DEFENSE NUCLEAR AGENCY
ARMED FORCES RADIOBIOLOGY RESEARCH INSTITUTE
BETHESDA, MARYLAND 20889-5145

RSDR

2 April 1992

SUBJECT: Submission of Startup Report on Fuel Follower Control Rod Installation

50-170

Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Gentlemen:

The AFRRI TRIGA staff have prepared a startup report as required by Technical Specification 6.6.1.a. Enclosed are copies of "Startup Report on Fuel Follower Control Rod Installation at AFRRI". If you have any questions or comments, please contact myself or the Reactor Operations Supervisor, Capt Matt Forshacka, at (301) 295-1290.

Sincerely,

Mark L Moore

MARK L. MOORE
Reactor Facility Director

Enclosure:
as stated

Courtesy Copies to:

USNRC - Region I - Project Engineer
Division of Reactor Projects
Mr. T. Dragoun

USNRC - Headquarters - Project Manager
Nuclear Reactor Regulation
Mr. M. Mendonca

IE26
1/1

AFRRI

Startup Report on Fuel Follower Control Rod Installation at AFRRI

Docket 50-170
License R-84

March 1992

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Submitted by:

MARK L. MOORE
Reactor Facility Director

I have determined that the modifications to the Reactor Facility, as described in this Technical Report (Startup Report as per Technical Specification 6.6.1.a), involve no unreviewed safety issues and were conducted in accordance with the 10 CFR 50.59 request approved by the NRC on 8 OCT 91. I submit this Technical Report to the Reactor and Radiation Facility Safety Committee (RRFSC) for review and concurrence.

Mark Moore

MARK MOORE
Reactor Facility Director

The RRFSC has reviewed this Technical Report and concurs with the determination that the modifications to the Reactor Facility, as described in this Technical Report, involve no unreviewed safety issues.

N.W. Manderfield

N.W. Manderfield
Colonel, USAF, MSC
Chairman, RRFSC

APPROVED FOR RELEASE

Robert L. Bumgarner

ROBERT L. BUMGARNER
Captain, MC, USN
Director

Introduction

This report is prepared in accordance with AFRRI Technical Specification 6.6.1.a. It addresses the license change of maximum steady state power increase to 1.1 MW maximum steady state power level and the installation of fuel follower control rods (FFCRs). The installation of fuel follower control rods (FFCRs) is described in chronological sequence and analysis of the results is provided. For a detailed description of FFCRs and their safety analysis with regard to installation at AFRRI, see AFRRI TR91-1, "Maximum Temperature Calculation and Operational Characteristics of Fuel Follower Control Rods for the AFRRI TRIGA Reactor Facility". FFCRs were installed to offset the long-term effects of fuel-burnup and increase the core excess reactivity. AFRRI first applied to the USNRC for a technical specification amendment to allow for the installation of FFCRs on 30 Apr 90. The FFCRs arrived at AFRRI from General Atomic on 8 Aug 91, and the NRC approved installation of the FFCRs on 8 Oct 91. The FFCR installation project at AFRRI began on 8 Nov 91 and concluded on 12 FEB 92.

Receiving and Storage of FFCRs Prior to Installation

Prior to receiving the FFCRs, the Hot Cell was prepared for fuel storage. The room was made free of dust and debris, a gamma detector (criticality monitor) was in place, a high security lock was installed, and cradles for holding the fuel were built.

The FFCRs entered AFRRI through the shipping and receiving department (LOGS). LOGS personnel were instructed to not open the containers holding the FFCRs. LOGS personnel called RSDR and SHD immediately upon receipt of the FFCRs. SHD performed a radiological survey in accordance with HPP-0-3 of external radiation and external contamination of the packaging in the loading dock area prior to moving the FFCR containers to the Hot Cell. No measurable contamination was found.

Once the FFCRs were cleared by SHD to be moved to the Hot Cell, RSDR staff conducted a series of tests within the Hot Cell to determine if any uranium was on the outer surface of the FFCR cladding. The testing methodology was similar to the series of measurements outlined in 10 CFR 70.39 which deals with the certification of calibration or reference radiation sources. The following tests were conducted:

1. Dry wipe test. The entire surfaces of the FFCRs were wiped with filter paper using moderate finger pressure. No radioactivity was found on the filter paper.

2. Wet wipe test. The entire surfaces of the FFCRs were wiped with filter paper, moistened with water, using moderate finger pressure. No radioactivity was found on the filter paper.

3. Water Boil Test. The FFCRs were completely immersed in boiling water for one hour. The residue obtained by evaporating the water showed no presence of uranium using the SHD counting lab.

Appendix 1 contains radioanalysis reports of the above tests.

Core Preparation

Prior to shutdown and FFCR installation, neutron activation foils/wires were used in ER1 with the bare core configuration at a fixed position near the center of the room. An approximate neutron energy spectrum was determined and the data was saved for later comparison with FFCR loaded core.

Fuel unloading commenced 8 Nov 91 and was completed on 12 Nov 91 (see AFRRI TRIGA Refueling Plan, Appendix 2). Following the removal of fuel, the standard control rods and transient control rod were removed. The rod drive support structure was then modified to allow for the ease of transient rod drive maintenance. A platform was built approximately 40 inches above the rod drive mounting plate to accommodate the transient rod drive mechanism. Work to modify the transient rod drive platform was completed on 18 NOV 91.

