High-Efficiency Ultrasonic Fuel Cleaning (HE-UFC)

Industry Experience & Adaptations in the COVID-19 Era

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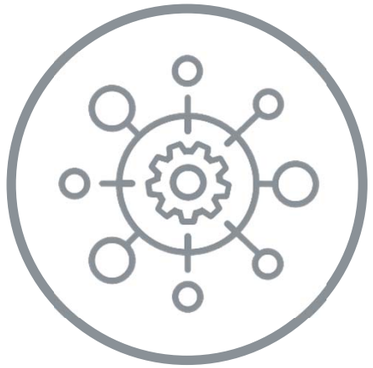
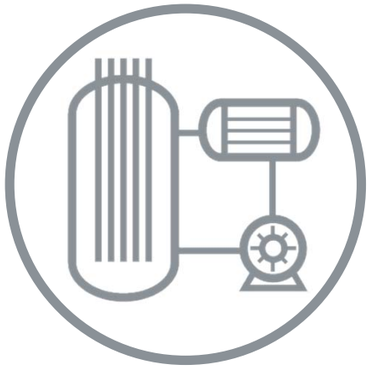


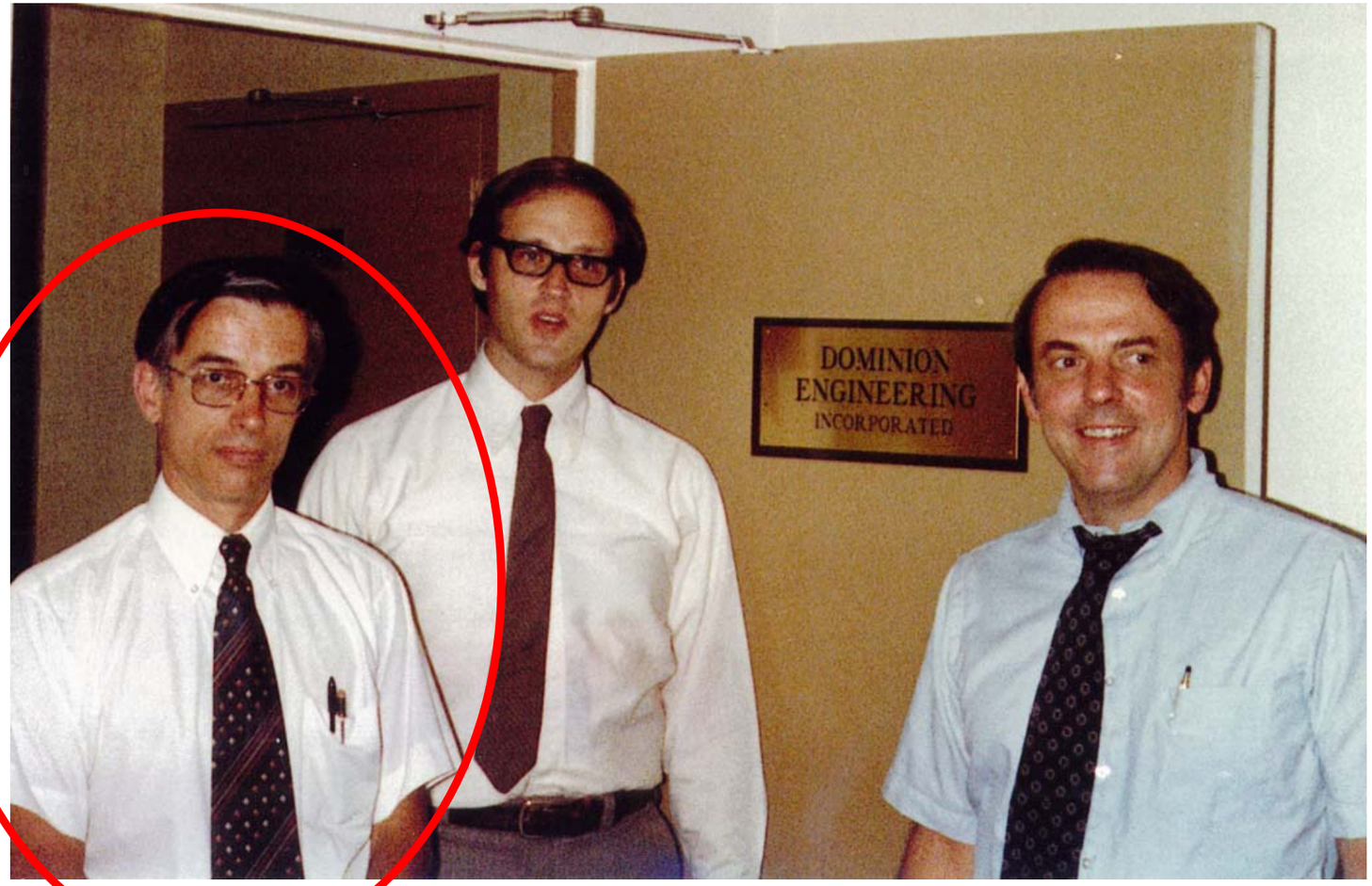
PRODUCTS & TECHNOLOGY

CONSULTING SERVICES



TESTING AND R&D

Name That ANS DC Section Member?

