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A COMPUTERIZED TOOL FOR PREDICTING NUCLEAR MATERIALS USAGE AND RESOURCE UTILIZATION IN PRODUCTION PROCESSES

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ABSTRACT

The UK Ministry of Defence in collaboration with AWE Aldermaston developed a spreadsheet to assist in planning nuclear materials inventories to support production programs. The spreadsheet tracks recovery of materials from service returns and materials recycle through nuclear materials production processes and forecasts future nuclear materials needs. The spreadsheet lends itself to "what-if" analyses for materials supplies, program modifications, and operational configuration scenarios. Calculations are based on input feed stocks, process efficiencies, and the resulting inventories for different materials. The nuclear materials management organization at Los Alamos National Laboratory adopted the spreadsheet to supplement analysis tools for nuclear materials usage predictions. The forecasting tools currently being used are structured to predict materials movements throughout the weapons complex and not necessarily usage in production. Upgrades to the spreadsheet to enhance functionality are the incorporation of material movements through process exchanges and the introduction of personnel and instrument resources. The modified spreadsheet is modeled after the process accountability flow diagrams used by Los Alamos to define material flows through individual production processes. This approach enables materials management personnel to predict not only materials usage and accumulation, but also the utilization of non-destructive assay and analytical chemistry resources.

INTRODUCTION

The Special Nuclear Materials Planning Committee (SNMPC) spreadsheet was developed in 1984 by the UK Ministry of Defence (MoD) to predict stocks of nuclear materials necessary to fulfill future weapons production and research commitments. MoD is primarily interested in strategic planning spanning decades for the weapons stockpile. This software tool serves as an integral part of the planning process. The Atomic Weapons Establishment (AWE) Aldermaston facility was issued the spreadsheet to evaluate the affect that short-term production changes have on materials stockpiles. Impacts on production can be manifested by the unavailability of processes or facilities, changes in processing efficiencies, changes in process configuration, or a shortage of feed materials.

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Input data for the spreadsheet application are input feed stocks, process efficiencies processing paths for each material matrix, and the resulting product, residue, and waste side-streams. The spreadsheet produces predictions of materials supply and availability of recycled materials based on the inputs. The accuracy of the predictions is improved through a quarterly reconciliation process where the spreadsheet is updated with actual materials balances.

Throughout the years the spreadsheet was enhanced to accommodate changes in software and hardware technologies. In 1999 a new version of the SNMPC spreadsheet was distributed to the nuclear materials management organization at Los Alamos National Laboratory (LANL) under the auspices of JOWOG 22. LANL evaluated the spreadsheet for its use as a materials management planning tool. Current forecasting tools are structured to predict materials movements throughout the weapons complex but not expenditure in production. The SNMPC spreadsheet allows the materials management organization to track the flow of materials through production processes and determine materials shortfalls and excesses. To increase the flexibility of the SNMPC spreadsheet, Aldermaston is planning a significant upgrade to the software [1]. The changes will facilitate ease of representing production areas in the spreadsheet as well as incorporating a variety of ancillary activities that use resources and impact production. This paper describes the rationale behind development of a spreadsheet for LANL to predict nuclear materials usage, the processes included in the analysis, and the information obtained from such an analysis.

NUCLEAR MATERIAL MANAGEMENT

The end of the Cold War has dramatically changed the role of the nuclear-weapon stockpile and the associated research, development, and testing of weapons by the Department of Energy (DOE) weapons complex. In the past, nuclear deterrence was achieved by large-scale production and a commensurate large-scale budget. The Strategic Arms Reduction Treaty I (START) and START II called for reducing the strategic-weapons arsenals of the United States and the former Soviet Union. The existing, reassembled, or retrofitted weapons in the enduring stockpile will be stored indefinitely to ensure nuclear competency. The streamlined weapons complex of the future will focus on long-term storage of nuclear materials, weapons dismantlement, and a modest fabrication and rebuild capability.

The reduction in fissile materials available from the stockpile for future fabrication has necessitated that DOE effectively manage its inventories to ensure that materials are available to meet programmatic commitments. The emphasis of the nuclear material management organization is on programmatic oversight. The functions of the organization include assessing nuclear materials inventories, forecasting materials requirements, controlling excess inventories, and forecasting and administering materials shipments/receipts between DOE facilities.

A Material Balance Area (MBA) is the basic accounting unit for the control and accountability of nuclear materials at LANL. Each MBA has a least one process status that defines a specific process boundary where materials can be processed, combined, split, or measured [2]. Each process status has an associated process accountability flow diagram (PAFD) which defines materials flows through individual processes. A PAFD specifies measurement points at various stages of processing and indicates the disposition of materials resulting from processing. An example of a PAFD is shown in Figure 1.

