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August 12, 1994
Docket No 50-356

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

SUBJECT: Report of Abnormal Occurrence in compliance with LOPRA Technical Specifications section 6.7 (c) (3) and 1.12 (d & f).

Please find attached a report intended to meet the 14 day reporting requirement of LOPRA Technical Specification section 6.7 (c).

Respectfully,

Richard L. Holm
Reactor Supervisor

Attachments (4)

c: Mr. Alexander Adams, Jr., Project Manager, USNRC
Mr. Tim Reidinger, USNRC, Region III
Dr. Barclay G. Jones, Head, Department of Nuclear Engineering
Mr. Anthony Graziano, Associate Dean, College of Engineering
Prof. Dan Hang, Interim Director, Nuclear Reactor Laboratory
Dr. Sheldon Landsberger, Chairman, Nuclear Reactor Committee
Campus Health Physics Office
File

STATE OF ILLINOIS

COUNTY OF CHAMPAIGN

Richard L. Holm, being first duly sworn on oath, deposes and says that h s affixed his signature to the letter above in his official capacity as Reactor Supervisor, University of Illinois Nuclear Reactor Laboratory\; that in accordance with the provisions of Part 50, Chapter 1, Title 10 of the Code of Federal Regulations, he is attaching this affidavit\; that the facts set forth in the within letter are true to his best information and belief.

Richard L. Holm
Reactor Supervisor

Subscribed and sworn to before me, a Notary Public, in and for the County of Champaign, State of Illinois, this 12 day of August, A.D., 1994.

Notary Public of Illinois

8/19/96
My Commission Expires

" OFFICIAL SEAL "
KATHLEEN M. DYSART
NOTARY PUBLIC, STATE OF ILLINOIS
MY COMMISSION EXPIRES 8/19/96

SUBJECT: Incident report in accordance with LOPRA Technical Specification 6.7 (c) (3) for a reportable occurrence as defined in section 1.12 (f) - *An observed inadequacy in the implementation of either administrative or procedural controls, such that the inadequacy could have caused the existence or development of an unsafe condition in connection with the operation of the reactor.* Although there were no instrumentation indications of a fission product release; calculations would suggest that it was possible. Therefore, this occurrence is also being reported as potentially meeting section 1.12 (d) *Release of fission products from a fuel element.*

REPORTABLE OCCURRENCE: Damage was noted on an aluminum clad fuel element in the LOPRA reactor. The damaged area is approximately 0.25 inch wide by 1.0 inch long and exposes the fuel meat [see attachment 1]. This damage is believed to have occurred in November of 1993 when a burr was removed from the LOPRA upper grid plate. No fission product activity was noted at the time that would have indicated that the damage had occurred. **The proper procedural controls were not implemented at the time to prevent the damage from occurring.**

DESCRIPTION OF EVENT: During the routine annual inspection of the LOPRA fuel elements [located in the Bulk Shielding Tank (BST)] in August and September of 1993 two element positions were noted as being difficult to remove the elements from positions D3 and D4. After inspection of the elements in these positions it was found that they could not be reinserted properly. The elements did not appear to have any damage. Upon inspection of the top of the grid plate it was noted that the plate appeared slightly damaged from being struck by the elements upon reinsertion over the years such that a few "burrs" were evident that prevented the elements from going back into position. The remainder of the elements were inspected with no significant problems. A tapered reaming tool was utilized to clean up the hole in the grid plate. It would appear that the top of the reaming tool cut into the side of element #2475 [see attachment 2 and 3] in position C4 and created a gash approximately 0.25" x 1.0". The elements from the C row near D3 and D4 were not removed, only the elements from the E row were removed to enhance visibility and to make the LOPRA Inoperative.

Although no Continuous Air Monitor (CAM) anomalies were noted at the time the element was damaged the strip chart record has been reviewed and no release of fission products was noted. The CAM strip chart was also reviewed for the two days on which the LOPRA was operated at greater than 1 watt (12/23/93 - 2.27 kw-hrs and 5/13/94 - 2.67 kw-hrs) for surveillances and no anomalies to indicate a fission product release were noted. This lack of observance of significant fission product activity is borne out in "Technical Foundations of TRIGA", General Atomic, August 27, 1958 [an excerpt is presented as Attachment 4]. The surface area of exposed fuel is approximately 7 times larger [10 cm^2 vs 1.5 cm^2] than what is presented in the study and the reactor is assumed to have been operating for an infinite time at

10 kW. The LOPRA is a 10 kW reactor, but operations are extremely minimal as discussed above.

