August 15, 2022

ATTN: Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Subject: Docket Number 50-184 restart plan

Dear Sirs/Madams:

In our October 1, 2021, letter (Accession Number ML21288A555), we requested NRC permission to restart the reactor upon completion of listed corrective actions and recovery efforts. Attached please find a copy our plan for restarting the reactor after receiving permission from NRC.

Sincerely,

Thomas Newton
Deputy Director
Chief, Reactor Operations and Engineering
NIST Center for Neutron Research

I declare under penalty of perjury that the following is true and correct.

Executed on August 15, 2022

By: ______________________

Plan for the Restart of the NBSR

August 15, 2022

Introduction

As a result of the fuel failure incident of February 3, 2021, a number of corrective actions and recovery items were identified as necessary for reactor restart. Details of these items and their contribution to readiness for reactor restart are given below. Additional corrective action items will be addressed in responding to the NRC Confirmatory Order issued August 1, 2022, and are not covered here except as needed in the context of reactor restart.

Procedure Development

Adequacy of procedures and procedure compliance are two issues identified in the root cause reports from the incident. A total of 167 procedures were identified as being necessary to be modified prior to restart. This list was supplied to NRC on May 20, 2022. As of this writing, over 90% of these procedures have been modified and approved, with the remaining to be approved by the end of August 2022. In addition, AR 5.0, Procedure Use and Adherence, was developed and approved and all full time ROE personnel underwent training on it, which covered procedure compliance. Procedure compliance is now part of routine training and personnel evaluations.

Proficiency Training

In April 2022, all licensed operators underwent refueling and latch verification proficiency training using the newly developed refueling and latch verification procedures. Further proficiency training, including fuel loading and latch checking procedures, will be performed during filter element removal so that personnel involved in fuel movements will be qualified prior to refueling in preparation for restart. Fuel manipulation proficiency requirements have been finalized as part of the updated operator training program:

- AR 4.0 Fuel Manipulation Proficiency Requirements
- AR 4.1 Fuel Manipulation Initial Requirements
- AR 4.2 Fuel Manipulation Requalification Requirements

General operator qualifications have been detailed in the updated training program:

- AR 2.0 Conduct of Operations Training
- AR 2.1 ROE Training Practices
- AR 2.2 NBSR Operations Initial and Continuous Training Program (categorized for each level of operator)

TS 3.9.2.1

In December of 2021, the NCNR requested a license amendment to change NBSR Technical Specification 3.9.2.1 to require two latch verifications, a rotational latch check and subsequent visual verification of latching. This license amendment was approved by NRC on July 21, 2022. Procedures for these checks (OI 6.1 series) have been developed and approved and used in the training mentioned above. These procedures include the use of a rotation fiduciary device and visual check video equipment.

Refueling plan

As mentioned in our report to NRC on June 29, 2022, a decision was made to not use fuel elements that were present in the core on February 3, 2021, in the initial startup core. NBSR fuel elements are normally in the reactor for either 7 or 8 fuel cycles prior to discharge. As a result, we have a number of 7-cycle elements in storage available for use in the reactor that can be used for one additional 38-day cycle at 20 MW. We have made the determination that we can use a combination of twenty 7-cycle elements and ten new elements in the initial startup core. Note that the use of ten new elements equals a total mass of 3.5 kg of U-235, well below the license limit of 5 kg for unirradiated fuel.

An evaluation, given in Engineering Change Notice (ECN) 1241, has shown that parameters such as power peaking and excess reactivity values fall within the envelope of all normal operation and accident analyses given in the NBSR SAR. A 50.59 evaluation has been made and is part of this ECN. Subsequent cores will consist of a combination of (other) 7-cycle elements, the (newer) fuel from the previous core and up to 6 new elements. It is expected that it will take about ten fuel cycles to reach a typical equilibrium NBSR core configuration. All of these cycles will be configured and analyzed so that all safety-related parameters listed in the NBSR SAR will fall within the envelope of the 50.59 evaluation.

