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# LOW ENRICHED URANIUM HOLDUP MEASUREMENTS IN KAZAKHSTAN

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## INTRODUCTION

Quantification of the residual nuclear material remaining in process equipment has long been a challenge to those who work with nuclear material accounting systems. Fortunately, nuclear material has spontaneous radiation emissions that can be measured. If gamma-ray measurements can be made, it is easy to determine what isotope a deposit contains. Unfortunately, it can be quite difficult to relate this measured signal to an estimate of the mass of the nuclear deposit. Typically, the measurement expert must work with incomplete or inadequate information to determine a quantitative result. Simplified analysis models, the distribution of the nuclear material, any intervening attenuation, background(s), and the source-to-detector distance(s) can have significant impacts on the quantitative result.[1]

This presentation discusses the application of a generalized-geometry holdup model[2] to the low-enriched uranium fuel pellet fabrication plant in Ust-Kamenogorsk, Kazakhstan. Preliminary results will be presented. Software tools have been developed to assist the facility operators in performing and documenting the measurements.[3, 4, 5]. Operator feedback has been used to improve the user interfaces.

## HARDWARE TOOLS

Nuclear facilities need portable automated tools to perform measurements of process holdup in facility equipment and ventilation systems. These tools should have the following capabilities:

- acquire and manage several hundred spectra in an 8-h shift,
- produce prompt, reliable quantitative results,
- be self powered, easily portable, and possible to operate by individual users,
- accommodate varying levels of user expertise,
- correct for the effects of attenuation by intervening materials,
- tolerate facility variables such as temperature fluctuations and equipment inaccessibility, and
- accommodate various measurement geometries.

The hardware delivered to Ust-Kamenogorsk for the initial holdup measurement training is shown in Fig. 1. This includes a compact, shielded low-resolution gamma-ray detector, self-contained spectroscopy electronics ($M^3CA$), and a laptop computer.

The hardware shown in Fig. 2 was delivered subsequently. It shows facility personnel using the automated system, where the laptop computer has been replaced by a programmable bar-code reader.

## GENERALIZED GEOMETRY HOLDUP MODEL

Because holdup occurs in production facilities with a wide variety of production equipment and material or ventilation transport systems, holdup measurements encounter a wide variety of measurement geometries. For simplicity and in order to perform the measurements rapidly, the actual geometries are approximated as either point, line, or area sources.[2] This introduces a possibility for bias in the results, but this bias is generally smaller than that caused by other unknowns in the measurement problem, such as the actual distribution or location of the nuclear material or the actual attenuation of the measured signal. This potential bias is more than offset by the relative ease of applying a simple model and the speed with which many diverse items can be measured. It is also understood that most holdup measurements have uncertainties of 10%–20% (or larger), consequently it is a waste of time collecting data with excellent counting statistics.[1] Short counts with a simple model allow the operator to make many measurements in a short time. Additionally, shorter counting times allow more measurements in a given time interval which tends to sample the population of potential holdup locations more fairly.

*Fig. 1. Picture of $M^3CA$, detector, computer in Ust-Kamenogorsk during training.*

*Fig. 2. Picture of $M^3CA$, detector, Intermec bar code reader in field measurements.*

## SOFTWARE TOOLS

The setup and calibration of a detector-$M^3CA$ pair and the initial holdup measurements are made manually. This requires a flexible software interface which a knowledgeable facility operator can use to control the hardware and acquire data, such as HU_Acq.[3, 4] The first time a specific location is measured, the operator must make many decisions about what geometrical assumptions to make, what to do about background, where to measure, how many measurements to make on a specific item, and what direction to point the detector. Additionally, the operator may not yet have sufficient information about the signal attenuation to allow accurate corrections to be calculated. The analysis program must have sufficient flexibility to allow the user to enter additional information as it becomes available, yet not require it in every calculation. After the measurement point(s) are defined and these questions have been answered, it is much simpler and faster to perform replicate measurements with a database tool like HMS3.[5] The database can store the measurement point details such as geometry, attenuation materials, and their thickness; all of which are easily identified and retrieved by associating each individual measurement with a unique identifier (bar code.)

