RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

RE: LICENSE RENEWAL APPLICATION FOR

FACILITY OPERATING LICENSE NO. R-120 FOR

THE NORTH CAROLINA STATE UNIVERSITY

PULSTAR RESEARCH REACTOR (EPID NO. L-2020-NFR-0007); DATED SEPTEMBER 21, 2021

NORTH CAROLINA STATE UNIVERSITY

LICENSE NO. R-120; DOCKET NO. 50-297

NOVEMBER 30TH, 2021

(1) A description of the corrective action measures, including non-administrative measures, taken to date and planned (include dates of work completed and planned, as appropriate) to address the leak(s) and characterize the efficacy of those corrective actions;

Response:

A leak rate in the reactor primary system was identified in March 2015. In the period from March 2015 through December 2017, the leak rate was on the order of the lower limit of detection for available leak detection equipment. By January 2018, the leak rate had started to rise above this detection limit, so significant efforts to locate and mitigate the leak ensued. Testing and patching activities continued from 2018 through 2020 with numerous suspected leak sites on the pool liner patched. In October 2020, the leak rate rose quickly and significantly, and a new leak site was identified. The newly identified site was quickly patched, lowering the leak rate to 2.8 gph, where it currently remains. A summary of liner inspection and repair activities for this period is given below, along with planned additional activities.

Liner Inspection & Repair Summary; 2015 through the present:

In March 2015 based on the facility procedure for determining primary water loss (SP-5.10 Primary Water Inventory), the leak was officially confirmed after reviewing the data trend over the previous 4 to 6 weeks. Maintenance Log Number 808 was opened and assigned to the pool liner leak. Investigation of the water loss began as required by procedure SP5.10. It was confirmed that the leak was not coming from the primary piping and, using biweekly primary and secondary water assays, it was confirmed that the leak was not in the heat exchanger. Therefor it was concluded that the leak was in the pool liner. Hydrophone and visual inspection with an underwater camera of the liner were performed. Historically suspect areas were examined around the thermal column weld and south fuel storage pit, but no leak sites were identified. The leak rate was less than 1.0 gph and therefor was below the lower limit of sensitivity for the leak detection company previously utilized. The company utilizes acoustic emission (AE) testing equipment which has a nominal leak site detection limit in the range of 2 to 4 gph depending on the type of flow produced within the leak and conditions at the site. The campus radiation Safety Committee, Reactor Safety and Audit Committee, NRP Director, and facility staff actively monitored the status of the pool leak.

In May of 2016 the reactor commenced an extended period of 24/7 operations. At the time the leak rate continued to be in the range of the AE testing equipment detection limit, therefor it was decided to closely observe and trend the leak rate and continue with operations. An internal memo on repair plans was written and discussed with the staff and the NRP Director. In March of 2017, the leak rate had

increased to 3 gph and the leak detection company was contacted to further discuss options and obtain a quotation for services. Following a discussion with the company, it was determined that the leak rate was still too close to the AE testing equipment detection limit and their ability to detect it would be uncertain, so it was decided to continue with 24/7 operations.

In January 2018 the period of 24/7 extended operations ended. The leak rate had increased by this time to 5.3 gph. The Pool Liner Repair Plan (documented in memos from 2016 and 2018) was put in effect and the hydrophone was utilized to scan suspected areas around the liner sites that were previously patched. In March 2018 it was decided to remove old epoxy patching material from the site of the 2011 leak on the thermal column weld seam and reapply new epoxy with an aluminum backing plate. Following the re-application of the patch, the leak rate dropped by 1.5 gph to 3.6 gph. Additional hydrophoning of the liner was performed and another suspect area was identified (a previous leak site) on the south vertical thermal column weld seam. In August 2018 when preparing to apply a patch to this area, the underwater camera failed due to radiation exposure. The leak rate increased in September 2018 to 5.3 gph. In December 2018, a new camera was purchased and the patch was applied to this area. The leak rate remained the same after the patch was applied.

In January 2019 the leak rate had increased to 5.5 gph. It was determined that the existing in-house hydrophone equipment was not sensitive enough and AE leak detection equipment was ordered. The equipment arrived on site in September 2019 and was put to use scanning the reactor pool liner. During the period when the new AE equipment was procured and then used to scan for a leak, the leak rate increased to 7 gph. The leak detection company was contracted and arrived on site on December 3, 2019 and utilized their AE equipment to locate two suspected leak sites. The first site was on the upper weld seam of the thermal column and the second on the weld seam of the outer rim of the south storage pit. The necessary tooling to apply a patch to the thermal column weld seam was configured and a patch was applied on December 6, 2019. Subsequent monitoring indicated that this patch was not effective in reducing the leak rate. Attempts to isolate the leak in the rim weld of the south storage pit using temporary patching material were made but were unsuccessful. A custom aluminum patch plate ring for the south storage pit was subsequently ordered from a local area machine shop.

On February 7, 2020 it was decided to remove old epoxy patching material on the lower south side of the thermal column weld seam and apply new epoxy with an aluminum backing plate. This new patch did not result in a reduction in the leak rate. On February 24, 2020, a second patch on the upper thermal column weld, adjacent to the patch applied on December 2019, was applied. The leak rate subsequently dropped by 2 gph to approximately 5.6 gph. In July 2020, additional patches were placed on the top welds of the thermal column liner plate, and on the suspect location along the south fuel pit weld identified the prior December. No significant reductions in the leak rate were observed.

In early October 2020, the leak rate was observed to increase from approximately 8 gph to approximately 9 gph over the period of about a week, and then to approximately 19 gph by October 12, 2020. The leak detection company was contracted to come on site at their first availability. Testing in the reactor pool with the AE detection equipment and hydrophone were immediately undertaken by the reactor staff, with inconclusive results. By October 21, 2020, the leak rate had increased to 21 gph. The leak detection company personnel arrived on site on October 21st with their specialized AE testing equipment and immediately commenced testing in the reactor pool. A new leak site was identified on the west pool wall liner in the lower north west corner under beamport five (reference Maintenance Log #859). A temporary suction cup patch was placed over the suspect pinhole leak site which decreased the leak rate to about 8 gph. The suction cup was then filled with epoxy and applied to the pinhole and the leak rate dropped to 6-7 gph. While the epoxy was curing, additional hydrophone and AE inspections were performed. Another leak indication with an apparent field of several pinholes was found a few inches below and to the south of the patched pinhole on the lower west liner wall. It was determined that a large epoxy patch with an aluminum plate backing would be applied to this area consistent with the methodology utilized for applying previous liner patches.

On 10/22, a 10”W x 16”H epoxy patch plate was applied to the field of pinholes on the lower west wall site. Overnight, the leak rate dropped to 2.8 gph. Follow up video inspection of the patch indicated that the liner wall is not flat in this area and is bulged outwards at the approximate center of the patch,

causing the patch plate to stand away from the wall along its lower side and bottom edges. Following the full cure of the epoxy, hydrophone inspection indicated that leakage continues behind the applied patch plate in this spot. A nominal leak rate of 2.8 gph has persisted since that time.

Planned Activities

In July 2020, reactor staff began discussions with an industry vendor concerning options for the inspection and repair of the reactor pool liner. At the time, the focus was on evaluating and repairing the thermal column liner potential leak sites, as the west wall leak site had not yet been identified. Following initial discussions, the vendor generated an 'Engineering Information Record' dated August 12, 2020 titled "NC State Reactor Cavity Leak Detection Inspection Plan'. Vendor staff engineers then came on site for a review and walkdown of the facility on April 9, 2021. They reviewed the status of both known leak sites at the thermal column liner and west wall. On October 27, 2021, the vendor provided their 'Proposal 47238 for Reactor Pool Lining Inspections' with Phase 1 and Phase 2 steps for evaluating and remediating the reactor pool west wall leak site. In Phase 1 of the scope, they propose to perform video evaluations and measurements on the reactor pool wall to support the design and future installation of a long term leak repair over the west wall patch plate site. They would also epoxy a 2" aluminum angle on the pool floor for future patch box support. Phase 2 of the scope would include the design and installation of either a long term vacuum box as an interim repair, or a permanent patching solution for the west wall site. The vendor has also been engaged to evaluate additional pool liner inspection methodologies, including ultrasonic testing, to support the ongoing assessment of liner integrity.

The facility is currently evaluating the vendor's proposal received at the end of October 2021. A request for funding to support these proposed evaluations and repairs has been submitted. Depending on the availability of funding, it is anticipated that the repair activities would be pursued in FY'2023.

(2) Additional information for the period of 2015 to 2019 that includes the following:

a. **Provide activity levels for all quantified activation products, as applicable. [Note that this request is in addition to the information already provided for reactor coolant system (RCS) water activity for tritium and volume of water released to unrestricted areas in Section 6.7.4.f, "Liquid Waste," subsection iv., "Release to Unrestricted Areas," of the supplemental reports];**
b. **RCS water activity for tritium, activation products, and water volumes assumed released to the unrestricted areas for the 2020 reporting period;**
c. **The results of the latest (2020) environmental monitoring results for the facility's surveillance well (MW-1) and surface water (stream) monitoring sites inclusive of gross alpha, gross beta, tritium, and gamma spec. results.**

Response:

2a, 2b: Activation product activity, tritium activity, and water volumes of RCS assumed to be released for 2015 to 2020 are summarized below. The sum of the concentrations for the radioisotopes listed in RCS samples relative to the limits given in 10 CFR Part 20 Appendix B Table 2 Column 2 ranged from 18 percent to 55 percent.

