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May 6, 2011

Mr. Alexander Adams
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Research and Test Reactors Branch A
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Reference: Oregon State University TRIGA Reactor (OSTR)
Docket No. 50-243, License No. R-106
Report on the Circumstances of the Event of April 6, 2011

Subject: Self-reporting of a Technical Specification Violation Involving Reactivity Limits

Mr. Adams:

We would like to respectfully submit the attached supplementary report to the Commission on the self-reported violation of our Technical Specification Limiting Condition of Operation 3.8.1, *Reactivity Limits*. The intent of this report is to reiterate the circumstance of the event described in the report of April 6 and to describe the corrective actions taken on our part to prevent reoccurrence.

Should there be questions regarding the information in this report or should you require more information, please do not hesitate to contact me.

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

Executed on: 5/6/11

Sincerely,

Steven R. Reese
Director

cc: Craig Bassett, USNRC
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ADZD
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Violation of L.C.O. 3.8.1, *Reactivity Limits*

Summary of Events

The Oregon State University TRIGA® Reactor (OSTR) is a circular grid Mark II TRIGA® reactor. Maximum licensed steady state power is 1.1 MW_{th}. The reactor may also be pulsed by reactivity insertion of up to $2.30 which corresponds to a peak power of approximately 2500 MW_{th}. The OSTR contains several experimental facilities. In-core facilities include a hollow aluminum In Core Irradiation Tube (ICIT), a Cadmium Lined In-Core Irradiation Tube (CLICIT), a G-Ring In-Core Irradiation Tube (GRICIT) and a pneumatic rabbit. The ICIT and CLICIT are located in the B-ring (B-1 position). The GRICIT and the rabbit are located in the G-ring. There are no other approved in-core experimental facilities. Ex-core experimental facilities include the rotating rack, the thermal column and four beam ports.

The OSTR staff was designing a new experiment which will utilize reactivity oscillation to measure reactor parameters. A preliminary test absorber was created to examine the reactivity worth vs. axial position of the absorber in the core at low power. During attempts to measure the maximum worth of this preliminary test absorber on Wednesday, April 6, it was determined that its worth was $0.60 at the mid-plane of the core. Technical Specification 3.8.1, *Reactivity Limits*, states in part that "The absolute value of the reactivity worth of any single unsecured experiment shall be less than $0.50." Measurements were taken in a manner such that the apparatus qualifies as a movable experiment, and moveable experiments are taken to be a subcategory of unsecured experiments.

The preliminary test absorber was fabricated by crushing an existing 1.25 cm segment of solid B_4C and placing 29.8 grams of the material in a sealed aluminum TRIGA® tube. The reactivity of the absorber was not formally calculated, but it was believed that the worth of the absorber would be less than $0.20. This was based on the fact that a full length control rod absorber also made of B_4C (38.1 cm) is worth about $2.00. Past experience has also shown that 20 grams of Cadmium tubing used for axial flux measurements has a reactivity worth of $0.19 in the B-1 position where the absorber was being tested.

To characterize the worth of the absorber, the reactor was first taken critical with the ICIT installed in the B-1 position. Critical rod heights were measured and core excess was calculated. The reactor remained critical at 15 watts in automatic mode. The absorber was then manually lowered to the bottom of the ICIT by an operator. The regulating rod was observed to behave as anticipated, automatically withdrawing until some maximum worth position near core center was reached by the absorber, and then automatically inserting as the absorber was lowered to the bottom of the core. The worth of the absorber when resting at the bottom of the core was calculated by comparing regulating rod position with and without the absorber present. The worth was calculated to be less than $0.07.