### Holdup Data Acquire (HU_Acq) Description

The initial setup and calibration of a $M^3CA$-detector pair is made with a software tool such as HU_Acq. In addition to being a complete $M^3CA$ emulator (hardware and communications interface), HU_Acq allows the user to

- define regions-of-interest (ROIs) and read or save ROI definitions from or to a disk file,
- save or read a hardware configuration file to or from a disk,
- acquire and save to a disk or read from a disk, a background spectrum,
- acquire and save to a disk or read from a disk, an unknown (assay) spectrum,
- dynamically display spectra and counting statistics during acquisition, and
- automatically or "manually" initiate the holdup analysis program, HU_Anlz.

Figure 3 shows the HU_Acq screen with the unknown (assay) acquisition panel and spectrum display panel. With the dynamic display of the spectrum during acquisition, the locations of significant facility holdup may be identified, the appropriate geometric model (detector to item geometry) selected, measurement parameters such as detector to item distance examined, and background conditions examined.

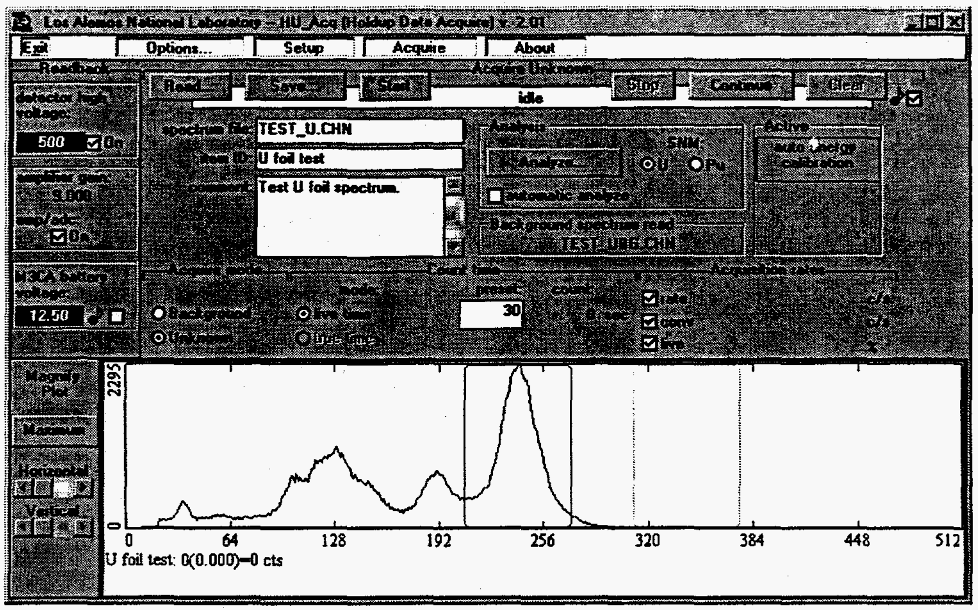

*Fig. 3. HU_Acq unknown acquisition screen.*

**Holdup Data Analyze (HU_Anlz) Description**

The data collected with HU_Acq can be analyzed automatically or by user direction with the holdup analysis software, HU_Anlz. Alternatively, parameters and data can be entered manually into HU_Anlz and analyzed. Figure 4 shows the HU_Anlz initial or parameter and data input screen. HU_Anlz has the capability to correct for special nuclear material (SNM) self-absorption, multiple (two) attenuating materials (containers) between the sample and the detector, and different isotopic percentages. If the SNM composition or attenuating materials are not known, effective correction factors of 1.0 are used. The different geometry models (point, line, or area) or changes to the matrix material or container (attenuation) material parameters may be made and the results recomputed without having to re-acquire the spectrum. If an unknown spectrum and its associated background spectrum are acquired and saved through HU_Acq, the analysis may be reperformed later as additional information is acquired. The results of a holdup analysis calculation is shown in Fig. 5, the HU_Anlz analysis results screen.