As a precaution, loading of fuel in this configuration will be made using an inverse multiplication (1/M) approach to verify proper loading and that reactivity values are as expected. A procedure specific for this loading, OI 6.3.1, "1/M Core Loading and Approach to Critical" has been written and approved. This loading, as well as all subsequent loading will be making the use of new rotation (OI 6.1.7) and visual check (OI 6.1.8 and OI 6.1.9) procedures in accordance with the updated TS 3.9.2.1.

Primary system readiness

NCNR efforts to remove debris from the primary system have been multi-pronged. First, a contractor (Framatome) was hired to use Foreign Object Search and Retrieval (FOSAR) equipment to remove all debris larger than 1/16" diameter from the reactor upper and lower grid plates. Smaller debris (both lower and upper grid plate) was removed using a vacuum wand driven by an eductor system operated by a pump that moved the heavy water already present in the reactor vessel, so that all visible debris was removed. Secondly, filter elements were installed in the core in April of 2022 to capture debris from the primary system. Framatome was also tasked with ultrasonic cleaning of several hotspots in the Process Room, followed by running the primary pumps, which moves water through the (20 micron) filters that temporarily occupy the fuel positions. Ultrasonic cleaning was somewhat successful, but very difficult to apply in the hottest areas, without significant personal dose commitment. Additional cleanup efforts included filling and draining of the primary system, removal of accessible components with hot spots, and introduction of CO_2 into the primary system (ECN 1229) in an attempt to dislodge particles via induced buoyancy. Further details are given in the June 29, 2022, submittal to NRC and are results are summarized in Table 1.

All these efforts had some success in cleanup of the primary debris but have now reached the point where no discernable debris can be dislodged without direct mechanical means. It is now unlikely that any significant particles can be removed under normal flow conditions, which makes any scenario by which loose fuel particles make it into the core even more unlikely. Conservative estimations are that the largest single piece remaining in the primary system would have a mass of less than 0.14 g. Release (and retention) of such a particle into the core would have negligible heating and reactivity effects, would be easily detected and have negligible off-site dose consequences. We are protecting against any such scenarios by performing a gradual approach to power, with all effluent major scram setpoints significantly reduced as given in the startup procedures discussion below. Thus, if any debris becomes dislodged and makes it into the core, automatic actions (most likely preceded by operator intervention) will prevent any significant release of fission products.

Calculations of the potential release of fission products during startup have been performed and have been reviewed by experts at Brookhaven National Laboratory. These calculations, along with the conservative effluent monitor settings discussed below confirm that effluent releases and boundary dose consequences will have no health or safety impacts to the general public and will remain well below emergency and regulatory limits, even in the worst-case scenario.

Restart readiness

Prior to reactor restart, a restart readiness evaluation will be made. This evaluation will be reviewed by a subcommittee of the NBSR Safety Evaluation Committee (the Reactor Restart Readiness Subcommittee) and will include verification that:

- All required surveillances are complete.
- Identified corrective actions necessary for restart have been completed.
- LCOs are met, and all required effluent monitors are in working order. This will include a review of instrument setpoints and their validity.
- The reactor plant is in adequate condition for operations, including valve lineups.
- Operators have met training, proficiency, and requalification requirements.
- Training has been given to operators on special precautions for the initial startup.

Startup Procedures

Detailed special procedures for initial startup have been written and approved. All these procedures include instructions to:

- Reduce the major scram setpoints of Normal Air, Irradiated Air, and Stack effluent monitors to 5 kcpm. This is a factor of ten below their normal setpoints of 50 kcpm. This very conservative setpoint will automatically shut down the reactor well before any possible fission product effluents would even reach the lowest emergency action levels (NOUE).
- Require that operators shut down the reactor if fission product activity is detected outside the core.