While the transient rod drive platform was being fabricated, RSDR staff set up two BF_3 chambers in the core to be used for subcritical multiplication measurements during fuel reloading. The counting systems consisted of ANPDR-70 neutron detectors which were modified to use a Harshaw Type S212414AB BF_3 chamber. The output from the ANPDR-70 was sent to a scaler. The BF_3 chambers were located in core grid positions F-18 and F-7. A fission chamber was set up over core grid location F-11 as an additional neutron monitor during fuel reloading. The signal from the fission chamber was sent through a PA-15 amplifier and scaler.

The FFCR and transient rod connecting rods were assembled on 18-19 Nov 91. The method for determining the correct length of the connecting rod was as follows:

- Using blueprints, the center of the poison section was located on each control rod. The center of the poison was marked on each rod using a magic marker.
- The old control rod was attached to the barrel assembly and was extended to its full length. The center points of the old rod and the FFCR were then matched and the new connecting rod length was measured from the top of the FFCR to the connection point on the barrel assembly.

Installation of FFCRs into AFRRI TRIGA Reactor Core

With the core free of fuel, FFCRs were inserted without danger of activation. The FFCRs were centered in their grid locations using the set screws for the barrel assemblies. The goal was to minimize any rubbing of the FFCR as it travels up and down. Once the FFCRs were centered, drop time tests were performed to insure compliance with the technical specifications.

Refueling AFRRI TRIGA Reactor Core

Refuelling of the AFRRI TRIGA reactor core commenced on 26 NOV 91. 1/M plots were made to insure that a conservative approach to refueling the reactor core was taken. The actual fuel loading steps were recorded in the reactor operations logbook; shown below are the 1/M plots during the approach to a critical configuration:

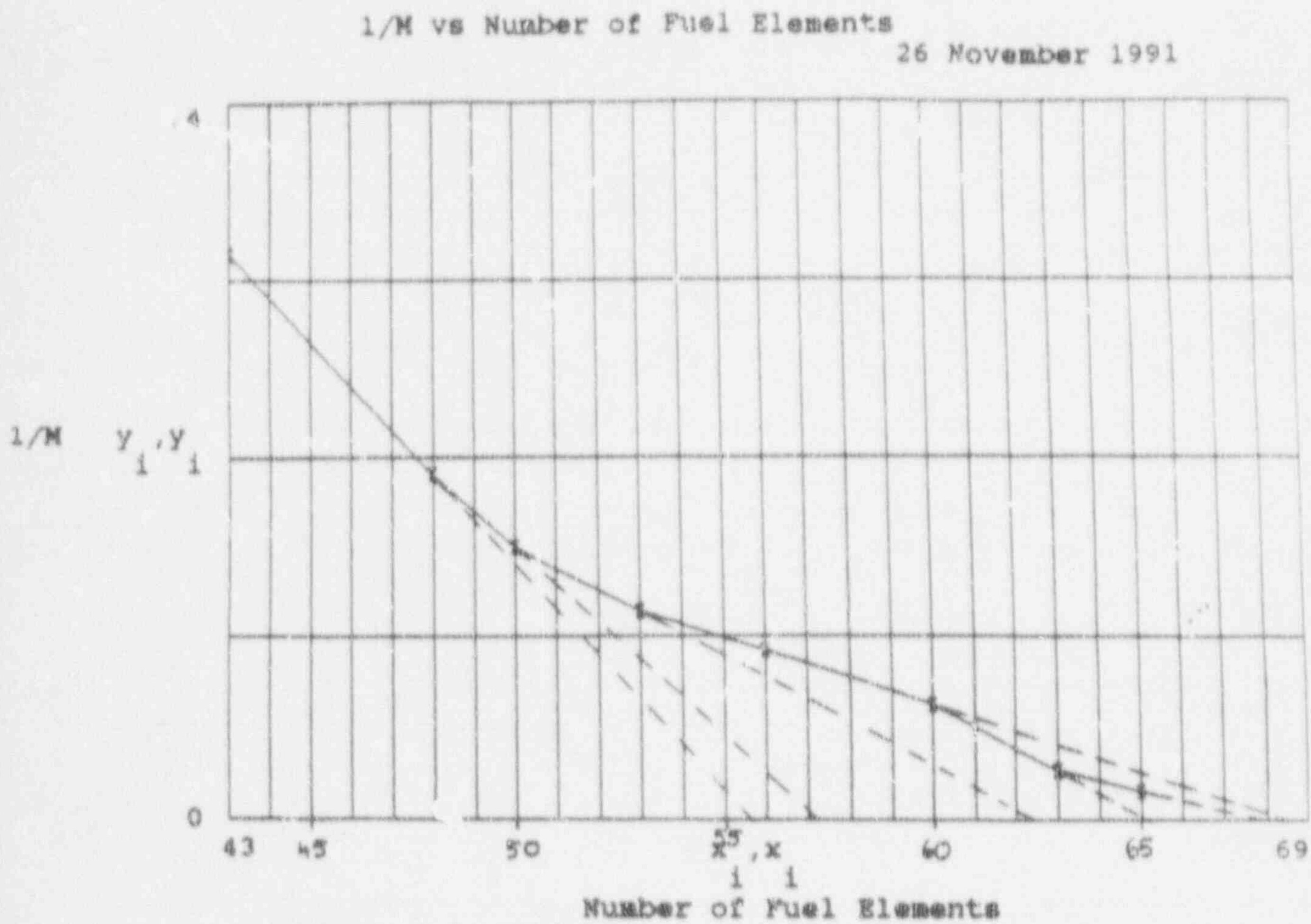

Figure 1. 1/M plot for approach to criticality (BF_3 at core grid location F-7).

