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NUCLEAR ENGINEERING R&D AT THE SAVANNAH RIVER SITE (U)

by

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INTRODUCTION

The Westinghouse Savannah River Company (WSRC) is the prime operating contractor for the U. S. Department of Energy at the Savannah River Site (SRS), located near Aiken, South Carolina. One division of WSRC, the Savannah River Laboratory (SRL), has the primary responsibility for research and development, which includes supporting the safe and efficient operation of the SRS production reactors.

Several Sections of SRL, as well as other organizations in WSRC, pursue R&D and oversight activities related to nuclear engineering. The Sections listed below are described in more detail in the following pages.

SRL - Nuclear Reactor Technology and Scientific Computations Department:
Nuclear Engineering Section
Scientific Computations Section, in part
Materials Technology Section

SRL - Safety Analysis and Risk Management Department:
Reactor Safety Research Section

WSRC - New Production Reactor Program
NPR Development Section, in part

WSRC - Environment, Safety, Health, and Quality Assurance Division:
Reactor Safety Evaluation Section

NUCLEAR ENGINEERING SECTION

The Nuclear Engineering Section (NES) is a multi-discipline organization involved in research and development (R/D) and support activities related to reactor operations. The Section is divided into three R/D groups and a support group. The R/D activities are staffed by approximately 60 engineers. NES has one major laboratory area.

Mission: Support safe and efficient operation of SRS nuclear reactor facilities through:

- Assessing current and future operational safety
- Computing thermal-hydraulic limits for design basis accidents
- Supporting development of advanced computational methods
- Developing advanced reactor concepts to ensure compliance with nuclear materials production objectives.

The R/D groups of the NES are described below.

Code Development Group

Purpose: The Code Development Group (CDG) develops computational methodology for SRS reactor power limits and thermal-hydraulic codes for reactor analysis. CDG also develops Loss of Cooling Accidents (LOCA) and other single-phase and two-phase models. This group is the custodian for all major reactor-related thermal-hydraulics codes.

Activities:

- Benchmark codes against data
- Participate in experimental design
- Develop advanced numerical solution methods
- Develop codes for statistical uncertainty analyses
- Document power limits methodology
- Maintain and upgrade thermal-hydraulics codes.

Applied Reactor Technology Group

Purpose: The Applied Reactor Technology Group (ARTG) has primary responsibility for controlled, formal calculations of reactor thermal-hydraulic-based power limits. ARTG is the primary interface to external organizations supplying power-related technical information as well as the source of technical data related to limits calculations. ARTG generates thermal-hydraulic flow limits for SRS reactors for potential accidents related to flow instability of cooling water. ARTG also generates input power transients for thermal-hydraulic limits using methodology and data developed by the Reactor Physics Group.

Activities:

Develop Thermal-Hydraulic Limits -

- Apply new computational technology to plant operations
- Compute flow instability power limits for Loss of Cooling Accidents (LOCA), Loss of Pumping Accidents (LOPA), Control Rod Withdrawal Accidents, and Pump Shaft Break Accidents

- Develop and implement statistical models to treat uncertainties and biases in model predictions in a rigorous manner that leads to quantitative confidence levels in the power limits
- Adapt methodology and computational tools to other Design Basis accidents
- Perform safety analysis for the reactor Safety Analysis Report (SAR).

Plant Technical Support -

- Provide analytical and test support to WSRC Reactor Restart Division
- Develop critical parameters for Technical Specifications and operating procedures
- Make practical enhancements in reactor safety and productivity through code improvements, improved instrumentation and surveillance, and reactor hardware.

Experimental Thermal-Hydraulics Group

Purpose: The Experimental Thermal-Hydraulics Group develops the experimental data bases required for normal operation and to ensure safe shutdown under postulated accident conditions. This information is used to maximize production while maintaining adequate safety margins. The Group operates the Heat Transfer Laboratory.

Activities:

Support Computational Methods -

- Provide experimental bases for correlations and benchmarking of computational models of the thermal-hydraulic performance of SRS reactors through separate-effects studies in the Heat Transfer Laboratory, prototypical tests by contractors, and full-scale reactor tests as appropriate
- Provide technical oversight of experiments performed by contractors
- Design new reactor assemblies.

