Oregon State University

Radiation Center
Oregon State University
100 Radiation Center
Corvallis, Oregon 97331

P 541-737-2341
F 541-737-0480
radiationcenter.oregonstate.edu

June 17, 2020

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

Reference: Oregon State University TRIGA Reactor (OSTR)
Docket No. 50-243, License No. R-106
Phase 0 Public Meeting held on January 8, 2020
Phase 0 Public Meeting (supplemental) held on March 18, 2020

Subject: License Amendment Request to Remove Technical Specification Requirements related to Instrumented Fuel Elements and Return from Pulsing Preclusion, as well as Requested Administrative/Grammatical Changes

Commission:

This letter serves as a request for a license amendment for the purpose of modifying the existing Technical Specifications (TS) to remove all TS requirements related to Instrumented Fuel Elements (IFEs) and to allow for pulsing without an IFE. Previously the NRC approved a license amendment request to allow for operation without an IFE as long as pulsing was precluded. The OSTR has been operating without an IFE with pulsing operations precluded since July 2019.

Introduction

A Phase 0 public meeting with NRC was held on January 8, 2020 and again on March 18, 2020. During these meetings, OSTR staff outlined the process by which we intended to justify how the removal of the IFE would not adversely impact safety. As explained in both public meetings, all analysis presented then and within this request originates from our current Safety Analysis Report (as amended). We believe that the analysis already present in our SAR shows that the OSTR can be operated safely without the need for an IFE in any mode of operation. Specifically, we can show that the maximum temperatures during steady-state mode cannot reach the Safety Limit of 1150°C (Tech Spec 2.1) or the Limiting Safety System Setting of 510°C (Tech Spec 2.2) or the Pulsing Limit of 830°C (Tech Spec 3.1.4). As such, this LAR requests that any technical specification which requires the IFE be removed.

Steady-State Mode Analysis

The results of the steady-state neutronic analysis in the SAR show that the OSTR can be safely operated at the licensed power of 1.1 MW. Shown in Figure 1, the assumed limiting core configuration predicted a highest power-per-element of 18.52 kW.

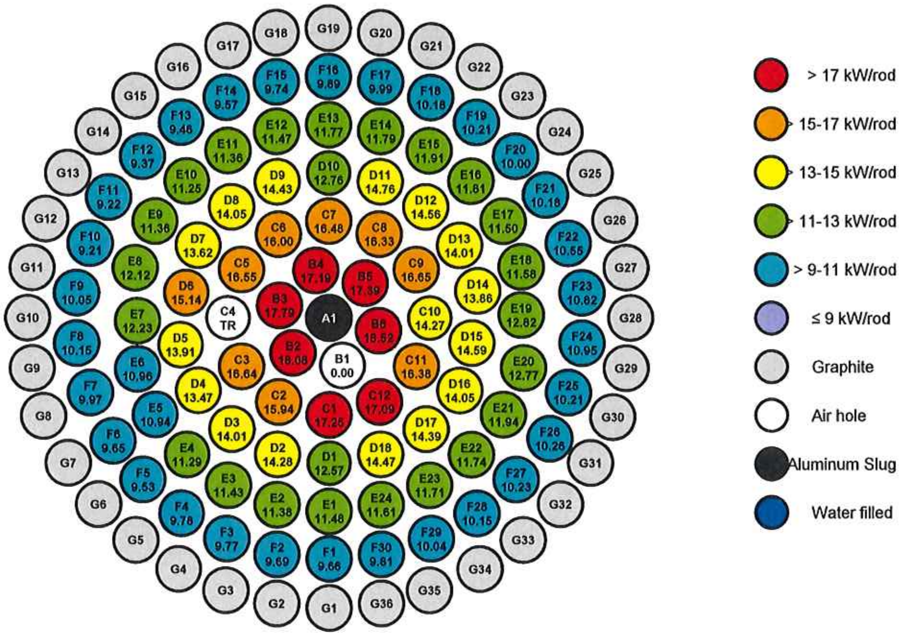

Figure 1 – Limiting core configuration and corresponding power-per-element

Shown in Figures 2 and 3, the ensuing thermal hydraulic analysis for steady-state operation produced results that allows one to evaluate the temperature of the fuel centerline and the departure from nucleate boiling ratio (DNBR) as a function of fuel element power.