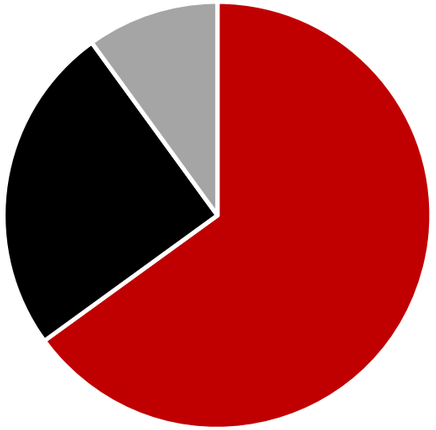


Jeff Gorman

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
  - Advanced nuclear technology
  - Decommissioning & waste management
- Unique equipment & technology for plant maintenance and waste management
  - Ultrasonic cleaning and decontamination (fuel, piping, etc.)
  - AMFM™ reusable filter technology (eliminates secondary waste)
  - Smart-Sip™ high definition fuel sipping
  - …



Approx. distribution of DEI business areas

Facilities Overview

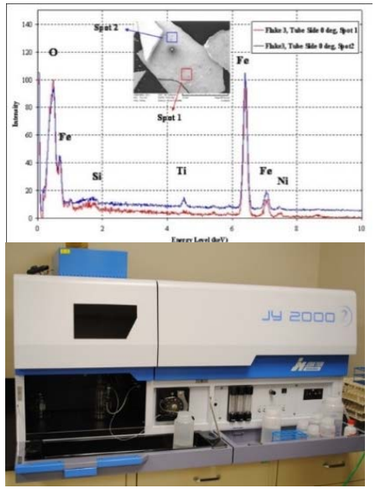
- DEI HQ
  - 40,000 ft^2 co-located office and applied R&D facility
  - Reston, VA (Washington DC metro)

- 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

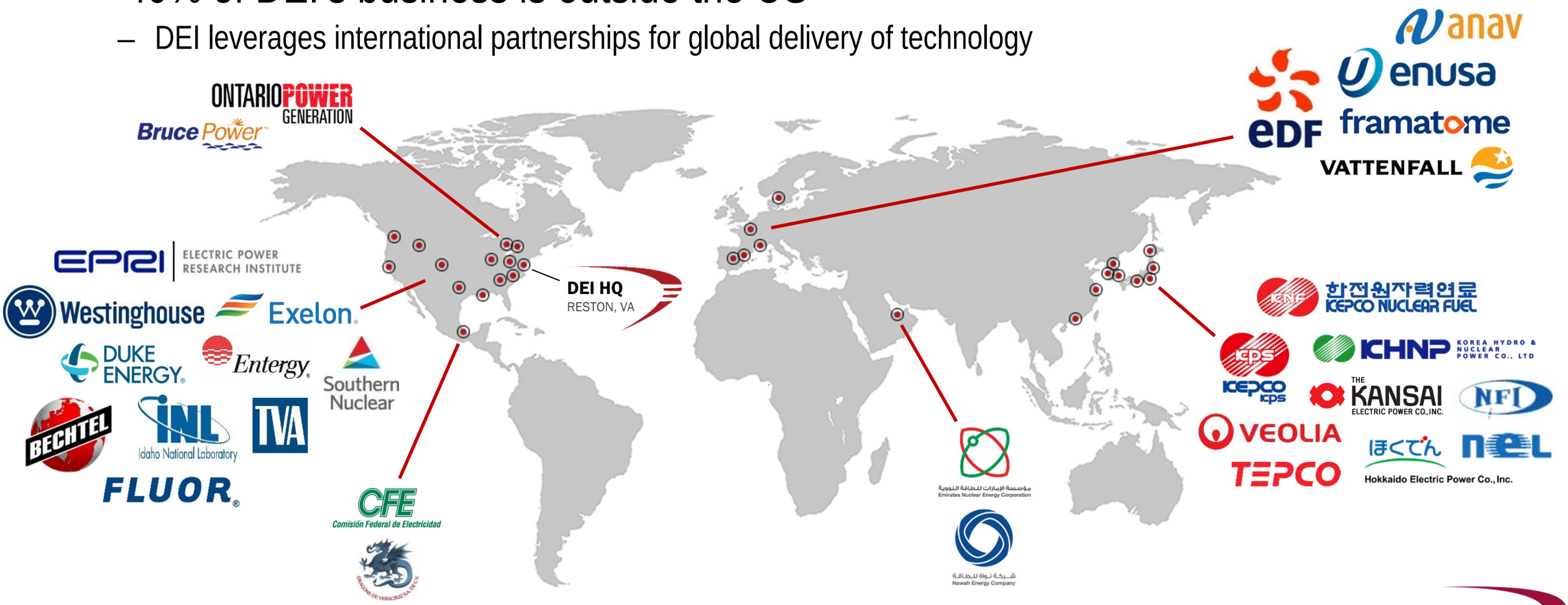
- Facility snapshot
  - Custom test facilities (large and small scale)
  - Autoclaves and corrosion test loops
  - Equipment development, assembly & qualification
  - Chemical process development & scale-up
  - Instrumentation for chemical and metallurgical analysis

- 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

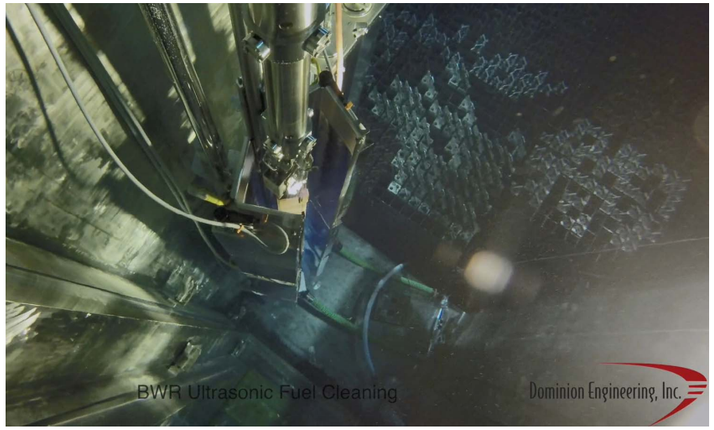
- How it works
  - High frequency sound waves are focused toward object to be cleaned
  - Alternating high/low pressure waves cause cavitation which disrupt deposits and impurities

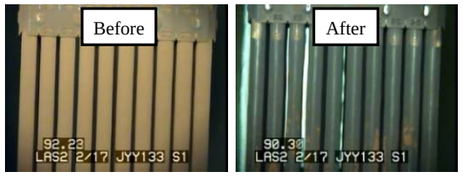


- Benefits
  - "Line-of-sight" cleaning not required (effectively cleans in difficult-to-access areas)
  - Generally much less expensive than chemical cleaning / decontamination or equipment replacement
  - Energy intensity can be optimized to achieve effective cleaning without harming surfaces being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

