ABSTRACTS of the Technical Poster Session

1FD8

The 8th International Forum on the Decommissioning of the Fukushima Daiichi Nuclear Power Station

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Alios Iwaki Performing Arts Center in Iwaki city,

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Session セッション		
A	Research and Development related to Decommissioning	廃炉関連研究開発
B	Remote and Digital Technologies	遠隔・デジタル技術
C	State Inside the Reactors/Fuel Debris Properties and Fuel Debris Storage	炉内状況・燃料デブリ性状、燃料デブリ保管
D	Spent Fuel Removal	使用済み燃料取り出し
E	Radiation Measurement Technologies and Radiation Durability	放射線計測技術と放射線耐性
G	Analysis	分析
H	Investigation of Integrity	健全性確認
I	Radioactive Waste Management	廃棄物対策
F	France	フランス
J	JAEA	日本原子力研究開発機構

廃炉・汚染水・処理水対策事業による研究開発とエンジニアリングへの連携

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株式会社　三菱総合研究所

平成 25 年度より経済産業省は、技術的難易度の高い研究開発の支援を目的とし廃炉・汚染水・処理水対策基金（旧：廃炉・汚染水対策基金）を造成している。当該基金を活用し、公募による補助事業として「廃炉・汚染水・処理水対策事業」が今日に至るまで実施されており、 本講演では、本事業における各種補助事業の関連性、また本事業の福島第一原子力発電所廃炉への貢献について紹介する。

B01 Remote Control Technology for Monitoring Inside RPV Pedestal during Retrieval of Fuel Debris: Integrated Experiments

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燃料デブリ取り出し時における炉内状況把握のための遠隔技術：統合実験

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本研究では、福島第一原子力発電所の廃炉に向けて、遠隔技術分野を中心とした研究人材の育成を行った。遠隔操作ロボットアームによる燃料デブリの取り出し作業を安全かつ確実に行うためには、作業前に格納容器内の 3 次元状況を正確に把握する必要がある。そこで、ペデスタル内を観察するためのプラットフォームの構築を提案した。このプラットフォーム上をカメラ、ガンマ線検出器、中性子検出器などの各種センサーが移動し、燃料デブリ取り出しに必要な計測や可視化を行う。最終年度は各研究項目の検証とともに楢葉センターに設置したモックアップを用いて、統合実験としてプラットフォーム上を移動する観察ロボットのカメラ画像から、3 次元環境モデルの再構築、観察対象の適切な視野をオペレータに示す実験を行い、コンセプトの有効性を確認した。また、人材育成として 1F の現状と今後の課題を紹介する講義を実施し、若手による研究や学会発表を行った。

B02 Navigation and Control of a Novel Shock-resistant Mechanical Manipulator for Fuel Debris Retrieval

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燃料デブリ取り出しのための機械式マニピュレータのナビゲーションおよび制御

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本研究では，福島第一原子力発電所の燃料デブリ取り出しに向けた，図 1 に示すマニピュレータの開発を目的とする．CVT(無段変速機構) を備えたマニピュレータの，英国 Sussex 大学との共同研究に焦点を当てる．機械的可変インピーダンスアクチュエータを用いたロボットマニピュレータの開発および効率的な探査・廃止措置のための人工知能を使った制御手法の構築に取り組む。研究課題は、(1)CVT-VIA*の設計、(2)衝突に頑健なロボットマニピュレータおよび把持力の計測可能なグリッパーの開発、(3)センサの計測精度が保証される局所領域内における 3 次元環境モデルの生成手法の開発、(4)マニピュレータのコンフィグレーション計画手法の開発、という 4 項目で構成される。(1)、(2)については、英国 Sussex 大学において実施し、(3)、(4)については、東京大学および連携ラボ（JAEA）において実施する。

B03 Consideration of Harmonic Van-Atta Array consisting of Dual-Band Unidirectional Antennas

Kakeru Murata, Takuto Oyama, Nobuhiro Kuga
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単一指向性デュアルバンドアンテナで構成されるハーモニック Van-Atta アレーの検討

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電源供給やバッテリ交換が困難な高放射線環境下では，受信波を動力源とするパッシブタグが有効であり，中でも受信波の高調波を送信するハーモニックタグは干渉の影響低減の点で優れている．タグと基地局との高効率な通信において，タグに用いるアレーアンテナには到来波方向へのビームトラッキングを行うレトロディレクティブ機能が求められ，その一つである Van-Atta アレー(VAA)は回路のみという簡易な構造である．ハーモニック VAA について，シングルバンドアンテナを用いた原理検討はなされているが、開口効率が半減しているという課題に対し，本稿ではデュアルバンドアンテナを用いたハーモニック VAA を提案する．単一指向性を有するパッチアンテナにスリットを設けることにより 2 周

波で動作するアンテナを実現した．また VAA の有効性について、メインビーム方向が固定のアレーとの比較により、通信有効角度が拡大していることを示す.

B04 Retrodirective harmonic tag using omni-directional pattern antenna

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無指向性アンテナを用いたレトロディレクティブハーモニックタグ

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ハーモニックタグは電源を必要としないため，放射線環境下において有効的である．また長距離通信のために，ハーモニックタグのメインビームを到来波方向に向けることが求められる．Van-Atta アレー(VAA)では電子機器を用いずに再放射を入射波方向に向けるレトロディレクティブ特性をもつため，電子機器が動作しない放射線環境下において同様に有効である．現在単一指向性を有するハーモニック VAA の動作が確認されている．一方で，本稿では二共振無指向性アンテナを用いることで，水平面において無指向性であるハーモニック VAA を提案する．タグに対して一定の距離を保ちながら基地局を回転させることで，ハーモニック VAA の動作が一定であることを評価した．また，アレーでない単素子のハーモニックタグと動作を比較することで，利得の上昇を確認した．

B05 Energy harvesting harmonic tag using modified tapered slot antenna

Kiyoku Hamada, Iori Serizawa, Nobuhiro Kuga
Yokohama National University

改良型テーパスロットアンテナを用いた電力ハーベスティングハーモニックタグ

濱田 清空, 芹澤 伊織, 久我 宣裕
横浜国立大学大学院

高放射線下において遠隔操作型ロボットが自由度のある動作をするためには，無線電力伝送(WPT)技術が有望である．長距離での電力伝送には大型の送信機器が必要となるが，電力ハーベスタを装荷したハーモニックタグは無線機器の消費電力が小さく，アンテナサイズを抑える解決策となる．そのため，本稿では形状を改良したテーパスロットアンテナを用いたハーモニックタグを提案し，充電性能を実験的に示した．提案タグには円形の地板をはさんで改良アンテナと電力ハーベスタが装荷されている．実験は電波暗室で行われ，送信アンテナとして 16 素子ダイポールアンテナが用いられた．送信アンテナから周波数 2.33 GHz，入力電力 43 dBm の送信波が 6 m 離れたタグに送信された．提案タグは 24 分後に 1 V の充電が可能であった．

B06 Unlocking Value in Decommissioning through broad use of Digital Technologies

Toshi Yamanouchi, Kevin McMahon
Jacobs Decommissioning & Regenerative Solutions (D&RS)

デジタル技術の広範な活用を通じてさらに廃止措置の価値を引き出す

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ジェイコブス　アジア株式会社

Jacobs は、廃止活動におけるデジタル テクノロジーの利点を最大化するためのさまざまなアプローチを開発しました。視覚化と 4D 計画のためのデジタル ツイン、教育や高度なプロジェクトデリバリーのためのリアルタイム拡張現実、トレーニングと開発をサポートするアバターの挿入機能、さらにはシミュレーションから物理的なデモンストレーションまでを介したロボット システムの制御ソフトウェアの生成などが含まれます。設計中に、デジタル シミュレーションに人間型のアバターを挿入する機能は、ヒューマン ファクターが考慮されることを意味しますが、これにより作業前の習熟とブリーフィングのためのトレーニング環境も提供できます。ロボティクスソリューションの開発が必要な場合、完全な物理エンジンシミュレーションを使用してテスト環境を作成しますが独自開発の制御システムコードによりデジタルから物理プロトタイピングへの迅速な移行が可能です。

B07 Progress of the fuel debris trial retrieval using the telescopic-type debris retrieval equipment in Fukushima Daiichi Unit 2

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Tokyo Electric Power Company Holdings Inc.

福島第一原子力発電所 2 号機におけるテレスコピック式試験的取り出し装置による燃料デブリの試験的取り出しの進捗について

菅原　良昌, 中川　雄介, 新井　知行
東京電力ホールディングス株式会社

福島第一原子力発電所 2 号機における燃料デブリの試験的取り出しは、早ければ 2024 年 8 月からの開始予定である。PCV から採取した燃料デブリは構外分析施設へ輸送され、事故分析に活用されるとともに、段階的に規模を拡大した取り出しの設計に活用される計画である。

Session C: State Inside the Reactors/Fuel Debris Properties and Fuel Debris Storage ····· 11

炉内状況・燃料デブリ性状、燃料デブリ保管

C01 Establishment of Tousou Mirai Manufacturing Co., Ltd. and Plans for Producing Decommissioning Products

Tomokazu Harada, Hiroshi Kawaeda
Tousou Mirai Manufacturing Co., Ltd.

東双みらい製造の設立と廃炉関連製品の製造を通じた今後の計画

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東双みらい製造株式会社

当社は、福島第一・福島第二原子力発電所での廃炉作業において利用される金属キャスクや燃料デブリ保管容器等の製造を通じて、浜通り地域をはじめとする福島県全域の復興に貢献したいとの思いから、東京電力ホールディングス株式会社および日立造船株式会社により共同で設立されました。これまで県外で製造されていた原子力関連製品を、ここ浜通りで地元の皆様、企業と密接に連携し製造することで、廃炉の推進、浜通りの経済発展、雇用創出、人材育成等に貢献してまいります。「復興と廃炉の両立」に取り組んでいる廃炉関連製品のユーザーである東京電力と、使用済燃料保管容器製造に関する技術・技能を有する日立造船により、ユーザー・メーカーというそれぞれの知見のもと共創された東双みらい製造株式会社は、地域に深く根差した会社を目指してまいります。

C02 Challenge for screening of nuclear fuel debris by innovative spectral imaging and its verification by LIBS mapping

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革新的分光画像解析による燃料デブリの可視化への挑戦と LIBS による検証

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1F 内部において塊状・棚状堆積物など、様々な未知物質が確認されているが、これら物質の組成に関する情報はほとんど得られていない。本研究ではこれら炉内物質を遠隔識別する技術として、2 つの分光学的手法：ハイパースペクトルイメージング（HSI）とレーザー誘起ブレークダウン分光（LIBS）を組み合わせることを提案する。本研究は英国ストラスクライド大学、NNL、ランカスター大学との共同プロジェクト（英知事業・日英共同研究）であり、同技術実証のための標準試料の合成と評価、解析手法、遠隔操作技術の開発を進めている。

C03 The reaction between cesium hydroxide and stainless steel oxidation products in a steam environment at 573K-773K

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573K-773K の蒸気雰囲気における水酸化セシウムとステンレス鋼の酸化物との反応

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本研究では、573K-773K のアルゴン(Ar)およびアルゴン-蒸気(Ar-H_2O)環境における水酸化セシウム（CsOH）とステンレス鋼の酸化生成物であるマグネタイト（Fe_3O_4）およびクロミア（Cr_2O_3）との反応を調査しました。CsOH·H_2O と Fe_3O_4 または Cr_2O_3 の粉末を混合し、円柱状のペレットを成形した後、指定された条件下で加熱しました。その後、試料の重量変化、元素分布、結晶相評価の分析を行いました。CsOH と Fe_3O_4 の反応において、温度や雰囲気により生成物の外観は変化しますが、温度や雰囲気に関係なく $CsFeO_2$ が生成され、反応速度は 673K 付近で最も高いことが示されました。生成物は CsOH と比較して吸湿性が低いことも示されました。一方、水酸化セシウムと Cr_2O_3 の反応では異なる条件下でも類似した外観を示し、高い吸湿性があることが示されました。

C04 Preliminary study on delayed neutron Cij(τ) functions of a fast-thermal weakly coupled reactor system for fuel debris criticality impact analysis

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For criticality impact analysis of Fukushima Daiichi NPS fuel debris removal works, multi-region integral kinetic analysis code MIK2.0 has been under development by considering fission reactions by delayed neutrons. Fuel debris to be removed from the damaged reactor can be a fast-thermal weakly coupled reactor system due to spatial distribution of fuel debris and spatial difference in neutron spectrum. In this study, characteristics of delayed neutron $C_{ij}(\tau)$ functions, which are necessary for MIK2.0 analysis, are under discussion for a fast-thermal weakly coupled reactor system consisting of metallic uranium pulse cores and subcritical polyethylene-moderated fuel assembly.

C05 Fuel Debris Monitoring Collaboration and Experiences in Criticality Monitoring

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Fukushima Daiichi fuel debris removal provides technical challenges and opportunities for the international criticality safety community. Neutron monitoring of neutron multiplication (or degree of subcriticality) is required to help inform fuel debris removal activities and reduce the risk of re-criticality during the removal process. The US (DOE NCSP) and France (IRSN) will support Fukushima Daiichi fuel debris efforts through collaboration on real-time criticality monitoring. This work will describe a collaboration that is starting soon and includes focus areas on neutron analysis, radiation detection, radiation transport simulations, and a capability demonstration. In addition, this work will describe previous efforts associated with criticality experiments and neutron analysis of unknown systems.

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福島第一原子力発電所１号機の燃料取出し大型カバーの建設状況および残存する瓦礫の撤去に向けた技術的取り組み

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鹿島建設

本稿では、福島第一原子力発電所 1 号機の燃料取出し用大型カバーの建設状況と、オペレーティングフロアに残る瓦礫の撤去に向けた技術的取り組みについて紹介する。

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福島第一原子力発電所近郊のコンクリートの汚染調査結果の概要

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東京電力福島第一原子力発電所事故により放出された放射性セシウムによるコンクリートの汚染について、大熊町の様々な場所から採取したサンプルを用いて調査した結果を報告する。調査は、現場でのサーベイメータでの表面線量率計測と採取コア断面のイメージングプレート（IP）を用いたオートラジオグラフィに依った。コンクリートの表面線量率は、雨に曝された屋外に比べ、屋根により雨水が遮断された場所ではかなり低かった。コンクリートの汚染は主に特定のコンクリート骨材と炭酸化したセメントペースト部分に集中していた。炭酸化されていない部分では、放射性 Cs は表面近くの骨材に濃縮され、IP による評価の限界もあり、セメントペーストへの浸透は検出できなかった。雨にさらされたコンクリート試料は、時間の経過とともに汚染が減少した。まとめると、雨への暴露、骨材の特性、炭酸化の程度が、コンクリートの汚染を予測する上で極めて重要である。

E02 Detection characteristics and equipment development of radiation detection systems based on PV cells

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太陽電池型放射線検出システムの検出特性と装置開発

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太陽電池素子を応用した放射線検出システム(SRDs)は、高い放射線耐性および長距離の信号輸送など、1F の PCV 等の高レベル放射線環境中での線量計測に優れた特性を有している。これは、人工衛星に搭載されている宇宙用太陽電池の開発技術を利用して加速的に開発を進めたものであり、現在、社会実装にむけてその検出特性の解明や装置開発が最終局面にある。本報告では、SRDs の開発状況やその検出特性を発表することで、1F 環境中で想定される利用方法などについて総合的な議論を行う。

E03 Development of in-pipe exploration technology in high background radiation environment

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高バックグラウンド放射線環境における配管内探査技術の開発

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福島第一原子力発電所の廃炉作業において、施設内外の配管内の非破壊検査及び配管取り外し後の内部の汚染検査は重要な課題である。配管内部の非破壊検査のターゲットを設定するため東京電力にヒアリングを行い、1F 施設内の配管内に α 線放出核種や水素ガス、堆積物、水分を含むことなどが確認されている。この状況を踏まえ研究のデザインとしては、内部透過を目的とする非破壊検査及び放射線イメージングを 2 つの大きなテーマとして設定した。本発表では、研究の計画及び放射線イメージングに関する成果の一部を紹介する。

E04 Luminescent lanthanide complexes with high detection sensitivity for α-particles

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α線を高感度で検出できる発光性希土類錯体

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α線汚染を高精度に検出するシステムを構築するために、α線存在下で強く光る材料の開発が望まれている。本研究ではα線プラスチックシンチレーター用の新規発光材料探索を行った。具体的にはポリスチレンに発光性希土類錯体を分散させたプラスチックシンチレーターの発光特性について検討した。プラスチックシンチレーターにおける希土類励起の発光効率を検討したところ、赤色発光を示すユウロピウム錯体において高い効率を示した(発光量子収率>60%)。このユウロピウム錯体を分散させたプラスチックシンチレーターは市販のプラスチックシンチレーター(サンゴバン社、BC400)と比べてα線存在下で 12.5 倍高い発光強度が検出された。また、緑色発光を示すテルビウム錯体においても、市販のシンチレーター(サンゴバン社、BC400)と比べてα線存在下で 3.0 倍高い発光強度が検出された。

E05 Establishment of 3-D dose dispersion forecasting method and development of in-structure survey using the transparency difference of each line gamma-ray

Shinya Sonoda[1], Atsushi Takada[1], Tohru Tanimori[2], Minoru Tanigaki[2], Haruyasu Nagai[3], Hiromasa Nakayama[3], Daiki Satoh[3], Tetsuya Mizumoto[4], Shotaro Komura[4]
[1]Kyoto Univ., [2]KURNS, [3]JAEA, [4]FSiC Inc.

3 次元線量拡散予測法の確立とγ線透過率差を利用した構造体内調査法の開発

園田 真也[1], 高田 淳史[1], 谷森 達[2], 谷垣 実[2], 永井 晴康[3], 中山 浩成[3], 佐藤 大樹[3], 水本 哲矢[4], 古村 翔太郎[4]
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我々はガンマ線の到来方向を一意に決定し，ガンマ線全単射画像を測定可能な電子飛跡検出型コンプトンカメラ (ETCC) を開発している. 福島第一原子力発電所 (1F) 内の sub-mSv/h 環境下で使用可能な 3 次元汚染物質飛散検知・予測システムの実用化を行う．また，建屋内の 3 次元 Cs 分布測定法の開発，1.5MeV 以上のデブリガンマ線探査を行いデブリの全容把握を目指す．1F 構内の高線量環境下で動作するようにトリガーロジックの改良と詳細な遮蔽計算を実施した．日本原子力研究開発機構が所有する校正用線源を用いて高線量環境下における ETCC の動作試験を実施して正しく動作することを確認した．2024 年 3 月 26 日，27 日に 1F 構内で ETCC を用いて原子炉建屋周辺の放射線分布を二地点から測定し，Cs-137 由来の 662keV ガンマ線と高エネルギー成分のイメージングを実施した．また，ガンマ線スペクトロメーターを用いて建屋周辺のガンマ線スペクトルの測定を複数地点で行った．

E06 The World’s Highest Radiation Tolerant Performance Camera

Mikio Katsura, Hazuki Nakazawa, Yudai Suzuki, Motoki Mizumura, Naoki Kajihara
CORNES Technologies Ltd.

世界中の原子力施設で活躍する耐放射線カメラシステム

桂　幹夫, 中澤 葉月, 鈴木 雄大, 水村 元貴, 梶原 尚樹
コーンズ テクノロジー株式会社

コーンズテクノロジー株式会社は、原子力施設や研究所に耐放射線性カメラを供給する英国 Mirion Technologies (IST)社の国内代理店です。Mirion 社は 40 年近くにわたり耐放射線カメラの供給と技術開発を続けており、原子力施設内の監視用途（CCTV）や炉内調査・メンテナンス、ロボットやアーム装置の操作や監視等、世界中の原子力施設で幅広く活躍する耐放射線性カメラをご提供しております。 最近では CMOS 技術を採用した高い耐放射線性（1MGy 対応）を持つカラーシステムカメラも開発され、線量が高く厳しい環境下でもカラー映像の取得が可能になりました。小型軽量のカラーカメラやパンチルト機構や照明オプションを持つシステムカメラ等、ユーザ様のご要望を満足する幅広いカメララインナップをご紹介しております。

E07 Study on Molecular Structural Influences of Radiation Resistant Oils for Their Properties

Yoshikazu Hayashi
MORESCO Corp.

耐放射線性潤滑油の分子構造が各特性に及ぼす影響に関する研究成果

林 義和
株式会社 MORESCO

世界最高水準と言える当方の耐放射線性潤滑剤モレスコハイラッドを基軸に、様々な照射評価/共同研究を国内外学術機関と近年進めている中で、直近では世界三大加速器 PJ の一つ、欧州 PJ の核を為す CERN(セルン)との、全 6 種に及ぶ構造体のオイルへのガンマ線照射評価にて、分子構造差異による耐放射線性と放射線ダメージの機構解析を試みた。更に世界初と思われる被曝前後の潤滑特性変化も、6 種の構造体全てに対し実施した。 結果、各オイル間の微細に思える分子構造差が、被曝による分子レベルの変性度差異を生じさせる事のみならず、各々の潤滑性やそれらの被曝後の変化度にも明確な差異をもたらす事などの知見が多く取得され、同時に耐放射線性と潤滑性の何れもにおいて、既存品のモレスコハイラッド RP-42R が最もバランスが取れ、安定的な特性を発揮できる分子構造を持つことの特定にも至った。これらを通じた成果を、今回包括的に発表する。

E08 Holographic memory optimization method for an Optically reconfigurable gate array

Takumi Fukumoto, Minoru Watanabe and Nobuya Watanabe
Okayama University

光再構成型ゲートアレイにおけるホログラフィックメモリの最適化手法

福本 拓海, 渡邊 実, 渡邊 誠也
岡山大学

廃止措置下の原子力発電所の格納容器内や宇宙空間などの放射線環境下で集積回路を動作させる場合、集積回路上でソフトエラーや恒久故障が発生する。我々は光を用いて並列的に回路を構成することで高い放射線耐性を実現する光再構成型ゲートアレイの開発を進めている。ただ、光再構成型ゲートアレイでは回路構成に多数のフォトダイオードを用いるが、そのばらつきによって光エネルギーを効率的に使用できない問題点があった。このため、フォトダイオードのばらつきに合わせて適切な光パターンを供給するホログラフィックメモリの最適化手法を提案する。本稿ではフォトダイオードのばらつきを補正した回路実装の試験結果について報告する。

E09 Decontamination & Decommissioning Technologies for the Civil Nuclear Industry

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Innovative Physics Limited

The nuclear industry confronts challenges in decommissioning, striving for efficiency, safety, and cost reduction. Advanced technologies like robotics, sensors, and AI offer solutions by automating tasks, enhancing accuracy, and minimizing human error. In sorting and segregating nuclear waste, computer vision, machine learning, and robotics automate processes, improving efficiency, reducing costs, and ensuring safety by eliminating worker radiation exposure. The technology's potential extends beyond nuclear industry applications to waste management, mining, and construction. Gamma imaging systems, developed in collaboration with Japanese partners, detect radiation hotspots, aiding in decontamination efforts by providing remote observation and identification of radioactive materials. For decommissioning planning, mapping the radiological environment is crucial, especially locating fissile material. Custom solid-state neutron detectors offer high tolerance to gamma radiation, enabling monitoring of neutron flux in highly radioactive environments for criticality monitoring and emergency management. Very low-level and low-level waste management involves surface contamination measurement and radioactivity isotope identification using large scintillators and TDI techniques for enhanced security and variable speed detection.

E10 Development of Optical Materials and Its Evaluation for the Radiation Dose-Rate Monitor under Ultra-High Dose-Rate II

Shunsuke Kurosawa[1, 2]
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新規機能性発光体の開発とこれを用いた高線量率場における線量計の評価　2

黒澤 俊介 [1, 2]
[1] 東北大学, [2] 大阪大学

ガンマ線と中性子線に感度をもつ赤色発光シンチレータを開発し、これを用いたリアルタイムに線量率を計測する検出器を開発した。

究プログラムの選定課題「ペデスタル部鉄筋コンクリート損傷挙動の把握に向けた構成材料の物理・化学的変質に関する研究」のプロジェクトの概要の紹介である。

H02 Corrosion Behavior of Carbon Steel in Humid Environment Simulating γ Irradiation

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ガンマ線照射下を模擬した湿潤環境における炭素鋼の腐食挙動

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燃料デブリから放出されるγ線は水や酸素を放射性分解し、過酸化水素やオゾンを生成する。これらの生成物は、格納容器に使用される炭素鋼の腐食を促進する可能性がある。そこで本研究では、格納容器の健全性を評価する為に、湿潤環境に曝された炭素鋼の腐食速度に及ぼすオゾン濃度と湿度の影響を検討した。腐食速度計測には、腐食速度センサである Atmospheric corrosion monitor (ACM)センサ及び Resistmetric corrosion monitor (RCM)センサを用いた。どちらの腐食速度センサを用いた場合でも、炭素鋼の腐食速度は、オゾン濃度が高いほど大きくなった。ACM センサで計測した腐食速度は、湿度が高くなるにつれて大きくなった。一方、RCM センサで計測した腐食速度は、湿度が高くなるにつれて小さくなった。当日の発表では、腐食速度へ与える湿度の影響が腐食速度センサによって異なる傾向が見られた理由について考察する。

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廃棄物対策

I01 Waste Management Symposia: The Annual Phoenix Conference Exchanging Knowledge from Around the World

Kazuhiro Suzuki[1], Gary Benda[1], Takashi Mitsui[2], Katsunori Koarai[3]
[1]Waste Management Symposia, [2]Tousou Mirai Technology Co. Ltd., [3]Createc East-Asia GK,

Waste Management Symposia: 世界中の知識を交換する年次フェニックス会議

鈴木 一弘[1], ベンダ ゲリー[1], 三井 崇[2], 小荒井 克典[3]
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毎年 2 月末～3 月上旬にかけて、アリゾナ州フェニックスで開催されている WM 国際会議は、米国 NPO の Waste Management Symposia(WM Symposia)により実施されています。今年で 50 回目となる WM2024 は、2024 年 3 月 10 日(日)～3 月 14 日(木)に、日本からの 47 名を含めて 30 か国の政府機関、産業界、学界、地方自治体、そして国際機関等からの 3,300 名の参加を得て開催されました。WM 会議では、放射性廃棄物とそれに関連するタイムリーな原子力バックエンドの問題に焦点を当て続けてきています。2013 年からは、毎年、福島第一の廃炉に関する特別セッションも設けています。この NPO は、人材開発や学生支援も重要なミッションとして取り組んでいます。毎年 30 万ドル以上をその教育使命に提供し、原子力科学と工学の学生に奨学金を支給する等、廃棄物管理に必要な要員の増強に努めています。

I02 Retrieval and management of radioactive materials and wastes supporting facility decommissioning

David John, Junichi Hikosaka
Cavendish Nuclear Limited

原子力施設の廃止措置における放射性物質および廃棄物の取り出しと管理

John David, 彦坂 淳一
Cavendish Nuclear Limited

キャベンディッシュ・ニュークリア社は、解体・除去・環境修復といった複雑な業務の遂行および管理に携わってきた確かな実績を有し、英国での廃炉事業で最も長い経験をもつ会社です。私たちは多くのプロジェクトを遂行してきましたが、この概要書は、特に福島第一原子力発電所におけるスラッジやプール内廃棄物の取り出しおよび処理に関連する知見を示すものです。セラフィールドの第一世代のパイル・レガシー・ポンド（B29）の廃止措置プロジェクトは、プール内廃棄物やスラッジの取り出しおよび処理の大規模なプロジェクトの一例になります。また、弊社が小規模プロジェクト向けに開発したプール内廃棄物やスラッジの処理および固化のための技術モジュールは、マグノックス社にて少量のスラッジ廃棄物やイオン交換樹脂を経済的に処理する目的で積極的に実プロジェクトに導入されています。

I03 Development of adsorbent sampling technology from cesium adsorption vessels

Keito Toda, Naoya Nakamura, Nobuyuki Nakashio
ATOX CO., LTD.

セシウム吸着塔からの吸着材採取技術の開発

戸田 渓斗, 中村 直哉, 中塩 信行
株式会社アトックス

福島第一原子力発電所の水処理二次廃棄物の性状把握に向けて、セシウム吸着装置吸着塔および第二セシウム吸着装置吸着塔から高線量の使用済吸着材を安全に採取するための吸着材採取技術を開発した。本研究で開発した試料採取装置（ISM: Integrated Sampling Module）は事前の線量評価に基づき設計され、吸着塔上部の穿孔、吸着材試料の採取および穿孔部の閉止機能を有する。本装置により作業員の過剰被ばくなく使用済吸着塔実機 7 基からの採取を完了し、吸着材採取技術の有効性を実証した。

I04 Design and Characterization of Metakaolin-Based Geopolymers with Enhanced Properties for Neutron-Containing Fuel Debris Removal

Xiaobo Niu, Yogarajah Elakneswaran
Hokkaido Univ.

