Lessons Learned from Sandia National Laboratories' Operational Readiness Review of the Annular Core Research Reactor (ACRR)

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Abstract

The Sandia ACRR (a Hazard Category 2 Nuclear Reactor Facility) was defueled in June 1997 to modify the reactor core and control system to produce medical radioisotopes for the Department of Energy (DOE) Isotope Production Program. The DOE determined that an Operational Readiness Review (ORR) was required to confirm readiness to begin operations within the revised safety basis. This paper addresses the ORR Process, lessons learned from the Sandia and DOE ORRs of the ACRR, and the use of the ORR to confirm authorization basis implementation.

Introduction

Historically, the ACRR, a 2MW pool reactor fueled with UO_2BeO, has been used to support R&D activities for the DOE-Defense Programs (DP) weapons program, Nuclear Regulatory Commission (NRC) safety experiments, and other DOE nuclear development programs. These uses primarily involved pulse and steady state operations for irradiating experimental apparatus located in a dry central cavity or several out-of-core cavities. The ACRR was modified to eliminate the pulse mode of operation and to replace the dry central cavity with a water-moderated grid to allow irradiation of enriched uranium targets from which specific fission products, such as ^{99}Mo, are subsequently extracted for use in medical diagnosis and treatment.

The DOE determined that an Operational Readiness Review[1] was required based on the modifications and the change of mission. The purpose of an ORR is to independently verify that the system being started up is "constructed" per the approved design; can be operated safely; will be operated, maintained, and supported by trained and competent personnel; is designed and operated in accordance with applicable regulatory and corporate requirements; will be operated with acceptable risk to employees, mission, the environment, and the public; and, that all of these items are properly and adequately documented. The Operational Readiness Review Process involves three major steps: 1. A Management Self Assessment performed by the operating organization; 2. An independent Operational Readiness Review; and, 3. A DOE Operational Readiness Review. DOE advised Sandia that the ACRR ORR would be the first nuclear reactor ORR within the complex, and that they expected Sandia's independent ORR to be broad, in depth and rigorous.

ACRR operational constraints dictated a two-phase ORR. The first phase, which is the subject of this paper, was designed to verify that the modifications to the ACRR that were required to produce medical isotopes had been completed to the approved design and that procedures; operator qualifications and proficiency; and management systems were adequate to ensure operations remain within the authorization basis. The first phase of the ACRR ORR was conducted during March (Steps 1 and 2) and May 1998 (Step 3). The second phase, which addresses the readiness to operate in a full production mode, will be conducted in mid-1999.

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[1] The Sandia ORR was conducted to DOE 5480.31. DOE 5480.31 has been superceded by DOE O425.1. At the time of the ACRR ORR, DOE O425.1 had not been added to the DOE/Sandia Management and Operating Contract. The DOE ORR was conducted to DOE O 425.1.

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The Sandia and the DOE ORR Team Leaders recommended start-up of the ACRR Phase 1 operations once the pre-start findings had been corrected. The combined cost of the management self assessment, the Sandia ORR, and the DOE ORR for the first phase of the ACRR ORR exceeded one million dollars and required nearly six months. This phase of the ORR resulted in DOE approval to commence fuel loading, physics experiments, and sample irradiation.

ORR Process

An ORR consists of four distinct phases: Planning; Self-Assessment; Readiness Review; and, Approval to Operate. The system[2] definition, including requirements; hardware and software design and definition; and, the authorization basis form the bases for the ORR. These elements are coupled with the owner/operator's operations and maintenance procedures and infrastructure to establish the breadth of review. The depth of the review is based on the severity and likelihood of consequences that could affect public or worker health and safety, and/or the environment. It is not the purpose of the ORR to provide a tool for the system owner/operator or management to achieve a state of readiness. Rather, the system is deemed by "ready" by the owner/operator as the outcome of a self-assessment before the readiness review begins. The Readiness Review confirms that the system is indeed ready to operate. The Approval to Operate provides formal confirmation of readiness and the authorization to begin operations.

Planning for the ORR begins during system design. Consideration is given to each of the "Core Requirements" (CRs) shown in Table 1, knowing that the subsequent ORR will assess the system and infrastructure against these Core Requirements. The system owner develops a "Plan of Action" (PoA) that defines how each of the core requirements apply to the system being started-up, and the prerequisites that must be met for the system to be declared "ready to operate". For example, a prerequisite for CR3, "Level of knowledge of the operations support staff", might be: "Operators and Supervisors have completed formal training on the system and have demonstrated understanding of the system including likely anomalies and corrective actions by cold operations or simulation". The PoA also provides a description of the system and its intended function.

The PoA is reviewed and approved the Contractor Operational Readiness Review Team Leader. It is also reviewed and approved by the DOE. The Team Leader prepares an "Implementation Plan" based on the PoA. The Implementation Plan defines how the review team will assess the system and infrastructure against each Core Requirement identified as applicable in the PoA. It also identifies the likely schedule for the ORR; the resources needed, establishes criteria for determining that the system is "ready to operate", and profiles the Team members. Once the system has been constructed, the system owner performs a formal Management Self-Assessment (MSA) to verify that the prerequisites have been met. When all prerequisites have been met, the owner formally declares the system "ready to operate". This action is the last precursor to the independent Readiness Review.

The Readiness Review is performed by a Team comprised of technically knowledgeable persons who are independent from the designers, management, owner, and operators of the system being started-up. The Team Leader oversees and directs the ORR. He or she is responsible for:

1. defining the team membership;
2. reviewing and approving the Plan of Action; preparing and approving the Implementation Plan;
3. planning, conducting, and coordinating the ORR;
4. estimating the level of effort and schedule for the ORR, including milestones;
5. obtaining and distributing the supporting documentation and information needed by the Team (such as design definition and test plans, for example);
6. preparing the ORR report; and,
7. ensuring the completeness, accuracy and quality of the ORR.

[2] "System" means the facility, operation, or activity for which an ORR is required.