A critical configuration was achieved on 29 Nov 91 with 69 elements in a close packed array. Fuel was then added to get enough excess reactivity to allow for the calibration of control rods. A thermal power calibration was performed to insure that the placement of the fission chamber was correct (data is recorded in the core physics logbook). For an operational fuel loading of 84 standard fuel elements and three FFCRs, control rod calibrations yielded the following results:

Control Rod	Worth of rod at 500
Transient	$4.14
Reg	$2.63
Safe	$2.06
Shim	$2.41

With the excess reactivity of $4.40 measured on 6 Dec 91, this insured a shutdown reactivity of $6.71. With the most reactive rod removed (the transient rod), the shutdown reactivity is $2.57 which is well in excess of the technical specification limit of $0.50. The predicted value of the shutdown reactivity with the transient rod removed (see AFRRI TR91-1) was $2.80, with the measured value reasonably close to the predicted value. A mechanical stop was placed on the transient rod by an administrative directive to limit its travel and prevent an inadvertent reactivity insertion of greater than $4.00.

Operational Testing Program

Power operations greater than cold critical commenced on 2 DEC 91 with a 100 kW steady state power run to perform a thermal power calibration. 1.0 MW was attained on 4 DEC 91 to calibrate the high-flux safety channels. During the period of 5 Dec 91 to 25 JAN 92 the reactor operated exclusively in the steady state mode to continue checkout and system calibrations.

Pulsing operations commenced on 25 JAN 92. The sequence of pulse operations listed in the refueling plan was followed. The purpose of the pulsing program was to gradually stretch the fuel cladding in a controlled manner. Following the pulsing program, the reactor was operated at full power for two hours to ensure that the cladding had not failed during the course of testing. No increase in radiation levels in the CAMs or water monitor box were observed. Routine tests of the water performed by SHD have shown no presence of fission products in the reactor pool water.

The operational testing program was completed on 12 FEB 92 with the final full power test to the license power limit of 1.1 MW. This test was conducted in accordance with the refueling plan. The following table shows rod positions, fuel temperatures, and radiation levels during the approach to the license limit of 1.1 MW:

Power Level (kW)	Trans Rod	Reg Rod	Safe Rod	Shim Rod	Fuel Temp #1	Fuel Temp #2	Stack Gas (CPM)	CAM (CPM)	RAM #1 (mR/hr)
100	602	582	585	599	128C	118C	3	30	5
500	670	731	669	669	322C	295C	7*	40*	20
1000	751	818	799	799	431C	430C	7*	40*	50
1050	750	828	817	808	440C	441C	8*	45*	70
1070	750	850	817	808	44[illegible]	443C	8*	45*	70
1090	Scram	-----	-----	-----	-----	-----	-----	-----	-----

Table 1. Key reactor parameters recorded during approach to full power limit.
* Increase in level is due to shine from the high energy ^{16}N gamma ray.

Note that the scram set point is set at 1.09 MW to insure that the 1.1 MW power limit is not exceeded. The maximum temperature attained was 443C: this is 557C less than the technical specifications safety limit and 157C less than the limiting safety system setting for fuel temperature.

Conclusion

FFCR installation at the AFRRI reactor was completed in a safe and timely manner. All radiological surveys and measurements indicated that there was no release of fission products during any phase of testing or operations. The installation of FFCRs resulted in the reduction of the core fuel inventory by three standard fuel elements. The increase in excess reactivity is expected to extend the current core operational capabilities for five to ten years.

Appendix 1

Radioanalysis Reports of FFCR Surveys

DISPOSITION FORM

REFERENCE OR OFFICE SYMBOL	SUBJECT		
SHDH	Analyses of fuel elements		
TO	FROM	DATE	CMT 1
Capt Forsbacka RSD	HM2 Castle SHDH	5 Nov 91 wlc	

1. Analyses were performed 30 Oct 91 - 1 Nov 91 for the fuel elements recently received by RSD. Please note the enclosed AFRRI Form 144 sheets. Each is described briefly below.

2. Enclosure (1) contains results from smear surveys of the cap encasing the elements, the plastic wrap surrounding each element, a wet smear of the first element, a dry smear os the first element, and a dry smear of the first rod after boiling. All activity was less than 10 pCi/smear.

3. Wet and dry smears were also performed on the second, third and fourth rods. Results of these smears are contained in enclosures (2) and (3). Activity was less than 10 pCi/smear.

4. Water samples were taken after each rod was boiled. 100 ml of each sample were boiled down and analyzed for alpha and beta activity. All were less than 10 pCi/smear. 1000 ml samples were analyzed for gamma activity. No peaks were found in any sample.

