A FULLY RECONSTITUTED SAFETY BASIS FOR THE UNIVERSITY OF FLORIDA TRAINING REACTOR

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ABSTRACT

The University of Florida Training Reactor, (UFTR), is restructuring its licensing framework to help facilitate its upgrade to a digital controls system. The strategy focuses on creating an encompassing safety analysis to prove, unequivocally, that the UFTR represents a negligible risk to the health and safety of the public. This will allow a change in the Limiting Safety System Settings (LSSS) and for a reduction in the number of safety system and components (SSCs) that are defined as safety related by the Code of Federal Regulations.

The safety analysis is predicated on two postulated events: a rapid insertion of a large amount of positive reactivity and the release of fission products caused by mechanical damage to a spent fuel plate. These have been selected as limiting scenarios, whose extremity bound all other accidents of consequence.

The rapid insertion of positive reactivity was modeled using PARET/ANL software. Analysis shows that a reactivity insertion of $2.00 creates a maximum peak fuel temperature approximately 250° below the failure limit of 530C. The radioisotope inventory of the fission products is modeled using the ORIGEN-S module in SCALE6.1. The doses to the workers and members of the public are determined with COMPLY software and shows that the worst-case hypothetical exposures are approximately 6.5% of the annual regulatory limit.

1. Introduction

The University of Florida Training Reactor (UFTR) operating came up for 20-year renewal 2001. As part of relicensing, the facility is creating an encompassing safety analysis to prove, unequivocally, that the UFTR represents a negligible risk to the health and safety of the public. The new licensing approach allows for a reduction in the number of safety systems and components (SSCs) that are classified as safety related by the Code of Federal Regulations, Title 10, Part 50, Section 2 (10CFR50.2) and a reformatting of the UFTR's technical specifications to better conform to industrial standards.

The current revised safety analysis is predicated on two of the five postulated events from NUREG/CR-2079: an insertion of as large an amount of positive reactivity as is possible and the release of fission products caused by mechanical damage to a spent fuel plate. [1] These have been selected as limiting scenarios, whose extremity bound all other accidents of consequence. No new analysis of graphite fires or explosive chemical reactions is deemed necessary for our revised Safety Analysis.

We propose to demonstrate that under no circumstances with the UFTR Technical Specification loading limits of 22 fuel bundles will the reactor reach or come within any reasonable margin of the Safety Limit of 530C cladding or fuel melting temperature. To that end an analysis was conducted that takes no credit for protective functions of the UFTR or corrective actions on the part of personnel.

3. Analysis

Two scenarios were chosen for analysis as bounding for accidents that have the potential to cause radiological consequences to the public and workers. The first is a rapid insertion of a large amount of positive reactivity into the reactor and the second is the Maximum Hypothetical Accident (MHA) of a core crushing event which strips the cladding entirely from one face of an end of life fuel element to open air. [1]

An updated MCNP model was validated against previously measured parameters for excess reactivity and blade worth. The revised kinetics parameters of Neutron Lifetime, Beta Effective, Void, Fuel Temperature and Coolant Temperature coefficients or reactivity and hottest channel were selected for all accident analysis scenarios from the results of the MCNP analysis.

4. Insertion of Reactivity

An accident in which a rapid insertion of a large amount of positive reactivity is added is considered to be the method by which fuel and cladding temperatures are raised to a level that can hypothetically approach the Safety Limit of 530C. In order to evaluate large insertions of reactivity, a model of the UFTR was developed using the PARET-ANL software, a coupled reactor kinetics-hydraulics code developed by Argonne National Labs.

The code was able to complete the analysis of transients as large as $2.00 or 1480 pcm inserted in 0.5 seconds. The Maximum fuel temperature vs. time is shown in figure 1. Demonstrating the safety of larger insertions is not feasible with this code at this time. As such, a change to the Technical Specifications of the UFTR is called for that would limit the maximum loading so that there is an excess reactivity of no greater than 1480 pcm.

The 1480 pcm insertion caused a peak power of 116 MW, resulting in a 10.9 MWs first-excursion energy release. The peak power occurred 15 ms after the half-second reactivity insertion had completed. The insertion created a temperature rise in the fuel of 131.3 ˚C, to a maximum of 191.3 ˚C, and the fuel reached its peak temperature 53 ms after the insertion had completed. At times beyond those shown on Figure 1, the fuel temperature reached a relatively stable equilibrium.

