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## Development of a Systems Engineering Model of the Chemical Separations Process

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## Task 8

# Development of a Systems Engineering Model of the Chemical Separations Process

Y. Chen, D.W. Pepper, and S. Hsieh

## BACKGROUND

The chemical processing of used nuclear fuel is an integral component of any strategy for the transmutation of nuclear waste. Due to the large volume of material that must be handled in this first step of the transmutation process, the efficiency of the separations process is a key factor in the potential economic viability of transmutation strategies. The ability to optimize the chemical separation systems is vital to ensure the feasibility of the transmutation program.

Systems analysis, or total systems modeling, is one of the strongest tools available to researchers for understanding and optimizing complex systems such as chemical separations processes. Systems analyses permit researchers to present decision-makers concise evaluations of system options and their characteristic features. The primary goal of this project is to develop a systems model that can be used to parameterize and optimize chemical separations processes.

## RESEARCH OBJECTIVES AND METHODS

This work includes reviewing and analyzing the AMUSE code structure, examining other possible implementations, defining software activities, developing a verification plan, and modifying and improving the software. This work also involves redefining the graphical user interface (GUI) to increase the utility of the AMUSE code suite as a stand-alone analytical package.

Developing a systems engineering model required discussions with Argonne National Laboratory personnel to identify pertinent

components of the chemical separations process. Each step required model development to establish its significance with regards to the overall process. Comprehensive model development involved defining the inputs and outputs from individual models and establishing how each connected to the other within in the chemical separations process.

## RESEARCH ACCOMPLISHMENTS

This project developed software for a general-purpose systems engineering model named TRP System Engineering Model Program (TRPSEMPro) that will be used to improve productivity in the design process. The system model also includes various numerical optimization technologies and “Design of Experiments” study technologies.

Object-Oriented Analysis and Design was used for developing and implementing the TRPSEMPro system. A graphical notation, Unified Modeling Language, was employed to express object-oriented designs. Microsoft.Net architecture was used for system development and Visual Basic.NET was the major programming language behind the system. XML (Extensible Markup Language) was used widely to describe data and sets of elements and attributes that can be defined by researchers. XML Schema was used for describing the structure of the system engineering model. XML Database was used to store all the run-time data for the AMUSE module. Since significant experimental data will be generated and require systematic analysis, MS SQL Server 2000 database was selected for housing all run-time parameters and simulation results.

The model is combined with commercial software packages MATLAB OPTIMIZATION toolbox and SIMULINK module from Mathworks.

The system model, TRPSEMPro, considers input simulation modules from multiple disciplines with inconsistent input/output handles. The package with the aid of middleware can communicate with various simulation modules developed by other research groups and create an XML-based model description file. The critical components for the system engineering modeling include System Manager, Model Integration, Study Plan, and Solution Viewer.

The introduction of the middleware design provides flexibility

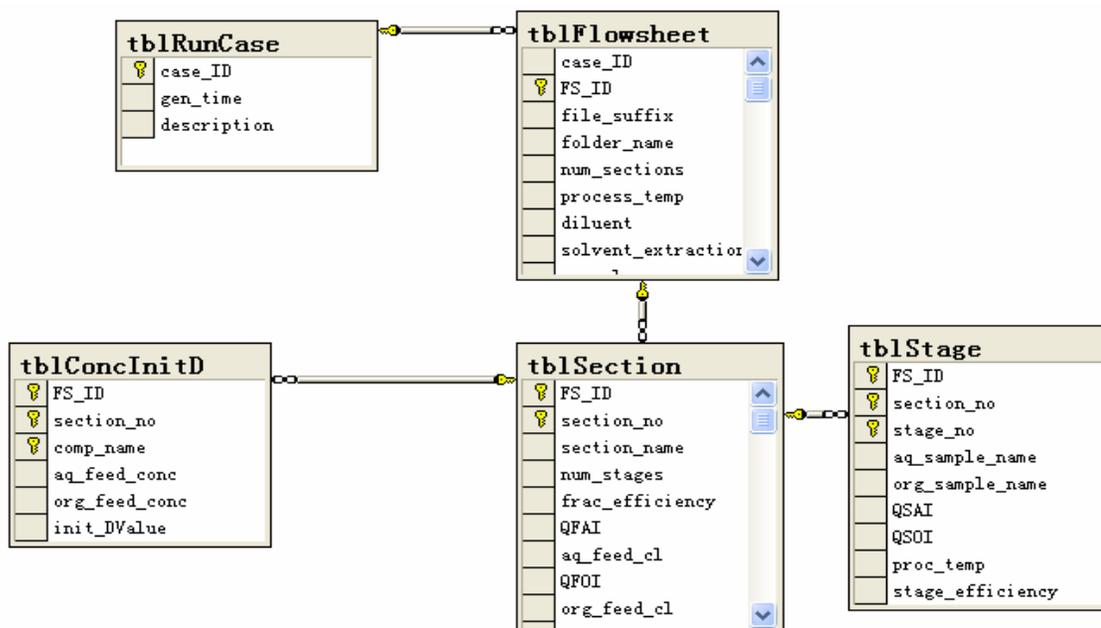


Diagram for the Structure of the Database Design.

to interface to other simulation modules without significant program modification. The demonstration code from AMUSE macros is kept intact during all system development stages. AMUSE-Simulator, is the middleware software package which was designed and implemented to serve as a bridge between the AMUSE code, and the systems engineering model, TRPSEMPro. Such an approach can reduce the time-consuming modification on the system model side and keep flexibility on the simulation modules development side.