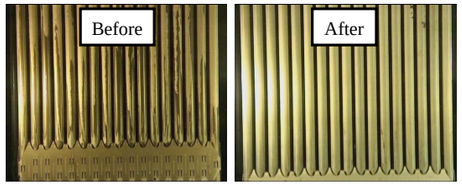
Example Applications for Nuclear Components

HE-UFC™ ULTRASONIC FUEL CLEANING





BWR fuel

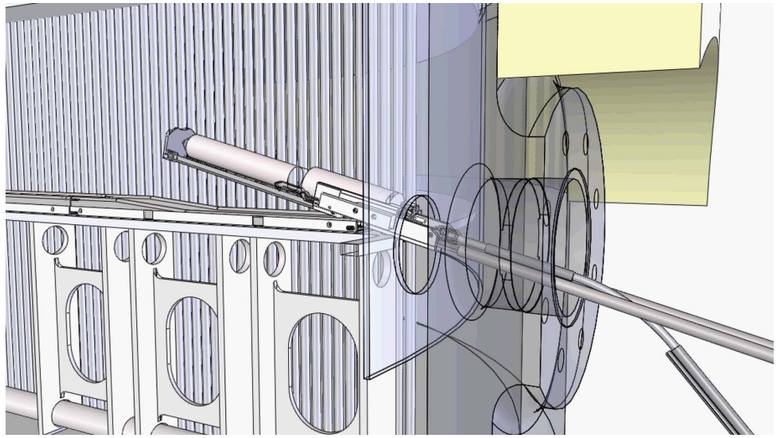


PWR fuel

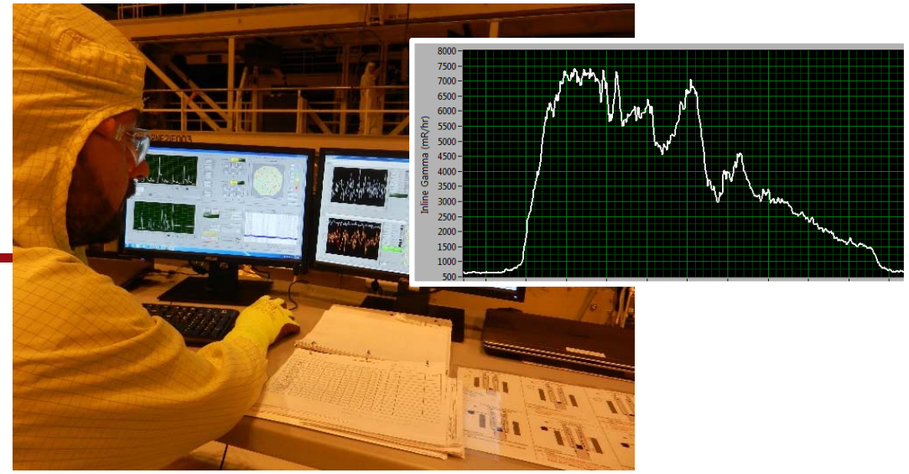
BWR JET PUMP CLEANING

NU-DEC™ NON-INTRUSIVE DECONTAMINATION

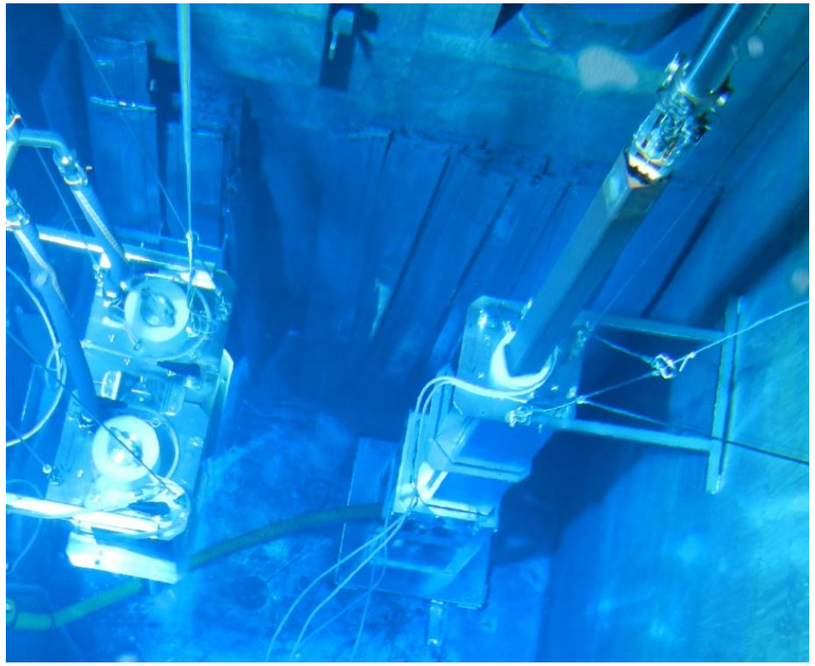
STEAM GENERATOR SECONDARY SIDE UEC™ INSTALLATION



HE-UFC Basics



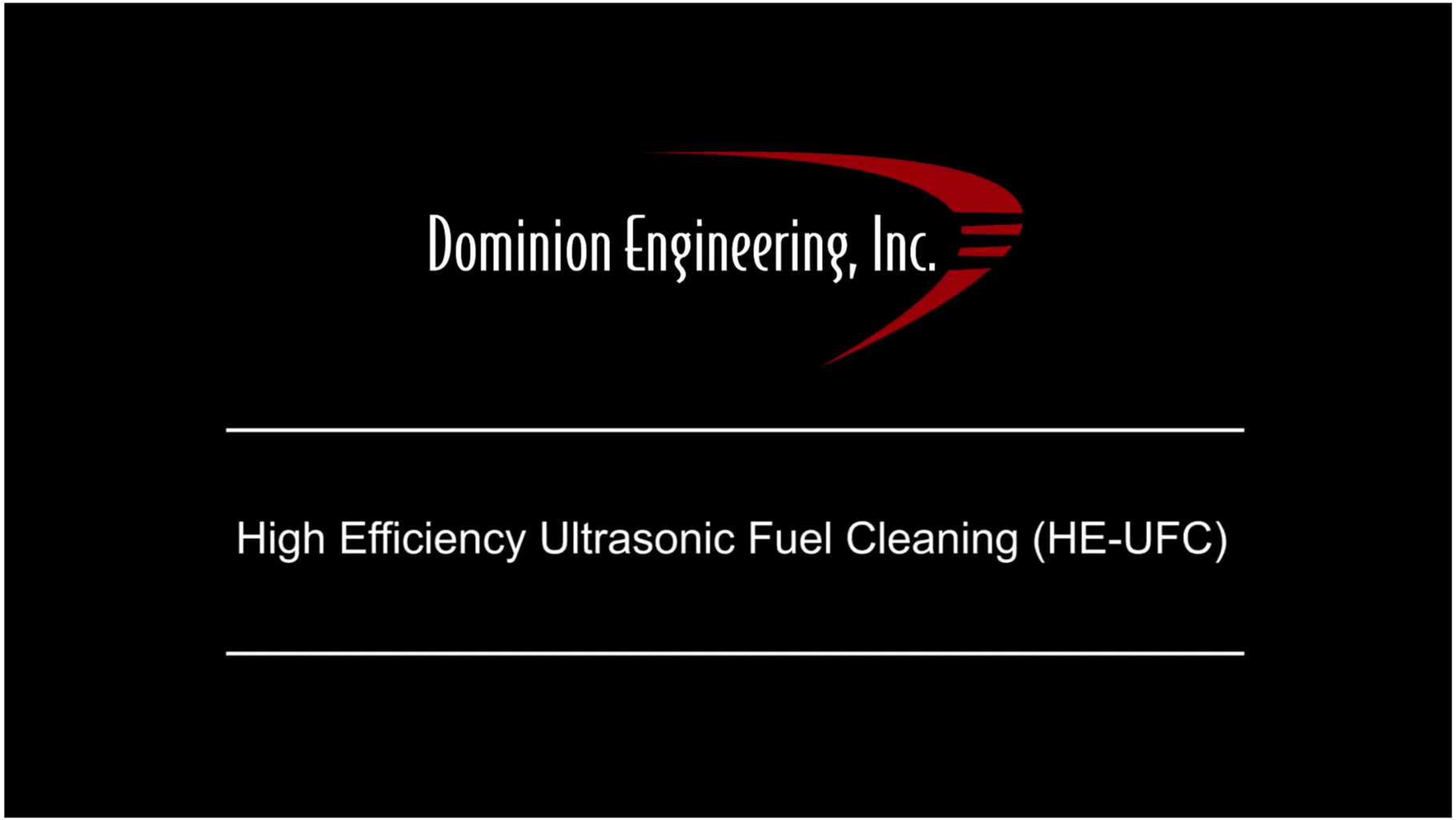
- Ultrasonic energy used to disrupt crud and foreign material from reinsert fuel
- Liberated material is swept away and captured in filtration system
  - In-line gamma monitor is used to monitor cleaning progress
- Cleaning time is 2-3 minutes per fuel bundle
  - Typically applied in parallel with fuel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



HE-UFC operations

HE-UFC Equipment & Operations

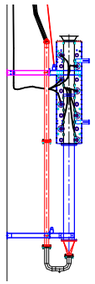
Video link: https://domeng.com/pt-video/high-efficiency-ultrasonic-fuel-cleaning-he-ufc/



Ultrasonic Fuel Cleaning – Industry Evolution

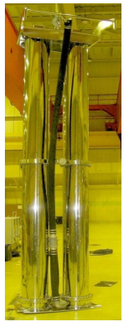
Venturi cleaning at nuclear plant in Japan using DEI's non-intrusive ultrasonic cleaning (NU-DEC™) system

Hokkaido Electric Power Co., Inc.

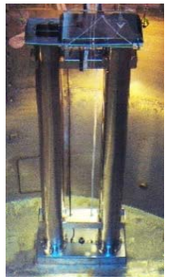


