EPRI Fuel Reliability Program

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EPRI and FRP

- **What is EPRI?**
  - The Electric Power Research Institute (EPRI) is an international, non-profit R&D organization aimed at providing objective, scientific research, development, and support to improve the safety, economics, and reliability of electric power.

- **What is FRP?**
  - The Fuel Reliability Program (FRP) focuses on research and support specific to nuclear fuel and other core components. Some examples:
  - Work with the industry to aggregate OE and develop guidance to prevent fuel failures
  - Support industry on change management with assessments, lab testing, poolside/hot cell examinations
  - Investigate innovative fuel technologies and plant operational domains that can lead to performance improvements and cost savings while improving safety and reliability
  - Develop technical bases to support licensing/regulation

Evolution of EPRI Fuel Programs

NFIR – Nuclear Fuel Industry Research
RFP – Robust Fuel Program
FRP – Fuel Reliability Program

NFIR - formed in early 80s

RFP formed in 98 – focused on high burnup

INPO SOERs – 1996 and 2003

RFP to FRP – shifted focus to reliability

INPO Zero-by-Ten Initiative (2006-2010)

FRP guidelines, handbooks, codes, training and assessments

Fukushima accident (2011)

Delivering the Nuclear Promise (2018)

ATF, HBU, LEU+

Increased power demand

Power Uprates, Cycle Length Extension

INPO – Institute of Nuclear Power Operation
SOER – Significant Operating Experience Report

Nuclear fuel continues to play a crucial role for the industry

EPRI Fuel Reliability Program

Fuel Reliability and Performance

- Support current operating fleet to minimize and avoid fuel failures and fuel performance issues
  - Develop and update Fuel Reliability Guidelines, Tools, and Handbooks - technical basis and operating experience
  - Inform industry to support change management

Cost and Operational Efficiencies

- Perform research to capture cost and operational efficiencies
  - ATF
  - HBU/LEU+
  - KOH
  - Cycle Length Extension
  - Power Uprates
  - Time-at-Temperature
  - Flexible Power Operation
  - Control Rod/Blade
  - NDE

Regulatory and Safety Technical Bases

- Develop technical basis for regulatory and safety issues
  - ATF
  - HBU/LEU+
  - FFRD

FRP Research Focus Areas

- Advanced Fuel Technology (AFT)
- Debris-Induced Failure Mitigation (DFM)
- Guidance, Methods, and Tools (GMT)
- PWR Crud and Corrosion (PWR C/C)

FRP research focus areas aim to address current industry issues

- BWR Crud and Corrosion (BWR C/C)
- Nondestructive Evaluation (NDE)
- BWR Control Blade Integrity (CRB)
- Structural Component Integrity (SCI)
- Pellet-Clad Interaction (PCI)

FRP Research Focus Areas

Advanced Fuel Technology (AFT)

- Evaluate fuel reliability and performance benefits of ATF/HBU/LEU+, updated EPRI guidelines, tools, and handbooks for implementation of ATF/HBU/LEU+
- Perform research to enable safety and economic benefits of ATF/HBU/LEU+ and power uprates

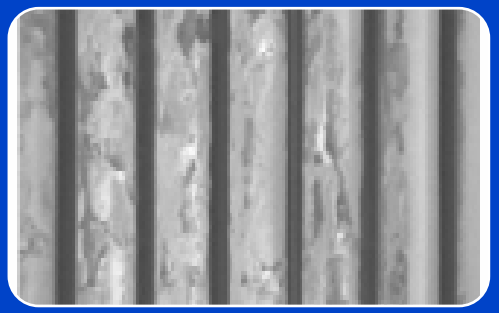
Debris-Induced Failure Mitigation (DFM)

- Guidance and training on FME control
- Research that enables debris-resistant fuel
- Research and development to support improvements in debris-resistant fuel technology

Guidance Methods and Tools (GMT)

