High-Efficiency Ultrasonic Fuel Cleaning (HE-UFC)

Industry Experience & Adaptations in the COVID-19 Era

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Name That ANS DC Section Member?

Jeff Gorman

with DEI co-founders
Steve Hunt & Bob Ward
(1980)
DEI Company Overview

- Specialized engineering firm founded in 1980
- DEI has led >500 EPRI R&D programs and authored hundreds of nuclear industry guidelines documents
- Consulting services directly to nuclear operators
  - Corrosion and materials
  - Chemistry & environmental
  - Radiation protection
  - Fuel reliability
- Unique equipment & technology for plant maintenance and waste management
  - Ultrasonic cleaning and decontamination (fuel, piping, etc.)
  - AMFM\textsuperscript{™} reusable filter technology (eliminates secondary waste)
  - Smart-Sip\textsuperscript{™} high definition fuel sipping
  - …
Facilities Overview

- **DEI HQ**
  - 40,000 ft$^2$ co-located office and applied R&D facility
  - Reston, VA (Washington DC metro)

- **Other locations**
  - Active global field operations and partners in 10 countries
  - Offices
    - Atlanta, GA
    - Denver, CO
    - Oakland, CA
    - Toronto
  - Auxiliary facility in Dulles, VA
    - 4,300 ft$^2$ facility
    - Testing, equipment assembly and storage
# DEI Applied Engineering & Research Center

## Facility snapshot
- Custom test facilities (large and small scale)
- Autoclaves and corrosion test loops
- Equipment development, assembly & qualification
- Chemical process development & scale-up
- Instrumentation for chemical and metallurgical analysis

## Unique features
- 30-ft high bay area with 3-ton crane
- 13 MW of backup power for mission-critical test programs
- Secure, 24/7 operation
- Radioactive materials handling license
International Clients & Project Landscape

- ~40% of DEI’s business is outside the US
  - DEI leverages international partnerships for global delivery of technology
Ultrasonic Cleaning – Background

How it works
- High frequency sound waves are focused toward object to be cleaned
- Alternating high/low pressure waves cause cavitation which disrupt deposits and impurities

Benefits
- “Line-of-sight” cleaning not required (effectively cleans in difficult-to-access areas)
- Generally much less expensive than chemical cleaning / decontamination or equipment replacement
- Energy intensity can be optimized to achieve effective cleaning without harming surfaces being cleaned
Example Applications for Nuclear Components

HE-UFC™ ULTRASONIC FUEL CLEANING

Before

After

BWR fuel

PWR fuel

NU-DEC™ NON-INTRUSIVE DECONTAMINATION

Before

After

STEAM GENERATOR SECONDARY SIDE UEC™ INSTALLATION

BWR JET PUMP CLEANING
HE-UFC Basics

- Ultrasonic energy used to disrupt crud and foreign material from reinsert fuel
- Liberated material is swept away and captured in filtration system
  - In-line gamma monitor is used to monitor cleaning progress
- Cleaning time is 2-3 minutes per fuel bundle
  - Typically applied in parallel with fuel shuffle / offload
- Fuel remains on handling tool throughout cleaning process
HE-UFC Equipment & Operations


High Efficiency Ultrasonic Fuel Cleaning (HE-UFC)
Ultrasonic Fuel Cleaning – Industry Evolution

- Callaway CIPS issue. DEI conceives of, qualifies, and deploys prototype ultrasonic fuel cleaning (UFC) system in 12 weeks with support from EPRI. (CIPS issue arrested.)
- DEI designs/builds Westinghouse vacuum canister sipping system based on DEI dual-chamber UFC design
- Ultrasonic cleaning of radwaste cement solidification system using DEI NU-DEC™ system (Japan)

Year Events
- 1995 Venturi cleaning at nuclear plant in Japan using DEI’s non-intrusive ultrasonic cleaning (NU-DEC™) system
- 1997 Ultrasonic cleaning equipment R&D (US Navy)
- 1999 Development of ultrasonic energy cleaning (UEC) systems for cleaning steam generator crevices (>20 applications at PWRs in US and Japan)
- 2001 UFC licenses executed
- 2002 1st PWR UFC campaign with dual-chamber system
- 2003 1st BWR UFC campaign
- 2005 KNF UFC license executed
- 2006 AMF/M ultrasonically regenerable filtration technology developed
- 2008 Ultrasonic cleaning system developed for BWR jet pumps

EPRI

Southern Nuclear

Entergy

Hokkaido Electric Power Co., Inc.
**Ultrasonic Fuel Cleaning – Industry Evolution (cont’d)**

- **2011**
  - 1st PWR HE-UFC™ campaign
  - DEI develops Smart-Sip™ system for high definition fuel leak detection & characterization
  - HE-UFC™ widely adopted by BWRs to improve fuel integrity and source term control
  - Exelon, Entergy, CFE, DTE Energy, ... DEI NU-DEC™ systems delivered to BWRs & PWRs for ultrasonic decontamination to reduce radiological exposure at operating plants and in support of decommissioning / dismantling