Summary of Potential Fission Product Release

"Summary of TRIGA Fuel Fission Product Release Experiments", Foushee and Peters, Gulf TRIGA Reactors, September 1971 indicates a release fraction of gaseous fission products from the fuel of 1.5×10^{-5}. The damaged fuel element has 480 kw-hrs burnup prior to 1965 while at the AFRRI reactor. This is shown as actual burnup on the element. Between 1965 and 1971 the element was utilized in a subcritical assembly that eventually got commissioned as the LOPRA. Since the inception of the LOPRA, and utilization of this element, 114.6 kw-hrs have been generated on the LOPRA core.

Assumptions for Potential Fission Product Release

- The fission products produced in the core since the inception of the LOPRA (114.6 kWhrs) was produced in the damaged element.
- For the 480 kWhrs at AFRRI it was assumed that it was instantaneously fissioned on the last second of 1965.
- The release fraction for iodine was conservatively assumed to be the same as for xenon and krypton - 1.5×10^{-5}. This is extremely conservative given that the documentation suggests that iodine is not released unless the element is heated to above 1000 C.
- Kr-85 was the only gaseous fission product present at the time of the break. [The LOPRA was not operated for 158 days before the date of the break (11/15/93).]
- Gaseous fission products potentially released were immediately dispersed into the building atmosphere.
- The building exhaust half-life is 20 minutes. It was assumed in calculating the yearly average that for seven half-lives, building concentration was constant.

The calculated potential fission product release is presented in Table 1. Summing the yearly concentrations for each release, it is shown that with the extremely conservative assumptions, no 10 CFR 20 limits were reached. All potential releases were well below the annual average concentration limits (by a factor of 100 or greater) of 10 CFR 20 so no dose assessment was performed.

Water from the BST is not released in any form other than evaporation. No tank samples were taken on the above dates since the problem was not recognized at the time. A water sample was taken on August 2, 1994 after the damaged element was discovered that showed no activity above background.

As mentioned earlier, the Continuous Air Monitors and the Exhaust Stack Monitor for the Nuclear Reactor Laboratory showed no indications of any release.

VISUAL INSPECTION OF FUEL ELEMENT:

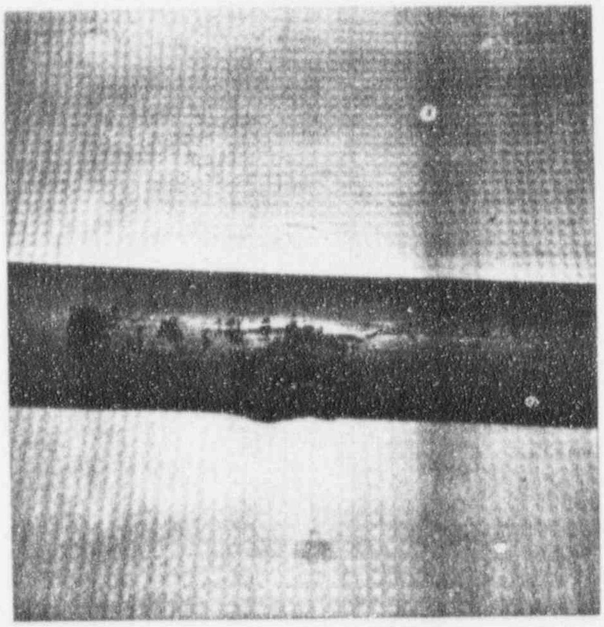
The fuel element shows an exposed area of the fuel element approximately 0.25 inches axially by 1.0 inches vertically (approximately 0.25 in^2 [1.6 cm^2]). The fuel meat shows no signs of cracking or degradation.