中性子を含む燃料デブリ除去に向けた様々な特性をもつメタカオリンベースのジオポリマーの設計と特性評価

牛 暁博, エラクネスワラン ヨガラジャ
北海道大学

東京電力福島第一原子力発電所の廃炉作業において、汚染水の処理によりさまざまな放射性廃棄物が発生し、それらは現地で保管されている。廃炉の中長期ロードマップでは、廃棄物の処理と処分に関する技術的な見通しを示すことが目標とされた。過去、北海道大学とシェフィールド大学は、日英原子力共同研究英知プロジェクトの一環として、放射性廃棄物処理におけるジオポリマーの研究を実施した。ジオポリマーは ^{137}Cs と ^{90}Sr の固化性能と安全性を有し、高流動性と高アニオン保持性も備えている。さらに、ジオポリマーの実用規模の固化施設の設計と要件を確立した。以上を踏まえて、このプロジェクトの目標は、福島第一原子力発電所から発生する燃料デブリ、汚染水、その他の放射性廃棄物のために、商業化可能なメタカオリンベースのジオポリマーを開発することである。特に、ホウ素の有無によるメタカオリンベースのジオポリマーの適用性について検討する。

I05 Solidification of ALPS Sediments Wastes Using Phosphate Ceramics

Anna Gubarevich, Ryotaro Kubo, Shintaro Yasui, Katsumi Yoshida, Kenji Takeshita
Tokyo Institute of Technology

リン酸塩系セラミックスによる ALPS 沈殿系廃棄物の安定固化技術の開発

グバレビッチ アンナ, 久保 遼太郎, 安井 伸太郎, 吉田 克己, 竹下 健二
東京工業大学

福島第一原子力発電所の安全な廃炉のためには、ALPS 沈殿廃棄物の安定固化が重要であ

る。本研究では、リン酸塩セラミックスとコールドシンタリングプレス（CSP）を用いた安定固化技術の開発に取り組んでいる。リン酸塩セラミックスは、高い耐放射線性と水中耐久性で知られており、リン酸塩の結晶構造には、放射性元素を安定的に取り込むための特定のサイトがあり、放射性廃棄物を固定化するために有望である。模擬 ALPS 沈殿廃棄物を 2 段階のプロセスで多結晶リン酸セラミックスに固化させた。まず、ALPS スラリーを化学置換と縮合反応により不溶性リン酸塩型に変換し、CSP によりそれを緻密化した。放射性核種の安定固化を確実にするために、CSP によって促進されるリン酸塩の結晶化と緻密化に対する CSP プロセスパラメータの最適化について議論した。

I06 SIAL® : Geopolymer solidification technology approved by Slovak / Czech Nuclear Authority

Hisashi Mikami[1], Kazutaka Hirata[1], Nobuyuki Sekine[1], Marcela Blazsekova[2], Milena Prazska[2], Maros Juraska[2], Marek Meciar[2]
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SIAL®：スロバキアとチェコの規制当局から認可されているジオポリマー固型化技術

見上 寿[1], 平田 一尭[1], 関根 伸行[1], Blazsekova Marcela[2], Prazska Milena[2], Juraska Maros[2], Meciar Marek[2]
[1]富士電機株式会社, [2]Jacobs Slovakia s.r.o.

スロバキアとチェコの規制当局から認可されている SIAL®ジオポリマー固型化技術の特徴と性能の実績を紹介します。この技術は約２０年に亘り運用されています。近年、ジオポリマーは、温暖化ガス削減に効果のある固型化剤であるとともに、核種閉じ込め性能や耐熱・耐酸性能に着目され、セメントでは固型化困難な廃棄物への適用が EU PREDIS Pj 等で検討されています。この特性は、福島第一原子力発電所の汚染水二次廃棄物に対しても、スラッジや各種スラリー等の模擬廃棄物固型化試験で示されています。また、最近では、安全なデブリ取り出しを目的に、炉内のデブリの安定化のため温水中での固型化、高温表面への接触環境での固型化維持、残存炉内構造物への充填性等の検討を実施しています。

I07 Unprecedented fabrication method of granular layered double hydroxide with remarkable antimony adsorption properties

Naoki Asao, Tsukasa Terashima, Yuta Morioka
Shinshu University

粒状層状複水酸化物の新規作製法の開発とアンチモン吸着特性評価

浅尾 直樹, 寺島 司, 森岡 佑太
信州大学

層状複水酸化物（LDH）はアニオン吸着剤として機能するため、工業廃水に含まれるアン

チモンに対する吸着研究が進められている。しかし、従来の作製法では材料が粉体として得られるため、カラム通水条件で吸着を行うためには造粒化が必要であり、通常その際に吸着性能の低下を伴う。今回我々は、福島第一原子力発電所の放射性汚染水に含まれる放射性アンチモン除去を目的としてLDHの新規作製法について検討を行ったところ、本材料を粒状体として直接作製する方法を開発するとともに、アンチモンに対して優れた吸着性能を示すことを見出したので報告する。

I08 Study on the Methodology for Rational Treatment/Disposal of Contaminated Concrete Waste Considering Volume Reduction of Waste (1)

Yuka Morinaga[1], Daisuke Minato[1], Naoko Watanabe[2], Takafumi Sugiyama[2], Katsufumi Hashimoto[2], Shinichiro Uematsu[2], Munemichi Kawaguchi[2], Daisuke Kawasaki[3], Satoshi Yanagihara[3], Yukihiro Iguchi[3], Toru Kitagaki[3]
[1]CRIEPI, [2]Hokkaido Univ., [3]Fukui Univ., [4]JAEA

放射性コンクリート廃棄物の減容を考慮した合理的処理･処分方法の検討 (1)

森永 祐加[1], 湊 大輔[1], 渡辺 直子[2], 杉山 隆文[2], 橋本 勝文[2], 植松 慎一郎[2], 河口 宗道[2], 川崎 大介[3], 柳原 敏[3], 井口 幸弘[3], 北垣 徹[3]
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福島第一原子力発電所の廃炉を完遂する上で、合理的な廃棄物管理計画の立案は必要であり、その中でも大量のコンクリート廃棄物の処分･処理に関する検討は重要な課題の一つである。放射性コンクリートを骨材とセメント部分に分離して再利用することはコンクリート廃棄物を大幅に減容する上で有効な方法の一つであるが、骨材分離によって生じる汚染したセメント粒子･粉末の処分方法として廃棄体化を想定する場合、セメント微粉と固化材の比率や条件に関する検討例は数少ない。本研究では骨材分離によって生じた模擬セメント微粉を用いて模擬廃棄体を作製し、摸擬廃棄体の性状評価を行った。

I09 Study on the Methodology for Rational Treatment/Disposal of Contaminated Concrete Waste Considering Volume Reduction of Waste (2)

Katsufumi Hashimoto, Yingyao Tan, Junxiao Liu, Takafumi Sugiyama
Faculty of Engineering, Graduate school of Engineering, Hokkaido University

放射性コンクリート廃棄物の減容を考慮した合理的処理･処分方法の検討 (2)

橋本 勝文, Tan Yingyao, Liu Junxiao, 杉山 隆文
北海道大学大学院　工学研究院

福島第一原子力発電所の廃炉に伴い、放射性コンクリート廃棄物の合理的処分と減容化が求められる。本研究では、放射性コンクリート廃棄物を再利用した際の核種の移行挙動を評価することを目的とし、模擬汚染コンクリート中での核種の移行挙動を観察した。このとき、コンクリート構造物から採取した再生骨材を異なる濃度の CsCl および SrCl2 の水溶液に一定期間浸漬した。これにより、核種イオンを含む環境下で供用された模擬汚染コンクリートを破砕して得られる汚染再生骨材（再生粗骨材）を模擬的に作製した。浸漬期間は 1 週間あるいは 2 か月とし、X 線 CT による画像解析と LIBS や EPMA を用いた元素分析を適用した。また、浸漬期間終了後に、セメントペーストで再生骨材を被覆して 2 か月経過した時点で核種イオンの移行挙動について、上記の画像解析および元素分析による核種イオンの移行性状を評価した。

I10 Study on the Methodology for Rational Treatment/Disposal of Contaminated Concrete Waste Considering Volume Reduction of Waste (3)

Munemichi Kawaguchi, Keigo Sokugawa, Kazuhiro Sawa
Hokkaido Univ.

放射性コンクリート廃棄物の減容を考慮した合理的処理･処分方法の検討 (3)

河口 宗道, 束河 慶吾, 澤 和弘
北海道大学

本研究は、模擬 Cs 汚染コンクリートの骨材分離時に発生する粉塵中の Cs 濃度を測定する実験を行った。実験には骨材の異なる 2 種類の模擬 Cs 汚染コンクリート塊（約 30mmL）を使用し、ポットミル内にこのコンクリート塊とステンレス球（10mmφ）を入れて骨材分離実験を行った。Cs 濃度は、骨材分離前のコンクリート、骨材分離中にポット内に浮遊している粉塵、骨材分離後 20 分間にポット内に浮遊している粉塵をサンプリングして原子吸光分光分析装置により Cs 濃度測定を行った。その結果、粉塵は主にモルタルから発生するため、コンクリートの Cs 濃度よりも粉塵の Cs 濃度の方が約 4 倍高くなることが分かった。

I11 Radioactive Scrap Metal Recycle, Japanese Demonstration.

Colin Austin, Tomoaki Fujikawa, Makoto Kikuchi
Energy Solutions

Energy Solutions (ES), with its rich experience in D&D, is now re-illustrating the international business strategy to design D&D around recycling, not just with the metals, but also with assets such as radio nuclides that can be harvested to be re-used as radioisotopes. Marubeni Utility Services (MUS), as ES’s agent for the metals melt business, believes that this is going to be a paradigm shift for the D&D to become recycle projects, not a waste management project, and is very excited to work together through this phase to establish a new standard for Japan and the world.

I12 Transformational Technology Driving the Paradigm Shift From Nuclear Waste Disposal to Valuable Resource Recycling.

Tim Milner, Colin Austin, Makoto Kikuchi
Energy Solutions

Energy Solutions (ES) with its rich experience in D&D and nuclear waste management and disposal is applying its knowledge and expertise to create value from what was traditionally referred to as nuclear waste. In doing so, this preserves strategically important radioactive waste disposal site capacity via diversion and resource recovery and reduces carbon footprint by repurposing and reusing metals avoiding the considerable greenhouse gas emissions from metal ore processing and steel manufacture. Additionally, providing a source of radionuclides harvested for beneficial use from what was once considered waste, to drive forward, radio-medicine, instrumentation, space flight and agriculture. This paradigm shift from waste to resource further enhances the credibility and vital role the nuclear industry will play in a sustainable energy future and combating climate change.

I13 International Best Practice Management and Disposal of Radioactive and Hazardous Wastes: Developing a Collaborative Partnership between Japan and Australia

Bill Miller, Nate Smith
Tellus Holdings

Tellus is an Australian company that develops advanced radioactive waste management solutions. Tellus operates a LLW and hazardous waste disposal facility (Sandy Ridge) excavated in high purity kaolin. This kaolin can be used to manufacture geopolymers for use in the nuclear industry. Tellus is also developing an international deep geological repository (Chandler) and a deep borehole demonstration project. Tellus is offering to work with Japanese organisations to develop collaborative partnerships.

F01 Innovation : from Orano Internal Needs to the International Market

Vincent Tran, Daphne Ogawa, Victor Guillon
Orano

Answering ordinary and complex challenges arising during dismantling & decommissioning operations, Orano developed an agile culture where innovation can

grow from the needs of the field. Strong of our operators and experts, their experience in our own facilities decommissioning and projects worldwide, proven solutions supporting decommissioning projects can now be proposed to customers, improving worksite productivity and safety.

F02 Orano's HRB: a dedicated facility for the development and qualification of FOAK projects in La Hague

Nicolas Breton, Vincent Janin, Daphne Ogawa, Guillaume Grandjean
Orano

A major part of the challenges in 1F D&D, especially the retrieval and conditioning of the fuel debris, are first-of-a-kind projects, requiring significant efforts in development & qualification (D&Q), and operator training. For the operation, maintenance and D&D of La Hague reprocessing plants, Orano has built a dedicated facility called HRB (Hall de Recherche de Beaumont), allowing the deployment of resources such as mockups, with the aim to properly prepare and implement complex operations especially for waste retrieval and conditioning projects.

F03 Investigation on Estimation Method for the Characterization of Highly Radioactive Waste Using Non-Destructive Measurement Data

Philippe Bernard[1], Frederic Met[1], Damien Gerard[1], Ken Kojima[2], Yoshikazu Koma[3]
[1]Veolia Nuclear Solutions France, [2]Veolia Nuclear Solutions Japan, [3]JAEA

ベルナール フィリップ[1], メット フレデリック[1], ジェラール ダミアン[1], 小嶋 健[2], 駒 義和[3]
[1]Veolia Nuclear Solutions France, [2]株式会社ヴェオリアニュークリアソリューションズジャパン, [3]日本原子力研究開発機構

福島第一原子力発電所事故で発生した廃棄物の保管にあたり、その管理に向けたパラメータの取得を遠隔で行うことが求められている。保管容器表面中央で最大 10 Sv/h と高線量率となる放射性廃棄物について、ガンマ線スペクトルを測定することで、廃棄物中の核種ごとのインベントリを推定する鍵となる核種（^{137}Cs, ^{60}Co, ^{154}Eu）を定量する測定系について、モンテカルロシミュレーションを用いて、その実現可能性を提示できた。また、保管容器内にインベントリが偏在することによる測定結果の不確かさについても評価を行った。この仕組みは市場で入手可能な検出器とディジタル式の信号処理装置で構成可能であり、その実現に向けたロードマップに沿って、実際の測定を実現するまでの間に考慮すべき問題点とその解決方策についても検討している。

F04 Study of the applicability of GeoMelt® vitrification treatment to various radioactive solid wastes in Fukushima Daiichi Nuclear Power Plant (1F).

Mirai Kuramata[1], Ken Kojima[1], Kevin Finucane[2], Brett Campbel[2], Hiroaki Nakauchi[3], Mitsuhiro Sato[3]
[1]Veolia Nuclear Solutions Japan Corporation, [2]Veolia Nuclear Solutions Federal Services, [3]Daiei Kankyo Co., Ltd.

福島第一原子力発電所（1F）内の様々な放射性廃棄物に対するGeoMelt®ガラス溶融処理の適用性の検討

倉又 未来[1], 小嶋 健[1], Finucane Kevin[2], Campbel Brett[2], 中内 博昭[3], 佐藤 充宏[3]
[1]株式会社ヴェオリアニュークリアソリューションズジャパン, [2]Volia Nuclear Solutions Federal Services, [3]大栄環境株式会社

福島第一原子力発電所（1F）には、様々な放射性廃棄物が存在する。GeoMelt® ICV™は、幅広い廃棄物の処理実績がある汎用性の高いガラス固化技術である。今回、「雑多な瓦礫」（タスク 1）、「ALPS 炭酸塩スラリー脱水物および保管容器」（タスク 2）を対象に、GeoMelt® ICV™の適用性を検証した。タスク 1 は、三重中央開発（株）の 1t 規模の試験設備を使用し、コンクリート、鋼材、断熱材、PCV ホース等および模擬 1F 土壌の一括溶融試験を実施した。製作された固化ガラスは、金属層と緻密かつ耐久性の高いガラス相を形成した。タスク 2 は、米国リッチランドにある 200kg 規模の試験設備を使用した。鋼製保管容器は完全に溶融し、底部に金属層を形成した。模擬スラリー脱水物もガラスに溶け込み、緻密で耐久性のあるガラス相を形成した。各廃棄部の溶融処理が可能であることを確認できたことから、次のステップとして、溶融処理による廃棄物の減容化の検討を行っている。

J01 Prospects for Environmental Radioactivity Assessment Considering Environmental Dynamics of Radionuclides and Human Activities

Hiroshi Kurikami, Yoshito Sasaki, Motoki Terashima, Kazuya Yoshimura, Hironori Funaki, Yukihisa Sanada
Japan Atomic Energy Agency

放射性核種の環境動態と人間活動を考慮した環境放射能評価の展望

操上 広志, 佐々木 祥人, 寺島 元基, 吉村 和也, 舟木 泰智, 眞田 幸尚
国立研究開発法人日本原子力研究開発機構

日本原子力研究開発機構 CLADS はこれまで、福島第一原子力発電所事故後の環境回復研究を行ってきた。令和 5 年度より、福島国際研究教育機構（F-REI）からの委託を受けて

放射性核種の環境動態と人間活動を考慮した環境放射能評価に係る研究を開始した。本研究は、避難区域の設定や食品の出荷制限の観点から被ばく線量を指標とした総合的評価結果をわかりやすく住民に情報提供することを目的としている。地域に応じた住民の懸念や関心に応えることで福島復興に向けた安全安心なまちづくりに貢献することを目指し、次の二つの計画を進める。(1)現地調査、室内試験、数値シミュレーションを通して、避難指示解除後の人間活動と環境動態の関係を明らかにし、被ばく線量に基づく総合的な環境放射能評価を行う。(2)情報発信のためのウェブサイト設計を進める。

J02 Research and Development of Digital Technologies to Explore Radiation Source Distributions for Exposure Reduction -Development status based on evaluation tests inside 1F Unit 5-

Masahiro Suzuki, Yuto Aoki, Kazuhisa Aoki, Susumu Yamada, Minsik Kim, Takashi Yamaguchi, Masahiko Machida, Koji Okamoto
Japan Atomic Energy Agency

被ばく低減のための線源分布評価に係るデジタル技術の研究開発 ～1F５号機での検証試験等を踏まえた開発状況～

鈴木 政浩, 青木 勇斗, 青木 和久, 山田 進, 金 敏植, 山口 隆司, 町田 昌彦, 岡本 孝司
国立研究開発法人　日本原子力研究開発機構

東京電力福島第一原子力発電所（以下、「1F」という）の廃止措置において、燃料デブリ取り出し作業の本格的な実施に先立ち、線量率の高い原子炉建屋（以下、「R/B」という）内でのアクセスルート構築を安全にかつ効率的に行うためには、1F 現場の環境改善が必須である。JAEA は、現場の線量率データ等を基に、汚染源（線源）の特定を迅速に行うこと、その特定された線源に対する除染や遮へい等の線源対策をサイバー空間上（VR 等）で柔軟に検討が可能となる解析評価システムの開発を進めている。本報告では、プロトタイプシステムから 1F 現場で実際に使えるシステムを開発することを目指し、１F５号機での検証試験を踏まえた現在までの開発状況を紹介する。

J03 A phoswich detector for detecting alpha emitters in piping

Yuki Morishita
Japan Atomic Energy Agency

配管内のα核種検知のためのフォスウィッチ検出器

森下 祐樹
日本原子力研究開発機構

福島第一原子力発電所の廃止措置では、アルファ線やガンマ線を放出する核種を内包する配管の汚染の有無を調査・測定する必要がある。そこで、アルファ核種から放出される低エネルギーガンマ線検出用のフォスウィッチ検出器を開発し、実験とシミュレーション計算により検証した。この検出器は YAP:Ce と BGO シンチレータと信号増幅用の光電

子増倍管で構成した。パルス形状弁別（PSD）プロットは低エネルギーと高エネルギーのガンマ線を区別し、シミュレーション計算でも同様の結果を得た。

J04 Flexible Remote Radiation Measurement System on the Multiple Radiation Platform

Masaaki Kaburagi, Yuki Sato, Susumu Tagami, Koki Hirai, Naruto Sano, Koji Usami
Japan Atomic Energy Agency

マルチ放射線プラットフォームにおけるフレキシブル放射線計測システムの開発

冠城 雅晃, 佐藤 優樹, 田上 進, 平井 功希, 佐野 成人, 宇佐美 浩二
JAEA

本発表は、高線量率γ線場の利用に特化した高性能放射線計測システム、高機動性の６脚ロボット、多様な試験が可能な放射線実証場（マルチ放射線プラットフォーム）という３つの要素からなる燃料デブリ取り出しに向けた研究プログラムである。それぞれ、放射線計測システムは、^{137}Cs の高線量率環境下において ^{60}Co 線源を測定できる能力を有し、また、６脚ロボットは、階段などの障害を乗り越えることができる高機動性を有する。マルチ放射線プラットフォームは、JAEA の廃棄物試験施設(WASTEF)のホットセルに構築し、多様な放射性物質を利用した放射線計測器性能評価、ロボットのモックアップ（ホットモックアップ）、機器の耐放射性試験が可能な多機能な実証場である。最終的には、６脚ロボットに放射線計測システムを搭乗させたホットモックアップを実施することで３つの要素技術を統合させることでの相乗効果を期待している。

J05 Development status of the debrisEye at TEPCO's Fukushima Daiichi Nuclear Power Plant - Addition of object display function -

Kenta Shimomura[1], Takuya Yamashita[1], Eiichi Nagai[2], Satoru Nakashima[3], Nobuyuki Kumakawa[3], Shoichi Shinzawa[3]
[1]Japan Atomic Energy Agency (JAEA), [2]Prometech Software, Inc., [3]Tokyo Electric Power Company Holdings (TEPCO)

東京電力福島第一原子力発電所の debrisEye の開発状況 -物体表示機能の追加-

下村 健太[1], 山下 拓哉[1], 永井 英一[2], 中島 悟[3], 熊川 喜之[3], 新沢 昌一[3]
[1]日本原子力研究開発機構, [2]プロメテック・ソフトウェア社, [3]東京電力 HD

福島第一原子力発電所(1F)の内部調査が行われ、原子炉格納容器内の状況が徐々に明らかになりつつある。内部調査により得られた情報については、JAEA と東京電力が構築した廃炉研究基盤データベース(debrisWiki)で管理されている。しかし、個々のデータだけでは、事故の経過全体を把握することは困難である。そのため、1F の CG モデルを表示し、

内部調査結果等の付加情報をユーザーが追加して表示できる debrisEye の開発を実施している。debrisEye は、任意の断面での切抜、任意の位置に付加情報(サンプル分析結果等)を書込/表示する機能を有している。今回物体を表示する機能を実装することで 1 号機の内部調査で使用されたドローンと類似のドローンを debrisEye 上に表示できるようにし、ドローンと同等の視覚での確認を行うことを可能とした。debrisEye を用いることで、視覚的な理解の促進ができ、事故の進捗状況の把握や廃炉作業の効率化に寄与できると考えている。

J06 Measurement methods for the radioactive source distribution inside reactor buildings using a one-dimensional optical fiber radiation sensor

Yuta Terasaka
Japan Atomic Energy Agency

一次元光ファイバ放射線センサを用いた原子炉建屋内放射線源分布計測

寺阪 祐太
国立研究開発法人日本原子力研究開発機構

福島第一原子力発電所（1F）原子炉建屋内外等の廃炉作業環境においては、放射線業務従事者の作業安全確保のため、空間線量率や放射性物質分布等の把握が随所で進められているが、1F 原子炉建屋内には 10 mSv/h を超える高線量率エリアも多数存在する。現状では最低限の頻度で人が立ち入ることで空間線量率の測定やスミアサンプル採取による汚染密度の測定が行われている。日本原子力研究開発機構・廃炉環境国際共同研究センターでは英知を結集した原子力科学技術・人材育成推進事業の一環として、光ファイバを用いた放射性物質分布測定法の高度化研究を行った。本事業で開発した光ファイバ型放射線検出器を 1F 実環境に導入し、高線量率環境での放射線分布測定およびホットスポット検出に成功した。1F 実環境で本検出器の有効性を確認できつつあることから、将来的に現状人手で行われている測定手段の代替とすることで、作業者の線量低減に寄与できると考えられる。

J07 Study and development of laser-induced breakdown spectroscopy (LIBS) for decommissioning of Fukushima Daiichi Nuclear Power Station

Takahiro Karino[1], Katsuaki Akaoka[1], Ikuo Wakaida[1], Hironori Ohba[1], Joey Kim Soriano[2], Yuji Ikeda[2]
[1]Japan Atomic Energy Agency, [2]i-Lab., Inc.

福島第一原発廃止措置に向けたレーザー誘起ブレークダウン分光法（LIBS）の研究開発

狩野 貴宏[1], 赤岡 克昭[1], 若井田 育夫[1], 大場 弘則[1],

Kim Soriano Joey[2], 池田 裕二[2]
[1]日本原子力研究開発機構, [2]アイラボ株式会社

福島第一原子力発電所の廃止措置の際に取り出された燃料デブリや瓦礫のうち詳細な分析が行えるのはごく僅かである。レーザー誘起ブレークダウン分光法（LIBS）は、試料の前処理不要で短時間に元素分析が可能であり、耐放射性にも優れるため、デブリと瓦礫を迅速に分離する方法として適している。 燃料デブリ中の核分裂性 U-235 の測定は重要だが、U-238 との同位体シフトが小さいため困難である。高分解能分光器を用いると測定可能だが、スペクトルの強度が低下する。そこで、マイクロ波を用いてスペクトルを増強し、この欠点を補った。本発表では、マイクロ波アシスト LIBS による U-235 検出について紹介する。

J08 Development of HCl-free and rapid analytical method for radioactive waste from FDNPS

Yasuyuki Tanaka, Yuki Ohta, Noriyasu Kodaka, Riku Kikuchi, Irvin M. Banjarnahor, Van-Khoai Do, Takahiro Furuse, Kosuke Tanaka, Masahisa Watanabe
Japan Atomic Energy Agency

福島第一原子力発電所由来の放射性廃棄物分析に向けた塩酸フリーで迅速な分析手法の開発

田中 康之, 太田 祐貴, 小髙 典康, 菊池 里玖, バンジャルナホー イルビン, ド　ヴァン コハイ, 古瀬 貴広, 田中 康介, 渡辺 将久
日本原子力研究開発機構

福島第一原子力発電所放射性廃棄物の測定対象核種の多くは、従来の放射能測定法をそのまま適用した場合、目的核種の化学分離操作や長半減期核種の測定に時間を要し、数週間の工程がかかる核種分析が発生する。このため大熊分析・研究センターでは、これら核種の分析手法の簡易化・迅速化を実施してきた。最も時間を要する Se-79、Zr-93 及び Mo-93 等の難測定長半減期核種に対しては装置自体が高い分離性能を持ち、短時間での高感度測定が可能な ICP-MS/MS での測定と簡易な固相抽出分離を組み合わせることにより、数日程度で分析可能な新しい手法を開発した。一方、α核種、Sr-90 及び Ni-63 など従来の放射線計測が有効と考えられる核種は、1 つの試料から複数の核種を逐次的に分離することで化学分離操作の合理化を図った。また、開発した分析手法は分析設備への負荷を低減することを目的として塩酸を使用しない手法とした。

J09 Third-Party Analysis of ALPS Treared Water in Radioactive Material Analysis and Research Facility

Yoshihiro Tsuchida, Naoya Kaji, Makoto Ooka, Ritsuro Tokumori
Japan Atomic Energy Agency

JAEA 大熊分析・研究センターにおける ALPS 処理水第三者分析

土田 佳裕, 鍛治 直也, 大岡 誠, 徳森 律朗
国立研究開発法人日本原子力研究開発機構

JAEA 大熊分析・研究センターでは、放射性物質分析・研究施設第 1 棟において ALPS 処理水の第三者分析を実施している。2024 年 5 月末までに 6 回の分析を実施し、JAEA の Web サイトで分析結果を公開している。

J10 Chemical state elucidation of trace nuclides in microparticles using scanning transmission X-ray microscopy

Yusuke Watanabe, Goro Shibata, Masaaki Kobata, Kazuma Koarai, Yukiharu Takeda
Japan Atomic Energy Agency

走査型透過 X 線顕微鏡を用いた微小粒子中微量核種の化学状態解明

渡辺 勇輔, 芝田 悟朗, 小畠 雅明, 小荒井 一真, 竹田 幸治
国立研究開発法人日本原子力研究開発機構

本研究では福島第一原子力発電所事故由来の放射性物質や廃炉によって発生する廃棄物中の放射性核種の化学状態解明を目的として、SPring-8・RI 実験棟に設置された走査型透過 X 線顕微鏡(STXM)を用いた微小粒子分析手法の開発を実施した。環境中において放射性核種を吸着しその移行挙動に影響を与える河川懸濁粒子を対象に STXM を用いた粒子の性状把握と、粒子中微量元素の化学状態分析を行った。 pH や元素組成が異なる上流と下流の 2 地点で採取した河川懸濁粒子中の Fe と Al の元素分布と X 線吸収スペクトルを測定した。酸性を示す上流で採取した試料では Fe と Al は別々に分布しており、Fe は 3 価として存在していることが示された。一方下流の中性の河川水から採取した試料は 2 価の Fe が多く存在しており、Al の分布と強い相関を示した。STXM を用いた粒子中元素分布と化学形態の比較により、上流から下流にかけて pH の変化に伴い粒子の形成プロセスが異なることが示唆された。

J11 Towards establishing safe management of solid radioactive waste from 1F decommissioning - Cooperation between data collection and safety assessment –

Kazuki Iijima, Yoshikazu Koma, Takeshi Osugi, Mitsuru Sambongi, Takashi Okada
Japan Atomic Energy Agency

1F 廃炉廃棄物の安全な管理方法の確立に向けて ～データの取得と安全評価の連携～

飯島 和毅, 駒 義和, 大杉 武史, 三本木 満, 岡田 尚

日本原子力研究開発機構

福島第一原子力発電所の廃炉工程で発生する様々な種類の固体の放射性廃棄物の廃棄物ストリームを考える上で、安全に保管管理、処理、処分を進められることが第一であり、安全評価はそのための重要な手法の一つである。しかし、現状では、発生する廃棄物の性状、廃棄体性状、想定される処分環境など、入力データに様々な不確実性が存在する中で安全評価を実施する必要がある。本研究では、現在各研究開発で得られているデータに基づく処分安全評価結果の例を示し、それらを踏まえて今後各分野における不確実性を低減することが期待されるデータについて考察する。

Organizational Profile of IRID

A01

Naoaki Okuzumi, Osamu Seki, Hideki Yoshikawa
International Research Institute for Nuclear Decommissioning (IRID)

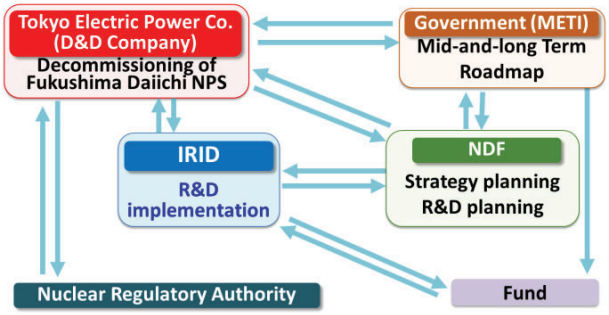
Abstract

Ever since the International Research Institute for Nuclear Decommissioning (IRID) was establishment in August 2013, IRID has engaged in research and development (R&D) of technologies necessary for the decommissioning of the Fukushima Daiichi Nuclear Power Station (NPS) which is an urgent issue. IRID focuses on strengthening the platform of decommissioning technology.

