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Alternative Fuel Cycle Materials Verification and Monitoring Using Advanced High-Dose Neutron Detectors

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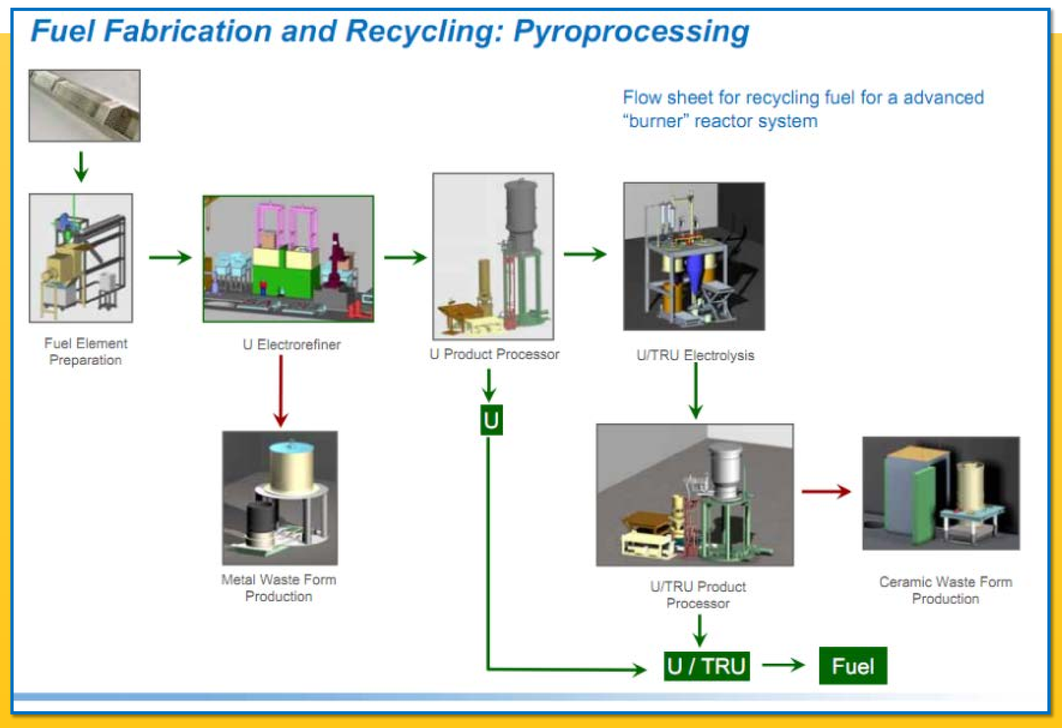
ABSTRACT

- Advanced nuclear fuel cycles often involve novel methods of processing and handling of nuclear material in a range of chemical and physical forms (oxides, nitrides, carbides, metal, molten salt; pins, plates, pebbles, liquid)
- Innovative safeguards instrumentation and approaches will be needed to encompass the increased complexity and new challenges
- This research focuses on neutron detection technology to address the unique challenges of advanced nuclear fuel cycle materials and to offer potential improved performance over the standard Non-destructive Assay (NDA) methods
- The technology is discussed here on application to a pyroprocessing facility

BACKGROUND

- Flexible reprocessing capabilities are often cited as one component of a comprehensive approach to accommodate innovative nuclear fuel materials
- Pyroprocessing addresses some of these flexibility needs:
  - Accommodates range of fuel forms
  - Compact (on-site colocation possible)
  - Can treat highly radioactive fuels (minimal cooling time)
  - Group recovery of U/TRU
- ***How do we efficiently safeguard such a broad range of nuclear materials in an extremely challenging processing environments?***



CHALLENGES OF PYROPROCESSING AND IMPACT ON SAFEGUARDS TECHNOLOGY

WHAT ARE THE KEY CHALLENGES?

- High neutron and gamma dose rates
  - 10^6-10^9 n/s, tens to thousands R/h
- Environmental conditions
  - Temperatures, radiation, inert gas
- Remote handling, hot-cell environment
  - Use of manipulators
  - Inability to access equipment
  - Contamination

IMPACT ON NEUTRON DETECTION PERFORMANCE

- Neutron detection unaffected by high gamma dose rates
- Low sensitivity to background
  - Good low count rate capability to confirm absence of nuclear material
- Capable to accommodate high count rates

Neutron NDA will require high efficiency and a broad dynamic range with low gamma sensitivity