TABLE 1 - Calculated Potential Fission Product Release

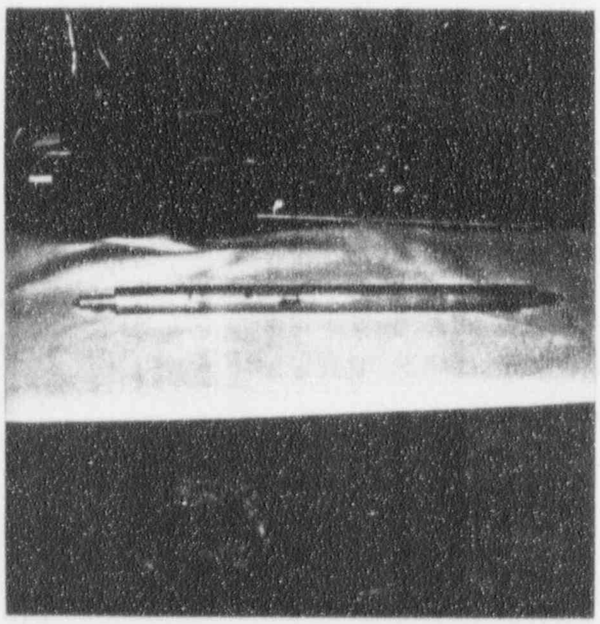
	November 15, 1993			December 22, 1993			May 13, 1994		
	Activity Released (Ci)	**Building Concentration (μCi/ml)**	**Annual Average Concentration (μCi/ml)**	**Activity Released (Ci)**	**Building Concentration (μCi/ml)**	**Annual Average Concentration (μCi/ml)**	**Activity Released (Ci)**	**Building Concentration (μCi/ml)**	**Annual Average Concentration (μCi/ml)**
Total Xe	6.9E-9(Kr85)	3.45E-12	9.18E-16	1.23E-3	6.15E-7	5.77E-11	1.35E-3	6.75E-7	6.72E-11
Total Kr	----------	----------	----------	2.17E-3	1.08E-6	1.64E-10	2.41E-3	1.20E-6	1.79E-10
Total I	----------	----------	----------	6.07E-5	3.04E-8	8.08E-12	7.09E-5	3.54E-8	9.43E-12
Total Activity	**6.9E-9**	----------	**9.18E-16**	**3.46E-3**	**1.73E-6**	**2.30E-10**	**3.83E-3**	**1.91E-6**	**2.56E-10**

CORRECTIVE ACTION TAKEN:

- The fuel element has been removed from the LOPRA core, surveyed, wrapped in polyethylene and placed in dry storage in a lead cave in our fuel storage cage.
- The maintenance procedure for the Nuclear Reactor Laboratory, including LOPRA maintenance, has been rewritten (see Attachment 5) to be more definitive as to when a written procedure will be required and the approval requirement.
- The individuals involved in the evolution that caused the damage have been counseled as to the need for written procedures and team effort such that all potential side effects to an action will be evaluated before an evolution takes place.
- Further corrective actions will be evaluated if necessary.



#2475 E



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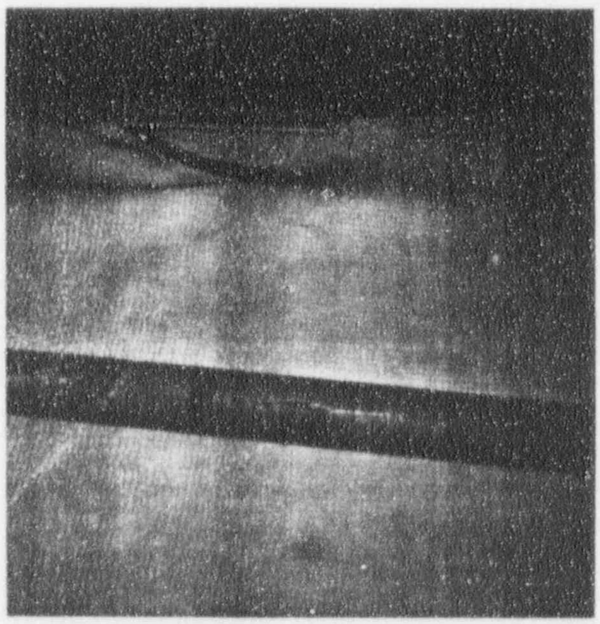


#2475E

Attachment 1

LOPRA FUEL LOCATION MAP

DATE: 8/27/93

STORAGE PITS

NW	NE	SW	SE
2564E	2572		2197

HOT STORAGE ROOM

COMMENTS	

LOPRA STORAGE RACKS

R I	GD	GD	GD		GD	GD
R II	2594			[illegible]		
R III						

R IV						
R V	–	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
R VI	[illegible]	2487	2380	2490		

note 1 (over R V): note 1: NORTHERN ELEMENT HIGH DOSE

LOPRA CORE

damaged element (arrow to C4)

areas where burns removed (arrows to D3, D4)

Thermal Column

WEST — GRAPHITE (col. 1), REFLECTOR (col. 2); GRAPHITE (col. 10), REFLECTOR (col. 11) — EAST

