Case Study

CANBERRA

Measurements and Expertise

Feasibility Study of an NDA System for Fuel Debris Characterization at Fukushima, Japan

Scope:

After the Fukushima accident in Japan, a project was initiated by the International Research Institute for Nuclear Decommissioning (IRID) for the retrieval of fuel debris from the Daiichi reactor.

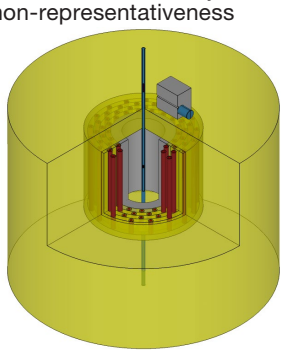
IRID and one of its members, Mitsubishi Heavy Industries, Ltd. (MHI), engaged in collaborative research project entitled, "Business subsidies for decommissioning and radioactive water waste: development of the techniques for investigating inside the reactor pressure vessel" which was funded by the 2014 supplementary budget of the Government of Japan's Ministry of Economy, Trade and Industry (METI).

The results of this undertaking were obtained with support from Mirion Technologies.

- Mirion performed a feasibility study for the design of a Non Destructive Assay system for fissile mass assessment in corium samples.
- Three measurement techniques were investigated as part of this study:
  - Gamma Spectroscopy
  - Passive Neutron Coincidence Counting
  - Active Neutron measurement through Differential Die Away
- Samples will be made of an unknown mixture of concrete, stainless steel and melted spent fuel.
- Loading of Boiling Water Reactors consists of various types of fuel, which lead to additional unknown parameters compared to Pressurized Water Reactors.

Key Drivers of the Project:

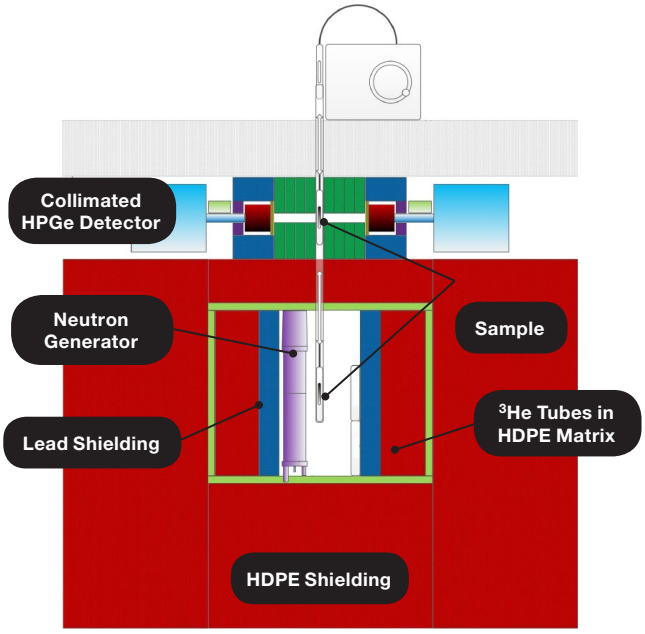
- Criticality Safety Management, as well as Fissile Material Management, are key in this project.
- The NDA system is meant to measure the mass of the main fissile isotopes.
- Classical Burn-Up measurement methodologies do not apply on damaged fuel: the samples may consist of a mixture of various types of fuel.
- Multiple unknown parameters require multiple measurement techniques so as to be able to solve the problem.
- Highly inhomogeneous materials means that laboratory analysis will lead to difficulties of non-representativeness of samples. Therefore a Non-Destructive Technique is required.
- Dose rate around the NDA system must not exceed the maximum permissible value.
- Detectors themselves must be protected from the highly radioactive material to be measured.



MCNP Modeling

CANBERRA™ Solution:

- A bibliography study based on existing designs resulted in the definition of a Basic Design of a System:
  - Collimated Gamma spectroscopy with HPGe detectors
  - Neutron measurement system with Cadmium wrapped ^{3}He tubes in a moderator (HDPE), allowing for Passive and Active measurement (PNCC & DDA)
  - D-T pulsed neutron generator
  - The sample capsule is moved into a tube that goes through the whole system.
  - Lead and HDPE shielding will prevent damage to the ^{3}He tubes and will maintain a low dose rate outside the system.
- Full modeling of the NDA system was performed using the MCNP® calculation code.
- Parametric studies were performed to cover the whole range of sample compositions that could be encountered.
  - Several hundred calculations were performed.
- Realistic gamma and neutron system responses were calculated.
- Assessment of gamma spectrometry measurement uncertainties was performed with the Uncertainty Estimator module of the ISOCS™ Software.
- Analysis of spent fuel data to find intrinsic characteristics valid for all types of fuel in the reactor.



