REVIEW OF COMPLETED READINESS ASSESSMENT ACTIVITIES

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The Annular Core Research Reactor (ACRR) is a hazard category II nuclear facility located in Technical Area V at Sandia National Laboratories (SNL). The ACRR is an epithermal pool-type research reactor capable of operating in steady-state or pulsed-power modes, with multiple irradiation facilities available for programmatic operations. ACRR has five main experimental facilities: central and fueled ring external cavities, on or in a neutron radiography system, and an in-core facility. ACRR is a Department of Energy (DOE) regulated facility.

Restoring readiness and receiving permission to restart is conducted using a graded approach in stages of Readiness Assessment (RA):

- Level 3 – Completion of Checklist and Management Self-Assessment (MSA)
- Level 2 – Conduct of an MSA and Contractor Readiness Assessment (CRA)
- Level 1 – Conduct of an MSA, CRA, and Federal Readiness Assessment (FRA)

I will briefly review readiness assessment methodology, the scope of each activity, a review of the assessment results, and the lessons learned.

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1. General Facility Description

The ACRR is a water-moderated low-power research reactor using individual cylindrical uranium dioxide–beryllium oxide (UO_2-BeO) driver fuel rods enriched at 35 wt.%. Each fuel rod contains about 101 grams of ^{235}U. The ACRR core is configured with 228 fuel elements, 6 fuel followed control rods, and 2 fuel-followed safety rods. Each contains about 104 grams of uranium. There are 3 transient poison rods made of boron-carbide that can be quickly withdrawn (electromechanically) or ejected (pneumatically) in ~80 ms for rapid reactivity changes. The ACRR core is reflected by nickel rods surrounding the fuel. The Fuel Ringed External Cavity, version II (FREC-II) is a subcritical assembly with a 20-inch diameter cavity that can be coupled with ACRR to provide an additional external radiation cavity. FREC-II contains 182 uranium-zirconium hydride (UZrH) fuel rods with 4 additional fuel-followed control rods, all of which are enriched to 20 wt.%. A UZrH fuel rod contains about 54 grams of ^{235}U.

Along with the central dry irradiation cavity, the facility has additional experimental cavities, experiment setup areas, and storage locations. The primary mission of the ACRRF is to subject various components and systems to self-terminating prompt critical power excursions (a pulse) or steady-state combined field neutron and gamma irradiation environments; these are referred to as experiments. Reactor operations have been successfully conducted for more than 64 years at SNL. ACRR is currently allowed to operate in steady-state mode up to 2.4 megawatts (MW) or pulse mode operations up to 60,000 MW and 500 megajoules. We routinely conduct more than 400 operations a year, with ~85% of all operations being pulses in the 0.3 GW to 30 gigawatts range.