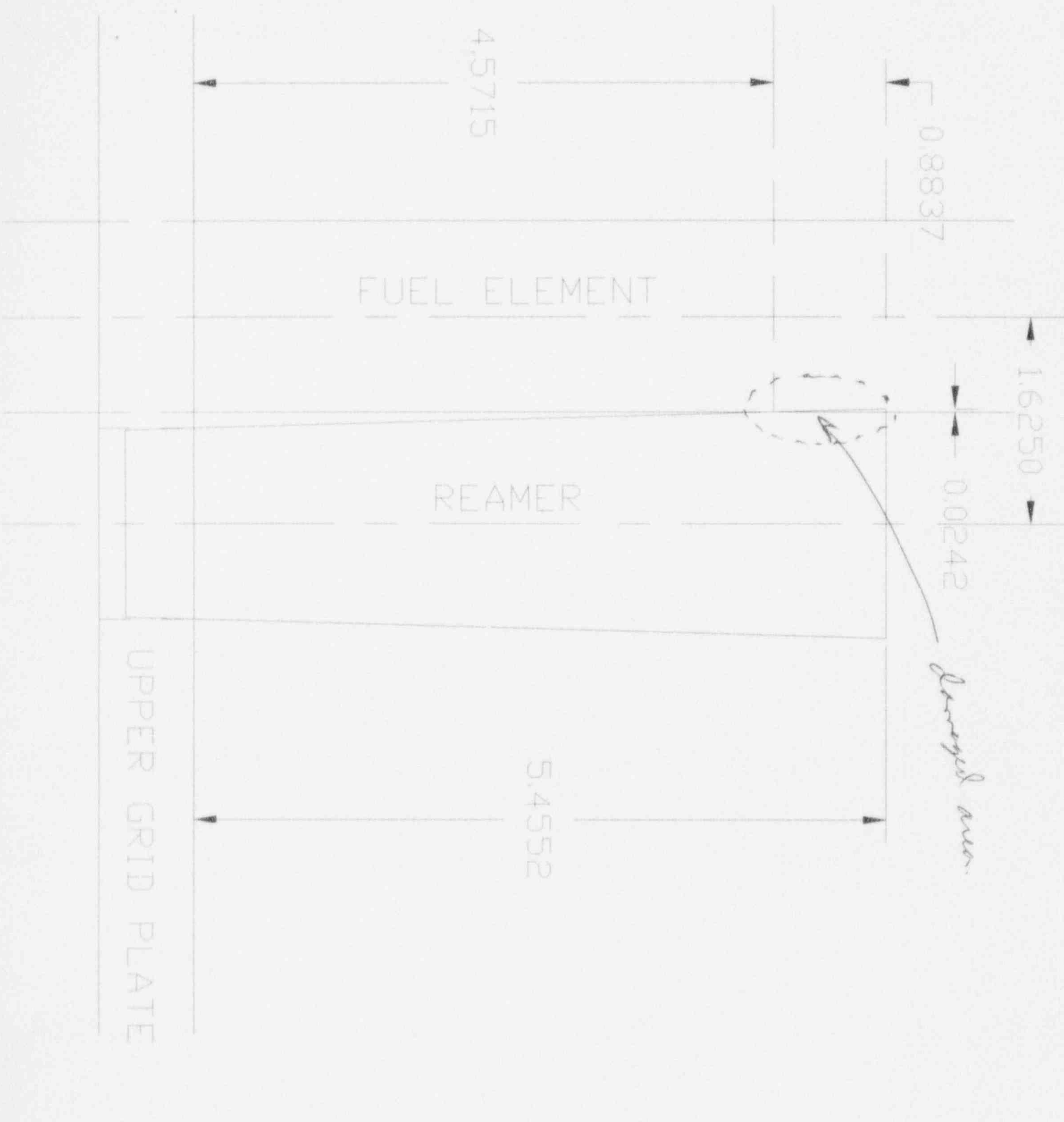
	1	2	3	4	5	6	7	8	9	10	11
A	*	*	2595	2185	2567	2555	TC	2718	2485	*	*
B	*	*	2192	2570	2464	2556	2590	2467	2589	*	*
C	G R A	*	2560	2475	2562	2559	2478	2471	2491	G R A	*
D	P H I	R E	2936	2956	2582	2607	2545	2563	2469	P H I	R E
E	T E	F L E	2495	2608	2474	[illegible]	[illegible]	2614	[illegible]	T E	F L E
F	*	C T O	2505	2555	2489	2576	2608	2468	[illegible]	*	C T O
G	*	R *	2485	2615	2571	[illegible]	2212	2472	2577	*	R *
H	*	*	GD	[illegible]	[illegible]	2467	2181	[illegible]	D	*	*
I	*	*				[illegible]				*	*

