summary & Path Forward

- The important non-sampling PM measurements will be:
  - Triple Bubbler for the ER salt
  - Voltammetry for OR and possibly drawdown steps
  - Current and Voltage monitoring in the ER
  - Mass measurements of the product processing steps.
  - (Also following the results of the potentiometric sensor and spectroscopy to determine their potential role.)
- These PM measurement options have been added into the SSPM, but more work is required to determine how all the information will be integrated. Various diversion scenarios will be analyzed.