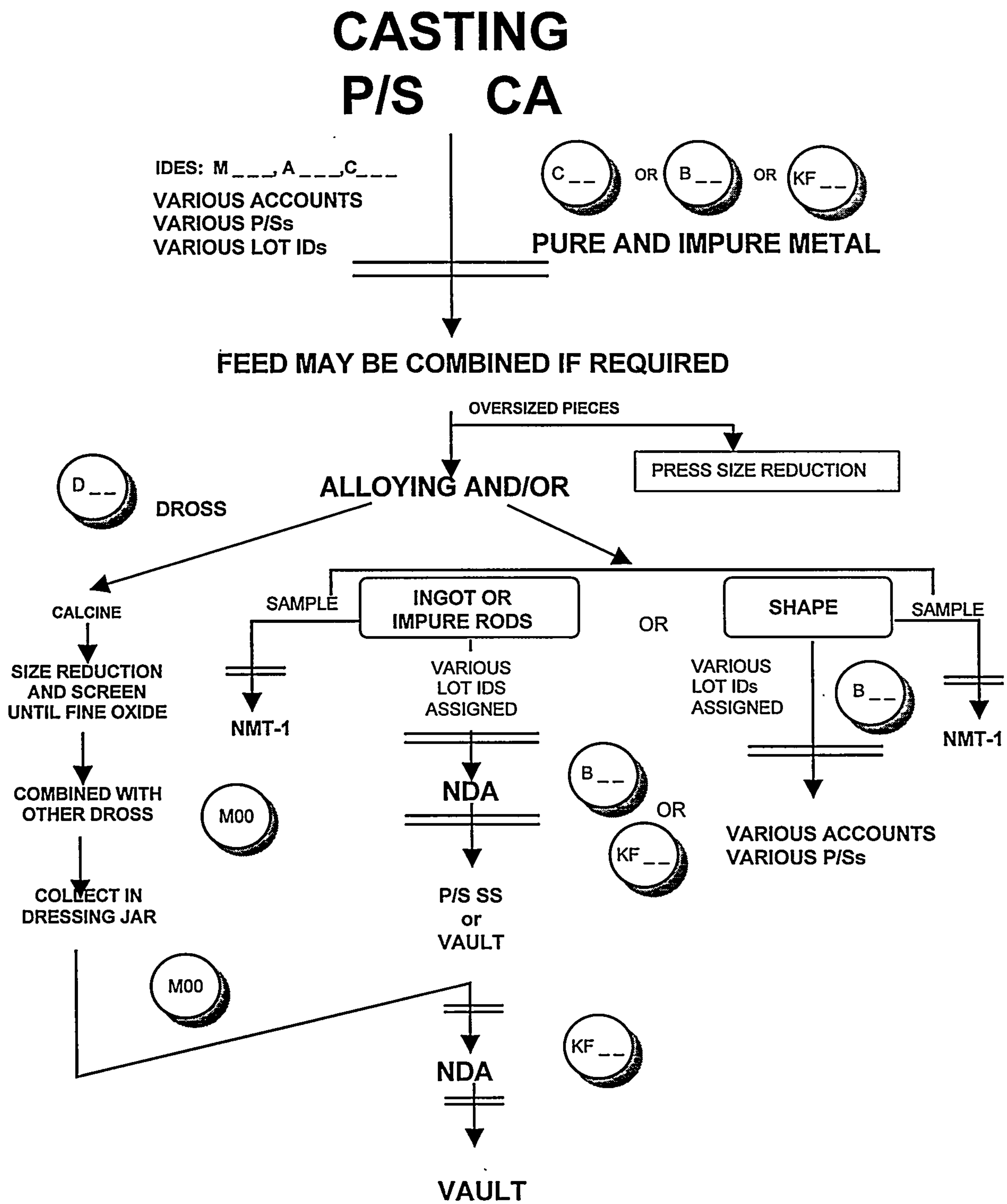

Figure 1. Process Accountability Flow Diagram for Casting Operation

The limited use of PAFDs was initiated in 1979 by the accountability organization at LANL. PAFDs were used as a mechanism for standardizing nuclear materials coding practices for the computerized accountability system. The practice was later adapted for all process statuses to formally record process flows and required non-destructive assay (NDA) and analytical chemistry points. Currently, PAFDs contain information on naming conventions, process flows and materials form changes, measurement points, materials disposition (storage and waste management) and materials ownership. Once strictly an accountability tool, PADFs are now utilized by a variety of organizations including materials management. The production flows modeled by the LANL version of the SNMPC is based on the materials flows of represented by the PAFDs. In this way, all the pertinent materials management information is included. Additionally, predictions of throughput for auxiliary production processes such as waste management, NDA, analytical chemistry, and storage are possible.