Table 1
Readiness Review Core Requirements [3]

1. There are adequate and correct procedures and safety limits for operating the hardware and utility systems.
2. Training and qualifications programs for operations and operations support personnel have been established, documented, and implemented; and encompass the range of duties and activities required to be performed.
3. The level of knowledge of operations and support personnel is adequate.
4. Documentation is in place that describes the operating envelope of the system. The documentation should characterize the hazards and risks associated with the system, and should identify mitigating measures that protect the mission, business, workers, public, and the environment from those hazards/risks. Elements deemed essential to mitigating hazards/risks are defined and a system to maintain control over the design modifications affecting these elements is established.
5. A program is in place to confirm and periodically reconfirm the condition and operability of support systems, utility systems, and elements deemed essential to mitigating hazards/risks. This includes examination of records of tests and calibrations. All systems are currently operable and in a satisfactory condition.
6. A process has been established to identify, evaluate, and resolve deficiencies and recommendations for improvement.
7. A systematic review of the system's conformance to applicable regulatory or Corporate requirements has been performed, and any non-conformance's have been identified, and schedules for achieving compliance have been justified in writing and formally approved.
8. Management programs are established, sufficient numbers of qualified personnel are provided, and adequate facilities and equipment are available to ensure operational support services (e.g.: training, maintenance, waste management, environmental protection, industrial safety and hygiene, radiological protection and health physics, emergency preparedness, fire protection, quality assurance, criticality safety, and engineering) are adequate for operations.
9. A routine and emergency operations, including program records, has been established and implemented.
10. An adequate start-up test program has been developed that includes adequate plans for graded operations testing to simultaneously confirm operability of equipment, software, the viability of procedures, and the training of operators.
11. Functions, assignments, responsibilities, and reporting relationships are clearly defined, understood, and effectively implemented with management responsible for control of safety.
12. The implementation status for DOE order 5480.19, "Conduct of Operations Requirements for DOE Facilities" is adequate for operations.
13. There are sufficient numbers of qualified personnel to support safe operations.
14. A program is established to promote a site-wide culture in which personnel exhibit an awareness of public and worker safety, health, and environmental protection requirements, and, through their actions, demonstrate a high-priority commitment to comply with these requirements.
15. The facility systems and procedures, as affected by facility modifications, are consistent with the description of the facility, procedures, and accident analysis described in the safety basis.
16. The technical and managerial qualifications of those personnel at the DOE Field Organization and at DOE Headquarters who have been assigned responsibilities for providing direction and guidance to the contractor, including the Facility Representatives, are adequate (DOE ORR only).
17. The breadth, depth, and results of the responsible contractor ORR are adequate to verify the readiness of hardware, software, personnel, and management programs for operations (DOE ORR only).
18. Modifications have been reviewed for potential impacts on procedures and training and qualification. Procedures have been revised to reflect these modifications and training has been performed to these revised procedures.
19. The technical and management qualifications of those responsible for system operation are adequate.
20. DOE Operations Office Oversight Programs and Occurrence Reporting, Facility Representative, Corrective Action, and Quality Assurance programs are adequate (DOE ORR only).

[3] DOE O 425.1, "Start-up and Restart of Nuclear Facilities", U.S. Department of Energy, Washington, D.C. 20585, September 1997, pp. 9-11.

Team members must have technical expertise in their area of review and be knowledgeable of evaluation processes and methods, and of the specific system being started-up. The make-up of the team will depend on the complexity of the system and the depth of the assessment as well as the functions to be performed by the system.

Planning, teamwork, and technical expertise and coordination between the DOE ORR Team Leader, operations management, and the independent ORR Team Leader are key for a successful readiness review. As discussed previously, the Plan of Action, the Implementation Plan, the Criteria Review and Approach Documents, and the Lines of Inquiry must be well researched and prepared. The expertise of the review team must be such that the team readily grasps the essence of the system being reviewed, its functions, and design. The team also must work well together and remained focused. Because of the short time for a review, little time can be spent on resolving personality clashes or trivia. The Team Leader must have a broad understanding of assessment methodology, understand the system being reviewed, be skilled in facilitation and negotiation, and be able to use various leadership styles/methods as conditions warrant. Finally, the team must be provided with adequate resources to accomplish their responsibilities. Funding and chain of command for the ORR process should be independent from the system owner or operator to ensure the Team's independence and objectivity.

Each team member prepares a "Criteria Review Approach and Document" (CRAD) that describes how he or she will assess each of the Core Requirements to which they are assigned. The CRAD should be complete enough to allow a subsequent reviewer of the CRAD to follow the Team member's logic and understand the approach used to verify system performance with respect to the criteria. Table 2 describes the topics addressed in a CRAD. They also prepare a "line of inquiry" outline that describes how each interview will be conducted.

Resolving deficiencies identified during the ORR is essential to ensuring that systems can be started-up. Deficiencies identified in each CRAD should be formally reported to the system owner in a "Deficiency Form" (DF), Table 3. The DF summarizes the deficiency and the element of the Core Requirement that led to the deficiency. Deficiencies can be characterized as those requiring correction before start-up (pre-start deficiencies), or those that can be corrected after start-up (post-start deficiencies). Pre-start deficiencies are deficiencies that if not corrected, would substantially impair the ability of the system to meet its design requirements, or which would result in undue risk to mission, business, health, safety, or the environment. Post-start deficiencies are deficiencies that do not substantially impact the ability of the system to meet its design requirements, and do not pose unacceptable risk, but which should be corrected in a timely manner to increase efficiency or to prevent future undesired consequences. Team members may also identify "Observations". Observations can be either positive or negative, and compare what is observed to "good business practice".

Corrective actions are not required for negative observations, but are required for pre-start and post-start findings. A "Deficiency Resolution Form" (DRF), Table 4, is used to record the corrective action to be taken, and documents completion of the corrective action as reviewed by the responsible Team Member and the Team Leader.

A typical ORR for a complex system requires at least two months to prepare and obtain DOE approval of the Plan of Action, one month to prepare the Implementation Plan, two or three weeks in preparation by the Team, one or two weeks to execute the ORR, and a minimum of four weeks to prepare the ORR report and the Recommendation to Start-up after the system owner has corrected all pre-start deficiencies. Note that this sequence is repeated for both the contractor and the DOE ORRs, although some work for the DOE ORR may be done in parallel with the contractor ORR (preparation of the DOE Implementation Plan, for example).

Table 2
Criteria Approach and Review Document[4]

Functional Area: Identify the functional area of the CRAD (e.g.: Quality Assurance; Training; Management Systems).

Core Requirement: List the core requirement being addressed by the CRAD.

Date:

Method of Appraisal: Describe the approach taken for the review.

Personnel Contacted/Positions:

Records/Documents Reviewed:

Operations Observed: Briefly describe the observations personally observed/witnessed.