Callaway CIPS issue. DEI conceives of, qualifies, and deploys prototype ultrasonic fuel cleaning (UFC) system in 12 weeks with support from EPRI. (CIPS issue arrested.)

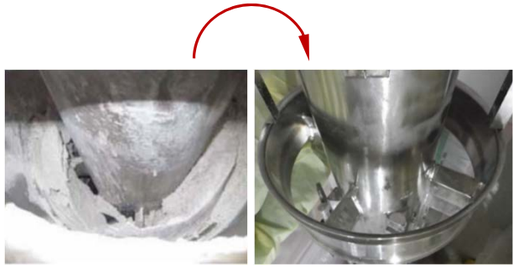
EPRI



1st BWR UFC campaign



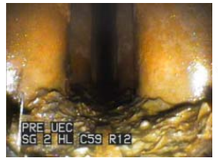
DEI designs/builds Westinghouse vacuum canister sipping system based on DEI dual-chamber UFC design

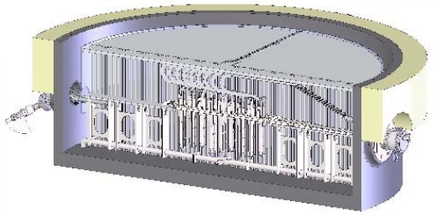


Ultrasonic cleaning of radwaste cement solidification system using DEI NU-DEC™ system (Japan)

1995 | 1997 | 1999 | 2001 | 2003 | 2005 | 2006 | 2008 | 2010

Ultrasonic cleaning equipment R&D (US Navy)



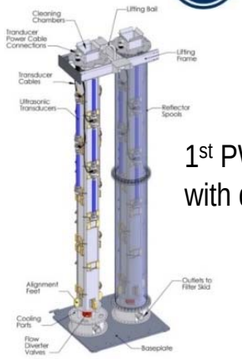


Hokkaido Electric Power Co., Inc. | Southern Nuclear | Entergy

Development of ultrasonic energy cleaning (UEC) systems for cleaning steam generator crevices (>20 applications at PWRs in US and Japan)

UFC licenses executed

AREVA | enusa



1st PWR UFC campaign with dual-chamber system

KNF | 한전원자력연료 KEPCO NUCLEAR FUEL

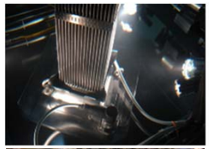
KNF UFC license executed

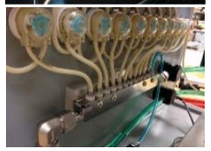
AMFM ultrasonically regenerable filtration technology developed

Ultrasonic cleaning system developed for BWR jet pumps

Dominion Engineering, Inc.