	2015	**2016**	**2017**	**2018**	**2019**	**2020**
Nuclide	**µCi**	**µCi**	**µCi**	**µCi**	**µCi**	**µCi**
Sb124	1.0	4.5	0.5	0.0	14.8	19.5
Ag110m	5.4	48.2	104.2	197.0	165.4	143.0
Co58	0.0	1.4	76.6	42.2	6.4	1.4
Mn54	0.3	0.7	5.0	4.4	13.6	8.4
Fe59	2.9	16.9	47.2	6.2	22.2	2.0
Zn65	2.4	14.1	38.3	25.6	20.1	35.2
Co60	1.6	6.3	35.7	17.6	26.4	35.7
Subtotal excluding H3	14	92	308	293	269	245
Subtotal for H3 only	5,843	11,941	29,754	20,363	14,373	13,262
Total	**5,857**	**12,033**	**30,062**	**20,657**	**14,643**	**13,507**
Total liters	45,699	70,732	135,650	153,342	188,685	212,284

2c. Gross alpha, gross beta, tritium, and gamma spectroscopy results for surface water as provided in the 2020 PULSTAR Reactor Annual Report, Attachment A 'PULSTAR Reactor Environmental Radiation Surveillance Report' are given below:

SURFACE WATER (TABLES 4.1 AND 4.2)

Table 4.1 gives the gross alpha and beta activities for water from Rocky Branch at points where it enters (ON) behind Carmichael Gymnasium (GYM) and exits (OFF) the campus. The LLD value for gross alpha and beta activities is approximately 0.4 pCi Liter $^{-1}$. For gross alpha activity the Investigation Level is 5 pCi Liter $^{-1}$ and the Regulatory Limit is 15 pCi Liter $^{-1}$. For gross beta activity the Investigation Level is 12.5 pCi Liter $^{-1}$ and the Regulatory Limit is 50 pCi Liter $^{-1}$.

Gamma analysis of all samples was also performed. All the results are consistent with the presence of naturally-occurring radionuclides and none of the gamma emitters listed in Table 4.2 were detected.

TABLE 4.1 GROSS ALPHA AND BETA ACTIVITY IN SURFACE WATER (pCi Liter $^{-1}$ ± 2σ)

LLD_{α} ~ 0.4 pCi Liter $^{-1}$ LLD_{β} ~ 0.4 pCi Liter $^{-1}$

DATE	LOCATION	GROSS ALPHA	GROSS BETA
FIRST QUARTER 2020	ON	0.1± 0.1	3.4 ± 0.7
	OFF	0.1± 0.1	3.5 ± 0.7
	GYM	0.2 ± 0.2	2.0 ± 0.6
SECOND QUARTER 2020	ON	0.2± 0.2	3.6 ± 0.7
	OFF	0.1 ± 0.2	2.3 ± 0.6
	GYM	0.1 ± 0.2	3.9 ± 0.7
THIRD QUARTER 2020	ON	0.3 ± 0.2	3.1 ± 0.7
	OFF	0.1 ± 0.1	1.5 ± 0.6
	GYM	0.1 ± 0.1	3.0 ± 0.7
FOURTH QUARTER 2020	ON	0.2 ± 0.2	4.2 ± 0.7
	OFF	0.1 ± 0.2	2.6 ± 0.6
	GYM	0.1 ± 0.2	2.6 ± 0.6

NOTE: 1 pCi/l = $1x10^{-9}$µCi/ml

TABLE 4.2 LLD VALUES FOR GAMMA EMITTERS IN SURFACEWATER

Nuclide	LLD (pCi Liter $^{-1}$)
Co-60	0.4
Zn-65	0.7
Cs-137	0.3
Cs-134	0.4
Sr-85	0.4
Ru-103	0.3
Ru-106	3.0
Nb-95	0.4
Zr-95	0.5

2020 Results for Monitoring Well 1 (MW-1)

No activity above background was detected for MW-1 samples in 2020. MDA for Tritium, Gross Beta, and Gross Alpha analyses are given below. All MDA are less than the regulatory limits.

Sample	Date	Tritium MDA	Gross Beta MDA	Gross Alpha MDA	Units
MW1	15-Jan-20	7.7E-07	1.8E-08	2.9E-10	µCi/ml
MW1	9-Apr-20	7.3E-07	1.9E-08	2.5E-10	µCi/ml
MW1	27-Jul-20	7.6E-07	1.1E-08	2.3E-10	µCi/ml
MW1	12-Oct-20	7.6E-07	1.3E-08	2.3E-10	µCi/ml
Regulatory Limits		*2.0E-05*	*5.0E-08*	*1.5E-08*	µCi/ml

2020 MW-1 Gamma Spectroscopy Analyses:

All results in 2020 for MW-1 samples were below detection limits for gamma emitting activation products. The MDA for common activation products from reactor operation are listed below. At MDA levels, the Effluent Concentration (EC) fraction for each radionuclide was less than 0.15. The sum of the EC fractions for tritium and gamma isotopic activation product detection limits, i.e. $\Sigma C_i/[EC]_i$, was less than 0.5 for all MW-1 samples. Radionuclide specific EC are listed in 10 CFR Part 20 Appendix B Table 2 Column 2.

Nuclide	Jan 2020	Apr 2020	Jul 2020	Oct 2020	Units
Sb124	1.9E-7	2.5E-7	4.4E-8	1.7E-8	µCi/ml
Ag110m	2.7E-7	2.6E-7	4.6E-8	3.2E-8	µCi/ml
Co58	2.2E-7	2.6E-7	6.4E-8	2.7E-8	µCi/ml
Mn54	2.2E-7	2.6E-7	6.8E-8	1.5E-8	µCi/ml
Fe59	1.5-E7	4.5E-7	1.2E-7	2.9E-8	µCi/ml
Zn65	5.3E-7	7.3E-7	1.2E-7	6.4E-8	µCi/ml
Co60	1.5E-7	4.0E-7	3.5E-8	1.2E-8	µCi/ml

Discussion of 2020 Results for MW-1 Samples

Quarterly grab samples from MW-1 are taken and analyzed for tritium, gross beta activity, and gamma emitting radionuclides. Regarding MW-1 results, the following are noted:

- Gross alpha and/or gross beta activity may be present in groundwater from naturally occurring radionuclides.
- Gross alpha activity was not detected in reactor coolant system (RCS) or MW-1 samples. Gross alpha detection limits were < $4x10^{-10}$ µCi/ml for RCS samples and < $3x10^{-10}$ µCi/ml for MW-1 samples. Detection limits are below the regulatory limit of $1.5x10^{-8}$ µCi/ml.
- Gross beta activity is measureable in RCS samples. Long-lived gross beta activity in RCS samples was less than $1x10^{-7}$ µCi/ml. Gross beta activity is based on Co-60 giving a conservatively high estimate of beta activity. Ag-110m beta energy is similar to Co-60.
- Gross beta activity for MW-1 samples was not detectable. Detection limits are below the regulatory limit of $5.0x10^{-8}$ µCi/ml. Therefore, activity from activation products is not considered to be present in MW-1 samples.
- No fission products were detected in RCS samples.
- All results in 2020 for MW-1 samples were below detection limits for gamma emitting activation products. Detection limits for individual radionuclides were less than 15 percent of regulatory limits.

(3) A summary of any reporting made related to the leak(s) that NCSU PULSTAR Nuclear Research Reactor has provided to oversight bodies at NCSU, including reports made to the environmental regulatory agencies for the State of North Carolina (specify dates reported); provide copies of any written reports submitted to oversight bodies and State environmental regulatory agencies as well as written responses from the aforementioned entities over the last 5 years (2015-2020).

Response:

Reactor coolant inventory is monitored every work day by the reactor staff using a facility procedure. The procedure requires notification to the Reactor Safety and Audit Committee (RSAC) and Radiation Safety Committee (RSC) at NCSU with 2 days if a leak rate is detectable based a period of at least 14 days.

A detectable leak rate was identified in March 2015 based on review of data for Feb. 2015. On March 13, 2015 the RSAC and RSC were informed about the leak rate. Leak rate information was reviewed and discussed at each RSAC and RSC meeting from March 2015 to the present. Additionally, NCSU Environmental Safety personnel (Radiation Safety) have been informed about the leak rate typically at 1 to 2 week intervals by email since March 26, 2015. NCSU Environmental Safety personnel have relayed information to NCSU administrators.

The measured leak rate and monitoring results are reviewed at committee meetings. Copies of the following reports provided at these meetings are attached:

- Letter dated March 15, 2015 to RSAC and RSC (*See Attachment #1*).
- RSC reports May 15, 2015 to present (*See Attachment #2*).
- RSAC meeting minutes from meeting 2014/15 Number 4 to present (*See Attachment #3*).
- October 2020 emails regarding leak rate change and repair status (*See Attachment #4*).

The committees are informed if repair plans and actions for the leak are taken by the NRP at the meetings. The committees are given leak rate information and discuss leak status at the meetings.

It is noted that there is no exposure pathway to the public occurring. However, public dose estimates based on direct consumption of the leaked water taking dilution into account are well below 1 mrem annually.

