New Safety Basis Strategy for Concurrent Testing at TREAT

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The Transient Reactor Test Facility (TREAT) is capable of an array of transient testing on different types of experiments. The main experiment is placed in the center of the TREAT core and other devices, called concurrent tests, can be placed in various places around the reactor core, however, to date that has only been coolant channels. The concurrent tests consist of various sensors, detectors or fission wires housed inside titanium holders. The safety basis strategy for allowing concurrent testing into the core was questioned and found to be lacking. This stemmed from interpretation of the definition of experiment by DOE. The current process for allowing concurrent tests at TREAT was altered to better comply with regulator expectations. Every item to enter the core is now considered an experiment and held to the same evaluation requirements regardless of the level of risk involved.

1. Introduction

The Transient Reactor Test Facility (TREAT) is a research reactor located at the Idaho National Laboratory. TREAT can perform a large array of transients on experiments and has a maximum reactor power of 20 GW for short durations or shaped transients at intermediate powers and times. Experiments to date have ranged from sodium loops, water loops, and static capsules, however, due to TREATs modular core deign other experiments are possible.

Experiments usually contain a fuel specimen housed in a capsule or loop that is inserted into a containment vehicle. These experiments are placed in the center of the core, and they dictate how the reactor transient is carried out, as they are the primary customer. There are other assemblies that can be inserted into the reactor for these transients, and they are known as Concurrent Testing (CT). CT are typically housed in small diameter titanium tubes and placed in cooling channels inside the reactor. Cooling channels are located on the corners of the TREAT fuel elements and are formed by a chamfer on the edge of each element. Figure 1 shows the arial view of four fuel elements and the cooling channel formed at the corner of each element.

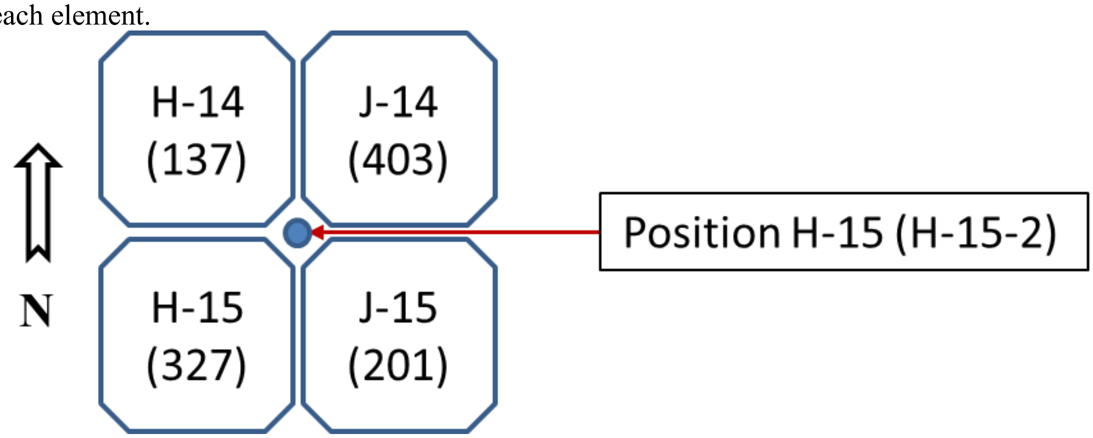

Figure 1. Arial View of TREAT Fuel

CT consists of dosimeters, detectors, flux wires, or other radiation detecting devices.

During a meeting with The Department of Energy (DOE) discussing how sensors are evaluated in the reactor. It was mentioned that the interpretation of what an Experiment is, per the TREAT Safety Analysis Report (SAR) [1] Experiment definition, was in question. CT was expected to be considered experiments and have the same evaluation rigor as a fueled experiment. This paper will address the interim changes made and the long-term safety basis changes to better comply with DOE expectations.

2. Experiments and Concurrent Testing

TREAT SAR defined an Experiment as "any hardware or capsule (excluding devices such as detectors, flux monitoring devices, etc.) that contains test material, subject to evaluation against Section 10.2.3.8 criteria, intended for irradiation in the reactor during steady-state reactor and/or transient reactor operation." [1]

Since restart of TREAT many different types of experiments have been performed in static capsules with loop type experiments expected in the future. If an Experiment contains test material, it must have one credited safety-related containment system. This containment vessel must be shown through analysis to maintain integrity throughout both normal and accident scenarios as well as meet national consensus codes (ASME Boiler and Pressure Vessel Code). Test material is defined as fissile or hazardous material. These Experiments must all meet a list of criteria contained in the TREAT SAR.

