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Demonstration of the Triple Bubbler for Pyrochemical Nuclear Safeguards Applications

September 2024

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Introduction

- The triple bubbler system has been integrated into to the pyrochemical fuel reprocessing flow sheet (Fig 1.) for light water reactor fuels

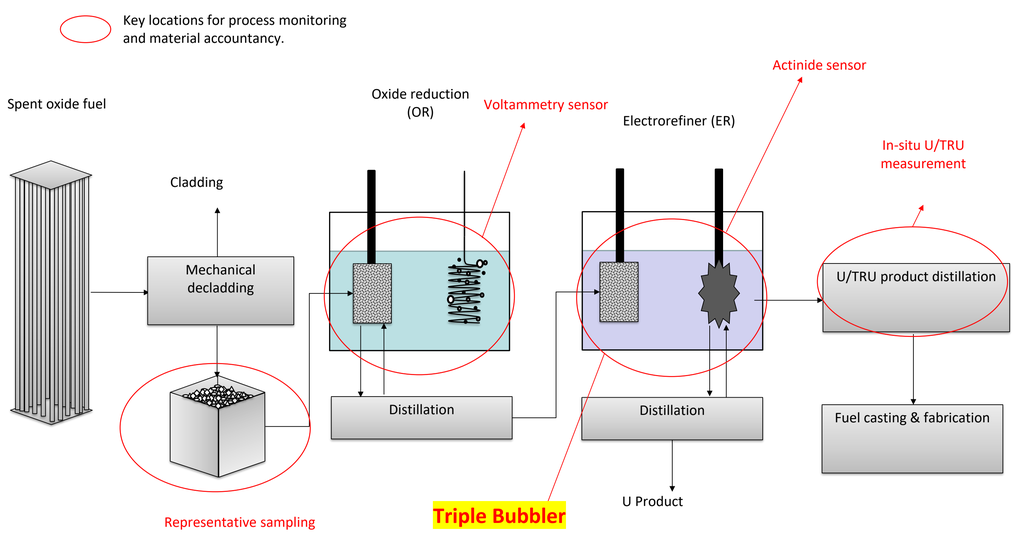
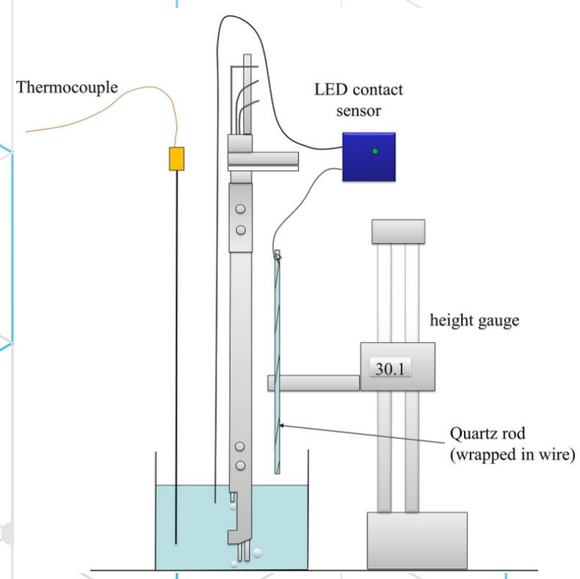


Fig. 1: Pyrochemical fuel recycling unit operations including process monitoring equipment.

- An important aspect of safeguards, material accountancy, and process monitoring of nuclear facilities involving liquids is vessel/tank level measurements to accurately determine the fluid volume
- Investigations are under way, utilizing a triple bubbler (see Fig. 2) capable of precisely monitoring molten salt density and depth within a vessel, enabling the calculation of total salt volume and mass of special nuclear material
- The triple bubbler utilizes three dip tubes strategically placed in a fluid
- With this setup the fluid density ρ, surface tension γ, and the depth d_1 can be calculated simultaneously