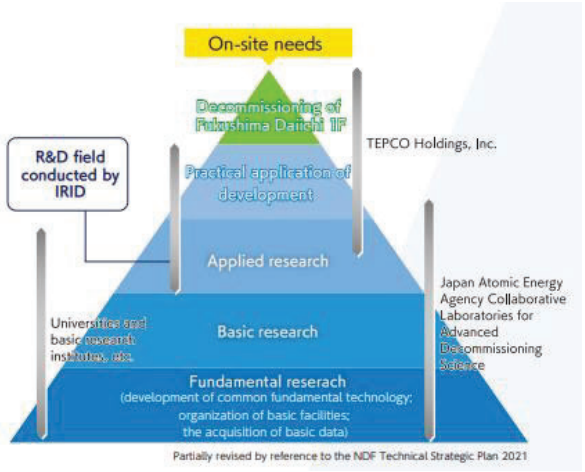
1. Scope of Work

- R&D for nuclear decommissioning
- Promotion of cooperation on nuclear decommissioning with relevant international and domestic organizations
- Human resource development for R&D

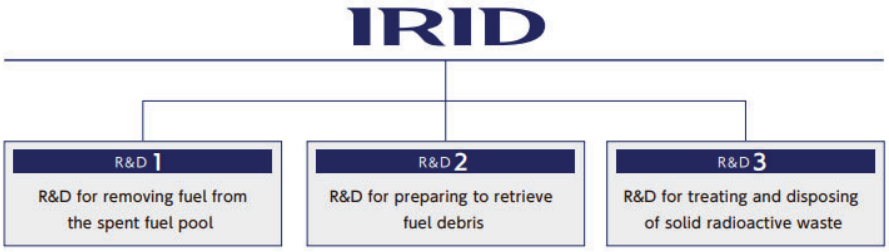
2. Roles of Organizations in the Decommissioning Projects of the Fukushima Daiichi NPS.



3. R&D Scope of IRID



4. Three major R&D for Nuclear Decommissioning



A02

Overview of IRID R&D Projects

Naoaki Okuzumi, Osamu Seki, Hideki Yoshikawa
International Research Institute for Nuclear Decommissioning (IRID),

Abstract

For the decommissioning of the Fukushima Daiichi Nuclear Power Station (NPS), four key players including TEPCO, the Japanese government, NDF and IRID are closely working together. IRID is a complex entity consisted of nineteen organizations that have responsibility in research and development (R&D) for the decommissioning of the Fukushima Daiichi NPS. IRID engages in three major R&D projects: (1) Project of fuel removal from spent fuel pool, (2) Project of preparation for retrieving fuel debris and (3) Project of the treatment and disposal of solid radioactive waste. These R&D projects are being conducted under the Mid-and-Long-Term Roadmap issued by the government. The period until completion of the decommissioning is divided into three phases. Currently, the second phase, R&D for preparation for retrieving fuel debris is underway.

1. Progress of R&D

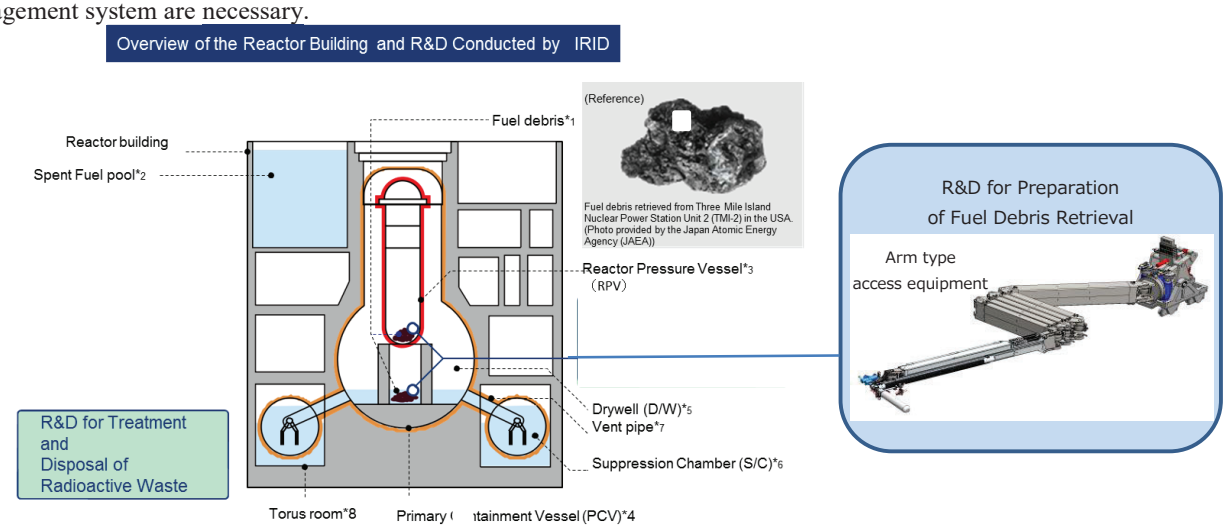
IRID proceeds with preparation of fuel debris retrieval based on a strategy indicated in the "*Technical Strategic Plan*" issued by the Nuclear Damage Compensation and Decommissioning Facilitation Corporation (NDF). IRID was developed element and robotic technologies for the Fukushima Daiichi.

First, detection technology to directly access fuel debris in the PCV was developed. In April 2015, a robot successfully entered the Unit 1 PCV. In FY 2016, a preparation for fuel debris investigation outside the pedestal started. At the same time, investigation robots for inside the pedestal, and remote-operated equipment to make an opening of the Unit 2 PCV penetration was developed to reduce worker's exposure. Additionally, fuel debris investigation inside the pedestal was conducted for Unit 3 by using an underwater swimming robot, and investigation equipment mounted a telescopic pipe and cameras for Unit 2. These robots can access fuel debris by remote operation and successfully obtained visual data of the PCV interiors. The Severe Accident Analysis Code was upgraded to identify fuel debris inside the reactor, and investigations through the cosmic-ray muon were performed. The distribution of fuel debris in the Unit 1 reactor was investigated from outside the reactor building by cosmic rays muon. The results of muon investigation revealed that almost no fuel remains in the reactor core. The muon transmission measurement was performed for Unit 2 from March to July 2016, and for Unit 3 from May to September 2017.

Furthermore, IRID developed the arm type access equipment to conduct a trial retrieval of fuel debris in the Fukushima Daiichi Unit 2 for more detailed investigation inside the PCV through the existing X-6 penetration. An original model of the investigation equipment is a robot arm used for maintenance of an experimental fusion reactor, placed in UK. The robot arm was redesigned to meet requirements for the Fukushima Daiichi.

2. Future Development

IRID aims to proceed with R&D for the decommissioning of the Fukushima Daiichi NPS and to acquire knowledge and expertise from around the world. Specifically, overseas technology for removal and storage of damaged fuel as well as the safety management system are necessary.



A03 Research and Development of the Project of Decommissioning, Contaminated Water and Treated Water Management and Connection to Engineering

Hironori Kato[1], Hotaka Minatomoto[1]

[1] Mitsubishi Research Institute, Inc. (Management Office for the Project of Decommissioning, Contaminated Water and Treated Water Management)

Abstract

The Ministry of Economy, Trade and Industry (METI) has established the fund since FY 2013 and implemented the "Project of Decommissioning, Contaminated Water and Treated Water Management" as the subsidy program by solicitations to support R&Ds with high technical difficulties. In this presentation, it shall be introduced the connections among the various subsidized projects with this program and the expected contributions to the decommissioning of the Fukushima Daiichi NPS.

1. Introduction

In order for the decommissioning of the Fukushima Daiichi NPS safely and steadily, it is important to conduct R&Ds by gathering wisdom in Japan and overseas. Therefore, METI has established the fund since FY 2013 and implemented the "Project of Decommissioning, Contaminated Water and Treated Water Management" as the subsidy program by solicitations to support R&Ds with high technical difficulties. The R&D projects have been managed by the Management Office for the Project of Decommissioning, Contaminated Water and Treated Water Management. In order for the results of the R&Ds to contribute to the decommissioning of the Fukushima Daiichi NPS, the R&Ds are conducted in cooperation with TEPCO, which manages the site and considers the applicability.

2. Subsidized Projects of Decommissioning, Contaminated Water and Treated Water Management and Connection to Engineering

The R&D projects for the decommissioning of the Fukushima Daiichi NPS have been subdivided and subsidized. Each subsidized project is being conducted by domestic and foreign organizations. The subsidized projects are classified into "Internal Investigation", "Development of Fuel Debris Retrieval Method", "Improvement of Work Environment", and "Processing of Solid Waste, etc.". The R&D projects of Fuel Debris Retrieval have been conducted based on the information obtained by Internal Investigation. In addition, the results of R&Ds such as Development of Fuel Debris Retrieval Method are reflected to Improvement of Work Environment. The R&D projects of Processing of Solid Waste are also studied in cooperation with R&Ds for Fuel Debris Retrieval Method and Improvement of Work Environment. In this way, current projects are linked to each other, and One of the significant progresses of fuel debris retrieval are the launching of fuel debris retrieval at unit 2 in October 2024 at the latest[1] , it will be necessary to cooperate even more closely. To obtain the information on R&Ds from domestic and foreign organizations, the Management Office is also conducting RFI (Request for Information) each spring on the website. (https://en.dccc-program.jp/)

References

[1] TEPCO, May 30, 2024, Fukushima Daiichi Nuclear Power Station Unit 2 PCV Internal Investigation, TEPCO Handouts at Press Conference, (https://www.tepco.co.jp/en/hd/decommission/information/newsrelease/reference/index-e.html)

B01

Remote Control Technology for Monitoring Inside RPV Pedestal during Retrieval of Fuel Debris: Integrated Experiments

N. Matsuhira[1], R. Komatsu[1], S. Nakashima[1], A. Yamashita[1], R. Fukui[1], H. Takahashi[1], K. Shimazoe[1], H. Woo[2], Y. Tamura[3], T. Takahashi[4], Y. Yokokohji[5], K. Nakamura[6], K. Naruse[7], T. Hanari[8], K. Kawabata[8], S. Suzuki[1] and H. Asama[1]

[1]The Univ. of Tokyo, [2]Kogakuin Univ., [3]Tohoku Univ., [4]Fukushima Univ., [5]Kobe Univ., [6]Sapporo Univ., [7]Univ. of Aizu, and [8]JAEA

Abstract

This research aims to develop human resources in the field of remote technology for the decommissioning of the Fukushima Daiichi Nuclear Power Plant (1F). We have conducted research on a monitoring platform for fuel debris removal. Here, the integration of the developed subjects on prototype experiments were described. We expect to develop research personnel through participation in projects, lectures, and facility tours.

1. Introduction

To safely and reliably remove fuel debris using a remote-controlled robotic arm, it is necessary to accurately grasp the three-dimensional situation inside the containment vessel before each operation. We have proposed to construct a platform for monitoring inside the pedestal. Various sensors such as cameras, gamma-ray and neutron detectors will move on this platform to perform measurements and visualization necessary for fuel debris removal.

2. Development Subjects

2-1. Monitoring platform (The Univ. of Tokyo, Fukushima Univ.)

Technology for building modular, split-type platforms and highly rigid, lightweight arms that can be retracted compactly have been developed. The feasibility of the system was verified in deploying the track structure and moving the camera robot on the track. The collaborative tests were carried out with the 3D reconstruction system and showed the validity. On the lightweight arm, it was confirmed that automatic winding and extension could be carried out.

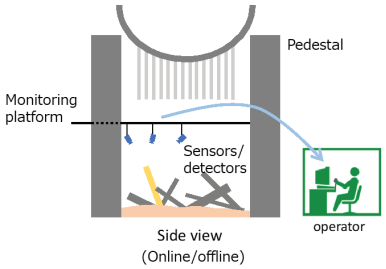


Figure 1. A monitoring platform concept

2-2. Remote control interface (The Univ. of Tokyo, Tohoku Univ., Kogakuin Univ., Kobe Univ.)

In a video presentation interface for operators and a highly realistic tele-operation system, a visualization target on a 3D environment model was specified and presented the unobstructed camera positions defined the "visibility" of the visualization target. The developed remote control method using multiple camera viewpoints was implemented and verified through a pile removal operation, simulating fuel debris removal on the mock-up.

2-3. Radiation monitoring device (The Univ. of Tokyo)

A compact sensor head for gamma and neutron detection capable of fast-response spectroscopy was developed, and its spectral separation performance and neutron peak detection performance under high-dose gamma radiation were confirmed.

2-4. A three-dimensional reconstruction method of environmental models (JAEA CLADS, Sapporo Univ.)

Developed methods for generating 3D environmental models from images were integrated and verified the efficient model generation both by assembling local 3D models with 2D code and the image selection algorithm. A prototype system was constructed to generate a 3D reconstruction model from images acquired from a camera moving on a monitoring platform.

3. Conclusion

The research and development have been conducted on a monitoring platform for fuel debris removal. Integration experiments from the camera images of the platform, reconstructed the 3D environmental model and showed the suitable view of the target to the operator were conducted using the mockup at the JAEA Naraha Center. In addition, lectures with the current status and future issues of 1F were introduced for students, and their research theses and conference presentations were done by younger people as a human personnel development.

The Collaborative Laboratories for Advanced Decommissioning Science (CLADS), Japan Atomic Energy Agency (JAEA), had been conducting the Nuclear Energy Science & Technology and Human Resource Development Project. This study has been conducted in the project from FY2019 to FY2023.

B02

Navigation and Control of a Novel Shock-resistant Mechanical Manipulator for Fuel Debris Retrieval

S. Nakashima[1], A. Moro[2], R. Komatsu[1], A. Faragasso[1], N. Matsuhira[1], H. Woo[3], K. Kawabata[4], A. Yamashita[1] and H. Asama[1]

[1]The Univ. of Tokyo, [2]RITECS Inc., [3]Kogakuin Univ., and [4]JAEA

Abstract

The aim of this research is to develop a novel manipulator for retrieving fuel debris on the Fukushima Daiichi Nuclear Power Plant (1F) as shown in Figure 1. We designed a shock-resistant CVT (Continuously Variable Transmission) robot in collaboration with the University of Sussex.

1. Introduction

Fuel debris retrieval at the bottom of the primary containment vessel (PCV) is one of the significant tasks for the decommissioning of the nuclear power plant and in particular for F1. It is challenging for conventional manipulators to perform the retrieval process due to the presence of radiation, water leakage and poor lighting conditions. We tackle those problems with the design and fabrication of a novel mechanical manipulator and its control and navigation algorithm. CVT-based actuation improves the robot's shock resistance. AI-based navigation algorithm enables semiautonomous navigation and grasping in the cluttered environment inside the PCV.

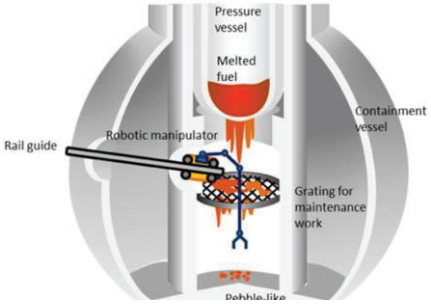


Figure 1. Robotic manipulator in PCV

2. Development Subjects

2-1. Optimal actuation parameters (The Univ. of Tokyo, RITECS Inc.)

We designed a simulation environment to evaluate the optimal parameters of the long-reach manipulator robot.

2-2. Navigation and Control of CVT-VIA manipulator (The Univ. of Tokyo, RITECS Inc.)

We simulated realistic environments to test our machine learning algorithms using PyBullet simulator. Here, a remote operator can set the gripper target position.

2-3. System evaluation and demonstration (The Univ. of Tokyo, RITECS Inc., Kogakuin Univ., JAEA CLADS)

The system performance was validated on the life-sized robot arm.

2-4. Demonstration of use-case scenarios (The Univ. of Tokyo, RITECS Inc., Kogakuin Univ., JAEA CLADS)

We will validate the proposed robot system in aim mock-up at the University of Tokyo and NARREC.

3. Conclusion

We conducted research on a decommission robot manipulator featuring CVT-based actuation and a learning-based navigation system. Currently, component development is in progress. Future works include the development of the whole manipulator and the integration of the navigation system to real robots.

The Collaborative Laboratories for Advanced Decommissioning Science (CLADS), Japan Atomic Energy Agency (JAEA), had been conducting the Nuclear Energy Science & Technology and Human Resource Development Project. This study has been conducted in this project since FY2021.

B03

Consideration of Harmonic Van-Atta Array consisting of Dual-Band Unidirectional Antennas

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[1]Graduate school of Engineering Science,Yokohama National University

Abstract

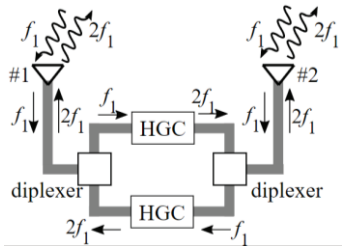
We propose a harmonic Van-Atta array using dual-band unidirectional antennas. The effectiveness of using Van-Atta array compared with an array that has a fixed main beam is evaluated.

1. Introduction

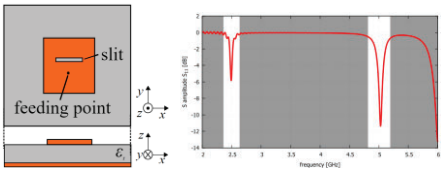
In high radiation environment, where it is difficult to supply the power directly or to change the battery, passive tags, which need no battery and harvest the RF energy from the received signal, are efficient. Array antennas for the passive tags should be retrodirective (RD) such as Van-Atta array (VAA) to track the direction of the incident wave and reradiate toward it. VAA for passive harmonic tags that consists of single-band antennas is presented [1]. In this paper, we propose the VAA using dual-band unidirectional antennas, enabling to miniaturize the array.

2. Configuration and calculation result

The configuration of VAA with dual-band antenna (DBA) is shown in Fig. 1. It shows one-subset antennas and both elements #1 and #2 operate at fundamental frequency f_1 and the second harmonic frequency $2f_1$. A pair of elements #1 and #2 are interconnected through a harmonic generator circuit (HGC), and diplexers between those split the fundamental and the second harmonic signal because HGC operates on only one-side input.



DBA model, consisting of patch antenna for f_1 with slit for $2f_1$, is shown in Fig. 2(a) and its reflection property is shown in Fig. 2(b). From the graph, at least -5dB is achieved at f_1 and $2f_1$.



(a)model (b)Reflect characteristics

Figure 2. dual-band antenna

Monostatic responses of two-element VAA and Beam-Fixed array (BFA), which has a fixed main beam [1], are calculated and presented in Fig. 3. It shows the reradiated second harmonics toward the incident wave. Coverage ranges, defined as the angle-range where the level is within -10dB of the maximum [1], are 82° (-41°~41°) for the VAA and 54° (-27°~27°) for the BFA, respectively. Therefore, it is obvious that the VAA has wider coverage range than that of the BFA.

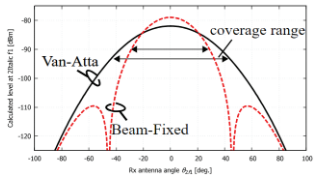


Figure 3. monostatic response

3. Conclusion

In this paper, the harmonic Van-Atta array consisting of dual-band antennas was proposed. It was presented that the Van-Atta array gives wider coverage area than the Beam-Fixed array.

References

[1] K.Murata, N.Kuga, “Retrodirective Harmonic Tag using Van-Atta Array,”, in 2024 International Workshop on Electromagnetics: Applications and Student Innovation Competition (iWEM), Taoyuan, Taiwan, 2024.

B04

Retrodirective harmonic tag using omni-directional pattern antenna

Takuto Oyama[1], Kakeru Murata[1] and Kuga Nobuhiro[1]

Graduate school of Engineering Science, Yokohama National University[1]

Abstract

We proposed a retrodirective harmonic tag antenna using an omni-directional pattern. Simulation results show that an improvement in antenna gain of approximately 5 dB is obtained by using the proposed antenna.

1. Introduction

Harmonic communications are promising techniques for highly radioactive environments because they do not require a battery to power the radio circuit [1]. To achieve long-range communication using harmonic techniques, it is desirable to use an array antenna to track incoming waves. However, tracking incoming waves typically requires an electronic device, which is unsuitable for highly radioactive environments. The Van-Atta array (VAA) antenna, a type of retrodirective antenna, offers passive beam tracking for incoming waves without the need for batteries or electronic control devices, making it suitable for harsh radiation environments [2]. While VAA has been used with harmonic tags in uni-directional antennas [3], it has not been applied to omni-directional antennas. This study proposes a harmonic VAA using dual-band omni-directional pattern antennas and demonstrates its effectiveness in improving antenna gain.

2. Structure of Harmonic VAA using dual-band omni antennas

Fig. 1 shows the configuration of dual-band omni-directional antennas used in the proposed harmonic VAA. Two elements are placed at each vertex of the square in horizontal symmetry. The incident wave arrives at an angle ϕ from the base station, where two independent antennas are used for transmission (Tx) and reception (Rx).

Fig. 2 shows a simulated monostatic scattering pattern, where the solid line represents the 2-element array, and the broken line represents the single-element antenna. The proposed VAA shows an improvement of approximately 5.39 dB compared to the single harmonic antenna.

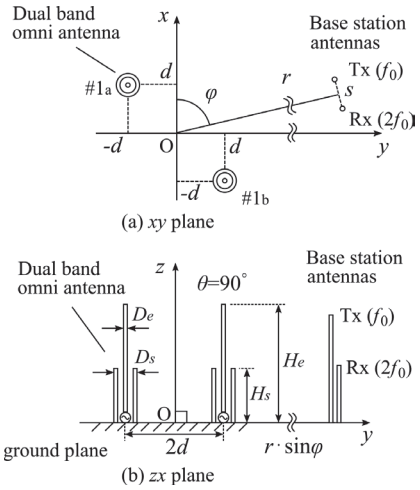


Fig.1 Simulation model of Harmonic VAA Using dual-band omni antennas.

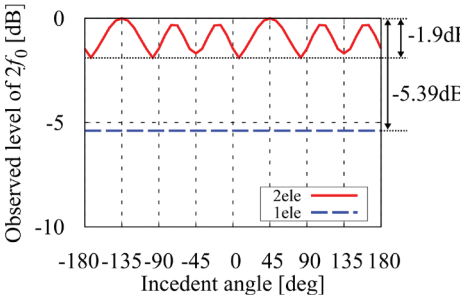


Fig.2 Received level of harmonics vs. angle of incidence of fundamental wave

3. Conclusion

Harmonic VAA using dual-band omni-directional pattern antennas were proposed and its effectiveness was presented through the simulation.

References

[1] N. Kuga, I. Serizawa and K. Xiao, "Passive Broadband Harmonic Sensor-Tag using Circular Disk Dipole Antenna," 2024 IEEE Topical Conference on Wireless Sensors and Sensor Networks (WiSNeT), San Antonio, TX, USA, 2024, pp. 69-72,

[2] X. -F. Li, Y. -L. Ban, Q. Sun, Y. -X. Che, J. Hu and Z. Nie, "A Compact Dual-Band Van Atta Array Based on the Single-Port Single-Band/Dual-Band Antennas," in IEEE Antennas and Wireless Propagation Letters, vol. 22, no. 4, pp. 888-892, April 2023

[3] K.Murata, N.Kuga, “Retrodirective Harmonic Tag using Van-Atta Array,”, in 2024 International Workshop on Electromagnetics: Applications and Student Innovation Competition (iWEM), Taoyuan, Taiwan, 2024.

B05

Energy harvesting harmonic tag using modified tapered slot antenna

Hamada Kiyoku[1], Serizawa Iori [1] and Kuga Nobuhiro[1]

[1]Graduate School of Engineering Science, Yokohama National University

Abstract

The energy-harvesting (EH) performance of a passive 2.45 GHz/4.90 GHz harmonic tag using a modified tapered slot antenna is verified through experiments in this paper. Results show that it takes 24 minutes to charge the capacitor over 1 V with a 43 dBm transmission power from an antenna located 6 meters away from the tag.

1. Introduction

Wireless power transfer (WPT) technologies are promising for remote-controlled robots in highly radioactive environments, providing significant operational freedom. However, long-range WPT systems require large power-transmitting equipment. To reduce antenna size, a harmonic tag with an energy harvester is a potential solution, requiring minimal power for radio equipment. This paper proposes a tag with a modified tapered slot antenna and experimentally verifies its EH performance in an anechoic chamber.

2. A passive harmonic tag with energy harvesting circuit

Fig. 1 shows the configuration of the employed harmonic tag. It consists of a modified tapered slot antenna and a harmonic generator with an EH circuit. Fig.2(a) shows the configuration of modified tapered slot antenna. It is mounted on a circular ground-plane, and a harmonic generator with energy harvester are connected below the ground-plane. Fig.2(b) shows its radiation pattern. It indicates that gain reduction occurs around $\phi =$ 90 and 270 degrees, which should be improved in our future study.

EH is performed using a continuous wave at 2.33 GHz, where rectifying efficiency is highest. A 16-element dipole array antenna is used independently for the uplink and downlink channels. The base-station antenna is located 6 m away from the tag in an anechoic chamber. The input power to the downlink antenna is 43 dBm. Fig. 3 shows the capacitor voltage as a function of time, which increases gradually, taking 24 minutes to reach 1 V, sufficient to drive a voltage up-converter.

3. Conclusion

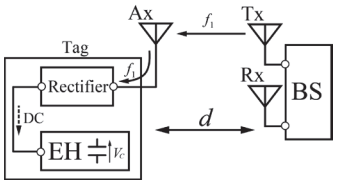
The EH performance of a passive harmonic tag using a modified tapered slot antenna is verified through experiments in this paper. Results show that it takes 24 minutes to charge the capacitor over 1 V with a 43 dBm transmission power from an antenna located 6 meters away from the tag.

References

[1] N. Shinohara, “Theory and technologies of wireless power transmission on various transmission distance,” IEICE Trans. B, vol. J96-B, no.9, pp.881-893, Sep. 2013

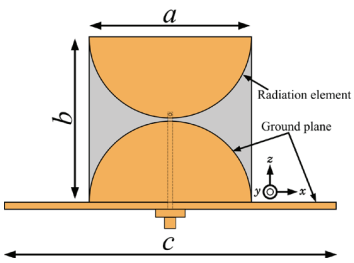
[2] C. Mikeka, H. Arai, “Energy-Harvesting in the Vicinity of a Cellular Base Station for Sensor Radio Applications,” IEICE trans B. vol. J95-B, no.2, pp.130-137, Feb. 2012.

[3] N. Kuga; et. al. “Passive Broadband Harmonic Sensor-Tag using Circular Disk Dipole Antenna,” IEEE WiSNeT, Jan. 2024



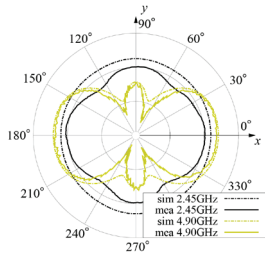
f_1 = 2.33 GHz, d = 6 m

Fig. 1 System diagram



a = 120, b = 121, c = 210 [mm]

(a) Configuration



(b) Radiation pattern of xy-plane

Fig. 2 Modified tapered slot antenna

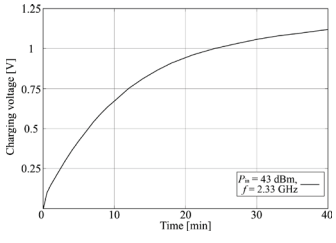


Fig. 3 EH performance

B06

Unlocking Value in Decommissioning through broad use of Digital Technologies

Toshi Yamanouchi & Kevin McMahon

Jacobs Decommissioning & Regenerative Solutions (D&RS)

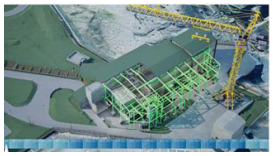
Abstract

Jacobs has developed a range of approaches to maximize the benefits of Digital technologies for Decommissioning activities. These include Digital Twins for visualization and 4D planning, real-time augmented reality for education and delivery, the ability to insert avatars into design and execution supporting training and development and even generating control software for robotic systems via simulation to physical demonstration.

Introduction

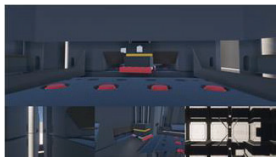
Jacobs works extensively across the End-to-End Nuclear Decommissioning lifecycle and utilises Digital Technologies in all phases. In design and planning the use of Digital Twins is paramount to support design options but then conversion to execution activities, delivering safer, higher quality and faster results. The ability to insert human type avatars into digital simulations during design mean Human Factors are considered but this can also then provide a training environment for pre-work familiarization and briefings. Where development of Robotics solutions is required we use full physics engine simulations to create a test environment – but also to directly develop control system code to enable moving from digital to physical prototyping at pace. With the importance of using available and new Digital Technologies in management of Nuclear Decommissioning we intend to hold a range of seminars with topics to include Waste Management, Robotics and Decommissioning Planning in the coming months and how the use of Digital technologies is unlocking progress.

1) **4D Planning** – Taking a build plan and being able to run multiple simulations on the build sequence to ensure optimal operations and resource usage. Enables testing risk scenarios and what ifs.



2) **Avatar use/training** – ability to insert a wide range of avatar type into a plant/operation design to identify risks and hazards and design them out, ensuring that the Human/Plant interactions are suitable and fit for purpose. Once design frozen can then be used with VR systems for operator familiarization and training away from the actual plant – allowing safer and more efficient operations in the hazard environment.