The containment vessel currently utilized at TREAT is the Broad Use Spectrum Transient Experiment Rig (BUSTER). BUSTER consists of a Schedule 40 stainless steel pipe with a welded bottom cap. An Experiment is lowered into BUSTER and the top is secured with a flange that will allow instrumentation to pass through. Figure 2 below shows the THOR experiment housed inside BUSTER.

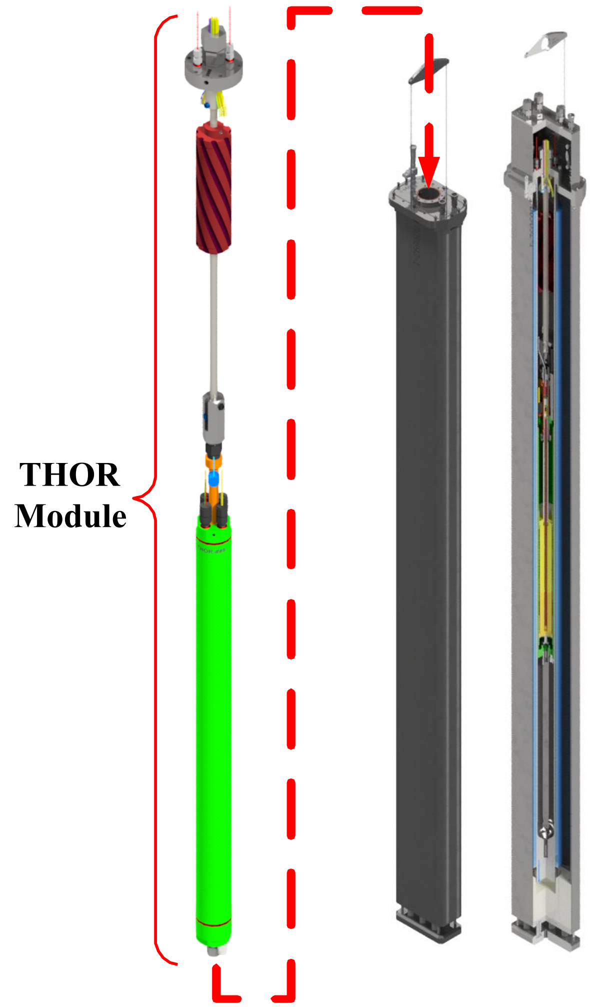

Figure 2. THOR Containment

CT consists of much smaller items and is usually housed in a ¼" titanium tube called the Monitor Wire Holder (MWH). The CT devices currently at TREAT are Gadolinium Self-Powered Neutron Detectors, Hafnium Self-Powered Neutron Detectors, Optical Fibers, Thermocouples, Impedance Sensors, and Transducers. Figure 3 shows a sketch of the Gadolinium Self-Powered Neutron Detector housed in the MWH [2].