- **2012**
  - HE-UFC™ licenses executed
  - AMFM-B500 / -P500 filtration systems widely adopted for general filtration and vacuuming in spent fuel pool and reactor cavity at BWRs & PWRs

- **2013**
  - 100th HE-UFC™ campaign
  - AMFM™ regenerable filter technology expands to general use ($500k-$1M annual savings in radwaste costs for typical BWR sites)

- **2017**
  - AMFMTM regenerable filter technology expands to general use ($500k-$1M annual savings in radwaste costs for typical BWR sites).
  - HE-UFC™ system for high definition fuel leak detection & characterization
  - DEI designs/builds ENUSA vacuum canister sipping system
  - DEI develops Smart-Sip™ system for high definition fuel leak detection & characterization

- **2018**
  - 1st BWR HE-UFC™ campaign
  - DEI NU-DEC™ systems delivered to BWRs & PWRs for ultrasonic decontamination to reduce radiological exposure at operating plants and in support of decommissioning / dismantling

- **2019**
  - 100th HE-UFC™ campaign
  - DEI NU-DEC™ systems delivered to BWRs & PWRs for ultrasonic decontamination to reduce radiological exposure at operating plants and in support of decommissioning / dismantling

- **2020**
  - HE-UFC™ system for high definition fuel leak detection & characterization
Ultrasonic Fuel Cleaning Summary

- ~250 applications performed in 6 countries

- Regularly applied at:
  - High duty PWRs (CIPS control)
  - High source term BWRs (dose control)
  - Units seeking improved fuel reliability through debris removal
Typical Activity / Dose Distribution in a BWR

- **Fuel**
  - ~700 fuel assemblies
  - Total surface area: ~90,000 ft² per unit
  - Total mobile activity (crud and debris on fuel): ~100,000 Ci per unit
  - Fuel crud represents >90% of mobile activity in the reactor system

- **Recirc piping**
  - Total surface area: ~3,000 ft² per unit
  - Total activity: ~100 Ci
  - 80-90% of dry well dose comes from reactor recirculation and RWCU piping during outages

- **Undervessel**
  - Total activity: ~100 Ci
  - Accounts for ~5% of collective dose during outages
Debris Removal from Fuel

- More compact BNDE™ system developed for cleaning fuel bundle bottom nozzles
  - Typical location where debris accumulates before causing fuel failures

- Same principle and application time as HE-UFC
  - But applied at bottom nozzle only

- Practical technique for removing debris from large numbers of bundles without large impact on refueling schedule

- Debris-related fuel failures arrested at 3 BWR units
AMFM™ Regenerable Filter Technology

- All-metal filter module (AMFM) features
  - All metal construction (304/316SS), including media
  - Same form factor and interfaces as a fuel bundle (PWR or BWR type)
  - Patented ultrasonic regeneration process enables very high capacity and long service

- Originally developed to support HE-UFC (especially at BWRs)

- BWR HE-UFC OE confirmed high volume reduction factors
  - 1 AMFM equivalent to capacity of several hundred disposal plastic filters

- AMFM filtration systems subsequently adopted for general use as operating nuclear facilities and decommissioning sites
  - Primary motivators are improved economics and reduced radwaste volume
Example AMFM™ Installations

Submersible systems

- Fuel pool and reactor cavity vacuuming and filtration

Portable skid-mounted systems

- Mobile treatment at commercial NPPs and DOE waste sites
COVID-19 Impacts on Outage Activities

- DEI supported 20 outages in Spring 2020 during COVID-19 pandemic
  - Including 5 non-US outages

- Examples of changing protocols
  - For US outages, DEI personnel travel in personal vehicles whenever possible
  - Some sites require a negative COVID-19 test within 72 hours of arrival
  - Other sites make contractors take a COVID-19 test upon arrival (similar to fitness-for-duty testing)
  - Temperature checks upon arrival
  - Delaying maintenance activities when possible / limiting number of contractors in a given location on-site
  - Face coverings required
  - Social distancing required (with floor stickers indicating proper spacing)
Effects on International Work

- In the midst of an HE-UFC operation in Europe in March 2020, US and UE border closures went into effect
  - Personnel (including DEI team) had to return to home country unless prepared to remain overseas indefinitely
  - MS Teams was used to remotely control the remaining operations from the US

- This approach has subsequently been utilized for 5 US and non-US outages
  - Has become more common for walkdowns and outage activities to minimize crew sizes on-site

- In the COVID era, most people are becoming more comfortable with the use of remote networking technology in this capacity

Remote Operations Snapshot

**EQUIPMENT INSTALLATION**
Live Expert Supervision

**CLEANING PROCESS**
Process parameters are controlled from US under Framatome supervision
Underwater cameras are live streamed and controlled from Paluel

**HOLOLENS 2**
Driving remotely: operators wearing connected glasses

**VIDEO CONFERENCE**
4 Screens online
Innovative products, expert consulting, and R&D for the next chapter in nuclear energy

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