State Regulatory Agencies:

Notification of the leak from March 2015 was made on March 26, 2015 to NCSU Environmental Health and Public Safety (EHPS), a unit of the NCSU Office of Finance. NCSU EHPS makes notifications to off-site agencies regarding environmental concerns following NCSU policies and procedures. No official notification was made.

The release is below reporting requirements given in state of NC regulations (General Statute chapter 130a-310). The release was below the reportable quantity (rq) limits for the radionuclides present in reactor coolant given in table 3024 of 40 CFR part 302. The release was not affecting a public water system or in need of removal or remediation.

In October 2020, the NC Radiation Protection Section was contacted by telephone and email regarding a change in the leak status *(see Attachment #4)*.

No written responses have been received from State regulatory agencies or oversight bodies at NCSU.

(4) A characterization of the likely pathways for the subject pool leak water through the building substructure and to soil, groundwater, storm water, and surface water including likely travel times (note: this characterization may be based on an existing environmental site or geotechnical characterization, site conceptual model, or other available information to supplement the licensee's characterization provided in Section 2.4.2 of the updated safety analysis report.)

Response:

In January 2021 a new monitoring well (MW-2) was installed in the reactor bay floor. The results from the installation of MW-2 were used in a hydrology study completed by an external environmental contractor. Detectable leakage into groundwater and subsurface soil is occurring based on tritium results from MW-2 sample analyses. Tritium is the only radionuclide detected in MW-2 samples. The 2021 Hydrology Report and other observations and measurements do not indicate that leakage to storm or surface water has occurred. Local storm sewers have been observed to be dry if no rain is occurring.

The 2021 Hydrology Report states:

1. It appears that ^{3}H activity greater than 1 pCi/ml in the unaccounted water loss from the reactor vessel has not yet moved beyond the footprint of the reactor building basement.
2. Depending upon the simulated groundwater gradient, the movement over the next ten (10) years of the 1 pCi/ml may be as much as 100 feet down gradient.

These values are well below the regulatory limit of 2.0E-05 µCi/ml.

A summary of the 2021 Hydrology Report provided by the vendor follows:

> Site assessment and modeling were performed to assess the fate and transport of Tritium activity (^{3}H) contained in water from leaks from the PULSTAR Research Reactor on the campus of North Carolina State University (NCSU) in Raleigh, North Carolina.
>
> The following activities were completed to obtain additional site-specific information to assist in the assessment of ^{3}H in soils and groundwater beneath the reactor floor and in MW-1:
>
> - Installation of a new monitoring well (MW-2).
> - ^{3}H analyses of soil and water samples from MW-2 .
> - Laboratory testing of unsaturated flow properties of soils from MW-2.
> - Measurement of water levels and slug tests for hydraulic conductivity in MW-1 and MW-2.
>
> A report was received in May 2021 from the consultant. This report utilized data and information regarding site characteristics and reactor vessel construction provided by NCSU as well as a report documenting monitoring well MW-1 which is located outside the west side of Burlington Hall. NCSU has also provided records of the monthly rate of unaccounted-for water losses from the coolant vessel and monthly average ^{3}H activity in the vessel from 2010 through March 2021.
>
> Details on the installation and analysis results were provided in the report. The report conclusion states:
>
> "*Site investigations and laboratory tests were conducted to assess the presence of 3H activity in soils and groundwater beneath the floor of the reactor building by the installation, sampling, and testing of a test well (MW-2) located approximately 20 feet southeast of the reported location of the last repaired leak in the wall of the reactor vessel. This test well was installed by hand auger to a depth of 30 feet below the top of the floor of the reactor bay and was completed with well screen between depths of 15 and 30 feet. Soil samples for laboratory analysis of 3H were composited from the materials encountered over each 5-foot depth interval. Discrete samples were also retained for tests of hydraulic properties necessary for the modeling of water movement under variably saturated conditions. Groundwater was encountered in MW-2 at approximately 28 feet below the bay floor.*

MW-2 was developed and used to measure stabilized water levels, conduct tests for the hydraulic conductivity of the materials in the screened interval, and to obtain a groundwater sample to test for 3H activity. Water levels measured in MW-2 and in the existing MW-1 and measuring point elevations provided by NCSU showed that MW-1 is neither down-gradient from the reactor vessel nor from MW-2.

Laboratory tests showed the presence of ^{3}H in five 5-ft depth interval composited soil samples from 0 to 25 ft at concentrations of 10 to 16 pCi/gm. The analysis of the water sample from MW-2 showed a concentration of 2,279 pCi/l (2.28 pCi/ml). The analysis of the sample from MW-1 which was collected on the same date showed no ^{3}H present above the method detection limit.

Slug tests showed that the hydraulic conductivity of the materials in the screened interval of MW-2 averaged approximately 1.4 ft/day, and that in the screened interval of MW-1 averaged approximately 0.1 ft/day.

Three-dimensional groundwater flow modeling using the USGS ModFlow model of the vicinity around Burlington Hall was used to estimate the directions and gradients of groundwater flow based on limited available data for the depth to bedrock and water levels reported in geotechnical borings as well as in MW-1 and MW-2. This model was used to provide the basis for the orientation and dimensions of a detailed three-dimensional fate and transport model. However, because of the limited data used for its construction the vicinity model should be considered only semi-quantitative.

A three-dimensional variably saturated fluid flow and constituent transport model using the FEMWATER program was constructed and used to assess the likely present and future levels of ^{3}H in the subsurface beneath the reactor vessel and surrounding area. This model was constructed as a rectangular solid 130 feet long, 70 feet wide, and 40 feet thick. Vertically, the model was subdivided into seven layers corresponding to the approximate depths for which discrete sample hydraulic property data was available from the tests conducted by the NCSU Soil Materials Laboratory.

Input of water and ^{3}H to the model were simulated by a 6-month moving average of the monthly values provided by NCSU to enhance numerical convergence by the model. The ability of the model to reproduce the 3H concentrations in the water sample from MW-2 was achieved by adjusting the effective area beneath the reactor floor over which water from the leak moved into the top of the model. The best fit between the observed value of 2.8 pCi/ml and the modeled value of 1.9 pCi/ml was achieved using an effective area of 40 ft^2, or approximately 58% of the area beneath the reactor vessel.

Four scenarios were simulated with the best fit model for different assumed groundwater gradients between the north and south model boundaries of 0.0, 0.001, 0.002, and 0.003 ft/ft to account for uncertainty in the gradient from the vicinity model. All simulations were completed using a daily time step for the period from 4/14/2014 through 3/15/2031.

Based upon the FEMWATER model analyses, it appears that ^{3}H activity greater than 1 pCi/ml in the unaccounted water loss from the reactor vessel that has not yet moved beyond the footprint of the reactor building basement. However, depending upon the simulated groundwater gradient, the movement over the next ten (10) years of the 1 pCi/ml may be as much as 100 feet down gradient.

Installation, testing, sampling, and sample analyses for ^{3}H for three additional monitoring wells was recommended to address this uncertainty and the updating of the model to incorporate the additional information."

Additional Actions

A proposal and quotation has been provided by the vendor for the installation of the additional monitoring wells and is under consideration. A request for funding to support the installation of the proposed additional monitoring wells has been submitted. Depending on the availability of funding, it is anticipated that the installation would be pursued in FY'2023.

Section 2 of the SAR will be revised for the license renewal using the 2021 Hydrology Report and additional information gathered from any additional monitoring wells installed.

(5) A description of the nature and results (include dates) of any additional environmental characterization or subsurface surveys, including environmental sampling and analysis, conducted to assess the disposition of the leaks; describe any plans to conduct any such investigations and/or surveys.

Response:

In September 2020 an increase in the leak rate occurred. Following application of an epoxy patch to the reactor liner, the leak rate decreased on October 22, 2020. Following this leak, Monitoring Well 2 (MW-2) was installed in January 2021. MW-2 is located approximately 10 feet from the outside of the reactor shield inside the reactor building in the Southeast direction.

MW-2 water has been sampled and analyzed frequently since installation in January 2021 for tritium, gross beta activity, and activation product activity. Sampling and analyses are performed using the same method and procedures as for MW-1. MW-1 water is sampled quarterly.

2021 results for MW-1 and MW-2 water samples are given below for tritium, gross beta, and gross alpha analyses:

- All gross beta concentrations were below the detection limit (MDA) for all MW-1 and MW-2 samples. The MDA was less than 20 percent of the environmental gross beta activity limit of $5x10^{-8}$ µCi/ml.
- The tritium concentration in MW-1 water was below the MDA. The MDA was approximately 4 percent of the environmental limit of $2x10^{-5}$ µCi/ml.
- The Tritium concentration in MW-2 water was above the MDA for some samples and averaged $1x10^{-6}$ µCi/ml for results with detectable activity. The maximum tritium concentration was $1.5x10^{-6}$ µCi/ml, which is less than 8 percent of the environmental limit of $2x10^{-5}$ µCi/ml.

