Uranium Holdup Monitoring with Compton Imaging as Function of Depth and Mass

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INTRODUCTION

Material Control and Accountability (MC&A) programs track masses of materials flowing through production processes, where some material remains in process equipment as holdup. Quantification of these masses using gamma emissions typically involves usage of a well characterized radiation detector and assumptions of geometric configuration to constrain detection efficiencies, where the Generalized Geometry Holdup (GGH) method is often used. Uncertainties on the order of ±50% are observed, where the difficulties arise based on the asymmetric and gradient distributions of material that do not fall within the bounds of GGH. Gamma imagers provide a possible means to improve this geometric knowledge.

This work describes the process used in creating a series of mass standards to aid the development of imaging algorithms for quantification.

SOURCE DESIGN

Sources comprise depleted U_3O_8 powder packed at the bottom of an aluminum project box with gasket to constrain material. Various thicknesses of closed cell foam are packed above the powder to maintain uniformity of thickness during handling of sources. Rare earth magnets are affixed to the underside of the lid to allow attachment to metal structures, e.g. ductwork, this the outside lid has tape to add friction to limit sliding of the material along a surface.

Source materials comprising project box, gasket, closed cell foams and rare earth magnets

SOURCE CONSTRUCTION

Initial calculations with an estimated density defined the target masses for each of the samples, where the intended material thickness is a fraction of the infinite thickness for U_3O_8 at that density. A stainless steel block packed the material as closely as possible without removing material, with the powder height measured. A liquid volume measurement creating a height-volume relation provided for the resulting density in the below Table. Foam was loaded on top of the source material, where the lid, gasket, and internally attached magnets were attached to complete the source.

Material loading process and filled source container

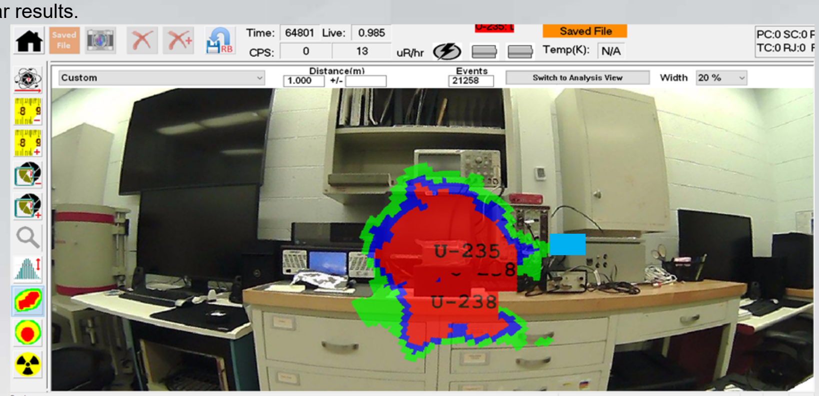
Sample	Load Weight (g)	Depth (mm)	Approximate Density (g/cm³)
L151	71.17	18.77	2.800
L301	136.83	20.39	4.028
L451	197.13	25.45	3.248
L601	252.22	26.93	3.682
L751	355.83	33.63	3.426
S18751	40.67	45.22	2.619
S37501	81.34	48.69	3.291
S56251	122.01	54.54	3.035

Sample Properties for Each Standard

Completed assemblies of S- and L- sources

COMPTON IMAGING MEASUREMENTS

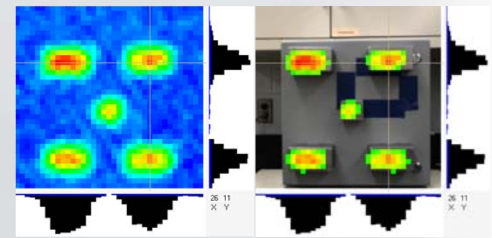
Compton imaging measurements were performed with a PHDS GeGI-5 gamma imager. The Compton mode shown below has the actual source location highlighted in blue, while the surrounding region shows the uncertainty around the source. Multiple gamma lines including 185-, 205-, 583-, 766-, and 1001-keV were used with similar results.



GeGI-5 Compton measurement of source with actual position highlighted in blue

CODED APERTURE MEASUREMENTS

Coded aperture measurements provide a greater spatial resolution than Compton imaging. The below measurements over a 24 hour duration provided. A single source shown below clearly overlays the actual location, where nearest edges are spaced 19.685cm vertically and 9.366cm horizontally. The images clearly show the definition of the material distributions. The top left has the largest mass, which decreases counter clockwise around the panel.



Coded aperture measurement with calculated image on left and visual image overlay on right

CONCLUSIONS

First attempts to create a set of DU standards have been mostly successful. Difficulty in estimating the achievable packing density led to some deviation from intended thicknesses; however, the gamma imaging results of the sources were still quite good. Compton imaging was able to determine approximate location quickly while coded aperture provide high spatial resolution images.

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