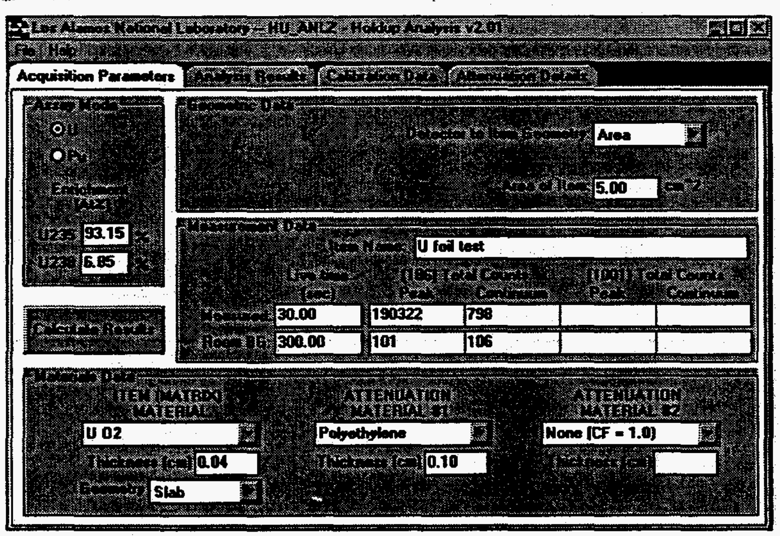

*Fig. 4. HU_Anlz parameter and data input screen.*

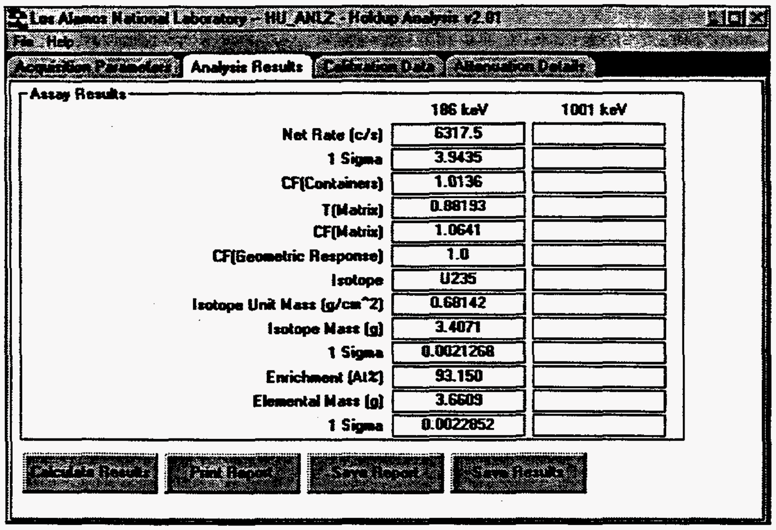


*Fig. 5. HU_Anlz analysis results screen.*

**Holdup Measurement System 3 (HMS3) Description**

HMS3 is a software package for performing and documenting holdup measurements. The primary purpose of HMS3 is to keep track of the multiple details associated with each measurement point. HMS3 includes two sets of programs: one runs on a host computer (usually a desktop computer), and the other runs on a bar-code reader/controller. The host computer program initializes the setup and calibration database for multichannel analyzer (MCA) and detector pairs, programs the bar-code reader, loads appropriate measurement point information into the bar-code reader, receives measurement data from the bar-code readers/controllers, performs calculations based on the generalized geometry holdup algorithms, maintains the measurements and derived results in databases, and provides summary reports. Figure 6 illustrates the initial HMS3 screen through which the routine measurement functions are initiated.

Generally the operator takes minimal hardware (bar-code reader, MCA, and detector) into the field. The bar-code reader/controller directs the holdup measurements in the field; initiating the MCA data acquisition, retrieving and storing the measurement results (including the spectrum if desired), and checking the reference and preliminary results for MCA-detector performance.