Discussion: Discuss performance against the Core Requirement criteria.

Issues: Describe the issues that result from the review.

Reviewed by: Identify by typed name and signature of the reviewer(s).

Approved by: The ORR Team Leader signs all CRADs, indicating concurrence with the conclusion and completion of the review.

Table 3
Deficiency Form

Identifier *(a unique identifier assigned to each deficiency)*

Functional Area

Finding Category

Issues (Transferred from the CRAD)

Requirement

References

Discussion

Reviewer signature and date

Team Leader signature and date

[4] Op cit., Appendix 4, pp. 12-13.

Table 4
Deficiency Resolution Form

Identifier

Names of persons responsible for the implementing the corrective action

Performance Objective

Evaluation Criteria

Finding(s)

Corrective Action(s)

Resolution (state the status of completing the corrective action)

Signature of person completing the corrective action and date

Signature of the team member who reviewed and accepted completion of the corrective action

Team Leader signature and date

The ORR Report documents the ORR process as applied to the system to be started-up as well as the deficiencies, corrective actions and conclusions. It is the basis by which Senior Management determines if a system is ready to be started. Hence, it is essential that the Report describe the logic of the approach taken as well as summarize the review activities. Of course, the report must be congruent with the Implementation Plan. An Executive Summary in the Report provides a synopsis of the review, a statement concerning the readiness of the system to start-up and operate throughout its life cycle, and an overview of significant strengths and weaknesses discovered during the ORR [5]. The report should also present differing opinions from any Team Member. The report is presented to Senior Management for review and consideration in determining if start-up should be authorized.

The formal recommendation to authorize start-up is made by the system owner to Senior Management. The documentation includes a description of uncorrected post-start deficiencies and the actions to be taken for correction (including schedule and resources) as well as a statement of readiness to start. If Senior Management agrees that the system is ready to start operations, a formal request is made to the DOE for approval to begin operations. This request initiates the DOE ORR.

The DOE ORR follows the same process as the independent internal ORR. The DOE ORR includes reviewing the readiness of the DOE to provide oversight of the system and a review of the completeness and adequacy of the internal independent ORR. The outcome from the DOE ORR is a report and formal recommendation (if appropriate) to the DOE/HQ authority for start-up. The DOE approval authority then authorizes start-up to the Senior Management of the system operations.

ACRR ORR

Facility Mission

The ACRR has been used to support R&D activities for the DOE/DP weapons program, NRC reactor safety experiments and other DOE nuclear development programs. The ACRR is a Hazard Category 2 Nuclear

Reactor Facility[5].. The reactor has no safety-critical structures, systems, or components.[6] Conversion of the ACRR from its historic use to medical isotope production will not measurably increase the risk to the public or the environment.[7]

For the ^{99}Mo production process, fission targets are prepared at Los Alamos National Laboratory by plating enriched uranium on the inner wall of hollow stainless steel tubes. The targets are then transported via truck to SNL where they are inspected and placed in temporary storage. As needed, targets are removed from storage and placed in the central core grid of the ACRR where they are irradiated for approximately seven days. The neutron irradiation produces a number of fission product isotopes. Using a shielded cask, irradiated targets are transferred to the adjacent Hot Cell Facility (HCF) for processing. Processing involves chemically dissolving the fission products and extracting isotopes of interest (^{99}Mo being the primary product). After packaging in transportable shielded casks, the product is ready for shipment via air-freight to a radiopharmaceutical company. At the HCF, the remaining fission products and other processing waste materials will be solidified and stored for approximately one year to allow decay of fission products. After adequate decay, wastes will be transported to an off-site waste repository for final disposition.

Facility Description

As shown in Figure 1, the ACRR Facility consists of the nuclear-fueled core in a reactor pool, reactor high bay and low bay, control room, equipment pit, cooling tower and support/experimental subsystems. The high bay is shared with the Gamma Irradiation Facility (GIF), which encompasses the east half of the high bay.

The ACRR is a water moderated and reflected low power research reactor using an enriched driver fuel of UO_2 - BeO. As shown in Figure 2, the reactor core is located near the bottom of a 3-m diameter, 9-m deep open water pool, which provides natural convection cooling and radiation shielding. A dry irradiation cavity was located in the center of the annular core where the neutron flux levels are highest. Experiments were installed into the central cavity using the vertical and offset loading tubes. The central cavity and loading tubes have been removed as part of the modifications to convert the ACRR for the medical isotope production mission.

The 5-meter deep Gamma Irradiation Facility (GIF) pool is adjacent to the ACRR pool. The GIF pool stores Cobalt-60 sources for gamma irradiation experiments. Pass-through ports between the pools provide a means to transfer irradiated fission targets underwater from the ACRR pool to the GIF pool where they can be loaded into a submerged shielded cask for transfer to the Hot Cell Facility.

The ACRR high bay is a large, dedicated usage building constructed of concrete block walls and a metal roof. It provides a confinement structure for the ACRR. Two ventilation systems remove air from the reactor confinement, one system dedicated to the high bay and the second system to the experiment spaces of the reactor. The high bay exhaust is equipped with a HEPA filter and the experiment exhaust (also known as the cavity exhaust) is equipped with both charcoal and HEPA filters.

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[5] DOE-STD-1027-92, *DOE Standard, Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports*, U.S. Department of Energy, Washington, D. C., December 1992

[6] *Safety Analysis Report for the Annular Core Research Reactor Facility (ACRRF)*, SAND93-2209, Sandia National Laboratories, Albuquerque, New Mexico, June 1996; Technical Safety requirements for the *Annular Core Research Reactor Facility (ACRRF)*, SAND98-0051, Sandia National Laboratories, Albuquerque, New Mexico, January 1998.

[7] *Medical Isotopes Production Project: Molybdenum-99 and Related Isotopes Environmental Impact Statement,* U.S. Department of Energy, April 1996; *Medical Isotopes Production Project: Molybdenum-99 and Related Isotopes Record of Decision*, U.S. Department of Energy, September 1996.