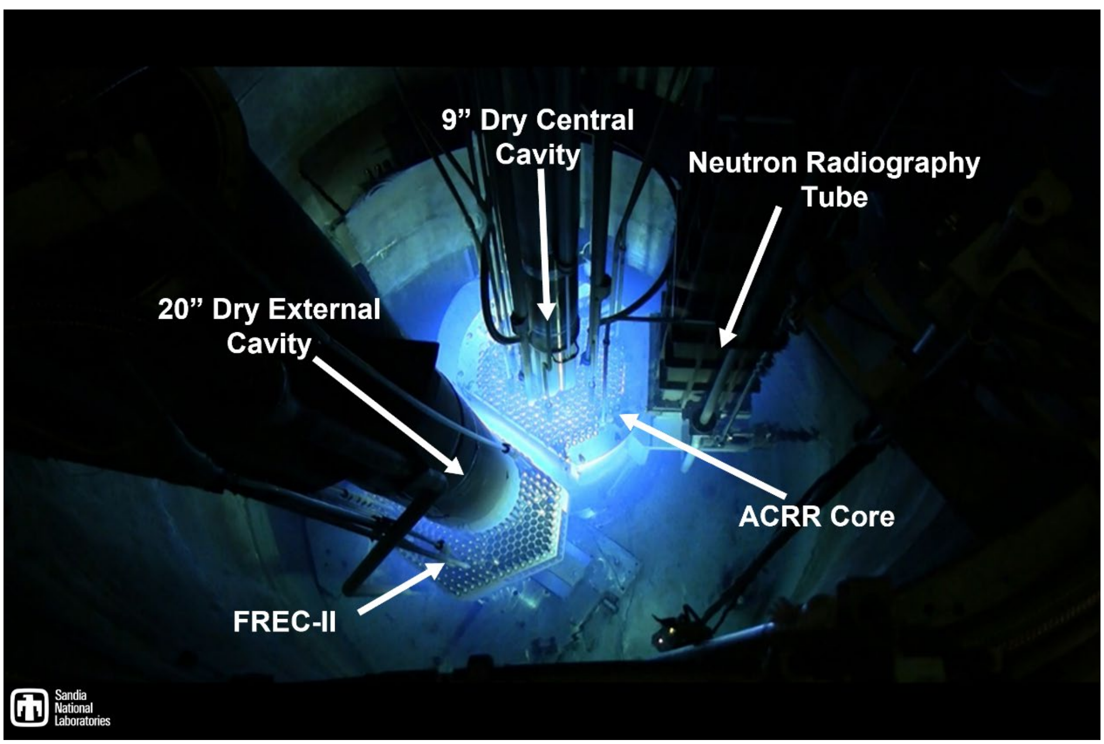

Figure 1: Annular Core Research Reactor in Decoupled Mode with FREC-II

Many of the facility's capabilities had been operated only on an 'as requested' basis and long periods existed between some experimenter requests. Recent operational needs have also required replacement/restart of some hardware and electronic capabilities, and these will be briefly reviewed.

ACRR is defined as a Category B reactor. Guidance given in DOE Standard DOE-STD-1027-92, Hazard Categorization and Accident Analysis [1], establishes the hazard classification for Category B reactors as Category 2. The ACRRF is therefore, a Hazard Category (HC) 2 facility with requirements for safety-class and safety-significant systems, structures, and components (SSCs). The summary of readiness reviews selected were all associated with safety-class or safety-significant SSCs.

This exciting and challenging period of replacing complex systems, restarting dormant processes, and training new operators demonstrated the capabilities, resourcefulness, and engineering prowess of our dedicated staff and management.

1.1. Readiness Assessment Process

DOE prescribes (DOE O 425.1D) [2] a graded approach process for verifying readiness for startup or restart of new Hazard Category (HC) 1, 2, and 3 nuclear facilities, activities, and operations that have been shut down or not functioned for an extended time period. SNL implements its readiness review graded approach process as directed by SNL GN470109, Implementing the Startup and Restart Process for Nuclear Facilities, Operations and Activities [3]. The Sandia Field Office (SFO) provides local DOE oversight.

ORR (Highest)	Both an SNL ORR and DOE ORR are required	DOE is the SAA
Level 1 RA	Both an SNL RA and an SFO RA are required	SFO is the SAA
Level 2 RA	An SNL RA is required, but an SFO RA is not required	The SAA is either SFO, the NFO Associate Laboratories Director or Center Director;
Level 3 RA	A Checklist RA is required, but an SFO RA is not required	The SAA shall be an NFO manager one or more levels of management above the NFO manager of the facility, operation, or activity where the RA will occur

Table 1: Levels of Readiness Assessments

The readiness reviews are not intended to be line management tools to achieve readiness, rather, the readiness reviews provide an independent verification that readiness has been achieved to start or restart operations. Readiness reviews required by DOE O 425.1D are grouped into two types: ORRs and RAs. The differences between an ORR and an RA involve the scope of the review. The DOE Order specifies 17 Core Requirements that must be considered when planning an ORR or RA. The process is a disciplined, systematic, documented, performance-based examination of facilities, equipment, personnel, procedures, and management control systems for ensuring that a facility can be operated safely within its approved safety envelope as defined by the facility safety basis plan.

The Readiness Review process was modeled after Naval Nuclear Propulsion and Nuclear Regulatory Commission programs and processes (10 CFR 50.59). Reviews are based on records review, observation of equipment and operations, and interviews of relevant personnel. In certain cases, three readiness reviews are required (management, independent contractor, and federal) to obtain sufficient confidence in contractor assurance systems.