3) **AWC Development** – taking a simulated environment with a full physics engine and developing code to manage dynamics in robotics systems to ensure safe operations.
(AWC: Automated Waste Containers)



Conclusion

• Jacobs has developed a wide range of capabilities that can help improve decision making quality and lead time.

• The ability for people to engage with these modern approaches and further develop their capabilities and adoption should be a key element in the Human Resource Development agenda.

• We plan to explore this further focused on Fukushima 1F with upcoming Tehcnical Seminars on the topics of Waste Management and Robotics.

B07

Progress of the fuel debris trial retrieval using the telescopic-type debris retrieval equipment in Fukushima Daiichi Unit 2

Yoshimasa Sugawara[1], Yusuke Nakagawa[1], Tomoyuki Arai[1]

[1]Tokyo Electric Power Company Holdings Inc.

Abstract

It is planned to start trial fuel debris retrieval using the telescopic-type fuel debris retrieval equipment in Unit 2 at Fukushima Daiichi NPS as early as August 2024. The equipment is developed based on the knowledge and experience of PCV investigations. The fuel debris sampled from PCV will be transported to the analysis facility and the results will help understanding of the accident and improving the design of the gradual expansion of fuel debris retrieval.

1. Introduction

TEPCO is preparing to begin the fuel debris retrieval (FDR) in the Unit 2 because of the perspectives of safety, reliability, timeliness, and a field-oriented stance. For understanding the accident and decreasing the risks in 1F by FDR, it is planned to start trial FDR using the telescopic-type FDR equipment (TFDR equipment) as early as August 2024.

2. Ready for the trial FDR

For the trial FDR, TEPCO plans to use the X-6 penetration because the fuel debris in the pedestal is directly accessible from the penetration X-6 in Unit 2. The deposit removal equipment made the space at inside of the X-6 penetration to install TFDR equipment for sampling the fuel debris.

3. The approach for the trial FDR

The TFDR equipment shown in Figure 1 is developed based on the knowledge and experience of PCV investigations. Given all of the location of the structure from the X-6 penetration to the opening of the platform are known, the equipment is inserted by the combination of the remote and manual operation into the inside of the pedestal. The functions of the equipment were verified in the full-scale mock-up facilities in the factory.

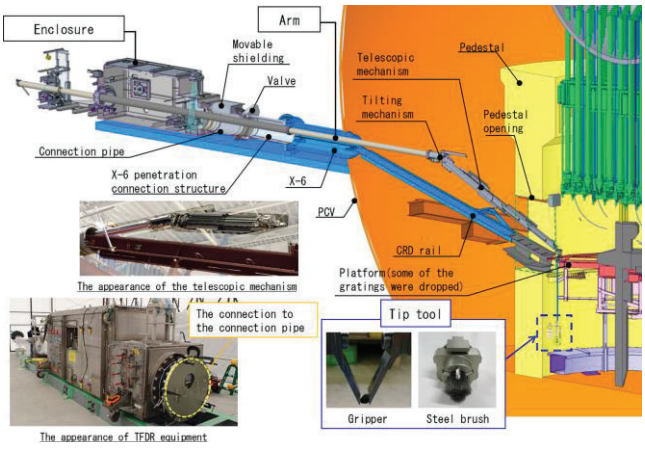


Figure 1. The specification of TFDR equipment

After collecting the fuel debris by the equipment, the gamma radiation rate from fuel debris is measured in the enclosure to confirm the radiation rate is acceptable for handling by the combination of the remote and manual operations. The fuel debris is finally transported to the analysis facility which is located outside of 1F.

4. Conclusion

The trial FDR will be started and the results of the trial FDR is planned to understand the accident and develop the design in the gradual expansion of the FDR.

C01 Establishment of Tousou Mirai Manufacturing Co., Ltd. and Plans for Producing Decommissioning Products.

Tomokazu Harada[1], Hiroshi Kawaeda[1]

[1] Tousou Mirai Manufacturing Co., Ltd.

Abstract

Tousou Mirai was established to support the decommissioning at both Fukushima Daiichi Nuclear Power Plant and Fukushima Daini NPP with providing spent fuel casks, fuel debris storage containers, and other products. We will contribute to the reconstruction of Hamadori area and Fukushima Prefecture by constructing a factory and manufacturing products. Construction plan for the factory has been developed.

1. Introduction

We will create jobs in Hamadori and provide employment opportunity for local students by manufacturing nuclear power components including spent fuel casks in Fukushima.

2. Location of Cask Factory

The cask factory is to be built in the parking, which is located at the outside of restricted area of Fukushima Daini NPP, providing spent fuel will be stored there for the time being.

3. Four Functions Required for a Cask

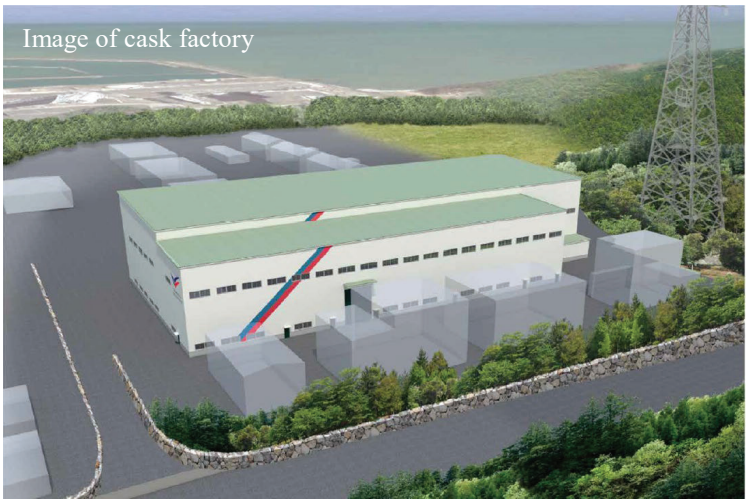
1. Prevention of Criticality, 2. Radiation Shielding: Reducing the effects of radiation outside the cask below acceptable levels, 3. Sealing: Preventing leak of radioactive materials from the cask body to the outside, 4. Heat Removal: Keeping temperature of the cask material below acceptable levels.

4. Schedule

We aim to start construction of the factory by the end of fiscal 2024, start production of the first unit by the end of fiscal 2026, and deliver it to the Fukushima Daini NPP by the end of fiscal 2027.

5. Conclusion

TEPCO is working on contribution to reconstruction of local area and decommission of NPPs. Hitachi Zosen is a nuclear power components supplier and has expertise of spent fuel storage and transportation. Tousou Mirai was established by bringing both parties' skill and knowledge together and aims to become a company rooted in the community.



C02

Challenge for screening of nuclear fuel debris by innovative spectral imaging and its verification by LIBS mapping

Hiroaki Muta[1], Kan Sakamoto[2], Ikuo Wakaida[3] and Paul Murray[4]
[1]Osaka Univ., [2]NFD, [3]JAEA, [4] The Univ. of Strathclyde

Abstract

We propose the combination of HyperSpectral Imaging (HSI) and Laser-Induced Breakdown Spectroscopy (LIBS) as a method for remotely analyzing materials in the 1F reactor. We are working on a development of the technique in collaboration with UK institutions.

1. Introduction

Various unknown materials, such as massive and shelf-like deposits, have been identified in 1F reactor. However, little information on the composition of these materials has been obtained. For efficient retrieval of the fuel debris, it is necessary to develop a remote-sensing technique to identify the in-reactor materials.

HSI analyzes spectral information of more than 100 colors, and is being applied to various fields; sorting plastics, vegetation distribution from satellites, and soil evaluation [1]. On the other hand, material composition cannot be directly evaluated by HSI. Therefore, we thought that the combination of HSI and LIBS could be an accurate and wide-ranging visualization technique for materials in 1F reactor.

2. Research plan and members

In order to demonstrate the HSI and LIBS, it is necessary to prepare appropriate standard materials that simulate in-reactor materials, and to acquire and accumulate training and trial data on them. In this study, Osaka Univ. is in charge of the preparation of standard materials and HSI data analysis, NFD is in charge of the preparation of uranium bearing materials and HSI/LIBS measurements, and JAEA is in charge of LIBS development. On the UK side, the Univ. of Strathclyde, NNL, and Lancaster University participate in the joint research project.

3. Research progress

The compositions of the standard samples were determined from past experiments such as the VULCANO test and thermodynamic calculation results. Several samples such as iron oxides and concrete made by stones from Niida/Abukuma river were prepared. HSI data from 350 nm to 1100 nm were obtained using a hyperspectral camera (NH-5H-1.7 by EBA Japan) installed in the NFD. Preliminary analysis using SAM or LDA confirmed that the materials could be classified to some extent.

This work was supported by JAEA Nuclear Energy S&T and Human Resource Development Project Grant Number JPJA23F23830470.

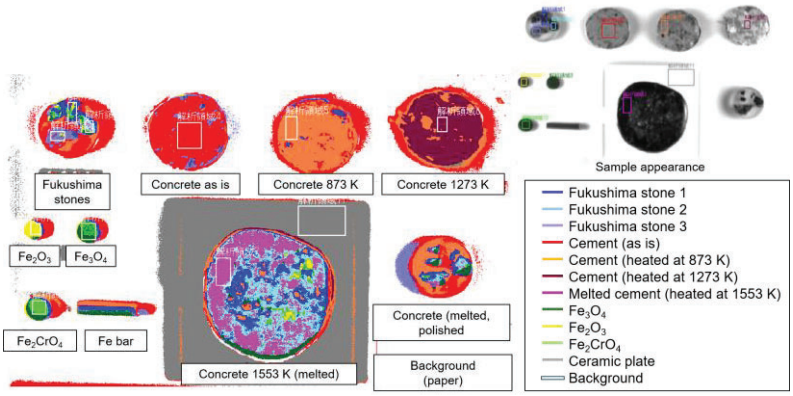


Figure 1. Classification result by HSI for standard samples.

References

[1] M. J. Kahn et al., *IEEE Access*, **6** (2018) 14118.

C03 The reaction between cesium hydroxide and stainless steel oxidation products in a steam environment at 573K-773K

Xin Tan[1], Tatsuya Suzuki[1] and Kenta Murakami[2]
[1]Nagaoka Univ. of Tech., [2]UTokyo

Abstract

This study investigates the reactions between cesium hydroxide (CsOH) and stainless steel oxidation products, magnetite (Fe_3O_4) and chromia (Cr_2O_3) in argon and argon-steam environments at 573K-773K.

1. Introduction

The interaction between CsOH and structural materials may change the form of Cs and attenuate or delay the transport. Recent studies have shown that CsOH can react with stainless steel to form ferrites below 600℃.[1] Reaction between CsOH and Fe_3O_4 as well as Cr_2O_3, as the most possible metal oxides of stainless steel in reactor environments, has been conducted in Ar gas and Ar-steam stream under 573-773K.

2. Experimental method

$CsOH{\cdot}H_2O$ powder (Combi-Blocks, 95%) and Fe_3O_4 powder (KOJUNDO CHEMICAL LABORATORY, 98%) or Cr_2O_3 powder (KOJUNDO CHEMICAL LABORATORY, 99.9%) was mixed in mortar and then formed into cylindrical pellets. The molar ratio was set as Cs:Fe = 1:1 or Cs:Cr = 1:1. Then the pellets were heated in the tube furnace in Ar or Ar-steam stream under 573K-773K for 1h. Then samples were crushed and grinded into fine powder. Scanning electron microscope (SEM) JSM-IT200 (JEOL) has been used for observation, elemental analysis and phase identification. Sample preparation was carried out in a glove box due to hygroscopicity of samples. The weight changes of the samples before and after the experiment have been recorded.

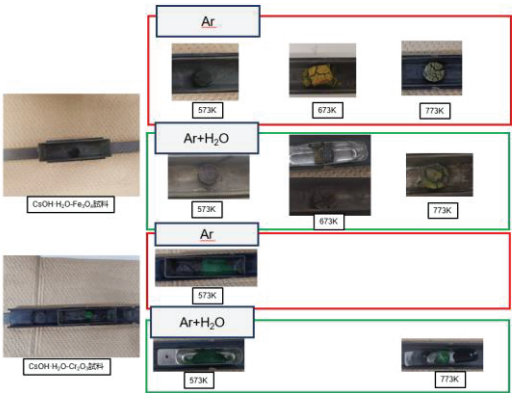


Figure 2 Change of sample appearance in different conditions

3. Results

The changes in appearance and weight are shown in Figure 1 and Figure 2 respectively. Results showed that the reactions between CsOH and Fe_3O_4 produced identical phases with different appearances and less hygroscopicity compared to CsOH regardless of temperature and atmosphere. The highest reaction rate was around 673K. In contrast, reactions between CsOH and Cr_2O_3 resulted in similar appearances across different conditions and still exhibited high hygroscopicity.

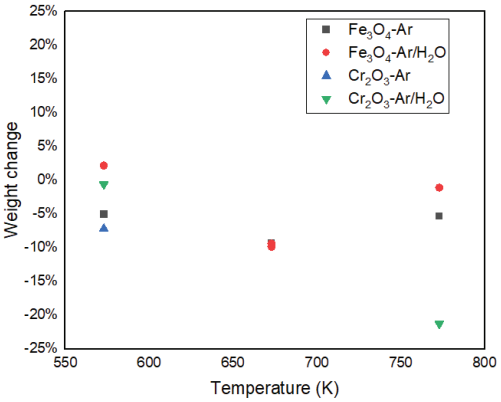


Figure 1 Weight change in different conditions

References

[1] Jumpei Imoto et al., AESJ Annual Meeting 2E17.

C04 Preliminary study on delayed neutron Cij(τ) functions of a fast-thermal weakly coupled reactor system for fuel debris criticality impact analysis

Letian Wang[1], Hiroki Takezawa[1] and Toru Obara[2]

[1]Nagaoka University of Technology, [2]Tokyo Institute of Technology

Abstract

For criticality impact analysis of Fukushima Daiichi NPS fuel debris removal works, multi-region integral kinetic analysis code MIK2.0 has been under development by considering fission reactions by delayed neutrons. For a part of verification of the MIK2.0, characteristics of delayed neutron $C_{ij}(\tau)$ functions obtained by Monte Carlo neutron transport calculation are under discussion for a fast-thermal weakly coupled reactor system.

1. Introduction

Fuel debris to be removed from the damaged RCV of Fukushima Daiichi NPS can be a fast-thermal weakly coupled reactor system due to spatial distribution of fuel debris and spatial difference in neutron spectrum. For a part of verification of the MIK2.0, characteristics of delayed neutron $C_{ij}(\tau)$ functions, which are used in criticality impact analysis by the MIK2.0, needs to be studied.

2. Methodology

The MIK2.0[1] calculates fission reaction rate $N_i(t)$ by using $C_{ij}(\tau)$ functions defined by $C_{ij}(\tau) = \int_0^\tau \alpha_{ij}(\tau')d\tau'$, where $\alpha_{ij}(\tau)$ is the probability density functions of secondary fissions in region i at the present time t generated by source fissions in region j at the past time t' (τ = t - t'). In this study, delayed neutron $C_{ij}(\tau)$ functions were calculated by using MVP3.0 and JENDL-4.0 for a fast-thermal weakly coupled reactor system[2] (Fig. 1) consisting of region-1: twin-core fast pulse reactor BARS-6 and region-2: Subcritical polyethylene moderated Thermal fuel Assembly (STA). In order to shorten the $C_{ij}(\tau)$ calculation time, an equivalent model was developed by homogenizing fuel cells in STA while maintaining volume and mass of each material of the hexagonal cells.

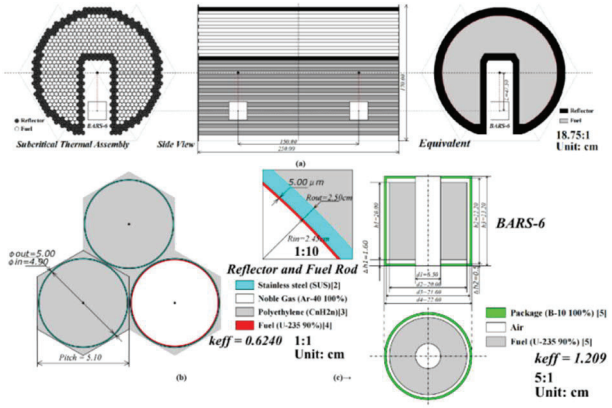


Fig. 1 (a)Original (Or) and Equivalent (Eq) models. (b)Cross section of STA cells. (c)BARS-6 structure.

3. Result and Discussion

The largest difference in delayed neutron $C_{ij}(\tau)$ functions between Or- and Eq-models was found in $C_{12}(\tau)$ functions of all delayed neutron precursor groups and is shown in Fig. 2. The first (τ = 10^{-8}-10^{-6} s) and the second (τ = 10^{-4}-10^{-3} s) increases of $C_{12}(\tau)$ functions are caused by fast and thermal neutrons transported from STA (region-2, source fission) to BARS-6 (region-1, secondary fission), respectively. The difference has been investigated in terms of neutron flux spectrum and macro cross sections in the original and equivalent fuel cells.

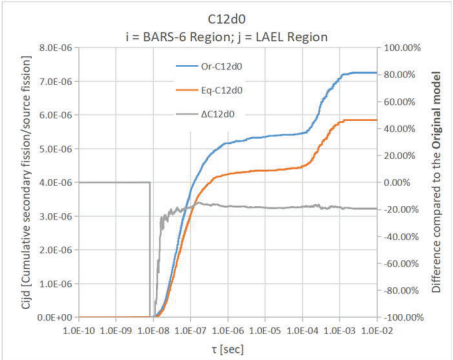


Fig. 2 $C_{12}(\tau)$ function of all delayed neutron precursor groups.

References

[1]Takezawa et al., Nuclear Science and Engineering 195(11)1236, 2021. [2]Dyachenko et al., Proceedings of the interindustry scientific conference "Pulse reactors: history of creation and prospects for use," Volume 1 p.53, 2015 (Russian).

C05 Fuel Debris Monitoring Collaboration and Experiences in Criticality Monitoring

J. Hutchinson[1], D. Bowen[3], J. Clavel[2], J. Goda[1], C. Kostelac[1], J. Miller[4], G. McKenzie[1], W. Monange[2], M. Nelson[1], S. Pignet[2], R. Weldon[1], N. Whitman[1], A. Chambers[5]

[1]Los Alamos National Laboratory, [2]IRSN France, [3]Oak Ridge National Laboratory, [4]Sandia National Laboratories, [5]DOE-NCSP

Abstract

Fukushima Daiichi fuel debris removal provides technical challenges and opportunities for the international criticality safety community. The US DOE-NCSP (Nuclear Criticality Safety Program) and France (IRSN) will support 1F fuel debris efforts through collaboration on real-time criticality monitoring. This work will describe a collaboration recently announced in the Joint Statement by Prime Minister Kishida Fumio and President Joseph R. Biden, Jr. on April 10, 2024 where the two leaders announced that "Our two countries plan to launch the Fukushima Daiichi Decommissioning Partnership focusing on research cooperation for fuel debris retrieval."

1. Introduction

Neutron monitoring of neutron multiplication (or degree of subcriticality) is required to help inform fuel debris removal activities and reduce the risk of re-criticality during the removal process. The upcoming Japan/US/France collaboration will focus on research and development associated with criticality monitoring. The US work is funded by the DOE-NCSP and the work in France will be performed by IRSN.

2. Previous work

The DOE Nuclear Criticality Safety Program has funded Research and Development efforts associated with subcritical neutron noise methods for over 10 years. This has included 5 International Criticality Safety Benchmark Evaluation Project (ICSBEP) benchmarks, which have included collaboration with IRSN.

In addition, two measurement campaigns on thermal reactor systems have been performed: one at the Reactor Critical Facility (RCF) at the Rensselaer Polytechnic Institute (RPI) (2017) and one at the Sandia National Laboratories 7uPCX (2022). The former experiments included placing 30 ^{3}He under approximately 10 feet of water (inside custom water-proof covers, not in dry-wells). For this measurement campaign, roughly 100 hours of continuous real-time streaming data were acquired.

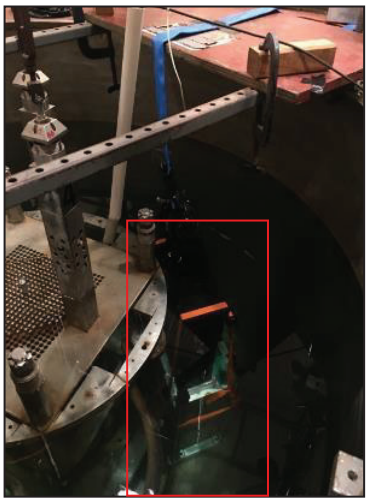


Figure 1. Real-time neutron data acquisition with 30 submerged ^{3}He tubes at a research reactor.

In addition to benchmark measurements, our team has experience in measuring unknown systems under field conditions. Last, we perform approach-to-critical operations for several new critical experiments each year. We will share this experience to assist in real-time criticality monitoring.

3. Conclusion

The US and France are excited to start collaborating on criticality monitoring associated with 1F fuel debris removal efforts. Work will begin later this year with a focus on neutron analysis, radiation detection, radiation transport simulations, and culminate in a capability demonstration.

D01

Construction status of large cover for fuel removal from Fukushima Daiichi Nuclear Power Station Unit 1 and engineering efforts to remove debris remaining on the operating floor

Kenji Toyoshima[1], Akio Hirata[1], Miho Miyazaki[1],
Ippei Matsuo[1], Takamasa Nishioka[1] and Ryota Mizutani[1]
[1]Kajima Corporation

Abstract

This paper presents current construction status of large cover for fuel removal from Fukushima Daiichi Nuclear Power Station Unit 1 and engineering efforts to remove debris remaining on the operating floor.

Construction status of large cover

It is planned to construct a large cover first, which is supported from existing reactor buildings, and to remove remotely high-dose debris inside the cover to reduce dust dispersal in the unlikely event of debris collapse. Under the latest construction status, almost all drilling for anchors and placement of base plates are completed, and steel frame structures are being installed.

Engineering efforts to remove debris

In order to study the debris removal plan in detail, a drone was first utilized to obtain detailed information on debris status. Since it is necessary to avoid damaging the spent fuels in the pool during dismantling work by collapsing the unstable and overlapping debris, a dismantling simulation analysis was conducted to "visualize" the removal work.

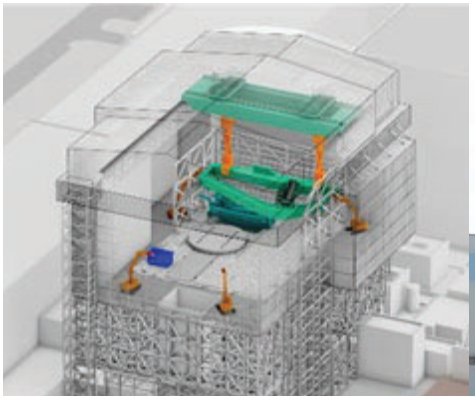


Image of debris removal in large cover of Unit 1

Current status of large cover

E01 Summary of the contamination survey in the concrete structures located near the Fukushima Daiichi Nuclear Power Plant

Kazuo Yamada[1], Kazutoshi Shibuya[2] and Ippei Maruyama[3]
[1]National Institute for Environmental Study, [2]Taiheiyo Consultant Co., Ltd., [2]Univ. Tokyo

Abstract

For dismantling of concrete buildings of the Fukushima Daiichi NPP (1F), basic understandings of concrete contamination characteristics is important. Therefore, actual structures near 1F were investigated. In cross sections of sampled core, r-Cs existed mainly in the carbonated cement paste and certain types of aggregates. Although no r-Cs movement was detected during storage, the surface dose rate assessments (corrected for attenuation) of concrete columns in field was halved from December 2015 to January 2024.

1. Introduction

The dismantling of the building superstructure concrete at the Fukushima Daiichi NPP (1F) requires prior understanding of the contamination characteristics and its mechanism, and consideration of decontamination, dismantling, reuse, storage, and treatment/disposal. Since it is not easy to analyze on-site concrete, we summarize the results of our investigations ([1],[2]) of a concrete facility (former Fukushima Prefectural Research Institute of Fisheries Seeds) near the 1F.

2. Survey and Results

2-1. Location

The facility investigated is located 500 m south of 1F and is on the coast. It was contaminated by radioactive Cs (r-Cs) after it was destroyed by the tsunami.

2-2. R-Cs distribution in a cross section of a concrete core sampled from a real outdoor structure

Autoradiographs of core sections taken from outdoor concrete columns indicate that r-Cs is present primarily in the 1 cm carbonated surface area and in certain aggregates in the vicinity. It is unclear if there is further penetration due to strong scattered lines from the surface concentrated areas.

2-3. R-Cs movement in concrete with time

The distribution of r-Cs in cores sampled in Dec. 2015 did not change when measured in Feb. 2024. On the other hand, surface dose rate measurements of collapsed columns at the site showed that the dose rate had halved in eight years. It is considered that Cs may have been leached out by substitution with K in the sea salt.

3. Conclusion

Investigations of real outdoor concrete contamination showed that r-Cs was predominantly present in the carbonated cement paste portion and in certain aggregates and did not move indoors, but leached out outdoors.

References

[1] K. Yamada et al., Assessment of Radioactive Cesium Contamination in Concrete Structures near Fukushima Daiichi Nuclear Power Plant, ChemRxiv. 2024; doi:10.26434/chemrxiv-2024-bqr88

[2] K. Yamada, et al., Field survey of radioactive cesium contamination in concrete after the Fukushima-Daiichi nuclear power station accident, Journal of Advanced Concrete Technology, 17 (2019) 659-672.

E02

Detection characteristics and equipment development of radiation detection systems based on PV cells

Yasuki Okuno[1], Tomohiro Kobayashi[1], Tomohiro Kobayashi[1], Mitsuru Imaizumi[2], Yukiko Kamikawa[3], Ryuta Kasada[4], Tetsuya Nakamura[5] and Tamotsu Okamoto[6]

[1]RIKEN, [2]Sanjo City Univ., [3]AIST, [4]Tohoku Univ., [5]JAXA, [6]NITKC

Abstract

Solar cell dosimeters can be configured for a wide variety of applications, including flexible sheeting, multi-connected mapping monitoring systems, and gamma/neutron detection structures. In this presentation, the radiation detection system using solar cells will be described and its applicability to PCVs, vertical and internal applications will be reported.

1. Introduction

In order to remove fuel debris from the containment vessel (PCV) of the Fukushima Daiichi Nuclear Power Plant and to efficiently decommission 1F, it is necessary to know the radiation sources and dose rate distribution in the PCV, to take appropriate decontamination and radiation shielding measures to ensure worker safety, and to optimize radiation resistance and other properties of equipment used for decommissioning. Optimization of radiation resistance of equipment used for decommissioning is also necessary. Radiation detection using solar cell elements has been developed as a self-driven dosimeter that outputs a radiation-induced current as a signal without applying an external voltage by means of a built-in potential drive. In this study, we will develop a system with high functionality based on the solar cell dosimeter for 1F mounting.

2. Experimental

The solar cells were prepared from silicon and CIGS solar cells. A source-measure unit (Keysight, B2901A) was used to measure signals in a radiation environment. As a neutron detection structure, a coated film such as boron was placed on the solar cell elements. A Co-60 source was utilized as the gamma source. RANS was used as the neutron source. A multiplexer was used to construct the mapping system.

3. Results and Discussion

Figure 1 shows a prototype gamma-ray sensing software based on solar cell type radiation detector. The system consists of a ammeter, cable, and solar cell detector. For comprehensive radiation measurement of the entire 1F building, the sensors are not only developed, but the signals from the sensors are analysed automatically. The dose information is then displayed in combination with map information, making the system easy for operators to understand.

4. Conclusion

By developing a system that can map radiation fields by applying a solar cell device-based sensor that is self-supporting and remotely driven, we obtained knowledge to implement a system that can guarantee safety for workers and residents by obtaining comprehensive and real-time radiation information in the PCV and monitoring leakage of gamma and neutron radiation, which are very penetrating and can cause accidents, in a real environment.

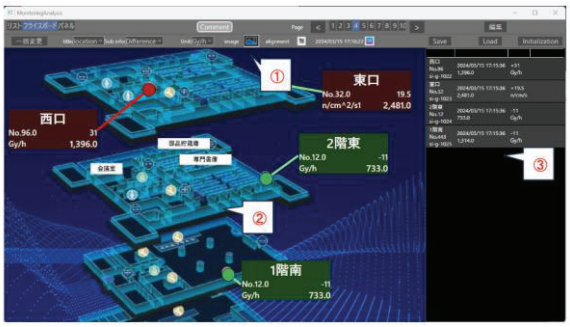


Figure 1. Solar cell-based dosimeter system

E03 Development of in-pipe exploration technology in high background radiation environment.

＊Tatsuo Torii [1,2], Yukihisa Sanada [3], Shunsuke Kurosawa [4], Takahiro Hayashi [5], Takahide Sakagami [6], Shohei Kodama [7]

1 Univ. Fukui, 2JAEA, 3 Tohoku Univ., 4 Osaka Univ., 5 Kobe Univ., 6 Saitama Univ.

Abstract

In this study, we plan to conduct elemental research on non-destructive pipe inspection techniques using lasers and thermography, imaging techniques for low-energy γ-rays emitted from U and Pu, and high-energy γ-ray detection techniques for high-background environments. In this presentation, we will introduce some of the results of this year's research on radiation imaging.

1. Introduction: In the decommissioning of the Fukushima Daiichi Nuclear Power Plant, non-destructive inspection of piping inside and outside the facility and inspection of contamination inside the piping after removal of the piping are important issues. To set targets for nondestructive inspection inside the piping, we interviewed TEPCO and confirmed the following conditions: the diameters of pipes commonly used in the 1F facility (500A and 25A), hydrogen gas containing α-ray emitting nuclides, deposits, and moisture inside the pipes. Based on this situation, the two major themes of the research design were nondestructive inspection for internal penetration and radiation imaging.

