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HB-Line Special Nuclear Material Campaigns: Model-Based Project Management

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ABSTRACT

A computer model was developed using COREsim to perform a time motion study for a project to convert Neptunium (Np) nitrate solution to Neptunium Oxide. The stabilized Np Oxide is to be shipped to the Oak Ridge National Laboratory for future production of plutonium-238. Pu-238 has a unique combination of high heat output and long life, allowing designers to keep weight at a minimum and still have a power source that is effective for many years where solar power is not practical. NASA uses Pu-238 as a heat source in Radioisotopic Thermoelectic Generators which covert heat to electrical power to operate various deep space vehicles, such as current Galileo, Ulysses, and Cassini missions.

With the realities of shrinking cleanup budgets, there is a need to strike a delicate balance between the campaign duration and the amount of precious Neptunium to recover. Moreover, the project requires interfacing with different facilities for disposing of waste streams and for secured vault storage space. This study is to show how a model was used to enable management to better estimate production capabilities to ensure contract milestones/commitments are met, to cope with fast changing project baselines and project missions, to ensure the project will meet the negotiated throughput, and to eliminate unnecessary but costly design changes.

In this study, other special nuclear material campaigns such as the Plutonium oxide campaign and Uranium dissolution will also be covered.

INTRODUCTION

HB-Line is located on top of H-Canyon, one of two chemical processing facilities at Savannah River Site (SRS). The facility was built in early 1980s to support the production of plutonium-238 (Pu-238), a power source for the nation's deep space exploration program.

HB-Line has three process lines. The Scrap Recovery Line is used to recycle legacy plutonium scrap for purification and concentration to a solid form. This line is also called Phase I. The Neptunium-237/Plutonium-239 oxide line, called Phase II, can produce solid oxide material from neptunium-237 or plutonium-239 nitrate solutions. The Plutonium-238 Oxide Line, called Phase III, can produce Pu-238 oxide from nitrate solutions. There is not a current mission for Phase III. Phase I & Phase III operated to supply Pu-238 for the Cassini mission.

The missions, programmatic requirements, and funding are changing rapidly for SRS and other DOE sites. HB-Line is no exception. To make the project management more challenging, flow sheets for various feedstocks to be processed in HB-Line are yet to be developed. To cope with ever-changing missions, funding uncertainty, and yet-to-be-developed flowsheets, HB-Line facility management has made a choice to take a model-based approach to manage HB-Line projects by developing a process model. The model will enable the facility to review process operations, identify bottlenecks, evaluate and optimize improvement, and assess impacts of flowsheet as it became available from Savannah River Technology Center (SRTC).

There are five versions of roadmaps since the model was developed and worked against: Vision 2006 Base Case roadmap, Vision 2006 Stretch Case roadmap, SRS 2020 Vision (projected from 2006 stretch case), 2025 Base Case, and current AT-6 roadmap (2006 accelerated Cleanup effort).

PROCESS DESCRIPTION

Phase I is currently operating to convert oxides of uranium and plutonium to a nitrate solution. The nitrate solutions are transferred to H-Canyon for disposition.

Phase II started operations for the first time in November 2001. It converts plutonium-239 and neptunium-237 to oxide power form. The plutonium material is shipped to FB Line for storage and eventual disposition. The neptunium material will be shipped offsite for further processing and conversion to reactor targets.

The HB-Line Scrap Recovery Facility (Phase I) routinely generates nitrate solutions of scrap suitable for purification in the canyon or in Phase II. The plutonium or uranium scrap is to be dissolved in hot nitric acid in the

Scrap Recovery Facility. Pu-239 and U-235/Pu-239 solutions are transferred to H-Canyon Hold Tanks and then transferred to HB-Line Pu/Np Oxide Facility (Phase II) where the Pu-239 is purified by anion resin columns and then converted to an oxide powder. If not processed in Phase II, the Pu-239 is discarded via the H-Canyon Waste Stream.

The Phase II Process Line is designed to convert nitrate solution of fissile plutonium to plutonium oxide suitable for dissolution, blending or long-term storage in other facilities. It is also designed to convert nitrate solutions of neptunium to neptunium oxide for additional processing at other facilities. For a process flow diagram, refer to Figure 1.