- Fuel Surveillance and Inspection Guidelines (FSIG), Fuel Design Handbook, FRP Wiki
- Fuel Failure Monitoring and Evaluation Handbook and associated training products
- Fuel Reliability Database (FRED) and Falcon fuel performance software

Cont'd FRP Research Focus Areas

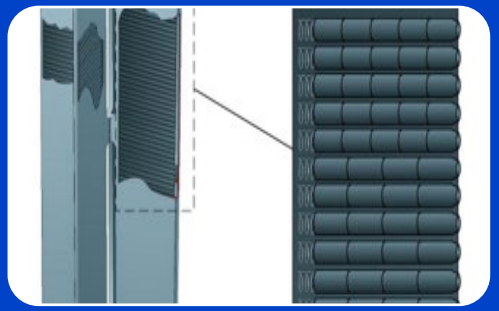


PWR Crud and Corrosion (PWR C/C)

- CIPS and CILC risk management, BOA CIPS/CILC risk assessment tool
- PWR Fuel Cladding Corrosion and Crud Guidelines
- Potassium hydroxide application demonstration (KOH)

BWR Crud and Corrosion (BWR C/C)

- BWR Fuel Cladding Corrosion and Crud Guidelines
- CORAL crud risk assessment tool
- Water chemistry changes (i.e., early/continuous OLNC)

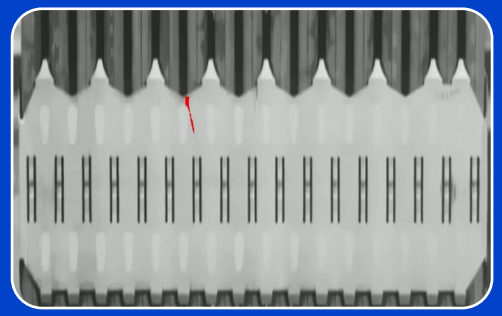


BWR Control Rod Blade Integrity (CRB)

- BWR CRB leakage and lifetime prediction improvements

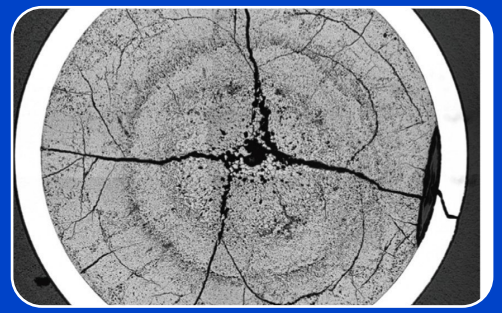
LEU+ is 5-8%

Cont'd FRP Research Focus Areas



Nondestructive Evaluation (NDE)

- Failed fuel identification
- Fuel assembly/rod anomaly identification and characterization
- Poolside fuel cladding corrosion, crud, and hydrogen content measurements (F-SECT)