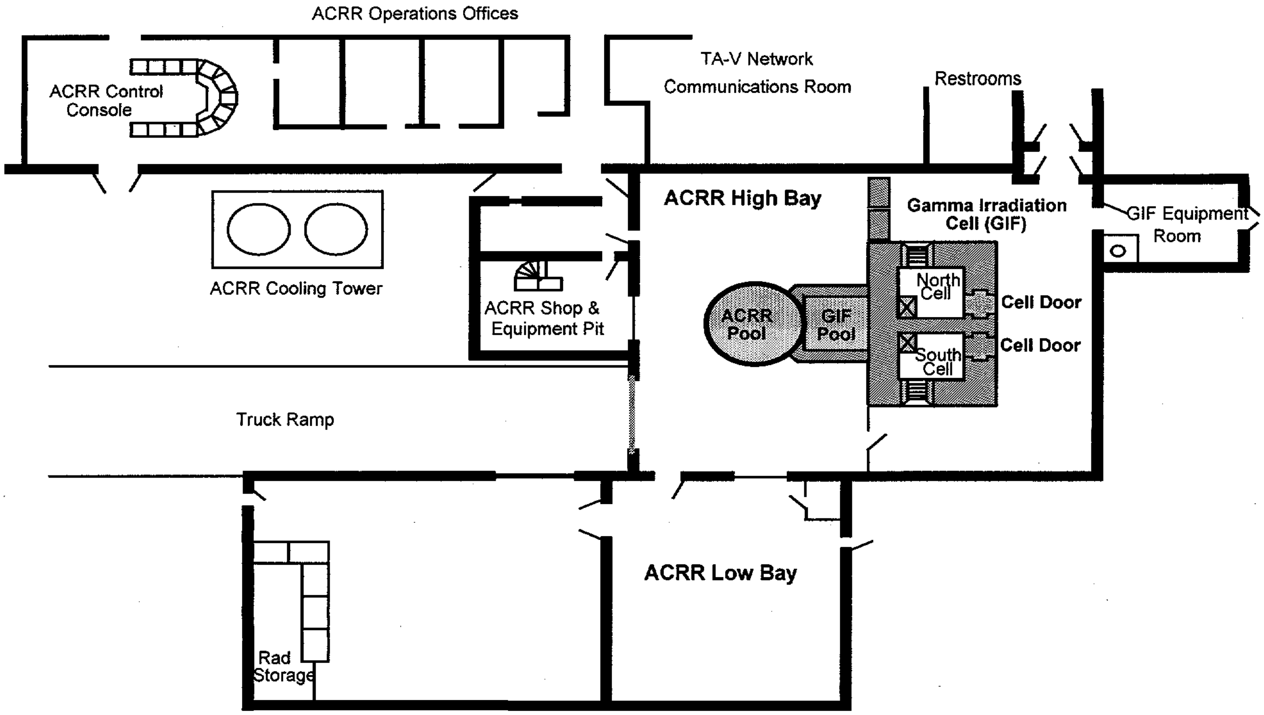

Figure 1. ACRR Facility Floor Plan.

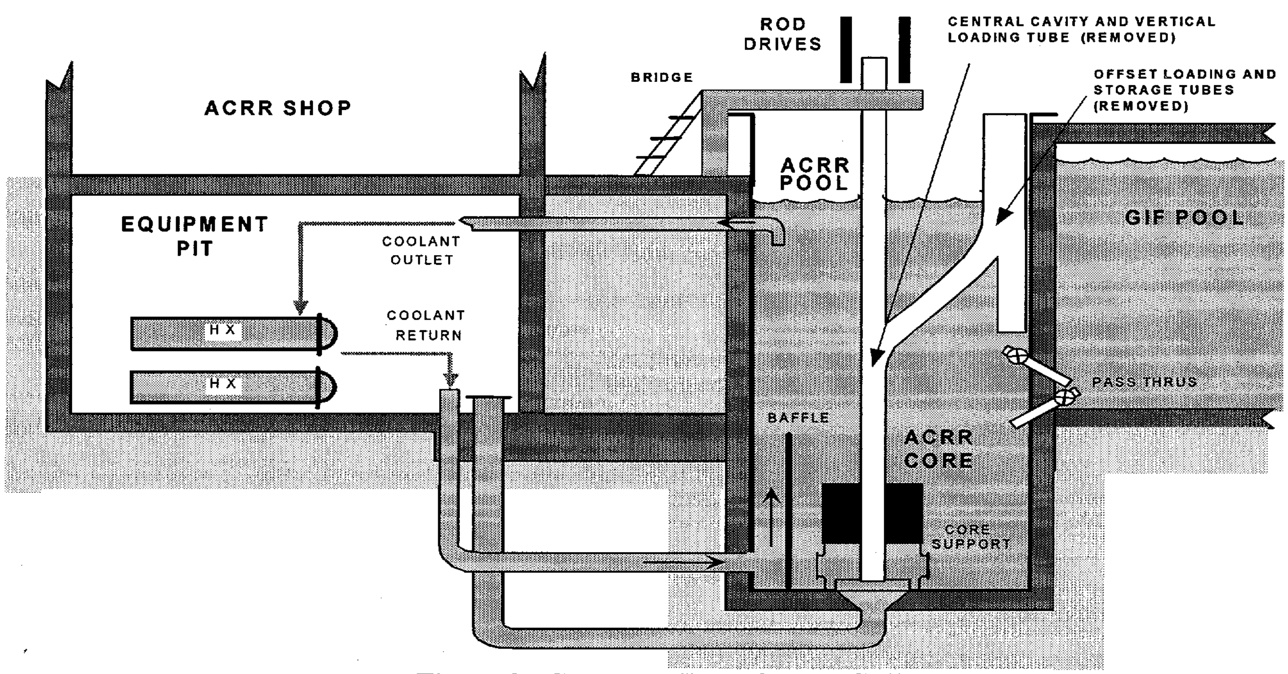

Figure 2. Cutaway View of the ACRR.

Core Modifications for Medical Isotope Production

The core modifications to convert the ACRR to medical isotope production involved removing the central irradiation cavity, vertical loading tube, and offset loading tube shown in Figure 2. These changes allow insertion of a target grid into the central region of the core where the central dry cavity was located. Figure 3A shows the original core configuration with the dry central cavity and Figure 3B shows the new configuration with fission targets installed in the central target grid. Two central target grids have been designed: one with 19 target locations designed to optimize fission in the targets, and a second with 37 target locations to maximize the number of targets which can be irradiated at a time. For both target grids, solid aluminum dummy targets will normally be located in empty locations to displace the moderator and reduce localized power density.