2. Non-destructive inspection: As non-destructive inspection research items, we focused on two techniques to establish a method to check for the presence or absence of liquid and solid materials inside pipes from the outside under high gamma-ray dose environments. Laser ultrasonic measurement, which uses ultrasonic waves generated by laser irradiation, has been developed mainly for remote visualization of pipe wall thinning. Here, we confirm the limitations of material imaging in contact with the inside of piping using a test object. On the other hand, infrared thermography, which uses infrared thermography to detect temperature changes caused by defects or damage that appear on the surface of the object to be measured, is another technique with potential. In this study, the applicability of xenon flashlamps and short-pulse lasers will be examined to realize pulsed heating. We will also develop a remote monitoring technique by transmitting the color change of a commercially available hydrogen detection tape via fiber for the purpose of hydrogen detection from pipes.

3. Radiological Imaging: To develop a radiation imaging technique to measure characteristic radiation from radioactive materials inside pipes and to clarify the internal radiation situation. Considering the use of Cs-137 in a high radiation background environment, low-energy γ rays (59 keV) emitted from Am-241, energies below 500 keV emitted from Pu and U, and high-energy radiation emitted by (α,n) and (n,γ) reactions between Pu and U and surrounding materials are considered for detection. The detection of high-energy radiation emitted by (α,n) and (n,γ) reactions of Pu and U with surrounding materials will be examined. In addition, we aim to develop an endoscope-type radiation detector and a robot for detailed inspection of pipes after their removal. In addition, we will develop an algorithm to discriminate background γ rays with high accuracy based on the shape of the spectrum.

*This research is supported by a grant from the JAEA/CLADS "Problem Solving Decommissioning Research Program" (FY2023-2025) entitled "Development of In-Pipe Inspection Techniques in High Background Radiation Environments.

E04

Luminescent lanthanide complexes with high detection sensitivity for α-particles

Yuichi Kitagawa[1] and Yuki Morishita[2]

[1]Hokkaido University, [2]Japan Atomic Energy Agency

Abstract

The development of luminophores with high detection sensitivity for α-particles is important for constructing systems capable of detecting radioactive contamination by α-particles with high precision. Herein, we report the fabrication of a polystyrene scintillator that contains novel luminescent lanthanide complexes. The emission intensity of the prepared polystyrene scintillator under an ^{241}Am source was found to be more than 12 times higher than that of a commercially available plastic scintillator.

1. Introduction

The development of luminophores with high sensitivity to α-particles is required to construct detection systems with high precision for α-contamination. Herein, we focus on plastic scintillators based on polystyrene that contain luminescent trivalent lanthanide (Ln(III)) complexes. Ln(III) complexes show narrow emission bands based on 4f-4f transitions, and hence, have attracted attention as light sensors [1-2]. In this paper, we report the synthesis of plastic scintillators containing Ln(III) luminophores and their emission properties under α−radiation.

2. Results and discussion

Trivalent europium (Eu(III)) complexes and polystyrene were dissolved in chloroform ($CHCl_3$). The resulting solution was poured into a vessel and evaporated until dry, forming a plastic film containing lanthanide luminophores (Figure 1); the photoluminescence properties were estimated by excitation using ultraviolet light. A strong, sharp emission band was observed at 610 nm, and the emission quantum yields from the 4f-4f excited states were estimated to exceed 70%. Luminescence from Eu(III) under an ^{241}Am radiation source showed strong emission intensity, which was more than 12 times higher than that of a commercially available plastic scintillator (Saint-Gobain, BC400). Moreover, we found that scintillators containing other luminescent lanthanides also showed high emission intensity under the ^{241}Am radiation source.

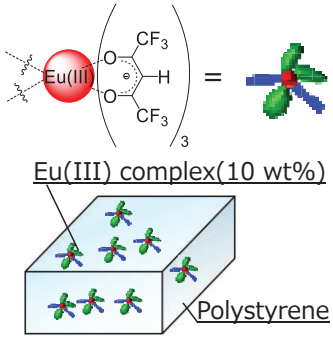


Figure 1. Schematic image of plastic film.

3. Conclusion

Novel plastic scintillators containing Ln(III) luminophores with high emission intensities were successfully fabricated. We believe that their high sensitivity to α-particles can be ascribed to their efficient energy migration from the polystyrene triplet states to the ligand triplet states. The Ln(III)-based plastic materials presented here provide new insights for the development of α-particle scintillators.

References

[1] Y. Kitagawa et al., *RSC Adv.* **12**, 810 (2020); [2] Y. Kitagawa et al, *ChemPlusChem* **88**, e202200445 (2023).

E05 Establishment of 3-D dose dispersion forecasting method and development of in-structure survey using the transparency difference of each line gamma-ray

Shinya Sonoda[1], Atsushi Takada[1], Tohru Tanimori[2], Minoru Tanigaki[2],
Haruyasu Nagai[3], Hiromasa Nakayama[3], Daiki Satoh[3], Tetsuya Mizumoto[4], Shotaro Komura[4]
[1]Kyoto Univ., [2]KURNS, [3]JAEA, [4]FSiC Inc.

Abstract

We have been developing an Electron Tracking Compton Camera (ETCC), which can acquire bijection images of nuclear gamma-rays with MeV energies. In March 2024, we measured gamma-rays in a 1 km square area at a time and obtained the dose distribution images around the area including the reactor buildings from two points. We are also developing an ETCC that can operate in a sub-mSv/h environment.

1. Introduction

Nuclear gamma-rays imaging method has the potential to be effective in confirming the nuclear materials integrity. However, conventional gamma cameras, such as Compton cameras, do not provide bijection imaging equivalent to optical cameras, and therefore have not been applied to fields where quantitative measurements are required and regulated by laws and regulations. The ETCC measures the recoil electrons direction produced by Compton scattering using the time projection chamber and measures the scattered gamma-rays using the pixel scintillator array, to uniquely determine the nuclear gamma-rays arrival direction and energy. ETCC can acquire 3D distribution of radioactive materials by stereo observation from multiple directions using the same technique as an optical camera. By combining ETCC data with WSPEEDI developed by JAEA, it will be possible to predict the dispersion of radioactive materials.

2. Instruments and Measurement

We found that the previous trigger logic tended to miss some events in high-dose environments. Therefore, the trigger algorithm was modified to solve this problem. Since lightweight and efficient radiation shielding by Pb plates is required to operate ETCC in high-dose environments, we investigated the radiation tolerance of ETCC using simulation-based shielding calculations and a high-intensity source owned by JAEA. In addition, the method has been developed to estimate the 3D distribution of Cs inside the reactor buildings from 2D gamma-ray images using Cs-134 line gamma radiation through the reactor wall. In late March 2024, we measured the direction including the reactor buildings on Fukushima Daiichi Nuclear Power Plant from two points. Gamma-ray spectra around the building were also measured using a spectrometer.

3. Conclusion

The ETCC trigger logic has been modified to operate under high dose environment. The operation test using a high intensity source and the shielding calculations has demonstrated that the current ETCC can work properly at several tens uSv/h. The 3D distribution of Cs-137 around the reactor buildings will be obtained by combining the 3D reconstruction program developed by JAEA and the gamma-ray data measured by ETCC. The current ETCC will be modified and designed and fabricated through detailed computational simulations to operate in a sub-mSv/h environment to make measurements in the vicinity of the reactor buildings.

E06 The World's Highest Radiation Tolerant Performance Camera

Mikio Katsura, Hazuki Nakazawa, Yudai Suzuki and Naoki Kajihara
CORNES Technologies Ltd.

Abstract

Mirion Technologies (IST) Ltd. is an industry leader in supply of Radiation Tolerant Cameras and specialist CCTV & imaging systems for the Nuclear Industry. The Mirion IST-Rees brand of radiation tolerant cameras is recognized as the market leader in the Nuclear Industry (Power Plant, Reprocessing and Decommissioning) worldwide. With a comprehensive range of products to suit all applications in every part of the Nuclear fuel cycle, Mirion is able to offer standard or customized solutions to meet customer needs and expectations.

Hyperion™ Compact Camera System

The Hyperion Compact Gen II Camera follows many years of extensive Research and Development and considerable investment in new technologies. Featuring all new Radiation Tolerant zoom lens and optics with integrated pan and tilt, this new version offers all the benefits of the earlier generation Hyperion camera but in a lighter and more compact outstation. The Hyperion camera has been independently tested to 1 MGy with Cobalt-60 sources.

In addition, Mirion is pleased to offer both monochrome and color variants without a pan/tilt unit for even greater deployment flexibility on Servo-Manipulators, custom deployment mechanisms, and tooling applications.

Solid-State, 1M Gy Radiation Tolerant & Robust Camera

- 100 Mrad / 1 MGy total dose (gamma)
- Digital performance, high radiation tolerance
- Color or Monochrome options
- Pan/Tilt-free version available
- In air or underwater operation
- System-on-Chip flexibility
- Superior picture geometry
- High performance solid-state 1x megapixel sensor
- Low cost of ownership, driven by low maintenance and long life

Web Application operation

The camera video stream can be viewed, and the camera controlled using a web application via Ethernet.
The System provides a web application on the camera IP address on a port number as set by the camera configuration.
The web application can be accessed by a web browser connecting via HTTP.

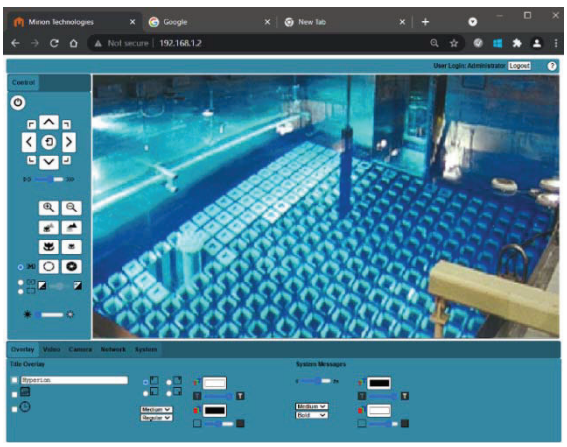


Figure1: Web application

Conclusion

The new Hyperion Compact high radiation tolerant digital cameras extends on our years of research and development into digital radiation tolerant electronics combined with our unique Mirion color processing algorithms to provide an unsurpassed user experience for high radiation tolerant imaging.

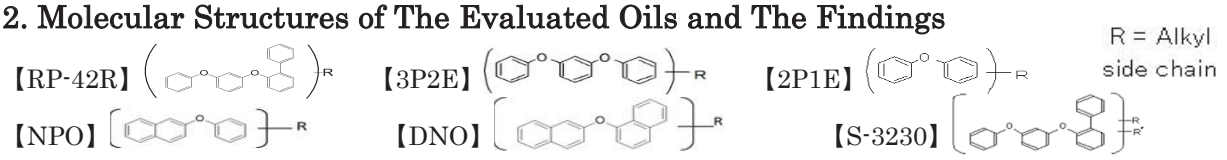
E07 Study on Molecular Structural Influences of Radiation Resistant Oils for Their Properties

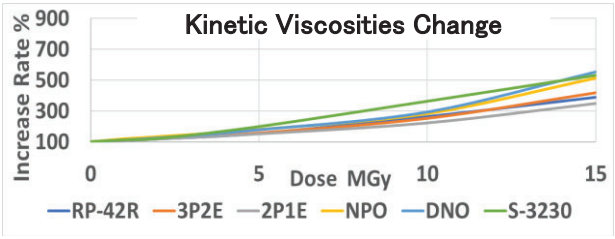
Yoshikazu Hayashi, MORESCO Corp. (hayashi@moresco.co.jp)

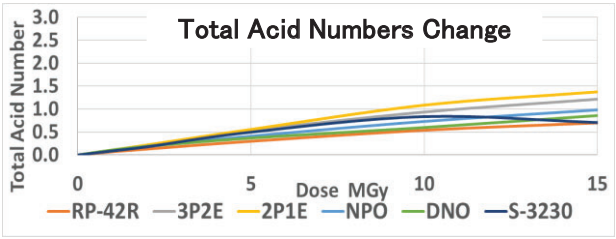
1. Abstract and Introduction

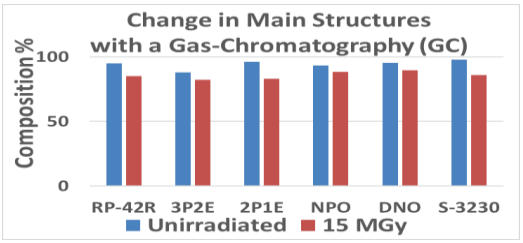
This presentation showes the findings from our latest joint study with CERN on Radiation Damages to the world's highest Radiation Resistant Lubricants, MORESCO-HIRADs.
A γ Irradiation evaluation up to 15 MGy was conducted to research the radiation-resistance differences between our 6 Synthetic Oils. Also Lubricity Changes before and after irradiation was evaluated which seemed a World First. These allowed for ranking among the structures and identifying RP-42R's structure as having the most superior balance in proprieties.

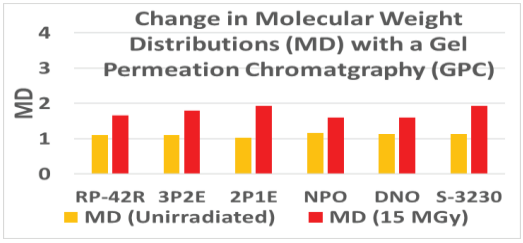
2. Molecular Structures of The Evaluated Oils and The Findings

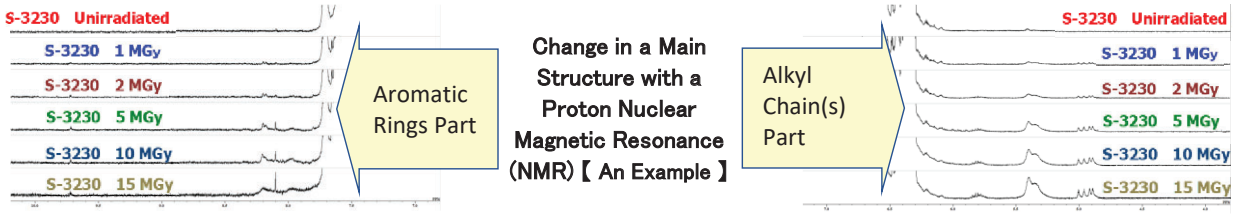










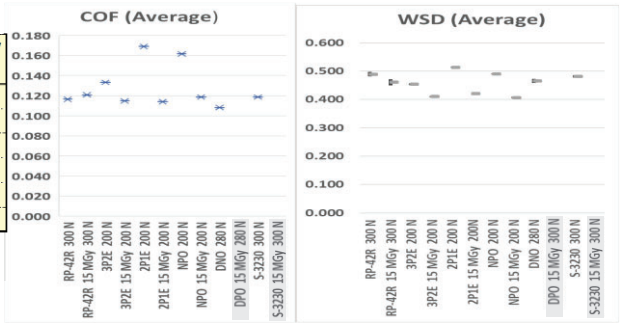


Rank in Order of Excellence	1	2	3	4	5	6	(Evaluated Properties Against a γ Irradiation)
Kinetic Viscosity	2P1E	RP-42R	3P2E	NPO	DNO	S-3230	Effects of Molecular Shear / Polymerisation
Total Asid Number	RP-42R	S-3230	DNO	NPO	3P2E	2P1E	Oxidation Resistance
GC	NPO	3P2E	DNO	RP-42R	S-3230	2P1E	Main Structure Maintainability
GPC	NPO	DNO	RP-42R	3P2E	S-3230	2P1E	Molecular-Weight-Distribution Maintainability
NMR	DNO	NPO	RP-42R	S-3230	3P2E	2P1E	Main Structure Maintainability

Lubricity Change with a SRV

	Loads	Unirradiated COF	Unirradiated WSD	Lubricity Rank	At 15 MGy COF	At 15 MGy WSD	Lubricity Rank
RP-42R	300 N	0.116	0.489	A	0.121	0.461	A
3P2E	200 N	0.133	0.454	B'	0.115	0.410	B
2P1E	200 N	0.169	0.513	C	0.114	0.421	B
NPO	200 N	0.162	0.490	C	0.119	0.407	B
DNO	280 N	0.108	0.465	A'	Measurement		D
S-3230	300 N	0.119	0.482	A	Range Over		B'

COF; Coefficient Of Friction WSD; Wear Scar Diameter
< Conditions > Temperature: 20 dC, Frequency: 10 times/s, Duration: 1 h



3. Conclusion

The chemical stability with irradiation is superior in NPO and DNO, and slightly inferior in 2P1E, 3P2E and S-3230.
The lubricity unirradiated is virtually proportional to the oils' molecular weight, while that in DNO and S-3230 is reducd and somewhat improved in 2P1E, 3P2E and NPO, with irradiation.
RP-42R was identified as having the best balance of all properties, which can be attributed to a combination of its "number of aromatic rings" and "flexibility from the bonding form" and "optimum number of alkyl side chain".

E08 Holographic memory optimization method for an Optically reconfigurable gate array

Takumi Fukumoto, Minoru Watanabe and Nobuya Watanabe
Okayama University

Abstract

When a very large scale integration (VLSI) functions in a radiation environment such as nuclear power plants or in outer space, VLSIs with high radiation tolerance is required for systems. We have been developing an optically reconfigurable gate array. In this paper, we propose holographic optimization method to reduce necessary optical power.

1. Optically reconfigurable gate array

An optical reconfigurable gate array consists of three components: a laser array, a holographic memory, and a programmable gate array VLSI (Fig 1). The holographic memory stores a lot of configuration contexts which are addressed by laser beams. An optical reconfigurable gate array VLSI has many photodiodes to receive a configuration context. This parallel configuration architecture allows the programable gate array VLSI to be reconfigured for a short period. On the other hand, photodiode response time is different from each other due to the process variation. Since the reconfiguration period must be decided by the worst response time, there was energy loss. If strong light is applied to the slowest photodiode, the configuration period can be improved.

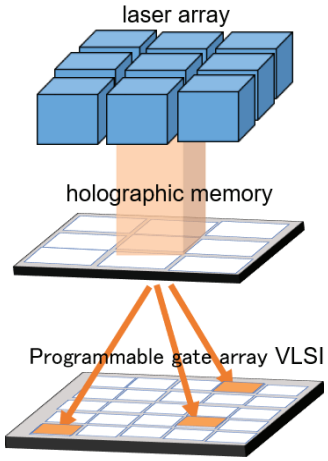


Figure 1. Structure of an optically reconfigurable gate array.

2. Compensation of photodiode characteristics variation

In this experiment, we implemented an AND circuit including eight bright points as shown in Fig 2 and confirmed the configuration time of the AND circuit for an optically reconfigurable gate array using a green laser with an irradiation power of 200 mW. By adjusting holographic memory pattern to change the light intensity of the eight configuration points, the reconfiguration speed could be improved from 1395 ns to 1255 ns without any laser power increase. As a result, the configuration performance was improved up to 1.04 times.

Figure 2. context pattern of an AND circuit.

References

[1] T. Fujimori and M. Watanabe, ``Parallel light configuration that increases the radiation tolerance of integrated circuits, " Optics Express, Vol. 25, Issue 23, pp. 28136-28145, Oct. 2017.

E09 Decontamination & Decommissioning Technologies for the Civil Nuclear Industry

Michael J. Anderson, Victoria E. Anderson-Matthew, Kazushi Watanabe, Sarah A. Peirce

Innovative Physics Limited

Abstract:
The nuclear industry faces numerous challenges in decommissioning, including improving efficiency and safety while reducing costs. Advanced technologies, including robotics, sensors and artificial intelligence, have the potential to address these challenges by automating hazardous tasks, improving accuracy and reducing human error.

Introduction:
Below outlines some examples of technologies that Innovative Physics Limited (IPL) have developed.

Sort & Segregation of Nuclear Waste

Utilising advanced computer vision, machine learning, and robotic technology to automate the sorting and segregation of nuclear waste. The system accurately identifies and sorts different types of debris while improving efficiency, reducing costs, and enhancing safety. Notably, the automated system eliminates the need to expose workers to harmful radiation. The future potential of this technology is significant as it can be applied to other industries, such as waste management, mining, and construction.

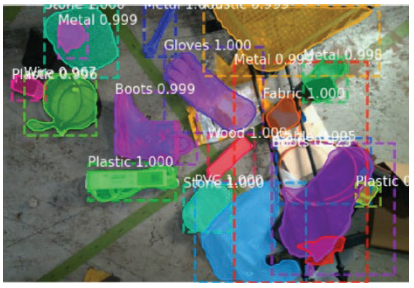


Figure 1: Object and Material Identification

Gamma Imaging Systems

Decontaminating an area containing nuclear waste is difficult due to the intangible nature of radiation. Working closely with Japanese partners, IPL designed and developed a gamma imaging system capable of showing "hot spots" of radioactivity. The systems provide an image/video of a large area, allowing workers to quickly and remotely observe where radiation hot spots are located and determine, within minutes, the radioisotope being emitted.

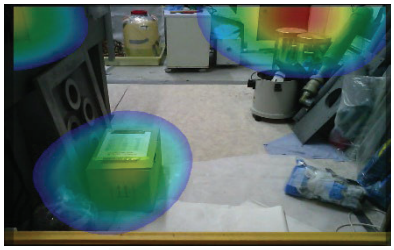


Figure 2: Gamma Imaging

Neutron Detection

Decommissioning planning requires a comprehensive mapping of the radiological environment. Importantly, the location of the fissile material is required, i.e. the neutron field. This allows path planning for removing such material while avoiding criticality events. Custom solid-state neutron detectors using a semi-conductor deposited with Boron-10 (B10), which show a high gamma radiation tolerance and gamma rejection ratio (Co-60, Cs-137up to > 1/106cps/cm2s) to enable monitoring of neutron flux in highly radioactive environments, such as criticality monitoring, emergency management, core monitoring. The novel neutron detector architecture is modular and thus can be integrated into many applications.

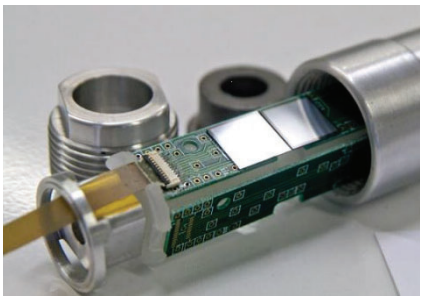


Figure 3: Semi-Conductor Neutron Detector

Very Low-Level and Low-Level Waste Management

To measure the surface contamination (gamma dose rate) and the isotope of radioactivity. Large scintillators and the relative movement of sensors and objects are used to identify the location of radioactivity. The system uses Time Delay Integration (TDI) techniques to provide additional security and variable speed detection.

E10 Development of Optical Materials and Its Evaluation for the Radiation Dose-Rate Monitor under Ultra-High Dose-Rate II

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Abstract

We have developed a real-time monitoring system for high-dose-rate with a wide dynamic dose range using a novel red-emission scintillation material with both neutron and gamma-ray sensitivities.

1. Introduction

Mapping of high-dose-rate distribution in Fukushima Daiichi Nuclear Power Station is one of the first steps for decommissioning. Since conventional techniques are hard to monitor the rate due to the high-dose-rate condition of over 0.1 Sv/h, we have developed a fiber-type dose-rate monitor consisting of a red-emission scintillator. Scintillation photons are read with a photo-detector under a lower dose-rate thorough an optical fiber. On the other hand, Cherenkov and scintillation photons excited by radiations in the glass are expected to be observed as noises and these noises have generally emission wavelengths of below 550 nm. To discriminate the noise, we have developed a red-emission scintillator, Cs_2HfI_6 with an emission band of over 600 nm and other materials [1]. These materials have a gamma-ray sensitivity, while neutron measurement is also required. In this paper, we report a novel scintillation materials with both gamma-ray and neutron sensitivities.

2. Methods

Li_2HfI_6 and other crystals were grown by the vertical Bridgman-Stockbarger method. Such crystal samples were installed into the fiber-type dose-rate monitor. This monitor was demonstrated with a 20-m-long optical fiber and CCD spectrometer. We have evaluated the neutron reaction at Institute for Integrated Radiation and Nuclear Science, Kyoto University.

3. Results

Li_2HfBr_6 had an emission wavelength of around 570 nm excited by X-ray, which is longer than that of commonly used neutron scintillators such as Li-glass. The light output excited by thermal neutron excitation was estimated to be 52,000 photons per one thermal neutron. We succeeded in obtaining calibration data between neutron flux and scintillation intensity.

4. Conclusion

This novel scintillator enables us to monitor high-dose-rate conditions with optical fiber, and we succeeded in demonstrating this monitoring system for neutron.

References

[1] S. Kodama and S. Kurosawa et al., APEX 13, (2020) 047002

G01 Progress in the development of the continuous monitoring of tritium water by mid-infrared laser spectroscopy

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Abstract

The present study aims to demonstrate the principle of short-time measurement of tritiated water using a cavity ring-down spectroscopic measurement system with a mid-infrared laser. A specially constructed optical cavity for mid-infrared CRDS was constructed. We have also demonstrated a mid-infrared laser that has a measurement advantage with broadband wavelength tunability. In addition, stable isotope heavy water samples were prepared as standard samples.

1. Introduction

Our group has been developing a detection technique for hydrogen isotopes using mid-infrared lasers. The mid-infrared region has very large absorption lines of vibrations of hydroxyl groups, which can be used for highly sensitive detection. Recently, we have demonstrated the H_2O and D_2O in the liquid phase were measured using mid-infrared lasers with wavelengths of 2.9 μm and 3.9 μm, respectively [1]. The present study aims to demonstrate the principle of short-time measurement of tritiated water at the "60 Bq/cc level" using a cavity ring-down spectroscopic (CRDS) measurement system with a mid-infrared laser. In order to achieve the above goal, (1) research on the CRDS system and (2) evaluation of hydrogen isotope composition under environmental conditions and preparation of standard samples (subcontractor: Hirosaki University) were conducted.

In (1), a mid-infrared CRDS test was conducted. An optical bench was set up in the laboratory, and a designed optical cavity with length of 1000 mm was constructed on the optical bench. In addition, a validation test of the isotope measurement using a heliot-cell was conducted before the CRDS test. The system was also constructed to introduce water vapor from the water sample into the cavity. Next, a laser source essential for the CRDS measurement was developed. We have constructed a 4 μm wavelength Fe:ZnSe laser using a 2.9 μm wavelength Er:YAP laser, which was originally developed by our group, as the pump source [2]. Furthermore, the output of a narrow linewidth distributed-feedback quamtum cascade laser (DFB-QCL) is amplified with a Fe:ZnSe gain medium to produce a tunable mid-infrared laser with both MHz linewidth and watt-class output power [3]. In the future, we aim to demonstrate isotope measurement with CRDS using this laser source.

In (2), we prepared hydrogen isotope standard solutions using commercially available heavy water standard solutions from several reagent companies to prepare stable isotope heavy water samples as standard samples. We also purchased commercially available heavy water reagents and prepared a standard sample of approximately 100 Bq/L. In addition, preparations were made for isotope ratio measurements both indoors and outdoors. The performance of a low-background liquid scintillation counter was evaluated, and the lower detection limit was confirmed to be approximately 0.6 Bq/L after 2,400 minutes of measurement with a sample volume of 10 mL.

References

[1] H. Kawase, H. Uehara, and R. Yasuhara, Plasma Fusion Res. 17, 1205057 (2022).
[2] E. Li, H. Uehara, S. Tokita, W. Yao, and R. Yasuhara, Opt. Laser Technol. 157, 108783 (2022).
[3] E. Li, H. Uehara, S. Tokita, M. Zhao, and R. Yasuhara, Infrared Phys. Technol. 136, 105071 (2023).

H01 Research on physico-chemical behaviour of constitutional materials to understand the failure behaviour of pedestal concrete General overview

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Ippei Maruyama[2], Shintaro Miyamoto[3], Yuji Nagae[4], Takumi Sato[4]
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Abstract

In this study, we examined the mechanism of the collapse of only concrete with rebar remaining at the pedestal observed in the containment vessel (PCV) of the Fukushima Daiichi Nuclear Power Plant (1FNPP).

1. Introduction

In the internal investigation of the PCV of 1FNPP Unit 1 in 2022, a damage condition unique to Unit 1 was observed in which the concrete in the pedestal disappeared, leaving the rebar behind. In this study, we examined the concrete-specific and Unit 1-specific external environmental factors related to this phenomenon.

2. Summary of Studies

2-1. Concrete-specific factors: Short-term dissolution mechanism by high temperature

Preliminary experiments were conducted by setting up conditions for melting experiments at high temperatures, and methods for obtaining data on dimensional change, stiffness change, and mineral composition after heating were studied. In addition, an analytical framework for determining dissolution was established through thermodynamic equilibrium calculations for solution composition change analysis and calcination experiments of hydrated cement. Furthermore, we developed a numerical analysis method to incorporate volume change by heating in rigid-body spring model analysis.

2-2. Concrete-specific factors: Long-term dissolution mechanism by temperature history

The temperature and water injection history of the actual pedestal section were compiled, and methods for determining the exposure conditions, selecting materials, and measuring the amount of expansion of the concrete used in the experiments were established. We also summarized the existing knowledge on the expansion phenomenon caused by water supply after high-temperature heating.

2-3. Special external environmental factors: Evaluation of concrete thermal conditions by heat transfer analysis of fuel debris

A preliminary heat transfer analysis was conducted to evaluate the thermal conditions of the Unit 1 PCV concrete during an accident, referring to published accident scenarios.

2-4. Special external environmental factors: Elemental behavior tests and comprehensive tests

A preliminary High Temperature Storage Test (HTS） was conducted on concrete materials in a water vapor atmosphere to examine the effects of temperature and water vapor on their alteration behavior. Preliminary reaction tests were also conducted on the reaction behavior of metal debris and concrete. Furthermore, uranium-containing suboxides were prepared for tests focusing on the oxygen content of uranium oxides.