When power and regulating rod position were stable, the absorber was slowly withdrawn 7.5" to the mid-plane of the core. The regulating rod automatically withdrew to compensate for the addition of negative reactivity as the absorber was moved to the higher worth position at the axial center of the core. The difference between regulating rod position with no absorber present and regulating rod position with the absorber at core center indicated that the worth of

the absorber at core center was $0.60. As soon as absorber worth was determined, the reactor was shut down. The absorber was then withdrawn from the ICIT. The fact that the absorber was moved while the reactor was critical qualified the experiment as a moveable experiment. Since $0.60 is in excess of the $0.50 limit specified by L.C.O. 3.8.1, reactor operation was suspended and the NRC was notified.

Chronological Sequence of Events

Events took place on Wednesday, April 6 and Thursday, April 7, 2011 as follows:

April 6, 2011	
0954 (PDT)	Reactor Startup commences.
0957	Reactor critical at 15 watts.
1005	NRC shutdown margin calculated: $2.32 (limit: no less than $0.55).
1006	Test absorber loaded in ICIT (fully inserted to bottom of core).
1009	Test absorber withdrawn 7.5" to core center. Reactivity worth of $0.60 calculated.
1010	Reactor shutdown.
1011	Test absorber removed from ICIT.
1224	Reactor operation suspended due to violation of Technical Specification 3.8.1. Reactor Operations Committee (ROC) chairman notified.
April 7, 2011	
0830	NRC operations center notified of violation of Technical Specification 3.8.1.
1234	Normal reactor operation is restored with the exception that the OSTR shall not be used to irradiate samples anticipated to have high worth until a root cause analysis has been completed.

Event Consequences

The reactor was critical for 16 minutes. Maximum power was 15 watts. There was no equipment damage, personnel exposure or release of radioactive material.

Lessons Learned

The reactivity effect of a sample in the vicinity of a reactor core is dependent on many factors. Reactivity will be affected by sample mass, cross section of major isotopes, moderating and reflecting effects, sample geometry and sample position. A simplistic attempt to estimate the reactivity worth of a test absorber was made by multiplying the total worth of a 38.1 cm (15 inch) B_4C absorber by the fraction of the absorber used for the test (1.25 cm or ~3.3%). This would indicate that the worth of the test absorber should be about $2.00 x 0.033 = $0.066. In hindsight, this approach underestimated the reactivity worth of the test absorber for the following reasons:

- A control rod (without a fuel follower) was estimated to be worth no more than $2.00, but that worth is observed in the C-ring. The absorber was tested in the B-ring where neutron importance and corresponding reactivity worth are higher.
- The differential worth of a control rod is much higher near core mid-plane than it is at the top or bottom of the core. Thus although the sample was measured to be worth

$0.07 when at the bottom of the core, the worth at core axial center would be much higher. As shown by this event, the worth of a sample near core center can be a factor of 10 higher than sample worth at the core edge.

- Geometry and particularly surface area affects reactivity worth. The tip of a control rod effectively has one unshielded absorber surface, and this surface is partially obscured to neutron absorption by the attached fuel follower. The test absorber consisted of small pieces of B_4C which had a much higher surface area to volume ratio than an intact control rod absorber. The available neutron absorbing surface was significantly larger than the same mass of B_4C at the tip of a control rod.

Corrective Actions

To prevent reoccurrence, all movable experiments in the ICIT, CLICIT and GRICIT shall have their maximum reactivity worth measured as a secured experiment (Tech Spec definition 1.10.a) before they are used as a movable experiment.

Movable experiments external to the core (i.e. rotating rack, thermal column and beam ports) do not need to be measured due to the fact that objects outside the core are unlikely to have a measurable reactivity effect. Reactivity of movable experiments in the pneumatic rabbit facility do not need to be measured due to the fact that they are performed at the edge of the core and sample mass and volume are limited by the size of the rabbit capsule.

This corrective action will be implemented by a change to OSTR Operating Procedure 10, *Operating Procedures for Reactor Experimental Facilities*. All licensed operators will also be trained on the requirement to measure the reactivity worth of any movable experiment as a secured experiment prior to conducting the experiment as a movable experiment. These changes will be implemented no later than May 31, 2011.