Sample	Date	Tritium	Tritium Error	Tritium MDA	Gross Beta MDA	Gross Alpha MDA	Units
MW1	6-Jan-21	6.6E-07	5.2E-07	8.4E-07	8.5E-09	2.0E-10	µCi/ml
MW1	9-Apr-21	2.1E-07	2.8E-07	4.6E-07	8.3E-09	*(a)*	µCi/ml
MW1	15-Jul-21	-4.3E-07	2.8E-07	4.9E-07	8.4E-09	1.7E-10	µCi/ml
MW1	4 Oct-21	-7.9E-07	2.8E-07	4.9E-07	8.5E-09	1.8E-10	µCi/ml
MW2	21-Jan-21	1.5E-06	2.0E-07	3.2E-07	8.2E-09	*(a)*	µCi/ml
MW2	2-Feb-21	-2.3E-06	4.2E-07	7.6E-07	8.5E-09	*(a)*	µCi/ml
MW2	15-Mar-21	0.0E+00	2.1E-07	3.5E-07	8.1E-09	1.8E-10	µCi/ml
MW2	14-Apr-21	9.5E-07	2.0E-07	3.1E-07	8.3E-09	*(a)*	µCi/ml
MW2	12-May-21	1.2E-06	4.7E-07	7.4E-07	8.3E-09	*(a)*	µCi/ml
MW2	9-Jun-21	1.1E-06	3.1E-07	4.9E-07	8.2E-09	1.7E-10	µCi/ml
MW2	15-Jul-21	5.0E-07	3.0E-07	4.9E-07	8.2E-09	1.7E-10	µCi/ml
MW2	23-Aug-21	7.0E-07	2.1E-07	3.4E-07	8.5E-09	1.9E-10	µCi/ml
MW2	15-Sep-21	2.0E-07	2.9E-07	4.9E-07	8.5E-09	1.7E-10	µCi/ml
MW2	4- Oct-21	6.6E-08	3.0E-07	4.9E-07	8.5E-09	1.8E-10	µCi/ml

(a) *Gross alpha activity was not detected in RCS samples taken monthly. The gross alpha detection limit was < $4x10^{-10}$ µCi/ml. If measured, any gross alpha activity detected for MW-1 and MW-2 are assumed to be from natural activity rather than the RCS.*

Per the additional actions discussed under RAI #4 above, installation of additional monitoring wells in the East to South direction on the reactor site are recommended and are being considered to help identify the flow path and environmental concentrations of H-3.

Gamma Spectroscopy Analysis:

No activity above background was detected for water samples taken from MW-1 or MW-2. MDA for common activation products from reactor operation are listed below. At MDA levels, the Effluent Concentration (EC) fraction for each radionuclide was less than 0.02. Radionuclide specific EC are listed in 10 CFR Part 20 Appendix B Table 2 Column 2.

MW-1 Gamma Spectroscopy MDA for 2021

Nuclide	Jan 2021	Apr 2021	Jul 2021	Oct 2021	Units
Sb124	2.1E-8	2.0E-8	2.1E-8	2.0E-8	µCi/ml
Ag110m	2.3E-8	2.2E-8	2.3E-8	2.1E-8	µCi/ml
Co58	2.2E-8	2.2E-8	2.2E-8	2.1E-8	µCi/ml
Mn54	2.3E-8	2.2E-8	2.3E-8	2.1E-8	µCi/ml
Fe59	4.1E-8	4.0E-8	4.1E-8	3.8E-8	µCi/ml
Zn65	4.0E-8	3.7E-8	4.0E-8	4.0E-8	µCi/ml
Co60	1.3E-8	1.3E-8	1.3E-8	1.2E-8	µCi/ml

MW-2 Gamma Spectroscopy MDA for 2021

Nuclide	Jan 2021	Mar 2021	Jun 2021	Jul 2021	Aug 2021	Sep 2021	Oct 2021	Units
Sb124	1.3E-8	2.1E-8	2.1E-8	2.1E-8	3.1E-8	2.0E-8	2.2E-8	µCi/ml
Ag-110m	1.5E-8	2.2E-8	2.2E-8	2.2E-8	3.4E-8	2.2E-8	2.2E-8	µCi/ml
Co58	1.6E-8	2.2E-8	2.2E-8	2.2E-8	3.3E-8	2.2E-8	2.2E-8	µCi/ml
Mn54	1.1E-8	1.6E-8	2.2E-8	2.2E-8	3.5E-8	2.2E-8	2.1E-8	µCi/ml
Fe59	2.9E-8	4.1E-8	4.2E-8	4.0E-8	6.1E-8	4.0E-8	3.9E-8	µCi/ml
Zn65	3.0E-8	3.9E-8	3.9E-8	3.9E-8	5.9E-8	3.9E-8	4.0E-8	µCi/ml
Co60	1.6E-8	1.4E-8	1.4E-8	1.3E-8	1.9E-8	1.3E-8	1.3E-8	µCi/ml

MW-2 Soil

Sediment from MW-2 ground water and soil samples were taken at 5 foot increments during the installation of MW-2 on January 22, 2021. Gamma spectral analysis was performed on these samples. No activity above background was detected.

The MDA for common activation products from reactor operation are listed below. At MDA levels, the Effluent Concentration (EC) fraction was less than 0.1. Radionuclide specific EC are listed in 10 CFR Part 20 Appendix B Table 2 Column 2.

Nuclide	0-5 ft Soil	5-10 ft Soil	10-15 ft Soil	15-20 ft Soil	20-25 ft Soil	Units
Sb124	6.4E-8	7.3E-8	4.5E-8	5.5E-8	6.0E-8	µCi/g
Ag-110m	5.3E-8	6.1E-8	6.0E-8	6.7E-8	7.0E-8	µCi/g
Co58	4.8E-8	6.8E-8	6.8E-8	5.3E-8	7.3E-8	µCi/g
Mn54	6.4E-8	1.2E-7	6.0E-8	5.4E-8	7.5E-8	µCi/g
Fe59	8.4E-7	1.3E-7	1.2E-7	1.2E-7	1.8E-7	µCi/g
Zn65	1.0E-7	1.4E-7	9.2E-8	1.3E-7	2.1E-8	µCi/g
Co60	6.0E-8	9.2E-8	6.4E-8	7.1E-8	9.0E-8	µCi/g

(6) For the requested power uprate and proposed fueled experiment activities, provide a comparative analysis with current operations at 1.0 MW and quantify any anticipated changes to occupational and public doses, gaseous and radiological liquid effluents (types and activity levels), and radiological solid waste generation.

Response:

Radiation doses are low at 1 MW and will only marginally increase at 2 MW. Activities in effluent and waste are expected to double in certain cases, but the amounts remain low and are well below limits. A discussion of radiation doses, effluent activity, and waste activity disposed is summarized in the following table:

Comparison of 1 MW and 2 MW Power Levels for Annual Radiation Dose and Releases:

Item	1 MW	2 MW	Comments
Occupational Dose	<0.1 to 1 rem	<0.11 to 1 rem	Dose is monitored and controlled.
Public Dose for airborne effluent	< 0.01 rem	< 0.01 rem	Dose constraint is in force for airborne effluent.
Public Dose from all sources	< 0.025 rem	< 0.025 rem	ALARA dose goal from all sources is specified in the facility radiation protection program (procedure HP1 Section 4.5).
Gaseous effluent	Variable. Dose is kept below dose constraint.	Similar to 1 MW for most nuclides. H-3 dose is very low.	All airborne effluent is monitored and controlled to be within dose constraints. PN system conversion to nitrogen is planned. H-3 activity will double. H-3 dose is < $2x10^{-4}$ mrem per year.
Liquid effluent	Variable	Activity is 2 times higher. Volume is similar.	Varies with experiments and maintenance. RCS activity is expected to double. Liquid effluent remains less than regulatory limits at the point of discharge.
Solid Waste	Variable	Activity < 2 times higher. Volume is similar.	Varies with experiments and maintenance. RCS purification resin activity is expected to be similar. Solid waste activity remains low at a few mCi per year and meets low level waste limits for Class A waste under 10 CFR Part 61.
Ground Water Pathway	<0.3 mrem	<0.3 mrem	Based on the 2021 hydrology model, public dose from this pathway is most likely zero. Gross beta analysis indicates only tritium is present.

Radiation doses, effluent activity, and waste activity disposed depend on integrated power (MW-h). The reactor is operated as needed. It is noted that an increase to 2 MW does not necessarily mean the reactor MW-h will double. Various controls are in place to keep radiation dose and production of radioactivity ALARA. Controls include limits on conditions for experiments and operations and following radiation monitoring practices and procedures based on sound engineering judgement. Specific topics are discussed in the following sections.

Occupational Dose

Occupational radiation dose is limited by the Radiation Protection Program to meet 10 CFR Part 20 regulations, including the requirement to keep doses ALARA. Occupational doses are monitored throughout the year. Radiation surveys, air sampling, and radiation monitors are used to meet regulatory and facility procedure requirements and for the assessment of personnel dose. Typical occupational doses are approximately at the annual public dose limit of 0.1 rem per year and less than 10% of regulatory limits. Doses above 10% of the regulatory limits are rare and require authorization. Air sampling results are typically well below 1 percent of the Derived Air Concentration (DAC) given in 10 CFR Part 20 Appendix B Table 1.

Reactor operating hours vary based on experimental needs. Continuous reactor operation is infrequent. Daily reactor operation during routine business hours is more typical. Occupational doses are related primarily to irradiation of experimental samples and maintenance work, both of which are closely monitored and vary in frequency and duration.