The ACRR has historically been operated in two modes: (1) steady state power runs of up to 4 MW for short duration (on the order of hours), and (2) fast, high-power transients (pulses) lasting less than a second. The peak yield for pulse operations was approximately 300 MJ. For medical isotope production, the pulse mode has been physically disabled to prevent any possibility of inadvertently damaging ^{99}Mo targets with a large reactor pulse.

Phase 1 of the ACRR ORR

The Sandia Phase 1 of the Annular Core Research Reactor Operational Readiness Review assessed the readiness to refuel the ACRR, perform physics tests, and irradiate sample fission targets safely in support of the DOE medical isotope production mission. An Operational Readiness Review was requested by DOE because substantial changes were made to the ACRR that required changing the safety basis prior to initiating medical isotope production. The ORR was conducted in accordance with DOE 5480.31, *Startup and Restart of Nuclear Facilities*, and Supplemental Directive AL 5480.31, *Startup and Restart of AL Facilities, Activities, and Operations*, and the guidance established in DOE Standard DOE-STD-3006-93, *Planning and Conduct of Operational Readiness Reviews.* The ORR focused on the 17 minimum core requirements applicable to contractors. A Plan of Action approved by the DOE was executed in the Phase 1 ACRR ORR Implementation Plan that guided the SNL ORR.

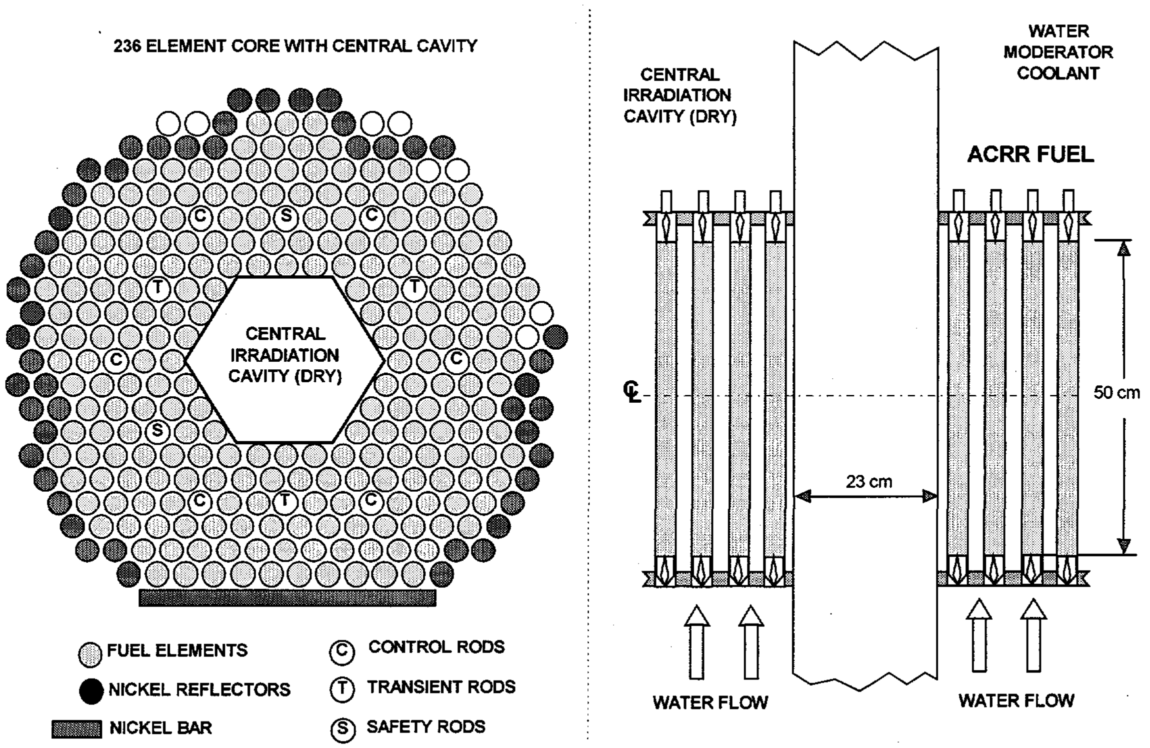

Figure 3A: Core Configuration for DOE DP Programs.