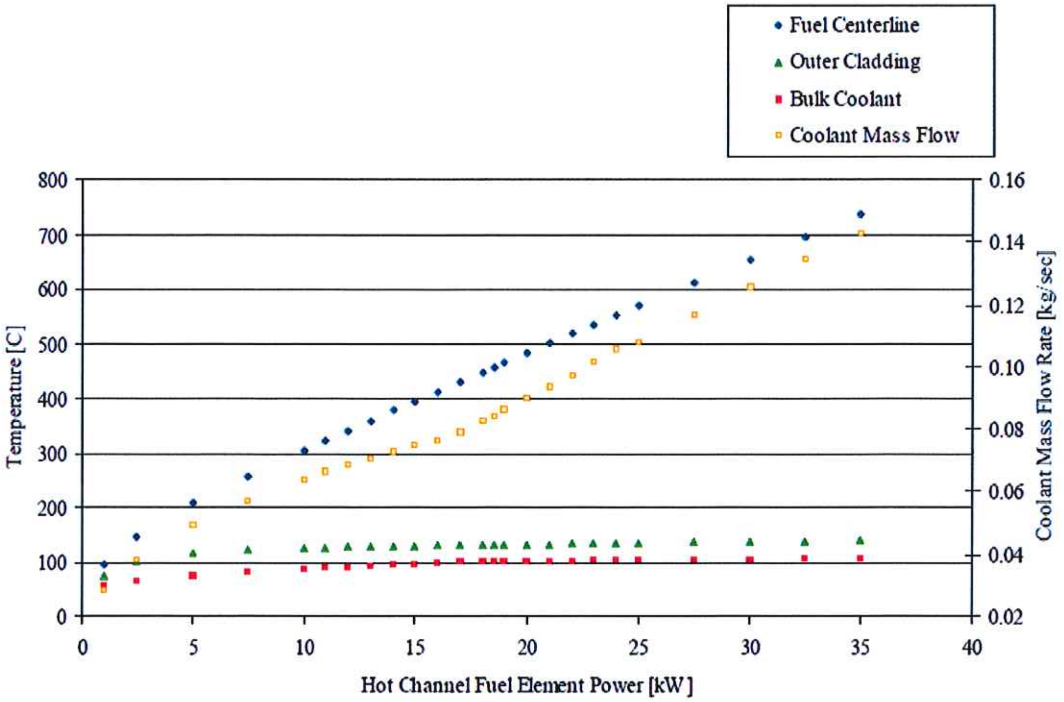

Figure 2 – Temperature and mass flow rate of the hot channel fuel element as a function of element power.