Regarding occupational doses, the following are applicable:

- Radiation fields will be measured during startup testing to verify dose rates are as expected inside and outside the facility.
- Experiments may be adjusted to maintain the activity produced and handled at similar levels; i.e. the activity needed for measurement should be similar. Reactor shielding is sufficient to keep external radiation levels negligible.
- Additional shielding has been added for areas affected by N-16 (reactor coolant system components) and reactor power (e.g. beam ports).
- Time spent by personnel in radiation areas (i.e. > 5 mrem/h) and areas affected by reactor beam ports will continue to be low. Most experiments and operations do not require personnel to be present at all times in higher, power affected radiological areas.
- Time spent in low radiation fields, which are typically < 1 mrem/h, will be similar for personnel who routinely work in the reactor building. Occupational doses for these personnel would increase slightly since low radiation levels in the reactor building would increase by less than a factor of 2 at 2 MW due to the installation of additional shielding.
- In addition to accredited dosimeters, alarming electronic personnel dosimeters and area radiation monitors are used to keep personnel aware of radiation doses and dose rates.

Due to the controls and monitoring used, adjustments to experiment conditions, and additional shielding, radiation dose to occupational personnel from increasing reactor power from 1 MW to 2 MW is estimated to be similar for most personnel and may potentially increase up to 15% for a few others who routinely work in the reactor building.

Public Dose

Sources of public dose are monitored and controlled as stated in the facility Radiation Protection Program and Health Physics procedures. Section 11 of the FSAR describes public dose monitoring and controls used at the facility.

Airborne activity releases are controlled to not exceed the 10 CFR Part 20 dose constraint of 0.01 rem per year to members of the public as an objective of the facility Radiation Protection Program. This principle of not exceeding the dose constraint applies at any reactor power level for airborne effluent.

N-16 affected areas have had additional shielding put in place to protect occupationally occupied and publicly accessible areas. Public areas affected by N-16 are pedestrian in nature, and are not continuously occupied.

Startup testing will include radiation surveys in public areas. Additionally, public areas may also be monitored with dosimeters or radiation monitors.

Gaseous Effluent

Airborne effluent is described and analyzed in Section 11 of the FSAR. The amount of gaseous effluent varies with MW-h of operation and use of the PN system. Airborne effluent includes releases of Ar-41, tritium, fission gases, vapors (e.g. Iodine), and particulates from reactor operations and experiments. Ar-41 accounts for almost all of the gaseous effluent. Conversion to nitrogen flow gas in the PN system is expected to offset any increase in Ar-41 activity from 2 MW operations. Experiments and maintenance work are evaluated prior to doing the work and monitored as required by the facility Radiation Protection Program and Health Physics procedures. If abnormal conditions are present or a dose constraint for airborne effluent is being approached, the airborne release is restricted or halted.

From the FSAR, tritium airborne activity concentration in the reactor air space at 2 MW is estimated as 2.4×10^{-9} µCi/ml. Activity of tritium to the environment based on normal exhaust is 0.07 Ci per year; 0.07 Ci/y = [$(2.4\times10^{-9}$ µCi/ml)(0.883 m^3/s)($1x10^6$ ml/m^3)(3.15×10^7 s/y)] using flow rates given FSAR Sections 6 and 11. Downwind concentration is reduced by atmospheric dilution using the sector averaged [X/Q] value of 9.15×10^{-5}s/m^3 given in FSAR Section 11. The downwind concentration for tritium is estimated at 1.9×10^{-13} µCi/ml = [$(2.4\times10^{-9}$ µCi/ml)(9.15×10^{-5}s/m^3 x 0.883 m^3/s)]. The analyzed annual public dose from tritium is trivial at < $1.9x10^{-4}$ mrem based on 10 CFR Part 20 Appendix B Table 2 Effluent Concentration for all age groups; [(100 mrem / 1×10^{-7} µCi/ml)(1.9×10^{-13} µCi/ml)]. Additional reduction by a factor of 2.5 may be taken if credit for R-63 fan operation is taken. Based on this analysis, tritium released is conservatively estimated to be insignificant.

Other airborne releases are estimated from experiment requests and reviews, including fueled experiments. Public dose for Ar-41 and other radionuclides is based on air monitoring of airborne effluent taken from the reactor exhaust and atmospheric conditions as stated in the FSAR. The dose constraint for all airborne releases is an objective of the facility Radiation Protection Program at 1 MW and at 2 MW.

Liquid Effluent

Liquid effluent is described and analyzed in Section 11 of the FSAR. There is a dependence on MW-h of operation and experiments that affects liquid effluent volume and activity. Liquid waste comes from experiments and maintenance, the RCS, and condensate from air conditioning of the reactor building.

- Activity produced from experimental samples should be similar since the experimenter should be making only the activity needed. Maintenance work, including decontamination, is the same at either power level. Experiment activity produces many of the same activation products produced in the RCS. Liquid waste activity from experiments is variable because of experiment conditions.

- RCS activity of long-lived activation products at 2 MW is twice the activity at 1 MW due to doubling of the fluence rate and long-term retention of water in the RCS. RCS volume in the liquid waste system should be low since the RCS is a closed loop system. RCS enters the liquid waste system from small overflows during reactor pool fills, beam tube drainage, and occasionally from RCS component leakage.

- Activity in the condensate of the air conditioning system contains a small amount of tritium due to evaporation of tritium from the reactor pool that enters the reactor air space. The volume of condensate collected should be similar at 2 MW. However, the concentration and activity of tritium in the condensate is expected to double at 2 MW since concentration of tritium in the RCS is expected to double.

Historically, radioactive liquid wastes from the reactor facility are low in activity, low in concentration, and low in volume. Concentrations are typically below the sanitary sewer limits at the point of discharge from the reactor facility. With dilution, all discharges to the sanitary sewer are significantly below 10 CFR Part 20 limits.

Activity of liquid waste at 1 MW is on the order of a 1 to 2 mCi per year. Most of the activity is tritium. At 2 MW the activity in liquid waste is estimated to double.

Solid Waste

Solid waste is described and analyzed in Sections 11 of the FSAR. Long-lived activity in the RCS purification system resin bed is expected to double at 2 MW as compared to 1 MW. Resins make up approximately half of the reactor waste volume each year.

Other solid waste is expected to be similar; e.g. gloves, disposable items, residues, and experimental samples. Adjustments to experiments should keep activity produced and disposed to similar amounts. Experiment use is variable at any power level based on demand. Contamination levels are kept below detectable levels to avoid adding volume and activity to the solid waste stream, e.g from decontamination of items or areas. Reactor components are rarely decontaminated or disposed.

Solid waste activity disposed in general is low, variable, and on the order of a few mCi each year. As discussed above, the activity in resins will double at 2 MW and other sources in solid waste should be similar to that observed for 1 MW. All solid waste will continue to be well below Class A waste limits given in 10 CFR Part 61.

The volume of solid waste is not expected to change. Resins are changed based on RCS chemistry and 2 MW operation is not expected to change RCS chemistry. The volume of other solid waste, e.g. gloves, plastic and paper items, disposable protective clothing, etc., is not expected to change.

Ground Water Pathway

The reactor coolant system leakage into the surrounding soil and groundwater has detected the presence of tritium in one well (MW2). Average tritium concentration in ground water is less than $1x10^{-6}$ µCi/ml, which is 1000 times lower than the regulatory limit given in 10 CFR Part 20 Appendix B Table 2 for liquid effluent.

Other radionuclides have not been detected by gamma spectroscopy at levels above 10 percent of the 10 CFR Part 20 Appendix B Table 2 limits for liquid effluent in MW1 and MW2 samples. Gross beta activity has not been detected in MW1 or MW2 samples. The MDA for gross beta analysis for 2021 data is less than $9x10^{-9}$ µCi/ml based on Co-60 and Ag-110m beta energies. Based on the gross beta analysis the concentration of other radionuclides in MW1 and MW2 samples is not detected at levels greater than 0.3 percent of the limits given in 10 CFR Part 20 Appendix B Table 2.

If the ground water was the sole source of liquid consumed, the public dose for tritium would be 0.1 mrem per year (100 mrem/y$x10^{-6}/10^{-3}$). At 2 MW, the tritium concentration is expected to double giving a public dose of 0.2 mrem per year. Based on the gross beta detection limit, the public dose would be 0.3 mrem per year.

However, the hydrology model from 2021 indicates that ground water migration would take at least 10 years to go beyond the site boundary. Given the slow migration of ground water and the absence of a pathway of human exposure to the ground water from the reactor site as stated in Section 2.2 of the FSAR, the public dose is most likely zero. This pathway will be mitigated once a repair to the leak is completed.

Attachment 1 - 2015 Notification sent to RSAC and RSC

North Carolina State University is a land-Grant university and a constituent institution Of The University of North Carolina

Nuclear Reactor Program

NC STATE UNIVERSITY

An Equal Opportunity/Affirmative Action Employer

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Director 919.515.4598
Office 919.515.7294
(Fax) 919.513.1276

Shipping Address:
NC State University
2500 Stinson Dr.
Raleigh, NC 27695

DATE: 13 March 2015

SUBJECT: Notification of Unaccounted Primary Water Loss at the PULSTAR Nuclear Reactor

Notification

PULSTAR Reactor procedures require notification to designated NCSU personnel if an unaccounted leak rate of primary water is identified.