Ultrasonic Fuel Cleaning – Industry Evolution (cont'd)





4-face visual inspection system & crud sampling system developed

2011

DEI designs/builds ENUSA vacuum canister sipping system

enusa

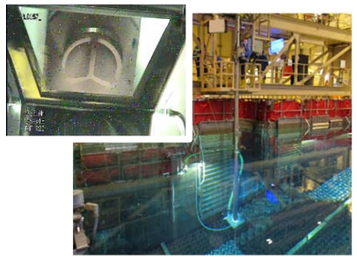
2012

1st BWR HE-UFC™ campaign

2013

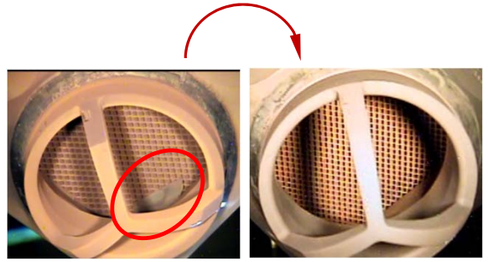
2017

DEI develops Smart-Sip™ system for high definition fuel leak detection & characterization



BNDE™ system deployed for bottom nozzle debris elimination

2018



Debris-related fuel failures arrested

HE-UFC™ widely adopted by BWRs to improve fuel integrity and source term control

Exelon. Entergy. CFE Comisión Federal de Electricidad DTE Energy ...

100th HE-UFC™ campaign

2019

HE-UFC™ licenses executed

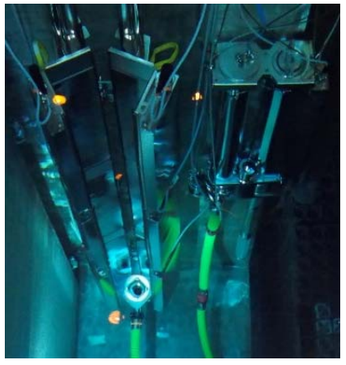
AREVA enusa

100th UFC campaign

1st PWR HE-UFC™ campaign

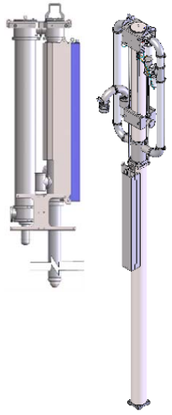
Southern Nuclear TVA DUKE ENERGY.

VATTENFALL ...



Side-entry HE-UFC™ system developed.

AMFM™ regenerable filter technology expands to general use ($500k-$1M annual savings in radwaste costs for typical BWR sites).



AMFM-B500 / -P500 filtration systems widely adopted for general filtration and vacuuming in spent fuel pool and reactor cavity at BWRs & PWRs

Exelon. CFE Comisión Federal de Electricidad DTE Energy

Entergy ENERGY NORTHWEST ...

DEI NU-DEC™ systems delivered to BWRs & PWRs for ultrasonic decontamination to reduce radiological exposure at operating plants and in support of decommissioning / dismantling

Ultrasonic Fuel Cleaning Summary

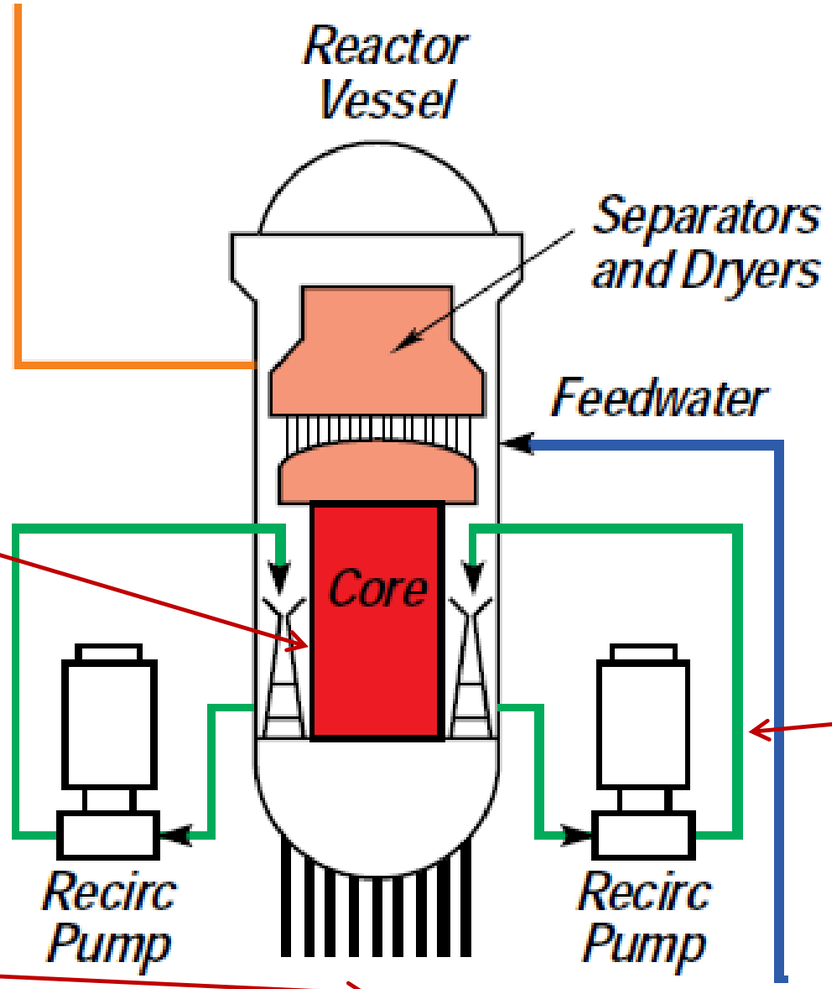
- ~250 applications performed in 6 countries