Further system enhancement allowed the user to select various process types. An interface for conducting multiple runs was created. The GUI included a list of variables, a range for those variables, all of which provide an envelope of end results.

### TASK 8 PROFILE

Start Date: August 2001

Completion Date: August 2004

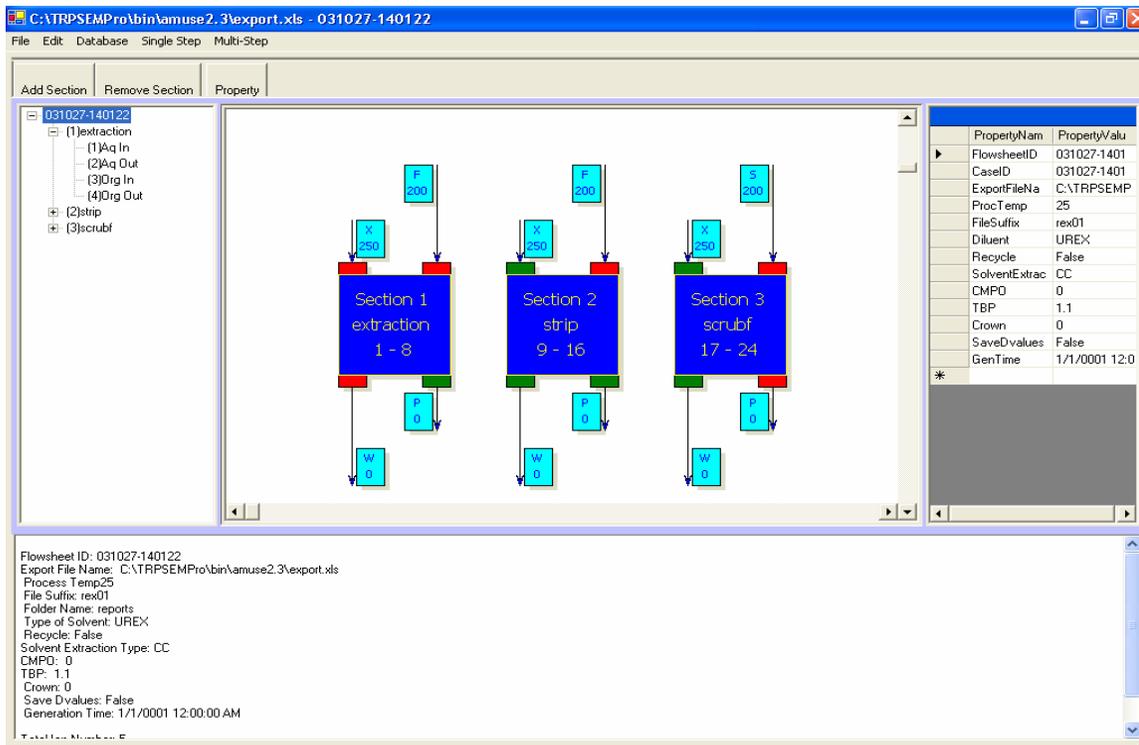
(This work is continued as Task 24, see pages 52-53.)

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### Conference Proceedings:

- "Development of Systems Engineering Model for Spent Fuel Extraction Process," IMECE 2004, International Mechanical Engineering Congress and Exposition Conference, Anaheim, CA, November 13-19, 2004.
- L. Sun, Royyuru, H., Hsieh, S., Chen, Y., Clarksean, R., Vandegrift, G., Copple, J., and Laidle, J., "Development of Systems Engineering Model for Spent Fuel Extraction Process," ICAPP-04, Pittsburgh, PA USA, June 13-17, 2004.
- H. Royyuru, Sun, L., Chen, Y., Hsieh, S., Clarksean, R., Pepper, D., Vandegrift, G., Copple, J., and Laidle, J., "Development of Systems Engineering Model For UREX Process," ASME International Mechanical Engineering Congress and Exposition, Washington, DC, November 16-21, 2003.
- H. Royyuru, Sun, L., Chen, Y., Hsieh, S., Clarksean, R., Pepper, D., Vandegrift, G., Copple, J., and Laidle, J., "Development of Systems Engineering Model For UREX Process," *AccApp'03: Accelerator Applications in a Nuclear Renaissance*, San Diego, CA, June 1-5, 2003.
- L. Sun, Chen, Y., Clarksean, R., and Laidler, J., "The Development of a Systems Engineering Model for the DOE Advanced Accelerator Applications Program," *International Congress on Advanced Nuclear Power Plants*, embedded topical meeting at the ANS Summer Meeting, Hollywood, Florida, June 9-13, 2002.



The main GUI for AMUSE-Simulator includes five parts as shown here. Menu and toolbar (Top Part) – where user can invoke all the available commands. Flowsheet contents displayed in tree view format (Left Part) – where user can select different section, stream. Flow-sheet contents displayed in way of drawing blocks (Middle Part) – where user can select different sections, streams by clicking mouse at corresponding area.

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