Task 4.b: Analysis Capability Development – Thermal-Hydraulics

To support confirmatory analyses for licensing reviews, the Nuclear Regulatory Commission's (NRC's) TRAC/RELAP Advanced Computational Engine (TRACE) system safety thermal-hydraulic code will need to be updated to analyze accident tolerant fuel (ATF) fuel performance. TRACE will be used to perform design-basis transient and design-basis accident (DBA) analyses and sensitivity studies. TRACE uncertainty quantification tools can be used to assess the impact that uncertainties in material properties have on fuel performance in DBAs. The existing TRACE fuel rod model assumes that the fuel is oxide fuel and the cladding is a Zirconium alloy. ATF designs may have different fuel or cladding or both. Therefore, updates to the TRACE fuel rod models will be needed to model the ATF designs. Small changes to TRACE should be able to accommodate cylindrical fuel with metallic cladding, including FeCrAl cladding and coated zirconium-based alloy claddings. Updates needed to model SiC tubing, any non-UO_2 fuel and metallic fuel in non-cylindrical fuel forms, would be more extensive. TRACE may also need to be coupled to external fuel rod models such as Fuel Analysis under Steady-state and Transients (FAST) or Department of Energy (DOE) BISON to model some aspects of ATF. The expected limiting factor on completion is getting adequate data for materials and testing from the DOE and/or fuel vendors.

Scoping Study – A scoping study will be conducted to determine what changes need to be made to allow TRACE to perform plant accident and transient calculations with ATF. A set of sample plant calculations will be selected to demonstrate the changes in plant response due to ATF.

Code Architecture Updates – TRACE will need updates to the fuel and cladding mechanical and thermal material properties for the new or different materials proposed for use in ATF designs. Additionally, the cladding oxidation and rupture models in TRACE are based on empirical data for zirconium alloy cladding and will need to be modified to model clad oxidation and rupture for the other cladding materials proposed for use in ATF designs. In the case of non-cylindrical solid metallic fuel rods, a method will be needed to analyze the non-cylindrical geometry and the impact it has on conduction and convective heat transfer and fluid flow. TRACE may also need to be coupled to external fuel rod models such as the FAST or the BISON fuel analysis models through the TRACE Exterior Communications Interface (ECI) to model some aspects of ATF.

Property and Model Development – The physical models that need to be updated are fuel and cladding mechanical and thermal properties, cladding oxidation kinetics models, clad rupture models, fuel convective heat transfer models, and critical heat flux (CHF) models. It is expected that most of this information will be provide by the industry or DOE.

Code Assessment and Validation – The updated code will be validated against steady state and transient data collected by DOE and the industry. Demonstration calculations of reactor accidents will be performed to examine the impact of the new fuel on the evolution of the accident and safety criteria.

The milestones are listed in the table below with their related trigger or needed input, lead time, and schedule driver.

"Evolutionary" ATF concepts (e.g., coated cladding, doped pellet, FeCrAl)

Activity	**Data Needs and Inputs**	**Duration**	**Needed By**
Scoping Study	Low level of resources needed; short duration task assuming models maintain same qualitative form as current models.		
Code Architecture Updates	Assumes models maintain same qualitative form as current models. Need conceptual design information (geometry, materials)	2 years	3 years before safety analysis topical report (TR) submittal
Material Property and Model Development	Data available from literature, fuel vendor, and DOE test programs, etc.	2 years	2 years before safety analysis TR submittal
Code Assessment and Validation and Sample Plant Calculations	Reactor physics capability to generate cross sections/point kinetics parameters for sample plant calculations. Data available from fuel vendor and DOE test programs. Assessment data needed 1.5 years before TR submittal	1.5 years	Safety analysis TR submittal.
Lead Time for T/H Analysis Capability for Evolutionary ATF	3 years		

“Revolutionary” ATF concepts (e.g., SiC, U_3Si_2, metallic pellets, or solid rods). Table assumes evolutionary fuel work has been completed.

Activity	Data Needs and Inputs	Duration	Needed By
Scoping Study	Low level of resources needed; short duration task assuming models maintain same qualitative form as current models.		
Code Architecture Updates (Remove Zr and UO_2 hard-wired properties)	Conceptual design information for ATF designs (geometry, materials)	1 year[1]	-
Code Architecture Updates (Remove assumptions related to fuel geometry and Zr-UO_2 interaction)	Completion of previous milestone	1 years[2]	-
Material Property and Model Development	Separate Effects Data	1 years[2]	-
Code Assessment and Validation	Integral Effects Data. Assessment data needed 1.5 years before TR submittal	1.5 years[2]	Safety analysis TR submittal.
Lead Time for T/H Analysis Capability for Revolutionary ATF	2 years		

[1] Task will not be required if the “evolutionary” activities are completed and new models have the same qualitative form as the current models.
[2] Tasks can be worked on in parallel assuming that the new models have the same qualitative form as the current models.

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