Heat Transfer Laboratory

NES has one major laboratory facility, the Heat Transfer Laboratory, to support development work in reactor hydraulics and heat transfer. The HTL is a hydraulics test facility located in a separate, dedicated building. The experimental area contains all of the equipment for performing separate-effects studies of simulated reactor components during normal operation and reactor accident conditions. One of five test stations contains a 3 ft diameter tank, 21 ft tall, suitable for electrically heated tests with mock-ups of full size SRS reactor components. A new extension to the building includes an additional test tank, overhead hoist, and associated piping and equipment. The electrical power bus in the HTL can be divided to run three simultaneous heated experiments. A flow test facility and a monitoring facility are additional non-heated test loops for development of reactor components. State-of-the-art PC-based data acquisition systems capable of monitoring up to 240 channels simultaneously are used for accumulating data.

SCIENTIFIC COMPUTATIONS SECTION

The Scientific Computation Section (SCS) provides a high-quality scientific environment consisting of software, hardware, and services so that the computing goals of scientific and technical professionals at SRS are accomplished. Of several Groups in SCS, the Reactor Physics Group is most closely related to nuclear engineering activities and is described below.

Reactor Physics Group

Purpose: The Reactor Physics Group provides support and methods to establish the neutronic characteristics and reactivity control of SRS reactors. These techniques are used to maximize reactor productivity while maintaining adequate safety margins.

Activities:

Support Computational Methods and Manufacturing Technologies -

- Develop computational methods for shielding, nuclear criticality, lattice physics, and reactor core design activities
- Develop and maintain nuclear data files
- Develop improved reactor cores - past examples include the Mark 16B-31, Mark 22, and Mark 15 charges.

Assess Operational Safety -

- Provide nuclear criticality safety evaluations for all SRS designs and operations
- Provide oversight of SRS reactor operations through review of the physics characteristics of each reactor charge before startup.

MATERIALS TECHNOLOGY SECTION

The Materials Technology Section (MTS) is responsible for the technologies necessary to assure the safe and efficient utilization of materials at SRS. Significant efforts are directed toward materials-related research and development in support of SRS reactors, separations areas, nuclear waste storage systems, and reactor fuel/target manufacturing facilities. The Section is staffed by approximately 40 engineers, metallurgists, and materials scientists, and is divided into four R/D groups. MTS operates one major laboratory facility and several smaller research laboratories.

Mission: Support safe and efficient operation of SRS facilities by

- Assessing materials used at SRS
- Supporting manufacturing, separations, and storage technologies to help maintain the Site's capability of meeting nuclear material production objectives.

Engineering Development Group

Purpose: The MTS Engineering Development Group (EDG) is a speciality engineering research and development organization whose goal is to develop and apply new and improved technology to provide the technical basis for establishing the reactor power limits and for predicting reactor service life. The EDG expertise is in the areas of reactor materials, analysis of reactor systems, and the quantification of reactor system safety margins. The objective of EDG is to aid customers to successfully accomplish their missions.

EDG provides continuing studies of reactor components to determine material behavior as a function of aging. This information is used as a basis for service life predictions and assessment of changes in reactor safety due to aging. These activities provide options to satisfy new environmental and DOE guidelines, overcome ongoing production problems, and endorse a more efficient and cost effective operation.

Activities:

Assessment of Materials -

- Measure the properties of reactor materials, components, and structures
- Determine how these properties change with service life because of radiation effects, and how these changes affect reactor life and safety
- Quantify existing and projected safety margins for critical reactor components by applying state-of-the-art fracture mechanics and structural evaluation techniques.

Materials Compatibility and Joining Technology Group

Purpose: The Materials Compatibility and Joining (MC&J) Technology Group of the MTS establishes and maintains the fundamental materials technology base required to meet the needs of current and future SRS missions. The Group projects a long-term technology base across the entire Site to provide experimental materials support to all areas, including reactors, tritium separations, and waste processing. Research areas include environmental degradation of materials, metals joining, high temperature materials, and non-destructive examination technologies. The MC&J Group maintains state-of-the-art facilities to support these types of experimental programs.

Activities:

- Improve and expand on the understanding of the mechanisms of gas and radiation induced environmental degradation so that service life can be predicted and extended
- Develop repair techniques for materials that have suffered service failure
- Improve joining techniques with emphasis on welding so that service life can be predicted and extended
- Develop and demonstrate nondestructive examination methods to improve safety and reliability of SRS processes and products
- Investigate high temperature materials compatibility problems associated with SRS process and possible severe accidents
- Develop a potentially safer fuel, such as a microsphere encapsulated type, for SRS reactors

- Design, construct and operate state-of-the-art experimental facilities for performing:
  - Fracture toughness and other mechanical property measurements
  - Welding and other joining techniques
  - Materials characterization by a variety of techniques including metallography, Scanning Electron Microscopy, Transmission Electron Microscopy, and Thermal Analyses
  - Nondestructive evaluation techniques including coherent optical methods
  - High temperature material compatibility studies.

