EPRI ATF Research and Development

Presentation to the IAEA Nuclear Back-End Webinar Series: Accident Tolerant Fuel

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Background: U.S. ATF History

- In 2012, U.S. Congress mandated DOE:
  - Develop LWR fuel with Enhanced Accident Tolerance
  - Facilitate loading of LTR/LTA into U.S. LWR by 2022

- DOE Three Phase Strategy:
  - Feasibility and down-selection to 3 ATF concepts
  - Develop and qualify ATF concepts
  - Commercialization for ATF concepts

- Utilities committed to accelerated deployment of ATF for improved safety and economic benefits

Incremental Benefits = Easier
Transformative Benefits = Harder
U.S. Industry Need for Accelerated ATF Implementation

- Challenge: traditionally long fuel design to deployment timeframes
- Limited window of opportunity:
  - Existing fuel testing facilities
  - Abundant R&D programs
  - Limited economic viability for ATF benefits to the existing fleet
- Milestone: mid-2020s for batch reloads of ATF (doped pellets and coated cladding), with increased enrichment to realize higher burnup

Accelerating ATF is a Heavy Lift
EPRI ATF Research and Development Efforts
EPRI ATF Safety and Economic Benefits Studies

EPRI ATF Safety Benefits Scoping Study

- Improved Fuel Characteristics & Performance
- System Safety Modeling & Simulation
- Risk Analyses

Conversion of ATF Safety Benefits to Economic Benefits

Industry ATF Business Case

- Costs
  - ATF/Higher Burnup/Enrichment R&D
  - ATF/Higher Burnup/Enrichment Licensing
- Benefits
  - Fuel Utilization: Higher Burnup
  - Fuel Efficiency: Higher Enrichment
  - Operational Flexibility
  - Increased Fuel Reliability

Utility Implementation
EPRI ATF Safety and Economic Benefits Studies

- Safety benefits vary among:
  - ATF cladding/fuel concepts
  - BDBA/DBA/AOO Accident scenarios
  - Reactor type and specifics

- For severe accident cases:
  - Enhanced coping times of ~1-3 hours
  - ATF delays core damage, however, restoration of core cooling needed to prevent core damage
  - Specific ATF concepts may have limited Three Mile Island-2 core damage

- For DBA/AOO cases:
  - Potential greater benefits through safety margin improvements to support operational enhancements

- General agreement of modeling results:
  - Vendors, MIT, UW, INL, and ORNL
Potential Benefits of Coated Cladding

- Current regulatory framework sufficient for licensing:
  - NRC ATF Interim Staff Guidance (NRC-ISG-1) (01/20)
  - NRC presentation at EPRI Extended Storage Collaboration Program Meeting
- Enhanced coping times for various accident scenarios
- Reduces potential for fuel relocation during LOCA
- Enables better efficiencies with increased enrichment to realize higher burnup

Photos provided with permission of Westinghouse Electric Corporation
Accelerating ATF Deployment with Increased Enrichment and Burnup

- 24 Month Refueling Cycles
- Enhanced Fuel Performance
- $9.4 Billion in Industry Fuel Savings
- Enhanced Fuel Reliability
- 20% Less Waste & $3.5 Billion Savings
- Improved Operational Flexibility
- Accelerate ATF Fuel Transition
- Fuel Cycle Optimization

SAFELY SUSTAIN THE FLEET

IMPROVED PLANT ECONOMICS

ENHANCED SAFETY

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Key U.S. ATF Fuel Milestones

- SNC Hatch: (GE/GNF)
- SNC Vogtle: (Framatome)
- Exelon Byron: (Westinghouse)
- Exelon Clinton: (GE/GNF)
- Exelon Calvert Cliffs: (Framatome)

Legend:
- Blue: Coated Cladding
- Orange: IronClad
- Green: Enhanced UO₂ Fuel
- Purple: High Density Fuel
+ Loadings
± Loadings & Removal

