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

Reference: U.S. Geological Survey TRIGA Reactor (GSTR), Docket 50-274, License R-113, Request for Additional Information (RAI) dated September 29, 2010

Subject: Response to Question 3 of the Referenced RAI

Mr. Wertz:

Here is the response to Question 3:

Question 3. NUREG-1537, Part 1 Section 4.2.3, " Neutron Moderator and Reflector," requests a comprehensive description of the moderator and reflectors. The GSTR SAR only describes the graphite reflector ring surrounding the core and does not discuss axial reflector regions or the moderating effect of the coolant or the fuel. Please provide information describing the contributions to the reflection and moderation provided by the fuel, coolant and structural members such as the grid plates.

Moderator:

The bulk of the neutron moderation, at all temperatures, in the TRIGA core is done by the U-ZrH in the fuel-moderator elements. The ZrH matrix is able to moderate neutrons down to 0.14 eV (West, Whittemore, Shoptaugh, Dee, & Coffer, 1976). At this point the neutrons are further moderated down by the water in the core region. At higher temperatures the moderation performed by the water increases slightly due to spectrum hardening that occurs in the fuel-moderator elements; however, most of the moderation is still done by the ZrH.

Reflector:

The radial reflector is graphite that is encapsulated in an air-tight aluminum shell and is located around the external radius of the core. If the shell leaked, then the reactivity of the core would decrease due to the difference in thermal diffusion lengths of graphite (59 cm) versus water (2.85 cm) (Lamarsh & Baratta, 2011). More neutrons would be absorbed in the reflector after it became flooded with water. Information gathered from Oregon State University's SAR

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gives additional information for a flooded reflector. The OSU facility is a TRIGA design that is very similar to the GSTR.

> "Flooding of the reflector can decrease the effectiveness of the reflector which decreases the reactivity of the reactor. Flooding does not pose any problem to safely implementing shutdown of the reactor."
>
> (From OSU SAR Section 4.2.3)

Axial reflectors are present inside of each fuel cladding section, above and below the fuel section of each fuel element. Each axial reflector is graphite that is approximately 3.5" long and 1.4" in diameter. The axial reflectors are much smaller than the radial reflector and therefore have much less potential for affecting reactor operation. A leak in the fuel cladding that could result in flooding of the axial graphite reflector would also result in leakage of fission products which would be detected and remediated. There would be no potential for creating a change in neutron reflection that would pose a safety problem to the reactor.

Coolant and structural members:

The reflection of neutrons by water outside of the core and by other core structural components is very small in comparison to that provided by the radial graphite reflector.

Neutronic/thermal-hydraulic analysis:

The most recent update (mid-June, 2012) for the neutronic/thermal hydraulic analyses is provided as an attachment to this document. Although this update states that the full-power model of the GSTR will be completed in June, this did not happen since the limiting core configuration has not yet been established.

Sincerely,

Tim DeBey

Tim DeBey

USGS Reactor Supervisor

I declare under penalty of perjury that the foregoing is true and correct.
Executed on 6/29/12

Attachment

Copy to:

Betty Adrian, Reactor Administrator, MS 975
USGS Reactor Operations Committee

Bibliography

Lamarsh, J. R., & Baratta, A. J. (2011). *Intro to Nuclear Engineering.* Upper Saddle River: Prentice-Hall, Inc.

Safety Analysis Support for the USGS Research Reactor
Battelle Energy Alliance Award #00114253 (CSM # 400305)
May 2012 Progress Report
Nicolas Shugart and Jeffrey King

Work in May involved constructing the PARET model for the thermal-hydraulic transient analysis of the GSTR core, and preparing the RELAP steady-state thermal-hydraulic models for both aluminum and stainless steel clad fuel rods.

The PARET model analyzes the limiting core hot-rod channel for the GSTR under transient conditions. The current PARET model consists of two channels, one representing the hot-rod channel in the B-ring of the reactor, and another representing the rest of the core. A third channel within the model is under development and will represent the aluminum hot-rod channel (in the F ring of the limiting core). The two-channel model is currently being validated. Once the two-channel model is complete and validated, the aluminum channel will be added to the model. Adding the third channel to the model will require the most recent version of PARET from the Argonne National Laboratory (ANL). The current version available to the university (dated 2001) is limited to three materials and the paperwork for access to the most recent version has been submitted to ANL. The PARET model will be operational in June.

The RELAP models for the GSTR are single-channel steady state models that analyze the fuel temperature and boiling conditions of the GSTR during steady-state operation. Both RELAP models are based on work done by OSU, for previous TRIGA re-licensing analyses (Radiation Center, Oregon State University, 2010; Marcum, 2008). The dimensions of the channel within the stainless-steel clad fuel model emulate the hot-rod channel within the GSTR, which is located in the B-ring of the reactor. This provides the most limiting conditions for flow rate, and the aluminum clad fuel channel uses the same dimensions even though the rod is located within the F-ring of the limiting core. The heat structure dimensions (both radial and axial) are based on a report from General Atomics (Tomsio, 1986). The channel model is a pipe broken up into segments to correspond to the fuel meat and other portions of the fuel rod, with the upper and lower limits of the channel located at the upper and lower grid plates of the reactor. This forces the total channel length to be the same in both models and is consistent with the operating conditions of the GSTR.

In the current limiting core, the highest-power stainless steel clad element has a power of 24.08 kW. The highest-power aluminum element has a power of 9.65 kW. Aluminum elements are limited to the F and G rings of the GSTR under the current technical specifications, and the GSTR staff has expressed a desire to maintain this condition in the updated technical specifications. Using the dimensions listed in literature (Tomsio, 1986), the RELAP model yields a peak fuel temperature of 554 °C for the stainless-steel clad element, and a peak temperature of 292 °C for the aluminum element. The water exit temperature is 96 °C for the former and 67 °C for the latter. A preliminary DNBR is not available for either channel.

These results, however, are based on published as-fabricated dimensions, and so may be off by up to 250 °C (Marcum, 2008). The RELAP models need to be matched to thermocouple data taken from the GSTR to ensure they are yielding the correct peak fuel temperatures. Previous work on this model shows that the gap thickness has a large impact on the central fuel

temperature (Marcum, 2008). Since the current gap thicknesses are not currently known, the model will be corrected by adjusting the gap thickness to match recorded temperature data from the GSTR. These measurements are planned for the 4th of June. The GSTR does not contain instrumented aluminum-clad elements, so gap thickness for the aluminum elements will be adjusted based on historic fuel temperature data from those rings using stainless-steel clad elements. As stainless steel has a lower thermal-conductivity than aluminum, the resulting temperatures will be conservative. Following this both RELAP models will be run over a range of rod-powers to yield both the fuel temperatures and DNBR as a function of rod power. These values, combined with the calculated power outputs from the MCNP model, will form the basis for the full-power model of the GSTR, which will be completed in June.

References

Marcum, W. R. (2008, June). Thermal Hydraulic Analysis of the Oregon State TRIGA Reactor Using RELAP5-3D. *Master's Thesis.* Oregon State University.

Radiation Center, Oregon State University. (2010). *Analysis of the Thermal Hydraulic Behavior of the Reed Research Reactor.* Corvallis, Oregon.

Tomsio, N. (1986). *Characterization of TRIGA Fuel.* General Atomics Inc.