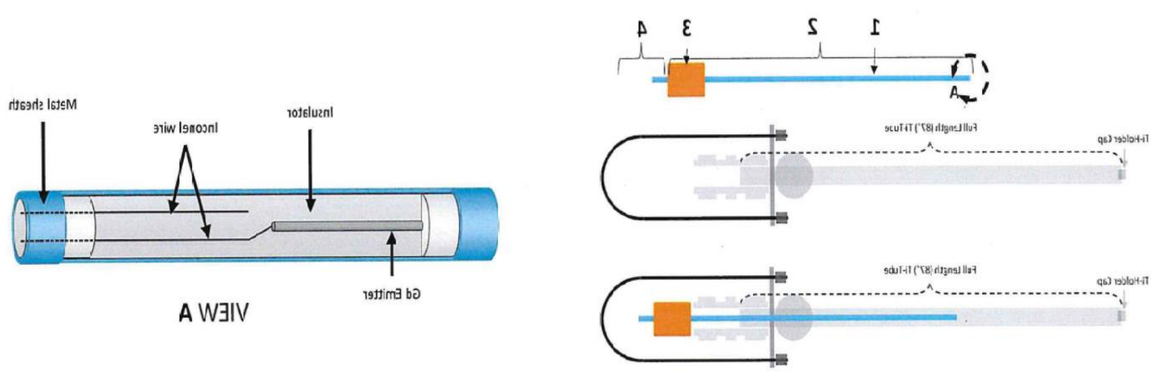

Figure 3. Gadolinium Self-Powered Neutron Detector CT

3. Safety Basis Analysis Criteria

Assemblies defined as Experiments must meet certain criteria and evaluation defined by the TREAT SAR to be allowed in the reactor for irradiation. To ensure all criteria are met for each experiment and containment vehicle an Experiment Safety Analysis (ESA) document must be created for each experiment or experiment type.
The ESA specifically looks at the hazards associated throughout the life of the Experiment at the TREAT facility including receipt of the Experiment, transient irradiation, storage, and disposal. Figure 4shows the process flow of what the ESA covers for an Experiment housed in BUSTER [3].

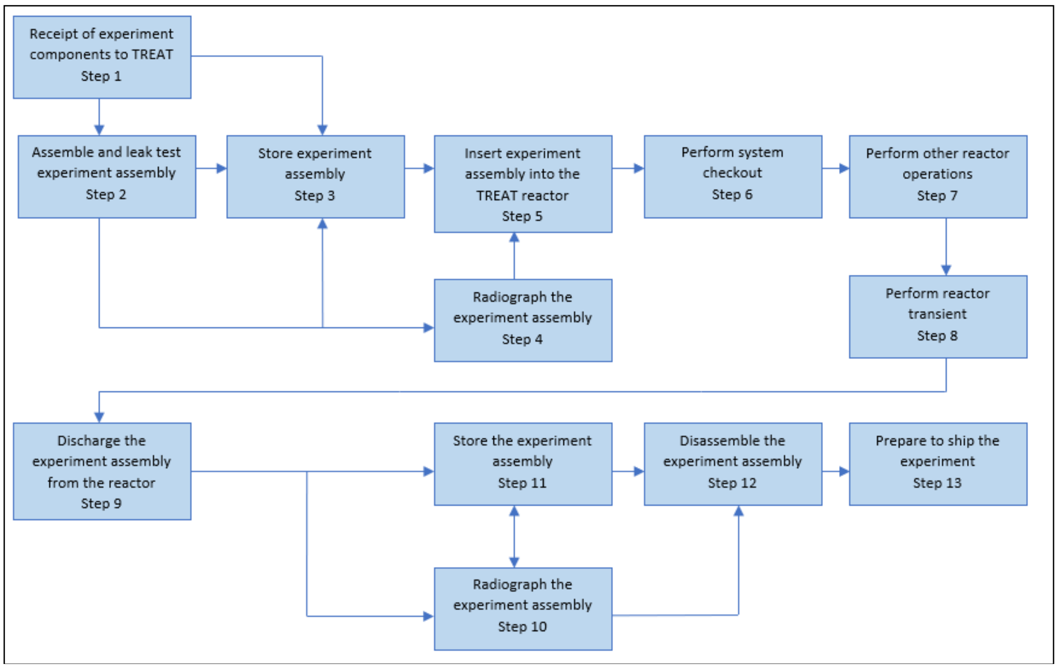

Figure 4 Typical ESA Experiment Process Flowchart

Experiment Safety Engineering (ESE) and TREAT management, during restart efforts, considered that CT did not meet the criteria to be classified as an experiment because these devices were typically sensors in which the SAR Experiment definition states that these may be excluded. These items were still evaluated with a separate analysis which was typically much shorter than an ESA and only addressed heating effects and reactivity effects within the main experiment's transient but did not follow TREAT's SAR Chapter 10 requirements.
During discussions with DOE it was determined that the interpretation of exempting CT as Experiments was not the intent of the Experiment definition at the time. The items exempted in the definition of the Experiment were meant to be detectors and flux monitoring devices that were associated with reactor performance and not external devices. DOE preferred to have all items being inserted in the core and intended for irradiation to have an ESA performed meaning everything inserted into the reactor be classified as an Experiment.

4. Interim Solutions

As soon as this difference in interpretations was understood the reactor was placed in a safe state by removing all CT and experiments from core, and all further operations were halted until a resolution of how the CT being currently utilized in the reactor must be evaluated. There were two ideas proposed that could allow TREAT to continue operation.