Years:
2018 2019 2020 2021 2022 2023 2024 2025 2026
EPRI ESCP Workshop on Evaluating Advanced Fuels Impacts on Back-End Operations
**EPRI Extended Storage Collaboration Program**

**2009**
1st ESCP meeting
1 country,
39 participants
2 subcommittees

**2010-2019**
Regular May and December meetings, in US
14 International SC meetings
6 subcommittees

**2020**
〜675 members from 22 countries
Over 185 participants, representing 10 countries, attended Winter 2019 meeting
4 subcommittees
Workshop on Advanced Fuels Impacts on Back-end (11/19)

1. ATF Description and Benefits
   - ATF/HE/HB Industry Perspective and Plans, John Williams (Southern)
   - ATF Industry Directions, Ben Holtzman (NEI)
   - DOE Advanced Fuels Campaign - ATF Program, Bill McCaughey (DOE)
   - ATF/HE/HB Program Benefits for Nuclear Industry, Al Csontos (EPRI)

2. Used Fuel Program Overviews
   - DOE UFD Program Overview & Perspective, Ned Larson (DOE)/ Sylvia Saltzstein (SNL)
   - NRC Activities and Perspectives on ATF and HBU/HE Fuel, Meraj Rahimi (NRC)
   - IAEA Perspectives, Christoph Gastl (IAEA)
   - A preliminary assessment of the disposability of spent accident tolerant fuels, David Hambley (NNL)

3. Descriptions for Advanced Fuels
   - Westinghouse Advanced Fuel Designs, Zeses Karoutus and Kallie Metzger (Westinghouse)
   - Framatome Advanced Fuel Designs, Chris Lewis (Framatome)
   - GE/GNF Advanced Fuel Designs, Paul Cantonwine (GNF)

4. Panel Discussion - Impact on Dry Storage Discussion Panel
   - Meraj Rahimi (NRC)
   - George Carver (NAC)
   - Debu Mitra-Majumdar (Holtec)
   - Prakash Narayanan (Orano)
   - Al Csontos (EPRI)
Potential Impact of ATF & Higher Burnup/Enrichment

Spent Fuel Pool
- Criticality
- SFP heat load management
- Accident Analysis

Dry Storage & Centralized Storage
- Criticality
- Heat Load Limits
- Cladding/Fuel Properties
- Accident Analysis

Transportation
- Criticality
- Fuel/clad properties during transportation
- Accident Analysis

Disposal
- Criticality (long term impact)
- Heat load management
- Fuel and cladding properties

Coated Claddings Limited Impact to Back-End Operations
Higher Burnup/Enrichment Potentially Greater Impact
Current ATF R&D Relevant to Back-end Operations

- High temp oxidation and coating stability
  - OECD/NEA KIT Quench Test Program
  - IAEA Coordinated Research Projects ACTOF & ATF-TS
- Hydrogen pickup and permeability
- Coated Cladding Performance Modeling:
  - Balloon/burst and relocation
- DOE data needs for ATF and higher burnup and enrichment for back-end operations
  - Report expected 2021
- EPRI Spent Fuel Pool Criticality Modeling
- EPRI Decay Heat Testing and Modeling
- EPRI Workshop: Sensors for SNF Operations
  - December 14-15, 2020 (Virtual)
Summary

- EPRI providing independent assessments to the nuclear utilities on potential ATF safety and economic benefits and regulatory hurdles:
  - 3002012250: ATF Technical Update: Valuation 1.0, Gap Analysis, Valuation 2.0
  - 3002015091: ATF Safety & Economic Benefits
  - 3002014603: Coated Cladding Gap Analysis

- Focused R&D to accelerate ATF deployment:
  - Domestic and international collaborations with numerous stakeholders

- Holistic considerations for the impact of ATF to entire fuel cycle:
  - EPRI Workshop on Advanced Fuels Impacts on Back-end Operations
  - EPRI Extended Storage Collaboration Program 2020 Conference
Together...Shaping the Future of Electricity