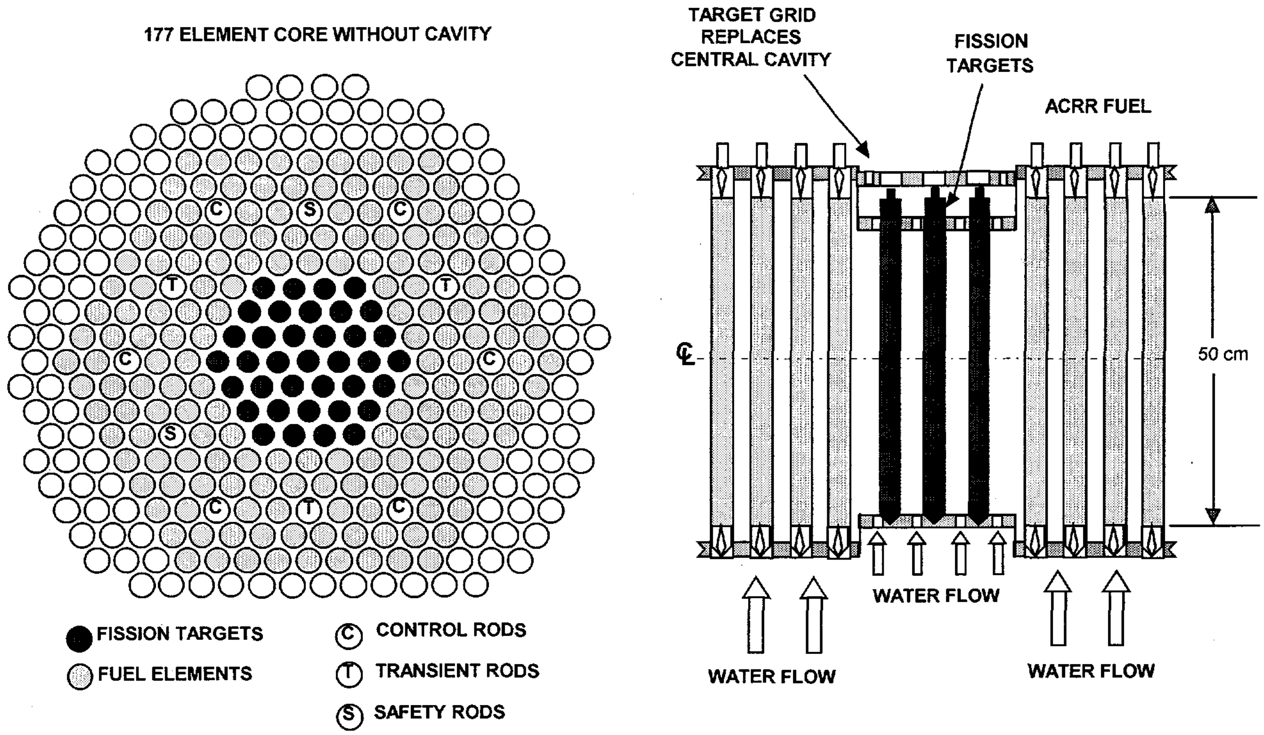

Figure 3B: Core Configuration for Medical Isotope Production.

The first phase of the ACRR ORR was designed to verify that the modifications to the ACRR to support medical isotope production were completed according to the approved design; and that procedures and operator qualifications and proficiency are adequate to ensure operations remain within the authorization basis during fuel loading, physics experiments, and sample target irradiation, including target receipt, and storage. During Phase 1 operations, the ACRR will be operated as an R&D facility similar to its historic role. The primary activities will be research, evaluation, and development of the reactor as a production facility for medical isotopes. Because it is not feasible to project all of the planned activities necessary to accomplish this goal, the existing processes for experiment plans, test procedures, and USQDs have been (and will be) used to evaluate the safety of all proposed activities and/or tests. These processes are well established and executed.

The authorization basis for Phase 1 fuel loading and physics experiments consists of the approved ACRR SAR and TSRs and a negative Unreviewed Safety Question (USQ) for the modified 19 fission-target grid configuration containing solid aluminum dummy targets. At the time of the Sandia ORR, the USQ for fission target irradiation was not complete. DOE agreed to carry this pre-start finding from the Sandia ORR forward to their ORR as a pre-start finding for sample target irradiation.

A second phase of the ACRR ORR will be conducted after Phase 1 operations are complete. This second phase of preparing for full production of medical isotopes consists of scale-up of ACRR capacity. The ACRR is expected to operate 24 hours-per-day, for various cycle lengths. The second phase of the ACRR ORR will be done to verify that the infrastructure, support programs, and staffing of qualified and proficient personnel are adequate to operate the ACRR for continuous medical isotope production. The Phase 2 ORR will be completed prior to full production operations. The authorization basis for Phase 2 will consist of a revised SAR and revised TSRs developed specifically to support high-volume medical isotope production

Sandia ORR

The Sandia ORR concentrated on three functional performance areas: Structure, System, and Component (SSC) Readiness; Management and Personnel Readiness; and, Program and Procedure Readiness. Interfaces between ACRR and TA-V-specific policy, programs, and procedures and SNL Corporate policy, programs and infrastructure were reviewed as appropriate to Phase 1 ACRR operations.

Structure, System, and Component Readiness

The ORR assessed whether or not the ACRR structures, systems, and components that have been reconfigured for medical isotope production can be operated safely within the authorization basis. Verification was done using equipment and system walk-downs, interviewing personnel responsible for the operation and maintenance of SSCs, and reviewing various types of SSC documentation including, but not necessarily limited to, modification, inspection, and maintenance records, procedures, and specifications, as well as the Phase 1 authorization basis documents. The following SSCs were reviewed:

- Reactor
- Reactor Control System
- Plant Protection System
- Reactor Ventilation System
- Radiological Protection System
- Fuel Element and Target Transport, Handling, and Storage Systems.

Management and Personnel Readiness

The ORR also assessed ACRR management, operations, and support personnel's ability to safely load fuel into the ACRR, and their capability to load the ACRR to critical and perform the Phase 1 physics experiments and sample target irradiation in a safe manner. This verification was accomplished by reviewing the qualifications, training and proficiency of ACRR management, operations, and support personnel, and ensuring that adequate staffing is available for safe startup and Phase 1 operation.

Management and Personnel Readiness was evaluated by:

- Reviewing training and qualification records of management, operations, and support personnel;
- Interviewing personnel to confirm they possess sufficient knowledge and understanding of their respective disciplines and duties to perform the Phase 1 operations;
- Interviewing personnel to confirm they possess sufficient knowledge and understanding of ACRR management programs (e.g., policies, procedures, and plans) and, as appropriate, SNL management programs and DOE Order requirements;
- Observing, as appropriate, the performance of personnel in their respective disciplines and duties through system and procedure walk-downs, drills, and exercises; and,
- Reviewing interfaces between ACRR management, operations, and support personnel with non-ACRR organizations, where appropriate, to ensure that clear lines of authority are established and understood by all personnel.

Program and Procedure Readiness

The ORR assessed whether or not programs and procedures have been developed and implemented to ensure that the ACRR can safely commence operations and continue to operate in a safe manner in performing the Phase 1 operations. Elements reviewed include:

- Safety Review process;
- Fuel and Target Loading plans, procedures, and checklists;
- Physics experiment and target irradiation plan, procedures, and checklists;
- Personnel training and qualification;
- Configuration Management;
- Maintenance;

- Environmental Protection and Waste Management;
- Occupational Health and Safety;
- Fire Protection and Life Safety;
- Emergency Preparedness;
- Quality Assurance and Conduct of Operations; and,
- Radiological Control.

ORR Team

The Sandia ORR Team was comprised of fourteen persons experienced in nuclear safety, radiation protection, risk assessment, environment, safety, health, quality assurance, human factors, emergency management, production operations and procedures, conduct of operations, and readiness assessments. The Team reviewed past occurrences involving the ACRR for corrective actions in progress or planned that could impact the ability to load fuel or perform the Phase1 physics experiments or target irradiation. The Team also reviewed the ACRR Management Self-Assessment to verify completion of prerequisites to the Phase 1 ORR on a sample basis. The performance objectives and review approaches were developed using a graded approach and were based on the combined expertise of the team members and DOE Orders, SNL and ACRR requirements and guidance documents, the potential hazards associated with ACRR operations, and the advice of internal and external review groups.