Conceptual System Drawing

Visit our Measurements and Expertise (M&E) page.

MIRION TECHNOLOGIES

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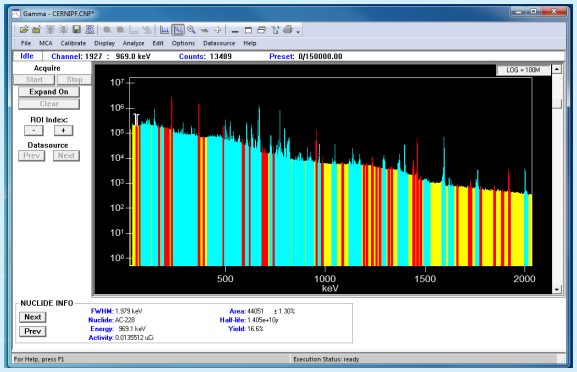
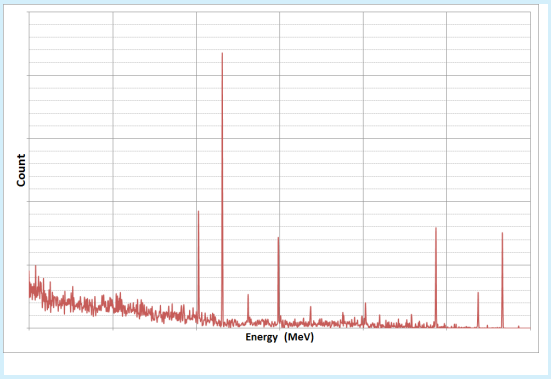
Instruments & Techniques Used:

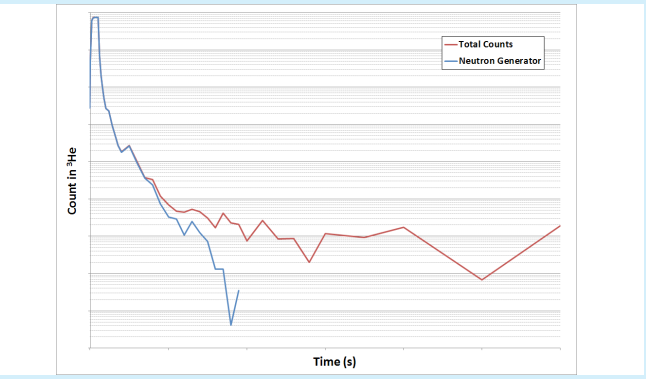
1. Genie™ 2000 Algorithms
2. MCNP Calculation Codes
3. ISOCS-IUE Module



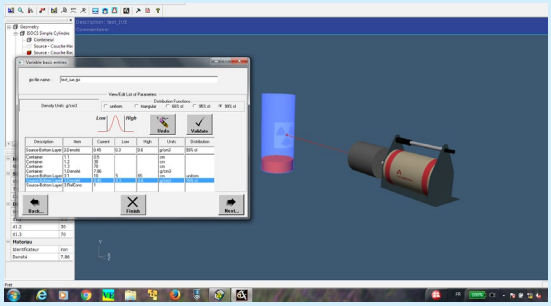
Genie 2000 - Gamma Spectrum



Simulated Gamma Response



Simulated Neutron Response



ISOCS Model of Corium Sample

ACHIEVEMENTS

- Proven NDA system technologies with standard & innovative data algorithms were combined to show how the total measurement uncertainty can be minimized to take into account all the variables. Example: For the DDA assay, both prompt and delayed neutrons were used.
- Automatic self-shielding assessment for neutron measurement using “DDA” technique.
- Calculation of Minimum Detectable Activity and mass for the nuclides of interest.
- Extensive uncertainty analysis for Total Measurement Uncertainty assessment.
- Design optimization in terms of performance, cost, weight and ALARA principles.

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