PROCESS DESCRIPTIONS

This spreadsheet analysis is intended to encompass only the materials used in DOE's Defense Programs (DP) activities, namely, metal production , component fabrication, and chloride and nitrate recovery. A simplified flowsheet of the materials flow through these production processes is shown in Figure 2. Approximately fifteen PAFDs describe these processes. Following are summary descriptions of the principal processes.

Chloride Recovery

The chloride aqueous process produces pure oxide for metal production or long-term storage. This process is used for the recovery of $CaCl_2$ salts, MgO crucibles and spent anodes from the pyrochemical processes.

Nitrate Recovery

The purpose of the nitrate aqueous process is to produce pure oxide for metal production or long-term storage. The primary feeds for this process are oxides from the pyrochemical processes and shape casting.

Direct Oxide Reduction

This pyrochemical process reduces plutonium oxide to plutonium metal for use by electrorefining. Residues are recovered by chloride operations or discarded by waste management.

Molten Salt Extraction

Americium must be separated from aged plutonium metal to reduce personnel radiation exposures before it is used for castings, parts, and assemblies. In this process, americium is extracted in a molten salt phase that separates it from the plutonium metal.

Anode Casting

In this process a plutonium metal anode is produced by compacting and induction furnace casting. Residues are produced for recovery by aqueous processing or discard by waste management.