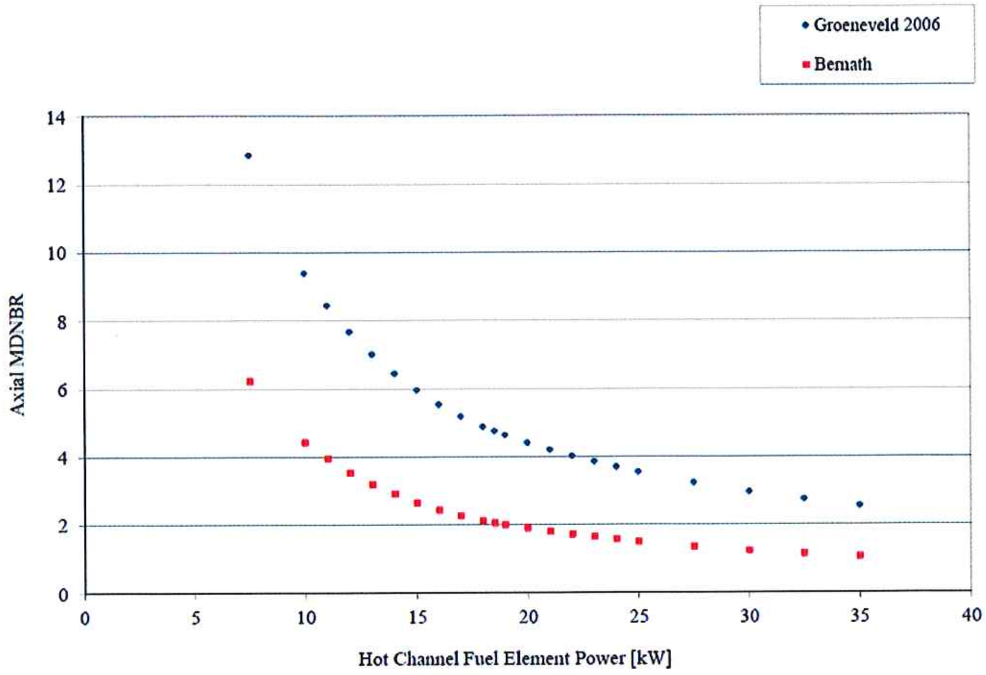

Figure 3 – DNBR as a function of fuel element power

As a result of this analysis, the corresponding hot channel maximum temperature was predicted to be 458°C at the licensed power of 1.1MW, which is far lower than the safety limit of 1150°C or the LSSS of 510°C. Furthermore, the DNBR was predicted to reach a value of 2 at approximately 19.85 kW, significantly larger than the 18.52 kW hot channel power-per-element. It should be noted that there is quite a bit of conservatism in this analysis including, but not limited to:

- The DNBR was analyzed using both the Bernath and Groeneveld 2006 correlations. Note that Groeneveld predicts DNBR reaching 2 at a power greater than 35 kW, which even at this power, the centerline fuel temperature is still below the Safety Limit.
- While the licensed power is 1.1MW, the nominal operating power is 1.0 MW.
- The limiting core configuration produces power-per-element values significantly higher than the nominal operating core of the OSTR. Furthermore, this is assumed to occur at the single point in the operating history of the reactor where the excess reactivity is the highest. This is due to the competing burnup of ^{235}U and natural erbium within the fuel. The core excess reactivity peaks momentarily at about 25% ^{235}U burnup.
- The thermal hydraulic values used to analyze the hot channel included the smallest subchannel flow area, conservative values for all calculational parameters (e.g., thermal conductivity, specific heat, initial temperature, etc.) and assumed the highest power-per-element for *all* the elements surrounding this subchannel.

Given the results of the analysis and the conservatism that was put into it, the conclusion to be drawn is that values that would exceed the Safety Limit or the LSSS are not possible given the licensed power of the reactor during steady-state operation. If that is true, then a TS requirement to measure fuel temperature is not needed. Furthermore, the license of the OSTR is robust towards ensuring that the licensed power is not exceeded. For example, there are three independent and diverse measuring channels which monitor reactor power and two safety channels that trip the reactor before power can exceed the licensed power of 1.1 MW even during anticipated transients (e.g., simultaneous withdrawal of all four control rods). This is in addition to all the surveillance requirements for ensuring that the safety and measuring channels are operable.

Pulse Mode Analysis

To begin with, it should be pointed out that although there are safety and measuring channels required for pulse mode in the TS, including those that require the use of the IFE during pulsing, none of them specifically protect either temperature or power from being exceeded; they cannot prevent the reactor from exceeding temperature or power limits once the button which ejects the control rod from the core is pressed. That which protects the fuel during a pulse can be boiled down to two things: (A) the physics of the extreme negative temperature coefficient of reactivity and (B) a good operational culture, meaning that calibrations and surveillances are being properly implemented and maintained.

To predict the temperatures that would be expected during a pulse, the SAR describes a point reactor kinetics (PRK) approach utilizing a commonly used and accepted thermal hydraulics code (RELAP-3D). The ability to model the pulse by RELAP-3D was found to be in good agreement with an PRK model developed by OSU independently and analyses performed by General Atomics. Shown in Figure 4, the results of this pulse thermal hydraulic analysis are presented for the pulse peak power and temperature as a function of reactivity inserted. This shows that the current pulse temperature limit of 830°C will be reached for a reactivity insertion of \$2.33. Based on this, the reactivity limit was set at \$2.30.