A net unaccounted leak rate of 0.9 (+/- 0.4) gallons per hour was identified by trending reactor pool water level data since 5 Jan 2015. By comparison, leak rates identified in the past ranged from 0.8 to 22 gallons per hour. This leak is steady and trending slightly and consistently above the detectable level.

This leak of reactor water is below regulatory limits for release to unrestricted areas. Official notification to regulatory agencies is not required.

Status

Actions as stated in facility procedures are being implemented. These include examination of the reactor pool and facility by the reactor staff and water sampling and analysis. Reactor water level is being maintained and monitored.

Follow up notifications will be made if there is a change in status.

If you have any questions, please contact me.

Ayman I. Hawari, PhD
Director, Nuclear Reactor Program

Distribution:
Y. Azmy, Ph.D., Head Department of Nuclear Engineering
M. Koci, Ph.D., Chair RSC
C. Gould, Ph.D, Chair RSAC
A. Orders, Radiation Safety Officer

Attachment #2 - Excerpts from RSC Reactor Safety Reports

The following leak information was provided to RSC on the dates indicated.

5 May 2015:

ACCIDENTS INVOLVING SIGNIFICANT EXPOSURES, SPILLS OR LEAKS

A minor leak from the reactor primary coolant system (pool) was reported to NCSU officials in Feb 2015. The leak rate is estimated at approximately 1 gallon per hour. This leak began in Jan 2015 and has not changed since then. Reactor water is within regulatory limits for release to unrestricted areas. Efforts to locate the leak have not been successful.

28 Sep 2015:

ACCIDENTS INVOLVING SIGNIFICANT EXPOSURES, SPILLS OR LEAKS

A minor leak from the reactor primary coolant system (pool) was reported to NCSU officials in Feb 2015. The leak rate is estimated to currently be 1.7 gallons per hour. The leak was initially reported at approximately 1 gallon per hour. Reactor water is within regulatory limits for release to unrestricted areas. Efforts to locate the leak have not been successful.

16 Dec 2015:

ACCIDENTS INVOLVING SIGNIFICANT EXPOSURES, SPILLS OR LEAKS

A minor leak from the reactor primary coolant system (pool) was reported to NCSU officials in Feb 2015 and is currently estimated to be 1.8 gallons per hour. Reactor water meets unrestricted release limits.

11 Apr 2016:

ACCIDENTS INVOLVING SIGNIFICANT EXPOSURES, SPILLS OR LEAKS

A minor leak from the reactor primary coolant system (pool) was reported to NCSU officials in Feb 2015 and is currently estimated to be 1.7 gallons per hour. Reactor water meets unrestricted release limits.

28 Sep 2016:

ACCIDENTS INVOLVING SIGNIFICANT EXPOSURES, SPILLS OR LEAKS

A minor leak from the reactor primary coolant system (pool) was reported to NCSU officials in Feb 2015 and is currently estimated to be 2.5 gallons per hour. Reactor water meets unrestricted release limits. No activity outside the reactor facility in ground water or a nearby creek has been detected. The leak site is not known.

6 Dec 2016:

ACCIDENTS INVOLVING SIGNIFICANT EXPOSURES, SPILLS OR LEAKS

A minor leak from the reactor primary coolant system (pool) was reported to NCSU officials in Feb 2015 and is currently estimated to be 2.3 gallons per hour. Reactor water meets unrestricted release limits. No activity outside the reactor facility in ground water or a nearby creek has been detected. The leak site is not known.

22 Feb 2017:

ACCIDENTS INVOLVING SIGNIFICANT EXPOSURES, SPILLS OR LEAKS

A minor leak from the reactor primary coolant system (pool) was reported to NCSU officials in Feb 2015 and is currently estimated to be 3.3 gallons per hour. Reactor water meets unrestricted release limits. No activity outside the reactor facility in ground water or a nearby creek has been detected. The leak site is not known.

4 May 2017:

ACCIDENTS INVOLVING SIGNIFICANT EXPOSURES, SPILLS OR LEAKS

A minor leak from the reactor primary coolant system (pool) was reported to NCSU officials in Feb 2015 and is currently estimated to be 3.8 gallons per hour. Reactor water meets unrestricted release limits. No activity outside the reactor facility in ground water or a nearby creek has been detected. The leak site is not known.

18 Sep 2017:

ACCIDENTS INVOLVING SIGNIFICANT EXPOSURES, SPILLS OR LEAKS

A minor leak from the reactor primary coolant system (pool) is currently estimated to be 4.5 gallons per hour. Reactor water meets release limits for unrestricted areas. No activity outside the reactor facility in ground water or a nearby creek has been detected. The leak site is not known. Repairs to a suspected leak site are being planned for early 2018 after the current extended operations are complete.

19 Mar 2018:

ACCIDENTS INVOLVING SIGNIFICANT EXPOSURES, SPILLS OR LEAKS

A minor leak from the reactor primary coolant system (pool) is currently estimated to be 3.6 gallons per hour. The previous leak site is suspected as being the current leak site. The epoxy patch from this site was removed and new epoxy patch with a backing plate was applied on 8 Mar 2018. Leak rates over 5 gallons per hour were measured in the weeks prior to this repair. Additional areas for repair near the same location are being considered.

Reactor water meets release limits for unrestricted areas. No activity outside the reactor facility in ground water or a nearby creek has been detected.

RSC comments given to RSC regarding Reactor Water Leak Repair Status

Regarding the status on the planned repair to the reactor pool please refer to the attached RSC report made in Sep 2017 which includes information on the pool leak. This information was discussed with RSAC in their two meetings in the Fall of 2017. The leak has been discussed in RSAC and RSC meetings since Jan 2016.

Please note:

- Based on hydrophone and camera inspections, the previous leak site patched in 2011 is suspected as being the current leak site.
- The release has been below unrestricted area limits in the reactor pool and has not been detected in water samples taken outside the reactor building.
- There is no sign of damage or leaking water inside the reactor building.
- Plans include preparing the suspect area for a new epoxy patch and then covering with a backing plate.
- No specific date has been set, but the repair should be attempted in March/April 2018.

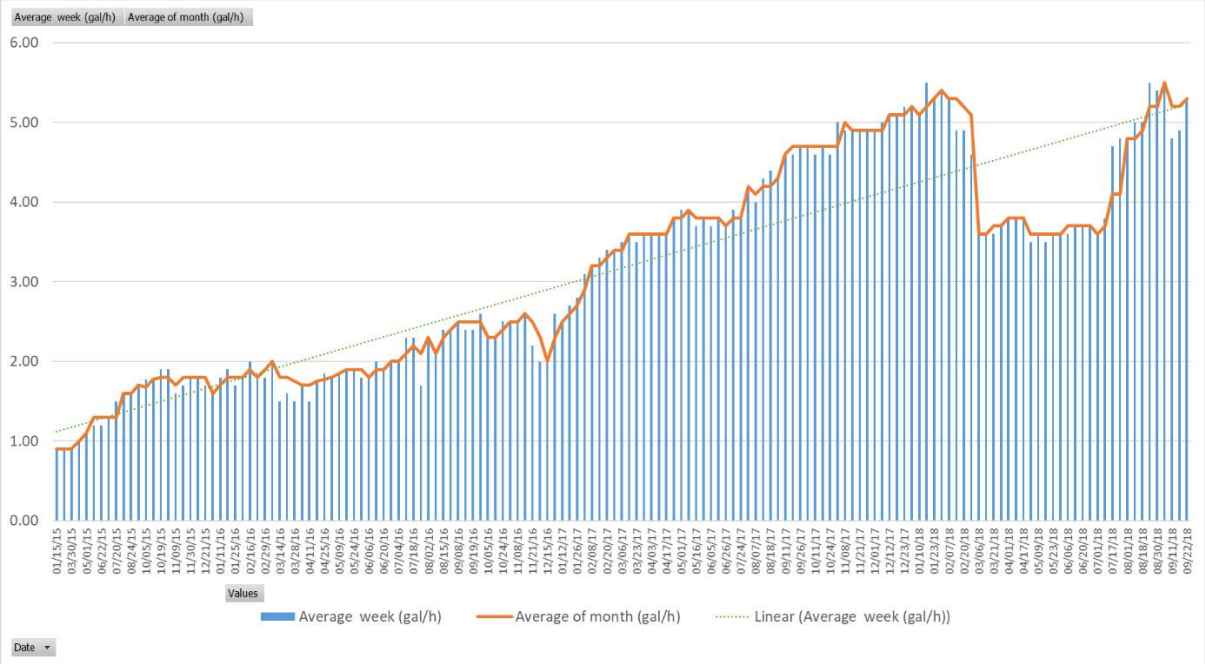
15 Oct 2018:

ACCIDENTS INVOLVING SIGNIFICANT EXPOSURES, SPILLS OR LEAKS

A minor leak from the reactor primary coolant system (pool) is currently estimated to be 5.3 gallons per hour. Anew epoxy patch with a backing plate was applied on 8 Mar 2018. Since July 2018 the leak rate increased to over 5 gallons per hour and has been stable for since Sep 2018. Repair is planned for Dec 2018.

Reactor water meets release limits for unrestricted areas. No activity outside the reactor facility in ground water or a nearby creek has been detected.