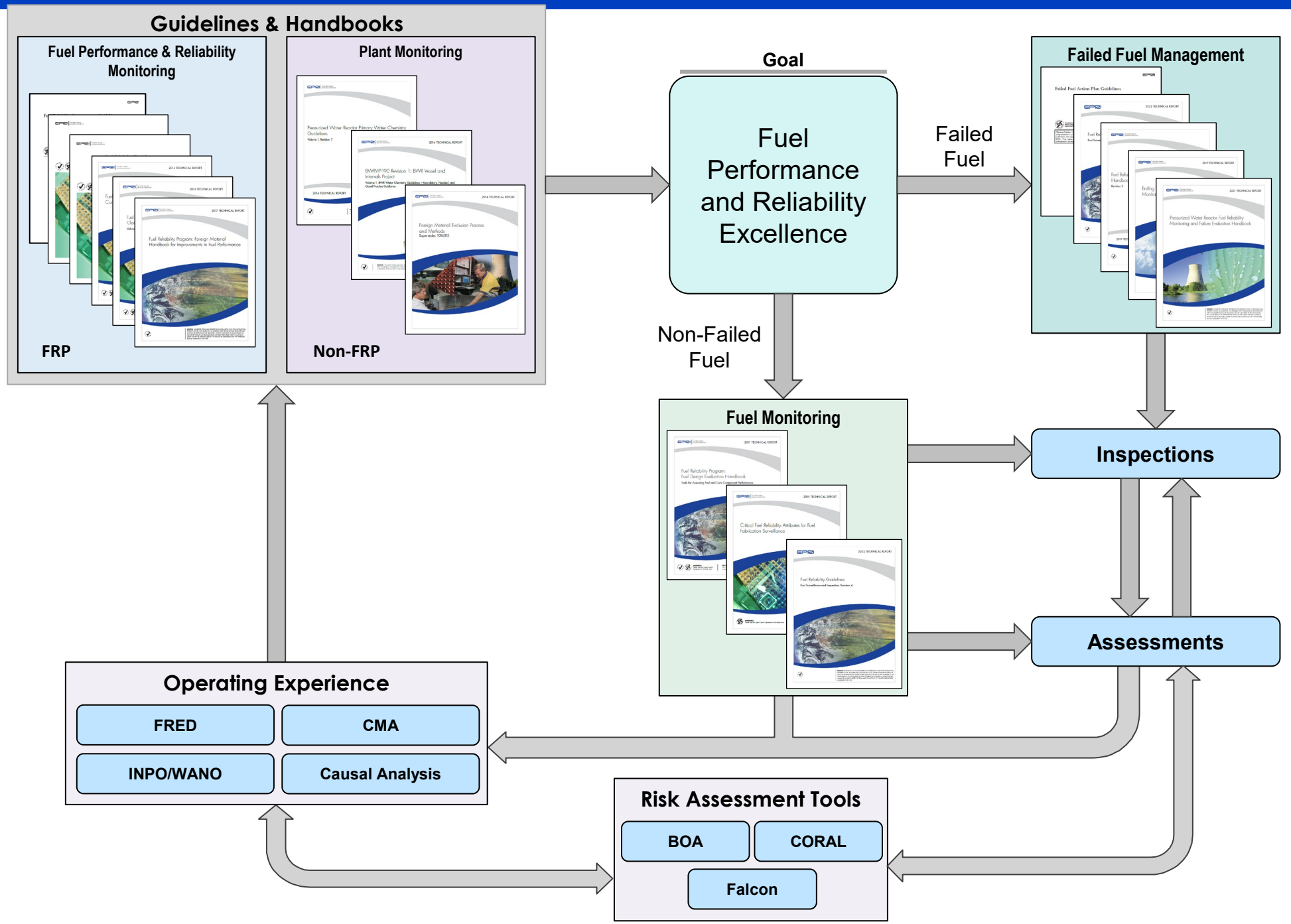


Pellet Cladding Interaction (PCI)

- Guidance to mitigate PCI risk and information on performing PCI margin evaluations
- Characterization of recent PCI operating experience
- PCI margin impacts from major operational changes

Structural Component Integrity (SCI)

- Irradiation impact on additive manufacturing of fuel components (i.e., debris filters)
- Lateral stiffness measurements on a PWR assembly – assembly bow



Key

Fuel Performance Monitoring
- Fuel Reliability Improvement Guidelines (TR-100659)
- PWR Grid-to-Rod Fretting (1015452)
- Pellet-Cladding Interaction (1015453)
- PWR Fuel Cladding Corrosion and Crud (3002002795)
- BWR Fuel Cladding Corrosion and Crud (3002029352)
- Foreign Material Handbook for Improvements in Fuel Performance (3002010740)

Plant Monitoring
- PWR Primary Water Chemistry Guidelines (3002000505)
- BWR Water Chemistry Guidelines (3002025550)
- Foreign Material Exclusion Process and Methods (3002003060)