NUCLEAR MATERIAL LIMITS VS. FACILITY CATEGORY

Special nuclear materials processing inside HB-Line facility are considered attractive targets for terrorists. The materials processing inside the facility can be assembled to produce weapons of mass destruction. To reduce the potential threats, the facility can either control the total SNM materials accumulated inside the HB-line, or increase the safeguard and security forces inside the facility to deter attractive level of the facility. Threshold limits for plutonium, uranium, and Neptunium material for different Safeguards and Security (S&S) Categories are summarized in Table I. The data provided pertain to nuclear materials handled and processed at HB-Line.

Table I. Facility Category vs. Material Limits

Facility Category	U235	Pu Oxides (>25 gm/liter)	Pu Oxides (1 to 25 gm/liter)	Neptunium Oxide
I	• 20 kg	• 6kg	NA	• 20 kg
II	• 6 kg <20 kg	• 2 kg <6 kg	• 16kg	• 2.8 kg <20 kg
III	< 6 kg	• 0.4kg < 2kg	• 3kg < 16kg	• 0.56kg < 2.8kg

The Facility Category is based on DOE 474.1 and DOE Manual M474.1-1.

HB-Line facility is a Category II facility. To upgrade a facility from a Category II to Category I facility is very expensive. However, upgrading to a Category I facility would provide HB-Line flexibility and increase throughput and shorten campaign duration (1).

PURPOSE OF MODELING

An operations research type of discrete event model was developed to assist in coping with ever-changing project scopes and project priorities. The project is relying heavily on the modeling effort to cope with mission uncertainty, technical baseline changes, and funding issues.

The discrete event simulation model is to analyze the dynamic performance and behavior of systems, and perform a time-motion study that can enhance the understanding of the HB-Line process. The simulation provides insight into utilization of resources and plant capacities. In addition, modified operating scenarios can be easily produced and analyzed to provide information on process pinch points and to support the planning and management decision making process.

The model will verify the required process throughput, the resources required for three different process rates, the impact of batch size in the Filtrate Tanks, and will evaluate the impact of different shift schedules on process rate.

CASE STUDY

Special Nuclear Material Vulnerability Study

The model has been used in the past three years to study the adequacy to maintain the HB-Line as a Category II facility and still meet the mission throughput requirements (2, 3). In each campaign, it was proven that upgrading HB-Line Phase I and Phase II to Category I facility is unnecessary. By staying as a Category II facility, the facility has resulted in significant cost avoidance as follows (1):

(1) Capital expenditure avoidance = $4.5 MM.
(2) Annual saving of operating expenditure from security personnel = $9 MM.
(3) Assume the total HB-Line campaign duration = 18 months, then the Life Cycle Saving = $18 MM.

Performance Based Incentive Milestone Negotiation

The model has played a very critical and vital role in establishing performance based incentive milestones. With very short notice, three options and associated campaign durations and accumulated Np loss were presented to the DOE as shown in Table II. The first option is not to recycle waste streams to recover lost Np. The second option is to recycle the lost Np collected in Recycle Tanks

(RT). The third option is to recycle and recover the lost Np in Recycle Tanks and Filtrate Tanks (FT).

Table II. Three Options Presented to DOE

Options	Np Loss (kg)	Campaign Duration (month)
No Recycle	70	18
Recycle RT	55	19
Recycle RT & FT	27	20

The final decision is to pick the Option A as the basis for contract negotiation.

Filtrate Tanks Replacement Project

Plans to improve throughput of HB-Line included a $1.2 MM Filtrate Tanks replacement project. The HB-Line model was developed to enable the facility to review process operations, identify bottlenecks, evaluate and optimize improvement, and assess impacts of flowsheet guidance as it became available from Savannah River Technology Center (SRTC). Being able to model these flowsheet changes quickly enabled the facility to determine if planned equipment modifications were still needed. When the final flowsheet was complete, the model showed that $1.2 MM Filtrate Tanks replacement project could be eliminated (4, 5).