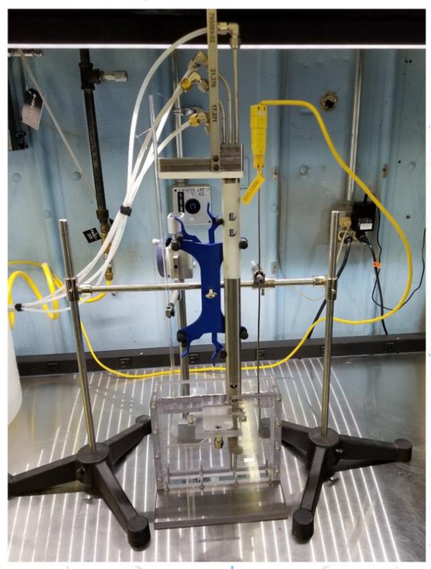


Fig. 2: Schematic of the experimental setup and components (left) and setup of the triple bubble in a non-rad lab.

Acknowledgments

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Demonstration & Results

- Variation in salt depth (Fig. 3) was tested by removing salt from the electrorefiner (ER) while changes in salt density (Fig. 4) were measured while varying the temperature.
  - ~410 grams of ER salt was removed
  - Bubbler depth: 140.40±1.80 mm (1.28%) & Measured depth: 139.01±1.02 mm (0.73%)
    - Measurements were consistent with a percent difference of 1%
- ~1.2% level uncertainty (Random & Systematic)
- Uncertainty for density and Surface tension was 0.54% and 12.4%, respectively

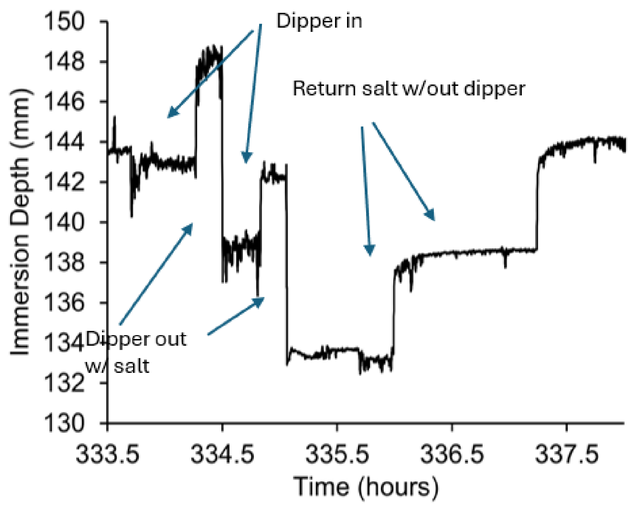

Fig. 3: Bubbler depth readings while adding/removing salt from the ER.

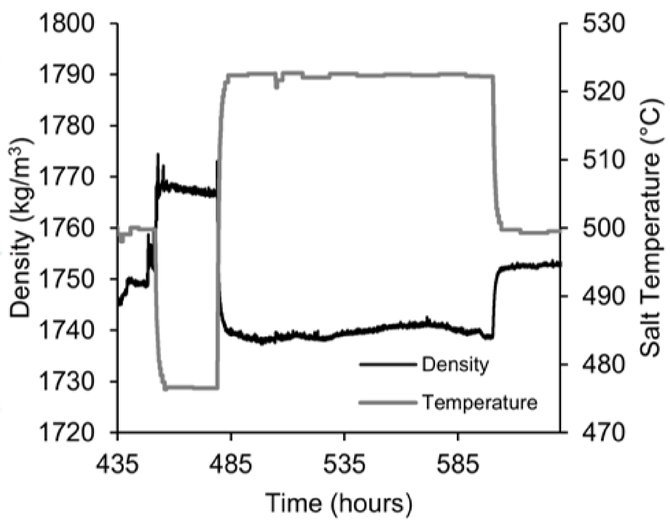

Fig. 4: Salt density measurements using the triple bubble as a function of temperature in the ER.

Fig. 5: Triple bubbler in the Hot Fuels Examination Facility (HFEF) hot cell.

Next Steps

- Continued testing in the ER during fuel reprocessing demonstrations
- Larger bubbler tube size and gas flow rate to reduce salt build up

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