Each member of the Phase 1 SNL ORR Team was assigned to one or more of four sub-teams. The teams were organized to address the Minimum Core Requirements (MCRs)[8] by functional area. The Teams were:

- SSCs, Authorization Basis, Procedures (MCRs 1, 4, 10, 15, 18)
- Quality Assurance (MCRs 5, 6, 12, 14)
- Management and Staffing (MCRs 2, 3, 7, 8, 11, 13, 18, 19)
- Emergency Preparedness (MCR 9).

The sub-teams developed Criteria Review and Approach Documents and Lines of Inquiry that guided their assessments. Assessments were performed by a variety of methods including:

- equipment, system, and procedure walk-downs
- interviewing personnel responsible for management, operation, maintenance, and support functions
- reviewing documentation such as modification, inspection, and maintenance records, procedures, and program documents as well as the Phase 1 authorization basis documents.
- reviewing the qualifications, training and proficiency of ACRR management, operations, and support personnel.

ORR Execution

The SNL Phase 1 ORR did not review SNL Corporate policy, programs, and infrastructure outside the context of Phase 1 ACRR operations because they were reviewed in detail in June 1997 by DOE/EH and action plans were developed to correct the deficiencies found. In addition, the DOE/KAO Facility Representatives (FRs) annually produce a Performance Assessment Matrix that identifies weaknesses in Sandia Corporate and site-specific policy, programs, procedures, and infrastructure. The combination of the DOE/EH assessment and the ongoing, daily FRs assessments provide an adequate benchmark that enabled the Phase 1 ACRR ORR to focus on ACRR and TA-V policy, programs, and procedures. In addition, the Sandia ORR excluded any consideration of readiness of the ACRR to support Phase 2 (production operations).

Daily team meetings were held in which team members discussed their activities, observations, and issues that resulted from their work that day. The ORR Team Leader, in consultation with the appropriate team

[8] As defined in DOE Order 5480.31, *Startup and Restart of Nuclear Facilities*, U.S. Department of Energy, Washington, D. C., September 15, 1993.

member(s), determined whether issues identified during the review had potential to be categorized as pre-start or post-start findings, or whether they constituted concerns or observations. The team leader also briefed ACRR Operations Management each day on the potential findings, observations, and issues identified by the team, thereby providing an opportunity for immediate verification of the factual accuracy of the Team's conclusions.

The field review resulted in 25 deficiencies of which 8 were categorized as pre-start findings and 6 as post-start findings. Pre-start findings were grouped into those pertaining to fuel loading and physics testing, and those pertaining to target irradiation. Post-start findings concerned program and documentation deficiencies.

Concerns, observations, and strengths were also identified during the review. "Concerns" is a category developed by the Sandia Team to delineate issues that do not involve non-compliance, but that may have a potential adverse impact on safety, mission, or public perception. Observations do not involve non-compliance, but are deviations from good business practice. Concerns and observations do not require corrective action plans. The Sandia Team identified 4 concerns and 6 observations.

Strengths noted include a strong safety review process and the high level of knowledge and dedication of the ACRR staff and management. The Sandia ORR Report[9] was issued on April 9, 1998. The field review began on March 2, 1998.

DOE ORR

Prior to the DOE ORR, the local area office conducted a review such that they could certify to the DOE ORR Team Leader that the area office was ready to meets its obligations to provide management and oversight to Sandia's Phase 1 operation of the ACRR, and that Sandia was indeed ready to begin operations (as evidenced by the completion of the Sandia ORR and closure of the resulting pre-start findings).[10] The area office review was completed one month after release of the Sandia ORR Report..

An eighteen-member team conducted the DOE ORR[11]. It was conducted according to an implementation plan[12] that focused on the facility modifications, safety basis implementation, safety programs, and the reactor operators and other personnel responsible for ACRR operations and maintenance. DOE O 425.1, "Startup and Restart of Nuclear Facilities", and DOE-STD-3006-95 provided the guidance for the DOE ORR. Ten functional areas were evaluated by the DOE Team: Conduct of Operations, Maintenance, Configuration management, Safety Basis, Systems Engineering, Training and Qualification, Industrial Safety, Radiological Protection, Management and Organization, Quality Assurance, Emergency Preparedness, and Sandia's Operational Readiness Review. These ten functional areas were assessed via 46 objectives and 191 acceptance criteria.

In contrast to the Sandia ORR, which was specifically limited to fuel loading and physics experiments, the DOE ORR also identified actions that needed to be taken for Sandia to begin production operations. The DOE ORR identified seven pre-start findings (one was rolled-up form the Sandia ORR), one pre-target irradiation

[9] Sandia National Laboratories "Annular Core Research Reactor (ACRR) Building 6588 Operational Readiness Review Report for Phase 1 Fuel Loading, Physics Experiments, and Sample Target Irradiation, Medical Isotope Production", April 9, 1998.

[10] Memo, "Kirtland Area Office's Recommendation to Initiate the DOE Operational Readiness Review of the Annular Core research Reactor at Sandia National Laboratories", DOE/KAO, May 8, 1998.

[11] U. S. Department of Energy: "Operational Readiness Review of the Annular Core Research Reactor, Technical Area V, Sandia National Laboratories, Albuquerque, New Mexico, Phase 1 Report", June 1998.

[12] U.S. Department of Energy: "Operational Readiness Review Implementation Plan for the Restart of the Annular Core Research Reactor", April 1998.

finding (which was rolled-up form the Sandia ORR), nineteen pre-phase 2 findings (one of which was assigned to DOE, and three of which were rolled up from the Sandia ORR), and three post-phase 2 findings.

The DOE ORR Report stated that, "the SNL ORR was, for the most part, comprehensive and addressed all of the core requirements of the Order". However, the DOE team found difficulty in determining the overall completeness of the Sandia ORR because Sandia addressed each of the Core requirements as a separate functional area. The DOE Team stated that this approach "also resulted in a cursory review of some areas important to safety that are generally included, but not stated explicitly in the core requirements (i.e., the design process and specific quality standards for the in-core modifications)". The DOE also stated that the SNL ORR Report provided a "fragmented, and in some cases, incomplete picture of the readiness of a specific functional area to support restart of reactor operations". Comments were also made regarding the "concerns" issue category that Sandia used. DOE took issue with not categorizing non-compliance, but safety-related issues as other than "findings". In an overall verbal assessment, the senior representative from DOE Headquarters stated that the SNL ORR was the most comprehensive and thorough contractor ORR he had seen.

