ATF Performance Benefits and Metrics

Increased Accident Tolerance of Fuels for LWRs
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Lars Hallstadius, Ed Lahoda

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Introduction - A vendors vision of ATF

- Tolerates loss of active cooling for longer time periods
  - Enhanced time for operators to react (“grace period”) in a severe accident
  - At least several hours, preferably days
- Maintain or improve fuel performance in all other situations
  - Normal operation and transients
  - Design base accidents (LOCA, RIA)
- Reliable and inexpensive manufacturing
- Superior economics – driver for utility acceptance

Accident tolerance as well as superior economy

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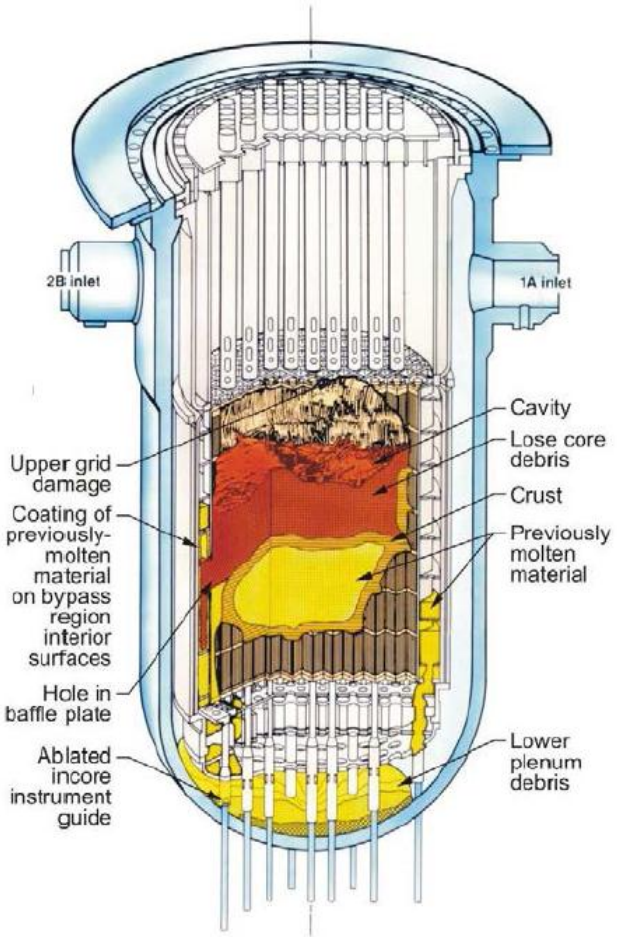
ATF - Reference Accident Scenarios

- Consensus from (NEA) workshop on ATF for LWRs, December 2012
- BWR: Fukushima 1-3
- PWR: Three Mile Island-2



Key Aspects of Accident Tolerant Fuel (ATF)

- Safety analysis for design basis and beyond design basis accidents
  - "Grace period" for reference accidents
    - Reduced reaction rate in high temperature steam
- Neutronic and economic analysis
  - Significant benefit required to offset industry risk
- Fuel rod performance analysis
- Thermal hydraulic analysis
- Fabricability and manufacturing costs

Success depends on meeting/exceeding current LWR fuel in all these areas

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Preliminary Specifications of ATF Cladding and Fuel

- <5% U235 enrichment for integration into current fuels system
- Mechanical properties to withstand earthquake, transportation & handling
- Composition to minimize parasitic neutron absorbtion
  - Also to minimize undesirable fuel phases
- Properties and behavior of fuel compatible with cladding
  - Thermal swelling vs.cladding mechanical properties
  - High density to maximize fuel content
- Fuel centerline temperature remains below melting
  - During anticipated transients

Current specifications and licensing criteria based on Zr cladding and UO_2 fuel

Architecture and Fabrication Methods for ATF

- Square pitch and ~4 m long tubes architecture
  - Maintain backwards compatibility with current reactor fleet
- Cylindrical fuel pellets
  - Compatibility with current manufacturing facilities
  - And, licensing knowledge base
- Use UF_6 as feedstock for fuel manufacture
  - Compatibility with existing fuel production infrastructure

ATF must work within the current LWR fuels environment

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Why ATF Needs both new Fuel and Cladding

- Cladding adds safety but minor financial benefit for utility
- Cladding provides margins that UO_2 (with <5% ^{235}U) cannot utilize
  - Burnup, corrosion, temperature, uprate capability
  - Low thermal conductivity and low ^{235}U content
- ATF needs a high density, high thermal conductivity pellet
  - Provides the economic incentive for utilities to fully support ATF

ATF can have excellent economic benefits as well as accident tolerance

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Accident Tolerance for Cladding - Criteria

- Assume maximum temperature ~1700°C
  - Consistent with reference cases w/o heat generation from cladding oxidation
- Low oxidation rate to avoid significant heat generation
- Minimal H_2 generation below 1700°C

- Maintain strength
  - Coolable geometry, Avoid fuel relocation
  - Contain non-gaseous fission products

- Allow recooling of core
  - Thermal shock resistance, Post-quench integrity
  - Control rods/blades
- Plant should be recoverable

- Good manufacturability at reasonable costs

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Fuel pellets for ATF - Criteria

- U metal loading greater than for current UO_2
- No centerline melting during normal operation, transients and accidents
- Well-behaved FGR and swelling at operating conditions
- Chemical and physical compatibility with cladding material
- Good manufacturability at reasonable costs

More to read

- Shannon M. Bragg-Sitton et.al.: Enhanced Accident Tolerant LWR Fuels: Metrics Development. TopFuel 2013, Charlotte, North Carolina, September 15-19, 2013.

- Lori Braase: Enhanced Accident Tolerant LWR Fuels; National Metrics Workshop report. Idaho National Laboratory, January 2013, FCRD-FUEL-2013-000087.

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