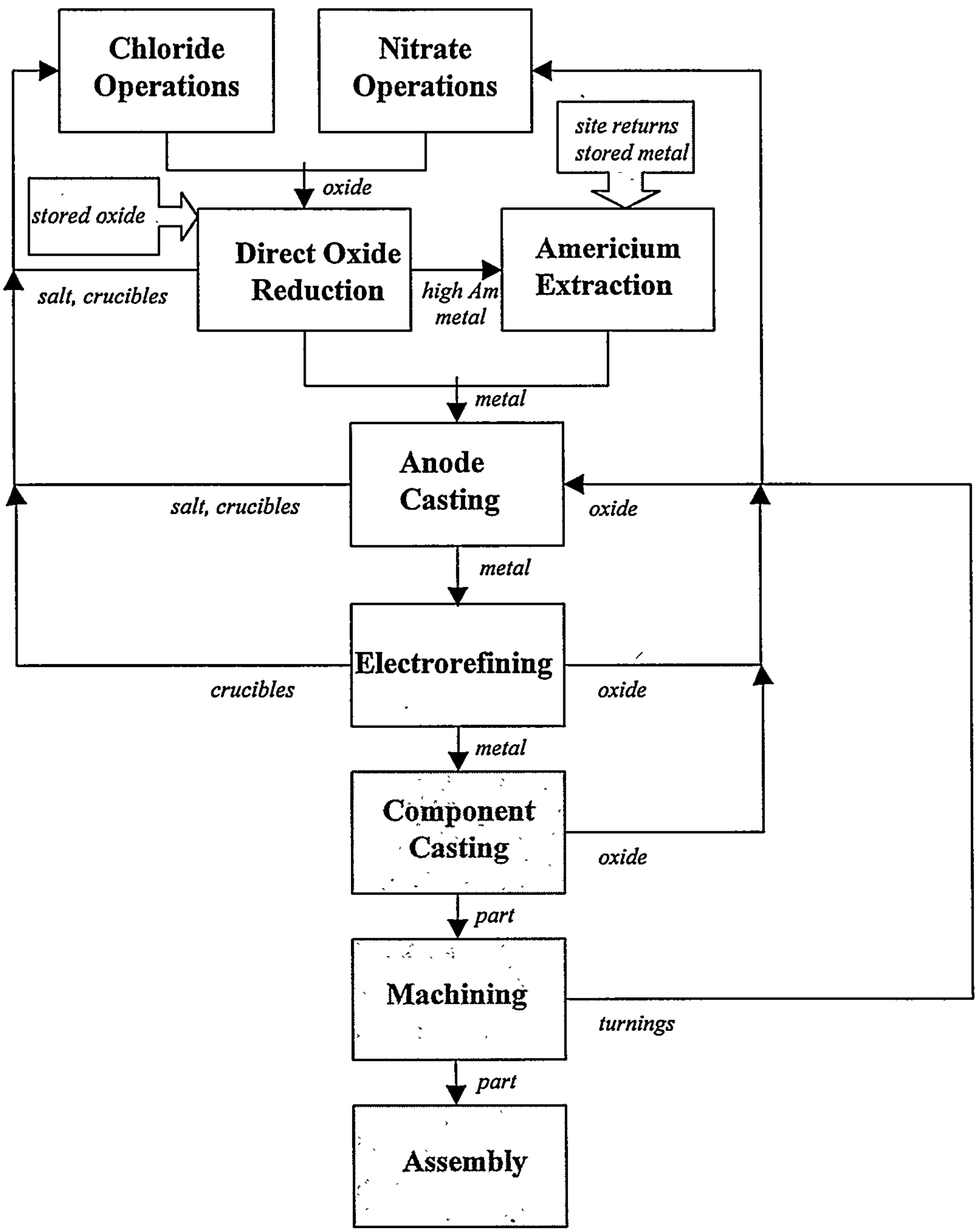

Figure 2. Simplified Flowchart for Pit Production

Electrorefining

This is the pyrochemical process for producing high-purity plutonium. The product metal is used as feed for the component casting process. Residues are produced for recovery by aqueous processing or discard by waste management.

Component Casting
This fabrication process produces shape castings from electrorefined metal. This process produces oxides that are sent to nitrate recovery.

Machining
Components are machined in this fabrication process. Metal turnings are produced that are used as feed for anode casting.

The spreadsheet details the materials flow through mainstream production processes such as direct oxide reduction, electrorefining, casting, machining, and aqueous processing. However, several auxiliary processes have a substantial impact on materials throughput in the production flow. These processes include NDA, analytical chemistry, waste management, and vault storage. The summary descriptions for these processes follow.

NDA
The Laboratory accounts for all nuclear materials in its inventories based on measured values. NDA is one method used to establish accountability values for items. These methods include balance measurements, gamma spectroscopy, gamma-ray isotopics, calorimetry, neutron, and solution assay.

Analytical Chemistry
Another method used to establish accountability values for nuclear materials is destructive analysis performed on samples of the original items. Analyses are performed using a combination of wet chemistry and instrument techniques.

Waste Management
Waste management organizations collectively are tasked with receiving, tracking, characterizing, treating, packaging, storing, and shipping a variety of solid and liquid wastes.

Vault storage
The TA-55 vault is the principal repository for process-generated residues and products. The space in the vault is limited by category and physical size of items stored. Vault holdings are closely monitored, and knowledge of anticipated use is crucial. Forecasts of glovebox and production floor holdings are also important to the safe operation of the facility.

SPREADSHEET FORMULATION

Decisions regarding changes in project direction, production processes, process flows, and/or resource allocations are made independently of materials management concerns. Often these changes affect the ability to ensure that the supply of materials is sufficient to meet programmatic needs. The SNMPC spreadsheet provides a mechanism for project management, production and materials management organizations to assess the impact that these changes have on the status of nuclear materials inventories.

The spreadsheet is organized into equal time intervals. For example, an analysis can be performed by month, quarter, or year for the number of time periods required. The spreadsheet models the throughput of nuclear materials for each process by tracking nuclear material mass and bulk weights. Each process is connected to succeeding processes with outputs from a process providing feed materials to linked processes. Inventories are reported at the end of each time period. Therefore, each process that is "bottlenecked" can be identified by an accumulation of feed stock.

Inputs are specified by process for each time interval and include the following: (1) operational status, (2) beginning inventory, (3) efficiency, and (4) maximum process throughput. Because inputs can vary by time period, processes can be "turned off" to reflect downtimes due to failure, maintenance, or decommissioning. Personnel resources are not explicitly managed in the model. These values are included in the maximum process throughput inputs that are based on the assumption of static resource loading. No stochastic effects are studied in the spreadsheet model.

SUMMARY

The SNMPC spreadsheet has been used successfully for several years by MoD AWE Aldermaston to forecast plutonium supplies for various production programs. The nuclear materials management organization at Aldermaston is implementing changes to make the tool more useful for predicting processing bottlenecks that impact materials supplies. They are also incorporating additional side-stream processes that utilize many of the same resources and affect throughput. LANL is collaborating with Aldermaston to develop a spreadsheet for fabrication and recovery operations in Los Alamos. The opportunity exists through this collaboration to implement a computerized tool that will greatly benefit both organizations and provide a basis for future exchanges.

REFERENCES

[1] Freeman, M. L., *Specification of Enhancements to the SNMPC Spreadsheet,* Directorate of Production & Process Technology, Technical Report No. 056/00, AWE Aldermaston, April 2000.

[2] Materials Control and Accountability Plan, Rev. 5, Los Alamos National Laboratory, March 1999.