First, an ESA could be created for every item placed into the core that would have more evaluation of each item and allow the continued use of each. This option would add a large amount of documentation to be processed and time to get each document approved. Typical reviews for ESAs are a minimum of 4 weeks from start to finish. This timeframe does not include the time to create each document. The second option was to stop doing CT going forward until a new process could be created to allow them to be used again. This was initially viewed as the quickest option to resume operation, but the CT was used to characterize the reactor core. Removing the CT would cause multiple new core characterizations to be performed that could take months out of the reactor schedule.

Management decided the data received from CT was important and the first option of creating ESAs for all CT was started.

An ESA that covered all the CT was created [2]. This ESA evaluated each test with the same rigor as a nuclear fueled experiment. Due to the types of compliances that require answering for experiments, answering these same questions were hard to answer for non-fueled CT devices. In addition, many of the CT did not have the analysis typically done for a full fledged experiment.

Initially every item was considered an Experiment, but this caused problems with the current SAR. For every Experiment a Nuclear Equivalent Device (NED) is used to run a practice trial transient. NEDs consist of a non-fueled assembly that has the same reactivity worth as the fueled Experiment vehicle. This allows the reactor performance to be verified prior to inserting the fueled Experiment. NEDs also used the same process as CT. Per TREATs Technical Specifications (TS) trial transients were required prior to running experiments which were performed by the NEDs. Calling a NED an Experiment created an interesting conundrum due to the fact that calling a NED an experiment would require it to also have a NED to meet the TS requirements. . In addition, it was realized that all CT would need NEDs for each device to run during trial transients. Due to the majority of sensors being small and insignificant reactivity wise, a NED for a non-fueled device would look identical to the CT itself. Another device for a CT would have to be inserted for trial transients and then the actual device would be inserted for Experiment transients. NEDs for CT was an unnecessary reactor operation that would cause more radiation to TREAT operators from changing out devices and did not improve safety. Therefore, CT the TREAT Nuclear Facility Manager (NFM) declared that CT and NEDs would not be considered Experiments but would require evaluation in an ESA as if it was an Experiment. This was allowed based on the interpretation of "test material" in which the NFM defined for TREAT. (ADD THIS DEFF HERE?) This allowed for more rigor in the evaluation of each device but still conformed to what the current SAR requirements were.

The ESA changes and all documentation were completed in around 6 months and normal operation of TREAT was resumed.

5. Long Term Solutions

TREAT identified a need to further clarify the experiment definition in a revision to the TREAT SAR [4]. The SAR was updated to define Experiments as "any hardware, material, or device that is intended for irradiation within the reactor (within the inner surface of the biological shield above the grid plate) during steady-state reactor operation or transient reactor operation."

The updated SAR now allows for different types of experiments to be evaluated differently. NEDs or other experiments that do not have the potential for radiological or hazards material release and that are indented for trial transients or core characterization must show they can maintain their integrity during a transient in which the safety limit of 820C is achieved in the core.

For fueled Experiments that have, "a potential to disperse radiological or hazardous materials or that could damage SSCs important to safety, one credited SR-SSC containment shall be required and designed to prevent a mechanical failure during all normal operation and accident conditions described in Chapter 15 while the experiment vehicle is within the reactor, thereby preventing an uncontrolled release of radioactive or hazardous materials to the environment and ensure SSCs important to safety can perform their safety function" the performance of the reactor must be verified through a trial transient with a separate non-fueled experiment described above. The safety requirements for transient analysis are also specified for fueled experiments.

Every experiment will have an ESA created but will use different analysis to perform the safety calculations based on the complexity and potential hazard the experiment poses to workers and the public. This new SAR update will allow anything to be inserted into the reactor with the proper analysis. For fueled experiments that could release radioactive material the analysis requirements are more complex and comprehensive. For non-fueled experiments the requirements are more simple and allow for a graded approach to experiment evaluation process.

References

[1] Idaho National Laboratory, "Transient Reactor Test (TREAT) Facility FSAR. SAR-420," Revision 6. 2022.

[2] Idaho National Laboratory. "Experiment safety Analysis- Coolant Channel Concurrent Testing Experiment Safety Analysis" TREAT-ESA-005. 2022

[3] Idaho National Laboratory. "Experiment safety Analysis- Experiments Operated in MARCH-BUSTER" TREAT-ESA-002. 2022

[4] Idaho National Laboratory, "Transient Reactor Test (TREAT) Facility FSAR. SAR-420," Revision 7. 2023.