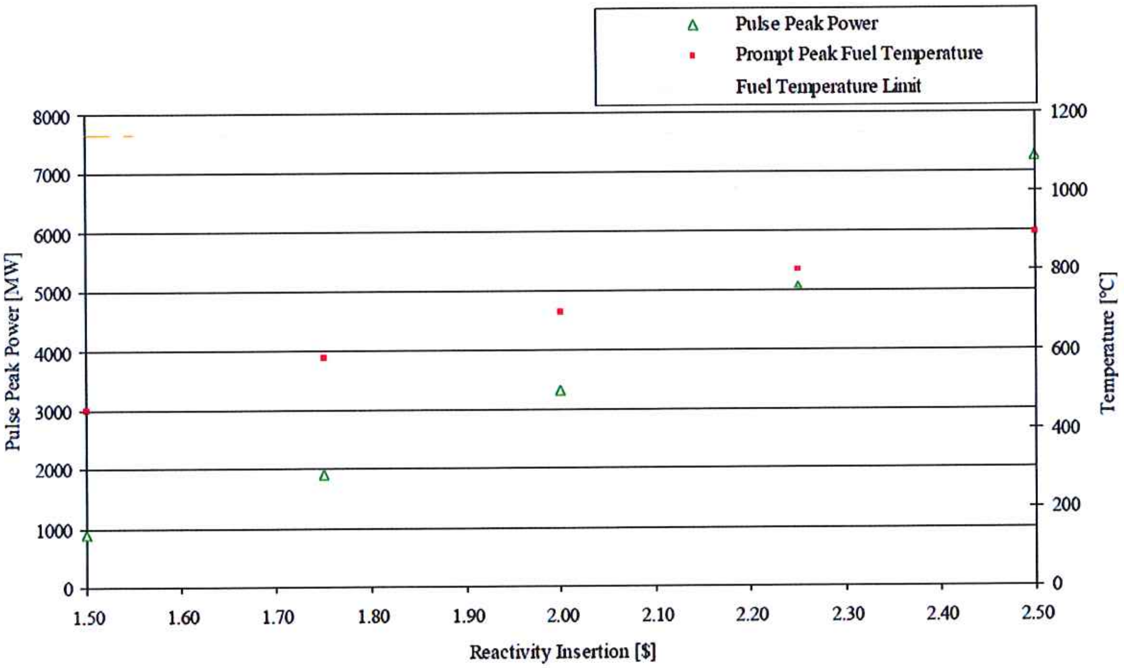

Figure 4 – Pulse peak power and temperature in the hot channel as a function of reactivity inserted.

Although RELAP-3D is a deterministic code that does not provide uncertainty, the value of \$2.30 was chosen as the pulse limit based upon the understood conservatism of the analysis and the relative insensitivity to reactivity changes (i.e., flatness of the slope). To understand how this is reflected operationally, we looked at the data generated by a series of standardized pulses (called test pulses) going back to mid-2013. These pulses were performed every six months by inserting \$1.75 and manually recording the peak temperature (in degrees C), peak power (in MW) and integrated pulse energy (in kW-hr). The purpose of these test pulses was to provide a consistent set of operational parameters so that any changes in pulse mode operations could be observed. These pulses were performed in a consistent manner, with a cold (room temperature), clean (xenon-free, Monday morning) core. Presented during the March 18, 2020 public meeting, the data for the peak temperature, power and energy of the test pulses over this time period are provided in Figures 5-7 below.