Reactor leak data shown to RSC:



30 Jan 2019:

ACCIDENTS INVOLVING SIGNIFICANT EXPOSURES, SPILLS OR LEAKS

A minor leak from the reactor primary coolant system (pool) is currently estimated to be 5.5 gallons per hour. A new epoxy patch with a backing plate was applied on 8 Mar 2018. Since July 2018 the leak rate increased to over 5 gallons per hour and has been stable for since Sep 2018. The leak rate did not change following placement of a patch in a second area in Dec 2018.

Reactor water meets release limits for unrestricted areas. No activity outside the reactor facility in ground water or a nearby creek has been detected.

13 May 2019:

ACCIDENTS INVOLVING SIGNIFICANT EXPOSURES, SPILLS OR LEAKS

A minor leak from the reactor primary coolant system (pool) is currently estimated to be 5.2 gallons per hour. Reactor water meets release limits for unrestricted areas. No activity outside the reactor facility in ground water or a nearby creek has been detected.

Purchase of leak detection equipment is being pursued by the Nuclear Reactor Program.

19 Sep 2019:

ACCIDENTS INVOLVING SIGNIFICANT EXPOSURES, SPILLS OR LEAKS

A minor leak from the reactor primary coolant system (pool) is currently estimated to be 6 gallons per hour. Reactor water meets release limits for unrestricted areas. No activity outside the reactor facility in ground water or a nearby creek has been detected.

Leak detection equipment has been purchased and testing is being conducted by the Nuclear Reactor Program in designated areas within the reactor pool weekly. No leak has been detected yet.

3 Feb 2020:

ACCIDENTS INVOLVING SIGNIFICANT EXPOSURES, SPILLS OR LEAKS

A leak from the reactor primary coolant system (pool) is currently estimated to be 7.2 gallons per hour. The leak rate has been stable at 7 to 7.5 gallons per hour for two months.

Testing by a leak detection company was performed in Dec 2019. Two suspect leak locations were identified. One area was patched without success. Patching of the other area is being planned.

Reactor water meets release limits for unrestricted areas. No activity outside the reactor facility in ground water or a nearby creek has been detected.

14 Apr 2020:

ACCIDENTS INVOLVING SIGNIFICANT EXPOSURES, SPILLS OR LEAKS

A leak from the reactor primary coolant system (pool) decreased in Mar 2020 from 7 gallons per hour to 5.5 gallons per hour.

Testing is being conducted to locate leak site(s), but none have been detected yet.

Reactor water meets release limits for unrestricted areas. No activity outside the reactor facility in ground water or a nearby creek has been detected.

2 Oct 2020:

ACCIDENTS INVOLVING SIGNIFICANT EXPOSURES, SPILLS OR LEAKS

A leak from the reactor primary coolant system (pool) has increased in from 5 gallons per hour to 7.5 gallons per hour starting in September 2020.

Testing has been inconclusive. Leak detection and repair is being pursued by an industrial contractor.

Reactor water meets release limits for unrestricted areas. No activity outside the reactor facility in ground water or a nearby creek has been detected.

29 Mar 2021:

ACCIDENTS INVOLVING SIGNIFICANT EXPOSURES, SPILLS OR LEAKS

A leak from the reactor primary coolant system (pool) increased to an average of 11 gallons per hour in Oct 2020. In Oct 2020, testing was performed by a contractor and a leak site was identified. The leak rate decreased to 2.8 gallons per hour following repair by the reactor staff. The leak rate has been stable since the repair. Leak detection and repair is being pursued with an industrial contractor.

A hydrology study of the reactor site began in Jan 2021 by an environmental contractor. The study will provide a reactor site hydrology model (flow path, flow rate). Low levels of tritium were detected in a sample taken in Jan 2021 from the newly installed monitoring well located inside the reactor building for the hydrology study. The tritium levels were below environmental limits and regulatory limits. A sample taken from the new monitoring well in Mar 2021 had non-detectable levels of tritium. The monitoring well at the site boundary had non-detectable levels of tritium.

28 Sep 2021:

ACCIDENTS INVOLVING SIGNIFICANT EXPOSURES, SPILLS OR LEAKS

A leak from the reactor primary coolant system (pool) has been stable since the repair in Oct 2020. Leak detection and repair is being pursued with an industrial contractor.

A hydrology study of the reactor site was received in May 2021 by an environmental contractor. The study provides a reactor site hydrology model (flow path, flow rate), which indicates tritium migrates in a downward direction primarily and slowly spreads in the South East direction. After 10 years the hydrology model has released tritium remaining within the reactor site boundary (surrounding streets).

Low levels of tritium were detected in samples taken from the new monitoring well installed in Jan 2021 inside the reactor building. The tritium levels were below environmental limits, drinking water limits, and regulatory limits. The monitoring well at the South West site boundary has had non-detectable levels of tritium in 2021. Additional monitoring wells are being considered for the South East site boundary.

Attachment #3 - Excerpts from RSAC Minutes

The following leak information was provided to RSAC on the dates indicated.

7 May 2015:
Reactor pool water level status update; A low level, unaccounted reactor water loss was reported as required by facility procedures in Mar 2015. No activity has been detected outside the facility. The release is ongoing. Monitoring plans were discussed with the committee.

25 Sep 2015:
Reactor pool water level status update was given. Monitoring up to 1 year at the present leak level was discussed.

25 Jan 2016:
Reactor pool water level status was updated.

28 Mar 2016;
Reactor pool water level status was reviewed.

7 Sep 2016:
Reactor pool water level status updated.

19 Dec 2016:
Reactor pool water level status update was given.

3 May 2017:
Updated reactor pool status

5 Sep 2017:
Updated reactor pool status

28 Nov 2017:
A minor leak from the reactor primary coolant system (pool) is currently estimated to be 5 gallons per hour. Reactor water meets release limits for unrestricted areas. No activity outside the reactor facility in ground water or a nearby creek has been detected. The leak site is not known. Repairs to a suspected leak site are being planned for early 2018 after the current extended operations are complete.

26 Mar 2018:
Water loss rate was at 5 gal/h in Feb 2018. Epoxy patch was made in Mar 2018 and water loss rate decreased to 3.6 gal/h. Water loss rate was stable at 3.7 gal/h through Jun 2018. It has increased steadily since July to 5.3 gal/h. No reason is known for the increase. A second repair was initiated, but the underwater camera failed. A new camera is being purchased. Once the new camera is received, a second repair will be scheduled. Activity in the reactor pool water meets release limits to unrestricted areas.

3 Oct 2018:
Water loss rate was at 5 gal/h in Feb 2018. Epoxy patch was made in Mar 2018 and water loss rate decreased to 3.6 gal/h. Water loss rate was stable at 3.7 gal/h through Jun 2018. It has increased steadily since July to 5.3 gal/h. No reason is known for the increase. A second repair was initiated, but the underwater camera failed. A new camera is being purchased. Once the new camera is received, a second repair will be scheduled. Activity in the reactor pool water meets release limits to unrestricted areas.

20 Feb 2019:
Current leak rate is stable at approximately 5.5 gallons per hour. An additional section on the pool

liner was patched in Dec 2018, but the leak rate was not changed. Alternate suspect locations are to be evaluated. New acoustic testing equipment is being purchased for use by NRP staff.

2 May 2019:

The current leak rate is 5.6 gal/h and has been 5 to 5.6 gal/h for many months. Acoustic test equipment for evaluating the reactor pool has been purchased and received. The NRP staff has setup the test equipment is becoming familiar with its operation. The acoustic range exceeds that of human hearing, so special equipment and software is used to evaluate the signal. The test equipment purchased was made after consultation with the testing company used in the past.

27 Aug 2019:

The current leak rate is 5.6 gal/h and has been 5 to 5.6 gal/h for many months. Acoustic test equipment for evaluating the reactor pool has been purchased and received. The NRP staff has setup the test equipment is becoming familiar with its operation. The acoustic range exceeds that of human hearing, so special equipment and software is used to evaluate the signal. The test equipment purchased was made after consultation with the testing company used in the past.

10 Dec 2019:

Leak rate of 7 gallons per hour was discussed. RSAC was informed about leak testing done on 3 Dec by an outside company which indicated two suspect areas may be leaking. Preparations are being made to patch these two areas.

