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NUMATH: A NUCLEAR MATERIAL HOLDUP ESTIMATOR FOR
UNIT OPERATIONS AND CHEMICAL PROCESSES

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NUMATH: A NUCLEAR MATERIAL HOLDUP ESTIMATOR FOR
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INTRODUCTION

A computer program, NUMATH (Nuclear Material Holdup Estimator), has been developed to permit inventory estimation in vessels involved in unit operations and chemical processes. NUMATH is a modular program which uses historical data along with continually measured process variables, such as solution volumes and densities, to estimate compositions of in-process solutions until such time as chemically analyzed compositions can be established. The estimated compositions are used to calculate near-real-time inventories in applicable vessels which, subsequently, permit automatic material balance calculations for transfers. When a plant operator informs the computer that a vessel has ceased its active involvement in the transfer (e.g., upon switching from one to another of parallel feed tanks), the program is automatically prompted:

1. to collect pertinent data;
2. to estimate the present composition of every vessel which is involved in the unit operation; and
3. to store the estimates in the physical inventory and other appropriate files in the system.

Present composition estimates are based on each vessel's process measurements, previous composition, and transfer characteristics (e.g.,

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flow rates, vessel connections), and on calculation routines for combining separating, or converting components. Records containing estimated compositions are identified as such until analyzed values supersede them.

NUMATH MODELS

For steady-state operations, three calculation routines have been developed: a blending (perfect mixing) model, a separation (distribution) model, and an empirical conversion model. These models are used to estimate compositions resulting from combining materials (solids or liquids) of differing compositions, from processing a fluid to separate its components, and from converting a solid substance to a liquid form (e.g., dissolution) or a liquid substance to a solid form (e.g., precipitation). Implementation of the models is directed toward inventory estimation as opposed to stream composition estimation normally found in simulators.

In addition to the models, other information (e.g., vessel inter-relationships and model parameters) used to describe processes for composition estimation is obtained from a special, source-data file. The structure and application of this file is such that normal process configuration changes (e.g., switching feed tanks or terminating feed flow) may be addressed without need of additional files for each process configuration.

A composition correction feature is provided to adjust the model calculations so that the results will agree with the compositions indicated by measured specific gravities in the vessels. The ratios of components calculated by the model are maintained, but the total amounts present are adjusted to agree with the measured specific gravities.

NUMATH IMPLEMENTATION FACILITY

The plant in which NUMATH has been implemented is the ^{233}U Radiochemical Processing Pilot Plant (RPPP) at Oak Ridge National Laboratory. Processes employed in the RPPP include solids dissolution, solvent extraction, ion exchange, evaporation, and solidification. All of these processes (with the exception of solidification) are performed remotely—behind thick, concrete shielding walls—due to a significant radiation hazard. Although all of the processes mentioned above have had source-data files prepared for NUMATH estimation, only two of them (solvent extraction and ion exchange) have undergone simulation testing and are addressed in this study.

Solutions containing ^{233}U are subjected to solvent extraction and/or ion exchange to separate the uranium from excess nitric acid, thorium, and the radioactive decay daughters of ^{232}U .

Process instrumentation used in the RPPP includes bubbler probes for liquid level and specific gravity measurements. Electronically operated, differential pressure transmitters are used to provide direct signal links from the bubbler probes to the computer which, in turn, permit near-real-time volume and specific gravity determination.

TRIAL NUMATH ESTIMATIONS

Trial NUMATH estimations were performed using historical solvent extraction and ion exchange run data. The performance of NUMATH may be best evaluated by how well it estimates inventories in relation to the measured inventories. This evaluation is presented in Figure 1.

For the simulated solvent extraction runs, twenty inventories (one for uranium and one for thorium in each of ten runs) were estimated and

Figure 1. NUMATH performance relative to measured inventories.

compared to their measured counterparts. For uranium, all but one of the estimated inventories were within 10% of the measured values--one value was high (by 24%) due to processing feed solution with off-specification uranium concentration. The estimated thorium inventories were also within 10% of the measured inventories in nine of the ten cases--one value was high (by 18%) apparently due to an inaccurate specific gravity measurement which was factored into the estimate.

Stringently controlled ion exchange operations permitted more accurate estimates. The simulated ion exchange runs yielded estimated uranium inventories within 4% of the measured inventories; thorium was estimated precisely at the measured values. (Accurate thorium estimates are attributed to ion exchange operating procedures which intend that all thorium in the feed is retained on the resin during product collection.)

The estimated uranium compositions appear to be biased ~1.5% low in the solvent extraction simulated runs, indicating that the involved distribution and conversion factors might be slightly inaccurate.

SUMMARY

NUMATH provides inventory estimation by utilizing previous inventory measurements, operating data, and, where available, on-line process measurements. For the present time, NUMATH's purpose is to provide a reasonable, near-real-time estimate of material inventory until accurate inventory determination can be obtained from chemical analysis. Ultimately, it is intended that NUMATH will further utilize on-line analyzers and more advanced calculational techniques to provide more accurate inventory determinations and estimates.