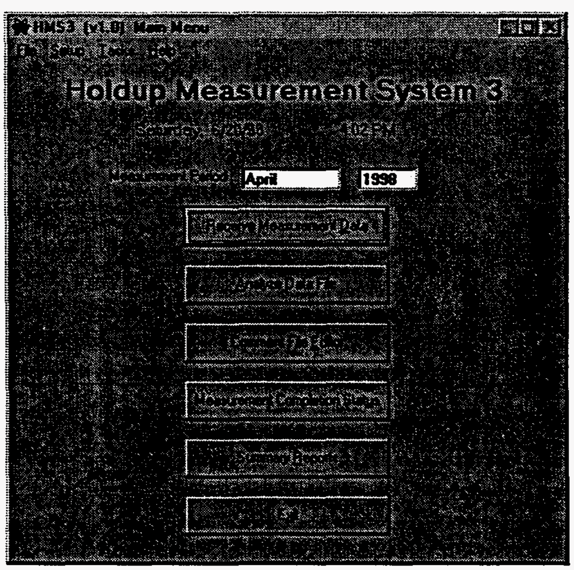


*Fig. 6. Initial HMS3 screen.*

## SOME MEASUREMENT PROBLEMS

Figure 7 shows two vertical ducts, indicated by the arrows, that contain "elevators" used to raise loose uranium powder to the feed portion of the pellet production process. These ducts are difficult to disassemble and clean out. Clean out data indicates several hundred kilograms of uranium oxide can accumulate in each elevator.

Figure 8 shows some air filters. The production building for RBMK pellets has several hundred air filters. Most accountability measurements are made after the filters are removed by weighing the filters. But some measurements are desired *in situ* to help assess if the filters are ready for replacement.

Figure 9 shows some of the storage tanks used in the solvent extraction process. Generally these tanks are emptied before the physical inventory verification, so a few might be measured to verify they are empty, but an overall tank measurement program has not been planned at this point.

Fig. 7. Vertical ducts.

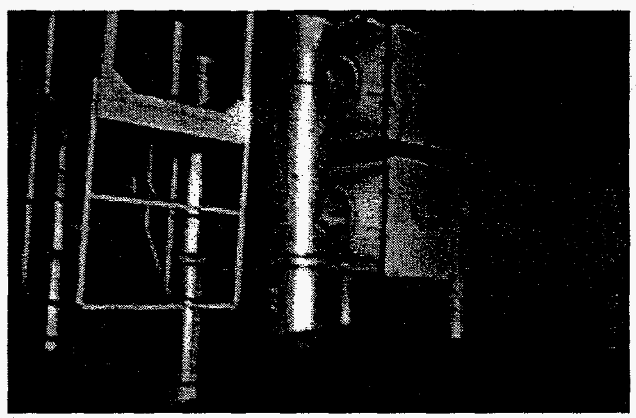

*Fig. 8. Air filters.*

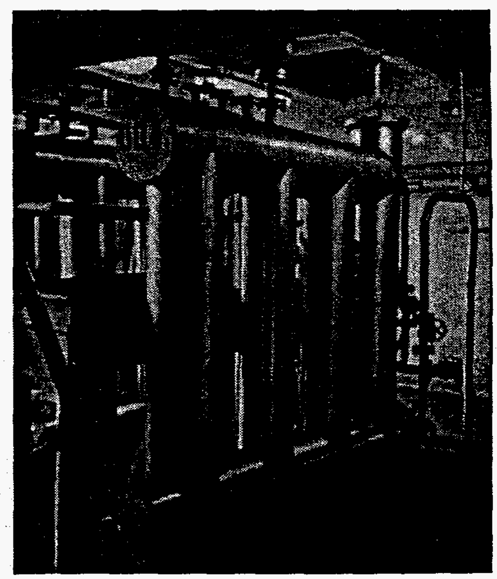

*Fig. 9. Storage tanks.*

**PRELIMINARY RESULTS**

To date, most of the holdup measurement effort at the Ulba Metallurgical facility has emphasized understanding the measurement need and training the operators. The International Atomic Energy Agency (IAEA) has expressed interest in knowing the results of the facilities' holdup measurements and has requested that measurements be made at certain locations. Now that the facility has established a baseline accounting system, passed annual IAEA physical inventory verifications, and upgraded its analytical laboratory measurement systems, there is a desire to include process holdup estimates in the nuclear material accounting system. This implementation will take the next few years, as the thousands of potential holdup measurement locations are identified, assessed, and a routine measurement program is implemented. It is perhaps useful to note that the IAEA significant quantity (SQ) of LEU is 75 kg of $^{235}U$. For LEU enriched to 3%, this is about 2250 kg of uranium or 2300 kg of oxide. Holdup of a few kilograms is not of very much interest, unless there are thousands of such deposits.