26 Feb 2020:

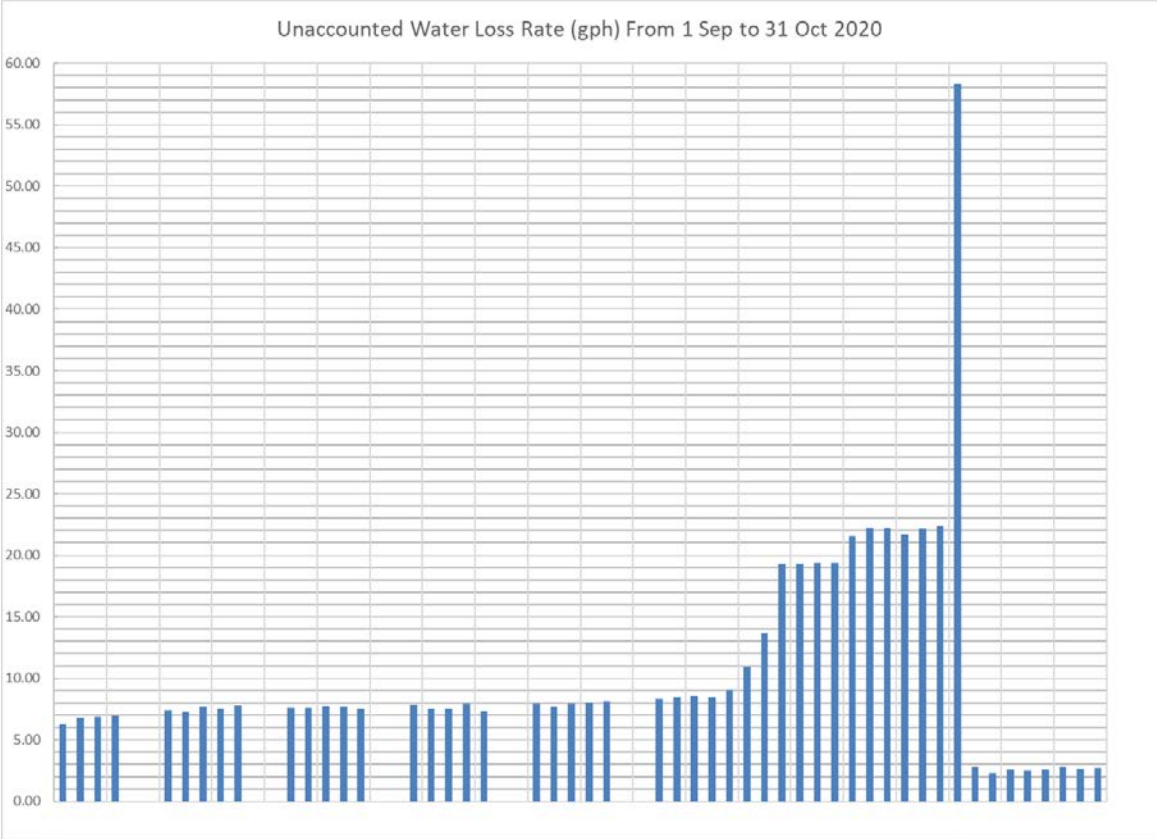
Leak rate decreased from 7 gallons per hour to 5.5 gallons per hour. Testing of and repair of suspect areas, including the thermal column is being planned.

26 Jun 2020:

Leak rate remains at 5- 5.5 gallons per hour. Testing and repair of suspect areas is being performed.

25 Sep 2020:

Current status, plans, and actions were reviewed. Site hydrology testing and modelling is being planned. A design change for drilling of reactor floor for hydrology testing. This item will be discussed and sent for RSAC review via email at a later date.



Summary of Oct 2020 Leak Site Repair:

An increased leak rate was observed on Oct 9-12, 2020. The leak rate increased to approximately 21 gph on Oct 13-22, 2020.

Leak location on lower north west side of the liner was found and repaired with an epoxy patch on Oct 22, 2020.. The leak site increased during the repair due to the location being cleaned and prepared for the application of the patch. Following the repair, the leak rate decreased to approximately 2.7 gph on Oct 23-31, 2020. Leak rate was steady in Nov 2020 at 2.8 gph.

The leak site was in the liner wall away from a weld. The exact cause of this failure is not known at this time.

11 Dec 2020:

Liner repair was made in October to address an increased leak rate. The leak rate was reduced. Ongoing efforts and plans will be discussed for the leak that remains active. Additional information is attached. Testing and patch repair was discussed.

The leak rate remains low. Discussions with leak detection and repair contractor are planned.

21 May 2021:

The leak rate remains low. Discussions with leak detection and repair contractor are planned.

Attachment #4 - Information on Oct 2020 Leak Status Change sent to RSAC

NC STATE

Gerald Wicks <wicks@ncsu.edu>

Reactor Pool Water Level Update

1 message

Gerald Wicks <wicks@ncsu.edu> Mon, Oct 12, 2020 at 4:01 PM
To: Nam Dinh <ntdinh@ncsu.edu>, "H. Henry Lamb" <lamb@ncsu.edu>, "Sit, Roger (Environment Health & Safety)" <RCSIT@ehs.unc.edu>
Cc: Amy Orders <aborders@ncsu.edu>, "Ayman I. Hawari" <ayman.hawari@ncsu.edu>, Scott Lassell <scott_lassell@ncsu.edu>

As of late August, the Unaccounted Water Loss Rate (UWLR) for the PULSTAR Reactor primary system had been trending at ~5 gallons per hour (GPH) for 2 months. In early September, the rate increased to ~7 GPH over about the period of a week. The increased rate for September was 7.6 GPH. The UWLR had increased to just under 8 GPH in late September. Over the period from 1 October to 9 October, the UWLR increased from 8 to ~9 GPH. The reactor staff have been closely monitoring the UWLR and on 11 October the rate was observed to increase to ~20 GPH. These increases in the UWRL have not been correlated with any known changes to primary system parameters or maintenance or experimental activities in the reactor pool. As of 12 October, the UWLR was ~20 GPH. This UWLR is capable of being replenished from the reactor service water system, and the primary water level is being maintained according to facility procedures.

Given this increase in the UWLR, the following actions are being taken:

- the reactor was shutdown on 9 October and will remain shutdown until this issue is resolved satisfactorily;
- the reactor staff are commencing acoustic emissions testing utilizing in-house equipment to attempt to determine the location of the leak; the external acoustic emissions testing vendor is available to support our efforts remotely, and to come on campus the week of October 26th to assist with leak detection.
- assuming the location of the leak is determined, efforts to repair and patch any identified leak site would commence immediately.
- sampling and radioassay of the primary water will be performed daily during weekdays;
- the facility environmental monitoring well will be sampled on weekly basis,

Given that the UWLR is well above the nominal detection limit for acoustic emissions testing, it is anticipated that the leak location will be found. Depending on the leak location, tooling and equipment may need to be designed and procured to support patching. Any corrective actions will be performed in accordance with facility procedures.

Additionally the following items are noted:

1. On 12 October, water is visible on the southside of the reactor bioshield, adjacent to a beam port
2. Sampling of the three environmental program locations (Rocky Branch Creek) and visual inspection of stormwater drains surrounding Burlington labs are being performed by NCSU Radiation Safety twice a week until the leak wanes.
3. NRC has been informed voluntarily of this situation. It is not an official report, but a courtesy update to an existing situation.
4. NCSU Radiation Safety Officer notified the Radiation Safety Committee Chair, EHPS leadership, select Radiation Safety staff and will contact NC RPS by phone as a courtesy update to an existing situation.

As the situation changes, we will provide updates.

thanks
--
Gerald Wicks, CHP
Campus Box 7909
2119 Burlington Laboratory
NC State University
Reactor Health Physicist
919-515-4601

Attachment #4 - Information Update on Oct 2020 Leak Status Change sent to RSAC

NC STATE

Gerald Wicks <wicks@ncsu.edu>

Reactor status

1 message

Gerald Wicks <wicks@ncsu.edu> Thu, Oct 29, 2020 at 10:56 AM
To: "Sit, Roger (Environment Health & Safety)" <RCSIT@ehs.unc.edu>, Nam Dinh <ntdinh@ncsu.edu>, "H. Henry Lamb" <lamb@ncsu.edu>, Amy Orders <aborders@ncsu.edu>
Cc: "Ayman I. Hawari" <ayman.hawari@ncsu.edu>, Scott Lassell <salassel@ncsu.edu>

A leak site in the PULSTAR pool liner was identified and repaired on 10/22. Following the repair, the unaccounted water loss rate has stayed below 3 GPH. During the period of the elevated unaccounted water loss rate, the activity of the primary water continued to be below regulatory limits for release to unrestricted areas. Reactor operations have now resumed in support of the facility mission.

Please let me know if you have any questions

thanks

--

Gerald Wicks, CHP
Campus Box 7909
2119 Burlington Laboratory
NC State University
Reactor Health Physicist
919-515-4601

Attachment #4 - October 2020 Notification to NC Radiation Protection Section:

NC STATE

Amy Orders <aborders@ncsu.edu>

NC State Reactor update 10.12.2020

Amy Orders <aborders@ncsu.edu> Mon, Oct 12, 2020 at 2:54 PM
To: "Cox, Lee" <lee.cox@dhhs.nc.gov>
Cc: David Rainer <darainer@ncsu.edu>, Ken Kretchman <kwkretch@ncsu.edu>
Bcc: Amy Orders <aborders@ncsu.edu>

Good afternoon Lee,

NC State is apprising NC RPS of an update to the PULSTAR Reactor pool water leak. As of today, the reactor pool is leaking approximately 20 gallons/hour and is shut down for immediate investigation and repairs. Under the Broad Scope License, we are collaborating with reactor personnel on heightened environmental sampling and testing and will continue this testing until the situation is addressed. Of note, reactor program personnel were already working with vendors to remedy the existing 5-7 gallon/hour leak; this increase in water loss may provide enough information to address the ongoing concern.

As the situation changes, I will provide updates, as well as contact you if immediacy of the situation arises. Please let me know if you have any questions.

Thanks,
Amy

Amy Orders, Ed.D., RT(R)
Director, Emergency Management and Mission Continuity &
Assistant Director, Environmental Health and Safety
Departments of Environmental Health and Public Safety
NC State University / CB 8007 / 2620 Wolf Village Way / Raleigh North Carolina 27695-8007
919.515.5208

Teaching Assistant Professor, College of Education / http://ced.ncsu.edu/