- Regularly applied at:
  - High duty PWRs (CIPS control)
  - High source term BWRs (dose control)
  - Units seeking improved fuel reliability through debris removal

Plant / Unit	Plant Type	Spr. '01	Fall '01	Spr. '02	Fall '02	Spr. '03	Fall '03	Spr. '04	Fall '04	Spr. '05	Fall '05	Spr. '06	Fall '06	Spr. '07	Fall '07	Spr. '08	Fall '08	Spr. '09	Fall '09	Spr. '10	Fall '10	Spr. '11	Fall '11	Spr. '12	Fall '12	Spr. '13	Fall '13	Spr. '14	Fall '14	Spr. '15	Fall '15	Spr. '16	Fall '16	Spr. '17	Fall '17	Spr. '18'	Fall '18'	Spr. '19'	Fall '19'	Spr. '20'	Fall '20'	Spr. '21'	Fall '21'	Comp. Total
Callaway	W	X			X			X			X*			X			X			X			X					X													9
STP 2	W				X*			X			X			X			X			X			X			X			X						X							10
STP 1	W					X				X			X			X			X			X			X			X										X				10
Vogtle 1	W						X			X			X			X			X			X			X			X			X			X				X			X	12
Quad Cities 2	BWR						X																																				1
Vogtle 2	W							X			X			X			X			X			X			X			X			X			X			X				11
Browns Ferry 1	BWR									X																																	1
McGuire 2	W									X			X			X			X			X			X			X			X			X				X			X	11
McGuire 1	W										X			X			X			X			X			X			X			X			X			X				11
Ft. Calhoun	CE									X			X*			X			X			X							X										X				6
Vandellós 2	W									X				X				X				X		X			X			X			X			X				X			10
Catawba 1	W									X			X			X			X			X					X			X			X				X			X		11
Catawba 2	W											X			X			X			X			X			X			X			X			X				X			10
ANO 2	CE												X			X			X			X			X																		5
ANO 1	B&W										*						X																										1
Seabrook	W												X			X			X			X			X			X			X			X			X				X			10
Watts Bar 1	W												X*			X			X			X			X			X			X						X							8
Ascó 2	W													X			X			X			X			X			X			X			X			X					10
Ascó 1	W														X			X				X			X			X			X			X			X				X		9
Palisades	CE														X																													1
Millstone 3	W																X			X			X			X			X			X			X				X				9
Hanul (Ulchin) 1	F-CP0																	X			X			X*																				3
Hanul (Ulchin) 2	F-CP0																						X*																					1
Hanul (Ulchin) 3	KSNP (CE)																											X				X												2
Waterford 3	CE																		X						*																			1
Davis Besse	B&W																			X							*																	1
Crystal River	B&W																				X*																							1
Ringhals 2	W																												X		X		X		X		X		X			6
Ringhals 3	W																												X		X		X		X		X		X			6
Ringhals 4	W																					*		X		X		X		X		X		X		X		X		X		9
Oconee 3	B&W								*															X				X				X			X				X				5
Oconee 1	B&W						*																		X				X			X				X				X			5
Oconee 2	B&W							*																			X				X			X				X				X	4
Turkey Point 3	W																											X			X			X			X				X	5
Turkey Point 4	W																												X			X			X				X			5
Point Beach 2	W																											X			X						X				X	3
Point Beach 1	W																												X			X					X					3
Sequoyah 2	W																								*			X			X												2
Robinson 2	W																												X														1
Kori 3	W																													X													1
Sequoyah 1	W					*																									X			X			X			X		3
Hanbit (Yeonggwang) 3	KSNP (CE)																														X												1
Hanbit (Yeonggwang) 4	KSNP (CE)																															X											1
LaSalle 2	BWR-5																															X			X			X			X		2
LaSalle 1	BWR-5																																	X			X						2
Nine Mile Point 2	BWR-5																																	X			X						2
Laguna Verde 1	BWR-5																																		X			X					1
Laguna Verde 2	BWR-5																																		X			X					1
River Bend	BWR-6																																		X			X					1
Watts Bar 2	W																																		X								1
Grand Gulf	BWR-6																																						X				1
Fermi 2	BWR-4																																						X				1
Paluel 2	F-P4																																						X				1
Hanbit (Yeonggwang) 5	KSNP (CE)																																						X				1
Hanbit (Yeonggwang) 6	KSNP (CE)																																							X			1
Total		1	0	0	2	1	2	3	0	7	4	1	8	6	3	8	7	4	9	7	3	10	7	5	9	6	3	13	8	8	11	11	5	12	6	10	9	14	4	17	6		245

Typical Activity / Dose Distribution in a BWR

- Fuel
  - ~700 fuel assemblies
  - Total surface area: ~90,000 ft^2 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

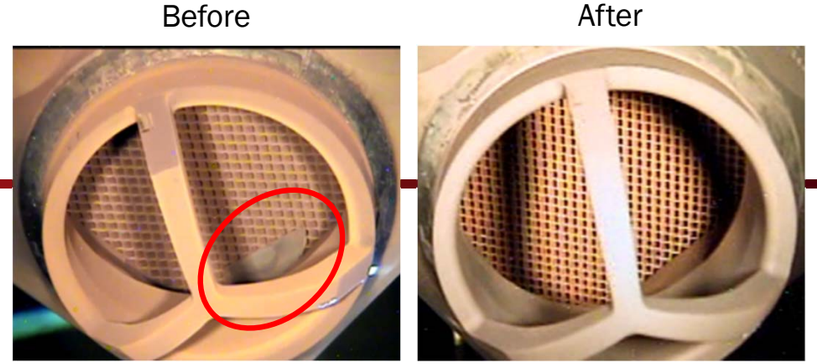


- Undervessel
  - Total activity: ~100 Ci
  - Accounts for ~5% of collective dose during outages