Failed Fuel Management
- Failed Fuel Action Plan Guidelines (NP-5521-SR)
- Fuel Surveillance and Inspection (3002031987)
- Fuel Reliability Monitoring and Failure Evaluation Handbook (3002016031)
- Boiling Water Reactor Fuel Reliability Monitoring and Failure Evaluation Handbook (3002025296)
- Pressurized Water Reactor Fuel Reliability Monitoring and Failure Evaluation Handbook (3002018465)

Fuel Monitoring
- Fuel Design Evaluation Handbook (1022424)
- Critical Fuel Reliability Attributes for Fuel Fabrication Surveillance (3002005549)
- Fuel Surveillance and Inspection (3002031987)

Operating Experience
- Fuel Reliability Database (FRED) (3002025070)
- Chemistry Monitoring and Assessment Database (CMA) (3002026560)

Risk Assessment Tools
- Boron-Induced Offset Anomaly Risk Assessment Tool (BOA) (3002012131)
- BWR Fuel Crud Risk Assessment Tool (CORAL) (3002010769)
- Falcon Fuel Performance Code (3002018499)

FRP Base Products
FRP Supplemental Products
Non-FRP Base Products

Fuel Reliability Guidelines (FRGs)

- Goal: **Fuel Performance and Reliability Excellence**
  - Improve overall unit performance, lower radiation dose, and lower operating cost through improved fuel performance
  - Eliminate fuel failures and other fuel-related performance issues

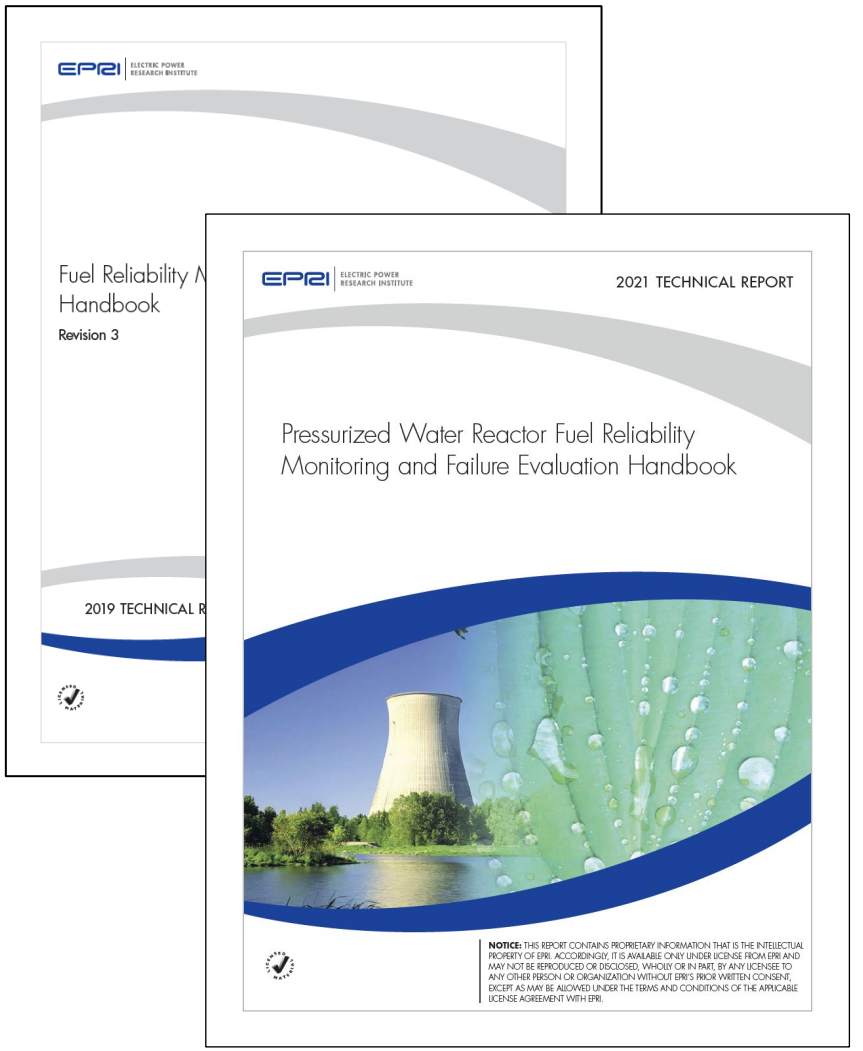
- Guidelines:
  - Fuel Surveillance and Inspection (FSIG)
  - BWR Fuel Cladding Corrosion and Crud (C/C)
  - PWR Fuel Cladding Corrosion and Crud (C/C)
  - Pellet-Cladding Interaction (PCIG)
  - Grid-to-Rod Fretting (GTRF)