W. L. Castle
HM2, SHDH

REQUEST FOR RADIOANALYSIS 12096

SAMPLE INFORMATION

DATE 10-30-91 NAME Castle

TIME 0810

NO. SAMPLES: 5
IDENT: CFF (Fuel element mw, (Kging)
COLLECTION DATE/TIME: 10-30-91 0805

SAMPLE NO.	TYPE ANAL	WT/VOL	FACTORS	REMARKS
1-5	αβ	[illegible]		

ANALYSIS RESULTS

SAMPLE NO.	TYPE ANAL	AS OF DATE/TIME	ACTIVITY ± 2σ UNITS: pCi/hr
1-5	α	30OCT91	<10
	β	1100	<10

ANALYSIS BY: [signature]

DATE: 30OCT91 TIME: 1100

RADIOANALYSIS RESULTS

DATE 30OCT91 TIME 1100 INT [initials]

INSTRUMENT USED: Tenn II

	α	β	γ			
BACKGROUND	0.00 cpm 2.00 min	1.50 cpm 2.00 min				
EFFICIENCY	241Am 31%	90Sr 47%				

MCA INFORMATION

COUNTING TIME ______

SHELF & GEOMETRY ______

DECAY TIME ______

OTHER: ______

(SECOND COLUMN HEADING FOR MCA ONLY)

SAMPLE	GROSS CTS / GAMMA ENERGY (keV)	MIN CTD / FWHM (keV)	NET CPM / BKGD CTS	EFF / NET AREA CTS	TRANS FACTOR / ERROR %	ACTIVITY pCi				ANALYSIS TYPE / NUCLIDE	CONCENTRATION ±2σ UNITS: pCi/hr
1-5	≤ 2	2.00	1.0	.3160						α	<10
1-5	≤ 4	2.00	0.5	.4700						β	<10

REMARKS

STD 241Am 54,603 cpm / 2.00 min 90Sr 102,242 cpm / 2.00 min

AFRRI FORM 144A 15 JUL 84 PREVIOUS EDITIONS OBSOLETE

PART A

chk 1

REQUEST FOR RADIOANALYSIS

12207

SAMPLE INFORMATION

DATE 11-1-91 TIME 1130 NAME Castle

NO. SAMPLES 2 IDENT #3,4 Fullelement H2O (boil) COLLECTION DATE/TIME 10-31-91/1400

SAMPLE NO.	TYPE ANAL	WT/VOL	FACTORS	REMARKS
#3,4	αβ	100ml		
#3,4	γ	1000ml		

ANALYSIS RESULTS

SAMPLE NO.	TYPE ANAL	AS OF DATE/TIME	ACTIVITY ±2σ UNITS: pCi/sm
1-2	α	04NOV91	<10
#3	β	1400	<10
#4	α		<10
	β		<10
#3	γ		No Peaks Found
#4	γ		No Peaks Found

ANALYSIS BY: [signature]

DATE: 05NOV91 TIME 1400

RADIOANALYSIS RESULTS

DATE 05NOV91 TIME 1330 INT [initials]

INSTRUMENT USED: MCA, Team I

MCA INFORMATION
COUNTING TIME 30,000 sec
SHELF & GEOMETRY 11
DECAY TIME Ø
OTHER:

	α	β	γ
BACKGROUND	0.18 cpm / 100.00 min	1.48 cpm / 100.00 min	
EFFICIENCY	^{241}Am 32%	^{90}Sr 41%	

(SECOND COLUMN HEADING FOR MCA ONLY)

SAMPLE	GROSS CTS / GAMMA ENERGY (keV)	MIN CTD / FWHM (keV)	NET CPM / BKGD CTS	EFF / NET AREA CTS	TRANS FACTOR / ERROR %	ACTIVITY pCi			ANALYSIS TYPE / NUCLIDE	CONCENTRATION ±2σ UNITS: pCi/sm
#3	16	100.0	0	.3240	1.0				α	<10
	108	100.0	0	.4140	1.0				β	<10
#4	20	100.0	.02	.3240					α	<10
	116	100.0	0	.4140					β	<10
									#3	No Peaks Found
									#4	No Peaks Found

REMARKS
STD ^{241}Am 10,111 CPM / 20.00 min ^{90}Sr 28,805 cpm / 20.00 min

AFRRI FORM 144A 15 JUL 84   PREVIOUS EDITIONS OBSOLETE

PART A

2 of 2

REQUEST FOR RADIOANALYSIS

12098

SAMPLE INFORMATION

DATE: 10-31-91 NAME: Castle
TIME: 0845

NO. SAMPLES	IDENT	COLLECTION DATE/TIME
2	fuel element H₂O	#1 10/30/91 - 1000 #2 10/31/91 - 1330

SAMPLE NO.	TYPE ANAL	WT/VOL	FACTORS	REMARKS
1-2	γ	1000ml		
1-2	αβ	100ml		

ANALYSIS RESULTS

SAMPLE NO.	TYPE ANAL	AS OF DATE/TIME	ACTIVITY ±2σ UNITS: pCi/gm
1-2	α	31OCT91	<10
	β		<10
#1	γ		No Peaks Found
#2	γ		No Peaks Found