3. Conclusion

This study provided comprehensive insight into the mechanism of concrete collapse in 1FNPP Unit 1.

4. Acknowledgements

This work was supported by JAEA Nuclear Energy S&T and Human Resource Development Project Grant Number JPJA23P23813418.

H02 Corrosion behavior of Carbon Steel in Humid Environment Simulating γ Irradiation

Akira Adachi[1,2], Saya Ajito[2], Hiroshi Kakinuma[2], Motomichi Koyama[2], Eiji Akiyama[2]
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Abstract

The effects of humidity and concentration of ozone, which is formed by radiolysis of oxygen under γ-ray radiation, on the corrosion of a carbon steel in humid environments at 50°C were evaluated using corrosion monitoring sensors. The corrosion rate increased with the increase in the introduced ozone concentration and decreased with the increase in the relative humidity.

1. Introduction

The fuel debris in the nuclear reactor of the Fukushima Daiichi nuclear power plant emits γ -rays and produces oxidants such as hydrogen peroxide and ozone through water and oxygen radiolysis. In order to maintain the integrity of the containment vessel, the corrosion rate of carbon steel was evaluated using corrosion monitor sensors, and the effects of the ozone concentration and relative humidity on corrosion of a carbon steel were investigated.

2. Experimental method

Corrosion behavior of a carbon steel was monitored using atmospheric corrosion monitor (ACM) sensor and resistmetric corrosion monitor (RCM) sensor. The ACM sensor is composed of a conductive silver paste layer on a carbon steel substrate with an intermediate layer of an insulating paste. A galvanic current between the substrate and the conductive silver paste was measured. The galvanic current was reported to show a good correlation with the corrosion rate in an atmospheric environment [1]. The RCM sensor is composed of a thin piece of a carbon steel. The corrosion loss and corrosion rate can be determined by measuring the electrical resistance of the carbon steel. The corrosion sensors were installed in a constant temperature and humidity chamber. The temperature was set to be 50°C and approximately 0, 288, and 576 ppm of ozone gas was introduced in the chamber. The relative humidity was increased in steps from 60%RH to 95%RH.

3. Results and discussion

The corrosion rate measured by the ACM sensor increased with increasing relative humidity and ozone concentration. The corrosion rate measured by the RCM sensor also increased with increasing ozone concentration, but the corrosion rate decreased with increasing relative humidity. The RCM sensor can directly determine the corrosion rate of the carbon steel. Therefore, the corrosion rate obtained by the RCM sensor are considered to be reliable. On the other hand, the corrosion rate obtained by the ACM sensor was calculated using the galvanic current. The conversion equation from the galvanic current to the corrosion rate of the carbon steel was obtained at ambient temperature [1], and this equation may not be applicable to the present experimental conditions at 50°C.

4. Summary

The corrosion rate of the carbon steel increased with the increase of the ozone concentration and decreased with the increase in relative humidity at 50°C. The application of the RCM sensor at 50°C was found to be more relevant.

Reference [1] W. Oshikawa, S. Itomura, T. Shinohara, S. Tsujikawa, Zairyo-to-Kankyo, 51 (2002) p.398.

I01

Waste Management Symposia: The Annual Phoenix Conference Exchanging Knowledge from Around the World

Kazuhiro Suzuki[1], Gary Benda[1], Takashi Mitsui[2] and Katsunori Koarai[3]
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Abstract

NPO WM Symposia's annual Waste Management (WM) International Conference attracts thousands of registrants from around the world and is widely regarded as the premier international conference for the management of radioactive waste and related topics, such as facility decommissioning, environmental cleanup, used fuel and nuclear materials management, and long-term environmental stewardship.

1. Introduction

The WM2025 Conference will be held March 9 - 13, 2025 at the Phoenix Convention Center in Phoenix, Arizona. Conference theme is "Empowering A Sustainable Future - Advanced Technologies, AI, and Workforce Development Across the Nuclear Landscape". WM2025 will highlight current state-of-the-art and emerging future-of-the-art technologies, enabling the full program lifecycle. WM2025 will feature over 500 papers and more than 80 panel discussions in over 200 technical sessions, complemented by nearly 200 exhibiting companies, the industry's largest.

2. Poster

The poster provides Conference details and describes Technical Panel, Poster and Oral Sessions, Exhibitor, Student and Sponsorship program, as well as the opportunity to network with over 3,300 industry specialists and managers. The conference cross-cutting theme will highlight how the rapidly evolving digital world is making transformational changes to the worldwide radioactive waste management, nuclear industry, and clean-up sectors. The conference will showcase how the digital world is leading to achieving more efficient operations, improved human-machine interactions, increased safety, and enhancement of data management and analytics. In addition, there will be a focus on remote and emerging technologies from universities, private enterprises, and governmental organizations. Details of WM annual conference are shown on the poster.

3. Conclusion

The Conference promotes, among Japanese and professionals from around the world, a broad exchange of knowledge in 12 Technical Tracks, including technologies on operations, safety, security & safeguards, fuel cycle, waste management, decommissioning and dismantling, environmental remediation, communication, advanced nuclear reactors and STEM education, etc.

The deadline for submittal of Abstracts for WM2025 is August 23, 2024. The submitted abstracts will be reviewed by PAC members, and selection will be made at Program Development Meeting to be held in Arizona on September 8-10.

WM2025 Registration will open in September, and registration rates will be released during registration opening.

References: www.wmsym.org
www.t-g-consulting.com

I02

Retrieval and management of radioactive materials and wastes supporting facility decommissioning

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Abstract

Cavendish Nuclear offer through life capabilities, from sludge retrieval, sampling and characterisation to long term sludge storage design, operating in a range of conditions including in-air, partially flooded and underwater.

1. Introduction

This abstract demonstrates the B29 (the Oldest legacy pond in Sellafield) Sludge Retrieval Project and two technologies deployed by Cavendish Nuclear to streamline waste processing and packaging.

2. B29 Sludge Retrieval Project: B29 is a redundant Pile fuel receipt, storage and decanning facility situated on the Sellafield site in Cumbria. It contains a cooling pond which contains an accumulation of sludge and debris. Cavendish Nuclear designed, manufactured, installed, and commissioned equipment to gather the sludges from the pond floor, skips and decanning bays. This included: mechanical handling equipment to consolidate the wastes in the part filled skips and to remove the settled sludges from the remaining skips; a suction hood to agitate the sludges on the pond floor and transfer them to an in-pond Corral, and a specially adapted Remotely Operated Vehicle and High-Pressure Lances to remove sludges from inaccessible areas.

Figure 1: Sellafield Local Effluent Treatment Plant
Photos © Sellafield Ltd.

3. Transportable Radioactive Sludge Dewatering Unit (TRSDU):

TRSDU dewaters wet ILW, including IX resins, spent fuel pond sludge, desiccants, decontamination fluids, and RPV cooling water systems, ready for solidification in TILWSP. It is a modular solution used where wastes quantities do not justify installation of a fixed plant. TRSDU utilises membrane filtration technology designed to treat a mixed variety of sludge types across a wide range of particle sizes, solids feed concentrations and fluid viscosities. TRSDU has been successfully deployed and utilised to dewater active sludges at Magnox Trawsfynydd site.

Figure 2: TRSDU During Manufacture

4. Transportable ILW Solidification Plant (TILWSP): TILWSP is used for the immobilisation of Intermediate Level Wet Waste. TILWSP is comprised of 4 individual transportable ISO modules linked together to form the following process: importation of empty containers, removal of container lid, filling with waste and mixing with cement powders, product removal, and a control console. Typical wastes treated include ion exchange resins, filter sludges/residues from active effluent treatment systems, pond sludges e.g., Magnox sludge, desiccants, and some decontamination fluids. TILWSP has a throughput of 2-3 liners per 5-day week and has been used previously to clear the majority of the sludge from the main sludge vault at Trawsfynydd Decommissioning Site in North Wales.

Figure 3: Processing container (Module 2)

I03 Development of adsorbent sampling technology from cesium adsorption vessels

Keito Toda, Naoya Nakamura and Nobuyuki Nakashio
IRID/ATOX

Abstract

We developed the Integrated Sampling Module (ISM) that bores the top of a cesium adsorption vessel, extracts an adsorbent sample, and plugs the borehole. We performed sampling tests from the spent adsorption vessels of the cesium adsorption apparatus (KURION) and the secondary cesium adsorption apparatus (SARRY) at Fukushima Daiichi Nuclear Power Station (1F), and the samples for analysis were successfully extracted.

1. Introduction

The characterization of radioactive waste is crucial for developing effective disposal and treatment strategies. However, the high radiation levels of the adsorbents and the structure of cesium adsorption vessel that makes sampling impossible had hindered the sampling of adsorbents from the spent vessels of KURION and SARRY. This paper presents our technology designed to safely extract samples from them.

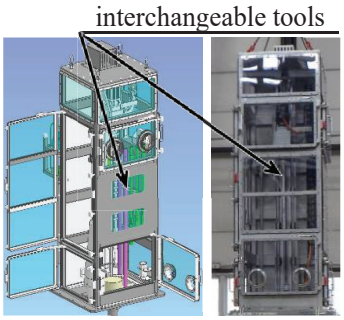


Fig.1 ISM

2. Development overview

The ISM (Fig.1) and its peripheral equipment were designed to minimize radiation exposure of workers, incorporating dose estimation results (Fig.2) into the equipment specifications. Fig.3 illustrates the four-step procedure of the sampling test, with operations that expose the surrounding areas to high radiation doses being conducted remotely. Cold tests were conducted in FY2022, and sampling adsorbents from spent adsorption vessels was successfully completed in 2023.

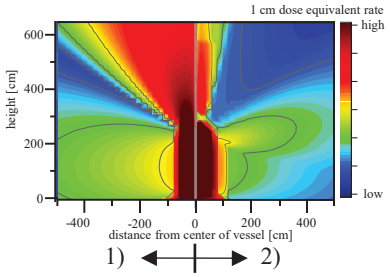


Fig.2 Dose rate distribution from cesium adsorption vessel 1) before, 2) after taking overexposure counterplan

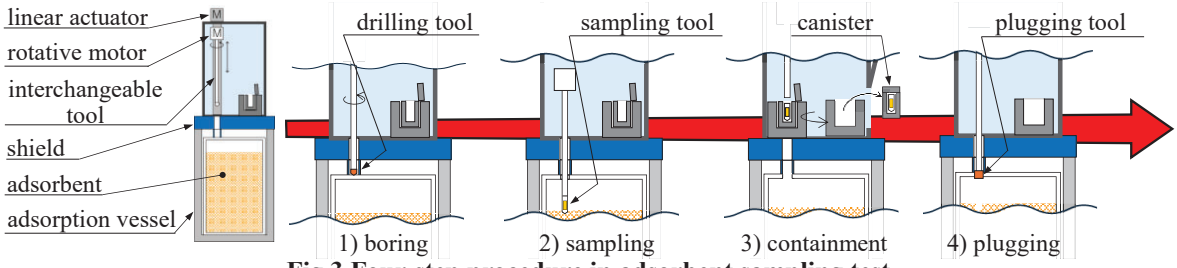


Fig.3 Four-step procedure in adsorbent sampling test

3. Conclusion

Samples were successfully extracted from seven spent adsorption vessels of the KURION and SARRY at 1F, ensuring that worker radiation exposure remained within safe limits and no radioactive dust dispersed. The obtained samples have been transferred to the Japan Atomic Energy Agency (JAEA) outside 1F for analysis.

Acknowledgements

This work was supported by the Ministry of Economy, Trade and Industry (METI) through the subsidy program for the “Project of Decommissioning, Contaminated Water and Treated Water Management”.

I04 Developing technology and specifications for metakaolin-based geopolymers as robust and promising stabilizers for fuel debris removal

Xiaobo Niu[1], Yogarajah Elakneswaran[1], Tsutomu Sato[1], Ryosuke Kikuchi[1], Takashi Okada[2], Takeshi Ohsugi[2], Junya Sato[2], Yoshihisa Hiraki[2], Brant Walkley[3], Hajime Kinoshita[3]

[1]Hokkaido Univ., [2]Japan Atomic Energy Agency, [3] Univ. of Sheffield

Abstract

This research is centered on the development and design of specifications and formulations for metakaolin-based geopolymers. These geopolymers are engineered to possess high flowability and superior confinement properties. By incorporating boron, they also gain neutron-absorbing capacity, making them ideal for stabilizing and solidifying radioactive wastes from fuel debris and contaminated water treatment processes.

1. Introduction

In the decommissioning of TEPCO's Fukushima Daiichi NPS (1F), various radioactive wastes have been generated and stored on-site due to contaminated water treatment. The "Mid- and Long-term Roadmap for Decommissioning" aimed to outline technical prospects for waste treatment and disposal by FY2021.

Hokkaido University and the University of Sheffield solidified spent synthetic zeolite and titanate into alkali-stimulated materials (geopolymers) and conducted safety evaluations under the Japan-UK Nuclear Energy Joint Research Eichi-Project from FY2016 to FY2018. The results showed these adsorbents could be effectively solidified, safely disposing of ^{137}Cs and ^{90}Sr. However, challenges include improving fluidity, enhancing anion retention, and scaling up to practical solidification devices. From FY2019 to FY2021, joint research by Hokkaido University, JAEA, Advan-Engine Corporation, and the University of Sheffield focused on developing high-fluidity, high-anion-retention alkali-stimulated materials. This research identified a viable recipe and the requirements for a full-scale solidification facility. Efforts to improve geopolymer flowability involved testing metakaolin from various suppliers mixed with simulated waste. Variations in mixability and compressive strength highlighted the need for standardized specifications for metakaolin, similar to cement's proven low-temperature treatment capabilities. The "TEPCO Technology Strategy Plan 2022" outlines goals for fuel debris removal, waste management, and contaminated water treatment. Strengthening and applying metakaolin-based geopolymers are crucial for stabilizing and solidifying radioactive waste from fuel debris and contaminated water.

2. Content of the project

This project focuses on fuel debris and contaminated water in the primary containment vessels (PCVs) of Units 1, 2, and 3 at the Fukushima Daiichi Nuclear Power Plant, as well as other radioactive waste generated during core dismantling and past cleanup operations. To demonstrate the potential of metakaolin-based geopolymers, with and without boron, for stabilizing and solidifying degraded fuel and contaminated waste in Japan and the UK, the following four joint studies will be conducted:

(1) Design of metakaolin geopolymers with varying properties, incorporating boron as a neutron absorber.
(2) Study of interactions between metakaolin-based geopolymers and key cations and anions.
(3) Examination of metakaolin-based geopolymers with colloidal and simulated waste.
(4) Specification of metakaolin-based geopolymer properties.

The Japan Atomic Energy Agency (JAEA), experienced in field requirements such as hydrogen generation control, will oversee the physical property testing and evaluation of test specimens prepared in studies (1)-(3).

I05 Solidification of ALPS Sediments Wastes Using Phosphate Ceramics

Anna Gubarevich[1], Ryotaro Kubo[1], Shintaro Yasui[1], Katsumi Yoshida[1], Kenji Takeshita[1]
[1]Tokyo Institute of Technology

Abstract

Simulated ALPS sediment wastes were solidified into polycrystalline phosphate ceramics using a two-step process. First, ALPS slurries were converted into insoluble phosphate forms via chemical substitution and condensation reaction. This was followed by densification at mild temperatures through cold sintering pressing. The effect of process parameters on the crystal form of phosphates and the degree of densification was evaluated to ensure stable immobilization of radionuclides.

1. Introduction

Stable solidification of Advanced Liquid Processing System (ALPS) sediment wastes is crucial for safely decommissioning the Fukushima Daiichi nuclear power plant. This study develops a solidification technique using phosphate ceramics and cold sintering. Phosphate ceramics offer high radiation resistance and aqueous durability, with crystal structures that incorporate radioactive elements. Cold sintering pressing (CSP) is a low-temperature process driven by chemo-mechanical pressure-solution effect. In this study, we aim to achieve stable ALPS waste solidification while minimizing energy use and processing time, addressing challenges like long-term stability and preventing radioactive leaching.

2. Results and discussion

2-1. Synthesis of crystalline phosphate form

Simulated ALPS carbonate wastes were converted into phosphate form utilizing the chemical substitution and condensation method. Control of the reaction parameters permitted to achieve full transformation of carbonate slurry into insoluble phosphate forms, which were separated from solution using a standard vacuum filtration method. Formation of whitlockite (WH: $Ca_{18}Mg_2(HPO_4)_2(PO_4)_{12}$) was confirmed. WH has a complex crystal structure with many substitution sites (Fig. 1), suitable for immobilization of various ions.

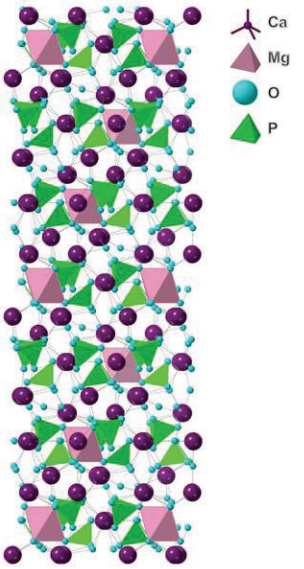


Fig. 1 Crystal structure of whitlockite.

2-2. Cold sintering (CSP) of polycrystalline phosphate ceramics

CSP process was conducted using self-made apparatus. Effects of heating rate, maximum temperature, holding time and mechanical pressure during CSP were investigated. As a result, the conditions of densification were optimized. Further improvement of crystallinity of whitlockite after CSP was observed.

3. Conclusion

The solidification of simulated ALPS sediment wastes into stable phosphate ceramics was successfully achieved through the condensation reaction followed by the cold sintering process. Further research including hot experiments will be conducted to evaluate the feasibility of this method for practical applications.

I06 SIAL®: Geopolymer solidification technology approved by Slovak / Czech Nuclear Authority

Marcela Blazsekova, Milena Prazska, Maros Juraska and Marek Meciar , Jacobs Slovakia s.r.o.
Hisashi Mikami , Kazutaka Hirata and Nobuyuki Sekine , Fuji Electric Co.,Ltd.

Abstract

We present the features and the performance records of SIAL® geopolymer solidification technology is licensed by both the Slovak (ÚJD SR) and Czech Nuclear (SUJB) regulators, and the technology has been used successfully for 20 years. Recently, geopolymer has been noted as an immobilization technology and which shows potential of immobilizing sludge and slurry generated by treatments of contaminated water at Fukushima Daiichi Accident. More recent research on the advanced SIAL® geopolymer has focused on a flodding application implemented for combined resistance under hot water and direct contact with hot surfaces.

1. Introduction

The Nuclear Power Plant (hereinafter called NPP) Unit A1 located in Jaslovske Bohunice, which was completed in 1972 and had been operated for 5 years until two accidents happened in 1976 and 1977. After the second accident (INES level 4), NPP Unit A1 was permanently shut-down for decommissioning. Damaged fuel assemblies and claddings in the accidents caused contamination of strontium-90, caesium-137 and transuranic. As a result of a long-term corrosion of barrier's materials, highly contaminated sludge were accumulated, and the waste could not be effectively immobilized with using conventional methods such as Cementation or Bitumen treatment due to negative impact on physical-chemical properties and high specific activity (caesium-137) of the waste. This challenge led to developing SIAL® solidification technology. Today, SIAL® is proven and widely used for on-site solidification of radioactive waste streams such as sludge, resins, sorbents and organic liquids. This is directly applicable to the conditions at Fukushima Daiichi as well as other Japanese NPPs where the waste streams are not well understood.

2. Feature

SIAL® geopolymer can provide efficient and practical on-site treatment of radioactive waste streams at room temperature. The equipment used to deploy SIAL® solidification technology is also modular, flexible and versatile. It can encapsulate waste streams quicker than Cementation, and can be applied under water. SIAL® solidification technology can realize higher compressive strength and lower leachability compared to Cementation, and posing a low fire risk and excellent physical stability in the presence of frost and water (no distortion or cracking).

Figure 1 200L Indrum kneading machine and SIAL® solidified body of resin

Figure 2 Areva sludge and Fe and Carbonate slurry waste streams cross section observation

3. Performance Record Example

About 3×10^6 kg of radioactive waste streams (resins, sludge and crystalline borates) is successfully immobilized using SIAL® . This comprehensive scope of works started with licensing processes, solidification, and then were followed by decontamination and cleaning of the workplace post cleanup and transports of all equipment to off-site.

4. Flodding application

More recent research on the advanced SIAL® geopolymer has focused on a flodding application. Laboratory-scale trials have been proven that it is possible to apply the grout under water at 90℃ and can mature to the required strength even in contact with a surface at around 300℃.

Figure 3 SIAL® matrix surface after 1hr at 300℃

I07 Unprecedented fabrication method of granular layered double hydroxide with remarkable antimony adsorption properties

Tsukasa Terashima, Yuta Morioka and Naoki Asao
Shinshu University

Abstract

A direct synthetic method for granular layered double hydroxides (LDHs) for capturing radioactive antimonate ions under a fixed bed column system has been developed. The materials exhibit not only high adsorption capacity but also excellent removal efficiency in the coexistence of highly concentrated competitive anions.

1. Introduction

LDH materials are layered compounds consisting of divalent and trivalent metal hydroxide layers and interlayer anions, and they have been investigated for removal of antimonate ions from industrial wastewater. However, most of the adsorbents reported so far are given in powder-forms based on the ordinary synthetic methods, which require the granulation process for the practical use in the column operation. Here we report a direct synthetic method for granular Mg-Al LDH for capturing radioactive antimonate ions in Fukushima Daiichi Nuclear Power Station.

2. Results and discussion

Mg-Al LDH was synthesized via the formation of phosphate precursors. Most of them were found to be granular with sizes ranging from 0.3 to 1 mm, with an average particle size of 0.78 nm, as shown in Fig. 1. Adsorption experiments in Sb(V) solution were carried out for 24 h, and the maximum adsorption capacity was found to be more than 500 mg g^{-1}. Even with the coexistence of highly concentrated common anions, such as Cl^-, NO_3^-, Br, SO_4^{2-}, HCO_3^-, any remarkable effects were not observed on Sb(V) removal as shown in Fig. 2. On the other hand, $H_2PO_4^-$ caused the decrease in removal efficiency, probably due to the formation of magnesium phosphate on the surface of adsorbents, which might block the adsorption sites.

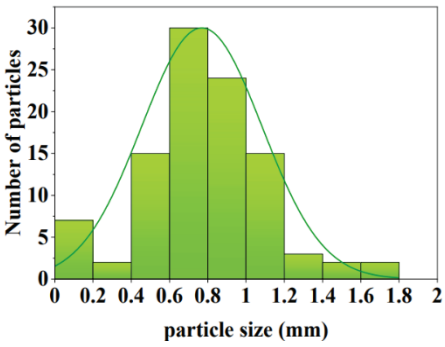


Figure 1. Particle size distribution of granular Mg-Al LDH.

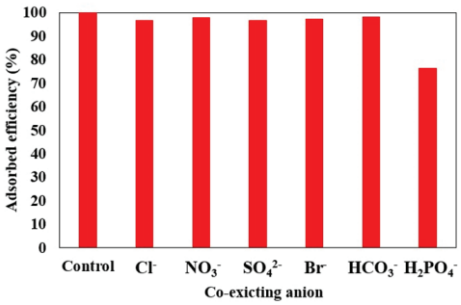


Figure 2. Effect of coexisting anions on Sb(V) adsorption. Initial concentration: Sb(V) = 0.2 mM, other anions = 100 mM; dosage of LDH = 0.5 g L^{-1}.

3. Conclusion

Granular adsorbents having high Sb(V) uptake ability were fabricated without granulation process. Further studies to elucidate the adsorption mechanism and to produce suitable waste forms for disposal are in progress.

I08 A Study on the Methodology for Rational Treatment/Disposal of Contaminated Concrete Waste Considering Volume Reduction of Waste
(1) Evaluation of properties of simulated waste

Yuka Morinaga[1], Daisuke Minato[1], Naoko Watanabe[2], Takafumi Sugiyama[2], Katsufumi Hashimoto[2], Shinichiro Uematsu[2], Munemichi Kawaguchi[2], Daisuke Kawasaki[3], Satoshi Yanagihara[3], Yukihiro Iguchi[3], Toru Kitagaki[4], Naofumi Kozai[4], Yoshikazu Koma[4] and Tamotsu Kozaki[2]
[1]CRIEPI, [2]Hokkaido Univ., [3]Fukui Univ., [4]JAEA

Abstract

A large amount of radioactive concrete waste is expected to be generated as a result of the decommissioning of the Fukushima Daiichi Nuclear Power Plant. In order to investigate a method for the rational disposal and treatment of concrete, an evaluation of the properties of a simulated waste body prepared using simulated fine powder was carried out as part of the investigation of a disposal method for cement fine powders generated during the separation of aggregate and cement, which is one of the issues in the re-use and recycling of concrete.

1. Introduction

In order to complete the decommissioning of Fukushima Daiichi Nuclear Power Plant, it is necessary to develop a rational waste management plan, and one of the most important issues is to consider the disposal and treatment of the large amount of concrete waste. Separation of radioactive concrete into aggregate and cement parts for reuse is one of the effective ways to significantly reduce the volume of concrete waste, but there are only a few examples of studies on the ratio and conditions of cement fine powders and solidifiers when waste body disposal of contaminated cement particles and powder produced by aggregate separation is assumed.
In this study, a simulated waste body was prepared using simulated cement fine powders generated by aggregate separation and the properties of the simulated waste body were evaluated.

2. Experimental

In the present study, fine powders obtained during concrete preparation and aggregate separation using Heating and Rubbing Method were obtained. The obtained simulated fine powders were characterised by X-ray diffraction (XRD) and ^{29}Si-Nuclear Magnetic Resonance (^{29}Si-NMR) measurements. Simulated waste materials were also prepared by varying the ratio of simulated fine powders to cement and measured for uniaxial compressive strength, XRD, NMR and Scanning Electron Microscope-Energy Dispersive Spectroscopy (SEM-EDS).

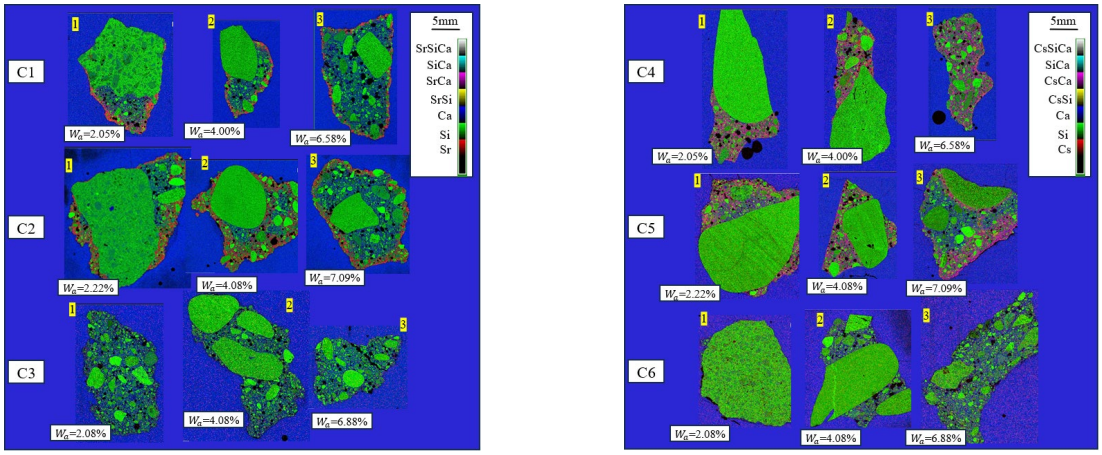
3. Results and Discussion

Uniaxial compressive strength tests of the simulated waste material showed a decrease in strength with increasing fine powders replacement rate. SEM image measurements showed a tendency for the porosity to increase with increasing fine powders replacement rate. This increase in porosity is considered to be one of the reasons for the decrease in strength.

I09 Study on the Methodology for Rational Treatment/Disposal of Contaminated Concrete Waste Considering Volume Reduction of Waste (2) Study on the safety of recycled aggregates producing by contaminated concrete

Yingyao Tan[1], Liu Junxiao[1], Katsufumi Hashimoto[1] and Takafumi Sugiyama[1]
[1]Faculty of Engineering, Graduate school of Engineering, Hokkaido University

The Fukushima nuclear accident and the subsequent spread of nuclides have produced a large amount of contaminated concrete, among which the contamination of strontium and cesium ions has attracted much attention due to their long half-life. A large portion of this contaminated concrete is low level contamination, and it is costly to dispose of all of it using underground storage. A solution worth exploring to reduce the total amount of contaminated concrete is to use the low contaminated level waste for the recycled aggregate production [1]. Whether the nuclides will migrate to the outside during the service stage of recycled concrete is a safety issue for contaminated recycled aggregate. This process is affected by factors such as the degree of nuclide contamination, the species of nuclide and the migration mechanism of nuclide in concrete. Study was conducted to provide a safety evaluation of the use of recycled aggregate produced by nuclide contaminated concrete. In this research, the recycled aggregate was immersed in a nuclide solution of CsCl and $SrCl_2$ with different concentration (10^{-1} mol/L and 10^{-4} mol/L) for a period of time to simulate the contaminated recycled aggregate obtained by crushing the parent concrete after serving under nuclide-rich environment. Contaminated recycled aggregate was then individually encapsulated in hardened cement paste to simulate recycled concrete. Simulated recycled concrete specimen was immersed into deionized water for one month which approximates to the service condition of concrete in long-term contact with water and the risk of nuclide leaching. Specimen after immersion test was cut in half and the element distribution on the cross section was detected by the Electron Probe Micro Analyzer (EPMA) method, as shown in Fig 1. Experimental results showed that nuclides migration in new concrete is very limited.