IMPACT ON HARDWARE/ELECTRONICS

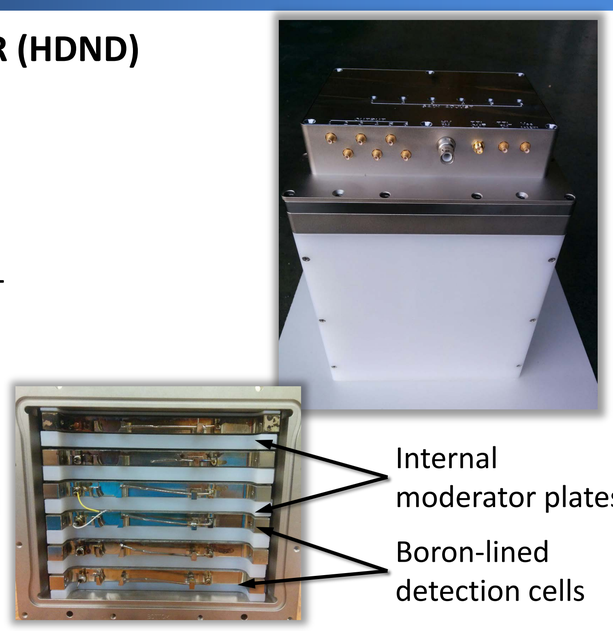
- Radiation, temperature tolerant materials
- Robust, reliable instrumentation
  - Minimum maintenance
  - Suitable for remote handling
- Compatibility with existing feedthroughs

Hardware will need to support remote handling and hot cell environments

ADVANCED NEUTRON NDA CONCEPT

HIGH DOSE NEUTRON DETECTOR (HDND)

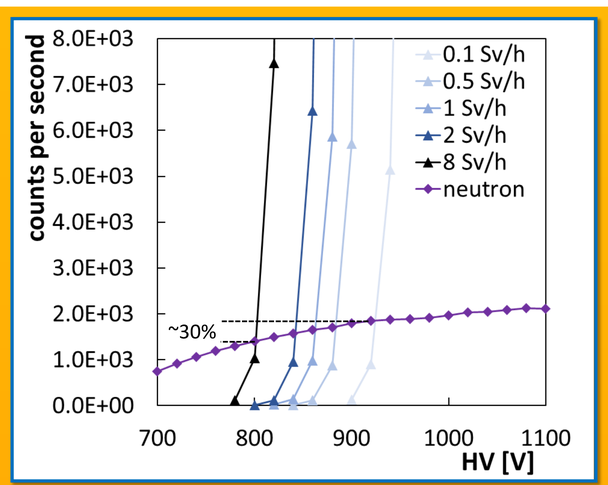
The HDND technology was developed by Precision Data Technology, Inc. (PDT) and is based on six boron-lined parallel-plate proportional counters. It uses six fast amplifiers and list mode data collection to improve high count rate performance and allow for advanced analysis.

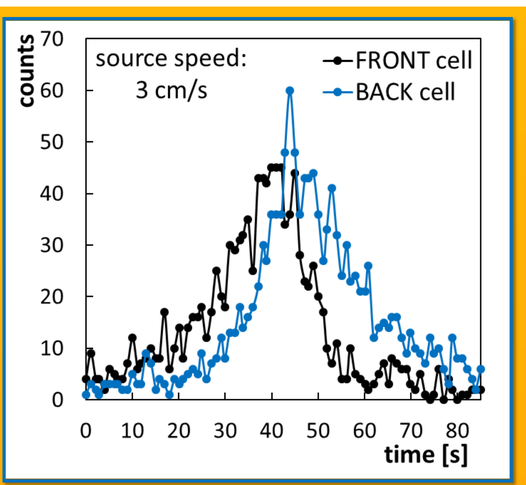


External and internal view of HDND

HDND KEY FEATURES:

- ✓ High neutron count rate capability and broad dynamic range;
- ✓ Low and tuneable gamma-ray sensitivity;
- ✓ Dual mode detection capability (simultaneous neutron and gamma detection);
- ✓ Directionality of motion measurement capability for process monitoring (from multi-plate design)
- ✓ Hardware and materials for hot-cell environments and to facilitate remote handling and maintenance (under development)





Neutron detection in high gamma background (left); sensitivity to direction of motion for neutron source moving from front toward back cell (right)

CONCLUSIONS

- Features of pyroprocessing will impact all aspects of safeguards instrumentation and require dedicated hardware, electronics and performance optimization
- HDND development focuses on advanced neutron NDA to support these challenges (high count rate, broad dynamic range in high gamma backgrounds, hardware to support remote handling and in-cell use)
  - Key design features relevant beyond pyroprocessing

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