Design/Fabrication Surveillance and Oversight

- Guidance provides a standard for utilities and fuel suppliers (and sub-suppliers) to successfully prepare for, execute, and close fuel fabrication campaigns with the goal of zero fuel failures and performance/operational issues
  - Recommends utility visits to fuel fabrication facilities to ensure standards are met
    - Oversight frequency
    - Manufacturing process change management considerations
  - Covers component manufacturing process and why they are important to prevent fuel failures and operational issues

During Operation - Monitoring for Failures

- Fuel Failure Handbook – a comprehensive reference on
  - Radiochemistry theory and monitoring
  - In-depth methodologies for assessing fuel failures with extensive sample cases
  - Startup and shutdown fission product spiking monitoring
  - Power level dependent cesium-burnup correlation for failed fuel burnup determination
  - Multiple failures evaluation



Fuel Failure Monitoring and Evaluation Training is available

Additional Tools and Sources of Information

- Risk Assessment
  - BOA and CORAL – crud/corrosion risk assessment software for PWRs and BWRs
  - Falcon – PCI assessment

- Operating Experience (OE)
  - FRED – source of industry fuel performance
    - Fuel performance, chemistry, operating data for over 2400 cycles
    - Access to causal analyses and other fuel assessment/inspection information
  - CMA – source of industry chemistry data
  - INPO/WANO – source of individual OE
  - Causal analyses

FRP Membership

Supplemental Program Funders

- All US utilities except AEP, DTE, and PG&E
- ETN
- CFE
- Shandong, CNNP
- TEPCO
- KHNP
- ENEC/NAWAH
- EdF/EdF Energy
- FORO/All Spanish Utilities
- Vattenfall
- KKL, AXPO
- RR SMRs, RR Sub

Full FRP Program Access and Influence

Nuclear Sector Base Only Funders

- AEP, PG&E, DTE
- NA-SA
- CANDU Owners Group
- CEZ a.s.
- PAKS
- Huaneng
- Chubu, Chugoku, JAPC, Kansai, Shikoku, Kyushu, J-Power, Tohoku
- KRSKO
- ESKOM
- OKG
- KKG
- TPC

Limited FRP Program Access and Influence

Members are from North and South Americas, Europe, Asia, and Africa

FRP Base vs. Supplemental

FRP RFA	Base (Generically applicable technology)	Supplemental (NSSS-specific technology)
AFT	FFRD Consequences Testing, International Program Membership (SCIP, FIDES, CRAFT, QUENCH ATF etc.)	ALS, ATF Performance Assessment and Implementation, Cycle Length Extension Assessment, hot cell PIE, t@T material testing
DFM	Training	Debris fretting testing, Outage Practices Handbook
PWR C/C	KOH demo (funded by the sector)	BOA, CIPS/CILC Assessment, Corrosion Issues
GMT	Falcon, FRP Wiki, training, several Handbooks and Guidelines generically applicable to all NSSS	BWR and PWR Specific Fuel Failure Handbooks
BWR C/C		All
BWR CRB	BWR CRB Cracking Inspection (funded by the sector)	BWR CRB Issues
NDE	F-SECT and Eddy Current Array	DREAM (Visual Inspection Tool) LiDAR applications to BWR and PWR fuel
PCI	Products applicable to all NSSS	Products applicable to PWRs and BWRs only
SCI	Lateral Stiffness Measurements (funded by the sector)	Additive Manufacturing