The readiness review process must, in all cases, demonstrate there is a reasonable assurance for adequate protection of workers, the public, and the environment from adverse consequences from the start (or restart) of a HC 1, 2, or 3 nuclear facility, activity, or operation.

An ORR, the highest-level readiness review, must be conducted for:
(1) Initial startup of a newly constructed nuclear facility. This criterion's purpose is a newly constructed nuclear facility requiring a new Documented Safety Analysis (DSA) and Technical Safety Requirements (TSRs);

(2) Initial startup after conversion of existing facility to a new nuclear mission with new DSA and TSRs;

(3) Nuclear facility or activity restart with upgraded categorization to HC 1, 2, or 3;

(4) Restart after a DOE directed facility shutdown, activity, or operation for safety reasons;

(5) Restart of nuclear facility, activity, or operation after violation of a Safety Limit; or,

(6) Any situation deemed appropriate by DOE line management.

An RA must be conducted for any of the following:
(1) Initial startup of new HC 1 or 2 activity or operation with new DSA and TSRs;

(2) Restart after extended shut down for a HC 1 or 2 facility, activity, or operation;

(3) Facility, activity, or operation startup/restart after substantial system, or facility modification. Local site implementing procedures must provide a process for determining whether a modification is substantial, based on the impact of the changes in the safety basis, equipment, operating procedures, training, or staffing, and the extent and complexity of these changes, whether or not these changes resulted in a positive Unreviewed Safety Question determination; or,

(4) Any situation deemed appropriate by DOE line management.

1.2. Sequence of Readiness Review (RR)

(1) The RR process starts upon the determination that a nuclear facility, activity, or operation is to be started or restarted, and the level of the review is then determined. At least six months before the projected date for achieving readiness, line management prepares a Plan of Action (POA) and identifies a Team Leader (TL). The POA describes the scope and lists prerequisites for achieving readiness.
(2) TL assembles a review team to prepare the Implementation Plan (IP), which includes the Criteria and Review Approach Documents (CRADs). The CRADs incorporate the complete review scope specified in the POA.
(3) As a part of achieving readiness, the contractor may conduct an MSA.
(4) When the contractor has achieved readiness to start or restart a nuclear facility, activity, or operation within the scope of the RR, a formal declaration of readiness is issued.
(5) The RR team conducts the review and the TL submits the final report to the startup authorization authority as a basis for approving the startup or restart.
(6) Identified findings are designated by the review team as prestart or post-start.

(7) Line management is responsible for developing corrective action plans to resolve the findings and determining when the findings are resolved.