COMMENTS ON FUEL INSPECTION: [illegible]

(D3) (D4)

2604 + 2294 removed from core due to difficulty in removal + replacement; 2467 + 2481 [illegible] [illegible] D4 [illegible]

Attachment 2



attachment 3

water will be too low to produce any appreciable induced radioactivity in the reactor cooling system.

Escape of Fission Products from a Minor Defect in a Fuel Element

The reactor fuel elements are jacketed with 0.030-in.-thick aluminum cladding, and each fuel element will be leak-tested before being installed in the reactor. Thus, it is anticipated that the fuel elements will not fail in operation; however, in any reactor system, the possibility exists that a fuel element may fail and release fission products into the coolant. In the event of a small fuel-element defect, it may well be possible and desirable to continue operation of the reactor without unscheduled shut-downs and without decontamination of the reactor system being required.

The type of accident most likely to occur is the release of fission products into the water through a small defect in the cladding of a fuel element. The zirconium of the fuel elements is not expected to undergo any chemical reaction, other than normal corrosion, with water at the temperatures at which this core will operate. The rate of diffusion of gases through the zirconium-hydride lattice is probably small, and the possibility of cracks existing in the fuel material is considered to be very remote. Thus, if the escape of fission-product recoils from fuel surfaces exposed to water is neglected, fission products can enter the water only through direct corrosion of the fuel-bearing material.

If fission products are detected in the reactor coolant, the demineralizer will be used to reduce the fission-product activity. In order to determine whether the demineralizer can adequately control activity in the system due to a minor fuel-element defect, a calculation was made in which it was assumed that 10 cm^2 of fuel surface were exposed to water. Experimental work at General Atomic, presented below under "Corrosion of Fuel Material," page 117, indicates that the corrosion rate of the zirconium-hydride-uranium mixture in water is about 2.3 mg/cm^2-yr. For the purposes of this calculation, it was assumed that the exposed fuel surface corroded uniformly at this rate and that only those fission products contained in the corroded material were released to the water. Fission products were assumed to be uniformly distributed throughout the fuel-bearing region. The reactor was assumed to have been operating for infinite time at a

Attachment 4 p. 1 of 3

power level of 10 kw. The demineralizer and filter were assumed to be 100% effective for all nonvolatile fission products, i.e., they removed all nonvolatile fission products from 12 gal of water per minute.

In calculating the activity due to nonvolatile fission products, this activity was taken to be the total fission-product activity. To account for the fact that many fission products are very short-lived and would decay soon after entering the water, the total fission-product activity was assumed to be that which would exist 5 hr after shutdown, as given by the Wigner-Way equation;* 5 hr is the effective "half life" of the demineralizer (i.e., the time it would take the demineralizer to reduce the nonvolatile concentration by a factor of two if no impurities were being added to the coolant).

The results of this calculation indicate that the demineralizer can limit the specific activity of nonvolatile fission products in the coolant resulting from 10 cm^2 of exposed fuel surface to an equilibrium level of 1.6×10^{-7} $\mu c/cm^3$ of water. This activity level is about equal to the AEC tolerance for continuous disposal of water to unrestricted areas.

Two of the fission-product elements, xenon and krypton, are volatile at the reactor operating temperature. The activity due to these fission products was calculated by the methods described above, except that the effect of the demineralizer was eliminated. For the long-lived xenon and krypton isotopes, the activity was calculated at a time 10 yr after the fuel-element defect had occurred (the short-lived isotopes reach equilibrium within this time). The calculated specific activity of Kr^{85} was 5.4×10^{-7} $\mu c/cm^3$ of water, and that of Xe^{133} was 2.8×10^{-7} $\mu c/cm^3$. All other xenon and krypton isotopes gave rise to activities considerably less than 10^{-7} $\mu c/cm^3$.

An experiment was also done to check the rate at which fission products appear in water that is in contact with active material, either by corrosion of the active material or by diffusion of volatile products out of the active material and into the water. Some fuel-element material was exposed to neutrons in order for fission products to be produced in it. The

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*K. Way and E. P. Wigner, "Rate of Decay of Fission Products," Phys. Rev., Vol. 73, 1948, p. 1318.