Maximize the benefit to all members using base and supplemental funding

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Future FRP Advisory Meeting Dates

2026

FRP Winter TAC Meeting (January) – In Person Only

- The DeSoto – Savannah, GA
  - January 20-22, 2026

Nuclear Advisory Meeting (February) – In Person Only

- Sheraton Grand at Wild Horse Pass – Phoenix, AZ
  - February 9-12, 2026 (FRP RIC on Monday, February 9)

FRP Summer TAC (July) – Hybrid

- EPRI Offices – Charlotte, North Carolina
  - July 14-16, 2026

Nuclear Advisory Meeting (August) – In Person Only

- Gaylord Pacific – San Diego, California
  - August 31-September 3, 2026 (FRP RIC on Monday, August 31)

FRP Resources and Training

https://www.epri.com/research/programs/061147/links

Program 41.02.01: Fuel Reliability Program

Program Home | Overview | Projects | Research Results | Supplemental Projects | Events | Trainings | Contacts | Committees | Announcements | Links

Links

General

- FRP Utility Advisor Onboarding Checklist
- FRP Strategic Objectives and Organization
- FRP Research Portfolio
- Nuclear Staff Expertise List
- Nuclear Sector Operations Protocol
- Base Library
- Fuel Reliability Guidelines
- Supplemental Library

Meeting materials

Available non-instructor-led training

Trainings

- General Debris Management Training
- Job Task Debris Management Training
- Foreign Material Exclusion: Striving for Industry Excellence Video (English Version)
- Fuel Reliability Database (FRED) Computer-Based Training
- BWR Crud and Corrosion Guidelines Training Slides
- PWR Crud and Corrosion Guidelines Training Slides
- Fuel Failure Handbook Computer-Based Trainings | Module 1: Fuel Failure Causes
- Fuel Failure Handbook Computer-Based Trainings | Module 2: Principles Fuel Failure Evaluation

FRP Communication Documents

Strategic Objectives and Organization

FRP Strategic Objectives and Organization

The structural integrity of nuclear fuel and reactor control components is essential to the safe operation of nuclear power plants under both normal and postulated accident conditions. While safety and reliability remain paramount, there are opportunities for coordinated research, development, and demonstration (RD&D) of proposed fuel innovations that could substantially reduce fuel-related costs while improving safety, performance, and reliability. Nuclear fuel accounts for approximately 20 percent of the annual generating costs at a nuclear power plant. Continued attention to the technical gaps associated with current fuel technologies, as well as opportunities to capitalize on benefits associated with advanced technologies, are critical to sustaining safety, reliable performance, and improving plant economics.

The Fuel Reliability Program (FRP) drives improvements in nuclear fuel performance, reliability, sustainability, economics, and safety based on operational experience and issues encountered at nuclear power plants around the world. Operating experience (OE) and ongoing research inform the development of fuel reliability guidance, fuel reliability- and performance-related software products, new/innovative fuel and core designs, and fuel-related improvements to plant operational processes. The program also provides technical input informing fuel-related regulations and licensing, as well as assessing the application of advanced nuclear reactor and nuclear fuel technologies.

The purpose of this document is to inform FRP advisors on the program's strategic objectives and mission, research focus areas, advisory structure, funding structure, interface with other organizations, project prioritization process, and support that the FRP provides. This document will be revised annually by FRP to keep it up to date.