A preliminary measurement of an elevator, similar to the one illustrated in Fig. 7, estimated 410 to 700 kg of LEU. Clearly this quantity of material in one piece of equipment is of interest. Fortunately, it is a simple measurement.

Measurement of a bottle of scrap yielded a result of 21.6 ± 1.8 kg uranium (LEU) in a 1000-s assay compared with sampling and destructive assay yielding 18.6 kg. Measurement of solutions in perhaps 20 bottles in a glove box yielded 1.3 ± 0.3 kg compared with adding up only the 4–5 largest items was nearly 1 kg. Measurements of plumbing next to the mixer settlers indicated that essentially no uranium was in the plumbing, thereby avoiding the necessity of another cleanout.

A comparison of net weight changes in filters with gamma-ray-based holdup measurements is shown in Table I. The filters are 745 mm × 645 mm × 355 mm. For most of these filters, the air flow enters and exits from the same 745 mm × 645 mm face. The gamma-ray measurement includes a transmission correction for self-absorption, additionally a sample of the loose powder inside the filter was analyzed for uranium content and enrichment.

Table I. Comparison of Weight Gain and Gamma-Ray Measurements of Uranium Content in Filters.

| Filter | Net Weight (uranium) | Uranium Content | Enrichment | Gamma-Ray Measurement | Gamma-Ray-Based Uncertainty |
|---|---|---|---|---|---|
| 312 | 22.77 kg | 85.5% | 2.98% | 11.5 kg | 3.7kg |
| | 9.42 kg | 86.5% | 2.58% | 8.0 kg | |
| | 20.0 kg | | | 10.0 kg | 1.8 kg |

The IAEA has expressed interest in measuring the ventilation ductwork. The primary purpose of such measurements would be to demonstrate that no large localized deposit exists that could be a safety concern or a potential target for theft. A thin layer of material spread over a large surface could add up to a large quantity of uranium, but it would be essentially impossible to remove and concentrate into a useful batch of material. Additionally, the potential for a small measurement bias to propagate into a large bias in the accounting system totals makes the value of careful duct measurements of small thin deposits very questionable. Any time large deposits are located in the ventilation system or filters, the deposits are removed and characterized. Preliminary results suggest that there are very few localized deposits in the ventilation system, but that the process holdup measurements are the best method for locating them.

We measured the ventilation ducts for the pellet presses in Building 600. One localized deposit estimated to contain 700 g was found. It was surrounded by ducts that had been cleaned out successfully, but this section was not easily accessed or easily examined by the cleaning crew. In this example, the gamma-ray measurement quite rapidly demonstrated where the equipment had been properly cleaned of uranium materials and were additional efforts would be useful. Next, we measured a vacuum ventilation duct for the oxide fill station. The vacuum duct was empty, but the measurement was complicated by a signal from neighboring equipment. A nearby transfer line contained up to a few kilograms/meter of uranium. It is always difficult to measure a small or empty item next to a large amount of nuclear material. Good practice dictates that you measure the largest items, remove them, then attempt to measure the items with smaller signals, if good results are desired.

## CONCLUSION

The Ulba Metallurgical facility was the first Former Soviet Union bulk facility to successfully undergo regular IAEA inspections. The facility is beginning a holdup measurement program to supplement the present measurement-based accounting system. The IAEA is participating in and encouraging the use of routine holdup measurements. Over the next few years, the facility will establish a procedure of replicate holdup measurements and it will study how these measured values can be used for process control and/or to supplement the accounting system.

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