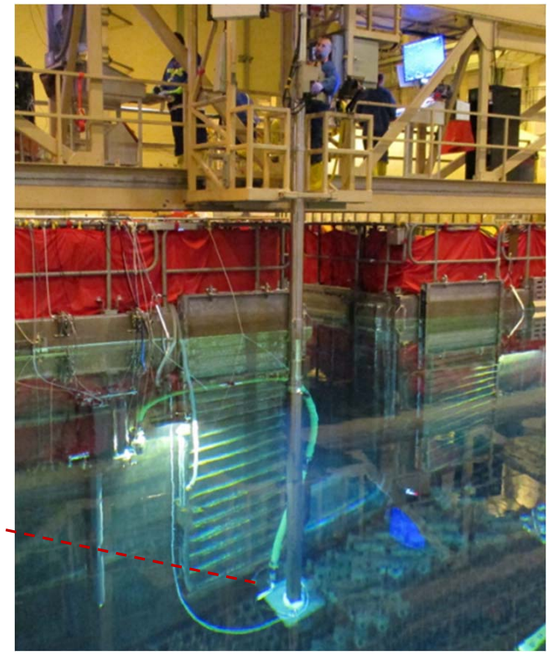
- Recirc piping
  - Total surface area: ~3,000 ft^2 per unit
  - Total activity: ~100 Ci
  - 80-90% of dry well dose comes from reactor recirculation and RWCU piping during outages

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

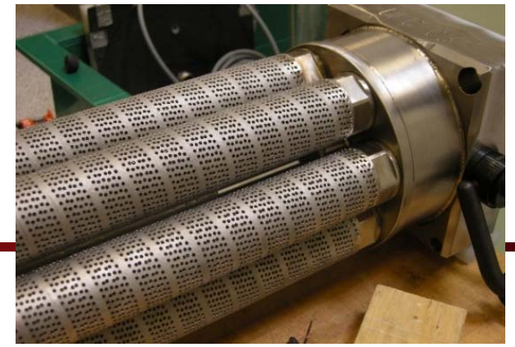


Debris removal from BWR fuel



BNDE™ operation at US NPP

AMFM™ Regenerable Filter Technology



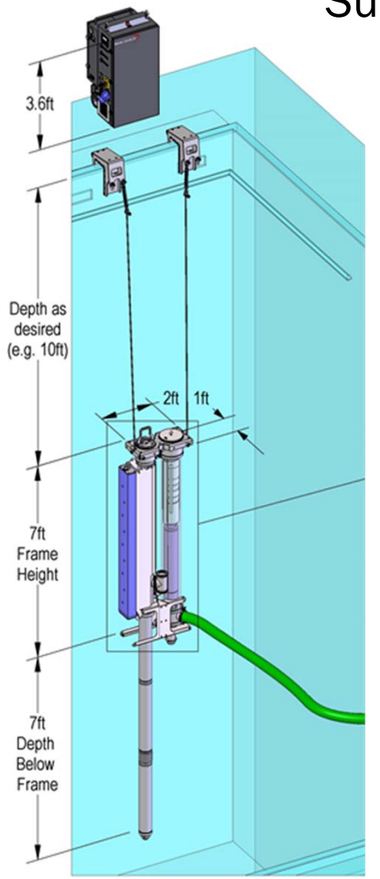
- All-metal filter module (AMFM) features
  - All metal construction (304/316SS), including media
  - Same form factor and interfaces as a fuel bundle (PWR or BWR type)
  - Patented ultrasonic regeneration process enables very high capacity and long service

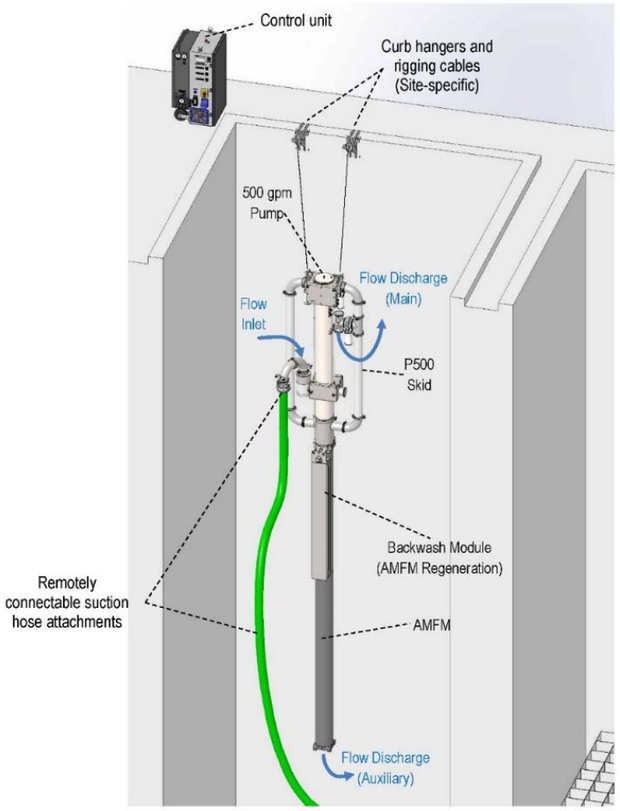
AMFM™ filter (PWR type)

