# Fuel Performance Modeling of the TWR

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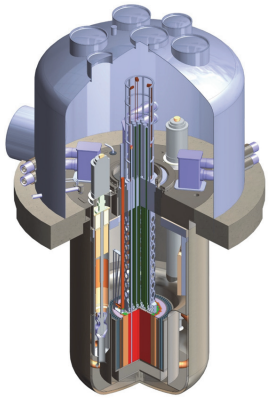
## Approach to Fuel Performance Modeling

TerraPower, LLC, is actively developing Traveling Wave Reactor (TWR) technology, a novel fast reactor concept relying on breed-and-burn technology to maximize fuel utilization, reduce waste, and improve safety.

Fuel performance is an integral part of the design process, setting limits that drive many engineering decisions. Through in-depth analysis of legacy sodium fast reactor fuel performance data, key design parameters have been identified to maximize fuel element burn-up.



**Traveling Wave Reactor - Prototype**

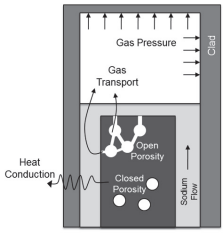
Turns depleted uranium into electricity, using a simple fuel cycle without requiring separations.

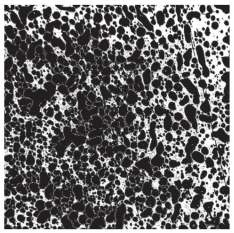
| | |
|---|---|
| SIZE | 600 MWe |
| TEMPERATURE | 500°C |
| PRESSURE | Low (Atmospheric) |
| COOLANT | Sodium |
| ENERGY CONVERSION | Steam (Rankine Cycle) |
| WASTE REPROCESSING | Not Required |
| OPERATION | Mid 2020s |

Fuel performance models were developed to incorporate the basic physics of fuel performance into a model with a minimum number of undetermined coefficients. The principal goal has been to develop straightforward models that have predictive capability but do not obscure behavior so that key trends can be identified and understood. This approach justifies extrapolation of performance from the current database.

In addition, probabilistic finite element methods are being developed and applied to quantify effects of model uncertainty to reduce risks associated with model extrapolation. Fuel irradiation tests using a factorial design are proceeding, which will provide comprehensive model validation and qualification data at the earliest possible date. The combined support of legacy data, defensible model abstractions, and near-term qualification experiments provides the basis for predicting and confirming TWR fuel element performance.

## ALCHEMY Fuel Performance Model

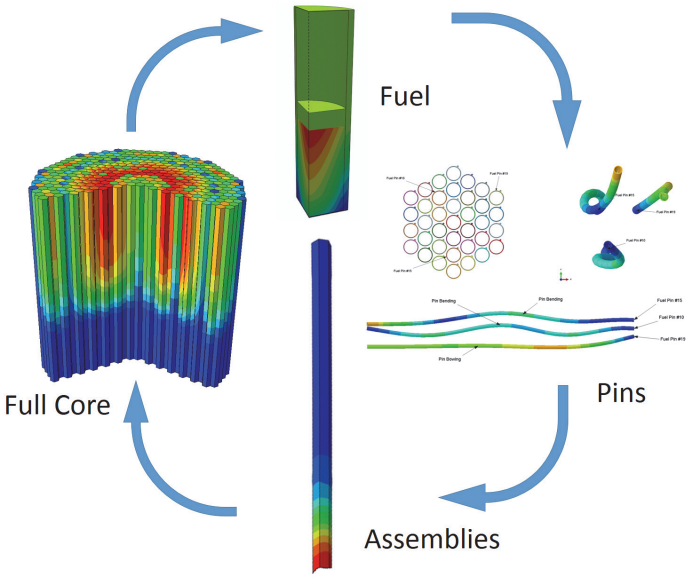


Constitutive models include the effects of (1) solid and gaseous fission product accumulation; (2) fission gas release; (3) creep behavior of internally pressurized porous solids under external loads; (4) combined effects of open and closed porosity; (5) clad deformation mechanisms; and (6) transport of thermal energy.

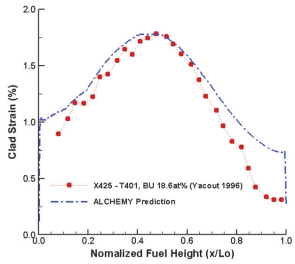
## Multi-scale Mechanical Behavior

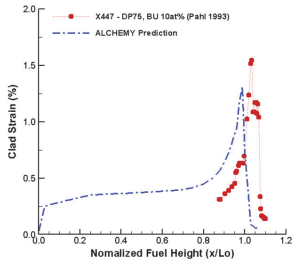
A commercial finite element code has been employed for a convenient mechanical model framework. This allows users to model fuel pins, assemblies, ducts, and interaction up to full core scale while focusing development work on the unique behavior of nuclear fuel and structural materials properties in an irradiation environment.




## Legacy Sodium Fast Reactor Fuel Performance

Analysis of legacy sodium fast reactor fuel performance data is central to understanding the limits of fuel elements. Primary data comes from the rich EBR-II and FFTF operating experience, where a large number of fuel and cladding types were used, at various operating conditions, to significant burn-ups. Several different fuel systems operated as "driver" fuel, while various test assemblies were ran to study the effects of temperature, power, geometry, and fabrication variables on fuel performance.




Benchmarking to diametral profilometry shows predictive capability through a wide range of geometries and operating conditions. These benchmarks, combined with near-term qualification experiments comprise the ALCHEMY validation database. In accordance with ASME: "*Validation* tests against independent data that have not also been used for calibration are necessary in order to be able to document the predictive capability of a model."

**References:**

ASME. (2006). Guide for Verification and Validation in Computational Solid Mechanics. *American Society of Mechanical Engineers*.

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