Materials Applications and Corrosion Technology Group

Purpose: The MTS Materials Applications and Corrosion Technology Group conducts short- and long-term research studies to examine the corrosion behavior of materials and to develop methods for monitoring corrosion. These studies are used to determine the lifetime of equipment and to aid in material selection. The Group is active in studying both low- and high-temperature corrosion processes in a variety of environments ranging from high-purity water to molten salts to reactive gases.

Activities:

- Provide the technical basis for understanding corrosion of materials used for SRS process vessels, storage tanks, and associated piping so that service life can be predicted and maximized while safety is maintained
- Develop and apply advanced techniques to monitor corrosion in SRS process vessels so that materials degradation may be determined in real-time
- Develop and install state-of-the-art corrosion testing laboratories to determine materials degradation in simulated SRS environments
- Develop the technology required to support materials selection and design for the New Production Reactor (NPR) to ensure safe startup and operation.

Fabrication Technology and Operations Support Group

Purpose: The Fabrication Technology and Operations Support (FT&OS) Group of MTS supports development work for reactor fuel and target fabrication and performs experimental studies in support of reactor safety.

Activities:

- Perform experimental studies in support of reactor safety - an example is the study to determine the reaction of reactor internal components to potential accident scenarios
- Develop new fabrication technologies for the production of fuel and targets - an example is the fabrication of fuel tubes utilizing the metallurgy process
- Evaluate present fuel and target production methods for potential enhancements - an example is the reduction/elimination of the use of lubricants during fuel tube fabrication
- Develop and fabricate full-size prototype equipment that is subsequently transferred to other production areas at SRS - an example of this prototypical equipment is the process to chemically dissolve rejected fuel tubes manufactured by the powder metallurgy process and reclaim the uranium oxide.

Fabrication Laboratory

The main facility of the FT&OS Group is the Fabrication Laboratory. This laboratory is a large open shop with sufficient space and equipment to support most manufacturing activity studies along with experimental studies related to reactor safety. Unique equipment that was originally installed for a specific task is available for different support activities. Examples of available equipment include:

-Glove boxes with equipment for pulverizing, sieving, characterization, and blending of radioactive powder
-A 12x36-in., 30,000-PSI cold isostatic press within a glove box for powder metallurgy fabrication of fuel elements, and other high pressure experimental work
-An inertia welder for end cap welding on target elements
-A 500-ton extrusion press for development of die design and lubrication studies, and for extrusion of small fuel elements
-A 400,000-pound tensile testing machine for both compression and tensile tests
-A 300-ton Forge press
-A 6-in. cold rolling mill
-Numerous furnaces with maximum temperature capability up to 1200ºC and size up to 2x3x6 ft
-A radiographic machine
-A crop shear with a capacity of up to 3 in. for non-ferrous metal.

REACTOR SAFETY RESEARCH SECTION

The Reactor Safety Research Section (RSRS) is an analytical and research organization. It is engaged in wide-ranging analyses and probabilistic risk assessments of potential effects of accidents and severe hazards associated with SRS reactor facilities, processes, and control, to ensure continuing reactor safety. RSRS is divided into five R/D Groups, staffed by approximately 60 professional engineers, physicists, and chemists. RSRS operates several small laboratories and frequently uses other laboratory facilities at SRS and off-site.

Mission: RSRS will expand the technological understanding of SRS reactor operation by

- Providing probabilistic risk assessment
- Providing oversight and preparation of reactor safety documentation
- Analyzing the consequences of hypothetical core-melt and other severe accidents
- Developing an integrated approach to reactor accident management to ensure the safe operation and control of SRS reactor facilities and processes.

Safety Analysis Group

Purpose: The RSRS Safety Analysis Group conducts R/D for additional or improved facilities to provide support for programs designed to increase reactor safety. The Safety Analysis Group's major functions are transient accident analysis, severe accident modeling and experimentation, accident management, equipment qualification, and functional analysis.

Activities:

Transient Analysis -

- Defining and licensing of methods, models, and safety analysis standards used in the non-LOCA safety analysis
- Performing safety analyses of non-LOCA plant transients for initial licensing and/or subsequent reload cores and various system design changes
- Interfacing with DOE and other regulatory bodies and other WSRC Divisions in the specification and defense of WSRC safety systems
- Defining plant technical specifications and associated set-points that reflect operating limits that remain within the bounds of the plant non-LOCA safety analysis assumptions.