ANALYSIS BY: [signature]
DATE: 31OCT91 TIME: 1300

RADIOANALYSIS RESULTS

DATE 31OCT91 TIME 1300 INT [initials]
INSTRUMENT USED: Tenn I

MCA INFORMATION
COUNTING TIME: MCA 200D
SHELF & GEOMETRY: "
DECAY TIME: Ø
OTHER:

	α	β	γ
BACKGROUND	0.00 cpm / 2.00 min	0.50 cpm / 2.00 min	
EFFICIENCY	^{241}Am 32%	^{90}Sr 41%	

(SECOND COLUMN HEADING FOR MCA ONLY)

SAMPLE	GROSS CTS / GAMMA ENERGY (keV)	MIN CTD / FWHM (keV)	NET CPM / BKGD CTS	EFF / NET AREA CTS	TRANS FACTOR / ERROR %	ACTIVITY pCi				ANALYSIS TYPE / NUCLIDE	CONCENTRATION ±2σ UNITS: pCi/gm
1-2	≤1	2.00	0.5	.3240	1					α	<10
1-2	≤2	2.00	0.5	.4110	1					β	<10
										#1	No Peaks
										#2	No Peaks

REMARKS
STD ^{241}Am $\frac{9{,}924 \text{ cpm}}{2.00 \text{ min}}$ ^{90}Sr $\frac{28{,}766 \text{ cpm}}{2.00 \text{ min}}$

Encl 3

AFRRI FORM 144A
15 JUL 84 PREVIOUS EDITIONS OBSOLETE

PART A

REQUEST FOR RADIOANALYSIS

12201

SAMPLE INFORMATION

DATE 31OCT91 NAME JW HOLMES
TIME 1445

NO. SAMPLES	IDENT	COLLECTION DATE/TIME
4	Rx FFCR DRY + WET wp's prior to H2O Bal	1430 31OCT91

SAMPLE NO.	TYPE ANAL	WT/VOL	FACTORS	REMARKS
1-4	Bal			

ANALYSIS RESULTS

SAMPLE NO.	TYPE ANAL	AS OF DATE/TIME	ACTIVITY ± 2σ UNITS: pCi/Sm
1-4	α	31OCT91	≤10
	β	31OCT91	≤10

ANALYSIS BY: Jean A Amway
DATE: 05NOV91 TIME: 1330

RADIOANALYSIS RESULTS

DATE 31 OCT 91 TIME 1600 INT JAD
INSTRUMENT USED: Tenn II

MCA INFORMATION

COUNTING TIME
SHELF & GEOMETRY
DECAY TIME
OTHER:

	α	β	γ			
BACKGROUND	0.15 cpm / 200 min	1.55 cpm / 200 min				
EFFICIENCY	241Am 31%	90Sr 47%				

(SECOND COLUMN HEADING FOR MCA ONLY)

SAMPLE	GROSS CTS / GAMMA ENERGY (keV)	MIN CTD / FWHM (keV)	NET CPM / BKGD CTS	EFF / NET AREA CTS	TRANS FACTOR / ERROR %	ACTIVITY pCi				ANALYSIS TYPE / NUCLIDE	CONCENTRATION ±2σ UNITS: pCi/Sm
1-4	≤4	2.00	1.85	.316						α	≤10
1-4	≤6	2.00	1.45	.470						β	≤10

REMARKS
STD 241Am 54476.5 cpm / 2.0 min 90Sr 103067.5 cpm / 2.0 min

AFRRI FORM 144A
15 JUL 84
PREVIOUS EDITIONS OBSOLETE
PART A

LAST ONE FOR HOLMES

LAST ONE FOR HOLMES

encl 4

REQUEST FOR RADIOANALYSIS

12100

SAMPLE INFORMATION

DATE 31OCT91 NAME Wampler
TIME 1115

NO. SAMPLES	IDENT	COLLECTION DATE/TIME
3	Swipes of control follower	31OCT91 @1105

SAMPLE NO.	TYPE ANAL	WT/VOL	FACTORS	REMARKS
1-3	Box		Tenn	

ANALYSIS RESULTS

SAMPLE NO.	TYPE ANAL	AS OF DATE/TIME	ACTIVITY ± 2σ UNITS: pCi/Sm
1-3	α	31OCT91	<10
	β	31OCT91	<10

ANALYSIS BY Joan A Gravely
DATE: 05NOV91 TIME: 1400

RADIOANALYSIS RESULTS

DATE 31OCT91 TIME 1200 INT [illegible]
INSTRUMENT USED: Tenn I

MCA INFORMATION

COUNTING TIME
SHELF & GEOMETRY
DECAY TIME
OTHER:

	α	β	γ			
BACKGROUND	0.30 cpm / 2.00 min	0.20 cpm / 2.00 min				
EFFICIENCY	^{241}Am 32%	^{90}Sr 41%				

(SECOND COLUMN HEADING FOR MCA ONLY)

SAMPLE	GROSS CTS / GAMMA ENERGY (keV)	MIN CTD / FWHM (keV)	NET CPM / BKGD CTS	EFF / NET AREA CTS	TRANS FACTOR / ERROR %	ACTIVITY pCi				ANALYSIS TYPE / NUCLIDE	CONCENTRATION ±2σ UNITS: pCi/Sm
1-3	≤0	2.00	0	.3240						α	<10
1-3	≤7	2.00	3.0	.4140						β	<10