Attachment 4 p. 2 of 3

irradiated material was then immersed in demineralized water. The initial rate of dissolution of the typical fission-product isotopes Sr^{89}, Ba^{140}, and I^{131} by the water was then measured. It was found that I^{131} dissolved the most rapidly of the three; it appeared in the cooling water at a rate corresponding to the dissolution of 100 μg of uranium-zirconium hydride per day per cm^2 of fuel element exposed to the water. Since initial corrosion rates are usually much higher than steady-state ones, and since iodine is rather volatile, this measurement can be considered to be in qualitative agreement with the above calculations.

On the basis of this analysis, it is expected that the demineralizer will be able to adequately control the fission-product activity arising from any fuel-element failure which might reasonably occur. Should a very major fuel-element failure occur (possibly from severe mechanical damage to the reactor core) which would cause more activity than the demineralizer could control, the reactor would be shut down and the defective fuel elements replaced. All of the water in the reactor system can be discharged, either directly or through the demineralizer, to a tank truck or other receptacle outside the reactor building; access to the area of the reactor pit is not required for this operation. Thus, the water in the reactor system can, if necessary, be replaced with uncontaminated water during removal and replacement of defective fuel elements.

A gamma monitor will be provided to detect fission-product release to the water. If the monitor actuates an alarm because of excessive gamma activity in the water, a water sample will be taken for radiochemical analysis to determine whether fission products are present and to quantitatively assess the extent of fission-product contamination.

Radioactivity from N^{16} in the Reactor Cooling System

Radioactive N^{16} will be produced in the water by the reaction $O^{16}(n,p)N^{16}$. The effective cross section for this reaction integrated over the entire fission spectrum is 0.020 millibarns.* The half life of N^{16} is 7 sec; the gamma energies are 6.1 and 7.1 Mev in the ratio 12.5:1. Eighty-two percent of the N^{16} disintegrations are accompanied by a high-energy

*H. C. Martin, "Cross Sections for the $O^{16}(n,p)N^{16}$ Reaction from 12 to 18 m.e.v.," Phys. Rev., Vol. 93, 1954, p. 498.

Attachment 4 p. 3 of 3

Title: General Maintenance
Periodicity: As needed.
Required By: n/a

Comments:
The following guidelines will be followed with respect to **all** maintenance to be performed at the Nuclear Reactor Laboratory.

This procedure is applicable to both the Advanced TRIGA and LOPRA reactors.

Procedure:

General Guidelines

1. The Maintenance Log Sheet shall be filled out for all maintenance to be performed.
2. The scheduling and approval for maintenance shall be done by the Reactor Supervisor (or designated alternate in his absence). If the maintenance involves radioactive material or the workers may be exposed to a radiation dose in excess of normal operation the reactor Health Physicist shall approve the performance of the maintenance.
3. Any precautionary steps that may be required shall be placed in a written form prior to the maintenance being performed. These steps shall be reviewed by the Reactor Supervisor and a pre-work briefing shall be held with the reactor staff involved.
4. A specific written procedure for the maintenance shall be formulated if deemed necessary by the Reactor Supervisor. A written procedure approved by the Reactor Committee shall be required if the maintenance involves a reactor safety system or movement of more than one fuel element.
5. If maintenance is to be performed when the reactor is **not secured** a licensed reactor operator shall be in direct control of the control console.
6. The Maintenance Log Sheet shall be reviewed upon completion of the maintenance by the Reactor Supervisor and then filed in the Maintenance Log Sheet binder.
7. The system on which the maintenance is performed shall be checked to be operable before it is utilized in reactor operations.

Written By: ____
Name Title Date

Reviewed By: ____
Name Title Date

Date Approved by Reactor Committee: ____________

UIUC Nuclear Reactor Laboratory Maintenance Log Sheet

Date:	**Personnel Involved:**	
Associated Surveillance Procedure:		**APPROVALS:** [Rx Sup at minimum] Rx Sup. - __________ HP - __________ [RAM/Dose involved] Rx Com. - __________ [Rx Safety System/Fuel]
Procedure Required : ______ [Mandatory for reactor safety system or movement of more than one fuel element - approved by RC]	**Description of Maintenance**:	☐ TRIGA ☐ LOPRA
Procedure/Comments [use additional sheets if necessary]		
System verified to be operable prior to return to service: ______		

Attachment 5 p. 2 of 2