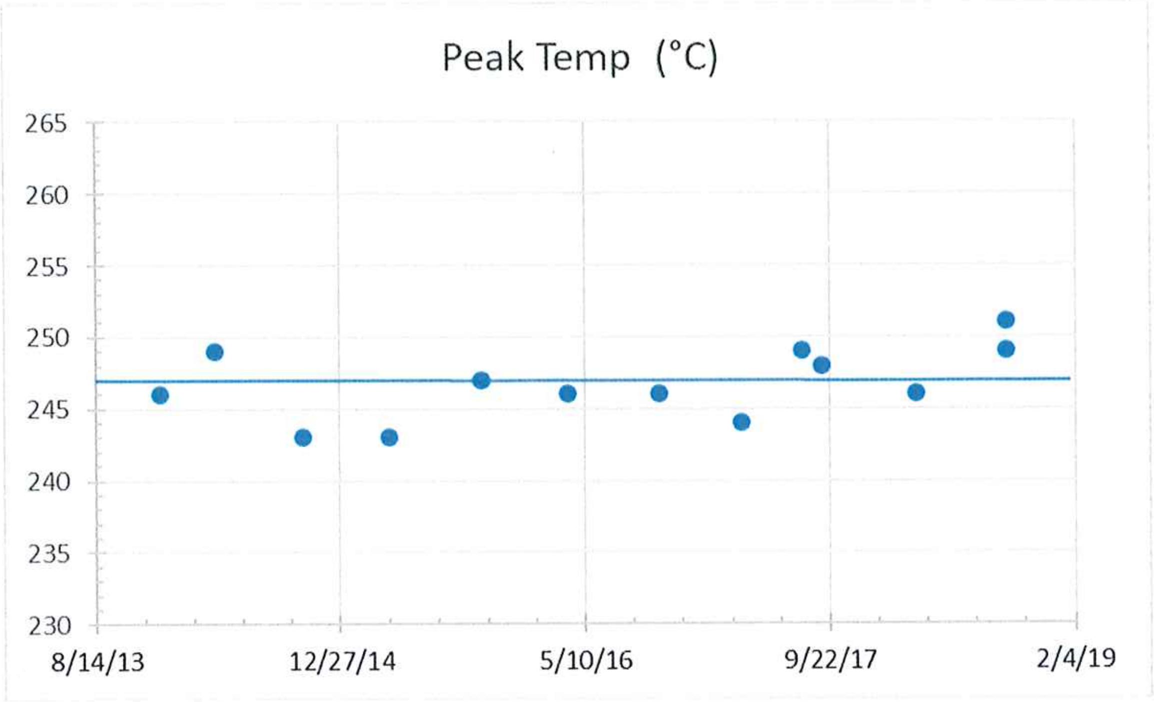

Figure 5 – Test pulse peak temperature over time

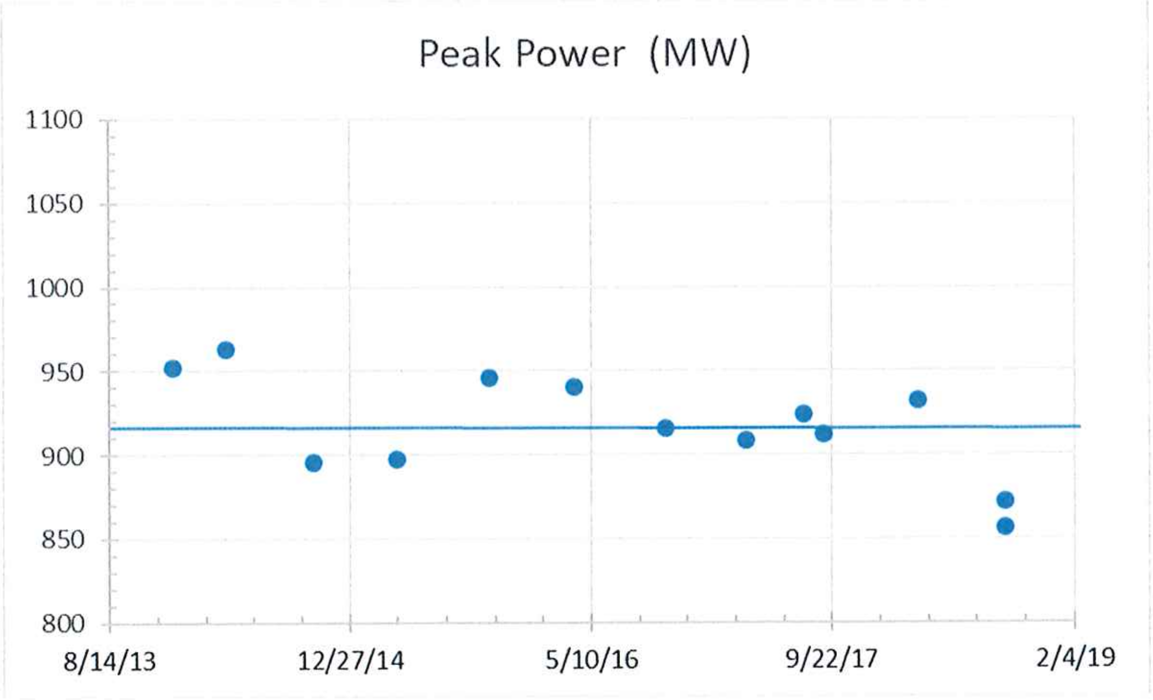

Figure 6 – Test pulse peak power over time

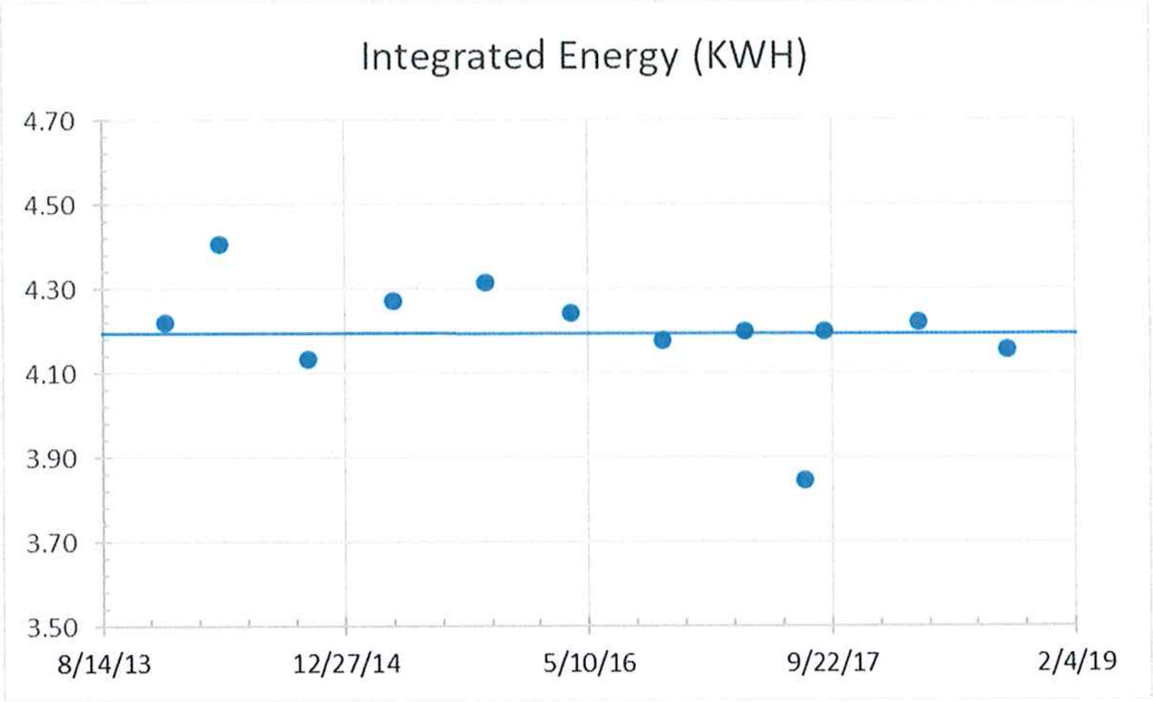

Figure 7 – Test pulse integrated energy over time

For these test pulses, the average peak temperature over this time period was 247 ± 4°C (max 251°C; min: 243°C), the average peak power was 916 ± 62 MW (max: 963 MW; min: 856 MW) and the average integrated energy released was 4.20 ± 0.27 kWh (max: 4.41 MWh; min: 3.84 MWh). These small changes in pulse characteristics can be attributed to small changes in environmental factors (i.e., room temperature), rod position set up for the pulse (i.e., changes below the resolution of the rod height indication), operator performance (i.e., observing the peak value of the temperature which is transitory) and rod calibration (i.e., rods are calibrated annually). Regardless, these pulses show that operational reproducibility of pulses is within 2%. Based on this and the conservative nature of the analysis found in the SAR, we can show that the OSTR can be safely pulsed without an IFE, especially considering that the IFE cannot prevent an adverse condition in the first place.