REMARKS STD ^{241}Am 13834.5 cpm / 2.00 min ^{90}Sr 28682.50 cpm / 2.00 min

AFRRI FORM 144A 15 JUL 84 PREVIOUS EDITIONS OBSOLETE

PART A

Appendix 2

AFRRI TRIGA Refueling Plan and Associated Documents

AFRRI/RSDR

25 NOV 91

MEMORANDUM FOR REACTOR STAFF

FILE

SUBJECT: Core Reloading and FFCR Installation

We will commence core reloading tomorrow. For the duration of this core reloading project, we will use the AFRRI TRIGA Refueling Plan which is more specific than Operational Procedure 7. Record all refueling related data in the refueling laboratory notebook which will be maintained on the reactor control console.

MARK MOORE
Reactor Facility Director

...VED BY THE REAC... ...OF

...ME	DATE	...ALS
~~...ALE~~		
...ORGE	25 Nov	RG
...ORSBACKA	25 Nov	[illegible]
...PENCE	25 Nov	[illegible]
~~...OLMES~~		
...LAUGHERY	25 Nov 91	[illegible]
...GUYEN	25 Nov 91	JN
...WENS	25 Nov 91	[illegible]

AFRRI TRIGA Refueling Plan

Receiving and Storage of FFCRs Prior to Installation

Prior to receiving the FFCRs, the Hot Cell will be prepared for fuel storage. The room will be reasonably free of dust and debris, a gamma detector (criticality monitor) will be in place, a high security lock will be installed, and cradles for holding the fuel will be available.

The FFCRs will enter AFRRI through the shipping and receiving department (LOGS). A memorandum will be prepared (See attachment 1) to instruct LOGS personnel to not open the containers holding the FFCRs. LOGS personnel will be instructed to call RSDR and SHD immediately upon receipt of the FFCRs. SHD will perform a radiological survey in accordance with HPP-0-3 of external radiation and external contamination of the packaging in the loading dock area prior to moving the FFCR containers to the Hot Cell.

Once the FFCRs have been cleared by SHD to be moved to the Hot Cell, RSDR staff will conduct a series of tests within the Hot Cell to determine if any uranium is on the outer surface of the FFCR cladding. The testing methodology is similar to series of measurements outlined in 10 CFR 70.39 which deals with the certification of calibration or reference radiation sources. The following tests will be conducted:

1. Dry wipe test. The entire surface of the FFCRs will be wiped with filter paper using moderate finger pressure. Any radioactivity on the filter paper will be determined by measuring the radiation levels using SHD's counting lab.

2. Wet wipe test. The entire surface of the FFCRs will be wiped with filter paper, moistened with water, using moderate finger pressure. Any radioactivity on the filter paper will be determined by measuring the radiation levels using SHD's counting lab.

3. Water Boil Test. The FFCRs will be completely immersed in boiling water for one hour. The residue obtained by evaporating the water will then be monitored for the presence of uranium using the SHD counting lab.

If measurable quantities of radioactivity are present following any of the above tests, the FFCRs will be thoroughly cleaned and the tests will be repeated. In the event that radioactivity is found after repeated tests and cleanings, the shipment will be rejected and returned to the manufacturer.

Following the cumulation of successful tests showing no contamination of the FFCR exterior cladding with uranium or other radioactive contaminants, the FFCRs may be moved to storage in the Reactor Room.

Core Preparation

Prior to shutdown and FFCR installation, neutron activation foils/wires in will be used in ER1 with the bare core configuration at a fixed position one meter from the core. Determine neutron energy spectrum, save data for later comparison with FFCR loaded core. Next, completely unload all fuel from the reactor core. Following the removal of fuel, the standard control rods and transient control rod will be removed. The rod drive support structure will then be modified as required to allow for the ease of transient rod drive maintenance. Next, the new transient rod will be installed.

The FFCR connecting rods will be set up to allow for the removal of FFCRs without bringing them out of the reactor pool. Once the FFCRs have been irradiated, they will become highly radioactive due to their fission product inventories, so it will be important to keep them under water for shielding purposes.

Installation of FFCRs into AFRRI TRIGA Reactor Core

Measurements of the required connecting rod lengths will be made by measuring the entire length of the standard rods connected to the barrel. Correcting for differences between the FFCRs and the standard rods, the connecting rod lengths for the FFCRs will be determined. The connecting rods will then be attached to the FFCR and the entire unit will be installed into the reactor core. The connecting rods will then be attached to the barrel assembly to complete the installation of the FFCRs.

Following installation, the FFCRs will centered in their grid locations using the set screws for the barrel assemblies. The goal is to minimize any rubbing of the FFCR as it travels up and down. Once the FFCRs have been centered, drop time tests will be performed to insure compliance the technical specifications.

Refueling AFRRI TRIGA Reactor Core

A conservative approach to refueling the reactor core will be taken. These instructions will supplement Reactor Operational Procedure VII. Once the critical loading has been achieved, excess reactivity will be estimated using the transient rod until there is enough excess reactivity to perform rod worth curves. Excess reactivity will be determined after each fuel loading step until the operational configuration is achieved. Care will be taken to ensure that the $5.00 maximum allowed excess reactivity is not exceeded.