Analysis of Reactor Core Melting and Other Severe Accidents -

- Develop state-of-the-art analytical models of severe accident senarios
- Conduct fuel melting experiments to expand the basic understanding of severe accident phenomena and chemical kinetics of melting
- Perform bounding calculations on fission product release and transport from potential fuel melts
- Compare alternate methods to improve the airborne activity confinement system (e. g., internal containment, remote storage, low temperature adsorption, containment domes)
- Develop improved methods for reactor room sealing
- Measure air flow and distribution through reactor ventilation systems, and perform experimental work to determine aerosol deposition.

Develop Integrated Approach to Reactor Accident Management -

- Analyze severe accidents and off-site dose response, integrating the results into a workable accident response plan
- Evaluate design alternatives and operational changes as they affect accident response
- Aid in emergency procedures development and training.

Study the Response of Equipment to Accident Phenomena (Equipment Qualification) -

- Develop justification for interim operation from Equipment Qualification (EQ) perspective
- Develop long term EQ program commensurate with commercial industry standards
- Develop zone maps that address normal and harsh environmental conditions and design basis transients
- Develop EQ equipment lists.

Provide Functional Requirements and Design Basis Acceptance Criteria Functional Analysis and Thermal Hydraulics -

- Principal activities center around plant control system functional designs, best estimate transient analyses, defining functional performance requirements of selected systems and components, and support in verification of control system and plant responses
- Perform analytic and experimental thermal-hydraulics modeling to support the non-LOCA transient analysis
- Analyze control system responses and select system setpoints - this generally involves special plant and controller models suitable for efficient parametric studies
- Develop and improve non-LOCA thermal-hydraulic acceptance criteria.

Reactor Risk Assessment Group

Purpose: Using probabilistic risk assessment (PRA) techniques, the Reactor Risk Assessment Group (RRAG) studies reactor facilities and system components in response to a range of potential accident phenomena. The objective is to identify areas of greatest relative weakness so that efforts can be focused on the most efficient and cost effective paths to increase the reliability of reactor facilities and systems. In addition, the RRAG is developing a measure of the risk of SRS reactor operation that can be assessed by the reactor technical and regulatory community. The Group uses existing methodology where appropriate, and modifies or develops other computer-based tools as necessary.

Activities:

Probabilistic Risk Assessment -

- Define accident initiating events and generate event trees and fault trees to analyze external events (e.g., earthquake, fire), recovery from abnormal conditions, event sequence, equipment reliability, human reliability, and other phenomena
- Employ and extend existing computer codes (e.g., FLOOD, NRC-145-2, MACCS, KENO, GASPAR, AXAIR, GRASS, SHIELD/GLASS, AA3/HMTABLE, CONTAIN, CORCON, CONTEMPT4, FTAP/Importance) and develop new codes to determine the characteristics, performance, and risks of various phenomena associated with SRS reactor operation
- Perform full-scope PRA using a base case, and conduct sensitivity studies against the base case of proposed reactor system modes, safety system improvements, system additions, and other changes.

Reactor Safety Control Group

Purpose: The Reactor Safety Control Group develops safety requirements and maintains the major technical documents associated with reactor safety, i. e., Technical Standards and Specifications, the Safety Analysis Report (SAR), etc. The documents provide for continuing control of reactor operations to ensure that safety dominates over all other considerations.

Activities:

Oversight and Preparation of Reactor Safety Documentation -

- Develop, update, and maintain basic reactor safety control documents such as Technical Specifications and the SAR
- Evaluate and coordinate SRL participation in development and review of reactor safety-related documents.

Develop Safety Bases for SRS Reactor Operations -

- Develop functional safety requirements for SRS reactor systems and equipment
- Develop regulatory (licensing) technical position papers for the SRS reactor process
- Integrate various ongoing reactor safety projects at SRS.

Human Factors -

- Maintain a human factors development center for SRS reactors and other technical processes.

Risk Application Group

Purpose: The Risk Application Group provides customer-oriented services with probabilistic risk assessment (PRA). A wide variety of short-turnaround assessments is available for reactor operations.

Activities:

Probabilistic Risk Assessment -

- Maintain and defend PRA credibility
- Evaluate proposed changes in reactor hardware and software
- Provide importance and failure data for reactor reliability-centered maintenance support
- Provide PRA support to Severe Accident Management Program
- Guide severe-accident training on the Reactor Simulator
- Provide PRA guidance for New Production Reactor design.