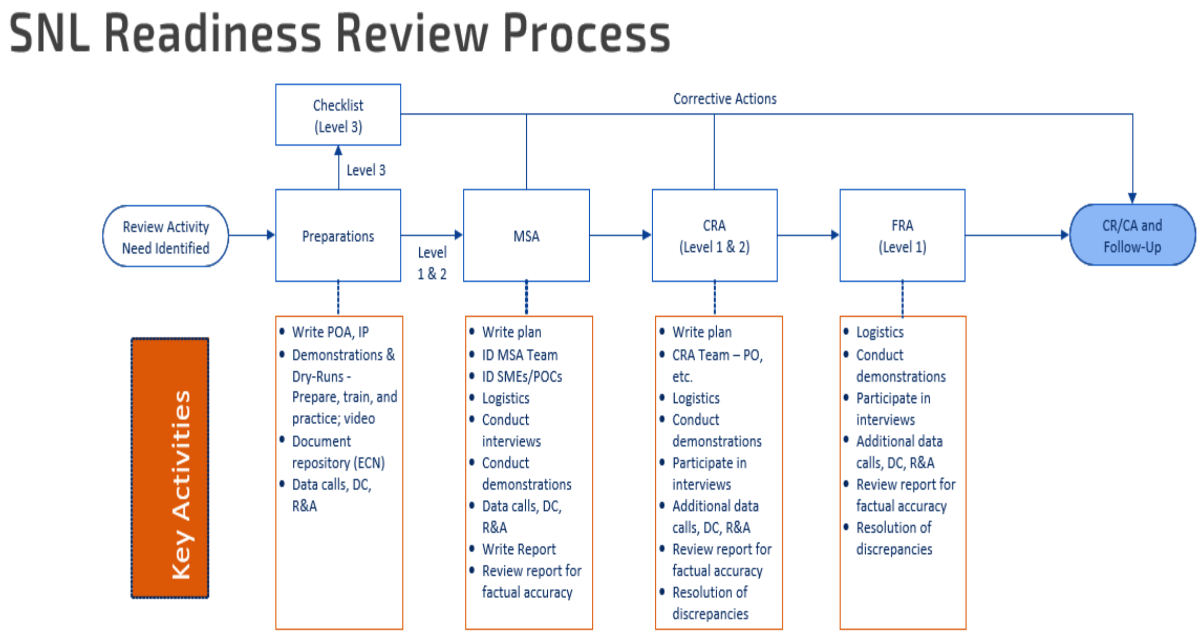

Figure 1 SNL Readiness Review Process

1.3. Definitions

Category B reactor facilities: Category B reactor facilities are those test and research reactors, designated by DOE, based on power level (e.g., design thermal power rating of less than 20 megawatts steady state), potential fission product inventory, and experimental capability.

Core Requirement: A fundamental area or topic evaluated during an ORR or RA to assess whether a facility can be operated safely.

Finding: Nonconformance with a stated requirement that represents either:
(1) a systematic failure to establish or implement an adequate program or control; or
(2) a significant failure that could result in unacceptable impact on the safety of personnel, the facility, the general public, or the environment during nuclear operations.

Hazard Category (10 CFR 830, Subpart B) [4] DOE nuclear facilities are classified into distinct hazard categories:

HC-1: The hazard analysis (HA) shows the potential for significant offsite consequences.

HC-2: The HA shows potential for significant onsite consequence beyond localized consequences.

HC-3: The HA shows the potential for only local significant consequences.

Note: DOE nuclear facility encompasses the facility, operation, or activity.

Management Self-Assessment (MSA): A quality process planned and accomplished by the Nuclear Facility Organization (NFO) management to assist in achieving readiness. The process, while not required by DOE O 425.1D [2], is an important element in ensuring readiness to start nuclear operations and thus achieve readiness to conduct the RR. The MSA process follows the guidance on approved approaches and methods for implementation from DOE-STD-3006-2010, Planning and Conducting Readiness Reviews. [5]

Noteworthy practice: A process or condition indicating exceptional or innovative policy, practice, or performance.

Observation: An item identified during the RR process that is not a regulatory requirement but that, if implemented, would lead to enhanced operations. A discussion of observations should be included in the RR report. The RR team is not required to track the completion of observations.

Operational Readiness Review: An independent, disciplined, systematic, documented, and performance-based examination of facilities, equipment, personnel, procedures, and management control systems to ensure that a(n) facility, operation, or activity will be operated safely within its approved safety envelope as defined by the safety basis.

Readiness Assessment: A Readiness Review that is conducted to determine readiness to start up or restart when the facility, operation, or activity has been assigned an HC and an ORR is not required.

Readiness Review: The independent process conducted to demonstrate that it is safe to startup a new SNL facility, operation, or activity or to restart an existing facility, operation, or activity that has been shut-down. Typically, a Readiness Review is either an Operational Readiness Review (ORR) or a Readiness Assessment (RA).

1.4. Description Of ACRR Activities That Have Recently Undergone Readiness Assessment

Resumption of Explosive Activities – Receipt, handling, and detonation of explosives during reactor operation testing.

Reactivity Control System Upgrade – This activity replaced portions of the Reactivity Control and Instrumentation and Control Subsystems. This included replacement of a majority of the system, including the existing data acquisition equipment, process control computer, operator workstations, and the network data communications devices.

In-Service Fuel Cladding Inspections – The activity was evaluation/inspection of in-service fuel elements in the ACRR and FREC-II to provide monitoring of the health and condition of the cladding for each fuel element. Fuel elements were removed from the core and examined one at a time, then returned to the core or sequestered for further evaluation.