- 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

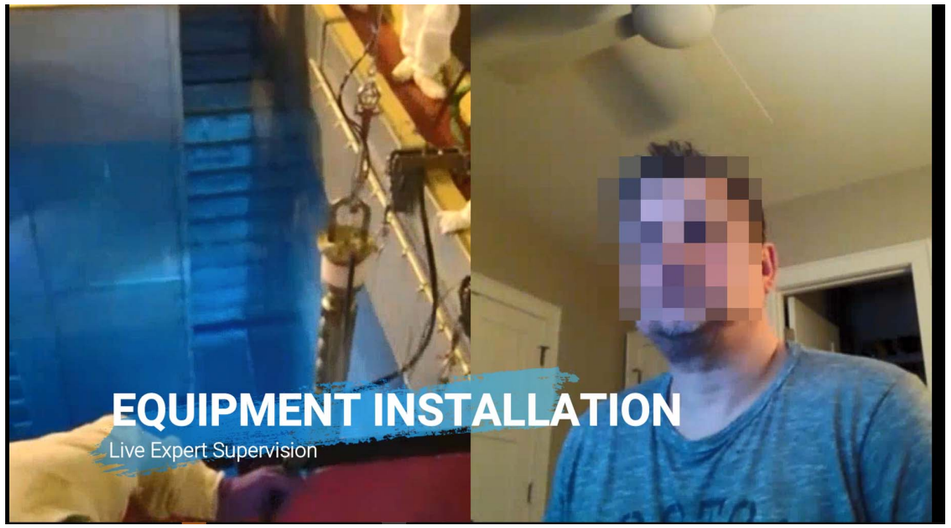
- Examples of changing protocols
  - For US outages, DEI personnel travel in personal vehicles whenever possible
  - Some sites require a negative COVID-19 test within 72 hours of arrival
  - Other sites make contractors take a COVID-19 test upon arrival (similar to fitness-for-duty testing)
  - Temperature 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)

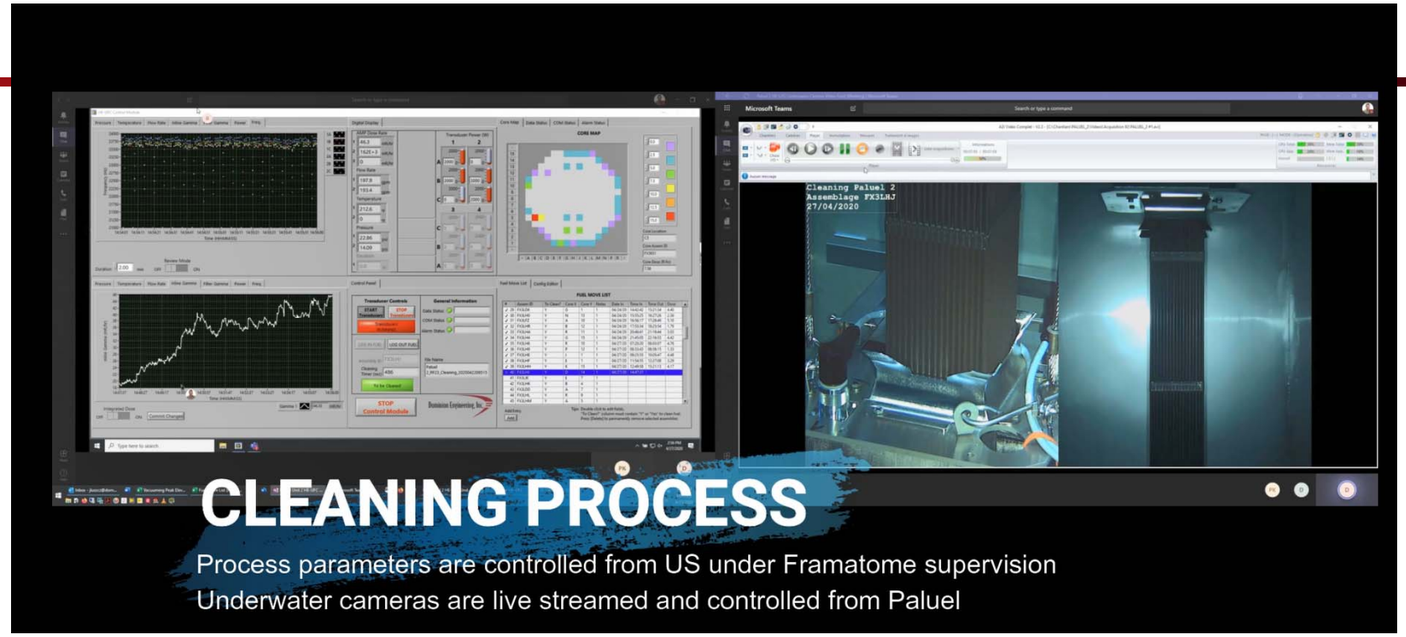
Effects on International Work

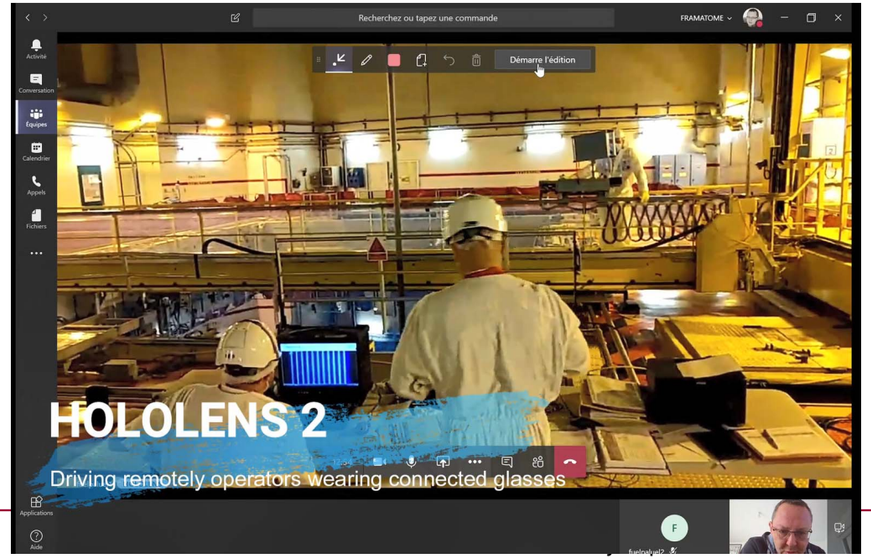
- In the midst of an HE-UFC operation in Europe in March 2020, US and UE border closures went into effect
  - Personnel (including DEI team) had to return to home country unless prepared to remain overseas indefinitely
  - MS Teams was used to remotely control the remaining operations from the US
- This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

ANS article link: https://www.ans.org/news/article-353/remote-fuel-cleaning-from-across-the-globe/

Remote Operations Snapshot







Questions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