(a) $SrCl_2$ solution immersion (b) CsCl solution immersion

Fig 1 Element distribution on the cross section of simulated recycled concrete

References

[1] Shimada, Taro, Kazuji Miwa, and Seiji Takeda. "Study on restricted use of contaminated rubble on Fukushima Daiichi NPS site.(1) Estimation of reference radiocesium concentration for recycling materials." Prog Nucl Sci Technol 6.6 (2019): 203-207.

I10 Study on the Methodology for Rational Treatment/Disposal of Contaminated Concrete Waste Considering Volume Reduction of Waste

(3) Experiments for Cs Concentration in Fine Particles Caused by Segregation of Aggregate in Simulated Cs contaminated Concrete

Munemichi Kawaguchi[1], Keigo Sokugawa[1] and Kazuhiro Sawa[1]

[1]Hokkaido Univ.

Abstract

This study performed experiments to investigate Cs concentrations in fine particles generated during aggregate segregation in simulated Cs-contaminated concretes. The experiments showed trends of the higher Cs concentrations remaining in fine particles than in the concrete.

1. Introduction

A huge amount of radioactive concrete remains in post-accident Fukushima Daiichi Nuclear Power Plants. According to past studies[1–2], the radioactive nuclides were attached to only the surface of concrete. However, it reported that they penetrate much deeper through a crack. This study performed experiments to investigate the Cs concentrations in fine particles generated by aggregate segregation of simulated Cs-contaminated concrete.

2. Simulated Cs contaminated concrete

The experiments prepared two kinds of simulated Cs-contaminated concretes, which were made of greywacke aggregate (#1) and river sand (#2). The sizes were ~30 mmL for aggregate segregation experiments. The Cs concentrations were 0.84 wt.% in #1 and 0.97 wt.% in #2 with atomic absorption spectroscopy (AAS).

3. Cs concentration of fine particles floated in the aggregate segregation

We set 350 g of the concrete and 415 g of stainless-steel bolls into the pot and rotated it at 30 rpm in 30 min. The fine particles floated in the pot were collected with a cascade impactor. The weights and Cs concentrations were quantified by a scale and AAS, respectively. Figure 1 shows Cs concentrations of the simulated concrete before the experiments, those of fine particles floating in the rotating pot, and after the termination of rotation. The Cs concentrations of fine particles were approximately four times higher because their origin is from the mortal.

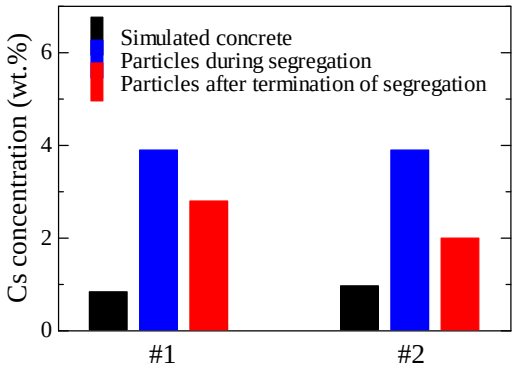


Figure 1. Cs concentrations in fine particles

3. Conclusion

The experiments investigated the Cs concentrations in fine particles generated by aggregate segregation in two kinds of simulated Cs contaminated concretes (#1 and #2). The Cs concentrations were approximately four times higher than those of the simulated Cs contaminated concretes.

References

[1] K. Yamada et al., J. Adv. Concr. Technol., 19, 756-770, 2021.

[2] K. Yamada et al., J. Adv. Concr. Technol., 17, 659-672, 2019.

I11 Radioactive Scrap Metal Recycle, Japanese Demonstration.

Colin Austin, Tomoaki Fujikawa and Makoto Kikuchi
Energy*Solutions*, Charlotte NC. USA

Abstract

1. Introduction

Energy*Solutions* (ES), founded in 2005, but with legacy dating back to the establishment of Envirocare and the original commercial US LLW Disposal in 1990, was established by acquiring companies both from the United States (US) and from the international market with market leading project delivery and technology to enable provision of the full value chain of nuclear backend service mainly in the areas of radioactive waste management, nuclear facility D&D and radioactive waste disposal. The company can bring together over 50 years of global experience, which provides the full suite of nuclear services in an integrated, often unique solution, for their customers across the globe. Notably in the US, ES have been involved in majority of completed D&D projects, including the La Crosse, SEFOR, and Zion sites which were fully managed by the company as commercial D&D business. One of the next major challenges is to complete D&D work at TMI-2.

2. Resource not Waste

Since the early 90s, ES have been accepting over 7,500t of radioactive contaminated metals from the international market to recycle for beneficial reuse, mainly to produce shield blocks that would be re-used in the nuclear industry. The key here is two-fold; no material would be disposed in the US, and concurrently, no material would need to be returned to the customer through this beneficial reuse process and that this solution can support the client create space on site. After close working relationships with the Japanese nuclear utilities, ES is now recycling Japanese spent fuel casks, into useful product, that have been delivered to ES's Memphis recycling facility this January and following decontamination and dismantling have been melted and repurposed for beneficial reuse at the company's Bear Creek Facility in Oak Ridge TN. This is the 1st shipment from Japan under the new system in law, introduced on January 11th, 2023, and it is a major achievement made by the industry to demonstrate that there is an outlet for recycle and beneficial reuse of these materials. This message is now shared and accepted globally, resulting in contracting vast volume of new metals from Europe just in these past few months, exceeding the total amount of metals ES has ever recycled from the international market. This has great benefits in carbon foot-print reduction through metals recycle, preservation of important disposal site capacity and generating much needed space on D&D sites by removing and recycling stored material.

3. Conclusion

ES, with its rich experience in D&D, is now re-illustrating the international business strategy to design D&D around recycling, not just with the metals, but also with assets such as radio nuclides that can be harvested to be re-used as radioisotopes. Marubeni Utility Services (MUS), as ES's agent for the metals melt business, believes that this is going to be a paradigm shift for the D&D to become recycle projects, not a waste management project, and is very excited to work together through this phase to establish a new standard for Japan and the world.

I12 Transformational Technology Driving the Paradigm Shift From Nuclear Waste Disposal to Valuable Resource Recycling.

Tim Milner, Colin Austin and Makoto Kikuchi
Energy*Solutions*, Charlotte, NC, USA

Abstract

1. Introduction

Energy*Solutions* (ES), employs over 50 years of global decommissioning, waste management and disposal experience to drive innovation from inception to project delivery. In the US, ES has safely and successfully executed the majority of completed D&D projects, including the La Crosse, SEFOR and Zion sites, which were fully managed by the company as a commercial D&D business. One of the next major challenges is to complete D&D work at TMI-2. Post-accident, immediate remediation and gross defueling of TMI-2 was completed in the 1990's. Today ES is completing the removal of the hard to remove post-accident fuel bearing material and remotely decontaminating, dismantling, and decommissioning the reactor vessel, primary loop components and associated infrastructure.

2. Transformational Technology

ES with its deep history and capability in nuclear waste management and disposal has embarked upon a transformation of the nuclear back-end. Applying innovative technologies that shift the paradigm from the accept notion of redundant plant and components being nuclear waste to a new understanding that these materials represent valuable resources for sustainable recycle. At the vanguard is Energy*Solutions*' new entity SUVA, who are bringing this capability to new international markets. Using our own projects to demonstrate this paradigm shift ES is engaged in deploying a suite of innovative technology at TMI-2 including, advances in electrokinetic filtration for spent fuel bearing material, targeted chemical decontamination for preferential dissolution of spent fuel bearing material, advanced liquid waste treatment with new elutable ion-selective media for selective harvesting of key radionuclides for beneficial reuse, advanced thermal volume reduction and stabilization techniques and a suite of remotely deployable dismantling techniques, informed by radiation dose visualization and point cloud digital twins, to guide and update the decommissioning process. The recycle process is completed by ES metal melt and recycling processes at Bear Creek in Oak Ridge, TN, where innovations in additive manufacturing to repurpose recycled metals into new products for use in the nuclear industry are being developed.

3. Conclusion

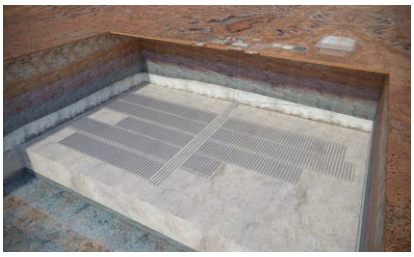
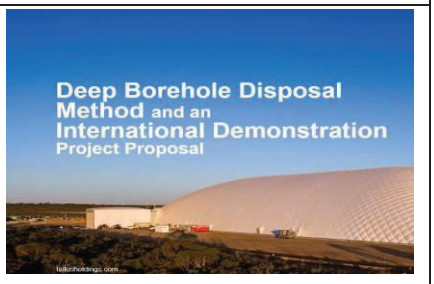
ES with its rich experience in D&D and nuclear waste management and disposal is applying its knowledge and expertise to create value from what was traditionally referred to as nuclear waste. In doing so, this preserves strategically important radioactive waste disposal site capacity via diversion and resource recovery and reduces carbon footprint by repurposing and reusing metals avoiding the considerable greenhouse gas emissions from metal ore processing and steel manufacture. Additionally, providing a source of radionuclides harvested for beneficial use from what was once considered waste, to drive forward, radio-medicine, instrumentation, space flight and agriculture. This paradigm shift from waste to resource further enhances the credibility and vital role the nuclear industry will play in a sustainable energy future and combating climate change.

I13 International Best Practice Management and Disposal of Radioactive and Hazardous Wastes: Developing a Collaborative Partnership between Japan and Australia.

Nate Smith and Bill Miller
Tellus Holdings, Sydney and Perth, Australia.

Abstract

Tellus is an Australian company that develops advanced radioactive waste management solutions. Tellus operates a LLW and hazardous waste disposal facility (Sandy Ridge) excavated in high purity kaolin. This kaolin can be used to manufacture geopolymers for use in the nuclear industry. Tellus is also developing an international deep geological repository (Chandler) and a deep borehole demonstration project. Tellus is offering to work with Japanese organisations to develop collaborative partnerships www.tellusholdings.com

Sandy Ridge LLW and hazardous waste repository Sandy Ridge is a near-surface geological repository and Australia's only facility licensed to dispose of LLW and hazardous wastes. The repository is located in a very arid environment and is excavated from high purity kaolin. Disposal is under one of the largest airdomes in the world – bigger than Tokyo Dome.	
Chandler international waste repository Tellus has regulatory approval and the support from the local aboriginal community to construct a deep geological repository at a depth of around 850 m in bedded salt rock in Australia. This repository will be unique because it is licensed for the disposal of wastes imported to Australia from other countries, including Japan.	
International Deep Borehole Demonstration Project For decades there has been international interest in the concept of deep borehole disposal. Tellus has obtained regulatory approval to drill 8 boreholes (c. 5 km deep) at its Sandy Ridge site. We are planning an international deep borehole demonstration project (IDBDP) to perform R&D into deep borehole disposal of HLW and spent fuel.	
Geopolymers for radioactive waste management Tellus' Sandy Ridge repository is excavated in high purity kaolin that is ideal for manufacture of metakaolin used in geopolymer formulations that can be applied in the nuclear industry, such as for waste immobilization. The Sandy Ridge site will produce approximately 5 million m^3 of this kaolin, so we can offer Japanese organisations a reliable and cost effective supply of metakaolin.	

F01 Innovation : from Orano Internal Needs to the International Market

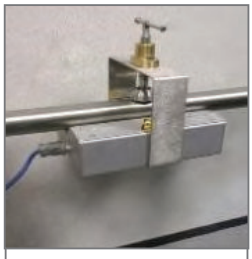
Vincent Tran[1], Daphne Ogawa[1] and Victor Guillon[1]
[1]Orano

Abstract

Answering ordinary and complex challenges arising during dismantling & decommissioning operations, Orano developed an agile culture where **innovation can grow from the needs of the field**. Strong of our operators and experts, their experience in our own facilities decommissioning and projects worldwide, proven solutions supporting decommissioning projects can now be proposed to customers, improving worksite productivity and safety.

1. Internal needs representatives of a global market

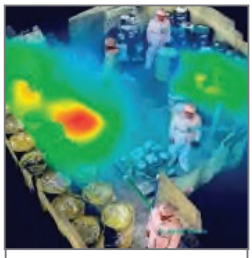
Innovation at Orano comes from a bottom-up approach, developed throughout the years across the world in our own facilities and projects encompassing all activities of nuclear cycle. The innovation culture puts forward our capacity to listen to everyone, from operators to experts. Orano accompanies our employees in their evolution, filling skill gap, strengthening our core competencies and allowing pain points to be solved with a holistic approach. As an example, **CANET was developed to answer an internal need of non-destructive water detection in piping**.



CANET

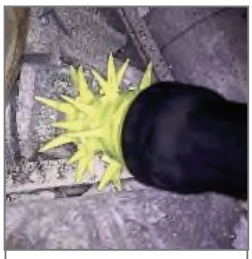
2. Agile development

Development is made with agility, giving strong ownership to individual initiative through an ecosystem emphasizing impactful ideas, sharing them through a collaborative platform assisting in the transmission, diffusion and adoption of new endeavors. One innovation that emerged from such a culture was **MANUELA and PoStLAM, a radiological 3D mapping technology.** Operational feedback allowed iterative improvement of both hardware and software to make this solution answers evolving engineering needs from multiple stakeholders.



PoStLAM

3. Adaptation of internal innovation to customer needs



ANEMONE

Orano internal solutions are built from multiple technological blocks and can be adapted to fit the needs of various environments, internal or external to Orano. One of them, ANEMONE is perfectly suited for a large range of retrieval operations, even in harsh environments. **ANEMONE can catch, imprison and recover any kind of solid element no matter its shape, material or density**. ANEMONE was used in La Hague to collect highly radiating graphite sample in April 2022 and is now under development for the recovery of 1F fuel debris in collaboration with MHI, in the frame of the Japanese National Projects.

4. Conclusion

Orano fostered a strong innovation culture, aligned with its strategy and operational goals supporting its operations worldwide. The results are several highly adapted and adaptable solutions that can be used to solve critical D&D issues and that can be applied to Fukushima 1F decommissioning. Example of solutions range from radiological mapping in an ever-evolving environment, operational safety during cutting of pipes to sampling of various solid elements in harsh conditions.

F02

Orano's HRB: a dedicated facility for the development and qualification of FOAK projects in La Hague

Nicolas Breton[1], Vincent Janin[1], Daphne Ogawa[1], Guillaume Grandjean[1],
[1]Orano

Abstract

A major part of the challenges in 1F D&D, especially the retrieval and conditioning of the fuel debris, are first-of-a-kind projects, requiring significant efforts in development & qualification (D&Q), and operator training. For the operation, maintenance and D&D of La Hague reprocessing plants, Orano has built a dedicated facility called HRB (Hall de Recherche de Beaumont), allowing the deployment of resources such as mockups, with the aim to properly prepare and implement complex operations especially for waste retrieval and conditioning projects.

1. Introduction

Retrieval and conditioning of nuclear waste, whether for 1F fuel debris or legacy waste retrieval at La Hague are **first-of-a-kind projects** and require significant efforts from the **development** of an applicable technical solution to the **qualification** of an industrial process and waste package, and until the **training** of operators. The availability of a suitable facility is essential to carry out these steps successfully in a representative environment.

2. Beaumont Research Hall (HRB)

Orano's HRB is a facility that develops and qualify innovative processes and equipment for use in a nuclear environment. It gathers all the capacity of a test hall, while also having access to extensive industrial and experts' resources, and a multi-disciplinary team supported by all the engineering of Orano. As it is located near La Hague site, future operators and maintenance teams are also involved for their training.

HRB overview

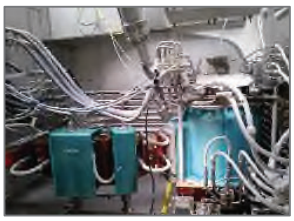
The D&Q of legacy waste retrieval solutions have been completed in HRB, among which:

- **Cementation of legacy resins and sludge**, with the development of various hydraulic binders, and qualification of industrial processes adapted to remote operated hot cells (GUEDU, lost paddle, etc.),
- **Treatment of sludge** by centrifugation for interim storage,
- **Vitrification** of high activity liquid waste in a Cold Crucible Induction Melter

3. CRISTALE: A full-scale inactive mock-up of Orano's Cold Crucible Induction Melter (CCIM)

CRISTALE is a **full-scale inactive mock-up of the CCIM** used in La Hague UP2-800 for HALW vitrification. CRISTALE has been installed in HRB at the time of CCIM operation start-up in 2010, and remains essential for the **D&Q of technological evolutions and operators training**:

- **Hot cell (red area) dimensions and arrangement are identical** to the industrial facility, including windows and remote manipulators (MSM),
- **Instrumentation and control are identical to the industrial system**,
- Other key items such as High Frequency Generator are also identical.



CRISTALE Cold Crucible Induction Melter in HRB

4. Conclusion

To benefit from such type of support facility is essential for the success of complex engineering projects from the viewpoint of design, qualification, and operator' training such as those to be managed in 1F.

F03

Investigation on Estimation Method for the Characterization of Highly Radioactive Waste Using Non-Destructive Measurement Data

Philippe Bernard[1], Frederic Met[1], Damien Gerard[1], Ken Kojima[2], and Yoshikazu Koma[3]
[1]Veolia Nuclear Solutions France, [2]Veolia Nuclear Solutions Japan Corporation, [3]JAEA

Abstract

In FY 2022, an evaluation model to estimate the parameters of waste management from the non-destructive measurement of the radiation was proposed. Base on this, the implementation example of estimating from non-destructive analysis of key-nuclides (^{137}Cs, ^{60}Co, ^{154}Eu) in radioactive waste was proposed and issues to be solved for implementation was organized and investigated.

(This study was performed under the subsidy program “Project of Decommissioning, Contaminated Water, and Treated Water Management (Research and Development of Processing and Disposal of Solid Waste)” conducted by the Ministry of Economy, Trade and Industry of Japan).

1. Introduction

The target has a very high dose rate (10 Sv/h on the surface of the container). Using Monte Carlo simulations, a measurement system was studied in order to verify the adequacy between these circumstances and the capacity of the system to respond to them. In addition, issues and solution policy for the system implementation was also examined.

2. Results of investigation

2-1. Investigation of example of system integration

The example of system integration contributing to inventory evaluation of high radioactive wastes was proposed base on Monte Carlo simulations of the gamma spectrometry.

As a result, using a small solid-state (CZT and HPGe) detector, we found that it can perform the gamma spectrometry of key nuclides (^{137}Cs, ^{60}Co, ^{154}Eu) in radioactive waste from a distance of about 5 meters (count rate < 200,000 c/s), coupled with the digital signal processing.

The performances concerning detection limit of ^{137}Cs and ^{154}Eu depending on the activity of ^{60}Co have been estimated. Radionuclides in the waste may be distributed unevenly in the container, and the uncertainty of the measurement results due to this was also considered.

2-2. Issues and solution policies for system implementation

With regard to the implementation conditions and the measurement to be carried out, the components of the measurement system have been studied with knowledge of the current state of the market. The components for construction are available, so we presented a roadmap of the steps that need to be taken before measurement can actually be made, and further consideration that may be required in the future, taking into account the risks.

3. Conclusion

We proposed the system, although there is still a high degree of uncertainty in measurement environment. We also recommended that the waste be placed in a hot cell and the measuring equipment be outside. It should be considered how to respond as the conditions will be clearer while fuel debris retrieval will be firmly planned.

F04 Study of the applicability of GeoMelt® vitrification treatment to various radioactive solid wastes in Fukushima Daiichi Nuclear Power Plant (1F).

Mirai Kuramata[1], Ken Kojima[1], Kevin Finucane[2], Brett Campbel[2], Hiroaki Nakauchi[3] and Mitsuhiro Sato[3]

[1]Veolia Nuclear Solutions Japan Corporation, [2]Veolia Nuclear Solutions Federal Services, [3]Daiei Kankyo

Abstract

This study conducted a series of cold melting test for “miscellaneous rubbles” and “ALPS carbonate slurry dehydrates with container” to confirm the applicability of GeoMelt® ICV™ to various radioactive wastes at Fukushima Daiichi NPP (1F) as METI subsidy project. Both series of tests included steel and the need of a relatively high glass temperature to melt the steel waste components, all wastes were successfully processed and solidified glasses with high durability were produced.

1. Introduction

There are various radioactive wastes at 1F. To treat them, pre-treatment, such as sorting, is generally required, but radiation makes it difficult. GeoMelt® ICV™ is a versatile joule-heated vitrification technology that has been used to treat a wide range of wastes. In this project, the applicability of GeoMelt® ICV™ was studied for “miscellaneous rubbles” as Task1 and “ALPS carbonate slurry dehydrates with container” as Task 2.

2. The result of melting tests

2-1. Task1; Bulk melting for miscellaneous rubbles

The melting tests for Task 1 were conducted with small scale GeoMelt® ICV™ test facilities (1t scale) in Mie Chuo Kaihatsu, Japan. Four bulk melting tests were conducted using concrete, steel, heat insulating material, PVC hose, etc. as miscellaneous rubbles and simulated 1F soil as glass formers. Solidified glass produced in the melting tests have metal layer made of steel and glass phase. The glass was dense and durable.

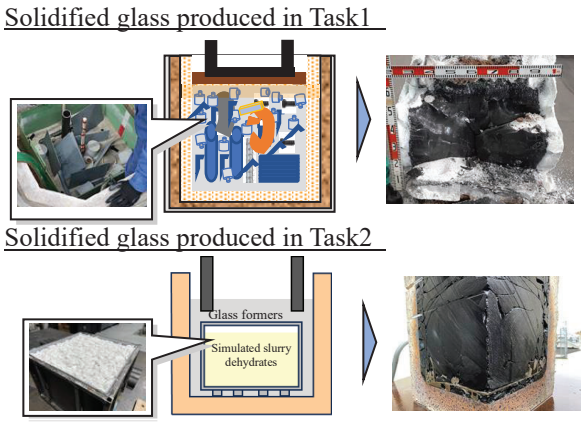


Figure 1. Solidified glass produced in this Study

2-2. Taks2; Melting ALPS carbonate slurry dehydrates together with container

The melting tests for Task 2 were conducted with engineering scale GeoMelt® ICV™ test facilities (200kg scale) in Richland, USA. One bench scale test and two engineering scale tests were conducted. In all melting tests, steel containers were completely melted to form an inert metal layer at the bottom. The simulated slurry dehydrates also melted into the glass, forming a dense and durable glass.

3. Conclusion

In each task, it was confirmed that melting wastes including steel was possible. In the next step, the study to optimize volume reduction potential of vitrification is planned.

J01 Prospects for Environmental Radioactivity Assessment Considering Environmental Dynamics of Radionuclides and Human Activities

Hiroshi Kurikami[1], Yoshito Sasaki[1], Motoki Terashima[1], Kazuya Yoshimura[1], Hironori Funaki[1] and Yukihisa Sanada[1]

[1]Collaborative Laboratories for Advanced Decommissioning Science (CLADS), Japan Atomic Energy Agency

Abstract

CLADS started a study on environmental radioactivity assessment considering environmental dynamics of radionuclides and human activities under the contract with F-REI. We plan to clarify the relationship between human activities and environmental dynamics after the lifting of the evacuation order through field surveys, laboratory tests, and numerical simulations, and to conduct a comprehensive environmental radioactivity assessment based on exposure doses. We also plan to design a website for information dissemination.

1. Introduction

CLADS has been conducting environmental recovery research after the Fukushima Daiichi NPP accident. In the last fiscal year, CLADS started a study on environmental radioactivity assessment considering environmental dynamics of radionuclides and human activities under the contract with F-REI. The objective of this study is to provide residents with easy-to-understand information on the results of a comprehensive assessment to respond to their concerns and interests in terms of setting evacuation zones and restricting food shipments, using radiation doses as an indicator.

2. Research prospects

2-1. Field surveys and model development

Even now, more than 13 years after the accident, some forest and fishery products such as wild mushrooms and freshwater fish continue to be restricted for shipment. It is important to understand and predict the status of these contaminations in preparation for the lifting of the evacuation order. It is also necessary to predict changes in the dynamics of radionuclides in forests, rivers, and urban areas due to human activities after the lifting of evacuation orders. We plan to conduct field surveys and laboratory tests and develop a simulation model to clarify the relationship between human activities and environmental dynamics after the lifting of the evacuation order and to conduct a comprehensive environmental radioactivity assessment based on exposure doses, based on our experience and knowledge of environmental dynamics studies that we have conducted.

2-2. Providing information to the public

The dissemination of easy-to-understand information on research findings and monitoring results related to environmental restoration is important for fostering residents' sense of security and promoting their return. CLADS has been operating a Q&A style website to disseminate information. In order to improve the website, we plans to conduct a survey on the needs of the website and consider ways to enhance its content.

3. Conclusion

This study aims to clarify the relationship between human activities and the environmental dynamics of radionuclides, and to contribute to the creation of a safe and secure community for the reconstruction of Fukushima district through environmental radioactivity assessment and information dissemination.

J02

Research and Development of Digital Technologies to Explore Radiation Source Distributions for Exposure Reduction ~ Development status based on evaluation tests inside 1F Unit 5 ~

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Takashi Yamaguchi, Masahiko Machida, Koji Okamoto
Japan Atomic Energy Agency

Abstract

In the decommissioning of TEPCO's Fukushima Daiichi NPP (1F), it is crucial to improve the environment of working spaces inside the reactor building (R/B) as the fuel debris removal works go into full-scale levels. Among various environmental improvement issues, one of the most essential ones is to reduce the exposure of workers as much as possible by utilizing advanced safety planning and designing tools. Thus, JAEA has so far developed a digital software tool revealing 3D distributions of air dose rates inside target working places. In the tool system, a core part is to inversely estimate radiation source distributions and their magnitudes even in limited monitoring results using a machine learning technique called LASSO [1]. This report presents that the core scheme was sufficiently successful in a test event performed inside 1F Unit 5. This result motivates us to further test the system in Unit 2~3 and reorganize the tool system to make it more useful inside 1F.

1. Introduction

The most fundamental process to avoid human exposure is to reveal radiation source distributions and resultant 3D distributions of air dose rates inside any workplaces. However, such attempt has been regarded as one of the most difficult mathematical problems as called an ill-posed one, since the monitoring is severely limited compared to widely spread radiation spaces due to strong radiation environments. Then, we have strongly paid attention to a solution using the machine learning technique called LASSO as a candidate scheme to overcome such ill-posed problems. So far, we have tested the scheme inside a JAEA test reactor, JMTR, and obtained satisfactory results, which successfully estimate the radiation sources. Based on these successful results, we have started to expand the scheme test into real fields like 1F, in which human exposure reduction is really a crucial issue. According to the plan, we performed an evaluation test of the scheme in 1F Unit 5 before going directly highly intensive fields inside Units 2~3. The Unit 5 test field is identical in space area and size as those fields, and its internal structures are also the same as those of the real fields, although Unit 2~3 is more complex since the accidents occurred and various decommissioning preparations proceeded.

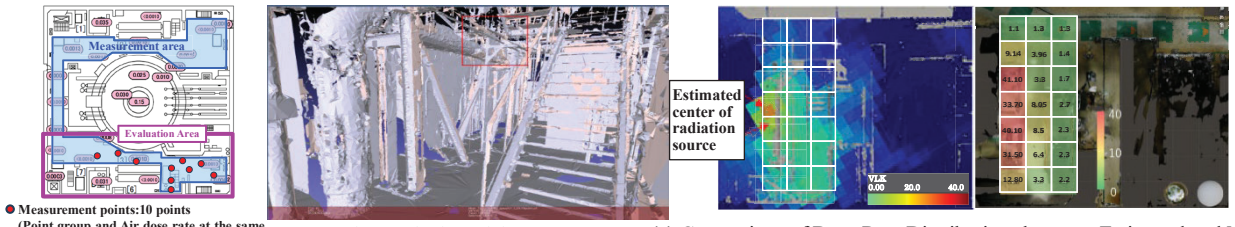
2. Evaluation Tests inside 1F Unit 5

This section presents the contents of the test processes inside 1F Unit 5 performed in December 2023. Although the field is sufficiently safe in terms of radiation strength, we employed remote-controlled systems composed of a dog-like robot called SPOT produced by Boston Dynamics Co.LTD to obtain point group and air dose rate data as seen in Fig.1(a). This system will be also used for real fields, Unit 2~3. Based on the above obtained data, we examined the following processes to inversely estimate source radiation distributions and calculate resultant 3D distributions of air dose rates,

(1) Making 3D mesh models as seen in Fig.1(b) from point group data in a rapid manner to execute the LASSO scheme soon after the data accumulations,
(2) Together with the above mesh models, estimating radiation source distributions based on air dose rate measurement data using LASSO,
(3) Calculating 3D distributions of air dose rate from obtained radiation source locations and magnitudes,
(4) The obtained 3D air dose rate distributions are evaluated by detailed monitoring results measured for the purpose of the evaluation tests of the estimated results as seen in Fig.1(c).

3. Results in Tests inside Unit 5 and Discussions to Improve Applicability at Real Radiation Sites, Unit 2~3

At the selected area in Unit 5, namely, the south and east part, we measured ten-point measurements of point groups and air dose rates at red circles as seen in Fig.1(a). Inside the area, mesh model as shown in Fig.1(b) was initially created, and radiation sources were found to be sparsely distributed along a CS tube elongated over a few tens meters by our scheme. The source distribution and consequent air-dose distribution (left panel of Fig.1(c)) were confirmed by detailed monitoring as shown in the right-hand panel of Fig.1(c). After these successful tests, we are now improving the system toward real field tests in Units 2 and 3 planned during this year, 2024. The improvement points are to execute the above-listed processes in a one-through manner with more easy operations.