FREC II Operations at the ACRRF – Restoration of programmatic experimental activities for the FREC when coupled to the ACRR.

Hazard Category III Experiments at the ACRRF – The activity included Class III experiments as defined in the TA-V Nuclear Safety Charter. Experiment canisters will contain HC-3 quantities of fissionable material in metal form. The experiment canisters satisfied appropriate containment requirements complying with safety basis controls.

Restoration of Transient Rod Withdrawal (TRW) Capability – TRW is a sub-mode of the ACRR Pulse Mode used for creating highly repeatable power profiles. TRW allows for programmed electro-mechanical movement of the transient rods from the reactor core at variable rod speeds, resulting in fast reactor periods up to and including prompt-critical periods. It can be used to create double pulses, higher energy output, and square waves.

1.5. Timelines of Readiness Assessments

Type of Assessment	Title	Plan of Action Issued	Implementation Plan and Final Report	
			Start	End
Level 3 Checklist RA's	Resumption of Explosive Activities	3/14/2017	3/17/2017	3/20/2017
Level 2 RA (Elevated to Level 1)	Reactivity Control System Upgrade (RCSU) Project	POA 11/30/2017		
		MSA	5/17/2018	5/20/2018
		CRA	6/18/2018	6/28/2018
		FRA	9/10/2018	9/14/2018
Level 1 RA	In-Service Fuel Cladding Inspections at the ACRRF	POA 8/26/2020		
		MSA	12/01/2020	1/04/2021
		CRA	1/15/2021	1/29/2021
		FRA	4/12/2021	4/21/2021
Level 1 RA	FREC II Operations at the ACRRF	POA, Rev. 1 12/14/2021		
		MSA	11/15/2021	11/27/2021
		CRA	1/10/2022	1/20/2022
		FRA	2/14/2022	2/17/2022
Level 2 RA	Class III Experiments at the ACRRF	POA 5/6/2022		
		MSA	5/31/2022	6/16/2022
		CRA	8/8/2022	8/16/2022
Level 1 RA	Restore Transient Rod Withdrawal (TRW) Capability	POA 10/3/2022		
		MSA	10/17/2022	10/21/2022
		CRA	11/5/2022	11/9/2022
		FRA	2/27/2023	3/3/2023

Table 2: Timeline of Readiness Assessments

1.6. Readiness Assessments Staffing Supporting Experience Levels

	Reactor Supervisors			
USN Reactor	1	1	0	2
NRC Reactor Licenses	0	1	0	1
DOE Reactor Licenses	3	1	1	3
BS Degree	NE	EE		NE
MS Degree	NE			NE
PE Certificate	Nuclear			Nuclear
Years Nuclear	38	15	37	44
Years SNL	20	7	32	33
Additional Tasking	CREST Senior Reactor Design Advisor, SSW	SPR/CX AS, MBA and CWS Custodian	Facility Training Coordinator, Nuclear Decommissioning	SSW, ASTM Subcommittee on Neutron Radiograph

	Reactor Operators					
USN Reactor	1	2	0	1	2	0
NRC Reactor Licenses	0	2	1	0	2	2
DOE Reactor Licenses	2	1	2	1	1	1
BS Degree	AST	NE	ME	MS		NE
MS Degree	MBA					NE
PE Certificate						Nuclear
Years Nuclear	20	24	8	10	26	15
Years SNL	13	1	4	4	2	3
Additional Tasking	ACRR FS, SPR/CX FS & AS, SSW	Pilot, Master Training Specialist, LOI	SPR/CX AO	Explosives Building License, DC	Master Training Specialist, LOI	Fuel Inspector and Drill Program Coordinator