The DOE concluded that the "SNL ORR adequately addressed the core objectives of the Order and provided good assessment and validation of the ACRR to safely restart" after interviewing several of the SNL ORR Team members.[13] The DOE field review began on May 11, 1998. The DOE ORR report was issued on June 11, 1998.

Lessons Learned

The ACRR readiness review produced several lessons learned concerning team organization and management, interface with the system owner and between the DOE and Sandia Team Leaders, the ORR process, and report preparation. The following lessons learned are a combination of those learned during the Sandia ORR and those learned during the DOE ORR.

<u>Team Organization and Management</u>

- Team members and their management must understand that being a member of the ORR team is a full time job for some period of time before the ORR, during the ORR, and until the final report is issued (for the ACRR ORR, 6 weeks).
- Team members must prepare the record of their review as the review is conducted.
- The Team should evolve a consistent approach to interviews.
- Flexibility on the part of the Team is essential because the planned start date may be revised several times as problems are discovered during the owner's self assessment, or duing the Contractor's ORR.
- The Team determined that time spent in Team Building before the ORR would result in better performance by the Team, and would reduce the time spent in resolving differences and issues. Training in interview skills should be a part of the Team Building activities. Because the team is typically comprised of technical experts who may have not worked together before, time and opportunity is needed to establish effective working relationships between the Team members.
- All Team members should receive the DOE Operational Readiness Review training provided by DOE/HQ.
- Administrative support is critical to ORR efficiency and to meeting milestones. Support required ranges from developing a project plan for the ORR, copying documents and making distribution, maintaining calendars for the Team, to technical writing and editing the CRADs, DFs, DRFs, and the ORR Report.
- Assigning Team members to more than one sub-team should be approached with caution, with attention to the skill and expertise of the Team member and the bread and depth of the sub-team's review. It is also important to ensure that each team member clearly understands their responsibilities on the sub-team, and the criteria for which they are responsible.

[13] Op cit., p. 12.

- The factual accuracy of findings needs to be determined quickly after it is determined that a finding exists rather than waiting until all the deficiency forms are completed.

System Owner Interface

- The Team Leader should provide schedules to the system owner for items required to be complete before the ORR starts.
- The Team Leader should insist on documents from the system owner before the ORR starts. Sufficient time must be scheduled between receipt of the documents and the start of the ORR to allow the Team to review the documents.
- Interviews and run–throughs need to be planned and communicated to the system owner at least two weeks before the ORR starts.
- Interview schedules should be based on 20 minutes per interviewer. A one hour interview is sufficient when more that two or three interviewers are involved. At least thirty minutes should be scheduled between interviews to allow for jotting down notes and conclusions.
- Time spent familiarizing the Team with the system and operations is well-spent.
- The facility management and operations staff contribute significantly to the success of the ORR. Although the Sandia and DOE ORR teams outnumbered the ACRR management and operations staff by over 3 to 1, the management and staff was highly rated by both teams for their cooperation, openness, and quick response to issues.

ORR Process

- A "pre-assessment" review performed by the Team Leader to assure that the owner is ready for the ORR would be beneficial in reducing "false starts".
- Programmatic aspects should be reviewed in addition to systems, structures, components, infrastructure, and management systems. Often, programmatic drivers (or the lack thereof) will significantly impact the owner/operator's ability to start-up and operate the system. The Sandia Team did not plan to review the programmatic aspects of the ACRR conversion to medical isotope production, but found during the field review the need to assess the program-driven budget and schedule impact on Sandia's ability to safely start-up and operate the facility.
- Recognize and plan for the resource requirements for the ORR Team. The Sandia Team expended over 3000 hours on Phase 1. The budget for the ORR Team should be separate from the facility owner's budget so as to preserve the independence of the Team.
- The ACRR ORR was schedule-driven. A more realistic schedule for ORRs would:
    - Reduce schedule pressure on the line and the ORR Team by more realistic performance-based planning.
    - Allow adequate time to prepare the ORR report and to close pre-start findings before the DOE ORR begins.

Conclusion

The Phase 1 Operational Readiness Review of the Sandia Annular Core Research Reactor was the first reactor ORR conducted in the DOE Complex, and the first DOE ORR at Sandia. The cost of the ORR exceeded one million dollars and required a concentrated six month effort by the ACRR staff and management, the Sandia ORR Team, the Kirtland Area Office of the DOE, and the DOE ORR Team. Sandia has additional ORRs pending: Phase 2 (production) operations of the ACRR, the Hot Cell Facility, and the Gamma Irradiation Facility. Implementing the lessons learned from the Phase 1 ACRR ORR is expected to result in significant cost reductions for these subsequent ORRs. For example, the Sandia Phase 2 ORR is expected to be accomplished at approximately one-half the cost of the Phase 1 ORR.

Author's Biography

Albert O. Bendure currently manages Sandia's Neutron Generator Production Operations. He previously managed Sandia's Risk Management Department where he developed software-based tools to identify and analyze workplace hazards and was responsible for Sandia's safety analysis and readiness review programs. He is a past member of a U.S. Department of Energy (DOE) Team that developed a risk-based resource allocation process, and was a member of the Environment, Health, and Safety Technical Advisory Board for SEMATECH from 1993 through 1998. Prior to joining Sandia, Mr. Bendure managed radiation-hardened integrated circuit and hybrid microcircuit production for the DOE. He is a past Chair of the Safety Analysis Working Group, and was a member of the SAWG Steering Committee for six years. He presently is a member of Sandia's Nuclear Facility Safety Committee. He is a registered Professional Engineer (California), a Senior Member of the Institute of Electrical and Electronics Engineers, Inc., and holds Bachelors and Masters degrees in Electrical Engineering and a Masters degree in Industrial Safety Management.

James W. Bryson currently manages Sandia's Nuclear Reactor Facilities, the Annular Core Research Reactor and the Sandia Pulse Reactor. He also manages Sandia's Gamma Irradiation Facility and Low Dose Gamma Irradiation Facility. Prior to a variety of management assignments at Sandia, Mr. Bryson was the Sandia liaison from 1983 through 1986 for an interlaboratory team investigating Neutron Vulnerability and Hardness issues for stockpile components. He is presently on the executive committee for the Test Research and Training Reactor organization for non-power reactors, and holds Bachelors, Masters and Ph.D. degrees in Nuclear Engineering from the University of Michigan.