Following Reactor Operational Procedure VII, install the thermocoupled fuel elements and load the B-ring. Place neutron source in source holder and BF_3 neutron detectors in F-7 and F-18. Then load elements for grid locations C-1, C-5, C-6, C-9, C-10, C-11, D-14, D-15, E-18, E-19,F-22, and F-23. Loading these elements will allow for the neutronic coupling of the FFCRs and the neutron source. At this point the rods will be withdrawn as described in step 2.a. of the

procedure, and the first subcritical multiplication measurements will be taken.

Complete loading the C-Ring, load D-ring elements 2, 6, 8, 12, and 18, and repeat the subcritical multiplication measurements. Complete loading the D-ring, and load E-ring elements 5, 6, 14, 15; perform subcritical multiplication measurements. Load E-ring elements 1, 2, 8, 9, 10, 16, 17, and 24; perform subcritical multiplication measurements. Load E-ring elements 2, 23, 7, 11, 13, and 20; perform subcritical multiplication measurements. Load the following sets of elements and perform subcritical multiplication measurements after each step (note: this load pattern may be modified to accommodate instrumentation or other items that may obstruct fuel loading): E-4 and E-12; E-21 and E-22; F-1 and F-2; F-3 and F-30; F-4 and F-29; F-5 and F-28; F-6 and F-27; F-26 and F-16; F-15 and F-17; F-14 and F-18; F-13 and F-19; F-12 and F-20; F-11 and F-21; F-10; F-9; and F-8. This loading pattern allows for the FFCRs to exercise a high influence over the neutron population while the core is still very subcritical.

Core Calibration

Once the core has been loaded to the operational excess reactivity, core calibrations will proceed in the same manner as following an annual shutdown. Differential and integral reactivity worth curves will be generated for each rod in core positions 250, 500, and 750. Up to this point all testing has been done at very low powers, so the fission product inventory in the FFCRs will be low. Since the probability that the FFCR cladding may fail is highest shortly after installation, a series of pulses will be performed to stress the FFCRs before the fission product inventory has much of a chance of building up. During this pulsing operation the water will be closely monitored for any fission fragments. In the event that fission fragments are found in the pool water, all activities will stop, the NRC and GA will be notified, and the leaking element(s) will be found and isolated.

A thermal power calibration will be performed in the usual manner. Next the power coefficient of reactivity curve will be generated followed by the reflection coefficient measurements in positions 250, 500, and 750. The neutron energy spectrum experiment in ER1 and ER2 will be repeated to ensure that the character of the radiation field has not been modified.

Refueling Checklist

Pre-shipment

1. Clean Hot Cell.
2. Inspect Hot Cell, ensure area is reasonably dust free.
3. Install high security lock on Hot Cell.
4. Ensure radiation monitor in hot cell is functional.
5. Prepare fuel cradles, install in Hot Cell.
6. Send memoranda to SHD and LOG on receipt of FFCR shipment.

Receipt of shipment

7. SHD performs radiological surveys of exterior of package in accordance with their procedures.
8. FFCR packages are transferred to Hot Cell.
9. Open FFCR shipping packages in Hot Cell.
10. Place FFCRs in prepared cradles.

Hot cell testing

11. Perform dry wipe test.
12. Perform wet wipe test.
13. Perform water boil test.
14. Repeat wet wipe test.
15. If all tests are successful, FFCRs may be moved to the Reactor Room for storage.

Core preparation

16. Use neutron activation wire set from Reactor Experiments to establish base line neutron energy spectrum using Ledney's set up.

17. Unload all fuel from the core in accordance with Procedure VII.

18. Modify the rod drive support structure.

FFCR installation

19. Install new transient rod.

20. Fabricate connecting rods for FFCRs.

22. Install FFCRs, insure that they are not "bottomed out" with they are fully down.

23. Measure FFCRs against FFCR standard, record results.

24. Reinstall FFCRs, install rod drive motors, and center FFCRs in their core grid locations.

25. Perform drop time tests to insure compliance with Technical Specifications.

Core refueling

26. Place neutron source in its holder, and place BF_3 or fission detectors in core grid locations F-7 and F-18.

27. Load the thermocoupled elements into core grid locations B-5 and C-6.

28. Complete loading the B-ring and load C-1, C-5, C-6, C-9, C-10, C-11, D-14, D-15, E-18, E-19, F-22, and F-23. Perform subcritical multiplication measurements.

29. Complete loading the C-ring. Load D-ring locations 2, 4, 6, 8, 10, 12, 14, 16, and 18. Perform subcritical multiplication measurements.

30. Complete loading of D-ring, and load E-ring elements 5, 6, 14, and 15. Perform subcritical multiplication measurements.

31. Load E-ring elements 1, 2, 8, 9, 10, 16, 17, and 24. Perform subcritical multiplication measurements.

32. Load E-ring elements 15, 19, F-22, and F-23, place neutron source into its holder, and perform subcritical multiplication measurements.