Other Operational Reactors Without a Requirement for an IFE

The United States Geological Survey (USGS) reactor (NRC License No. R-113) is a nominal 1MW TRIGA reactor, very similar to the OSTR in many critical aspects (i.e., fuel, grid plate, etc). In fact, the two facilities were licensed within two years of each other. The Technical Specifications for the USGS reactor do not requiring an IFE for operation. USGS also does not have a LSSS based on fuel temperature. As expected, they also have no IFE-based Limiting Conditions of Operation (LCO) nor IFE scram requirements. What they do have is a pulse limit based on preventing fuel from exceeding 830°C, a limit which was derived from analysis. In fact, the main safety conclusions reached and stated in the Safety Evaluation Report for the USGS reactor include:

- "The licensee's TSs, which provide limits controlling operation of the facility, offer a high degree of assurance that the facility will be operated safely and reliably." [Page 1-5]
- "Because the fuel temperature limit is established as a safety parameter in SAR Section 4.5.4.1, the NRC staff finds that the associated protective channels are the percent power and linear power channels. (The logarithmic channel is an additional monitoring channel,

but it does not have a safety function; therefore, it is not protective). The setpoint for the protective channels corresponds to 1,100 kWt and is acceptable." [Page 2-42]

- "Based on the above considerations, the NRC staff concludes that the licensee presented adequate information and analyses to demonstrate the technical ability to configure and operate the GSTR core without undue risk to public health and safety or the environment. The NRC staff's review included studying the facility's design and installation, controls and safety instrumentation, operating procedures, and operating limitations, as identified in the TSs. The NRC staff concludes that the T-H analyses in the GSTR SAR, as supplemented, demonstrates that the GSTR core has adequate safety margins for T-H conditions." [Page 2-54]
- "The NRC staff reviewed the steady-state operation and pulse analyses for the GSTR core and finds that the maximum core fuel temperature remains below the limit set by the known mechanical and thermal properties of the fuel. On this basis, the NRC staff concludes that the reactor design, reactor core components, reactivity limits, and related surveillance requirements provide reasonable assurance that the reactor will be operated safety in accordance with the TSs." [Page 2-55]

In summary, the conclusion reached by the NRC staff was that the USGS reactor could be safely operated in both steady-state and pulse mode without a required IFE measuring or safety channel. As these reactors are very similar both in design and in operation, we feel the same conclusion can be reached for the OSTR.

Conclusion

Considering that we are proposing to remove a requirement for measuring temperature, the OSTR staff feels that the current technical specification of limiting pulses to temperatures not to exceed 830°C should be rewritten to be based upon a reactivity value which produces a temperature of 830°C. Because we would no longer be required to measure temperature, it is more important from an operational point of view for a reactor operator to provide a limit in terms of reactivity. The current technical specification basis states that the reactivity should be limited to $2.30 and we believe the technical specification should be re-written as such and that the thermal hydraulic analysis is conservative enough to show that keeping reactivity insertions below this limit will permit safe pulsing of the OSTR. We also believe that we have shown enough justification to remove all technical specification requirements related to IFEs and would like to revise our Technical Specifications to resume pulsing operations without the requirement of an IFE.

IFEs cost significantly more than standard fuel elements and can be difficult to manufacture, as OSU has experienced with its two IFEs. The original OSTR IFE had a faulty thermocouple upon initial installation, and the spare IFE was found to have two faulted thermocouples upon its installation, which spurred this LAR process. According to the Department of Energy, there are 17 faulted IFEs awaiting disposition at six separate facilities. This is 17 out of 62 total IFEs for a 27% failure rate. The costs incurred by producing faulted IFEs can be limited by removing IFE requirements for Technical Specifications.

In conjunction with this LAR, we are requesting a number of non-substantive changes (mostly involving grammar and format changes) to the Technical Specifications. These proposed changes are provided in Attachment A. Additionally, the proposed final form of the Technical Specifications can be found in Attachment B and the proposed final form of the Technical Specifications identifying the location of specific changes can be found in Attachment C.

I hereby affirm, state, and declare under penalty of perjury that the foregoing is true and correct.

Executed on: 6/17/20.

If you have any questions, please do not hesitate to contact me.

Sincerely,

Steve Reese
Director

cc: Kevin Roche, USNRC
Mike Balazik, USNRC
Dr. Irem Tumer, OSU
Dan Harlan, OSU
Robert Schickler, OSU
Ken Niles, ODOE