(a) Test Target Area in Unit 5 (b) Meshed Model (1,000,000 surfaces.) (c) Comparison of Dose Rate Distributions between Estimated and Measured ones (The two white grids in the diagram show the same position.)

Fig.1 Scenes of Evaluation Tests in 1F Unit 5

Acknowledgements

This work was carried out in a subsidy program of "Project of Decommissioning, Contaminated Water and Treated Water Management", entitled "Development of Technologies for Work Environmental Improvement in R/B".

References

[1] S. Yamada et al., "Effectiveness of Fused LASSO for Prediction of Distribution of Radioactive Materials in Reactor Buildings-24309", Proc.of WM2024 Conference, (2023)

J03 A phoswich detector for detecting alpha emitters in piping

Yuki Morishita[1,*], Tsutomu Yamada[1], Takamasa Nakasone[1], Marina Kanno[1], Miyuki Sasaki[1], Yukihisa Sanada[1], and Tatsuo Torii[2,3]

[1]JAEA, [2]Univ. of Fukui, [3]Fukushima Univ.

Abstract

The Fukushima Daiichi Nuclear Power Station's decommissioning requires thorough measurement of piping for contamination, including alpha and gamma emitting nuclides. Therefore, a phoswich detector for low-energy gamma-ray detection was developed and validated experimentally. The detector comprises YAP:Ce and BGO scintillators with a photomultiplier tube for signal amplification. Pulse Shape Discrimination (PSD) plots distinguish low energy and high energy gamma-rays, confirming simulation predictions.

1. Introduction

In this study, we developed a detector adopted to selectively detect low-energy gamma-rays. Experimental measurements were conducted utilizing radiation sources, and subsequently, the feasibility of the detector was validated at an operational nuclear fuel facility.

2. Materials and Methods and Results

We developed a gamma-ray detector featuring a stacked configuration of scintillator layers. The detector comprises a 0.5mm-thick YAlO3:Ce (Ce:YAP) scintillator as the top layer, an acrylic light guide as an intermediate layer, and a 3.0mm-thick Bi4Ge3O12 (BGO) scintillator as the bottom layer. A Hamamatsu Photonics H7195 photomultiplier tube was employed as the photodetector, with a high voltage of -1500V applied to facilitate signal amplification. Figure 1 shows a conceptual diagram of the low-energy gamma-ray detector. The analog signal outputted by the photomultiplier tube was routed to a CAEN digitizer (DT5730s) for waveform acquisition and subsequent data processing on a laptop platform.

Figure 4 illustrates the Pulse Shape Discrimination (PSD) plots obtained from the measurements of radiation sources. During alpha particle measurements, a distinct cluster of counts was observed in area1 (corresponding to the first layer (YAP:Ce)). The count ratio between area1 and area2 was determined to be 1165.79. Conversely, when measuring γ-rays, clusters of counts were observed in both area1 and area2. The count ratio between area1 and area2 was found to be 0.76.

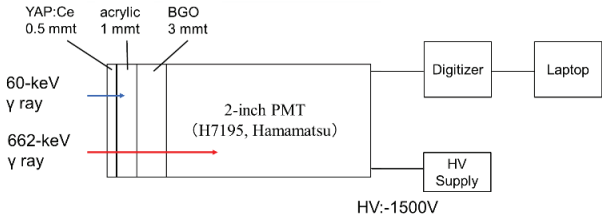


Fig. 1 Conceptual diagram of the low-energy gamma-ray detector

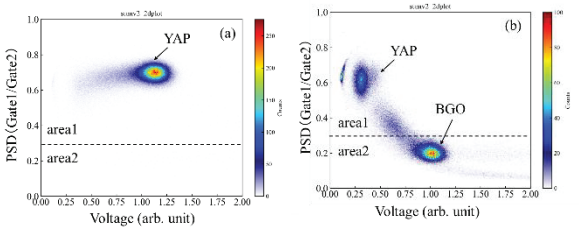


Fig. 2 PSD plots of radiation source measurements, (a) alpha particles, and (b) gamma rays.

3. Conclusion

When measuring alpha particles (or 60-keV gamma rays), counts were predominantly observed in the first layer. The phoswich detector shows promise for effectively detecting low-energy gamma-rays emitted by alpha nuclides in piping.

J04

Flexible Remote Radiation Measurement System on the Multiple Radiation Platform

Masaaki Kaburagi[1], Yuki Sato[1], Susumu Tagami[1], Koki Hirai[1], Naruto Sano[1], and Koji Usami[1]

[1]Japan Atomic Energy Agency

Abstract

We propose a research program consisting of the three components, radiation measurement systems in intense γ-ray fields, high mobility robots, and multi−purpose radiation demonstration fields for the decommissioning of the Fukushima Daiichi Nuclear Power Station. Finally, the systems and platform will be integrated.

1. Introduction

The research program consists of 1) radiation measurement systems in intense γ-ray field, 2) a high−mobility robot to extend the investigation area for increasing the survey area (hexapod robot), and 3) radiation demonstration fields for the multiple purposes (Multiple Radiation Platform).

2. Radiation Measurement System in Intense γ-Ray Field

γ-ray spectroscopy system for use at high dose rates has been developed [1]. In an intense ^{137}Cs γ-ray field, a sealed ^{60}Co source could be identified at high dose rates as shown in Fig 1, which is useful for the characterization of radioactive waste.

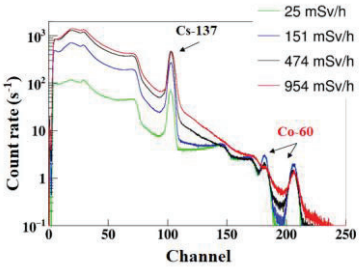


Figure 1. γ-Ray Spectroscopy System [1]

3. Hexapod robot

The concise specifications of the hexapod robot were developed by SHIMANO Inc [2], as shown in Fig. 2. The robot has high mobility and it can ascend and descend stairs, with a maximum height of 250 mm. The mobility performance is useful for passing under obstacles in a lowered posture, stepping over obstacles, and climbing up and down stairs.

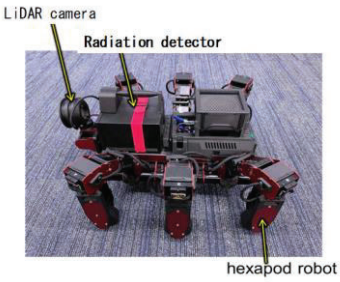


Figure 2. Hexapod Robot [2]

4. Multiple Radiation Platform

The Multiple Radiation Platform is being developed in a hot cell at the Waste Safety Testing Facility (WASTE) of the Japan Atomic Energy Agency. The platform has several attractive features. First, performance of radiation measurement systems can be studied in complex radiation fields. Second, the mock−up of robots can be performed in radiation environments (referred to as hot mock−up). Finally, the hot cell can be used to test the radiation resistance of large devices such as robots.

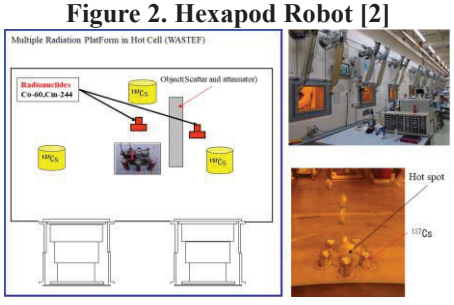


Figure 3. Multiple Radiation Platform

5. Future work

The systems and platform will be integrated as a result of this program, which will become a useful research resource for the retrieval of nuclear fuel debris at the Fukushima Daiichi Nuclear Power Station

References

[1] M. Kaburagi et al. Journal of Nuclear Science and Technology 59(8) (2022) 983-992

[2] Y. Sato et al. Nuclear Instruments and Methods in Physics Research A 1063(2024) 169300

J05

Development status of the debrisEye at TEPCO's Fukushima Daiichi Nuclear Power Plant -Addition of object display function-

Kenta Shimomura[1], Takuya Yamashita[1], Eiichi Nagai[2], Satoru Nakashima[3], Nobuyuki Kumakawa[3], Shoichi Shinzawa[3]

[1]Japan Atomic Energy Agency (JAEA), [2]Prometech Software, Inc., [3]Tokyo Electric Power Company Holdings (TEPCO)

Abstract

This paper shows the development status of the debrisEye, which interactively displays a CG model of the TEPCO's Fukushima Daiichi Nuclear Power Plant (1F) and allows users to add and display additional information, such as internal investigation results.

1. Introduction

Internal investigations of 1F have been conducted, and the conditions inside the reactor containment vessel are gradually being revealed. The information obtained from these internal investigations is managed in the decommissioning research infrastructure database (debrisWiki[1]) developed by JAEA and TEPCO. However, it is challenging to understand the overall progress of the accident with individual data alone. Therefore, we have developed debrisEye[2][3]) that interactively displays a CG model of 1F, allowing users to add and display additional information such as internal investigation results, sample analysis results, and accident progression.

2. Development status of the 3D view content (debrisEye)

The developed debrisEye mainly had the following features:

- Display from any viewpoint and angle
- Add additional information (such as sample analysis results) at any location

This time, by implementing the function to display objects, it has become possible to display the similar drones that was used for internal investigation of Unit 1 on the debrisEye, allowing for visual confirmation equivalent to that of the drones (see Figure 1).

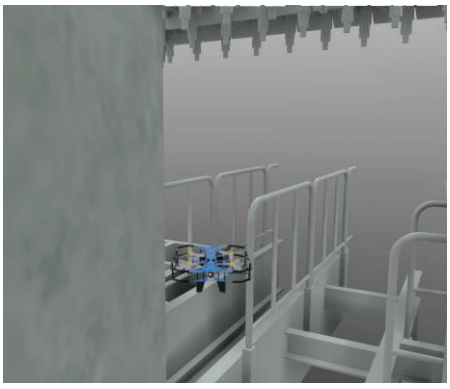


Figure 1. The state of displaying the drone on the debrisEye

3. Conclusion

By utilizing the developed debrisEye, it is expected to enhance visual understanding, aid in comprehending the progress of the accident, and contribute to the efficiency of decommissioning work.

References

[1] debrisWiki, "https://fdada-plus.info/"

[2] T. Yamashita et al., "Estimation of RPV damage and fuel debris relocation behavior in the PCV at Fukushima Daiichi Nuclear Power Station, 1;Development of 3D estimation diagrams and the debrisEye, 2024 Annual meetingOf AESJ (in Japanese)

[3] T. Yamashita et al., "Development of 3D view application debrisEye for decommissioning of Fukushima Daiichi Nuclear Power Plant", Proceeding of ERMSAR2024

J06 Measurement methods for the radioactive source distribution inside reactor buildings using a one-dimensional optical fiber radiation sensor

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[1]Collaborative Laboratories for Advanced Decommissioning Science, Japan Atomic Energy Agency.

Abstract

We have developed a method for measuring dose rates and radioactive material distribution using a plastic scintillation fiber. We tested and verified our method inside the Fukushima Daiichi Nuclear Power Station.

1. Background

Measuring the dose rate distribution or radioactive material distribution inside the Fukushima Daiichi Nuclear Power Station (FDNPS) reactor building is essential for the radiation protection of workers. The Collaborative Laboratories for Advanced Decommissioning Science, Japan Atomic Energy Agency, have been conducting the Nuclear Energy Science & Technology and Human Resource Development Project. As part of this project, we have developed a method to measure dose rate distributions or radionuclide distributions in an ultra-high dose rate field using plastic scintillation fibers (PSF).

2. Position-sensitive optical fiber radiation sensor based on wavelength-resolving analysis

Our method focuses on the wavelength of scintillation light generated by the interaction between the plastic scintillation fiber and radiation. Since the attenuation of light transmitted through the fiber depends on its wavelength, the incident position of radiation can be inversely estimated through wavelength-resolving analysis of the scintillation light. This sensor was installed into FDNPS Unit 2. Fig. 1 shows the measurement setup and radiation distribution measurement results. A PSF was laid in the high dose rate area (dose rate near the floor surface >100 mSv/h) of the Unit 2 air conditioning room. Scintillation light was transmitted to the low dose rate area outside the room using quartz optical fiber. The radiation distribution was obtained by analyzing the wavelength spectrum measured by a spectrometer outside the room. The reverse estimation result successfully reproduces the actual dose rate trend, which exceeds 100 mSv/h. In the presentation, we will discuss the potential improvements and adaptations required for broader application in various high dose rate environments.

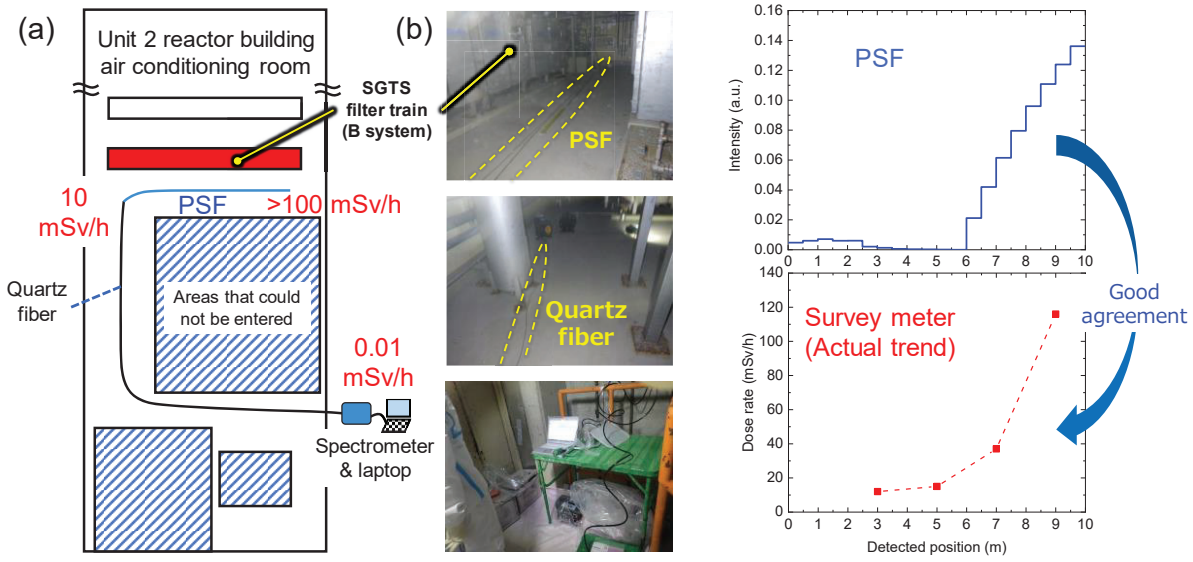

Fig. 1 Installation of plastic scintillation fibers in FDNPS Unit 2 and results of radiation distribution measurements[1].

References

[1] Y. Terasaka et al., Nucl. Instrum. Methods Phys. Res. A 1062 (2024).

J07

Study and development of laser-induced breakdown spectroscopy (LIBS) for decommissioning of Fukushima Daiichi Nuclear Power Station

Takahiro Karino[1], Katsuaki Akaoka[1], Ikuo Wakaida[1], Hironori Ohba[1], Joey Kim Soriano[2], Yuji Ikeda[2]

[1] Japan Atomic Energy Agency (JAEA/CLADS), [2] i-Lab., Inc.

Abstract

Laser induced breakdown spectroscopy (LIBS) is a quick and easy elemental analysis method being developed for the decommissioning of the Fukushima Daiichi Nuclear Power Plant (FDNPP) to analyze fuel debris. In this presentation, we show uranium isotope detection by microwave-Assisted LIBS.

1. Introduction

Laser induced breakdown spectroscopy (LIBS) is a quick and easy method for elemental analysis. Therefore, LIBS can be used to safely and efficiently detect fuel debris in the decommissioning of the Fukushima Daiichi Nuclear Power Plant (FDNPP). LIBS can be used remotely using optical fiber, allowing for direct analysis of fuel debris inside the reactor vessel.

Measurement of fissile U-235 is important in the characterization of uranium in fuel debris. Since the isotope spectrum shifts slightly in wavelength, using a high-resolution spectrometer allows for the detection of isotopes in LIBS. However, using a high-resolution spectrometer reduces the emission intensity. Therefore, we used microwave-assisted LIBS to increase the emission intensity to measure uranium isotopes.

2. Microwave-Assisted LIBS

Figure 1 shows the microwave-assisted LIBS setup. The experiments were conducted using samples with U-235 enrichment ranging from 0.20% to 7.99%. The microchip laser used had a wavelength of 1064 nm and a laser energy of 1.0 mJ. The resolution of the echelle spectrometer was λ / 150,000. The observation delay was 0.5 μs and the gate width was 1.0 ms. Microwave power was 1000 W and the pulse length was 1.0 ms. Figure 2 shows the ion spectra with and without the use of microwaves. In Figure 2, the U-235 enrichment is 7.99%. We can confirm that the use of microwaves greatly increases the spectral intensity and facilitates observation.

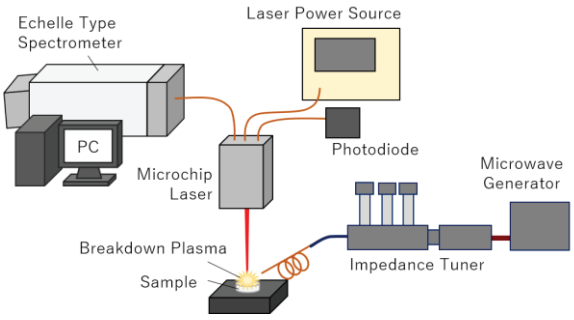

Figure 1. Experimental setup for microwave-assisted LIBS

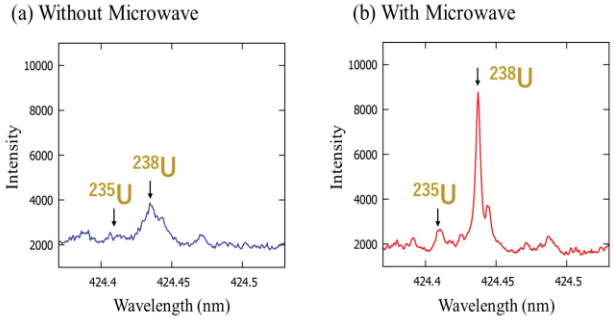

Figure 2. Spectrum of Uranium ion. (a) without microwave, (b) with microwave.

J08

Development of HCl-free and rapid analytical method for radioactive waste from FDNPS

Yasuyuki Tanaka, Yuki Ohta, Noriyasu Kodaka, Riku Kikuchi, Irvin M. Banjarnahor, Van-Khoai Do, Takahiro Furuse, Kosuke Tanaka and Masahisa Watanabe

Japan Atomic Energy Agency

The analysis of radionuclides in the decommissioning solid waste collected from the Fukushima Daiichi Nuclear Power Station (FDNPS) is required for the proper treatment of the massive contaminated waste. To develop the rapid analytical methods for the radionuclides, we have tried (1) to streamline and improve the previous reported chemical separation procedures and (2) to measure the long-lived radionuclides using inductively coupled plasma triple quadrupole mass spectrometry (ICP-MS/MS). Figure 1 shows an example of the streamlined analytical procedure designed for the sequential purification of α-emitting nuclides. Figure 2 shows suppression of isobar (^{93}Nb) by ICP-MS/MS using NH_3 as reaction gas in analysis for ^{93}Zr. In addition, all analytical methods were designed to avoid the use of hydrochloric acid, which is highly corrosive to stainless steel materials. Analysis time (Chemical separation time and measurement time) and method limits of detection (MLOD) of developed analytical method using simulated concrete are summarized in Table 1. For the developed analytical methods, it was confirmed that 1) all MLOD were lower than the regulatory trench disposal; and 2) those analysis times were practical as routine analysis.

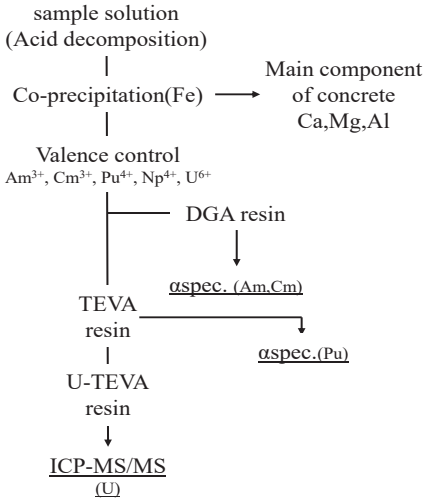

Fig. 1 Sequential chemical separation of α-emitting radionuclides.

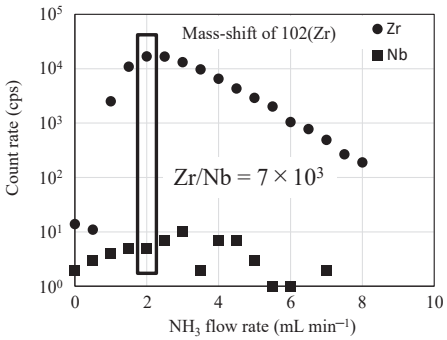

Fig. 2 Separation of impurity by ICP-MS/MS.

Acknowledgement

This report includes parts of the results obtained from the subsidy of "Development of technology for processing and disposal of solid wastes" by METI, allocated for "Project of Decommissioning, Contaminated Water and Treated Water Management.

Table 1 Analysis time and MLOD of developed analytical method using simulated concrete.

	Analysis time		MLOD*1		Analysis time		MLOD*1
	Separation	Measurement	[Bq/g]		Separation	Measurement	[Bq/g]
^{238}Pu		44 h.	10^{-3}	^{79}Se	15h.	5 h. *3	10^{0}
^{241}Am		44 h.	10^{-3}	^{93}Zr		5 h. *3	10^{-1}
^{244}Cm	25h.*2	44 h.	10^{-3}	^{93}Mo	10h.*2	5 h. *3	10^{0}
^{236}U		5 h*2.	10^{-6}	^{107}Pd	10h.	5 h. *3	10^{0}
^{41}Ca		600 min	10^{0}	^{126}Sn	10h.	5 h. *3	10^{0}
^{63}Ni	30h.*2	100 min	10^{-1}	^{36}Cl		1000 nin	10^{-1}
^{90}Sr		100 min	10^{-2}	^{129}I	10h.*2	5 h. *3	10^{-2}

*1 Order of radioactive concentration *2Streamlined chemical separation *3Developed ICP-MS/MS measurement

J09 Third-Party Analysis of ALPS Treared Water in Radioactive Material Analysis and Research Facility

Yoshihiro Tsuchida[1], Naoya Kaji[1], Makoto Ooka[1] and Ritsuro Tokumori[1]

[1]Japan Atomic Energy Agency

Abstract

JAEA, as a third-party organization, has been conducting measuring of radioactive materials contained in ALPS treated water in Radioactive Material Analysis and Research Facility Laboratory-1 (hereinafter 'Lab-1'). As of the end of May 2024, six analyses have been completed and the results published on the JAEA Website[1].

1. Purpose and background

In accordance with the government policy that ensures a high level of transparency and objectivity in the measurement of ALPS treated water, JAEA is responsible for analyzing the water prior to its discharge into the sea as a third-party organization. The analysis has been conducted since March 2023 at Lab-1 which was completed in June 2022.

2. Target nuclides

The analysis by JAEA measures the following items for ALPS treated water before seawater dilution. In addition, tritium concentration in ALPS treated water after dilution may also be measured at the request of the government.

- Confirm that the 29 nuclides specified in the implementation plan are below the regulatory standard (the sum of ratios to the regulatory concentration limits of nuclides is less than 1).
- Confirm that the 39 nuclides which TEPCO voluntarily confirms from the view point of reputational suppression are not significantly present.
- Confirm the tritium concentration.

3. Methods and quality assurance

The analysis is basically performed according to the analysis methods determined by the government (Series of Environmental Radioactivity Measuring Methods), however, there are some nuclides for which the official method has not yet established. In such cases, the analysis is conducted in accordance with the methods that have been verified by experts (peer-reviewed journals) or have been proved by JAEA.

As part of quality assurance activities, we have certificated ISO/IEC 17025 (General requirements for the competence of testing and calibration laboratories) accreditation for tritium analysis. We will continue to strive for reliable analysis of nuclides other than tritium by using the same or similar methods.

4. Results

JAEA has analyzed the ALPS treated water before seawater dilution six times and after dilution three times. The results of these analyses have been published on our website. As a third-party organization, JAEA intends to continue its efforts to conduct highly objective and transparent analyses.

References

[1] JAEA Website https://fukushima.jaea.go.jp/okuma/alps/index_e.html

J10 Chemical state elucidation of trace nuclides in microparticles using scanning transmission X-ray microscopy

Yusuke Watanabe[1], Goro Shibata[1], Masaaki Kobata[1], Kazuma Koarai[1], and Yukiharu Takeda[1]
[1]Japan Atomic Energy Agency

Radioactive wastes generated by the decommissioning of the Fukushima Daiichi Nuclear Power Plant (1F) have a wide variety of origins and properties, and to dispose of them safely, it is necessary to understand the contamination status of each waste before considering treatment and disposal methods. The chemical forms of radionuclides in wastes are important information for elucidating the waste contamination mechanisms and for considering handling methods during treatment and disposal. X-ray absorption spectroscopy (XAS) using synchrotron radiation is a powerful method to obtain information on the chemical state of elements in a small area, but facilities capable of analyzing samples containing radioactive materials are limited and no XAS analysis has been carried out for 1F waste.

The JAEA dedicated beam line BL23SU at SPring-8, the only one in Japan located in a radiation-controlled area, is developing scanning transmission X-ray microscopy (STXM) technic, a μ-XAS analysis for the soft X-ray region. STXM enables XAS measurements by scanning samples with a spatial resolution of several 10 nm (Fig.1). In this study, a microparticle analysis method using STXM is being developed to elucidate the chemical forms of radionuclides in debris and other 1F waste. As the fine particles in the environment adsorb radionuclides and have a significant influence on their migration behavior, this study attempted to measure trace elements using STXM on the fine particles in the environment as a preliminary step in dealing with radioactive materials.

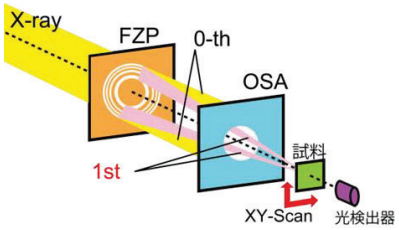

Fig 1. Conceptual image of STXM

Absorption coefficient distributions and XAS spectra of Fe $L_{2,3}$ edge and Al K edge in river suspension particles collected upstream and downstream in an acidic river derived from mine drainage were measured. The results for Fe are shown in Fig. 2. Samples collected upstream, which were more acidic, showed that Fe and Al were distributed separately, indicating that Fe was present as trivalent. On the other hand, samples collected from neutral river water downstream showed a high presence of divalent components and a strong correlation with the distribution of Al. STXM analysis suggested that different particle formation processes occurred as the pH changed. In the future, STXM analysis of trace elements such as heavy metal elements in these particles will be carried out and the influence of these particles on the migration behavior of nuclides will be discussed.

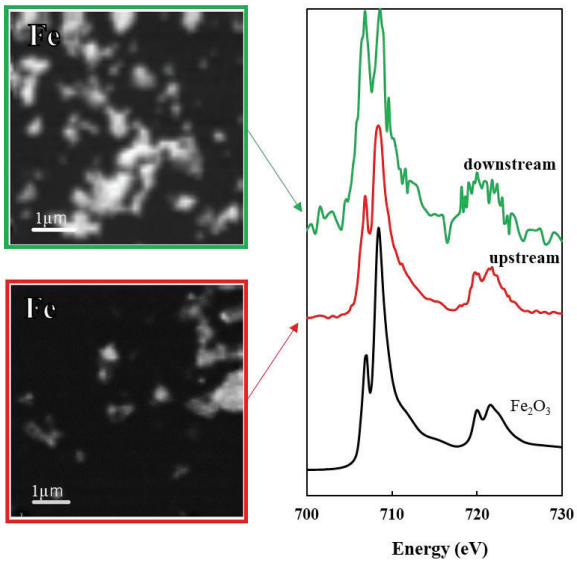

Fig. 2. Fe $L_{2,3}$ edge XAS spectra of suspended particles and reference material

J11 Towards establishing safe management of solid radioactive waste from 1F decommissioning - Cooperation between data collection and safety assessment -

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Abstract

We carried out the disposal safety assessment for some generated wastes using current optimal input data, and, based on the results, data that was expected to reduce uncertainty in the future regarding the waste management of 1F was extracted for more appropriate assessment.

1. Introduction

Safe management of storage, treatment and disposal is the first priority in considering waste stream for various solid radioactive wastes generated in the decommissioning process of the 1F, and, therefore, the safety assessment is one of the important methods in this process. However, at present, safety assessment must be carried out in the presence of various uncertainties in the input data, such as the characteristics of the generated waste, the performance of the solidified waste, the assumed disposal environment, and so on. In this study, we present examples of disposal safety assessment results based on data currently obtained in each R&D, and consider data that is expected to reduce uncertainty in each field in the future based on those results.

2. Parameters for safe management

Radioactive inventory for the generated wastes was estimated based on the analytical inventory estimation method together with the limited measurement data. Parameters for solidified waste, disposal facilities, etc. were set in accordance with the current study of representative disposal facility concepts. Radionuclide migration parameters such as distribution coefficients were set by referring to existing examples and databases.

3. Importance to reduce uncertainties

C-14 and I-129 mostly became the dominant nuclides in the groundwater scenario. The assessment results were greatly affected by radioactivity inventory, infiltration water velocity into the disposal facility, leaching rate from solidified waste, and distribution coefficient on the solidified matrix and host rock. Therefore, efforts to reduce the uncertainties in these parameters are desirable.

4. Conclusion

Such a two-way cooperation between data collection and safety assessment is essential for establishing waste streams for 1F radioactive solid wastes which have large uncertainties on their characteristics and management process.

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