Table 3: Readiness Assessment Staffing Supporting Experience Levels

1.7. Summary of Readiness Assessment Results

Assessment Level	Title	# Findings	# Observations	# Opportunities for Improvement	# Noteworthy practices
Level 3 Checklist RAs	Resumption of Explosive Activity	3	7	2	1
	Wide Range Replacement Project	0	5	0	0
Level 2 RA (Elevated to Level 1)	Reactivity Control System Upgrade Project	10 6 4	0 8 0	0 0 0	0 0 0
Level 1 RA	In-Service Fuel Cladding Inspections at the ACRRF	0 0 1	30 56 5	0 0 0	0 0 0
Level 1 RA	Restart of Fuel-Ringed External Cavity II (FREC-II) Operations	1 0 0	11 17 8	4 0 0	3 0 0
Level 2 RA	HC III Experiments at the ACRRF	0 0	12 44	6 0	7 0
Level 1 RA	Restore Transient Rod Withdrawal (TRW) Capability	0 1 8	9 7 15	10 0 0	9 0 3

Table 4: Summary of Readiness Assessment Results

1.8. Cost Estimate and Significant Feedback

<u>Cost Estimate</u>

An SNL internal review of the costs associated with readiness assessments identified that the baseline preparation evaluation for a Level I RA cost ~\$0.62 million, the MSA cost ~\$0.514 million, the CRA cost ~\$0.54 million and the FRA cost ~\$0.29 million for a total cost of ~\$2 million. This internal review stated that these costs were an underestimate of the full cost. Four Level I RA's have been included in this review.

Each finding requires that a root cause analysis be conducted to ensure that all necessary corrective actions are identified, registered, and completed. In the most extreme case a single finding produced 16 individual corrective actions.

<u>Significant Feedback</u>

From the Evaluators:

- The Facility Supervisor and certified Reactor Supervisor(s) are long-term members of the facility staff. They rely heavily on institutional process knowledge in the performance of their duties. They demonstrate an expert-dependent capability that may not translate well to the next generation of Reactor Operators since much of their knowledge and actions are not definitively described and clearly cross-linked in the supporting procedures and reference documents. A significant knowledge retention process should be instituted.
- Staffing is on a positive uptrend and will support a continuation of operations in the future.

- Communications during a remote assessment require constant telephone calls. FRA team members, field office staff, and contractor staff do not answer their phones as consistently as they would respond to the in-person interactions of an in-person review.

From the Evaluated:

- Scope creep of the assessment and multiple overlapping assessments over the same subject areas with differing recommendations. Literally one assessment team reviewing and contradicting the results of another assessment team.
- Every negative issue (finding, observation, or opportunity for improvement) that is in a readiness assessment report must be addressed, with an entry in the condition reporting and tracking system, appropriate corrective actions, closure of these actions, and maintaining objective evidence documentation. Even if every response was "thank you for the input, we do that process in that manner because that is the way we found works best", it is still a very real amount of administrative time to complete.
- Rarely are our assessors from a DOE-run equivalent research reactor facility. This often leads to assessors having their expectations unmet. It is up to our team to clearly manage this difference between their expectation and our compliance with requirements, since "Expectations are not requirements".
- Assessment teams have, at times, been unprofessional and confrontational.

1.9. Specific Challenges and Lessons Learned

Specific challenges associated with completion of these multiple assessments include;

- Pandemic related issues – many of the assessments were conducted while complying with multiple layers of COVID controls; federal, state, and local as well as SNL Corporate guidelines, requiring most of the assessment to be conducted remotely. Additionally, most interviews were conducted using a virtual meeting tool such as Teams, Zoom, or Webex.
- Significant staff turnover – losing experienced operators and hiring new operators, requiring extraordinary efforts and resources in qualifying new operators while absorbing the loss of experience and knowledge in departing staff.
- Multiple manager turnovers – seven different first line managers and two higher level managers presided over these assessments, thus requiring additional hours and effort to provide on-boarding and site training. This introduction to current site operational procedures further delayed responses to assessment preparations and finding resolution in addition to reducing the accumulation of experience overall.
- Continuing to conduct programmatic operations during and in between assessment periods – while important to maintain the capability to conduct operations this decision consumed significant resources.
- Multiple, hoisting and rigging errors, resulting in an extensive causal analysis (Blue Dragon), a significant number of findings, and exhaustive corrective actions. These events were outside the readiness review processes but were conducted concurrently.
- Actively supporting design of the replacement reactor facility (Combined Radiation Environments Survivability Testing or CREST). Dedicating operations staff to participate in design and development of the next version of the nuclear facility that will replace the ACRR. The supporting effort was outside the readiness review processes but were conducted concurrently.