33. Load E-ring elements 2, 23, 7, 11, 13, and 20. Perform subcritical multiplication measurements.

34. Load E-ring elements 4 and 12, and perform subcritical multiplication measurements.

35. Load E-ring elements 21 and 22, and perform subcritical multiplication measurements.

**** NOTE ****
When critical configuration is achieved,
estimate excess reactivity using the transient
rod. Continue loading until there is enough excess
reactivity to perform a control rod worth measurement
**** ****

36. Load F-ring elements 1 and 2, perform subcritical multiplication/excess reactivity measurements.

37. Load F-ring elements 3 and 30, perform subcritical multiplication/excess reactivity measurements.

38. Load F-ring elements 4 and 29, perform subcritical multiplication/excess reactivity measurements.

39. Load F-ring elements 5 and 28, perform excess reactivity measurements

40. Load F-ring elements 6 and 27, perform excess reactivity measurements.

41. Load F-ring elements 16 and 26, perform excess reactivity measurements.

42. Load F-ring elements 15 and 17, perform excess reactivity measurements.

43. Load F-ring elements 14 and 18, perform excess reactivity measurements.

**** NOTE ****
Do not exceed $5.00 excess reactivity!
. . . . . . Perform thermal power calibration at 500 to insure proper placement of operational channel. Perform rod worth curves for all rods in position 500 when operational loading is achieved
**** ****

44. Load F-ring elements 13 and 19, perform excess reactivity measurements.

45. Load F-ring elements 12 and 20, perform excess reactivity measurements.

46. Load F-ring elements 11 and 21, perform excess reactivity measurements.

47. Load F-ring elements 10, perform excess reactivity measurements.

48. Load F-ring elements 9, perform excess reactivity measurements.

49. Load F-ring elements 8, perform excess reactivity measurements.

Core calibration

50. Install all core instrumentation into their permanent positions.

51. Perform rod worth curves for all rods in core positions 250, 500, and 750.

52. Perform thermal power calibration and set safety chambers.

53. Repeat neutron energy spectra measurement in ER1.

Amendment to AFRRI TRIGA Refueling Plan

Introduction

The RFD has postponed the pulse testing of the FFCRs to allow for pulse testing during non-duty hours for the Institute. This is being done to prevent the interruption the work being performed in the Institute in case one of the new elements fail during the testing process. Pulse testing will commence during the last week of January. Full power testing to 1.1 MW will be conducted when it will not interfere with low dose studies being conducted in mid-January to early February.

Pulse Testing

The purpose of this pulse testing program is to gradually stretch the fuel cladding and test the integrity of the welds in the FFCRs. If the core is cold, it will be preheated at 50 kW steady state power for ten minutes. Allow the core to cool for 20 minutes before commencing pulse operations. Pulse operations will be performed in the following sequence:

At position 500 with balanced control rod configuration (monitor CAM levels and water monitor box radiation levels)

1. Pulse 1.05$
2. Pulse 1.10$
3. Pulse 1.15$
4. Pulse 1.15$
5. Pulse 1.20$
6. Pulse 1.25$
7. Pulse 1.25$
8. Pulse 1.25$
9. Pulse 1.25$
10. Pulse 1.25$
11. Pulse 1.30$
12. Pulse 1.35$
13. Pulse 1.40$
14. Pulse 1.45$
15. Pulse 1.50$
16. Pulse 1.50$
17. Pulse 1.50$
18. Pulse 1.50$
19. Pulse 1.50$
20. Pulse 1.55$
21. Pulse 1.60$
22. Pulse 1.65$
23. Pulse 1.65$
24. Pulse 1.65$
25. Pulse 1.65$

26. Pulse 1.65$
27. Pulse 1.70$
28. Pulse 1.75$
29. Pulse 1.80$
30. Pulse 1.80$
31. Pulse 1.80$
32. Pulse 1.80$
33. Pulse 1.80$
34. Pulse 1.85$
35. Pulse 1.90$
36. Pulse 1.95$
37. Pulse 2.00$
38. Pulse 2.00$
39. Pulse 2.00$
40. Pulse 2.00$
41. Pulse 2.00$
42. Pulse 2.05$
43. Pulse 2.10$
44. Pulse 2.15$
35. Pulse 2.15$
46. Pulse 2.15$
47. Pulse 2.15$
48. Pulse 2.15$
49. Pulse 2.20$
50. Pulse 2.20$
51. Pulse 2.20$
52. Pulse 2.25$
53. Pulse 2.30$
54. Pulse 2.35$
55. Pulse 2.35$
56. Pulse 2.35$
57. Pulse 2.35$
58. Pulse 2.40$
59. Pulse 2.45$
60. Pulse 2.50$

Move core to position 250

61. Pulse 2.00$
62. Pulse 2.00$

Move core to position 750

63. Pulse 2.00$
64. Pulse 2.00$

Move core to position 500

65. Pulse 2.50$
66. Pulse 2.50$
67. Pulse 2.50$
68. Pulse 2.50$
69. Pulse 2.50$
70. Pulse 2.50$
71. Pulse 2.50$
72. Pulse 2.50$
73. Pulse 2.50$
74. Stop operations for at least one hour
75. Run reactor at 900 kW for two hours, closely monitor CAM and water monitor box for any unexpected increase in readings.

Steady State Full Power Testing

Steadily increase state power level to 1.09 MW (SCRAM point). Record control rod positions, fuel temperatures, CAM and SGM readings, and R1 readings at 100 kW, 500 kW, 1.0 MW, 1.05 MW, and 1.07 MW.