Campaign Baseline Change

The HB-Line Np campaign is to recover at least 85% of current Np inventory stored inside H-Canyon. The campaign is to be completed within 18 months. The original plan was to use vault inside a facility within F-area as storage of Np finished product in 9975 containers before shipments are made to Oak Ridge National Laboratory. In this case, the weight of Np oxide product is measured by calorimeter. Since the product cans are not to be shipped to customer right away, the product containers can be stored inside the vault and re-measured if calorimeter is out of calibration. However, the project management team was informed that the facility vault was not available to store 9975 containers for the Np campaign. As a result, an empty chamber and electrical standard run were added to the packaging process. Since there is only one calorimeter, the logic for calorimeter failure and fixing were also added to the model. In this case, the total campaign duration will be stretched to 23 months instead of 18 months. An alternative was to package with risk, i.e., packaging of can occurs before calorimeter analysis is available. In this case, the total campaign duration becomes 20 months.

The next what-if case studied was to find a second calorimeter. The calorimeter used in Np campaign is a very special and custom-made instrument. After extensive search, one similar calorimeter was identified from another site which might be available. With two calorimeters, the campaign duration will be within 18 months as specified in the contract.

Plutonium Decontamination Plan

Quality agreement between Oak Ridge and Savannah River Site has an upper limit for the ratio of plutonium to neptunium that makes it imperative to have at least a 30% decontamination of plutonium from starting solution is made to ensure that the bounding limit is not exceeded (7). This reduction will account for laboratory analysis uncertainty and process nuances that could seemingly or actually cause the limit to be exceeded. As a result, a partition step was added in the column operations. Partition is a way to separate plutonium from neptunium. It is a proven technique for cases where the plutonium was 20% of the neptunium/plutonium makeup. The unknown here is the large differences in makeup, i.e., 611 ppm Pu per gram of Np (6). There is a limit in the facility in tank capacity and DCS controlled equipment. Existing chemical tanks are reassigned for partition, elution, and recondition & decontamination.

At this point of project, the facility vault originally designated to store 9975 containers was available for the Np campaign again. The calorimeter was to be replaced by coulometer instead. The model was used to determine the facility can handle all the design changes within 18 months.

Manpower Optimization

For manpower planning purpose, the project has assumed there are 4 process operators and 3 control room operators. There is a shortage of operators to perform deactivation and decommission (D&D) work on site; thus the program manager asked the project management to look into a possibility to cut staffing from the Np campaign. The model has predicted that the campaign can achieve the required throughput with 3 process operators and 2 control room operators. The life cycle saving from the manpower reduction is $300,000 (7).

CONCLUSION

The total cost of model development was about $200,000 over two-year time span. As can be seen from the cases shown in the Case Study section, the pay off from the model effort is very significant and return on investment is very high. The models were used for resource optimization, de-bottleneck, alternative analysis, and resulted in significant saving from cost avoidance.

REFERENCES

(1) Rainisch, R., "Cost/Benefits Analysis of Upgrading HB-Line To A Category I Facility", S-ESR-H-00004. (2000)

(2) Chang, R.C., Dixon, D., "Time Motion Study for HB-Line Phase I and Phase II Oxide Operations, Part 1 (U)", G-ESR-H-00057, Rev. A (2002).

(3) Dixon, D., "HB-Line Phase I Process Simulation Results for Uranium Roll-up Vulnerability Study, OBU-SED-2003-00015 (2003).

(4) D. Murdoch, "Engineering News", Issue 3, June 2003, Savannah River Site.

(5) Smith, B., "HB-Line Np-237 Flow Sheet", CBU-HCP-2003-00044, (2003).

(6) Smith, B., "Plutonium Decontamination Plan", Internal Memo (2003).

(7) Chang, R.C.., Coleman, H., "Time Motion Study for HB-Line Phase II Neptunium Oxide Operations (U)", Rev. A, (2002).

BIOGRAPHY

R.C. Chang has more than 15 years of hands-on chemical engineering and simulation modeling experience. He is a Principal Engineer in Westinghouse Savannah River Company. He received a Master Degree in Chemical Engineering from Oklahoma State University. He has presented several technical papers, holds several patents, and is currently working on developing modeling capability within the Systems Engineering Department of WSRC.

H.W. Coleman has 15 years engineering experience at Westinghouse Savannah River Company. She received a Bachelor of Science in Electrical Engineering from North Carolina A&T State University. She currently develops simulation models within the Systems Engineering Department at the Savannah River Site.

Figure 1: HB-Line Np Flow Sheet