- Recovery from inadvertently dropping a fuel element during the inspection process – recovering from this unique event also stressed the staff and consumed significant resources. This event occurred during the In-Service Fuel Cladding Inspections approved by completion of the RR process.
- Recovery from a failed fuel element – The ACRRF entered the shutdown mode after identification of a pinhole leak in Safety Rod #1 during a maintenance activity for inspecting fasteners. The pinhole leak in the weld joint degraded operability of the regulating rod, and efforts are underway to replace the safety rod and restore operability. This event was the impetus to conduct the In-Service Fuel Cladding Inspections RR.

Lessons learned from conduct of these readiness assessments.

- High turnover of personnel strains resources. Understanding and assessing the stress developed by repeated assessments is difficult, and development of a retention management plan prior to conducting these serial/concurrent assessments may have been effective in reducing the stress level among the staff and reducing the turnover. Unusually high staff turnover (ten reactor operators/system engineers over four years and seven level I managers and two more senior managers) attributed to and contributing to the increased stress levels.
- Total staff hours supporting RAs strains resources. At its low point the ACRR operations staff was reduced to four qualified operators with open understanding that these people were overwhelmed. During many of the assessments there were more assessors than operators.
- The management of stress, whether it is due to continuing audit and assessment or high tempo programmatic operations, must be a priority. Staff will suffer in an unmanaged environment. The actual methodology must be dependent on the specific circumstances but ignoring it will never be the best choice.

1.10. Acknowledgments

I would like to thank the dozens of support staff, assessors, managers (especially our current manager), subject matter experts, cognizant system engineers, experimenters and facility operators who prepared for and executed these multiple assessments – restoring exotic one-of-a-kind capabilities to our facility that had been paused or the starting of new activities. While the process was onerous the full functionality of the facility has been restored and we are more ready than ever to expand our programmatic offerings.

1.11. References

[1] DOE Standard 1027-92, Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports
[2] DOE Order 425.1D, Verification of Readiness to Start Up or Restart Nuclear Facilities
[3] SNL GN470109, Implementing the Startup and Restart Process for Nuclear Facilities, Operations and Activities
[4] 10 CFR 830, Subpart B
[5] DOE-STD-3006-2010, Planning and Conducting Readiness Reviews.
[5] The multiple MSAs, CRAs and FRAs Documenting Readiness Reviews

1.12. Acronyms

ACRRF – Annular Core Research Reactor Facility
AST – Associate in Specialized Technology
ASTM – American Society for Testing and Materials
CFR – Code of Federal Regulations
CRA – Contractor Readiness Assessment
CRAD – Criteria and Review Approach Documents
CREST – Combined Radiation Environments for Survivability Testing
CSE – Cognizant System Engineer
CWS – Classified Work Station
DC – Derivative Classifier
DOE – Department of Energy
DSA – Documented Safety Analysis
ECN – Engineering Change Notice
EE – Electrical Engineering
FS – Facility Supervisor
FRA – Federal Readiness Assessment
FREC-II – Fuel Ringed External Cavity
HC – Hazard Category
IP – Implementation Plan
LOI – Licensed Operator Instructor
MBA – Master of Business Administration
MSA – Management Self-Assessment
ME – Mechanical Engineer
MW – Mega Watt
NE – Nuclear Engineering
NFO – Nuclear Facility Operations
ORR – Operational Readiness Review
PE – Professional Engineer
POA – Plan of Action
POC – Point of Contact
R&A – Review and Approval
RA – Readiness Assessment
RCSU – Reactivity Control System Upgrade
RR – Readiness Review
SAA – Startup Authorization Authority
SFO – Sandia Field Office
SME – Subject Matter Expert
SNL – Sandia National Laboratories
SPR/CX – Sandia Pulse Reactor Critical Assembly
SSW – Senior Supervisory Watch
SSC – systems, structures, and component
TL – Team Leader
TRW – Transient Rod Withdrawal
TSR – Technical Safety Requirements
UO_2-BeO – Uranium Dioxide -Beryllium Oxide
UZrH – Uranium Zirconium Hydride
USN – United States Navy