After the core is loaded, the procedures will be performed in the following sequence:

1. MP 5.55, 1/M for Initial Criticality, covers the initial startup. This procedure includes instructions for the operator to shut down the reactor if abnormal indications are seen on any effluent radiation monitor.
2. TSP 4.1.2, Core Excess Reactivity/Shutdown Margin Reactivity Worth of each Shim Arm and Reg Rod. In addition to normal measurement instructions, this procedure will include special precautions in monitoring effluent activities, as mentioned above.
3. OI 1.1.1, Reactor Startup to 20 MW. This will entail a slow and deliberate increase in power. Power will be initially leveled at 100 kW for an hour then, if no abnormal activity is seen, power

will be increased to 1 MW and leveled for 8 hours. If no abnormal activities are seen, subsequent increases and leveling for 8 hours will occur at 5 MW, 10 MW, 15 MW, and finally, full power.

Summary

All corrective actions necessary for reactor startup, including identified procedure updates and proficiency training will be completed prior to reactor restart. Cleanup of the reactor and primary coolant system has been completed to the extent possible and is in a condition that will allow reactor startup. Effluent monitors setpoints will be set very conservatively that will preclude the possibility of significant fission product release and reactor operators will be specifically trained to take immediate actions to mitigate any abnormal fission product activity. We believe the plan outlined here fully addresses any concerns related to restart of the NBSR.

Table 1. Summary of Primary Cleanup Efforts

Date	Action	Results
5/21	Perform gamma imaging of primary system to identify locations of hotspots and extent of contamination	Gamma imaging identified that contamination was present in the heat exchangers, at dead ends, low flow locations and in bends/valves.
2/22	Removal of the vessel head and manual cleaning of the vessel using FOSAR tools and remote camera	All visible pieces of debris were removed from the vessel and a full visual inspection of the vessel indicated no further debris. Debris was placed in a receptacle and transferred to the pool.
4/1/22	Install primary filters	Multi-day activity, completed 4/12/22
4/14/22	Initial pump start	Each pump individually then 2 at a time.
"	1 pump (#4, 3, 2, 1)	Significant improvement in radiation levels by primary pumps. Small improvements seen elsewhere.
"	2 pumps (1&2, 2&3)	Small radiation level improvements seen in some areas.
"	3 pumps (2,3 & 4)	Small radiation level improvements seen in some areas.
4/19/22	4 pumps (1st time 4 pumps running was logged)	No significant changes.
4/29/22	Ultrasonic cleaning	Limited effectiveness. It was postulated that the inducers were able to move the material into the flow, but the flow was too low in most areas to move the material very far. Also, there were challenges with high dose rates in some areas. Overall, it did reduce the dose rate in a few areas.
5/3/22	Draining	Draining resulted in some movement of material. The were some minor reductions in some areas but overall, there was no significant change in dose rates in the process room.
5/3/22	Valve removal	A hot spot was identified in a dead-end header valve (HE-1C). The valve was successfully removed. The dose rate at the flange was reduced but dose is still significant. MP 5.45.07 partial drain and refill
5/3/22	Refill	No significant change.
6/6/22	Emergency Tank Drained/Start Primary Drain	HX's in dry layup. MP 5.45.01
6/8/22	Primary fully drained	No significant change.
6/13/22	MP 3.16	HE-1C hotspot mitigation. Some reduction seen.
6/17/22	MP 5.45.02/Primary refilled	No significant change.
7/13/22	CO_2 sparging	No significant change to dose rate levels in the process room.
7/21/22	He sparging	HE was used to assist with removal of CO_2 from the system. The HE injection into the system acted as a sparge and resulted in the reduction of dose in some areas. The heat exchangers showed some reduction in dose rate (~10%).
8/5/22	Draining	Additional hot spot removed (via draining) in HE-1C flange area, reducing dose rate significantly.
8/8/22	Valve removal	No significant change.
Future	refill	
	Manifold Flange 1 removal and replacement	
	Manifold Flange 2 removal and replacement	
	D_2O Storage Tank Cleanout	
	Drop out chute clean up	