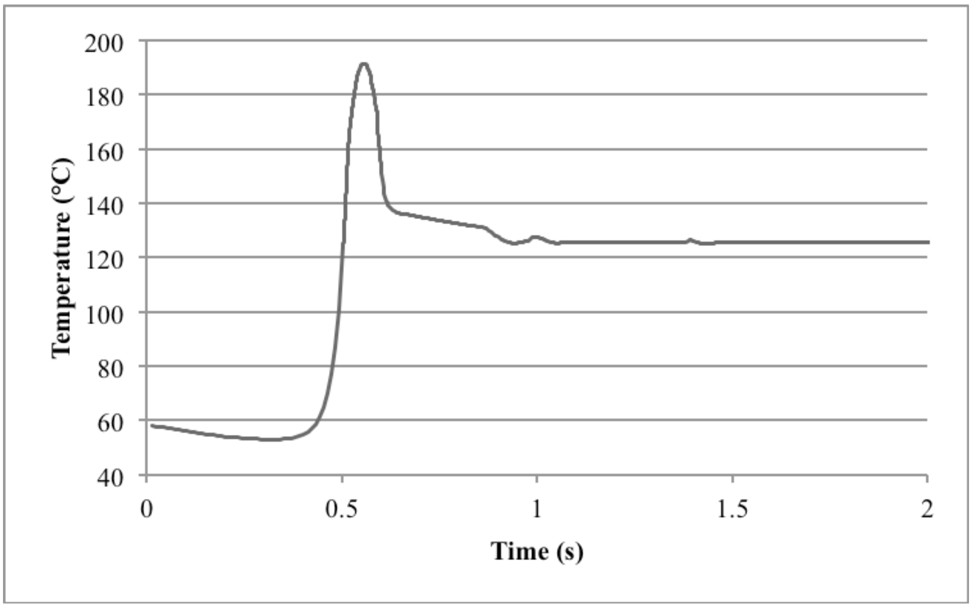

Fig 1: Maximum Fuel Temperature as a function of time for reactivity insertion of 1480pcm in 0.5 seconds

5. Maximum Hypothetical Accident

The most hazardous safety event for the UFTR is an accident in which fission products are released into the reactor cell as a consequence of some severe mechanical damage. The Maximum Hypothetical Accident (MHA) is one in which a 4500 lb concrete shield block is dropped on the core and causes severe damage in either the horizontal or vertical directions. This will cause a release of noble gasses and halogen fission products into the air of the cell. This event meets the NUREG-1537 definition of a Maximum Hypothetical Accident [2] as it involves the maximum mechanical damage to the fuel and the worst case event fission release. An analysis of this scenario is considered bounding on all other scenarios. Demonstrating that this accident poses no threat to the safety of the public or reactor personnel will satisfy the regulatory requirements of the NRC.

10 CFR 20.1201and 10CFR 20.1301 give the annual limits of radiation exposure to occupational workers and to the public from a licensed operation, respectively. For occupational workers the dose limit is as the more limiting of 2 exposures: an annual limit of the total effective dose equivalent (TEDE) of 5 rem or the sum of the deep-dose equivalent (DDE) and committed dose equivalent (CDE) of 50 rem to any individual organ. Additionally there are separate exposure limits for the skin (50 rem) and lens of the eye, (15 rem). The public exposure limit is 0.1 rem TEDE annually from any licensed operation.

Radionuclide inventories for the highest power fuel element were calculated using the ORIGEN-S code under the previous assumptions. Federal Guidance Reports numbers 11 and 12 give guidance on calculating dose from exposure to radionuclides for both the public and occupational workers. Of the radionuclides investigated, only Kr-88 yields a skin dose. Given its concentration, it is more conservative to assume the limiting dose will be the 5 rem TEDE or the 50 rem limit for the sum of DDE and CDE for an individual organ. Given the isotopes present, the thyroid was chosen as the individual organ that would accumulate the highest dose and was chosen for comparison against TEDE. Table 1 gives the summary and comparison for the two measures.

The reactor cell is considered to be the primary boundary for containment of any release of radionuclides. If an accident was to occur, egress from the cell is conservatively estimated to be less than 5 minutes even in the case of removing any injured personnel.

Calculations following the guidelines set forth in Federal Guidance Reports 11 and 12 yielded results that are well within the 10CFR 20 guidelines for occupational workers annual limit [3,4]. The results are given in Table 1.

Table 1 Summary of Occupational Exposure for the MHA

Location	Thyroid Dose		TEDE Dose	
	Rate (rem/hr)	5 Minute Exposure (rem)	Rate (rem/hr)	5 Minute Exposure (rem)
Inside Reactor Cell	50.37	4.197	1.626	0.136

The results for the most exposed member of the general population are given in Table 2. For comparison, according to the Radiological society of North America, a chest X ray gives approximately 0.01 rem of exposure. The 10CFR20 annual public dose limit due to licensed activities is 0.1 rem in one year. The worst possible scenario for the UFTR with a very conservative estimate of exposure yields approximately 6.5% of the annual allowed dose.

Table 2 Summary of Maximum Postulated Public Radiological Exposure for the MHA

Most Exposed Location	TEDE for MHA (rem/year)
10 m from the reactor stack	6.5×10^{-3}

6. Conclusion

The revised Safety Analysis of the UFTR supports the claim that there is no credible scenario that will cause the UFTR to approach its Safety Limit of 530C and poses no threat to the health and safety of the general public under any circumstances and with no credit taken for any of the instrumental or operational safety features of the control or safety system. In the worst case scenario of no corrective action and the greatest insertion of reactivity for the Technical Specification proposed loading limits, the maximum peak temperature that can be obtained is 191 C with a steady state temperature of 125 C after approximately 1 second. This steady state temperature is well below the fuel cladding blister temperature of approximately 530 C [5].

The release of nuclides as a consequence of a Maximum Hypothetical Accident (core crushing event) with the worst possible exposure scenario is shown to be approximately 6.5% of the allowed annual dose received by the public from a licensed facility and as such poses no credible potential to harm the general public.

It is recommended that the current LSSS be modified or eliminated and the UFTR Technical Specifications be modified to reflect that change. Current LSSS should be converted as necessary to Limiting Control Settings necessary to prevent the onset of nucleate boiling and to ensure that the departure from nucleate boiling ratio is maintained at greater than 2.0.

The inherent safety features of the design and operational loading limits ensure that there is no threat to the health and safety to the general public under any circumstances.

References

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