1. FRP'S STRATEGIC OBJECTIVES AND MISSION

FRP develops knowledge, guidance, and tools to inform the safe and efficient use of nuclear fuel, control rods/blades, and assembly components. The program also participates in international research efforts to improve fundamental understanding of in-reactor behavior of fuel, cladding, reactivity control materials, and other in-core components.

The mission of the FRP is to investigate the highest priority nuclear fuel issues and develop solutions to proactively ensure safe, reliable, and economical operation through research informed by utility members and other stakeholders. The associated R&D portfolio is centered around three primary objectives:

- **Cost and Operational Efficiencies** – investigate innovative fuel technologies and plant operational domains that can lead to performance improvements and cost savings while improving safety and reliability
- **Reliability and Performance** – improve understanding of nuclear fuel and related components to help mitigate fuel failures and other operational issues, which can result in significant operational impacts and costs
- **Regulatory and Safety Limits** – conduct research and analyses to inform the technical bases for existing and proposed regulatory and safety limits

2. FRP RESEARCH FOCUS AREAS

FRP has nine Research Focus Areas (RFAs):

- **Debris-Induced Failure Mitigation (DFM)**: Supporting the mitigation of debris fretting-induced fuel failures through guidance, risk assessments, and training tools, with emphasis on understanding debris of concern; sources of debris; identifying alternative parts, components, and materials that can reduce risk to fuel; and implementing advanced fuel technologies and standardized testing.

Utility Advisor Onboarding Checklist

Utility Advisor Onboarding Checklist

Use this checklist to familiarize yourself with the content of EPRI and the FRP

EPRI LOGIN AND INTRODUCTION

- Complete the new advisor introduction. Be sure to watch the videos and create your EPRI.com login credentials, if you haven't done so previously: Advisor Center
- Once logged in, create TIP subscriptions to the programs you wish to follow. A TIP subscription will send you an e-mail either weekly or daily (weekly is recommended) that details new program events or deliverables. Click the envelope next to the programs you wish to subscribe to: EPRI TIP Subscription
- Familiarize yourself with EPRI's training platform found on EPRI.com: EPRI Training and Development
- Additional help is available on the Frequently Asked Questions (FAQ) page: EPRI Help

FRP INTRODUCTION

- Familiarize yourself with the FRP page on EPRI.com. Make sure you are logged in so you can access all content and important links including research results, training, committees, events, and contacts: FRP Homepage
- The FRP Strategic Objectives and Organization document is recommended for all advisors to read to familiarize yourself with the program. This document includes FRP's strategic objectives and mission, description of all research focus areas (RFAs), advisory structure, funding structure, interface with other organizations, project prioritization process, and other types of supports that FRP provides.
- The FRP R&D Portfolio includes Research Focus Area (RFA) overview presentations that contain the issues, consequences, vision, and technical gaps for each RFA along with a list of projects within that RFA. This document is developed every year for the next two years' R&D planning.
- The FRP Links page also provides access to useful resources including links to the Trainings, FRP All-TAC meeting materials under either Base Library (Core-TAC) or Supplemental Library (B-TAC and P-TAC), latest versions and implementation letters for Fuel Reliability Guidelines, the latest FRP Self-Assessment report and the latest U.S. Fuel Failure Trend (courtesy of the Driving-to-Zero Team). In addition, the FRP Links page provides:
  - A link to the Fuel Reliability Database (FRED). Please note that only utilities who contributes data to FRED will have access. If your utility contributes data to FRED and you do not have access to it, please send an e-mail to FRED@epri.com to request access.
  - A link to the Nuclear Staff Expertise List. The Expertise List is an excellent resource for finding the appropriate staff members and contact information when you have questions.
  - A link to the FRP Wiki, which provides a condensed summary of key FRP guidance on topics impacting fuel reliability and performance.
- Should you have any other questions, please feel free to reach out to any of the FRP staff. Welcome to FRP!

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Documents can be found here: https://www.epri.com/research/programs/061147/links

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