Source Term Evaluation Group

Purpose: The Source Term Evaluation Group (STEG) is a new RSRS initiative. STEG ensures that operational, design basis, and severe accident radiological source term and resultant dose estimates are evaluated in a consistent and technically defensible manner with appropriate methodologies. There are five functional areas or sub-programs performed by STEG: design basis events (DBE) assessment; consequence assessment; emergency preparedness support; phenomenological issue analysis; and occupational dose assessment.

Activities:

- Preparation of the radiological source terms and subsequent dose analysis, including analysis of liquid pathways dose
- Identification of appropriate dose criteria for comparison against the elevated doses
- Calculation of population doses, health effects, and economic consequences due to postulated severe accidents as part of the Level 3 probabilistic risk assessment (PRA) of reactor operation - these analyses are required to complete revisions to the PRA to support safe restart of SRS reactors with minimal risk to the general public and As Low As Reasonably Achievable (ALARA) doses to onsite workers
- As methods improve for best-estimate prediction of dose and health effect consequences due to SRL and national laboratory advances in models, implement these tools in a timely manner to update the onsite and offsite risk documentation
- As new epidemiological studies are reported, review these studies for potential revision to health effect models used in PRA
- Support modification efforts to revise the source term code used in emergency response at SRS; the WIND System developed by the Environmental Technology Section of SRL uses the source term to predict downwind dose for emergency response decision-making; the source term code package is a critical element in demonstrating Site readiness and is fundamental for assuring SRS reactor restart
- Revised and technically defend postulated steam explosion analysis in a severe accident context - these assessments are updated for Reactor Risk Assessment and the Severe Accident Analysis assessments as new data and improved methodologies are developed
- To ensure ALARA incorporation in an operating configuration, develop new methods to predict doses to onsite workers
- To meet ALARA in a mode consistent with commercial reactor operation, develop radiological source terms and revise mitigation approaches as the reactor plant configuration is upgraded.

NPR DEVELOPMENT SECTION

Of several Groups in the NPR Development Section, the NPR Thermal Hydraulics Group is most closely related to nuclear engineering R/D activities and is described below.

NPR Thermal Hydraulics Group

Purpose: The New Production Reactor (NPR) Thermal Hydraulics Group will develop the thermal-hydraulic data and analytical capabilities required to support the NPR designers and to provide supporting technology to generate an adequate SAR.

Activities:

- Develop methods for qualifying the heavy water NPR design for Loss of Cooling Accidents (LOCA) and other design basis accidents
- Perform experiments for code benchmarking and validation
- Develop transient thermal-hydraulic codes to support the SAR.

REACTOR SAFETY EVALUATION SECTION

The Reactor Safety Evaluation Section (RSES) is involved in all activities important to the safety of the SRS reactors or to the components to be introduced into the reactors. Reactor safety pertains to all activities involving risk for health and safety of the public or operating personnel, the environment, and long-term operational continuity. RSES is staffed with about 25 senior-level engineers. In general, each staff member is involved in all RSES functions. The Section is divided into four groups: Surveillance; Assessment; Regulatory Compliance; and Major Programs.

Mission: To review, evaluate, and analyze existing SRS production reactor systems and processes to

- Highlight those programs and activities that are contributing substantially to safe reactor operation
- Identify opportunities for enhanced safety and reduced the risk from reactor operation
- Develop recommendations for improving the effectiveness and quality of reactor operation and related safety programs
- Apprise corporate management of the status of reactor safety
- Provide independent oversight of reactor safety activities.

Activities:

- Monitor reactor operations on a daily basis with formal, written reports issued periodically to corporate management
- Investigate significant events to identify root causes and recommend follow-up action
- Monitor the experience and practices of the commercial nuclear industry and transfer important lessons learned and recommended practices to reactor personnel at SRS
- Develop improved tools for analyzing operating experience and information to identify trends and patterns that may signify opportunities for improvement
- Perform topical reviews of major functional areas
- Conduct performance-based assessments of operational activities
- Review and provide concurrence with important safety documentation and revisions thereto.

Resources:

Certain RSES personnel maintain up-to-date knowledge of NRC and industry requirements, standards, and issues that apply to commercial nuclear reactors, as well as DOE requirements and standards, Those personnel serve as an important information resource for other SRS staff.

RSES maintains a computer-based data bank for SRS Reactor Event Reports. The data bank contains information on over 3000 reactor events. It can be accessed from the SRS computer local-area-networks to analyze and assess trends in operating experience data.

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